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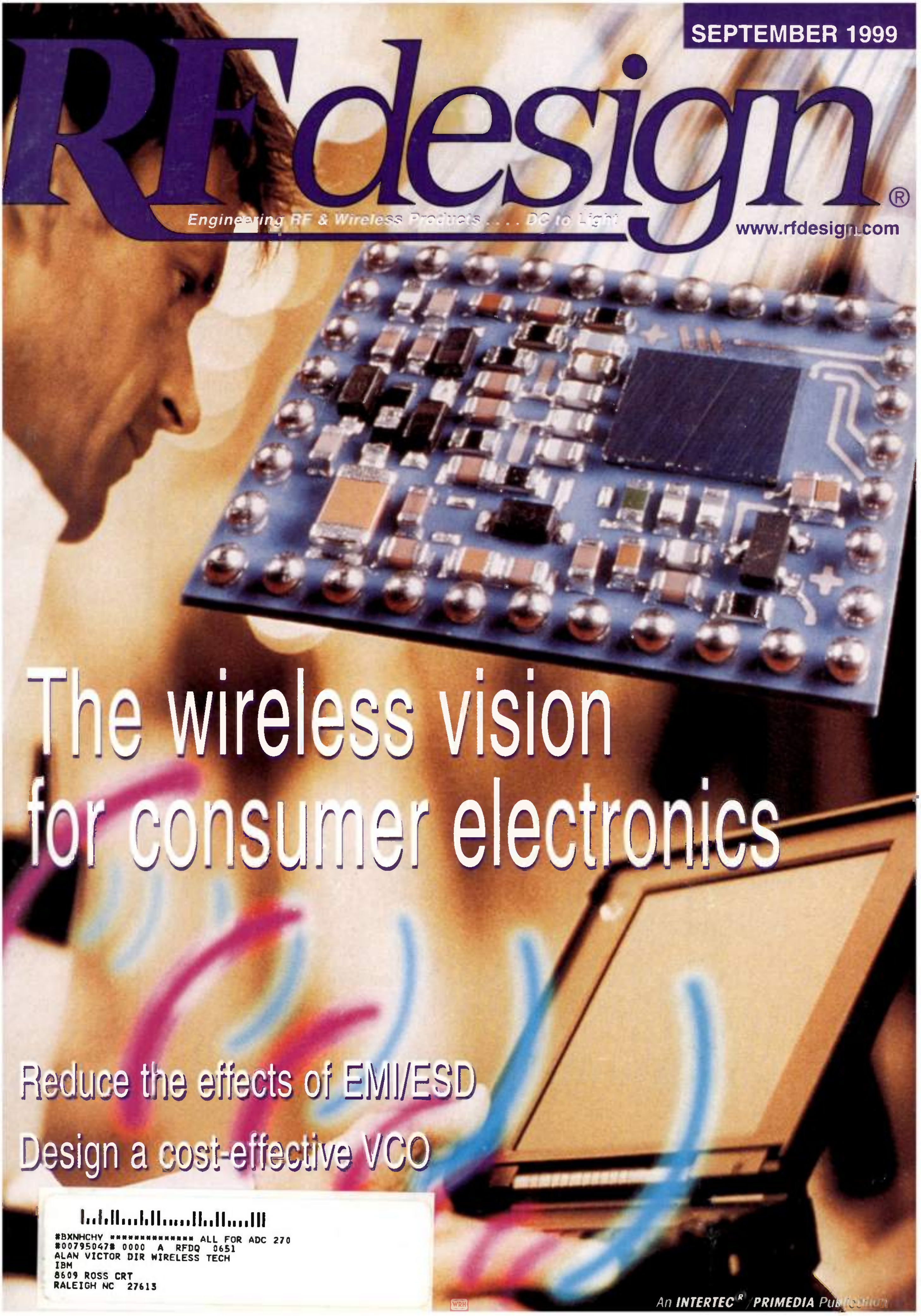

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INFO/CARD 74

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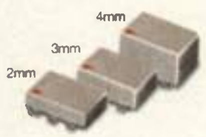

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ADE* TYPICAL SPECIFICATIONS:

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ADE-3L	4	0.2-400	+3	5.3	47**	10	4.25
ADE-1	4	0.5-500	+7	5.0	55**	15	1.99
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-4	3	200-1000	+7	6.8	53**	15	4.25
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-32	3	2500-3200	+7	5.4	29	15	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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DEPARTMENTS

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Goodbye, satphones?

By Don Bishop
Editor Director

First, Iridium ...

Iridium, thy name is legion, and thy bond is defaulted.

On Aug. 13, Iridium World Communications and three of its affiliates filed for Chapter 11 protection in the U.S. Bankruptcy Court in Delaware, the same day noteholders sought to place one of the affiliates in involuntary bankruptcy protection. Filing on Aug. 13 were Iridium World Communications, Iridium, Iridium Operating and Iridium Capital. Five more affiliates were expected to file: Iridium IP, Iridium Roaming, Iridium Potomac, Iridium Facility and Iridium Canada Facility.

Motorola is on the hook for a guaranteed bank facility of $742.2 million and a disputed trade claim of $591.4 million. Senior noteholders are owed $1.5 billion in high-yield debt, and a bank is owed $803.9 million. Earlier, Chase Manhattan had asked Motorola to guarantee $300 million of $800 million it was owed. On Aug. 11, Iridium said it had defaulted on the Motorola and bank loans. Motorola owns about 18% of Iridium.

Iridium's 66-satellite low-earth orbit (LEO) network cost $5 billion and took about 10 years to design, construct, launch into orbit and begin operating. Subscribers have been slow in coming, distribution has misfired, and the handsets have had technical problems. One of our sources said trouble extends to the satellite network, with individual satellites having problems aiming antennas properly, although most sources say the network is working well.

Second, ICO Global ...

On Aug. 27, a company with plans for a less-ambitious 10-satellite medium-earth orbit (MEO) network, ICO Global, filed for Chapter 11 bankruptcy protection. The company had failed to secure what it said were necessary financing commitments in mid-August.

Third, ... ?

If eyes weren't already turned to Globalstar, the international group led by Loral Space & Communications, the gaze must be upon it, now. Globalstar plans to orbit 48 LEO operating satellites and four spares. As of Aug. 17, 36 had been orbited. "Globalstar will meet the needs of cellular users and global travelers who roam outside of cellular coverage areas, as well as residents of under-served markets who will use Globalstar's fixed-site phones to satisfy their needs for basic telephony," company literature reads. Eeek! Echoes of Iridium, doesn't it?

Rapidly expanding terrestrial networks overtook the market envisioned for satphones. The wireless phone market's growing fine, thank you, but apparently it doesn't need the supplementary coverage offered from space.

Maybe the computer market does. Teledesic, backed by Craig McCaw and Bill Gates, will use 288 satellites to enable broadband telecommunications access. That means "affordable, worldwide, 'fiber-like' broadband Internet access, videoconferencing and high-quality voice," the company's literature reads.

Question is, Will land-based 'fiber-like' access, maybe provided by, uh, fiber, preclude the need for Teledesic services? The betting window is open. RF ntroducing Scorpion™ – the industry's first complete Vector Network Measurement System.

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INFO/CARD 35

Editorial Forum

By Nikki Chandler, Senior Associate Editor

The CDMA wars

In what could be compared to a love affair gone bad, Qualcomm and Motorola are fighting over chipsets and handsets. They started out their relationship in 1990 with good intentions, looking forward to developing and commercializing code division multiple access (CDMA) technology. Motorola agreed to invest in Qualcomm's development of CDMA, and Qualcomm agreed to give Motorola favorable licensing treatment and royalty-sharing rights.

Now Qualcomm claims that Motorola is infringing on its patents, and Motorola says that Qualcomm is infringing on its patents. Who's right? They're both taking advantage of the partnership, in which they both worked to develop CDMA technology. Now, CDMA is the pot of gold, and they're fighting over who found it first. So, they've dragged each other into court, hurtling legalese such as "infringement of patents," "breach of contract," "covenant of good faith" and "fair dealing" at one another. The latest judgment came in Qualcomm's favor, when a San Diego U.S. District Court judge ruled that Qualcomm's Q phone did not infringe on Motorola's patents on the appearance of the Startac phone.

Starting to sound like the movie "War of the Roses"? Both companies are in good positions in the burgeoning CDMA marketplace, and they are obviously trying to keep the upper hand. It is all about money (the root of all evil?), and there doesn't seem to be any kind of truce on the horizon. I just hope they don't spend it all in court, when they could be making substantial advancements to improve communications for the good of society.

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RF calendar

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 14–20 **1999 Engineering Workshops for Electromagnetic Compatibility, Telecommunications & Public Safety**—*Nashua, NH*—Information: Diane Querze, Silent Solutions, 20 Patch Road, Hollis, NH 03049. Tel. 603-465-3920; Fax 603-465-3921

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 Technologies, 9305-D Gerwig Lane, Columbia, MD 21045. Tel. 410-309-7032; e-mail *Lazaroff@lucent.com*.

November 1–4 **DSP World.ICSPAT**—*Orlando*—Information: Miller Freeman. Tel. 415-538-3848; e-mail *dspworld@mfi.com*.

December 5–8 **IEEE International Electron Devices Meeting (IEDM)**—*Washington DC*—Information: 101 Lakeforest Boulevard, Suite 270, Gaithersburg, MD 20877. Tel. 301-527-0900; Fax 301 527-0994; e-mail *pwmahoney@aol.com*.

5–9 **IEEE Global Communications Converence**—*Rio de Janeiro*—Information: Roberto de Marca Cetuc-Puc/Rio, Rua Marques de Sao Vicente 225, Rio De Janeiro, 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**

13–19 **7th International Symposium on Recent Advances in Microwave Technology**—*Malaga, Spain*—Information: Banmali Rawat, Technical Program Co-Chair, Dept. Electrical Engineering/MS 260, University of Nevada, Reno, Nevada 89557-0153. Tel 702-784-6927; Fax 702-784-6627; e-mail *rawat@ee.unr.edu;* Web site **www.is-ramt99.ic.uma.es**

RF courses

UCLA Extension— *Digital Signal Processing Applications in Wireless Communications*—Sep 29–Oct 1; *Optical Fiber Communications: Techniques and Applications*—Oct 12–15; *Integrated Circuit Design for WirelessTransceivers*—Oct 19–22; *Compression for Digital TV*—Oct 20–22; *MEMS for Optical and RF Applications*—Nov 1–3; *Automatic Test Equipment (ATE) Selection, Design and Programing*—Dec 6–7; *Design Testability and Built-in Self Test*—Dec 8–10, 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*—Sep 13–15, Detroit, Sep 21–23, Denver; Nov 3–5, Austin, TX; Nov 8–10, Houston. Information: UMR Continuing Education, Tel 573-341-4132/4200; Fax 573-341-4992.

University of Oxford— *Software Radio*—Sep 16–17; *RF Integration Using Integrated Passive Components and Multichip Modules*—Sep 16–17; *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— *RF and Wireless Engineering*—Oct 25–29, Atlanta. Information: Distance Learning, Continuing Education and Outreach, Georgia Institute of Technology, Atlanta, GA 30332-0385. Tel 404-894-2547.

R.A. Wood Associates—*Introductory RF and Microwaves*—Oct 4–5; *Phase Lock Loops and Frequency Synthesis for Wireless Engineers*—Oct 7–8; *RF Power Amplifiers, Class A thru S–How They operate and When to Use Each*—Oct 4–5, Utica, NY. Information: R.A. Wood Associates, 1001 Broad Street, Suite 450, Utica, NY, 13501. Tel. 315-735-4217; Fax 315-735-4328; e-mail *RAWood@rawood.com;* Web site **www.rawood.com**.

UC Berkeley—*Real-Time Programming for Embedded Systems, An Intensive Introduction*—Sep 21–22, San Francisco; Oct 25–26, Phoenix; Nov 9–10, Los Angeles; *Advanced Real-Time Programming for Embedded Systems*—Sep 23–24, San Francisco; Oct 27–28, Phoenix; Nov 11–12, Los Angeles; *Wireless Communications*—Oct 27–28, San Franciso; *Design for Electromagnetic Compatibility*—Nov 1–2, San Francisco; *Low -Power Circuits and Systems for Digital Wireless Communications*—Nov 11–12, Redwood City, CA Information: UC Berkeley Extension, Engineering. Tel. 510-642-4151; Fax 510-642-6027; e-mail *course@unx.berkeley.edu;* Web site **www.unex.berkeley.edu/eng**.

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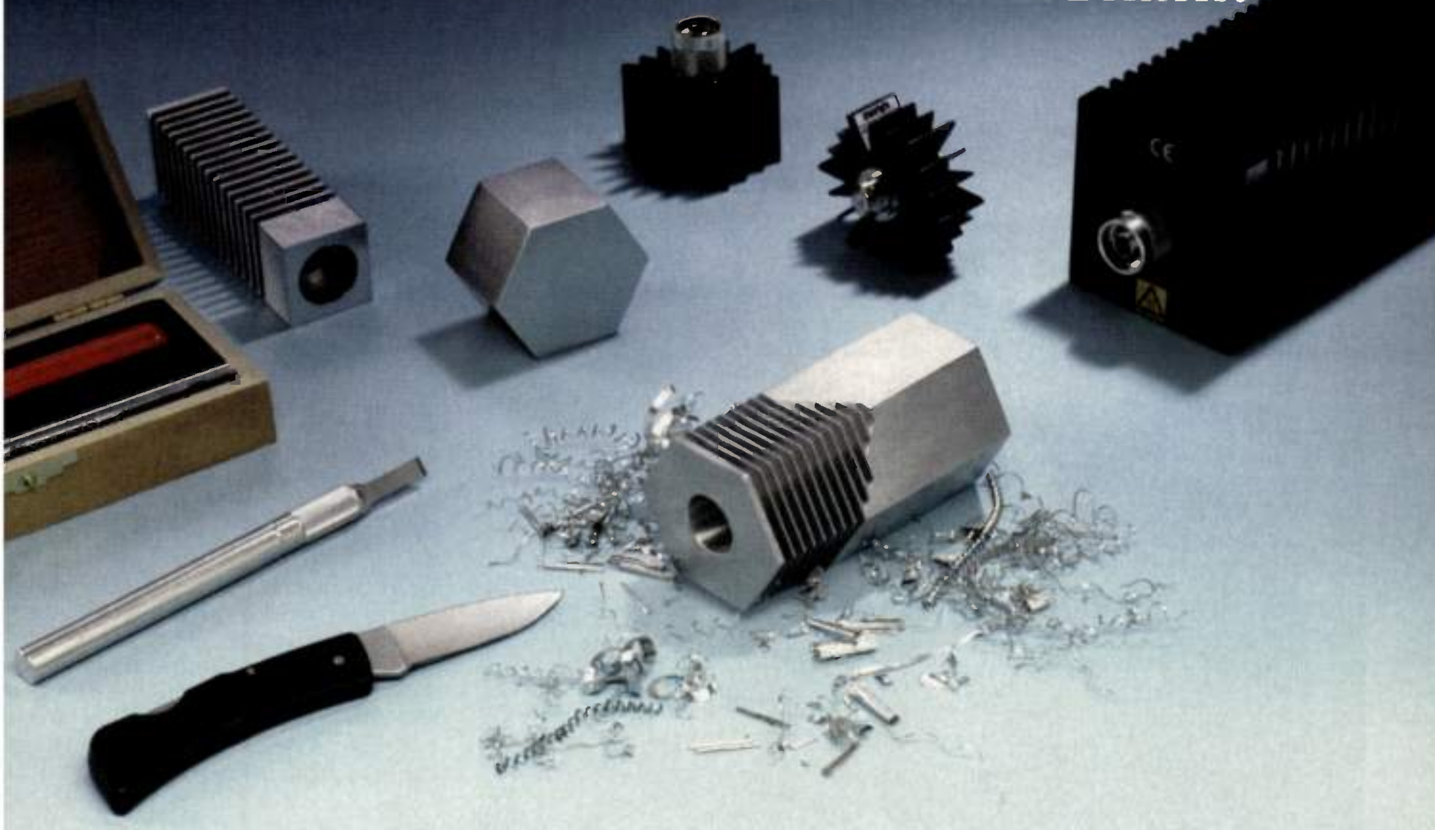

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INFO/CARD 82

GSM sees significant activity

What's been going on in the world of global system for mobile communications (GSM)? Plenty, according to recent announcements. Recent announcements include:

- In mid-August, the GSM Association launched its Associate Membership program for global GSM suppliers and manufacturers. The program's key goal is to enhance cooperation and sharing of information between suppliers and international network operators, thereby delivering increased product, feature and service benefits to global GSM customers. The first eight members, IBM, GTE Telecommunication Services, Mach, Bull CP8, Nera Satcom, IDEA System, Swiss Clearline and DanNet, represent a variety of GSM-related technology.
- GSM calls from aircraft have been simplified with an agreement formed by the GSM Association and SkyPhone to use *TAP (Transferred Account Procedures), the association's world standard mobile call billing protocol. Via special equipment onboard aircraft, GSM customers will soon be able to charge satellite calls that will be billed to their account by their home network. Customers who sign up for the service will use a swipe card that will automatically link call charges to the r mobile phone account.
- The take-up of PCS/GSM digital cellular services in North America continues at a breath-taking pace, according to the GSM Association. U.S. and Canadian PCS networks added 660,000 new subscribers in the second quarter of 1999, pushing total subscriber levels to 4.2 million. The total North American number should top six million subscribers by year-end, according to Bob Stapleton, the newly installed chair of the North American GSM Alliance and president of VoiceStream Wireless.
- In other association news, the GSM Association has appointed Robert G. Conway as its new director general. Conway was formerly head of global business development for Motorola's International Network Ventures Group and served as general counsel for Motorola's Subscriber Terminals Group. The GSM Association is responsible for the development, deployment and evolution of GSM and for promoting GSM open standards.

HP test group undergoes major reorganization

Hewlett-Packard (HP), Palto Alto, CA, has announced a major reorganization of business operations within its automated test group. The effort is being done to bolster its sales and service of test products, services and production-test solutions for the semiconductor industry.

The reorganization will result in four semiconductor test groups: system-on-a-chip (SOC) devices, radio frequency integrated chips (RFICs), memory ICs and semiconductor parametric test (process monitoring).

Also, HP's newly created silicon-systems test division (SSTD) will focus on delivering products for SOC IC designs. SSTD combines HP's Boeblingen semiconductor test division (Germany) with its Hachioji semiconductor division (Japan). The new division will be headquartered in Boeblingen, Germany. The division will develop a series of hybrid SOC test systems, while producing and supporting both product lines.

Harris Semiconductor gets name change

Harris Semiconductor, Palm Bay, FL, will change its name to Intersil when it separates from Harris as part of the previously announced sale. Under its new name, Intersil will operate as a subsidiary of Sterling Holding LLC, a Citicorp Venture Capital investment portfolio company.

According to Gregory Williams, president of Harris Semiconductor, the new name was selected for a number of reasons. "The first half of the new name signals our intention of pursuing Internet-related opportunities," Williams says. "The second half of the Intersil name underscores our legacy in world-class silicon technology."

Home automation networking turning on

The small office home office phenomenon has led to the emergence of the

wired broadband home, according to a new study from Allied Business Intelligence (ABI), Oyster Bay, NY. Although the market has gone virtually unnoticed in the past few years, 1999 marks the beginning of the residential network and home automation system industry's growth period, which will see revenues almost triple from $2.3 billion in 1999 to $6.2 billion in 2004.

The report, *"The Broadband Home:In-Home Networks, Control Subsystems, and Residential Gateways"*, found that Intel and Microsoft will play a crucial role in legitimizing the market with their emphasis on HANS industry stan dards.

The recent entrance of IBM and Be Atlantic has introduced the concept c structured wiring within the home. Th report notes that the prospect of a nev home being properly wired for futuris tic applications will no longer be "high-end adapter's dream" but rathe a common occurrence among residence priced above $100,000.

One of the key factors driving growt is the increase in multiple PC house holds. By 2004, nearly 33% of U households will have more than on computer, up from 15% in 1998. Als driving the industry's growth will b the continued momentum of the Inter net and broadband applications cater ing to the "data-needy", making US res idences truly broadband homes. B 2004, 10.8 million houses will hav broadband access.

For more information contact AB through its Web site a **www.alliedworld.com** or through th *RF Design* Web site a **www.rfdesign.com**.

Boonton Electronics win French military contract—Boonto Electronics, Parsippany, NJ ha received a contract to supply 70 of it model 1130 distortion analyzers to th French army. Total value of the con tract is up to $250,000.

Srico wins U.S. Air Force con tract—Srico, Columbus, OH, has wo a $100,000 contract from the U.S. Ai Force to develop an optical chip-base modulator component that reduces th noise figure of high frequency commu nications systems. The componen may be used for satellite communica tions, wireless and cellular communi cations and other data transmissio systems.

Andrews to support Trito PCS—Andrew, Orland Park, Il ha reached agreement with Triton PCS Malvern, PA, an affiliate of AT&T Wireless Services, for the buildout o Triton PCS' digital wireless network o the east coast. Andrew will suppl coaxial cables and connectors and cabl assemblies.

Decibel Products awarded Chin award—Decibel Products, Beachwood OH, has been awarded a contract t supply a cellular operator in China wit

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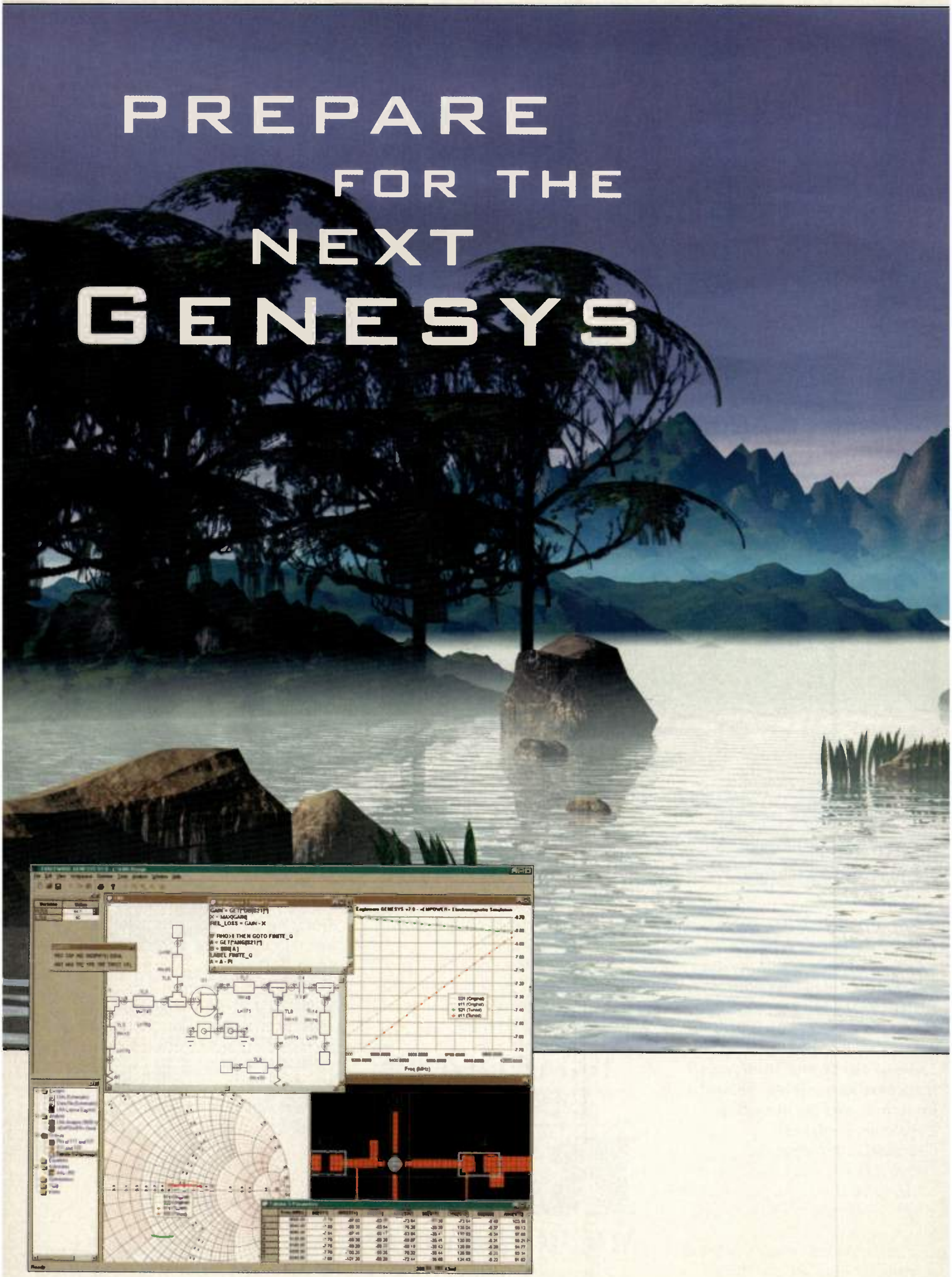
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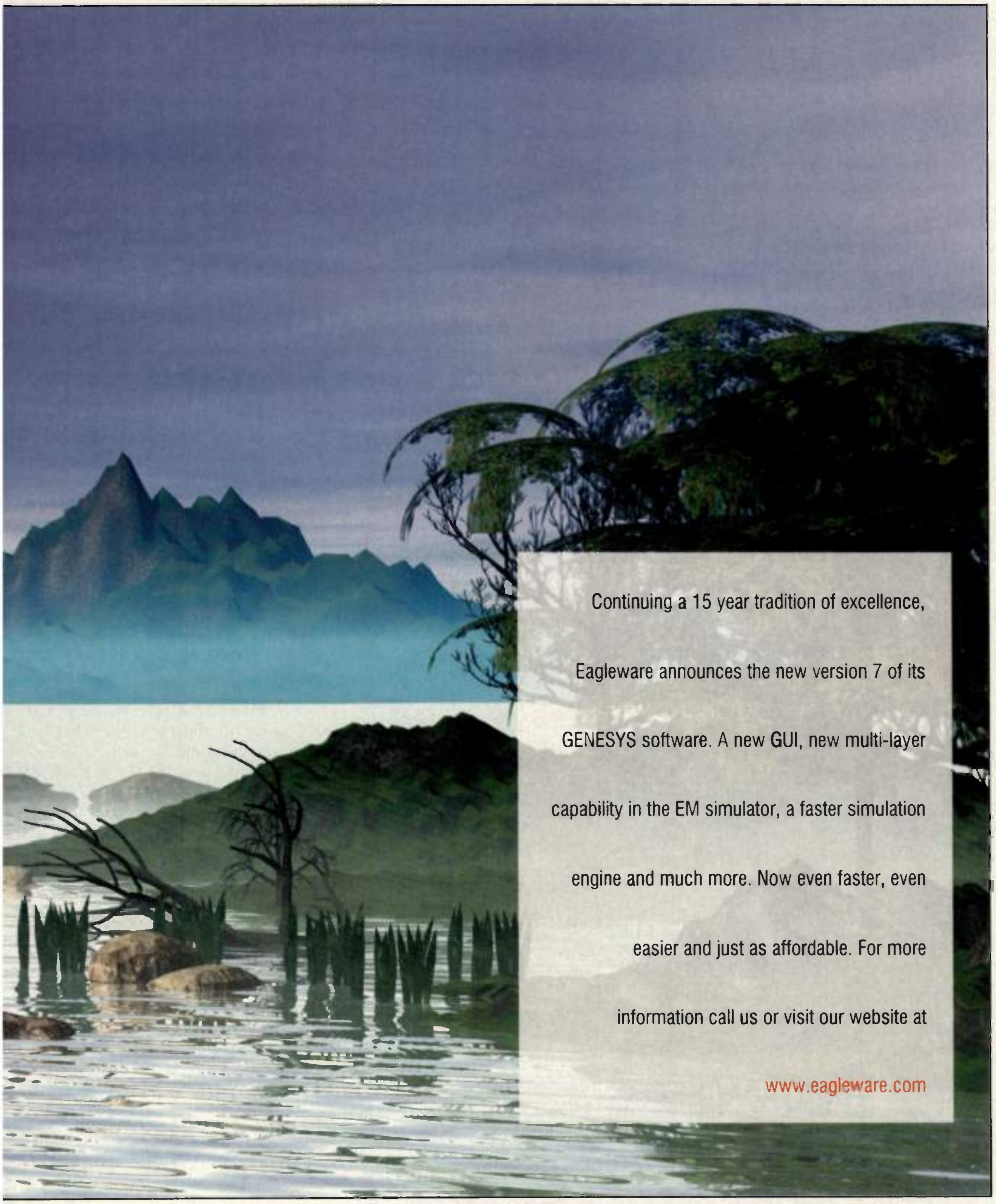
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key components to expand their existing wireless communications system. The contract is valued at $6.6 million.

Anritsu selects Noise Com product—Anritsu Company's microwave Measurement division, Morgan Hill, CA, has selected Noise Com's, Paramus, NJ, NC 346 series broadband calibrated noise source for the new Anritsu MS462X Scorpion vector network measurement system. The Scorpion is being designed to be the first such instrument with the ability to make error-corrected noise figure measurements on active devices used in wireless communications.

Berkeley Varitronics Systems wins Brazilian contract—Berkeley Varitronics Systems, Metuchen, NJ, has been awarded a contract by Procelbras, Brazil, to provide code division multiple access (CDMA) test transmitters.

Business Briefs

Phase Matrix purchases EIP Microwave—Phase Matrix, San Jose, has acquired substantially all of the assets of EIP Microwave, San Jose. The assets include manufacturing rights, intellectual property and inventory of EIP's microwave frequency counter lines.

Stellex Industries acquires Phoenix Microwave—Stellex Industries, Palo Alto, CA, has acquired the privately held RF and microwave component supplier Phoenix Microwave, Telford, PA.

SL Industries acquires Todd Products—SL Industries, Mt. Laurel, NJ has acquired the operating assets of privately-held Todd Products, Brentwood, NY. Todd Products supplies power supplies for data communications and telecommunications.

RF Micro Devices adds fourth product line—RF Micro Devices, Greensboro, NC, has established a fourth product line to further expand the company's cellular components business. The fourth line will focus exclusively on Nokia mobile phones.

Richardson Electronics signs distribution agreement with Siward—Richardson Electronics, LaFox, Il has signed a distribution agreement with Siward International, Taiwan. Richardson will serve as the worldwide distributor of Siward's crystal oscillators.

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RF system issues related to CDMA receiver specifications

A guide to the derivation of the essential RF front-end system level and block level specifications for the receiver section of a CDMA mobile station.

By Walid Y. Ali-Ahmad, Ph.D.

Wireless code division multiple access (CDMA) networks, based upon the IS-95 standard and protocol developed by Qualcomm, are being deployed, worldwide.

The harsh wireless environment, in which these CDMA phones must coexist with other multi-standard mobile phones, impose tough system conditions on the radio. These conditions demand a high performance radio RF front-end and DSP back-end. This is especially applicable when trying to decode the speech information present in a received signal with a carrier-to-interference ration (C/I) < 0 dB. This article, will discuss the minimum RF standards for the CDMA cellular mobile station receiver section. Such standards are described in the TIA/EIA/IS-98-A interim standard document [1]. Understanding these minimum standards allows us to derive minimum measurable RF specifications for the system level and block level performance of a CDMA cellular radio front-end.

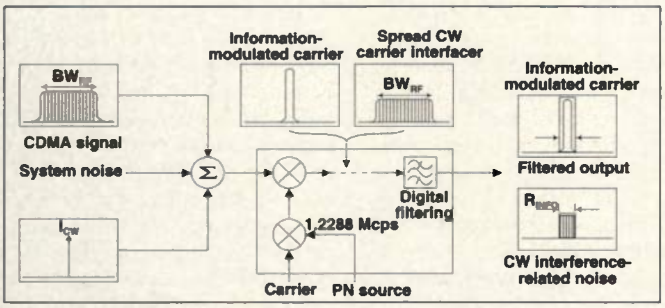

Figure 1. CDMA correlator.

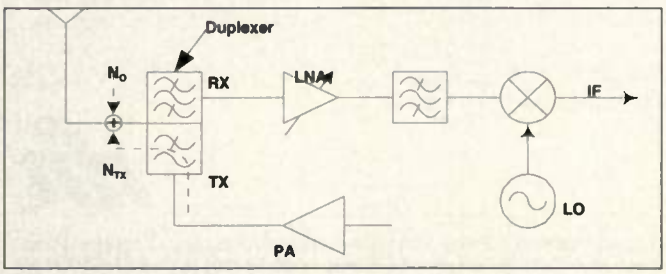

Figure 2. Receiver sensivity.

An Overview of Direct Sequence Spread Spectrum (DSSS)

The advantage of spread spectrum systems is that they provide excellent immunity to interference and allow transmissions to be hidden in background noise. In CDMA systems, which are based on the DSSS technique, the desired information carrier is modulated by a digital code that is represented by a pseudorandom noise (PN) sequence.

The PN code signal is independent of the data, and its data rate is much higher than the desired information data rate. As a result, the digital code signal has a bandwidth much larger than the minimum bandwidth required to transmit the information or the baseband data for a digital system. This act of modulating the information carrier by a digital code with a much larger data rate will result in the spreading of the carrier. This bandwidth can be as large as the code signal bandwidth

The spreading width depends on the particular type of modulation employed. This can be biphase, quadriphase, or minimum shift keying [3, Dixxon]. At the receiver, despreading is accomplished by the cross-correlation of the received spread signal with a synchronized replica of the spreading code.

In a CDMA base station, and on the down link (from base station to mobile station), the information from different users is encoded with a different digital coding signal or PN sequence.

Since these PN sequences are orthogonal to each other, and occupy the same bandwidth, there will be minimum cross-correlation, and hence minimum interference. This, even though different user's spread signals are multiplexed on top of each other at the base station's transmitter section.

The basics

In any CDMA system design, the most commonly used quantity in describing or specifying this system is that of "processing gain". (Gp)

Figure 1 shows a block diagram of the baseband of a CDMA correlator or despreader. A CDMA system develops its processing gain through the spreading and despreading operation of the information carrier signal. The CDMA signal, after being downconverted to baseband, is fed to the input of the CDMA correlator along with other interfering signals. When the correlator PN sequence matches the PN sequence embedded in the CDMA signal, the desired information signal collapses to its original unspread bandwidth. Any unmatched input signals (receiver noise, CW jamming signal, or other CDMA signals not code synchronised) are spread to a bandwidth equal to the PN coding sequence bandwidth.

The digital filter, which follows the despreader and has bandwidth equal to the information bandwidth only, lets through only a section of the spread interference signal spectrum, but completely selects the desired information. As a result, the interference level at the correlator output, I_{corr_out} is reduced, compared to interference level at the correlator input, I_{corr_in} by the ratio of the CDMA system transmission bandwidth BW_{RF} to the desired baseband data information rate, R_{info}. Also, the carrier-to-interference ratio at

correlator output, $(C/I)_{corr\_out}$, is increased, compared to, $(C/I)_{corr\_in}$ at the correlator input, by the ratio of BW_{RF} to BW_{INFO}. Hence, this ratio is called processing gain (Gp) and is given as: (1)

$$Gp = \frac{BW_{RF}}{R_{INFO}}$$

Where: (2)

$$I_{corr\_out} = \frac{I_{corr\_in}}{G_p}$$

and: (3)

$$(C/I)_{corr\_out} = (C/I)_{corr\_in} \bullet G_p$$

Since the correlator output, after filtering, and the carrier and interference have the same bandwidth, we can write the following: (4)

$$(C/I)_{corr\_out} = \frac{E_b \bullet R_{INFO}}{N_t \bullet R_{INFO}} = \frac{E_b}{N_t}$$

It follows that: (5)

$$\frac{E_b}{N_t} = \left(\frac{C}{I}\right)_{in} \bullet G_p$$

E_b/N_t is defined as the ratio of average energy per information bit to the effective noise power density at the correlator output. The noise power density actually consists of both thermal noise and interference from other jamming sources. With spread spectrum systems, interference is transformed into noise in the despreader. The term "jamming margin" (M_j) is used, which expresses the capability of a CDMA system to perform in the presence of jamming interference. M_j takes into account the required E_b/N_t for a particular modulation and coding scheme utilized in the system, and allows for system implementation losses (Lsys), [3]: (6)

$$M_j = G_p - \left[L_{sys} + \frac{E_b}{N_t}\right]$$

Furthemore, it is important to discuss the reaction of a direct sequence spread spectrum system to a single-frequency CW interference.

At first glance, we might consider that a CDMA system would be most affected by other CDMA interference. However, in most cases, this is not true. It is only true when there is high correlation between the interfering CDMA signal and the desired CDMA signal. This is because that the wider the bandwidth of the input interference, the wider the signal at the despreader output. As a result, the interference power density at the correlator output is lower. Therefore, less power falls in the correlator output digital filter, and lessens the effect of the CDMA interfering signal on the system perfor mance. Consequently, we can predic that the most effective interference to a CDMA system is a narrow band signal such as a CW single tone. This is because the power density in the corre lator output, from a CW carrier, is high er than from wide band signals.

The CDMA equation

The remainder of this article wil concentrate on derivations on the re ceiver performance related to th Forward traffic channel. This is be cause one traffic channel transports a single user traffic information, mainly the encoded speech information.

The forward CDMA channel, from the base station to the mobile station contains one or more code channels These are transmitted on the same CDMA frequency assignment and share a common pilot PN code phase o offset, related to base station or cel sector assignment. These code channel consist of a pilot channel, up to one Sync channel, up to seven paging chan nels, and up to 63 traffic channels Even though these channels share the same base station pilot PN code offset they are distinguished at the mobile station receiver by a set of 64 binary or thogonal PN codes based on Walsh functions.

The full speech information rate R_{INFO}, at the output of the mobile sta tion vocoder is 9600 bps. The speech in formation transmitted is convolution ally encoded to provide the capability o error detection and correction at the re ceiver. It is also interleaved to comba fast fading, and scrambled for privacy Next, the encoded, interleaved, and scrambled symbols of a single use traffic channel are binary phase shif keying (BPSK) modulated by an as signed orthogonal Walsh code and then quadrature phase shift keying (QPSK modulated by a pair of base station PN codes. The final data rate of a single user traffic channel is equal to the chip ping rate of 1.2288 Mcps. At the outpu of a base station/sector transmitter, al traffic channels along with pilot, sync and paging channels are multiplexed on top of each other, and assigned the same radio channel frequency. The power in each user's traffic channe represents a fraction of the total powe of the forward CDMA channel. After being bandlimited by a digital filter the 3 dB bandwidth, BW_{RF}, of a CDMA carrier or forward channel is 1.23 MHz

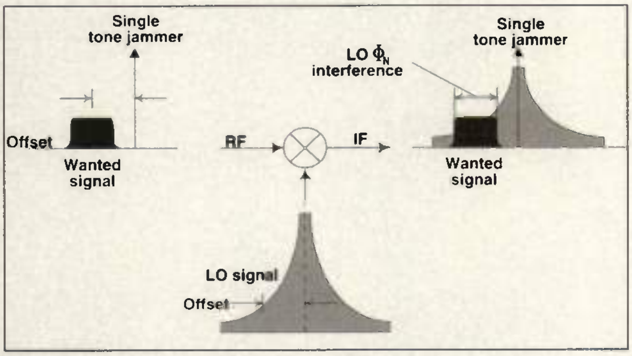

Figure 3. Reciprocal mixing phenomena.

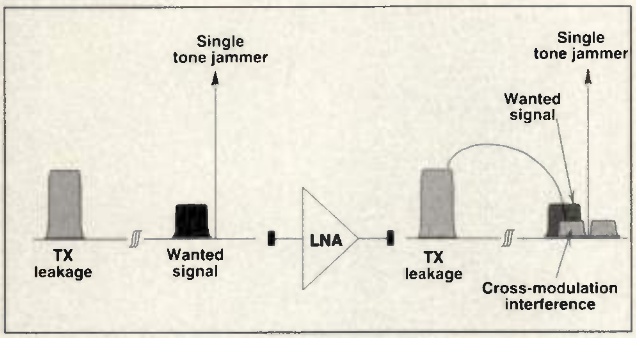

Figure 4. Cross-modulation phenomena.

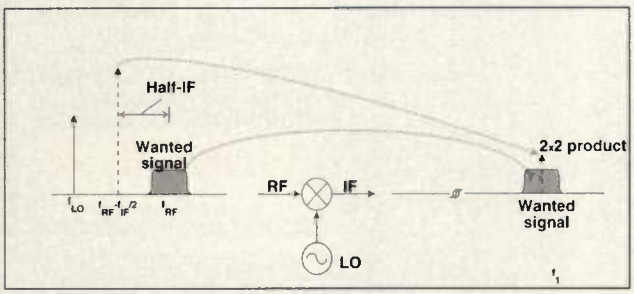

Figure 5. ½ IF mixer spurious product.

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ERA-3	DC-3000	20.8	12.1	3.8	23.0	35	2.10
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ERA-1 ERA-1SM
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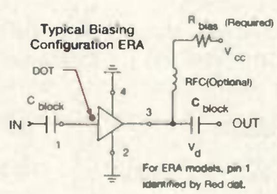

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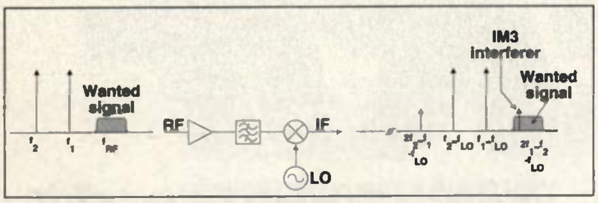

Figure 6. Third-order intermodulation products in a receiver.

In the case of a forward CDMA channel incident on the mobile station through a single-path, we can define the received spectral power of the forward channel. This is measured at the mobile station's antenna connector and is defined at 1.23 MHz (BW_{RF}) as $\hat{I}_{or}$. The transmitted power spectral density of the forward CDMA channel, measured at the base station antenna connector, is defined as I_{or}. Therefore, since a single traffic channel power represents a fraction of a forward CDMA channel power, the ratio of the average transmit energy per PN chip for the forward traffic channel to the total transmit forward channel power spectral density can be written as:

$$\frac{\text{Traffic } E_c}{I_{or}}$$

Recall that at the receiver's despreader output, the interference effect of CW carriers and other wideband jamming signals is equivalent to that of a band-limited white noise source. Hence, we can denote I_{oc} as the power spectral density of a band-limited white Gaussian noise source simulating receiver thermal noise, CW jamming signals, and other CDMA interfering signals. Note that CDMA traffic channels in the same cell are not considered as wideband interfering signals. This is due to their PN Walsh codes, theoretically, being orthogonal to each other.

The received forward CDMA channel at the mobile station antenna is filtered, amplified, downconverted, and demodulated in the receiver analog front-end. After clock recovery through the pilot channel and frame synchronization through the sync. channel, the assigned forward traffic channel to the user or mobile station is decoded in the receiver modem section. Based on equation (5), we can write:

$$\frac{\text{Traffic } E_b}{N_t} = \left(\frac{C}{I}\right)_{in} \bullet G_p$$

Note that:

$$\frac{\text{Traffic } E_b}{N_t}$$

is defined as the ratio of average energy per information bit in the Traffic channel to the effective noise power density at the correlator output. From previous definitions, the received single user forward traffic channel power spectral density is calculated as:

$$C_{in} = \frac{\text{Traffic } E_c}{I_{or}} \bullet \hat{I}_{or}$$

As a result, the receiver CDMA equation for a single user forward traffic channel can be written as:

$$\text{Traffic}\frac{E_b}{N_t} = \frac{\frac{\text{Traffic } E_c}{I_{or}} \bullet \hat{I}_{or}}{I_{oc}} \bullet G_p$$

It follows that: (7)

$$\text{Traffic}\frac{E_b}{N_t} = \frac{\frac{\text{Traffic } E_c}{I_{or}} \bullet G_p}{\frac{I_{oc}}{\hat{I}_{or}}}$$

CDMA receiver sensitivity and dynamic range

In the IS-98-A interim standard, the RF receiver sensitivity of the CDMA cellular mobile station is defined at the mobile station antenna connector (see Table 1). It is equal to the minimum received forward CDMA channel power, $\hat{I}_{or}$, at which the receiver's frame error rate (FER) does not exceed 0.5%. In a CDMA system, a frame has a basic timing interval of 20 ms. and consists of the information on the traffic channel (voice or data), the access channel, and the paging channel. The information link between base station and mobile station is established on a frame-by-frame basis. Therefore, the CDMA mobile station receiver performance is evaluated on the basis of FERs.

Test 1 specifies the minimum required sensitivity for the received forward CDMA channel as equal to –104 dBm. As discussed in previous section, the ratio:

$$\frac{\text{Traffic } E_c}{I_{or}}$$

specifies the power level of a single-bearer traffic channel relative to the total power level of the forward CDMA channel, in which the traffic channel is embedded. From Test 1 specifications, we can deduce that the minimum required receiver sensitivity for a single-bearer traffic channel is:

$$\hat{I}_{or} \bullet \frac{\text{Traffic } E_c}{I_{or}}$$

which is equal to –119.6 dBm (calculating in dB). For such sensitivity, the receiver FER will be ≤ 0.5%. In order to use the CDMA equation (equation 7), we need to find the corresponding:

$$\text{Traffic}\frac{E_b}{N_t}$$

in order to achieve a FER ≤ 0.5%. In the receiver sensitivity case, there are two sources of interference that are purely white Gaussian noise, the receiver's input referred thermal noise power spectral density N_o, and the transmitter's thermal noise power spectral density in the receive frequency band, N_{TX} (see Figure 2). N_o is determined by the receiver's noise figure (NF), and N_{TX} is determined by the amount of transmitter's output thermal noise leaking to the mobile station receiver's input through the duplexer. The IS-98-A standard specifies that the minimum:

$$\text{Traffic}\frac{E_b}{N_t}$$

that is required for a 0.5% FER should be ≥ 4.5 dB, assuming a full speech information rate of 9600 bps, using BPSK data modulation (Table 9.3.3.3-1 in [1]). A typical PA output thermal noise power spectral density in the receive frequency band is -135 dBm/Hz. Assuming a minimum -43 dB attenuation through the duplexer from TX to antenna input in the receive band, N_{TX} can be calculated as -178 dBm/Hz at the mobile station antenna connector. If we add 2 dB of margin to the required:

$$\text{Traffic}\frac{E_b}{N_t}$$

this improves the minimum required receiver sensitivity from –104 dBm to –106 dBm. Using CDMA equation (7)

Parameter	Units	Test 1	Test 2
$\hat{I}_{or}$	dBm/1.23MHz	-104	-25
$\frac{\text{Traffic } E_c}{I_{or}}$	dB	-15.6	

Table 1. Minimum Requirements for Receiver Sensitivity and Dynamic Range

in dB, we can write: (8)

$$\text{Traffic}\frac{E_b}{N_t}=\frac{\text{Traffic }E_c}{I_{or}}+10\log\frac{BW_{RF}}{R_{INFO}}+\hat{I}_{or}-I_{oc}$$

Knowing that:

$$\text{Traffic}\frac{E_b}{N_t}$$

≥ 6.5 dB

and:

$$\frac{\text{Traffic }E_c}{I_{or}}$$

= -15.6 dB

and:

$$G_p=10\log\frac{BW_{RF}}{R_{INFO}}=10\log\frac{1.2288\text{ Mcps}}{9600\text{ bps}}=10\log(128)=21.1\text{ dB}$$

and: $\hat{I}_{or}$ = –104 dBm, we deduce from (8) that ≤ –105 dBm (in 1.23MHz). Since we know that this equivalent white noise interference source, I_{oc}, consists of receiver's thermal noise and transmitter's thermal noise in the receive band, we can write, in linear form: (9)

$$I_{oc}=(N_o+N_{TX})\bullet BW_{RF}$$

We deduce that N_o should not exceed –166.2 dBm/Hz. We know that the receiver thermal noise power spectral density (in 1 Hz BW) can be written, in linear form, as N_o=K*T_o*NF_{RX} (10). If we write equation 10 in dB, we can also solve for receiver noise figure (NF_{RX}) as:

$$NF_{RX}(dB)=N_o-10\log(K\bullet T_o)=N_o-(-174\text{ dBm/Hz})$$

As, for the required sensitivity, we calculated that N_o ≤ -166.2 dBm/Hz. As a result, the required CDMA mobile station receiver noise figure (NFRX) should not exceed 7.8 dB in order to meet the minimum required sensitivity, specified in test 1 of table 1, with 2 dB of margin.

Test 2 of Table 1 specifies the high end of the CDMA receiver minimum dynamic range, (FER ≤ 0.5%), as measured at the mobile station antenna connector. In the actual mobile station design, the receiver is designed to handle a received forward CDMA channel power level higher than the one specified in the standards document.

Test 1 and Test 2 defines a minimum dynamic range of 81 dB (-104 dBm -25 dBm). Since the information data in a CDMA system is bi-phase modulated, the resultant modulated signal envelope is non-constant (a typical peak-to-average ratio for a forward CDMA channel is 10dB). As a result, for proper received signal detection and demodulation, the mobile station receiver should stay linear under the allowable received signal input power range. A typical CDMA mobile station receiver, designed for a 90 dB dynamic range, will have a gain control of over 90 dB. In a typical CDMA receiver design, the mixer input 1-dB compression point is the main system limiter, from a linearity point of view, for high level received signals (-30 dbm to -20 dBm).

In order to resolve this problem and for practical mixer design, the front-end LNA needs to have either a linear gain control over 15 dB of range or a low-gain mode with a gain reduction between 15 dB to 20 dB step.

CDMA receiver single tone desensitization

As defined in the IS-98-A standard, the single tone desensitization is a measure of the receiver's ability to receive a CDMA signal, at its assigned channel frequency, in the presence of a single tone spaced at a given offset frequency from the CDMA signal center frequency (Table 2).

Under the conditions set in Table 2, the receiver (FER) should not exceed 1%. The IS-98-A standard specifies that at the receiver's correlator output, the minimum

$$\text{Traffic}\ \frac{E_b}{N_t}$$

that is required for a 1% FER should be ≥ 4.3 dB, assuming a full speech information rate of 9600 bps and using BPSK data modulation (Table 9.3.3.3-1 in [1]).

As was done for the receiver sensitivity case, a 1.5 dB margin is added to the required:

$$\text{Traffic}\ \frac{E_b}{N_t}$$

for optimum receiver performance.

Using test parameters specified in table II and knowing that

$$\text{Traffic}\ \frac{E_b}{N_t}$$

≥ 5.8 dB, we can use equation (8) to calculate the allowable I_{oc}. This represents the power in 1.23MHz of a band-limited white noise source simulating interference at mobile station antenna connector. The equivalent white noise interference source, I_{oc} consists of the receiver's thermal noise (N_o), the transmitter's thermal noise in the receiver band (N_{TX}), and the equivalent in-band interference component due to the single-tone jammer (I_{st}). Hence, we can write, in linear form, $I_{oc}=I_{st}+(N_o+N_{TX})lBW_{RF}$ (11). The resulting I_{oc} should be ≤ 101.3 dBm (in 1.23MHz BWRF). N_o is set by the receiver noise figure for received low CDMA signal levels.

If we choose NF_{RX} equal to 7.8 dB as calculated previously, this sets N_o to -166.2 dBm/Hz (equation 10). N_{TX} is equal to -178 dBm/Hz, as defined in previous section. From equation (11), we deduce that I_{st} ≤ -103.7 dBm/1.23MHz.

Note that I_{st} is the equivalent interference level referred to the receiver's input due to single-tone jammer. The single-tone interferer normally comes from nearby analog cellular base stations, which transmit narrowband AMPS signals (30kHz BW, compared to CDMA signals with 1230kHz BW). Inside the mobile station receiver front-end, the single-tone jammer generates two interfering components, whose levels add up to I_{st}, when referred to the receiver's input,

As seen in figure 3, the first interference component caused by the single-tone jammer results from the reciprocal mixing phenomena. It is denoted by I_{RMXG}. It occurs when the forward received CDMA channel signal suffers from interference due to receiver UHF VCO phase noise (Φ_N) mixing with the single tone jammer and getting down-converted to IF. This noise is defined at the frequency offset, equal to the wanted signal to single tone jammer frequency separation [4].

The second interference component caused by the single-tone jammer results from the cross-modulation phenomena (Figure 4); it is denoted by I_{XMOD}. It occurs when the envelope modulation of the transmit TX power leakage, from the power amplifier output to the receiver LNA input through duplexer isolation, gets cross-modulated on the single-tone jammer in the receiver's front-end 3rd-order non-linearities. The problem occurs mainly in the front-end low noise amplifier (LNA), assuming that the BPF that follows the LNA filters out the TX leakage signal. Cross-modulation in the LNA will generate an in-band interference to the received forward CDMA channel signal, at the LNA output [4,5].

Table 2 calls for a frequency offset of 900kHz between the single tone jammer frequency and the CDMA signal center frequency. A ultra high

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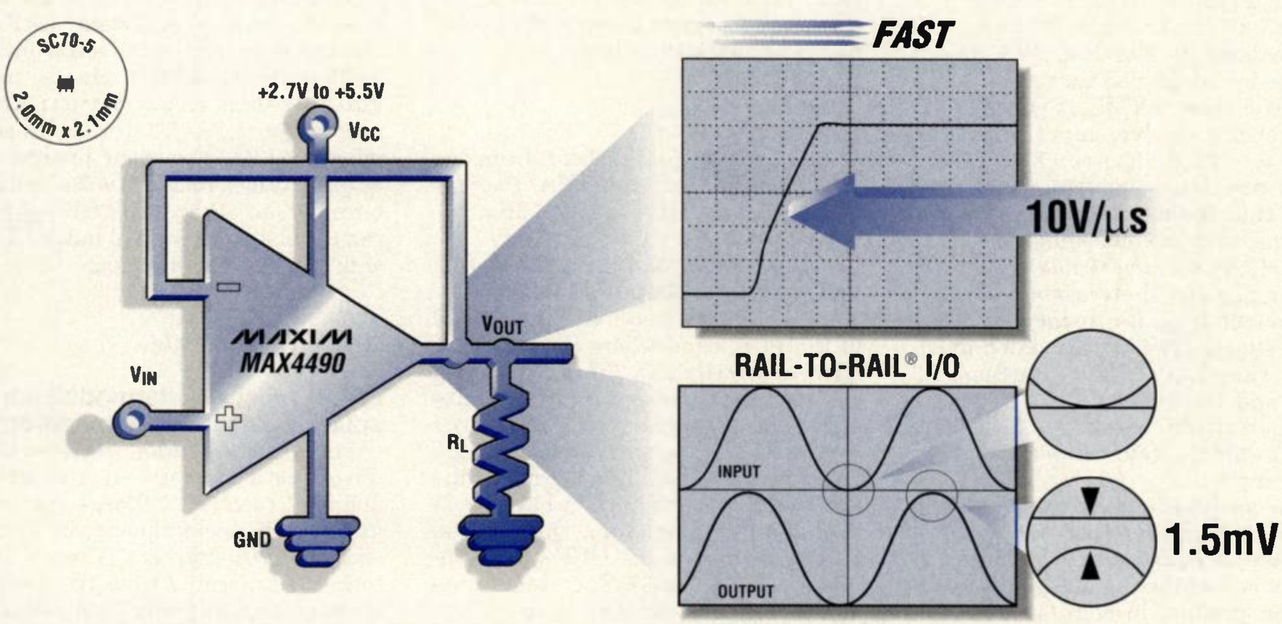

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frequency (UHF) voltage controlled oscillator (VCO) used for CDMA mobile station radios has a typical phase noise of -137 dBc/Hz at 900 kHz offset. The reciprocal mixing interference component I_{RMXG}, referred to receiver input is $I_{RMXG}=P_{st}+\Delta\Phi_N$ (12), where $\Delta\Phi_N$ is the integrated phase noise, in dBc, over 1.23MHz centered at 900 kHz [4]. Assuming that the VCO phase noise follows a typical $1/f^2$ characteristic over the 285 kHz to 1515 kHz frequency offsets (outside the PLL loop BW), we can deduce by integration that $\Delta\Phi_N$ = -75.6 dBc. We know that P_{st} is equal to -30 dBm at the receiver input, therefore I_{RMXG} = –105.6 dBm (in 1.23 MHz). From previous discussion, we also know that the referred input interference due to single tone jammer, I_{st}, consists of the reciprocal mixing component I_{RMXG} and the cross-modulation component I_{XMOD} (in linear form, $I_{st} = I_{RMXG} + I_{XMOD}$). Having calculated previously that I_{RMXG} = –105.6 dBm/1.23 MHz and Ist ≤ –103.7 dBm/1.23MHz, we conclude that I_{st} ≤–108.2 dBm/1.23MHz (referrenced to the receiver input).

The cross-modulation phenomena in CDMA systems has been simulated in [6], and an equation has been generated in order to estimate the cross-modulation product in cellular and PCS CDMA systems.

For a cellular CDMA system and assuming that all cross-modulation happens in the LNA, we can calculate that the cross-modulation component referred to LNA input as: (13)

$$I_{XMOD\_LNA}(dBm) = 2 \bullet P_{TX} + P_{st\_LNA} - 2 \bullet IIP_{3\_LNA} - 3$$

P_{TX} is the transmit leakage power level at LNA input and IIP_{3_LNA} is the LNA 3rd order input intercept point. As we can see from this equation, it is similar to the 3rd order intermodulation products equation with the -3 dB factor at the end. This is due to the fact that half of the cross-modulation products occur in-band and the other half occurs out-of-band.

In CDMA systems, the power amplifier output power is +28 dBm when the mobile station is receiving close proximity CDMA signals. A typical RX-TX duplexer isolation is -58 dB, resulting in a P_{TX} at the LNA input of -30 dBm. The single tone jammer level at LNA input, P_{st_LNA}, is equal to -33 dBm, assuming a typical -3 dB duplexer insertion loss. Also, as calculated earlier, the cross-modulation product level, when referred to LNA input, I_{XMOD_LNA}, should not exceed -111.2 dBm/1.23MHz in order for the receiver to meet the required performance at correlator output:

$$\text{Traffic } \frac{E_b}{N_t}$$

≥ 5.8 dB. We then deduce, from the last equation, that the LNA 3rd order input intercept, IIP_{3_LNA} ≥ +7.6 dBm.

CDMA receiver desensitization to ½-IF spurious response

In some CDMA systems, especially in the PCS, band where the receiver's RF bandwidth is 60 MHz wide, choosing a low IF receiver frequency can result in the ½-IF spurious problem. This occurs when a single tone jammer, which is lying inside the receiver RF bandwidth, is halfway in the frequency between the desired CDMA signal and the UHF local oscillator (see Figure 5). The single tone jammer will be down-converted to IF in the (2x2) mixer spurious product, which acts as an in-band interferer to the wanted signal at the IF output [4, Razavi].

In this case the equivalent white noise interference source, I_{oc}, consists of receiver's thermal noise (N_o), transmitter's thermal noise in the receiver band (N_{TX}), and equivalent in-band interference component due to ½-IF spurious mixer product (I_{st}). This is valid because the desired CDMA signal is only 3 dB above the minimum receiver sensitivity level. If we follow the same calculation methodology used in the previous section (for cross-modulation and reciprocal mixing) and assume a 1 dB margin for:

$$\text{Traffic } \frac{E_b}{N_t}$$

≥ 5.3 dB), we can deduce that I_{st} ≤ -102.9 dBm/1.23MHz. Note that I_{st} is the equivalent interference level referred to the receiver's input due to single-tone jammer.

A typical cascaded gain between antenna connector to mixer input is equal 7 dB. As a result, the single-tone level at mixer input P_{st_MXR} is equal to -23 dBm. Also, the required equivalent ½-IF spurious product level at the mixer input is ≤ -95.9 dBm/1.23MHz. Hence, in the mixer, we need a (2x2) spurious product suppression $\Delta_{½-IF}$ ≥ 73 dBc. In an active mixer, the (2x2) spurious product suppression can be related the 2nd order intercept point of the mixer (IIP_{2_MXR}). We can calculate the required mixer IIP_{2_MXR} with the following equation:

$$IIP_{2\_MXR} = P_{st\_MXR} + \Delta_{1/2-IF}$$

$$= IIP_{2\_MXR} \geq +50 \text{ dBm } [7].$$

CDMA receiver intermodulation spurious response attenuation

The intermodulation response attenuation is a measure of a receiver's ability to receive a CDMA signal on its assigned channel frequency in the presence of two interfering CW tones. These tone are separated from the assigned channel frequency and from each other such that the 3rd-order intermodulation product of the two interfering CW tones, which occurs in the receiver's odd order non-linearities, produces an in-band interfering signal to the desired CDMA signal (Figure 6). IS-98-A standard calls for three test cases of different two-tone levels and desired CDMA signal level, under which the receiver FER should not exceed 1%. It is valid to assume that in all these test cases that the receiver 3rd-order nonlinearity is the most dominant source of 3rd-order intermodulation products [4,7].

This article will only derive the required receiver 3rd order input (IIP_3) for the small two-tone level and large two-tone level cases. The reader is encouraged to follow the same calculation methodology to derive the receiver IIP_3 for the medium two-tone level case.

In both test cases, the two-tone frequency separation is 800 kHz and the closest CW interfering tone is either 900 kHz above or 900 kHz below the CDMA signal center frequency. As a result, the 3rd-order intermodulation product will be in the desired CDMA

Parameter	Units	Test 1	Test 2
Tone offset from Carrier	kHz	-900	+900
Tone Power (Pst)	dBm	-30	
I_{or}	dBm/1.23MHz	-101	
$\text{Traffic } \frac{E_c}{I_{or}}$	dB	-15.6	

Table 2. Minimum requirements for single tone desensitization.

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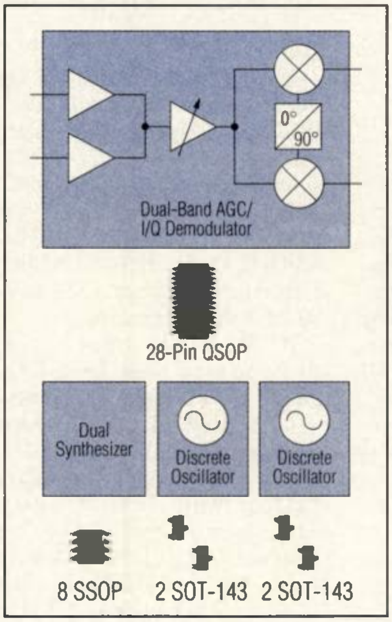

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signal band, either 100 kHz above or 100 kHz below the signal center frequency, respectively.

In the small two-tone level's case, the equivalent white noise interference source consists of the receiver's thermal noise (N_o), the transmitter's thermal noise in the receiver band (N_{TX}), and equivalent in-band interference component due to 3rd-order intermodulation product (I_{IM3}). If we follow the same calculation methodology used in the previous section (for cross-modulation and reciprocal mixing) and assume a 1.5 dB margin for required

$$\text{Traffic } \frac{E_b}{N_t}$$

$\geq$ 5.8 dB, we can calculate that I_{oc} should not exceed -101.3 dBm (in 1.23MHz BWRF). We can write, in linear form: (14)

$$I_{oc} = I_{IM3} + (N_o + N_{TX}) \bullet BW_{RF}$$

In the small two-tone level case, the CDMA desired signal level is only 3 dB above the minimum receiver sensitivity level. Hence, we can assume that N_o is set by the receiver noise figure. If we choose N_{FRX} equal to 7.8 dB, this sets N_o to -166.2 dBm/Hz (equation 10). N_{TX} is equal to -178 dBm/Hz, also as defined in the previous section. From equasion 14, we deduce that

$I_{IM3} \leq$ -103.7 dBm/1.23MHz, referrenced to the receiver's input. Knowing that $P_{st1}=P_{st2}$=-43 dBm, the 3rd-order intermodulation spurious response attenuation $\Delta_{IM3} \geq$ 60.7 dB. The receiver input IP3 is calculated with the following equation: (15)

$$IIP(dBm) = P_{st} + \frac{\Delta_{IM3}}{2}$$

The required receiver Input IP3 should be $\geq$ -12.7 dBm, for the small two-tone level case.

In the large two-tone level's case, the equivalent white noise interference source is totally dictated by the equivalent in-band interference component due to 3rd-order intermodulation product (I_{IM3}). This is because the desired CDMA signal level is 25 dB above the minimum receiver sensitivity level. Similarly, if we assume a 1.5 dB margin for

$$\text{Traffic } \frac{E_b}{N_t}$$

$\geq$ 5.8 dB,

we can calculate that I_{IM3}, which is equal to I_{oc}, should not exceed -79.3 dBm/1.23MHz, referred to the receiver input ($\hat{I}_{or} \leq$ 79 dBm in this case). Knowing that $P_{st1} = P_{st2}$ = -21 dBm, the 3rd-order intermodulation spurious response attenuation $\Delta_{IM3} \geq$ 58.3 dB. The required receiver input, IP3 should exceed $\geq$ +8.15 dBm, for the large two-tone level case.

The previous two-tone level test cases indicate that the CDMA receiver needs to have a minimum of two different linearity modes. As discussed in the receiver dynamic range section, this is achieved by using either a stepped gain LNA or a variable gain LNA.

Parameter	Units	Test 1	Test 2
Tone 1 offset from Carrier	kHz	-900	+900
Tone 1 Power (Pst1)	dBm	-43	
Tone 2 offset from Carrier	kHz	-1700	+1700
Tone Power (Pst2)	dBm	-43	
I_{or}	dBm/1.23MHz	-101	
$\frac{\text{Traffic } E_c}{I_{or}}$	dB	-15.6	

Table 3. Minimum requirements for intermodulation spurious response attenuation (Small two-tone level).

Parameter	Units	Test 1	Test 2
Tone 1 offset from Carrier	kHz	-900	+900
Tone 1 Power (Pst1)	dBm	-21	
Tone 2 offset from Carrier	kHz	-1700	+1700
Tone Power (Pst2)	dBm	-21	
$\hat{I}_{or}$	dBm/1.23MHz	-79	
$\frac{\text{Traffic } E_c}{I_{or}}$	dB	-15.6	

Table 4. Minimum requirements for intermodulation spurious response attenuation (Large two-tone level).

Summary

A thorough understanding of system level and block level specifications, based on the IS-98-A CDMA standard, is essential for designing a high performance CDMA mobile station receiver.

RF system issues related to CDMA receivers, like reciprocal mixing, cross-modulation, and ½-IF spurious response need to be considered in any CDMA receiver's system design.

It is hoped that the reader will be able to apply the theory and concepts developed in this article, to aid them in efficiently developing practical systems.

RF

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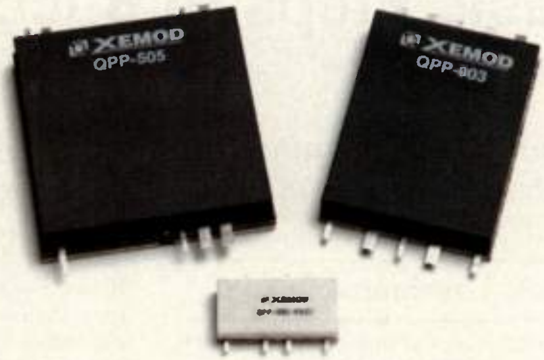

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Basic Steps to Successful EMC Design

Solid design techniques and common sense are your best tools to reduce the effects of electrical and thermal stresses on electronic systems.

By V. Lakshminarayanan

The effects of electromagnetic interference (EMI), electrostatic discharge (ESD) and thermal stresses have become important areas of interest to electronic system designers. EMI, ESD and thermal stresses constitute some of the major causes of failure of electronic systems. The advent of small size portable appliances, switching power supplies, wireless transmitters and receivers, high speed semiconductor devices, etc., has created the need for solving the electrical environmental pollution caused by EMI. The increasing trend towards miniaturization in electronics has heightened concerns over ESD induced failures of electronic devices, and thermal design of compact packages to avoid thermal overstress failures. This article will address some of these issues, how to deal with them and how to increase product reliability.

Some EMI/ESD background

EMI is generated wherever there are quick changing electric and magnetic fields. Fluorescent lights, electric motors, medical equipment, domestic appliances such as shavers, mixers, ovens, automobile ignition circuits, etc. are all familiar sources of EMI. Further, EMI may not necessarily be man-made. Lightning discharges, for example, are major sources of EMI.

Every year thousands of electronic and telecommunications systems suffer damage due to lightning generated EMI. While much EMI is a source of nuisance, it can also cause major damage in a critical applications such as life support systems. For example, the electronics in a pacemaker could fatally malfunction under the influence of strong EMI or an electronically guided missile could go off track if EMI corrupts the signals to it. EMI also jams communication transmitters and disrupts communications links. Thusly, the potential losses arising from EMI make EMI control a necessity.

Electrostatic discharge is generated by friction between two surfaces, which causes a voltage difference between them. The static voltage can reach levels as high as 20KV under dry conditions. ESD can be considered as a lightning discharge on a smaller scale. Even a simple event such as walking on a synthetic carpet can induce several kilovolts of static electricity in the human body. When such an electrically charged person comes into contact with a conducting surface, a short duration high current discharge occurs. This ESD discharge generates high levels of RF interference (RFI) that contain spectral components covering a wide frequency range. Apart from the direct device damage caused by ESD, the smaller device geometry and surface mount devices (SMD) technology has increased the propensity for ESD damage due to the thinner device layers involved. The problem of ESD damage to electronic components will increase over the years unless appropriate awareness is applied at the design, fabrication, assembly and handling stages of the components.

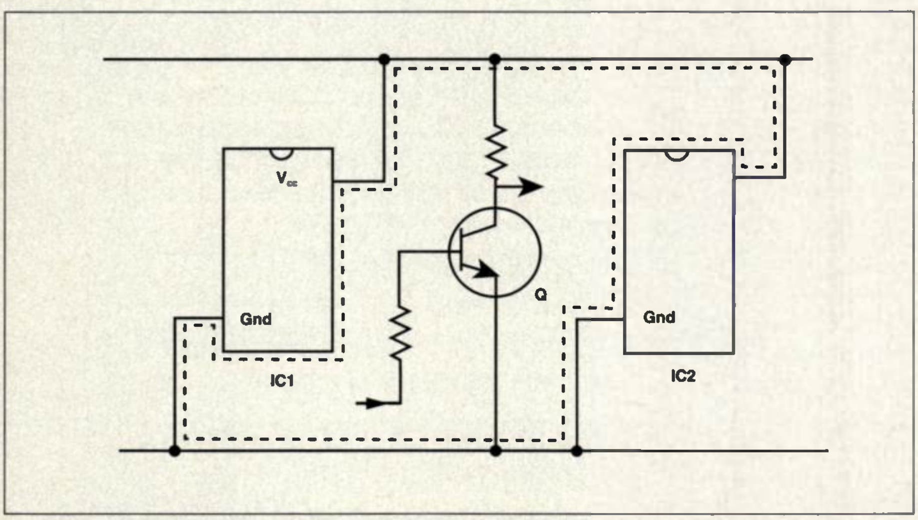

Figure 1a. A large loop area enclosed by a faulty PCB layout scheme.

The heat is on

Next to EMI and ESD, thermal problems are a major factor affecting the reliability of electronic systems. Thermal overstress is generally a by-product of electrical overstress in electronic components. High voltage transients, large current flow, etc. can exceed the designed levels of thermal dissipation in the device and cause thermal runaway. Good design practice dictates that a mechanism should exist for the transfer of heat from the component as it is generated so that build up of heat can be avoided. There should be a path for the transfer of heat from the hot component to the ambient environment. Then thermal equilibrium will be reached when the amount of heat generated is equal to the amount of heat dissipated to the surroundings. The reliability of electronic components depends on the temperature of the device reached during operation. It is very important to keep the junction temperature of the device within safe

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ADC-10-4	5-1000	10.5±0.5	±0.75	0.8	40	1.20	6.95
ADC-15-4	5-1000	15.5±0.5	±0.5	0.6	24	1.20	6.95
ADC-20-4	5-1000	20.0±0.5	±0.8	0.5	21	1.1	6.95
ADC-6-10-75	20-1000	6.6±0.5	±0.5	2.1	15	1.3	6.95
ADC-8-4-75	5-1000	7.9±0.5	±0.5	1.60	17	1.20	6.95
ADC-10-4-75	5-1000	10.5±0.5	±0.5	0.9	18	1.20	6.95
ADC-12-4-75	20-1000	12.6±0.5	±0.5	0.9	23	1.2	6.95
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ADC-16-4-75	5-1000	16.2±0.5	±0.5	0.7	30	1.15	6.95
ADC-18-4-75	20-1000	17.4±0.5	±0.5	0.4	18	1.15	6.95
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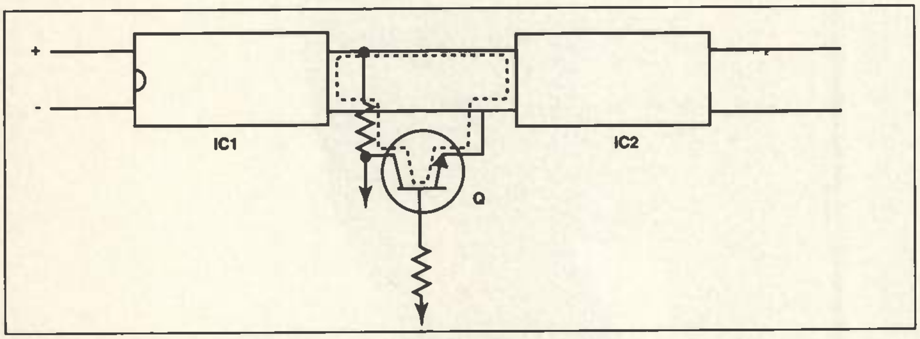


Figure 1b. A better layout technique which reduces the enclosed loop area.

limits in order to avoid device failure due to thermal overstress.

Sources and causes of EMI and ESD

Natural sources of EMI include lightning discharges, atmospheric charges and cosmic sources, including the sun. Man-made sources of EMI include any electrical or electro-mechanical apparatus, machine tools, automobile ignition systems, communication electronics, telephony circuits, power lines, welding systems, transformers, etc.

ESD can be generated by actions such as rubbing the hands on a synthetic seat cushion, walking on a carpeted floor or simply touching charged objects. Higher humidity conditions reduce the effect of static charges by providing a discharge path to ground for the accumulated charge. Therefore, dry air conditions tend to aggravate ESD problems and humid conditions reduce charge accumulation. A typical example is shown in Table 1. The table shows the voltages generated by various human activities under 15% to 30% relative humidity conditions.

For ESD to cause any effect, there must be a generator of ESD and a receptor (component).

Materials are classified according to their tendency to give up electrons. This series is called the triboelectric series. Table 2 lists commonly used materials within the series.

The top end of the table indicates materials which are more positive (they more easily release electrons) and the materials towards the lower end of the table are more negative (they easily absorb electrons).

EMI and ESD effects on electronic devices:

EMI becomes a nuisance in a system if there is a source of interference, a medium to transfer or couple the interfering signal and a susceptible system which will be affected by the EMI. A good design dictates that as much of the potential EMI environment be eliminated from the system during the design stage. An interfering electromagnetic signal can be conveyed from a source of EMI to a susceptible device by conduction or radiation. In conductive EMI transfer, a physical conductive path exists between the source and destination whereas in radiative EMI transfer, the EMI signal propagates through the medium from the source to the susceptible device. EMI reduction methods can be implemented in the most economical way only during the design phase of the product by choosing the appropriate methods such as using suitable circuit design techniques, proper choice of components, good PCB layout , and proper grounding and shielding methods to achieve compliance with EMI standards.

The major hardware failures caused by ESD are as follows: Rupture of the thin films of oxide in semiconductor devices due to dielectric breakdown; melting of metalization traces due to high levels of thermal overstress induced by electrical overstress (EOS); current crowding effect in p-n junctions due to high current densities; latch-up in complementary metal oxide semiconductor (CMOS) devices due to parasitic pnpn structures. One must also be aware of component degradation or latent defects in the device structures which will not lead to immediate failure of the device but cause intermittent malfunctioning and field failures after exposure to ESD stress.

The ESD susceptibilities of the devices varies depending on the technology used. The range of ESD thresholds vary from 10 V to 100 V in the case of metal-oxide semiconductor field-effect transistor (MOSFET), from 300 V-7000 V in the case of bipolar devices, and from 150 V to 3000 V in the case of CMOS. ESD and EMI circuit vulnerability should be taken into account during the device selection stage.

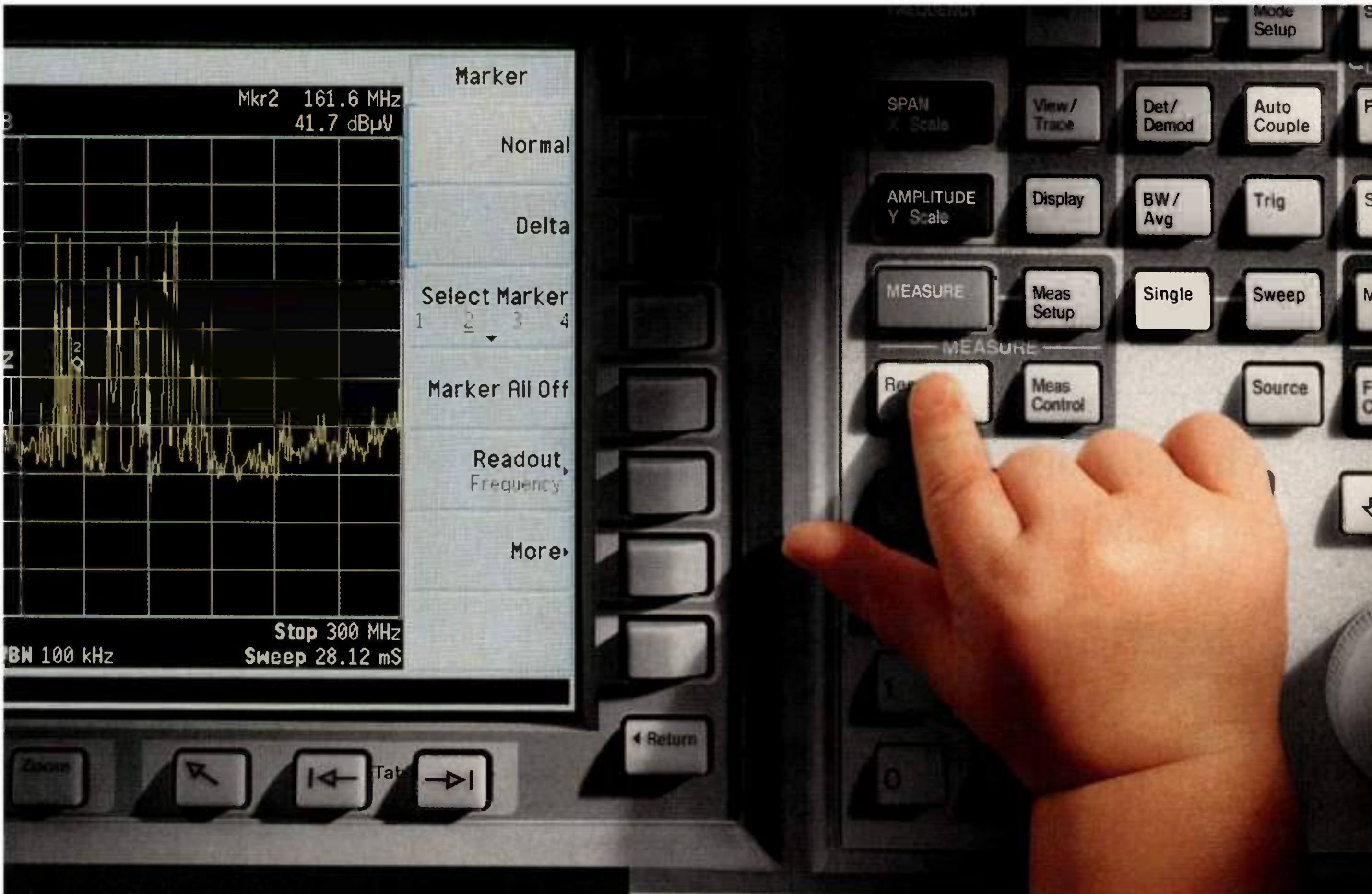
Circuit Design guidelines to reduce EMI and ESD effects

The following techniques will help in reducing EMI and ESD problems to a large extent.

- Use ICs with the right speed. Do not use high speed logic, unless your design needs it. Use of high speed devices will increase the problems of unwanted radiation because of the high speed of switching involved.
- Reduce slew rate of signals in analog circuits.
- Avoid fast rise time signals as much as possible.
- Use a multilayer PCB with separate ground and VCC planes if possible.
- Connect a sufficient number of decoupling capacitors from the power supply to the ground pins of ICs, very close to

Series number	Activity	Typical Potential generated	Maximum Potential generated
1.	Person walking across carpet	12, 000V	39, 000V
2.	Person walking across vinyl floor	4, 000V	13, 000V
3.	Person working at bench	500V	3, 000V
4.	16-lead DIPs in plastic box	3, 500V	12, 000V
5.	16-lead DIPs in plastic shipping tubes	500V	3, 000V

Table 1.



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the IC's supply pin.

- Use feedthrough capacitors at entry/exit points in the system enclosure.
- Use differential mode signal routing to achieve cancellation of mutual inductance and common mode effects.
- Terminate strip lines with appropriate impedance to prevent signal reflections.
- Use ferrite beads to unshielded wires to suppress EMI.
- Edge-triggered devices are prone to false triggering from ESD transients. Avoid if possible.
- Do not leave unused pins of an IC floating. Such pins can pick up nois which can affect the state of the de vice and cause spurious operation Unused pins should be tied low o high depending on the design.
- Use a level sensing logic with a vali dation strobe to improve ESD immu nity of the circuit. Parity and fram error checking should be used in th design to minimize errors.
- Keep all component leads short. Lea inductances and parasitic can caus cross-talk, higher propagation delay and oscillations at higher frequencies
- When selecting components, conside the bandwidth, rise and fall times switching speeds, voltage swing power handling capability, immunit of the device threshold to ESI damage, and similar factors.
- If shielded cables are used ensur that a full 360° contact with th shield is made to prevent antenna ef fects i. e., radiated fields. Follow al packaging guidelines as applicable t EMI reduction.
- Avoid protrusion of component lead in PCBs. Trim the component lead to the minimum level required fo mechanical strength.
- Electrolytic capacitors have highe series resistance and are not recom mended for higher frequencies. Mic and ceramic feedthrough capacitor are recommended for frequencies >

Series Number	Material
1.	Dry Air
2.	Human skin
3.	Bakelite
4.	Glass
5.	Mica
6.	Human hair
7.	Nylon
8.	Wool
9.	Silk
10.	Aluminum
11.	Paper
12.	Wood
13.	Steel
14.	Rubber
15.	Epoxy glass
16.	Copper, Nickel
17.	Silver, Brass
18.	Gold, Platinum
19.	Polystyrene
20.	Polyester
21.	Polyethylene
22.	PVC
23.	Silicon
24.	Teflon

Table 2.

MHz. A feedthrough capacitor provides suppression of unwanted electromagnetic interference signals at the boundary between an equipment and its surroundings. In this capacitor, the EMI signals are bypassed to ground at the interface and thus prevented from crossing the boundary.

- Components mounted on heat sinks which are to be connected to the chassis for better thermal design, should have a Faraday screen to avoid capacitive coupling.
- Use ferrite beads at critical points in the circuit. A ferrite bead can be used to suppress high frequency interfering signals above 1 MHz without affecting the low frequency performance of the circuit where it is used. A typical ferrite bead adds a few μH of inductance to the wire in which it is slipped on. Since a ferrite bead need not be directly connected into the circuit, it is advantageous in many applications.
- A series resistor can be connected to the input stage of a high impedance circuit to limit the inrush current from an ESD transient.
- Use a small value ceramic capacitor to decouple sensitive points in the circuit to ground. Such capacitors should be mounted very close to the pin. Avoid long trace lengths which can induce parasitics.

Minimizing catastrophic failures :

In some situations it may not be possible to provide total protection against all contingencies. In such cases it is preferable to provide protection to the extent possible and use circuit design techniques to provide a systematic shutdown of the processes at the instant of failure of the system. This means a system can go into a graceful shutdown instead of an abrupt failure. Such features can be incorporated through software techniques so that if a sudden power fault occurs, a power monitor resets the processor so it doesn't enter a faulty program execution stage and the whole system goes awry. In such situations, good hardware and software design can help cope with voltage transients and other problems without large-scale damage. Therefore, both hardware as well as software techniques can be used to avoid catastrophic failure of systems due to ESD or EMI problems.

Reducing EMI from transformers and switched mode power supplies

By their nature, transformers constitute one of the major EMI sources in electronic systems. In the case of switching circuits such as switched mode power supplies, motor drives, etc., the problem gets accentuated due to fast changing electric and magnetic fields. Usually the switching waveforms are rectangular pulses and a Fourier analysis of the spectrum of such a waveform shows that it is rich in harmonics. This creates a large frequency spectrum of interference. Th EMI in such a case will be both conducted and radiated.

Conducted mode EMI consists of tw types; common mode voltage and differential mode voltage. Common mod voltage is the voltage appearing between any of the input, output o supply lines with respect to the ground Differential line voltage is the voltag appearing between any two input output or supply lines.

Typical EMI sources in a switchin power supply are :

- radiation from the power supply circuits
- noise from the output stages of th power supply
- current changes in the rectifie diodes at high frequency can caus rapid di/dt transitions.
- high frequency switching of transistors, MOSFETs, etc.
- input/output coupling with poor isolation.
- radiated fields from coils, transformers, etc.

To reduce the effects of these, severa techniques can be used in a switche mode power supply design. Some are filters, shielding techniques or even a different design approach using a sinusoida waveform instead of a square wavefor to address the harmonic problem.

Reduce EMI and ESD effects usin sound PCB design techniques

The design of a printed circuit boar

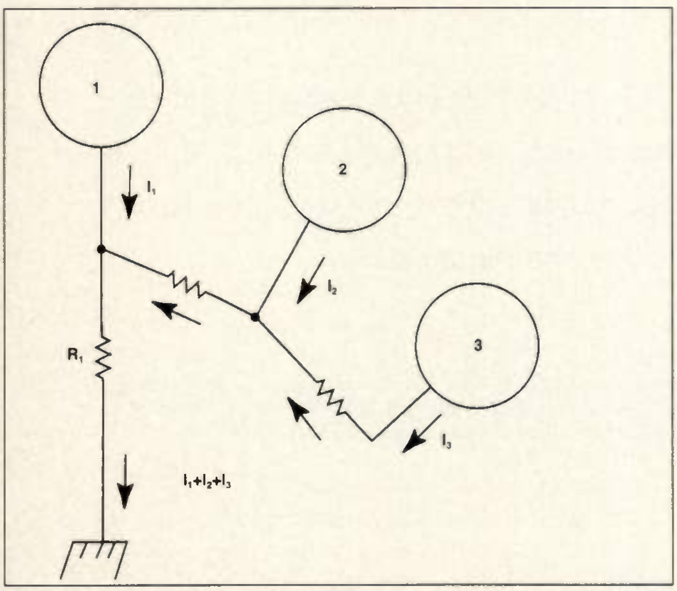

Figure 2a. A daisy-chain grounding scheme causes local voltage drops and introduces common impedance paths.

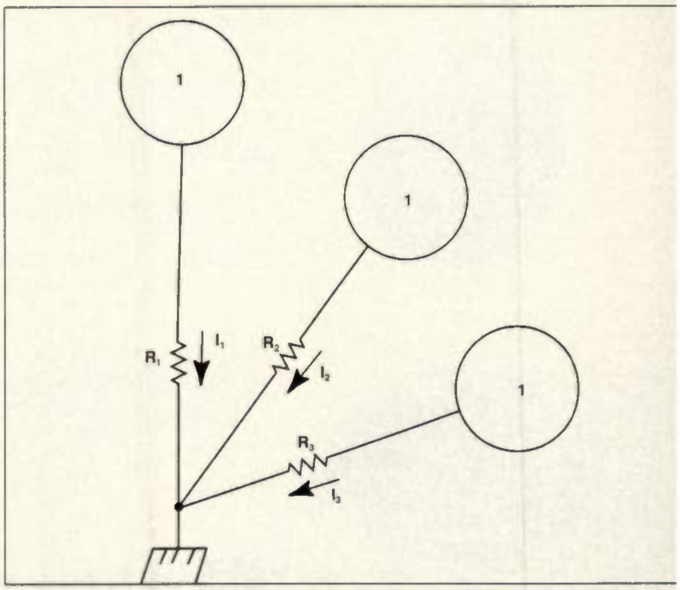

Figure 2b. Single-point grounding scheme avoids local voltage drops .

can affect the functioning of electronic circuits by defining the radiated and conducted electric and magnetic fields in the circuit. Significant reduction in electromagnetic interference can be achieved by following good board layout techniques. Some of the key points to be taken into consideration during the design cycle are:

- Components on the board should be zoned according to frequency of operation and power levels. Zoning into separate regions is a very economical way to reduce noise effects. The objective is to avoid interference and coupling of fields between adjacent circuits, especially with high frequency and highly sensitivity circuits.
- Keep analog and digital circuits isolated.
- Trace lengths should be kept as short as possible. A large trace length behaves like a transmission line.
- Traces carrying high frequency signals such as clocks should be routed with minimum number of bends using the shortest trace length to avoid leakage and reflections.
- Avoid sharp turns of tracks such as 90° bends.
- Reduce the overall loop area of the circuit. A large area enclosed by a current loop will cause a higher magnetic field interference. Figures. 1a and 1b show different routing examples and the resulting loop areas. One method to reduce loop areas is to have separate ground and power supply planes in multi-layer boards.
- Use filters on input and output lines.
- cross-talk.
- Possible EMI source and victim traces should not run parallel to each other for large distance on the board.
- A ground trace between the possible source and victim traces will considerably reduce the incidence and gravity of the problem of EMI, besides reducing loop area.
- Reduce the possibility of standing waves caused signal reflections by proper impedance matching.
- Provide large ground plane areas on the board.
- Minimize the effect of di/dt in the circuit by using the minimum possible switching frequency required in the design and by reducing the loop area enclosed by the current path.
- Keep high power circuits separated from low power circuits.
- Printed circuit board traces act like transmission lines at higher frequencies. The characteristic impedance of traces having larger width is lower than narrower traces. Parasitic inductance of traces and parasitic capacitance between traces exist in all types of PCBs and could become significant factors at the frequency of operation of the circuit. The properties of the laminate of the PCB such as dielectric constant are significant for transmission line effects and microstrip circuits.
- To prevent leakage of fields, do not place high frequency clocks, oscillator outputs, etc. near I/O points,.
- Route high speed clock lines between ground and power supply lines.

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• Reduce cross-talk between adjacent traces by proper spacing, minimizing the length of parallel run between them, routing the source and victim traces on the opposite sides of the ground plane, avoiding sharp bends in the traces, and by providing proper impedance matching.
• Use a low impedance ground in the design so that any electrostatic discharge currents can easily flow to ground without finding other low-impedance paths through electronic devices.
• Route a trace all round the PCB edge and connect it to ground to discharge any static charges due to human contact.
• Route reset lines of microprocessor or other logic devices away from I/O points in the circuit and isolate them.
• Convert unused areas in a PCBs into ground planes. Signal lines should have ground lines running close to them. Multilayer boards with separate ground planes are preferable from ESD point of view.
• Where high frequency clocks are required to interface with components, use a good distribution scheme to directly connect the clock to the components using shortest possible distance. This will prevent radiation leakage of high frequency clocks to nearby circuits which could occur if long traces are used to connect clock signals.
• Coils, transformers and similar elements should be properly shielded to avoid radiating EMI to nearby components and circuits.
• Mount sensitive electronic components away from board edges so that human operators cannot accidentally cause ESD damage while handling the boards.

Proper grounding techniques to reduce EMI/ESD problems

Proper grounding is an important tool for reducing interference in an electronic system. Although grounding techniques can solve a number of electrical noise and interference problems, faulty grounding can cause the very problems that grounding is supposed to solve. Maintaining a clean ground holds the key to the proper functioning of many electronic circuits using a mixture of analog and digital circuits.

One method of grounding is to have a common ground point from each of the 'local' ground points. A daisy chained ground connection will cause local circulating currents and hence voltage drops as shown in Fig. 2a. The individual ground points will be at different potentials with respect to each other. If different individual ground points are connected together, they could cause noise problems if the circuit has high power sections. Single point grounding can lead to long ground connections, but it avoids voltage drops across different ground paths and different potentials.

At low frequencies (<1 MHz) the parasitic inductances of the cables, PCB traces, and other interconnecting elements in the circuit do not contribute significantly to any parasitic impedances and , therefore, a single ground point can be used in the circuit (see Fig. 2b). At higher frequencies (>1MHz), the contributing factors for parasitic impedances due to parasitic inductances are many and it is preferable to use a large ground plane, to which the separate grounds are connected.

It is recommended to keep ground connections grouped according to their power and noise levels. One must also take care to avoid ground loops when these individual grounds are formed, preventing circulating currents and the possibility of such loops acting as antennas.

Proper packaging and production techniques

The effects of electromagnetic and electrostatic fields in a system can be minimized by using a shield of suitable material. The fundamental principle used for shielding a circuit or a system from electromagnetic field interference is reflection and absorption of the incident wave by the shielding material.

The type of shielding used in a particular application depends on the impedance offered by the shielding material at that frequency to the incident electromagnetic field. If the impedance offered by the material to the incident field is matched to the wave impedance of the field, the incident field will be absorbed (maximum power transfer theorem) and very little of the incident field will be reflected.

Ferromagnetic materials such as iron, iron-nickel alloys, mumetal, permalloy, etc. which have high permeability are efficient shielding materials for low-frequency magnetic fields. The permeability of these materials decreases as frequency increases, and at very high frequencies, these conventional magnetic materials will be ineffective as shielding materials.

Non-magnetic materials such as copper or aluminum are applicable to higher frequencies due to their ability to reflect the incident. Efficient shielding against electric fields can be achieved by high conductivity materials such as copper or aluminum. However, such materials cannot be used to shield against magnetic fields because the reflection loss will be negligible.

Some good guidelines for packaging design are:
• Mount a connector inside a cavity so that if a charged body happens to come in contact, it will get discharged through the shielded housing first before any charge transfer occurs to the cable.
• Cover unused connectors with a conductive shield to prevent charge build-up.
• All metallic parts of the system such as cabinet, cable shields, connector shells, etc. which are exposed to the outside world should be grounded.
• Electrical continuity to ground should be maintained at hinges and similar points of the enclosure.
• Avoid long joints and large openings in the enclosure. A discontinuity such as a vent hole in the cabinet can radiate fields. A conductive wire mesh should be mounted on the opening to cover it with smaller size apertures. As a rule any aperture should be less than l /20 wide to avoid leakage through it where l is the wave-length of the signal frequency in the system. It is preferable to use many small openings instead of one large opening in the enclosure.
• All non-conductive plastic components mounted on the front panel should have sufficient dielectric strength.
• All components, PCB traces, etc should be mounted away from any apertures in the enclosure, so that any arcing cannot occur from high voltage ESD pulses coming near the enclosure.

Dealing with shielding discontinuities

In practice, a system will have openings for cabling, cooling vent holes, cut-outs for fixing switches, hinges for doors, etc. All these discontinuities reduce the shielding effectiveness of the shield used by providing a path for leakage of lines of flux. These holes are more problematic from the point of view of leakage of magnetic field than

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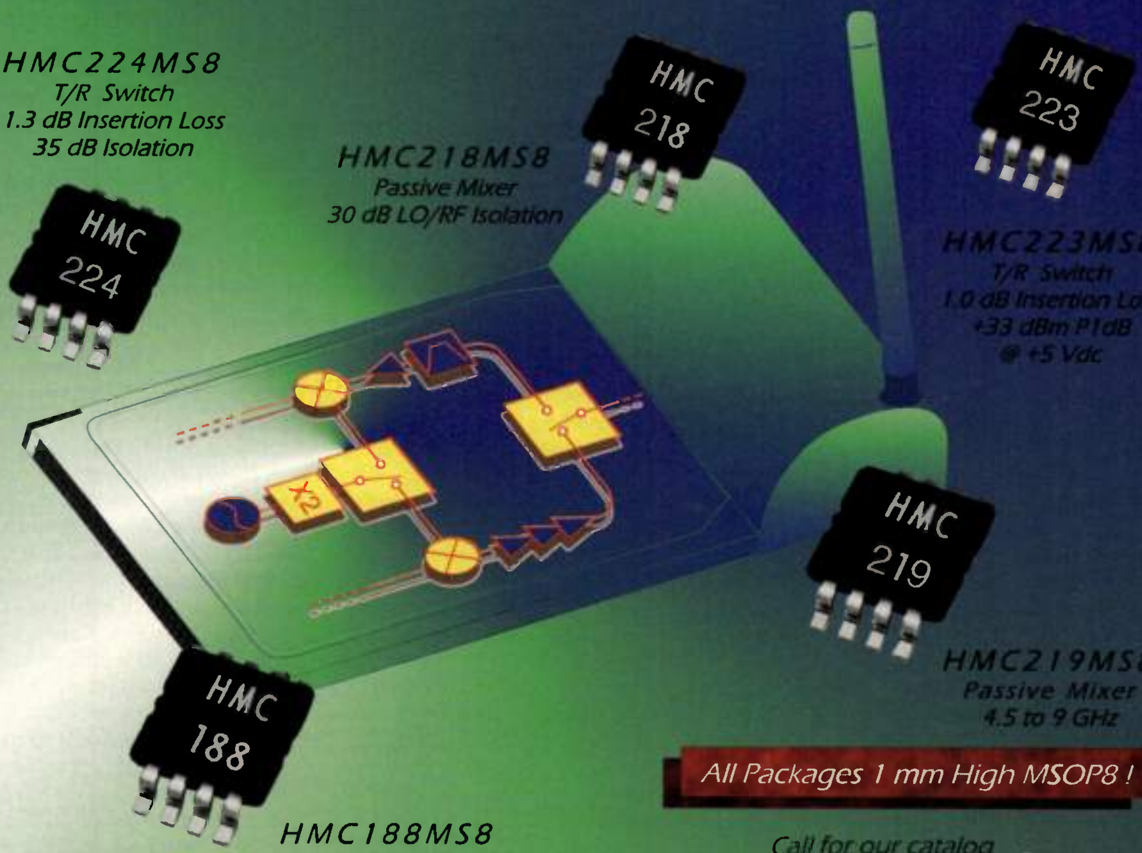

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Passive Mixer	HMC218MS8	4.5 - 6.0	8	30	+9	+7 to +10 dBm
Passive Mixer	HMC219MS8	4.5 - 9.0	8.5	25	+8	+10 to +13 dBm
T/R Switch	HMC223MS8	4.5 - 6.0	1.0	26	+33	+3 to +5 Vdc
T/R Switch	HMC224MS8	5.0 - 6.0	1.3	35	+33	+3 to +5 Vdc

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electric field. These openings can act like slot antennas and radiate unwanted EMI to the surroundings.

In practice, the radiation will be maximum when the maximum dimension of the opening is equal to l/2 where l is the wavelength of the signal. Thusly, the maximum length of an aperture should be less than l /20. A 60° array of holes is reported to reduce the effective hole area. Conductive gaskets, paints, screens, etc. can be used to reduce radiation leakage from openings and to maintain shielding integrity. Cables, wires, etc. entering the enclosure should have a shield which should be fully connected (360°) to the enclosure at the entry point.

Keeping environmental ESD under control

Sources of electric charge in a production set up include personnel, clothing, computer terminals, synthetic packaging materials, furniture coverings, etc. To help minimize ESD from such sources store sensitive components in ESD resistant environments. Plastic surfaces coated with chemicals such as ammonium salts, amidoamines, etc. are available for packing. Containers for storing sensitive components are available in the form of conductive plastic bins, trays, tubes, carbon-filled plastics, metal foil lined bags, etc. ESD control through anti-static flooring is a useful measure as well, with newer materials are now available for flooring, which achieve a conductivity level of 10 5 W/sq.

Assembled PCBs should be stored in static dissipative bags during storage and shipment. Such containers are specially coated to achieve the required level of surface resistivity. This allows for the bleed off of charges caused by triboelectric effect and prevent charge accumulation between the pins of the device.

Floor and work table areas should be covered with anti-static material. Use a soldering iron with grounded tip. Tools with plastic handles should be avoided because plastic can become charged from friction. Card rework such as insertion or removal of components with the PCB powered up should be also avoided. Workers should wear anti-static footwear, aprons and wrist bands with proper ground connections. Air ionisers can be used to neutralize free charges in assembly areas. Educate workers in observing ESD precautions and usage of good work methods to minimize ESD problems.

Cables—EMI and ESD purgatory

Cables contribute significantly to EMI problems especially in RF systems. Problem areas include connectors, cable length and type of cable used for interconnection and the way the cables are routed around the system. Shielded cables are preferable from EMI reduction point of view. The shield should be connected to the connector with a full 360°, to avoid the "pigtail effect" i. e., a short piece of the shield acting like an antenna. A single point contact through a piece of wire will have a higher inductive reactance at higher frequencies. EMI shielding tapes are can be used to wrap cables and reduce EMI problems. For low-frequency (< 1 MHz) electric fields, shield scan be grounded at one end, however, for higher frequencies (>1 MHz), the cable shield should be grounded at both ends. All conductors entering an enclosure should have a shield or filter. All component filters consist of inductors, capacitors and ferrite, should have short lead lengths and be mounted adjacent to entry/exit points. The filter casing should be firmly bonded to the enclosure which should be grounded.

RF designers should be particularly cautious about ESD induced into external cables running to and from the equipment. A piece of cable can act like an antenna to either pick up or radiate a field, and act as a transducer to convert a radiated field into a current or a voltage. Cables without shielding such as untwisted wires, flat cables, etc. are the main types of susceptible cables. The higher the conductivity of the shield, the lower is the sensitivity of the cable to ESD. Such a higher conductivity shield also provides an equipotential surface for the ESD charges and reduces arcing and discharge problems due to potential differences.

Insertion of a common mode choke in the interconnecting cable will help in dropping any voltage developed due to ESD voltages. To protect against very fast transients, bypass capacitors and transient suppressor diodes should be connected across the circuit input terminals to ground, Insertion of filters on the lines will also help in reducing the effects of transient voltages.

Minimize loop areas formed by cables and interconnecting wires. Group cables according to power level and type of signal carried. Maintain maximum separation between AC and DC cables. Use twisted wires for balanced lines. For unshielded cables use high frequency decoupling which could consist of a T-S filter having two ferrite beads and a ceramic capacitor of about 100 pF so that high frequency noise induced by ESD is filtered out.

Thermal issues

Thermal design is as important as the design of the electronics and this aspect should be addressed at the design stage of a system to prevent problems surfacing later on in the field under adverse environmental conditions of temperature, humidity, etc. Manufacturers of semiconductor devices generally specify the maximum range of junction temperature for continuous operation to be 125° C to 150° C. However, in order to achieve high reliability of operation, the junction temperature should be maintained as low as possible (<100° C). This can be achieved by providing heat sinks, cooling fans, blowers, etc., based upon the amount of heat generated and the cooling desired. The three fundamental mechanisms of heat transfer; conduction, convection, and radiation are all equally important. Each one plays a significant role in a different layer in the thermal management hierarchy and should be considered during the thermal design of any electronic system.

In places where ambient temperatures are much higher than the typical room temperature of 25° C, the thermal environment becomes far more critical and the power dissipation rating of the device should be derated appropriately.

The term thermal overstress includes factors responsible for device failure due to excessive heat dissipation beyond the safe heat dissipation limits of the device. Thermal overstress manifests itself in the failure of an integrated circuit in the form of charring of the device, melting of bonding wires, carbonation of the plastic encapsulating material. Some of the ways by which thermal overstress manifests itself are:

- Thermal fatigue—This is caused by switching action. It is seen as cracking and fracturing of a device due to differential thermal expansion and contraction between the different materials used.
- Thermal runaway—Under some conditions, a semiconductor device wil

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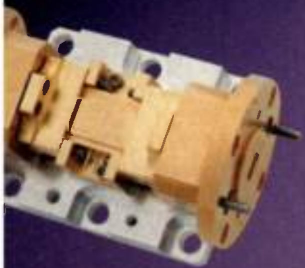
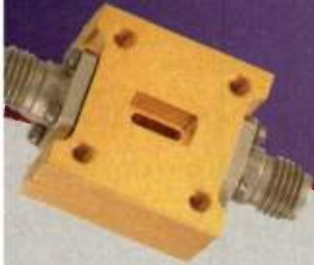


AMPLIFIERS

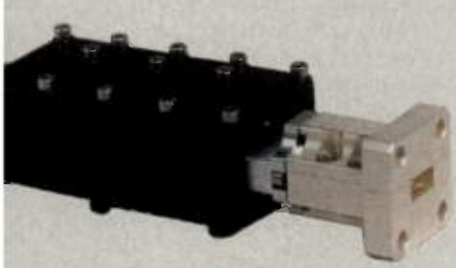
Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	I/O VSWR (Max.)	Output Power at 1dB Comp.* (dBm, Typ.)
JSW4-18002600-18-5A	18-26	28	1.0	1.8	2.0:1/2.0:1	5
JSW4-26004000-25-5A	26-40	25	2.5	2.5	2.0:1/2.0:1	5
JSW4-18004000-32-8A	18-40	21	2.0	3.2	2.0:1/2.5:1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



MIXER/CONVERTER PRODUCTS

Model Number	Frequency (GHz)			Conversion Gain/Loss (dB, Typ.)	Noise Figure (dB, Typ.)	Image Rejection (dB, Typ.)	LO-RF Isolation (dB, Typ.)
	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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have a multiplier effect due to a positive feedback mechanism where an increase in device current leads to higher power dissipation in a repetitive chain reaction. This will lead to the destruction of the device due to the excessive heat generated by such a reaction.

- Hot Spots—Any defect in a semiconductor device or improper provision for conducting the heat away from a device can cause hot spots in the device due to accumulation of heat in a particular spot even during normal operation and this can cause damage to the device. Hot spot related failures can occur not only in semiconductor devices but also in other components such as transformers, coils, capacitors, resistors, etc.
- Thermal problems on the PCB - The possible sources of heat generation on the populated PCB could be power transistors, high power resistors (such as wire wound types), transformers, power diodes, power MOSFETs, etc. Power devices such as power transistors are mounted on heat sinks to carry away the heat from the device and prevent abnormal rise in temperature. Heat transfer can occur from a hot device to another device on the board by any or all of the three fundamental heat transfer mechanisms - conduction, convection and radiation. Conductive heat transfer can occur through the lead of the power device to the PCB traces where the leads are soldered, which transfers to other components through interconnecting traces. Excessive temperature during soldering can cause damage to a PCB as well. In general, the effects of thermal stresses on a PCB are delamination, discoloration, warping, and in extreme cases, charring of the board.

Generally, components can withstand thermal shocks encountered during normal assembly/production operations such as soldering. It is only the sustained application of thermal stresses beyond the specifications of the component that will cause the device to malfunction or fail due to thermal mechanisms. For high reliability systems, screening tests are conducted to weed out infant mortality failures by conducting temperature cycling tests.

The following steps can be followed to achieve good thermal design:

- Proper placement of components on the board is critical. Components generating heat such as power devices, high power resistors, etc. should be mounted away from other components especially those sensitive to heat such as electrolytic capacitors, semiconductor devices, etc.
- Provide adequate heat sink for power dissipating components and provide baffles, if required, for better air circulation.
- Since hot air has lower density and rises up, cool air should be passed from the bottom so that it gets heated and rises up.
- Any dust filters used in the system cabinet should be kept clean to ensure proper air passage.
- Provide cooling fans for assisted air movement.

Conclusion

The demand for light-weight, compact and highly integrated devices has been increasing in the recent years. This tight integration of electronic components and packaging creates a new era of EMI and ESD problems. Incorporating good thermal design and maintaining EMI/ESD compliance within a small volume becomes a challenging task. Techniques to overcome these problems should include better circuit, PCB and system design, packaging, shielding, and application of cooling techniques.

Devices based on new technology and having built-in protection against ESD/EMI damage, and packaging materials to overcome EMI/ESD problems are now available.

Compactness of product design requires trade-offs in power dissipation, EMI/ESD susceptibility and emission, space constraints and cost of the product. Application of the various techniques can contribute significantly to the reduction of EMI, ESD and thermally caused failures of electronic components.

By integrating the various requirements in terms of standards and compliance right from the design stage of a system, the problem of EMI/ESD compliance and thermal design can be tackled at a lower cost. If sufficient precautions are not taken during the product development cycle, achieving EMC/ESD compliance may not be possible without expensive re-engineering or retrofits. Moreover, the product may have higher incidence of field related problems and failures and valuable time and effort will be lost for fixing them later.

RF

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Biography :

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About the Author

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Consumer electronics enters the wireless fast lane

Like so many other high-end technologies, wireless is permeating the consumer industry with blazing speed. Smart versions of homes, appliances and computer networks are all poised to stake a claim in this burgeoning industry.

By Ernest Worthman,
Technology Editor

Within the next year or so, the consumer will be presented with the next class of tetherless communication. These voice and data devices will be based upon technologies such as wireless local area networks (WLANs), family radio service (FRS), HomeRF, Bluetooth, infrared (IR), spread spectrum and power line carrier (PLC), for starters.

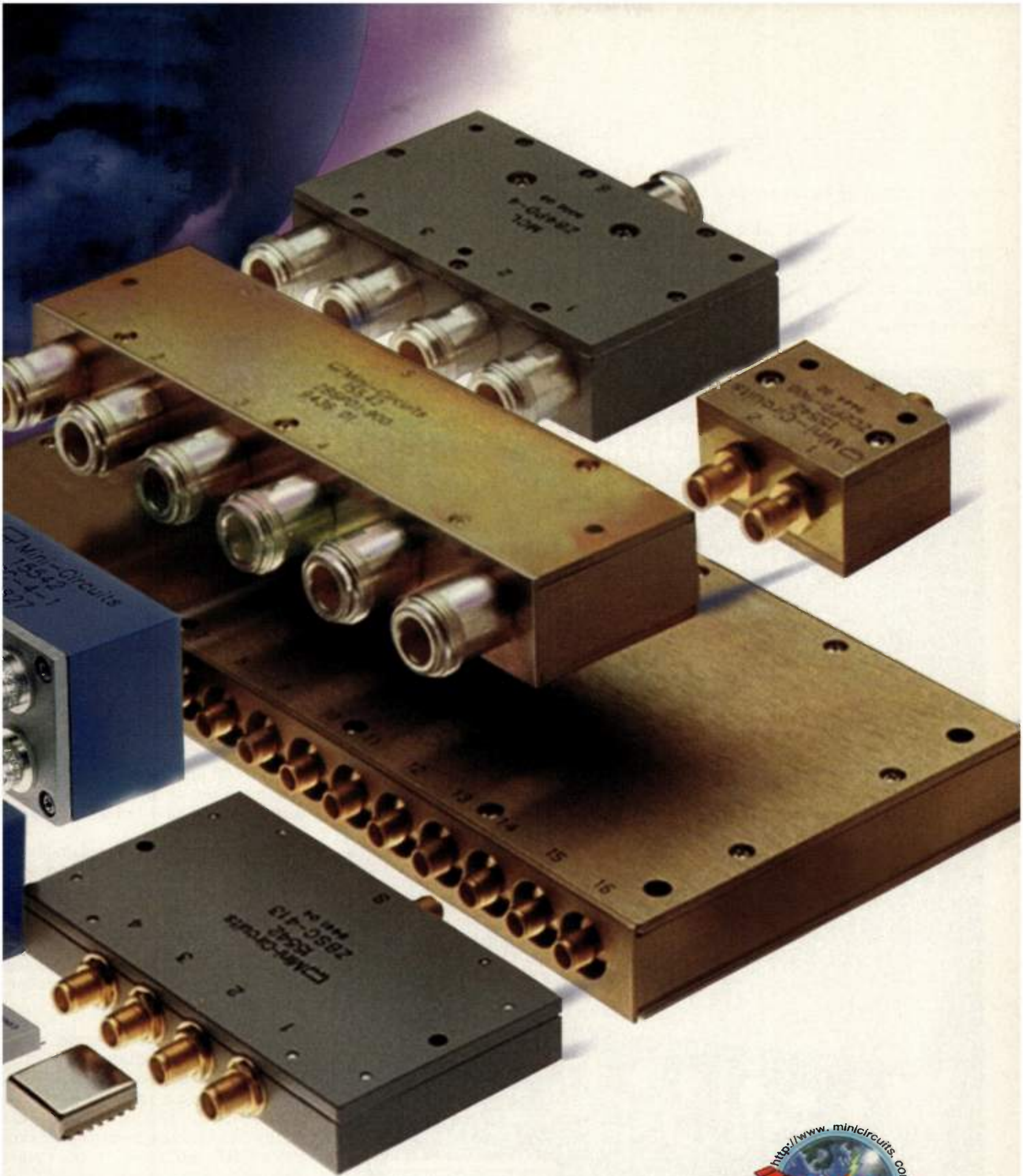
With these emerging technologies coming online, expect to start seeing the stuff science fiction movies are made of. Expect our lives to exist within a universe of terabits of data, controlling everything from our schedule to our environment.

Although most of the enabling technology isn't new, the ubiquity of devices coming online is. Much of this is due to the economic scaling of hardware and the pervasive volumes of uPC code developed within the last few years. Credit this movement to the ever-tightening integration of digital and analog circuits on ever-shrinking form factors, the mass production of high-density, custom application-specific integrated circuits (ASICs), and the marriage of the RF and digital technologies.

The top contender: Wireless Internetworking

The independent research firm of Frost and Sullivan predicts home and business wireless local area networking product shipments to exceed 1.7 million units, with product and infrastructure revenues exceeding $10 billion, by the end of 2005 (The most intriguing of these enabling enabling technologies, Bluetooth, is dissected later in this article). Industries include retailing, warehousing, manufacturing, transportation, health care, education, travel, professional and government. And no doubt more industries will implement wireless networking as the next century gets into gear. Many of these

Figure 1. (Courtesy of the HomeRF Working Group)



devices will end up in the hands of the consumer.

Recent, generally available boxed products for the home market, are no more complex than simply installing a RF-based PC card, some software, and...voila—an instant wireless network. Furthermore, interfaces for cordless modems and Ethernet bridges are coming online that tie into broadband cable and xDSL connections, allowing multiple-user, shared wireless Internet access.

For the road warrior, soccer mom and work-at-home types, there are palmtop computers and hybrid computerphones that, although currently only supported by proprietary Internet and packet protocols, can wirelessly cruise the Internet anywhere, anytime.As for local wireline providers, the handwriting is on the wall. AT&T has been setting aside one-third of its spectrum and slicing it up into 10 MHz chunks as a way of bypassing the local regional bell operating companies (RBOCs) with a plan to deliver fixed wireless services to the general public. The service will bring the consumer two voice lines and a 128 kbps Internet connection (sign me up!) Currently, AT&T owns enough spectrum to provide coverage to 93% of the U.S. population.

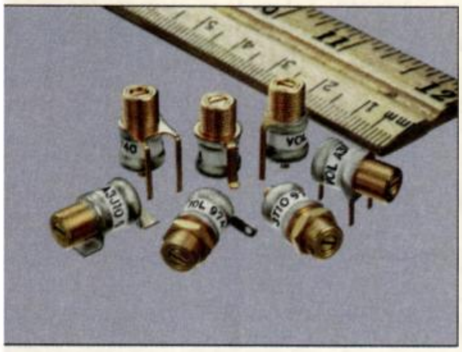
Furthermore, the "brundlefly" syndrome (a term borrowed from the latest version of "The Fly") is being applied to cellular telephones and personal digital assistants (PDAs). At Wireless 99, one device was unveiled that combined a PDA and a code-division-multiple access (CDMA) cellular telephone among several other similar devices.

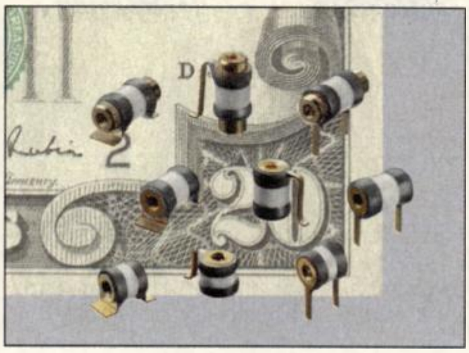
Although off in the future (no, the BSR X10 units don't count) eventually home appliances, climate controls videophones, security, entertainment and, of course, remote computing devices will all link, wirelessly, to the "master brain" at the core of this wireless nucleus (Figure 1 illustrates such a vision.)

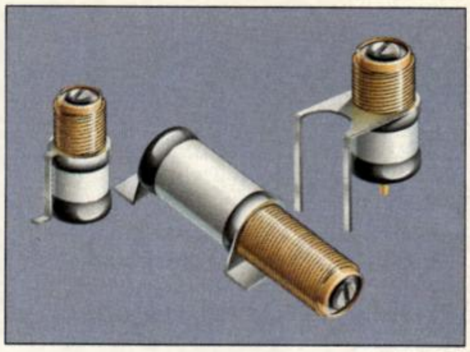
While much of the development is headed in this direction, there are some technologies outside of the wireless networking. FRS, IrDA spread spectrum and PLC to mention a few. Unfortunately, space limitations prevent us from discussing all of them, but stay tuned for future articles about these technologies.

FRS: Promising short-range consumer connectivity

FRS is one emerging segment of the wireless consumer market worth mentioning, mainly because it is here and online. The enabling technology is standard UHF radio, which isn't new. However, I hear rumblings that this technology may become the 21st century reemergence of the CB radio craze of the 1970s (in fact, one of my sources called it "UHF CB".) Although FRS hasn't caught on quite yet, as CB radios did, I see them on retailer's shelves, in catalogues and scattered throughout Sunday paper ad's. And the prices are dropping. This tells me that eventually these devices will catch on. I like them







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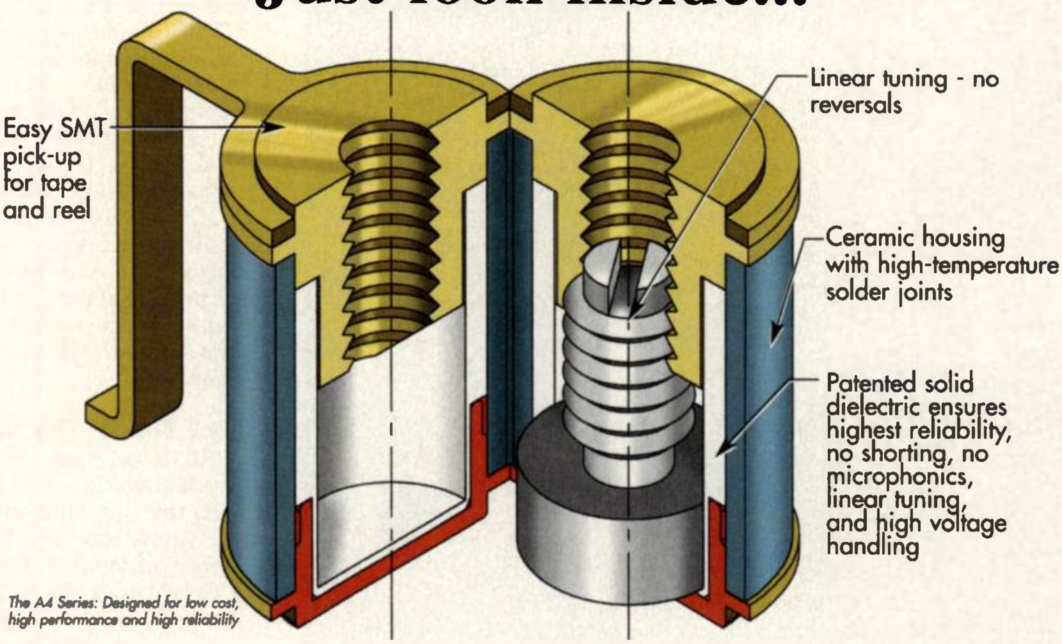

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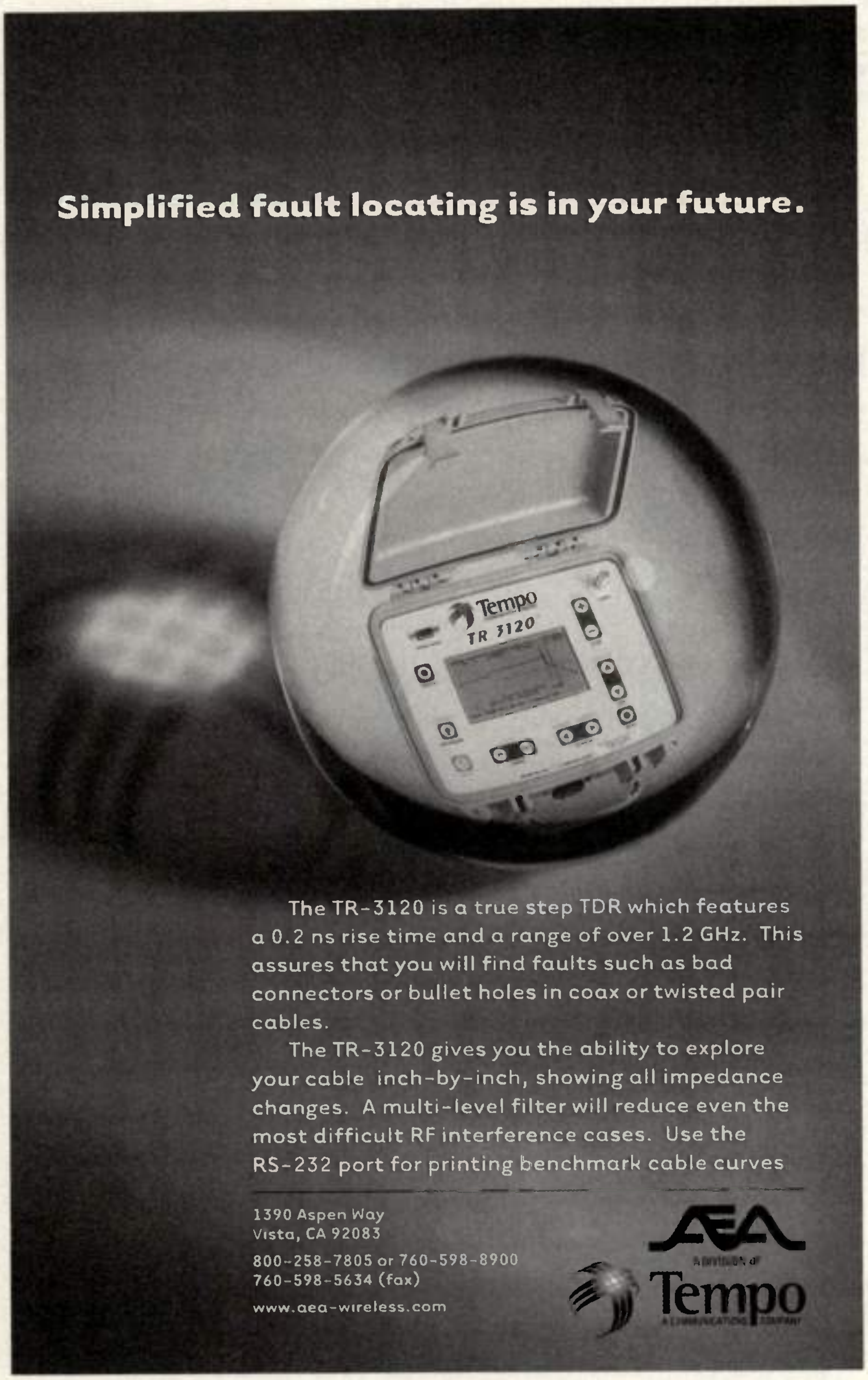
The FRS radios are neat devices. They operate on 14 channels within the UHF band on one of the authorized CB bands—from 462.5625 to 462.7125 MHz and from 467.5625 to 467.7125 MHz—as unlicensed two-way voice-only radios. Unlike CBs, however, FRS radios are limited to ½ W of power and can't use power amplifiers or gain antennas. Additionally, the FRS frequencies are near the general mobile radio service (GMRS) frequencies—limited to 2.5 kHz deviation with a 3.125 kHz audio frequency response.



Although FRS radios claim a range of up to 3 km, mileage may vary and usually does. Realistically, open-terrain range is fairly reliable up to about 2.5 km. Expect reliability up to 1 km for car-to-car and up to 800 m for in-building.

FRS should become a viable entity where the need for close proximity voice communications exists. Potential markets for such devices include mall crawling, visiting entertainment complexes and theme parks, outdoor recreation (biking, rollerblading, etc.) family outings and water sports.

A couple of interesting developments may add a bit of excitement to this wireless frontier. Although FRS is considered a consumer technology, there is the ability for RFS to communicate with GMRS radios on channels one through seven. There is still a bit of discussion about whether or not this will be allowed by the Federal Communications Commission, because GMRS radios operate under a different set of FCC rules.

There is also discussion of adding repeaters to FRS systems. To stay within the guidelines, a FRS repeater would have to act as a stand-alone retransmission station. Nothing non-FCC FRS—certified (repeater controllers, receivers, etc.) could be connected to it. Additionally, the FCC hasn't permitted data to be transmitted on these frequencies either, so it looks like this segment will likely stay consumer-oriented.

IEEE 802.11: The technology giver

All of the enabling subsets owe their creation to this 802.11 standard. Even with this standard coming out early in the game, this "about-to-explode" consumer information age still had a bit of a rough start. As with most emerging markets, there was some infighting in the early years. Fortunately, unlike so many other technology-age innovations, the smart wireless communications movement got its ducks in a row without years of bloodying each other's noses. Perhaps high-tech has finally learned a lesson from the VHS/BETA wars and the computer industry's early years. For whatever reason, the development and implementation of the 802.11 standard is the key to future development in this industry.

Under the hood

The IEEE 802.11 open WLAN stan

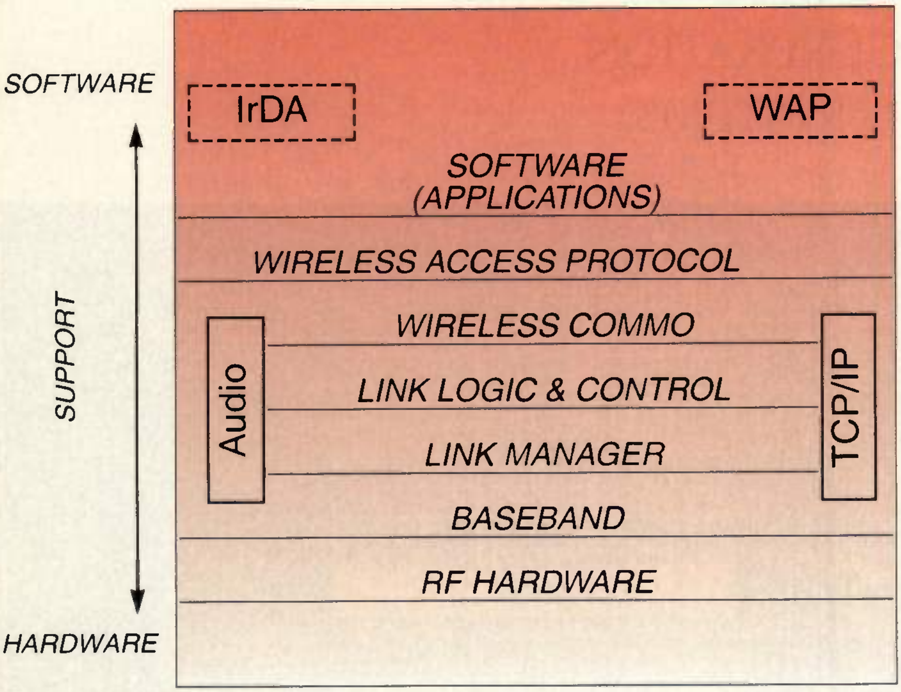


Figure 2.

dard has laid the groundwork for a plethora of interoperable WLAN products. Operating in the unlicensed 2.4 GHz spectrum, 802.11 devices are capable of transmitting data at rates as high as 2 Mbps (the next generation will be capable of as high as 10 Mbps data rates). Most of these devices are being beta-tested in the business world because cost and flexibility have not yet been economized to the scale of widespread consumer affordability. But have no fear, once the robustness is achieved, and peripherals and support electronics are mass produced, expect the technology to proliferate much like the computer has.

Currently there are several incarnations of this consumer and personal wireless interface. All fall under the IEEE standard. Each were developed by different parties to satisfy what they believe to be the best implementation of the standard for their particular market vision. The current contenders are The Shared Wireless Access Protocol (SWAP), Bluetooth, and HomeCast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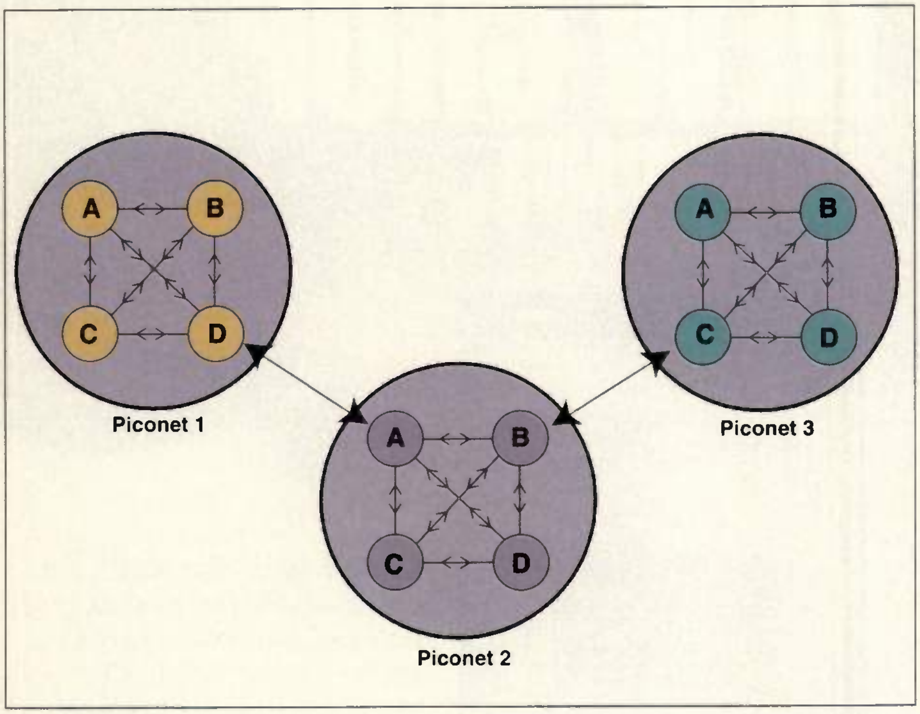


Figure 3.

Open Protocol (HOP). Each draw fron a common pool of technology designe to operate in that 2.4 GHz unlicense band, yet each has differing methodolo gies and technological structures.

Bluetooth, the most publicly prolific.

Bluetooth is the brainchild of th consortium of Nokia, Toshiba, IBM Intel and Ericsson. Originally focuse on mobile computing and cellular tele phones, Bluetooth was to be the com mon link among PDAs, cell phones, lap tops and palmtops. However, the proli eration of the wireless market has th Bluetooth participants widening thei vision. Now, Bluetooth is being market ed as the enabling technology for per sonal-area networks. This system i designed to share voice and data amon any technologically compatible devic within the net. Ideally, Bluetoot devices will all have access to each oth er's databases, making it unnecessar to worry about where the data i stored.

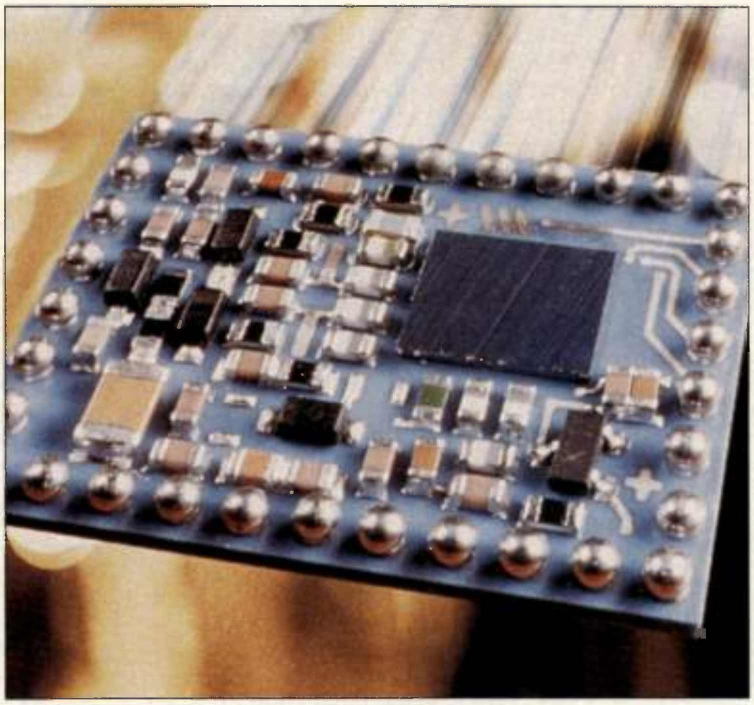
The Bluetooth specification is perhaps the most ambitiou of the set. Using frequency-hopping spread spectrur (FHSS), Bluetooth hops at the rate of 1.6k hops/s across 7 channels. Each channel is displaced by 1 MHz from 2.402 t 2.480 GHz. The main advantage of this is that such a proto col allows for a tremendous amount of data to be movin around at any one given time due to the quick hoppin speed and short packet length.

A Bluetooth transmitter has a transmit power of 0 dBm or about 1 mW (under some conditions power can b increased to +20 dBm, about 100 mW). Under ideal condi tions, this provides for about a 10 meter radius net. If botl devices are extremely close, a flexible transmit scheme ca drop the power to as low as -30 dBm. This saves on powe and ensures a peaceful coexistence with other neighborin RF devices. The next generation of specifications is lookin at operating in the 5 GHz band and pumping power level up one order of magnitude.

The major problem of power consumption has been clev erly dealt with in the Bluetooth protocol. Simply put Bluetooth devices spend most of their lives in sleep mode This is accomplished by a low-power, cleverly designe timing scheme that resembles paging protocols. Base upon the scheme's timing loop, the receivers perk up fror time to time to listen for their calling. This happens ever 1.28 seconds and lasts for the 32 hop frequencies assigne to the unit. This timing scheme is synchronized with th ransmission algorithms. Vhen the receiver wakes p to listen, it is in the calling segment of the transmitting unit's setup transnission.

Bluetooth's communicaions protocol uses 2-level aussian-filtered FSK modlation (GFSK) modulation chemes. Although the theoetical throughput is a 1-Ibp/s raw link, 1/3 and 2/3 ate forward error correcion (FEC) and automatic epeat requests (ARQ) depending on conditions), edundancy, header infornation and handshake proocols limit realistic data ates to just over 700 kbp/s naximum.

If one takes a look at the Bluetooth protocol (see Figre 2), one quickly notices he TCP/IP stack and the aseband protocol. These



The Bluetooth radio module. (Photo courtesy of Ericsson)

elements are borrowed from the cellular and Internet technologies. Bluetooth is capable of both packet and circuit switching, and it supports asynchronous connectionless (ACL) and synchronous connection-oriented (SCO) voice and data. Asynchronous channels (primarily data) can support up to a 432 kbp/s symmetrical link while a synchronous channel (primarily voice) can support up to 64 kbp/s. Unfortunately, space prevents discussion about the remaining protocols, but they will be dealt with in a future article.

Carrier sense multiple access with collision detection (CSMA/CD) is used for transmitting packetized data frames. This technology is load-sensitive, so speeds vary. Furthermore, multiple speed protocols are built into the standard. This benefits reliability by allowing fallback to slower speeds if the signal path becomes muddy. Thus, rather than cramming packets down the chute at full speed on weak links and risk data corruption, this built-in set allows slower speeds to increase data and overall link reliability.

The Bluetooth protocol is constructed to allow impromptu "piconet" or "scatternet" ad-hoc sessions to be set up in point-to-point and point-to-multipoint configurations (See Figure 3). The net sets up with two units and can grow to a maximum of eight. The structure is such that all devices are initially peer oriented but, as the net sets up, one unit will assume the role of master and the rest will act as slaves. Each unit will have a unique 48-bit identifier. Additionally, multiple piconets can be established and linked in the same ad-hoc fashion. Each piconet is assigned a different frequency-hopping scheme to maintain a unique identity. Therefore, it is quite possible to set up nets that encompass an area much larger than the typical 10 or so meters.

The rest of the Bluetooth story

Bluetooth has a myriad of related interfaces, and interoperability and security issues that are interwoven with the rollout of this technology. For example, Bluetooth implements security at the physical layer. Encryption is typically a stream cipher with secret key lengths up to 64 bits. In the software framework, Bluetooth will reuse a number of existing specifications, depending upon compliance requirements, for different applications (vCard/vCalendar, OBEX, infrared human interface devices (IRHID) and TCP/IP, for examples).

Bluetooth is also ready to take on the next generation of wireless devices such as wearable computers and wireless headsets, personal digital assistants and a some unique devices such as debit and credit interfacing.

The rest of the consumer RF stor

Although Bluetooth garners the lion share of the media coverage, som viable competitors loom on the horizo SWAP and HOP are the immediate tw looking to share the limelight.

Both of these technologies conform t the IEEE 802.11 open WLAN standar Each has its own particular interpreta tion of what the consumer wants fo wireless interoperability.

Neither, however, is too far, technol gy-wise, from its rivals. And, you can b that these platforms will offer up a pla compatible to the Bluetooth offerings.

It could be an interesting next coup of years. Although there is a treme dous reserve of resources behin Bluetooth, recent history has reveale that competing technologies can, an do, coexist (PCS and GSM, for exar ple). HOP and SWAP are competin platforms that are no less capable tha Bluetooth. I, for one, will be watchin them very closely — as should the re of the RF industry.

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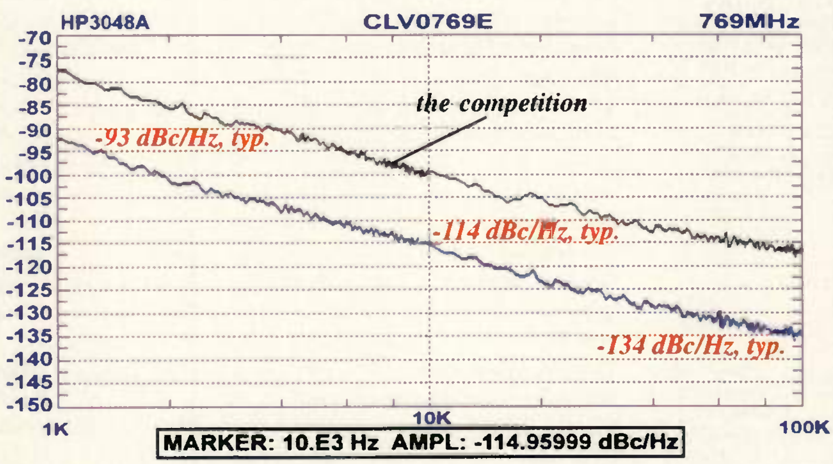

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INFO/CARD 50

Designing a low-noise VCO on FR4

Using a CAD program,you can design a cost-effective voltage controlled oscillator using inexpensive PWB materials.

By Randall W. Rhea

Although FR4 material and process handling are widely available, the poorly controlled dielectric constant and high-loss tangent challenge the design of high performance circuits. This article illustrates the use of modern computer aided design (CAD) techniques and provides tips on the design of a 900 MHz voltage controlled oscillator (VCO). It has a high tolerance to FR4 material and -100 dBc/Hz SSB phase-noise at 10 kHz offset. The techniques and tips are also applicable to other circuitry, such as filters and amplifiers.

FR4 material

FR4 is a flame-retardant version of G10. Both are thermoset fiberglass epoxy laminates. The resin has a relative dielectric constant of 3.4, the glass has a dielectric constant of 6.1. These figures represent the extreme range of possible dielectric constants. A typical board has a resin content from 40% to 70% for a dielectric constant range of 4.2 to 4.9. Dielectric constant variations of +-0.06 across the sheet is common.

The loss tangent of FR4 is typically 0.008 at VHF frequencies and 0.02 at microwave frequencies. This is an unloaded material Q of 125 to 50, which is adequate to support lowpass filters, broadband bandpass filters and many oscillators. Edge-coupled, hairpin and interdigital filters, have resonate quarter wavelength open ends with high field intensity and are not a good choice for filters on FR4. On the other hand, combline filters replace this end with loading capacitance. The remaining shorted length of line has high current but low field intensity, reducing the effect of dielectric loss and dielectric constant variation. This technique is used in designing the resonator for this VCO.

The VCO specifications are:

Frequency:	890-910 MHz
Pout:	7±1 dBm
Harmonics:	<-10 dBc
Vsupply:	9.7 Vdc nominal
Vtune:	2-13 Vdc maximum
Isupply:	40 mA maximum
SSB phase-noise:	95 dBc @ 10 kHz offset
Size:	1x1 inch maximum

The VCO will be phase-locked to 900 MHz. The expanded frequency range covers temperature variation. Excessive tuning range is avoided to minimize varactor noise.

Initial considerations

The output power, harmonic level and power supply specifications are unremarkable and are typical of systems with ample supply power. The design is driven by the phase-noise specification, the characteristics of FR4 and the narrow tuning range (2.2%). Circuit performance is based on satisfying fundamental criteria and circuit complexity is seldom helpful. In this case, low cost is achieved with a straightforward oscillator topology: a Mini-Circuits MAR-3 MMIC amplifier, a resonator printed on FR4 and few supporting components.

SSB phase-noise is predicted by Leeson's equation [1]

$$L(f_m) = 10\log\left[\frac{1}{2}\left(\left(\frac{f_0}{2Q_l f_m}\right)^2+1\right)\left(\frac{f_c}{f_m}+1\right)\left(\frac{FkT}{P_s}\right)\right]$$

where:

f_0 = carrier frequency
Q_l = oscillator loaded Q
f_m = carrier offset frequency
f_c = active device flicker corner frequency
F = oscillator amplifier noise factor
k = Boltzmann's constant

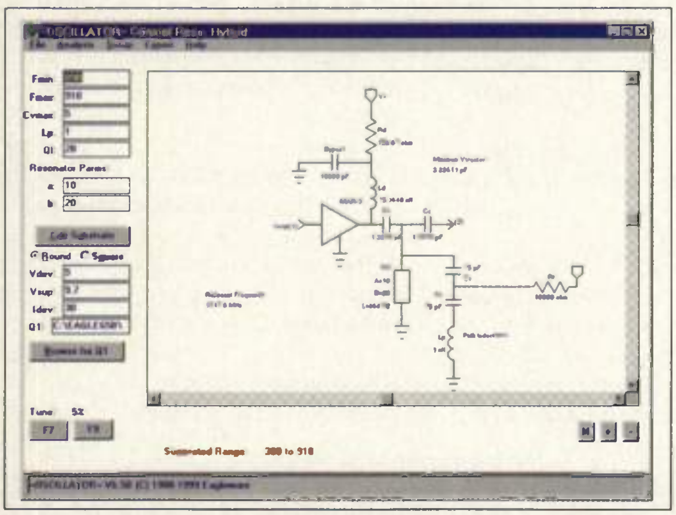

Figure 1. Initial oscillator design of the 900 MHz VCO in the =Oscillator= module of the Genesys software suite. Input parameters are given on the left and the design is displayed on the right.

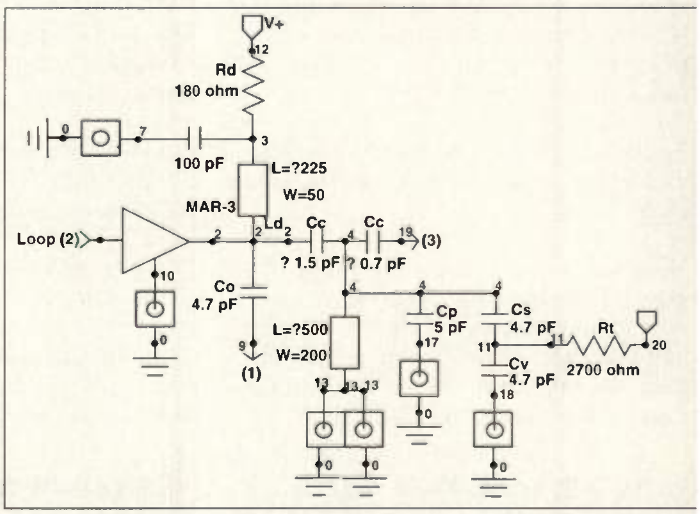

Figure 2. Schematic of the 900 MHz after the design modifications described in the text. The values with "?"s were optimized by the =SuperStar= Genesys module to satisfy the open-loop criteria for the oscillator.

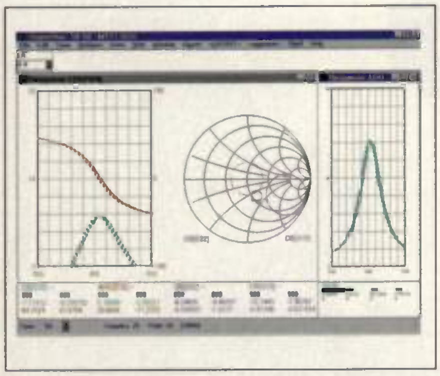

Figure 3. The open-loop responses and loaded Q of the VCO with a Monte Carlo analysis of FR4 dielectric constant variation of -2 to +10%. Notice the frequency variation is only about 3 MHz or 0.33%.

T = operating temperature

p_s = oscillator power output

The oscillator's fundamental properties, under the designer's control, that impact phase-noise are amplifier noise figure, the output power and the loaded Q. The noise-figure difference between an inexpensive and state-of-the-art amplifier design is only a few decibels. More important is the output power, which can be increased indefinitely to achieve a desired phase-noise performance. However, the parameter with the strongest influence is loaded Q (second power rather than linear). To keep DC current consumption down the designer should concentrate on loaded Q to achieve the desired phase-noise. With an output power of +7 dBm and an MAR-3 noise figure of 6 dB, a loaded Q of 28 yields a SSB phase-noise of better than -100 dBc/Hz at 10 KHz offset, providing a few decibels of margin to the desired -95 dBc/Hz.

The Design

The initial design is created using the =Oscillator= module of Genesys [2](a sample screen is shown in Figure 1). =Oscillator= uses the design parameters on the left to create the schematic shown on the right. The MAR-3 is defined by S-parameter data read from a industry-standard S2P file.

=Oscillator= used a ceramic-loaded TEM-mode coaxial resonator. These popular resonators achieve unloaded Qs as high as 1000. To minimize cost, this design will use a resonator printed on FR4 so I modified the =Oscillator= design as follows:

1) The coaxial resonator was replaced with a microstrip line. The effects of a poorly controlled dielectric were minimized by shortening the resonator to much less than quarter-wavelength and achieving resonance by loading with a lumped parallel capacitor (Cp). The tuning varactor (Cv) and its coupling capacitor (Cs) also load the resonator. A quarter-wave resonator is inductive near the ground end and capacitive near the open end. The capacitive end is dominated by dielectric properties, the inductive end is not. Replacing the line's open-end section with lumped capacitance minimizes the impact of the FR4 dielectric.

2) For improved simulation accuracy the ideal grounds in the schematic were replaced with via hole models.

3) The inductor choke that supplies power to the MAR-3 was replaced with a printed microstrip line.

4) A capacitor (Co) was added to couple output power to a 50 ohm load.

The final schematic from the Genesys =Schemax= module is given in Figure 2. The oscillator design is characterized by an open-loop analysis fron port 2 to port 3[3]. The resonator cou pling capacitors, the length of the res onator microstrip line and the length o the power coupling choke microstri line were optimized in the =SuperStar= circuit theory simulator. This step wa taken to achieve a gain margin of a least 7 dB, a phase shift of 0 degrees a 900 MHz (this sets the oscillating fre quency), matched impedances at th input and output and a loaded Q of a least 28. Figure 2 provides componen values after optimization.

Figure 3 illustrates the open-loo plots after optimization with a Mont Carlo analysis with a dielectric con stant variation of -2% to +10%. Notic the spread in the frequency of th phase zero-crossing is approximately MHz or only 0.33%. The desensitizain to dielectric constant variation sug gests the effects of dielectric loss ar also minimized. Although the gai margin is slightly less than desired, loaded Q of 28 was achieved and th matches are reasonable.

Creating a layout

Figure 4 shows the layout in th Genesys module =Layout=. Whe =Layout= is launched it places metal o the workspace for each object i =Schemax=. Microstrip metal is auto matically dimensioned to sizes set in th optimization and footprints are dropped for lumped elements. Originally, all c the metal and footprints are scattered i the workspace and connected togethe with rubber band lines. Figure 4 also il lustrates the layout after rubber ban lines have been resolved. Power is deliv ered to the circuit through Rd, the var actor tuning voltage through Rt an

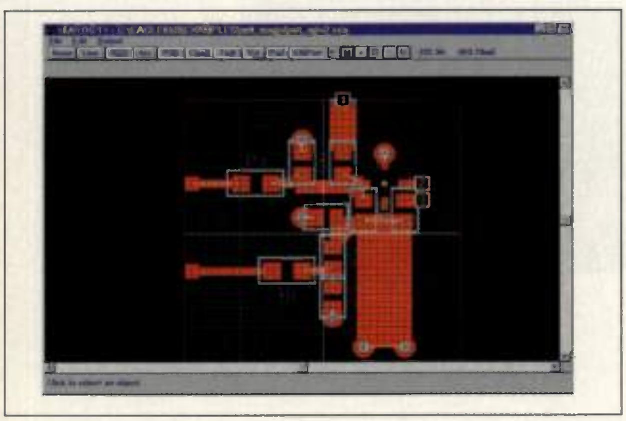

Figure 4. Layout of the VCO in the =Layout= module of Genesys. The output is taken at the top, power is supplied at the upper left and the tuning voltage is applied to the lower left.

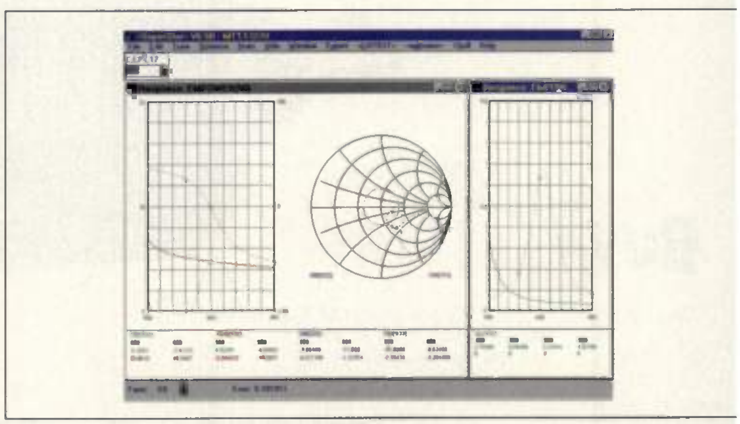

Figure 5. Oscillator open-loop responses computed by the Genesys electromagnet ic program =Empower=. The solid traces are the original results and the dashe traces are after dropping Cp to 3.6 pF to correct the frequency.

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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
ROS-765	485-765	16	-95	-27	12	22	15.95
ROS-1410	850-1410	11	-99	-8	12	25	19.95

*Phase Noise: SSB at 10kHz offset, dBc/Hz. **Specified to fourth.

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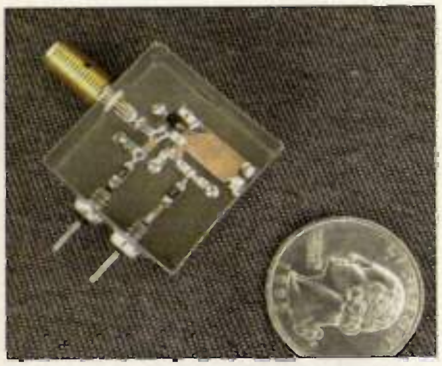

Figure 6. Completed VCO on FR4. The resonator is the large copper area on the right in the VCO.

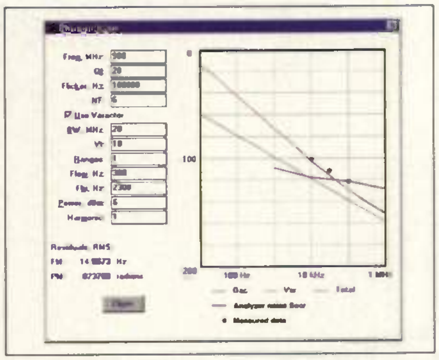

Figure 7. Predicted and measured (circles) VCO SSB phase-noise.

output is taken at port 1 through Co. Internal ports 2 and 3 are used for an electromagnetic analysis of the oscillator open loop. The oscillator is formed by bridging these ports with solder. =Layout= outputs AutoCad DXF files, Gerber files with an Excellon drill list and HPGL plotter files.

Electromagnetic Analysis

An electromagnetic analysis was performed before constructing the oscillator. The pads of the loading, tuning and coupling capacitors will add capacitance to ground. Additionally, other parasitic effects are likely to lower the oscillating frequency as well. The =Empower= module in Genesys will consider this, the cover and other packaging effects. =Empower= removes the lumped elements and replaces them with internal ports, performs a multiport analysis and then places the components back in the circuit. =Empower= performs these tasks automatically on the user's behalf. Other advanced =Empower= features include multimode analysis and decomposition, generalized S-parameter analysis, automatic detection of four types of symmetry and loss calculation in both metal and dielectric. Results are shown in Figure 5.

The initial responses are solid and indicate that the frequency is lower than circuit theory simulation predicts. In the dashed responses the loading capacitance Cp was reduced to 3.6 pF to correct the frequency. This lower parallel capacitance compensates for the footprint pad capacitance at the top of the microstrip resonator.

Measured data

A Gerber file from =Layout= was used with a Quick Circuit 5000 to machine a PWB. Bus wire feed-throughs were used for ground vias (a completed VCO is shown in Figure 6). With a

Metelics MSV34-082 varactor in place of Cv the VCO tuned from 852 MHz with Vt=0 V to 912 MHz with Vt=12 V. The output level was +7.5 dBm with a fixed capacitor for Cv and +6.2 dBm with the varactor. The second harmonic was -28 dBc; the 3rd harmonic was -34 dBc. The current at 9.7 V was 30 mA. The measured frequency with a fixed capacitor for Cv was 887 MHz, well within the expected frequency range considering an electromagnetic simulation prediction of 903 MHz and tolerances in the lumped capacitors.

The measured SSB phase-noise is given in Figure 7 for offsets of 10, 30 and 100 KHz superimposed on the phase-noise predicted by the =Oscillator= Genesys module and the noise floor of the spectrum analyzer used to take the data. Close agreement was achieved.

Concluding remarks

A number of issues associated with VCO design were illustrated using circuit theory and electromagnetic computer analysis and measured data. Quality performance is achievable on inexpensive FR4 material. Quick and accurate design is possible using advanced integrated tools. Tools to automate and simplify electromagnetic analysis, which is more accurate than circuit theory analysis. Finally, there are simple fundamental concepts that can be used to control phase-noise performance as, predicted by Leeson's equation.

In this case a simple design was employed using an easily applied MMIC amplifier. However, it should be noted that an output power of +7 dBm is somewhat low for nearly 300 mW of DC supply consumption. A discrete one-transistor design could be used to achieve a lower amplifier noise figure, with less resistance in the collector-emitter path and a higher output power. This would result in improved phase-noise performance at the expense of a few more components for biasing the discrete device. RF

References

[1] D.B. Leeson, "A Simple Model of Feedback Oscillator Noise Spectrum", *Proc. of the IEEE*, February 1966, pp. 329-330.

[2] Synthesis Manual GENESYS Version 6.0, Eagleware Corporation, Tucker, Georgia, 1997.

[3] R.W. Rhea, *Oscillator Design and Computer Simulation*, 2nd edition, Noble Publishing, Atlanta, 1995.

About the Author

Randy W. Rhea was an RF/microwave design engineer for 20 year with Boeing, Goodyear Aerospace and Scientific-Atlanta. In 1995 he founded Eagleware and later Noble Publishing. He can be reached at 770-939-0156.

Test and Measurement

If there is one constant in the world of test and measurement equipment its change. The degree of change is reflected by more features, smaller form factors and increased versatility. The products in this month's Product Focus reflect the changes in the test and measurement market.

Self-contained 65 GHz VNA

The Lightning family of vector network analyzers (VNAs) for microwave applications has been expanded with a single-unit, self-contained VNA with frequency coverage to 65 GHz. The 37X97 VNA is designed to meet for testing of higher frequency systems, such as wireless networking, low-earth orbit (LEO) satellite communications systems and Intelligent Transportation Systems (ITS). The 37X97 can measure four S-parameters at speeds that permit real-time tuning of components in manufacturing. It can make continuous sweeps from 40 MHz to 65 GHz and is built to perform in the >70 dB range and features >–5d Bm leveled output power.
Anritsu company
INFO/CARD 115

Oscilloscope offers one billion bit samples memory

The GageDMO family of specialty oscilloscopes allows as much as one billion points of data storage at a rate of 100 MS/s. It is available in 8-bit and 12-bit resolution models. The unit offers up to eight simultaneous channels and a 10″ LCD screen. Sampling up to 500 MS/s is possible with shorter buffers, and a time-stamped data capture and storage system is available for transient analysis.
Gage Applied Sciences
INFO/CARD 116

Spectrum analyzer features remote monitoring capability

Morrow Technologies has released the P9116 full-featured spectrum analyzer. The unit is capable of performing remote monitoring of transmit and receive sites outside of the main facility. The unit covers the frequency range from 100 kHz to 1.6 GHz, is contained in a ruggedized case and features serial and parallel ports for interfacing with port-enabled equipment. It employs digital tuning, with a resolution of 2 Hz across the entire spectrum and has frequency accuracy of 0.5 PPM. The unit also has the ability to act as a "server" and can be accessed by client-based

PCs, either directly, or over the Internet. Data can be retrieved and manipulated from any location capable of supporting standard PC peripherals.
Morrow Technologies
INFO/CARD 117

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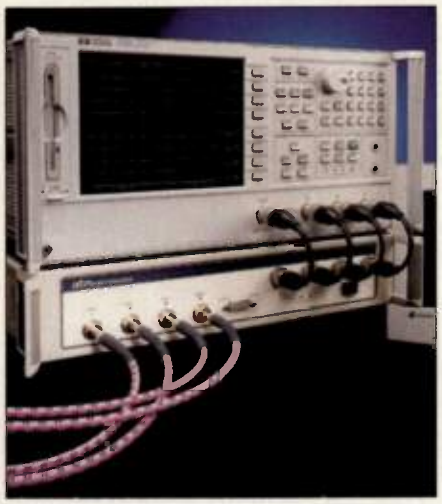
Differential characterization test system

Characterization of differential devices up to 20 GHz is possible with the ATN-4000 series test systems. The system is capable of determining both single-ended and mixed-mode s-parameters and TDR data can be measured on devices used in RF, analogue and data communications applications. A turn-key system includes the ATN hard-



ware and software, an Hewlett Packard (HP) vector network analyzer and general purpose interface–based PC.
ATNmicrowave
INFO/CARD 118

Bandwidth-independent power sensors

Hewlett-Packard (HP) has developed the E9300 series power sensors for its E-series power meters. These sensors offer the ability to measure the true-average power of RF and microwave signals, regardless of their modulation format. Furthermore, the sensors use HP-developed diode-attenuator-diode topology to ensure accuracy and repeatability of measurements across the sensor's -60 dBm to +20 dBm

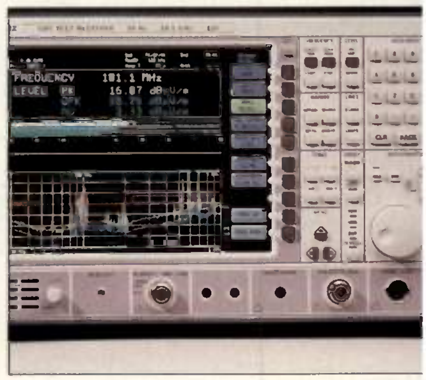
dynamic range The units also feature high power specifications to handle modulation-intensive formats such as wideband code division multiple access (CDMA) and OFDM.
Hewlett-Packard
INFO/CARD 119

CDMA/TDMA mobile phone test platform

Wandel Goltermann has unveiled the Model 4300 code division multiple access/time division multiple access (CDMA/TDMA) test platform. The system is designed to help design and repair facilities test D/TDMA phones with minimal setup and configuration. The unit incorporates computer-guided test sequences and remote control ability. The unit features softer handoff testing, PCS power class determinations, and pilot strength measurements. The unit is also designed t allow for future expansion via softwa upgrades, protecting the purchase initial investment.
Wandel Goltermann
INFO/CARD 120

EMI/EMC test receiver acts as spectrum analyzer

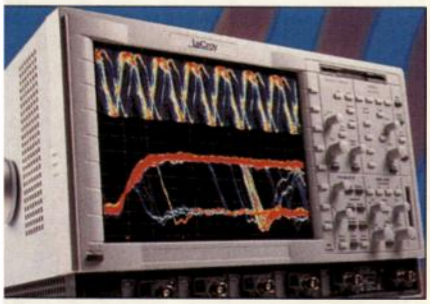
Electromagnetic compatibility /ele tromagnic interference (EMC/EMI) te capability has been significantl enhanced with the release of th Tektronix ESI family of EMC/EMI te receivers/analyzers. The units ca make peak-, average-, and RMS-dete tor measurements in 100 microsecond The series of units includes the ESI ESI26 and ESI40, covering frequen



ranges to 7 GHz, 26.5 GHz and 40 GH respectively. Additionally, the units a fully functional spectrum analyzers.
Tektronix
INFO/CARD 121

'XI-based, dual-channel ɔower meter

Boonton Electronics has introduced he Model 4730 series of power meters. The series included a CW power meter hat integrates into a VXI-based sysem. The unit has a built-in math funcion, which, along with the dual chanıel capability, can provide simultaneıus input/output power measurements. 'requency range is from 10 kHz to 100 GHz and power range is from –70 dBm o +44 dBm. Log or linear readouts can



e chosen and the unit can be integrated into ATE systems for multiple rack onfigurations.
Boonton Electronics
NFO/CARD 122

High performance digital color oscilloscopes

LeCroy has released four new color oscilloscopes based upon digital technology. The LC684D family features 10.4" flat panel color displays, 1.5 GHz bandwidth and sampling rates to GHz/s. They are also capable of handling records of up to 4Mbytes/channel or 16 Mbytes aggregate on a single channel. The series is able to scroll the signal in both forward and reverse modes so long, complex stored waveforms can be analyzed. Additionally, the units come with a plethora of troubleshooting tools including 42 signal parameters, an FFT package, advanced math functions and multiple interfaces.
LeCroy
INFO/CARD 123

Lightweight, scanning receivers

Wireless Valley Communications, Inc. has developed a family of scanning receivers for integration with their *Site Planner* wireless system design product. WaveSpy is a DSP-based, plug-and-play compatible scanning receiver that can operate with major wireless interfaces such as AMPS, ETACS, iDEN, TDMA, CDMA and GSM. The unit is completely portable, lightweight and offers options such as a GPS receiver, dual band operation and overhead traffic decoding. Completely self contained with the *InFielder* module, the unit is field-ready.
Wireless Valley Communications,
INFO/CARD 124

Microwave path alignment made simple

XL Microwave has introduced the Path Align-R model 2200 microwave antenna path alignment test set. This portable unit weighs less than 7 1/2 pounds, features a rechargeable lead-acid batter, and is quick and easy to set up. Additionally, the unit features 100 dB of effective dynamic range, a 0 dBm output, four separate frequency bands

up to 19.4 GHz, and band resolution of 1 MHz. Readings are taken from an LCD panel and have 0.1 dB resolution and a 300 ms update period.
XL Microwave
INFO/CARD 125

Get the data now

To get more information on the test and measurement products mentioned in the Product Focus go to **RF Design Online** at **www.rfdesign.com**.

Correcting for spectrum analyzer noise in digital modulation measurements

This simple procedure can help you compute correction factors for any difference values.

By Morris Engleson

Modern spectrum analyzers include extensive signal processing capabilities for the accurate representation and measurement of the spectra of digitally modulated signals. But even the most advanced performance instruments rarely provide for the automatic correction for the effect of the sensitivity noise internal to the spectrum analyzer. Accurate determination of the amplitude of such low level signals, therefore, requires the manual addition of a correction term. This article explains how to compute and use this correction term.

Sensitivity noise

There is a lower limit to the signal level that can be displayed and measured on a spectrum analyzer due to masking by internally generated noise known as the sensitivity. It can be shown that the sensitivity noise is equal to kTBF, where kTB is the well known thermal noise limit of –174 dBm per Hz of bandwidth and F is the noise figure (also known as noise factor). The result is a noise level of –100 dBm for a 30 kHz bandwidth, such as used for CDMA signal measurements, and a typical performance F=29 dB. Whatever the sensitivity noise level might be, it adds to the incoming signal showing a greater result than actual. The user needs to correct for this effect if an accurate measurement is to be made.

Correcting for additive noise

The spectra of most digitally modulated signals, such as quadrature amplitude modualtion (QAM) or code division multiple access (CDMA), appear to be random noise to the spectrum analyzer. This combines in a power addition with the kTBF sensitivity noise to show a larger value than actual. Fortunately it is easy to correct for this effect. All that is necessary is to measure the amplitude ratio, or dB difference, between the total and internal noise, from which the appropriate correction factor is determined.

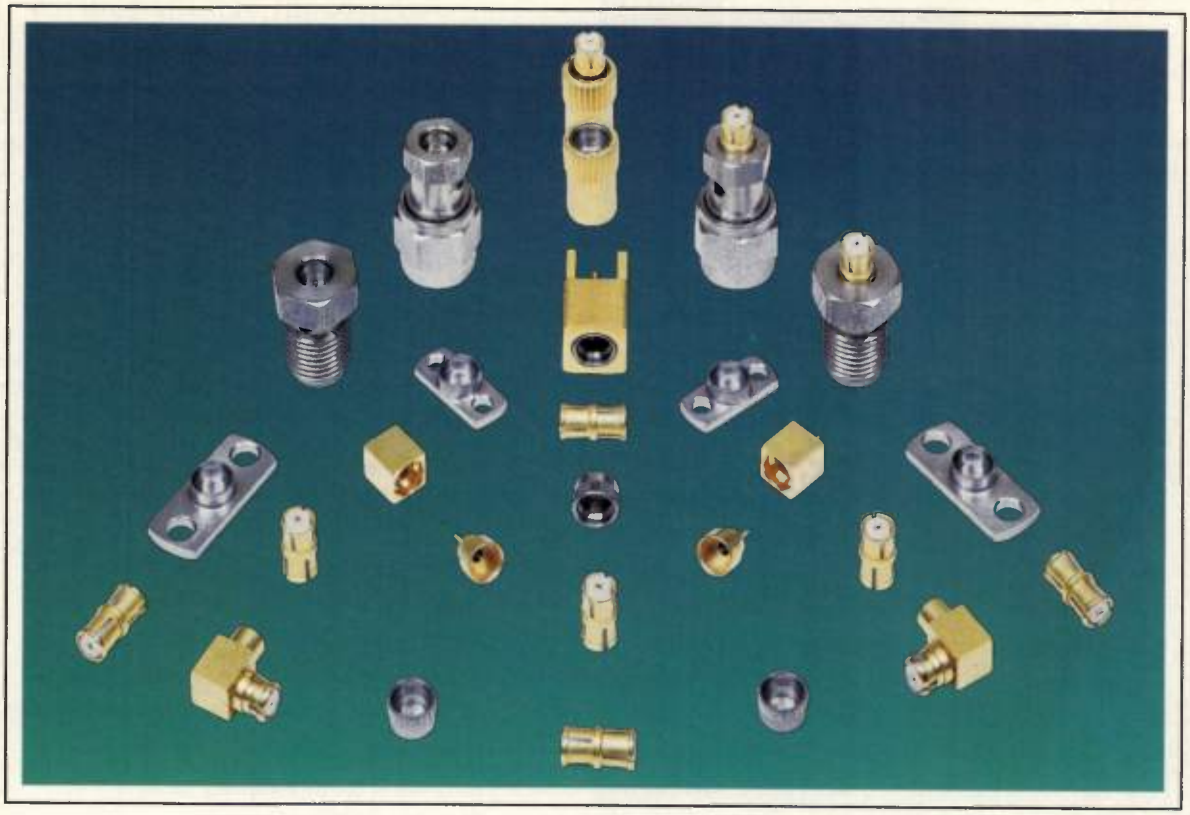
Thus, on a power basis, the internal noise Ni, plus the incoming noise-like signal level Ns yields the measured value Nm (Ni+Ns=Nm). Suppose the difference between Nm and Ni is 2 dB. The power ratio for 2 dB is 1.58. This leaves 0.58 after subtracting the internal noise, Ni, which we set to a normalized value of one. The correction facto is 10Log(0.58)=–2.33 dB minus th original 2 dB for a total of –4.33 dB The ratio is 2 times when the differenc is 3 dB, hence we have 10Log (2-1)=(minus 3 dB, for a total of –3 dB. A 6 dI difference yields a correction factor o 10Log(3.98-1)-6=–1.26.

Most people will stop this process a a level difference of more than 10 dI because the correction factor is les than 0.5 dB at that point. Note als that a difference of less than 3 dB indicates that the incoming signal, Ns, i smaller than the internal noise, Ni. Th following provides correction factors fo level differences between 1 dB and 1(dB in 0.2 dB increments. The reade can compute correction factors for othe difference values using the procedur outlined above. RF

About the Author

Morris Engleson is consulting director at JMS Consulting, Portland. He can be reached at 503-292-7035 or visit the JMS Web site at **www.pcez.com/~jms**.

Difference (dB)	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
Correction (dB)	-6.87	-6.17	-5.60	-5.11	-4.69	-4.33	-4.00	-3.72	-3.46	-2.84	-3.01
Difference (dB)	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Correction(dB)	-2.83	-2.65	-2.49	-2.34	-2.20	-2.08	-1.96	-1.85	-1.75	-1.65
Difference (dB)	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0
Correction (dB)	-1.56	-1.48	-1.40	-1.33	-1.26	-1.19	-1.13	-1.07	-1.02	-0.97
Difference (dB)	7.2	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.0
Correction (dB)	-0.92	-0.87	-0.83	-0.79	-0.75	-0.71	-0.68	-0.65	-0.61	-0.58
Difference (dB)	9.2	9.4	9.6	9.8	10.0					
Correction (dB)	-0.56	-0.53	-0.50	-0.48	-0.46					



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INFO/CARD 13

VCO developed for base station market

The CLV0945E voltage controlled oscillator (VCO) is designed for use in pager base stations. The device generates frequencies between 936 to 953 MHz within 0.5–4.5 Vdc control voltage. It is designed for use in harsh environments and it guaranteed to operate over the extended commercial temperature range of –40 to 85°C. It offers a spectral signal of –114 dBc/Hz, typical, at 10 kHz from the carrier while attenuating the second harmonic to better than –19 dBc. The VCO operates off a 5 Vdc source while drawing 20 mA, typical, and provides the end user nominally 3 dBm of output power into a 50W load. The pulling specification for the CLV0945E is less than 5 MHz/V with a 14 dB return loss, any phase, while pushing is less than 5 MHz within a 5% change of the supply voltage. The VCO comes in an industry standard MINI surface mount package measuring 0.50″ x 0.50″ x 0.22″.

Z-Communications
INFO/CARD 126

Isolator provides 20 dB isolation

Models 0470IED and 1425IED are drop-in isolators. The 0470IED is designed to provide 20 dB isolation with insertion loss of 0.4 dB over frequency bandwidth of 4.4- 5.0 GHz. The 1425IED is designed to provide 23 dB isolation with the same insertion loss over frequency bandwidth of 14-14.5 GHz. The VSWR over the frequency bandwidth for the 0470IEDis 1.25:1, while the VSWR over

the frequency bandwidth for the other isolator is 1.3:1. Both units can be operated from -20° to +85° C.

Nova Microwave
INFO/CARD 127

Amps keep output power constant

The models GRF3032 and GRF3038 are solid-state, broadband amplifier modules. The GRF3032 covers the 0.5-500 MHz frequency range while the GRF3038

covers the 10-1,000 MHz range. The GRF3032 operates off of a 24-32 VDC source and includes an optional internal ALC circuit that keeps the output power constant over wide input power and frequency ranges. The GRF3038 operates off of a 28-32 VDC source and also has an optional internal gain control circuit. The devices are designed for use in laboratory and medical applications and other applications.

OPHIR RF
INFO/CARD 128

Monolithic transistor offers two amps

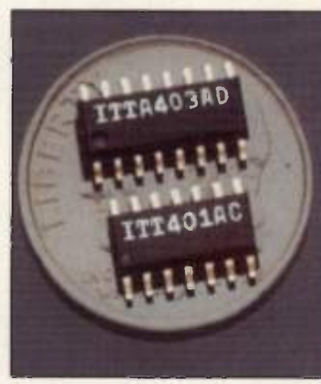
The Dual-MOSMICs are monolithic transistor devices that combine two automatic gain-controlled amplifiers on a single chip. Three transistor models are available: 24 mS for the TSDF52424, 30 mS for TSDF53030 and 40 mS for TSDF54040. All three feature integrated gate protection diodes and resistors, plus an on-chip biasing network. AGC range is 45 dB at 800 MHz for all three models. Each features a low noise

figure as high as 800 MHz. All three devices are rated for a 5 V supply.

Vishay Semiconductor
INFO/CARD 129

Switches offer low power consumption

The ITT501AJ and ITT801AN GaAs switches are designed for use in wire-



less handsets, local area networks (LANs), data, base stations and other wireless applications. The ITT501AJ is a SPDT high-power transmit/receive (T/R) switch that operates from +3V ±10 V. It features positive control and a 1 dB compression point of 35 dBm at +5 V. The ITT801AN is a SP8T switch with direct TTL control and a single 8 V positive supply. It features on-chip 3:8 decoder logic, low power consumption and non-reflective ports.

GaAsTEK
INFO/CARD 130

SEMICONDUCTORS/ICs

ICs directly synthesize sine wave

The AD9852 and the AD9854 are monolithic integrated circuits that directly synthesize a dc to 120 MHz analog sinewave. The AD9852 contains a built-in, 12-bit/300 MHz digital-to-analog converter (DAC), while the AD9854 features dual, on-chip 12-bit DACs. Both devices feature a 48-bit tuning word that yields a tuning resolution of 1.066 microHz.
Analog Devices
INFO/CARD 131

Semiconductor switches for broadband transmit

The AS169-73 is an IC PHEMT SPDT integrated switch for broadband transmit and receive chains operating from dc-2.5 GHz. It features an insertion loss of 0.4 dB at 2.5 GHz and positive voltage operation with low dc power consumption.
Alpha Industries
INFO/CARD 132

GaAs SPDT switch for dc to 3.0 GHz.

Model IS-2103 is a GaAs SPDT switch featuring 2 nS switching speed and isolation of 50 dB. It covers a frequency range of dc-3.0 GHz and offers other high-performance characteristics, including an insertion loss of 0.7dB and a typical third-order intercept of +49 dBm. The unit is housed in a SOIC-8 plastic surface-mount package and is available in tape and reel for automated assembly.
Signal Technology
INFO/CARD 133

SAW filter designed for clock applications

A 2.488 GHz timing recovery surface acoustic wave (SAW) filter for clock and data recovery applications is compatible with SONET OC-48 and SDH STM-12. The devices are packaged in a hermetically sealed, surface-mount leadless chip carrier measuring 9 mm x 7 mm. Frequencies between 2-3 GHz are available for such applications as digital video transport at 2.380224 GHz and forward correction peripherals t OC-48 at 2.6660571 GHz and 2.87539 GHz.
Vectron International
INFO/CARD 134

Transistor designed for solid-state power amps

The TIM5964-60SL is a 60 W C-Ban GaAs field effect transistor (FET) ha output power of 48 dBm at a frequenc range of 5.9-6.4GHz. The new device i designed for use in solid-state powe amplifiers for satellite earth-statio communication transmitter (SATCOM) and very small apertur terminals (VSAT).
Toshiba America
INFO/CARD 135

Schottky diode for miniature surface mount package

The ZHCS400 is a high curren Schottky diode in a miniature SOD32 surface mount package. The ZHCS40 will support a continuous forward cur rent of 400mA for a typical forwar voltage of 425mV. This Schottky diod offers a printed circuit board (PCB saving of 70% when compared to i 500ma ZHCS500 SOT 23 cousin. Th diode is rated under three different con ditions: continuous (400mA), averag (1.0A) and pulsed (6.75A). Power dissi pation at 25°C (ambient) is 250 mW.
Zetex
INFO/CARD 136

Regulator powers 2.5 V circuitry

The MIC39500 is a 5 A, ultra-low dropout (LDO) regulator designed t power 2.5 V circuitry in systems with 3.3 V610% power bus. Manufactured i TO-263 and TO-220 packages, th MIC39500 features a 500 V maximu dropout voltage at full load. It has fixed output voltage of 2.5 V and maximum input voltage of 16 V. It ca be operated in temperatures rangin from 0° C to 125° C.
Micrel Semiconductor
INFO/CARD 137

Regulators support portable devices

The GMT-72XX is a series of low dropout voltage regulators designed fo mobile phones, palm computers

NEW PRODUCTS

NO.62

RF/IF MICROWAVE COMPONENTS

10dB BI-DIRECTIONAL COUPLER MONITORS HIGH POWER

Monitor forward and reverse power up to 10W (max. input) with Mini-Circuits1500 to 2500MHz ZABDC10-25HP coaxial (SMA-Female) bi-directional coupler. With a 10dB±1dB nominal coupling value (±0.5dB flatness), these 50 ohm units typically display low 0.55dB insertion loss, high 26dB directivity, and excellent 1.1:1 VSWR. Operational in -20°C to +85°C (max.) temperature environments for communications applications, and shipped from stock.

270-320MHz SPLITTER/COMBINER IS AQUEOUS WASHABLE

Mini-Circuits LRPQ-320J is a 2way-90° power splitter/combiner for image reject mixer and I&Q modulator/demodulator applications in the 270 to 320MHz frequency band. Typically, important performance features include excellent 0.3dB amplitude unbalance and 0.5 degree phase unbalance, very low 0.3dB insertion loss (above 3dB), very high 21dB isolation, and excellent 1.20:1 in/out VSWR. This 50 ohm unit operates within a -20°C to +85°C (max.) temperature range.

it™ LEVEL 17 (LO) MIXER COVERS 0.5 TO 500MHz

The patent pending ADE-1H frequency mixer from Mini-Circuits offers wide band 0.5 to 500MHz VHF/UHF frequency coverage in a low profile .155" package. Excellent features such as low 5.3dB conversion loss, high 52dB L-R, 42dB L-I isolation, and high 23dBm IP3 (all typ. midband) make these level 17 (LO power) mixers an extraordinary price/performance value. Evaluation board TB-03 available, 5 year high reliability guarantee included.

12V VCO HAS LINEAR TUNING 200 TO 380MHz

A compact, low cost 12V (current 20mA max.) voltage controlled oscillator has been introduced by Mini-Circuits. Typically, the broad band ROS-400 provides 200 to 380MHz near octave band tuning, low -100dBc/Hz SSB phase noise at 10kHz offset, 9.5dBm power output, and excellent -24dBc harmonic suppression. The miniature 0.5"x0.5"x0.18" size conserves board space, and applications include test instruments such as signal generators.

SIMPLE 50 TO 75 OHM WIDEBAND MATCHING DC TO 3000MHz

Mini-Circuits has started shipping a low cost, wide band surface mount matching pad engineered for the DC to 3000MHz frequency band. Optimized to meet the stringent performance requirements of 50 to 75 ohm wide band matching, the ALMP-5075 provides 5.7dB±0.2dB nominal attenuation with excellent ±0.1dB typical flatness and excellent 1.2:1 return loss (typ). Height is only .080" and evaluation board TB-25 is available.

STEPDOWN 9:1 TRANSFORMER WORKS IN 0.3 TO 475MHz

This TC9-1-75 stepdown 9:1 autotransformer from Mini-Circuits is housed in a leadless surface mount package and operates within the 0.3 to 475MHz frequency band. With a 75/8 ohm impedance ratio (stepdown, 75 ohm primary, 51pF across secondary) this transformer has good 23dB typical return loss in 1dB bandwidth and referenced to midband loss (0.4dB typ), insertion loss is 3dB maximun. Applications include matching laser diode.

Mini-Circuits®

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pagers, global positioning equipment and other portable applications. The voltage regulators are available in either an 8-pin plastic DIP or SOIC package. They feature a logic-enabled sleep mode that results in a sleep-state current of only 0.5 mA. Typical quiescent current is 180 mA, independent of the load. Fixed output versions of the LDO voltage regulators have their outputs regulated to 62% over their entire operating range.
GMT Microelectronics
INFO/CARD 138

PASSIVE COMPONENTS

Resistor offers impedance matching

A four-element array version of the Z chip integrated resistor/capacitor device is now available. The 0612 four-element package is less than 25% the size of conventional R-C arrays. The array is designed to provide impedanc matching on multiple circuit traces The chip is available with capacitc values of 33-, 47-, 68- and 100 pF wit a tolerance of 610% and TCRs of 625 ppm/°C. The dc-rated voltage is 25 and the capacitor provides near NP dielectric performance. Standard rat ings available from stock include 47pF/100 V; 68pF/51 V; 100pF/47 and 47pF/47 V.
AVX
INFO/CARD 139

Transformers designed for balanced amps

The JTX-2-10T RF transformers ar designed for impedance matching an balanced amplifiers operating in th 50-1,000 MHz frequency range. Th surface mount components have a 2:1 impedance ratio and exhibit 26 dB re turn loss in 1 dB bandwidth. The POS 2120W plug-in voltage-controlled osci lator has output suitable for low driv

to 7 dBm mixers. Features include octave band 1,060-2,120 MHz tuning and 3 dB modulation bandwidth at 1 MHz.
Mini-Circuits
INFO/CARD 140

Inductors designed for electronic devices

The Power Wafer line of magnetics includes power inductors designed for electronic devices, Type 1 PC cards, disk drives and other low-profile power applications. The new LPT3305 series is a toroidal inductor in a 1.8 mm high ceramic case. The LPT3305 series is available in 11 inductance values from 1 to 47 mH. Saturation current ratings range up to 6 A, with rms current ratings up to 1.6 A.
Coilcraft
INFO/CARD 141

Resistors designed for high-frequency applications

The TCH35 TO220 and TAH20 series are non-inductive resistors designed for switching power supplies, high-frequency applications and pulse loading. Standard and custom resistance values are available from 0.05V to-10K V for the TAH20 series and 0.1 V to 10K V for the TCH35 series. Each resistor element is electrically insulated. The TCH35 series offers a thermal resistance to the heat sink of <4.28° C/W, while the TAH20 offers a thermal resistance of 6.25° C/W.
Ohmite Manufacturing
INFO/CARD 142

TRANSMISSION COMPONENTS

GaAs MMIC downconverter for 2.4 GHz applications

The C2304 is a fully-integrated gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) downconverter designed for use in 2.4 GHz ISM band applications. The device is packaged in an industry standard SOIC-14 package. Each internal sub-circuit is brought out on individual pins to allow custom filtering on the IF/RF mixer interstate or custom matching for specific bands. Broadband parallel feedback networks are used on the gain and L O driver stages and the mixer is singly balanced. Electrical features include 26 dB gain, 4 dB noise figure, single +5 V supply, 27 dBm output IP and comes with separate RF amplifier, mixer/ LO amplifier and IF amp cells.
Pacific Wireless
INFO/CARD 143

Ku band power dividers support 10.7 to 14.5 GHz

The A8338 series of Ku band power dividers are available in 2-way, 4-way and 8-way version. The devices operate at frequencies from 10.7 to 14.5 GHz covering both the uplink and downlink frequencies used for Ku band communications satellites. With high isolation, typically greater than 20 dB, these dividers are suitable for multi-channeling applications in the transmit and receive paths of ground stations and provide high levels of RF shielding..
Atlantic Microwave
INFO/CARD 144

Hybrid receivers for short-range wireless applications

RF Monolithics RX 5000 series second generation amplifier-sequenced hybrid (AHS) receivers are designed for short-range wireless control and data applications. The first two products in this series are the 433.92 MHz RX5000, designed for short-range wireless applications in Europe under the ETSI I–ETS 300 200 regulations, and the 315.0 MHz RX5001, designed for short-range data link applications in North America and Asia. The receivers can be configured to support a wide range of data rates and protocol requirements.
RF Monolithics
INFO/CARD 145

Mixers cover cellular, PCS, WLL

The new line of CSM mixers covering cellular, PCS and WLL bands are derivatives of the Hi-Rel and Space mixer product line. The package is 0.370" x 0.490" x 0.187", with a ceramic substrate that has metalization compatible with standard solder reflow processes. They are available in standard double-balanced and load-insensitive designs, with low power levels of 10 to 23dBm, achieving a third-order intercept of 27 dBm typical.
Stellex Microwave Systems
INFO/CARD 146

YIG filters offer reduced phase noise

New permanent magnet filters are designed to meet specifications for switching speed and stability. These filters are available in frequency ranges covering 4-26 GHz. The filters offer reduced phase noise and lower magnetic susceptibility.

Filtronic Solid State
INFO/CARD 147

Isolators cover 138-150 MHz

New drop-in and coaxial isolators and circulators cover the full 138-150 MHz range. Performance specifications include 15 dB isolation, 0.6 dB insertion loss and VSWR of 1.4:1. The operating temperature ranges from -40° to +85° C. The isolators and circulators measure 2" x 2.54" x 0.75".

Alcatel Ferrocom
INFO/CARD 148

Delay lines allow wider bandwidths

The FDC and FDD series are 3-pin SIP, fixed delay lines designed to allow for wider bandwidths and sharper waveforms. The combined FDC and FDD series offers a delay time of 50 ps to 27.0 ns. The delay time selection makes them suitable for insertion in high-speed and narrowly spaced clock and bus lines. The lines have maximum profiles of 6.0 mm and 8.0 mm respectively.

Toko America
INFO/CARD 149

Selective bandpass filter with 22 MHz bandwidth

Model 3303-280/302 is a selective bandpass filter with a 22 MHz bandwidth for frequency band isolation in headend equipment. The filter has a passband loss of 4 dB maximum and a rejection of 30 dB at ± 18 MHz from the center frequency. Impedance is 75 ohms and connector are type F. The unit is designed for indoor use. Other models of the 3303 can be custom configured for different passband bandwidths.

Microwave Filter
INFO/CARD 150

Combiner splits input signals to amp modules

The 4ATTA0405 is a four-way, high-power Adrenaline splitter/combiner for modular amplifiers, including DCS, PCS and W-CDMA applications. The splitter/combiner is designed to split input signals to amplifier modules and recombine the output signals with another Adrenaline for medium- or high-power base station amplifiers. The splitter/combiner has dc distribution to the amplifier modules, including decoupling capacitors for each module. The 4ATTA0405 covers the 1.8-2.2 GHz bands and has a maximum insertion loss of 0.4 dB and an amplitude balance of 60.4 dB.

Anaren Microwave
INFO/CARD 151

Filter passes C-band frequencies

The model 12086 filter is used to pass the C-band receive frequencies of 3.7-4.2 GHz with a maximum 0.1 dB insertion loss. The unit provides a minimum 50 dB rejection of the uplink frequencies of 5.9- 6.4 GHz. The unit has a VSWR of 1.1:1 across the entire passband. WR-229G flanges are standard with this unit, but other connectors are available.

Microwave Filter
INFO/CARD 152

Couplers operate with less than 0.2 dB insertion loss

Model S03A2150N1 is a 100 W surface-mount coupler operating in the 2- 2.2 GHz frequency range with less than 0.2 dB insertion loss and VSWR of less than 1.15:1. Phase balance of 62°, amplitude balance of 60.1 dB and isolation of >22 dB are combined in a laminated surface-mount package measuring .56" x .35" x .085". The 200W, 2.0-2.3 GHz surface-mount coupler, designated as model S03B2150N2, yields less than 0.2 dB insertion loss, VSWR of less than 1.25:1, and phase and amplitude balance of 62° and 60.2 respectively.

RF Power Components
INFO/CARD 153

Converter features unity plus gain

Model 12740 is a triaxial-to-coaxial converter and distribution module that features unity plus gain, dc to 200 MHz bandwidth, dc offset adjustment and 50 V or 75 V I/O impedance. The converter can also be used for coaxial-to-triaxia

pplications. It is designed for use with onverter modules and distribution amlifier modules.
rt Wroobel Company
NFO/CARD 154

SIGNAL SOURCES

requency translator come n gull-wing flatpack

he model FX070 frequency translator s a low-noise, narrowband PLL that enerates a 2488.32 MHz output deived from an external 12.96 MHz refrence clock. The units have an output ignal of 0 dBm minimum into 50-ohm nd are available in a 16-pin, surfaceountable, gull wing flatpack measuring 1" x 1" x 0.28". Supply voltage is .0 Vdc 65%.
ectron International
NFO/CARD 155

scillator operates over exended temp range

he V607TE01 voltage-controlled oscilator (VCO) is packaged in a 0.375" x .375" x 0.124" surface mount and genrates frequencies between 1,279-1,313 Hz within 0.4 Vdc and 2.8 Vdc of conrol voltage. The V607TE01 exhibits a ignal of -99 dBc/Hz, typically, at 10 Hz from the carrier while using 6 mA om a 3 Vdc power supply. The VCO is pecified to operate over the extended ommercial temperature range of -25°-5°C and has a linearity over frequency nd temperature that measures 1.1:1.
-Communications
NFO/CARD 156

CABLES/CONNECTORS

adiating cable supports n-building applications

he Nu-rad series of radiating cables is esigned for in-building, subway, ransit and tunneling applications. The ables offer a combination of a surface ave at lower frequencies, along with he generation of a radiating mode at igher frequencies. The combination alows multiple services, such as paging, ellular and PCS, to be provided on a

single broadband radiating cable. They are offered in non-flame retardant polyethylene, as well as flame retardant, low-smoke, non-halogen jacketed designs. Type N and 7/16 DIN connectors are offered for attachment purposes.
Times Microwave Systems
INFO/CARD 157

Antennas offer data, voice services

The Datamaster MMDS sector antenna range for two-way multichannel, multipoint distribution services (MMDS) systems provides data and voice services to multiple dwelling units and small businesses. Three Datamaster antenna versions are available: a 90° sector transmit antenna for two-way systems with 18 dBi gain in the 2,500-2,700 MHz frequency band and receive antennas for two-way systems with either 18 dBi (90° sector size) or 22 dBi (30° sector size) gain in the 2,150-2,360 MHz frequency band. The antennas are available in horizontal or vertical polarization, weigh 20 lbs., can withstand winds up to 150 mph and continue to operate in temperatures between -40° C and 70° C.
Andrew
INFO/CARD 158

AMPLIFIERS

Amplifier offers 1,000 W power

The 1000W1000A amplifier offers 1,000 W minimum power from 80-1,000 MHz, ns rise time and Class A operation. The amplifier is suited for use with non-invasive physiologic EPRI (electron paramagnetic resonance imaging).
Amplifier Research
INFO/CARD 159

DATA TRANSMISSION PRODUCTS

Modem ready to plug and play

The Neulink RF 9600 radio modem is capable of 9600 baud over the air. This transceiver comes ready to plug and play for data operation for point-to-point or multipoint operation. It i suited for use in irrigation control weather stations and remote site moni toring of oil, gas and water systems.
RF Neulink
INFO/CARD 160

SUBSYSTEMS

Digital radio modules offer A/D converter

The PEM-16DDC 16-channel dow converter module and the PMC-2MA dual A/D converter PMC module ar digital radio products. The PEM 16DDC is a double-width module tha features Graychip GC4014 quad digita down converters and operates as hig as 65 MSPS. Each GC4014 drives FIFO that stores as many as 2K x 32 bit samples, which provides 512 sam ples per channel if all four channels c the GC4014 are used. The PMC-2MA single-width PMC module hosts two 12 bit AD6640 A/D converters from Analo Devices and is capable of digitizin analog intermediate frequency (IF) sig nals from 130 kHz to 35 MHz. Two low voltage differential signaling (LVDS interfaces are provided on the fron panel of the PMC-2MAI for intercon nection to the PEM-16DDC module.
Spectrum Signal Processing
INFO/CARD 161

POWER SUPPLIES/BATTERIES

Power supplies target telecom applications

Lambda Electronics' PA, PM and P series power supplies target on-boar distributed power applications in th telecommunications. Each series pro vides an industry standard pinout an footprint to allow for easy integratio in existing systems. The PA series con sists of single output DC-DC converter with 48 V inputs. The PM series i available in single, dual and triple out puts with 12 V, 24 V and 48 V inputs The line offers 96 models in 10 W, 20 V and 30 W packages. Remote on/o output adjustment features are avai able and all models provide short ci

:uit protections
Lambda Electronics
INFO/CARD 162

.evel 2-compliant battery :hargers

The MAX1667 is an SBS IF specifica-ion v 1.0 for level 2-compliant battery :harger for Lithium-Ion cells. This one-:hip solution contains independent 'oltage and current mode to constant 'oltage mode during charge. The MAX1667 charges two- to four-series Lithium-Ion cells and regulates pro-grammed charge voltages to within ±).8%. The device uses an advanced syn-hronous buck topology for a duty cycle o exceed 97%. Using an SMBus-com-atible 2-wire interface, the MAX1667 eceives charging voltage and current ommands and reports status informa-ion about the state of the charger and atter. Charging voltage is program-nable from 0 to 18.432 V with 11 bits f resolution.
Maxim
NFO/CARD 163

ADHESIVES/GLUES/ SEALENTS

Jrethane foam resists water ind air permeation

SuperSheet materials are low-density ırethane foams that resist water and ir permeation. The material requires ittle pressure to compress and resist ermanent collapse, and are designed or gasket and sealing applications. 'hey are available in four standard rades varying by hardness, water-re-istance and density. They feature a hin, penetration-resistant skin on both he top and bottom surfaces and are ast as continuous sheets, rather than liced from bun stock.
:-A-R Specialty Composites
NFO/CARD 164

'hermal conductive ıdhesive

Supertherm 816H01 is a thermally con-uctive, electrically insulating, 2-part dhesive that can be used in a number f applications including staking resis-ors, diodes, transistors, heat sink at-achment, or any other application re-uiring thermal management. The adhesive can bond to numerous substrates including most metals, ceramics, glass and plastics. It is a room temperature curable system but elevated temperatures can be used to reduce cure time. For high speed manufacturing, the adhesive is compatible with automated dispensing equipment.
Tra-Con
INFO/CARD 165

Pressure sensitive adhesive offers .004 tolerance

Meyers Applied Components offers a variety of materials including foil, foam, and laminates that can be applied within a .004 tolerance regardless of the size or shape. The capability comes from a process that allows the components to produced in "roll" form (similar to roll labels), which permits automated applications.
Meyers Applied Components
INFO/CARD 166

ANTENNAS

Fixed station planar antenna for 800 MHz applications

The model ASPPA2988 is a fixed station discreet planar antenna for use in 800 MHz applications. The antenna incorporates a precision-engineered microstrip design and may be used in either indoor or outdoor applications and for use in voice and data communication. The ASPPA2988 covers the frequency band of 806 to 869 MHz with a VSWR of 1.5:1 across the entire band. The vertically polarized antenna is power rated at 20 W and offers a 7.5 dBi gain. The front to back ratio is 12dB.
Allen Telecom
INFO/CARD 167

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Schematic design software offers seamless transition

Intercept Technology's MoZaiX schematic capture software is designed for use on Win98, WinNT and UNIX platforms. It allows engineers to seamlessly transition between schematic, layout and manufacturing. The database is compiled in an open, ASCII, single file format. MoZaiX features multiple schematic sheets, flexible design hierarchy and design data verification. Additionally, the software is designed to integrate with Intercept's Pantheon printed circuit board/hybrid/multichip module design application.
Intercept Technology
INFO/CARD 166

Software for embedded systems

Altia Faceplate 4.0 simulation graphics software for embedded systems is designed to assist engineers in creating graphic front panels for simulation models. Interactive user interfaces and animated graphics can be designed without the need for programming or graphic design experience. It also contains debugging, optimizing and regression tools to assist the engineer with these functions.
Altia
INFO/CARD 167

Mathcad adds wavelets expansion pack

Mathcad's Wavelets extension pack for Mathcad 8 adds wavelets technology to its standard product, enabling analysis of signal and large data sets. Included in this expansion pack are 60 wavelet functions covering five orthogonal and biorthogonal families. These functions support advanced techniques for signal reconstruction, denoising, data compression and special numerical methods. All functions are integrated into Mathcad's core environment.
Mathcad
INFO/CARD 168

Automated signal analysis software

SPSS's AutoSignal signal analysis software enables users to automate spectral analysis, time domain analysis and signal processing without programming. The software is capable of performing complex signal analysis using fast Fourier Transform, autoRegressive, moving average ARMA, complex exponential modeling, minimum variance methods, eigenanalysis frequency estimation and wavelets.
SPSS
INFO/CARD 169

EMI software developed for HP spectrum analyzers

EMC Consulting's electromagnetic interference commercial measurement program (EMICMP) for use with the HP 8591E series spectrum analyzers. The software is designed to replace the HP EMC personality card with an alternative set of instructions. The software offers improved amplitude accuracy and can measure trace data, individual peak, average, and Q/P detection. Output includes printed tabular and graphic data plus data set storage on disk.
EMC Consulting
INFO/CARD 170

Extensible spectrum analyzer software

Spectrum Capture custom software, from Anritsu Company, is designed to expand the analysis capability of the company's MS2650/2660 series spectrum analyzers. Spectrum Capture offers the user the ability to take measurements at user-selected times and frequencies. The data can be transferred to a PC for detailed analysis. The data can also be stored and compared to future or previous captured data. Users can pull multiple traces simultaneously and create a trace overlay. Additional features include creation of trace makers for power and frequency, data categorization and other features.
Anritsu Company
INFO/CARD 171

Parametric software upgrade

Optotek's LASIMO, large and small signal modeling software, is designed to facilitate the development of large signal models by simplifying the procedures for the extraction of, metal semiconductor field-effect transistor (MESFET) and high-electron mobility transistor (HEMT) model parameters. The program provides the designer with a set of models, as well as the capability to incorporate user-defined models that can be optimized to match existing prod ucts. LASIMO is the latest component t its MMICADSuit.
Optotek
INFO/CARD 172

Microwave link design tool offers Internet interface

Comsearch's FiveNines V 1.1 is th latest version of its microwave lin design tool. The product is designed t analyze path profiles and evaluate lin performance. It is interactive an enables the user to download high-reso lution terrain data from the company' database over the Internet. The dat can be incorporated into existin screens without leaving the program.
Comsearch
INFO/CARD 173

Multifunction microwave design software

Johanson Technology's MLCsoft allows the designer to download s-parameters in SP2 format, or determine the spice parameters for a given JTI multilayer high-Q capacitor. Also, the user can find commonly available capacitor parameters such as SRF, 1st PRF, ESR Q as well as typical parameters such a effective capacitance, series inductance and impedance.
Johanson Technology
INFO/CARD 174

Software on the Web

Model semiconductor heat sinks on the Net

R-Theta has created a tool for modeling semiconductor heat sinks over the Internet and view an instant simulation of the application. The product will present a 3D thermal plot of multiple power sources. The engineer will be able to place their common insulated-gate bipolar transistor (IGBT) modules on a user configured heat sink template and move it around until a satisfactory design is optimized.
R-Theta
INFO/CARD 175

To get more information about the software described in this section, go to **www.rfdesign.com** for direct links.

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INFO/CARD 3

Brochure features low-frequency EMI products

Magnetic Shield's brochure provides information on cable, conduit, sleeving and wire using CO-NETIC AA alloy. This product is specifically designed to control low frequency electromagnetic interference (EMI). The brochure contains sizes and specifications.
Magnetic Shield
INFO/CARD 176

Thermal management described in brochure

BP Amoco offers a brochure describing its technique for pulling heat away from thermal devices. Detailing its ThermalGraph thermally conductive fibers, the brochure describes how these products can provide design engineers with new approaches to thermal management. Some of these materials can conduct heat at a rate of up to three times faster that of copper, at one-quarter of the weight.
BP Amoco
INFO/CARD 177

Brochure describes automated tuner system

Maury Microwave offers a new brochure describing the latest features of it's automated tuner system (ATS). New features include a harmonic tuner and harmonic tuner controller and an ADS/ATS load pull data module for Hewlett Packard EEsof's advanced design system software, and Widows 95/98/NT compatibility. The brochure also describes the systems options, latest innovations and applications.
Maury Microwave
INFO/CARD 178

Short form transistor catalogue

Advanced Semiconductor offers new short form catalog of microwav and RF power transistors. The catalogue contains both metal-oxide sem conductor field-effect transisto (MOSFET) and bipolar selections an includes application specific product for HF, VHF and UHF. Target applica tions include military communciation: avionics and radar, and CW m crowave.
Advanced Semiconductor
INFO/CARD 179

Brochure details LC filters for various applications

Piezo Technologies' LC filte brochure features the company's line (LC filters for lowpass, highpass, banc

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ɔass and band reject applications. The LC filters are targeted for commercial and military uses. Commercial applications include wireless communications infrastructure, point-to-point and multipoint microwave radios, satellite communications, navigation systems, instrument and medical. The filters military uses including aircraft communication and navigation systems.
Piezo Technology
INFO/CARD 180

Capacitor catalog offers quartz, sapphire products

Voltronics' 40-page catalog describes its complete line of PTFE, glass, quartz, sapphire, and air variable capacitors. The catalog includes detailed information about the company's latest solid dielectric trimmer line for GHz frequencies and offers detailed specifications for the devices.
Voltronics
INFO/CARD 181

Catalog features antennas for land mobile radios

Antenna Specialists', a division of Allen Telecom, new catalog for land mobile radio (LMR) features 48-pages of updates on all current lowband, VHF, and UHF antennas, as well as special purpose and handheld products. It also includes the new Mosaic antenna series as well as other special purpose antenna products. The antennas support a range of frequencies including 30 to 88 MHz, 130 to 174 MHz, 108 to 512 MHz, 210 to 230 MHz and 406 to 512 MHz.
Antenna Specialists
INFO/CARD 182

Short-form catalog describes I/O solutions

Systran offers a short-form catalog with details of its entire line of input/output (I/O) IPack solutions. Included are IPack carrier boards for VME, PCI, ISA and CompactPCI systems. The catalog also details Systran's IPack modules, including analog interfaces, digital/discrete interfaces, serial communications interfaces, counter/timers, software support packages and accessories.
Systran Corporation
INFO/CARD 183

On the Web

ICM offers online ordering

International Crystal Manufacturing (ICM) has added an online order page to its Web site. The site can be accessed at **www.icmfg.com.**
ICM
INFO/CARD 184

To get more information about the software described in this section, go to **www.rfdesign.com** for direct links.

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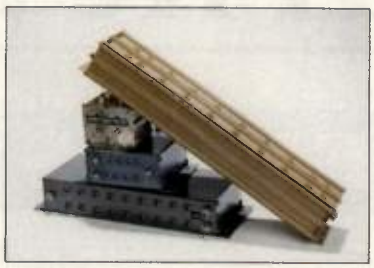

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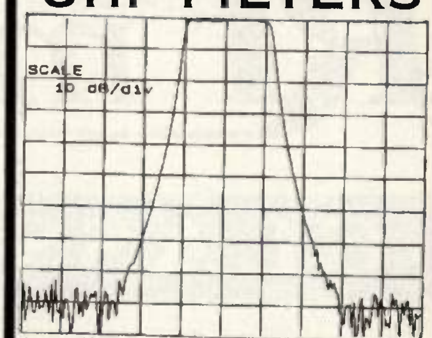

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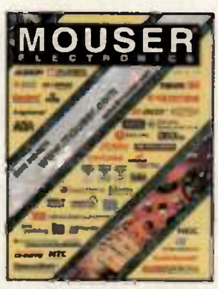

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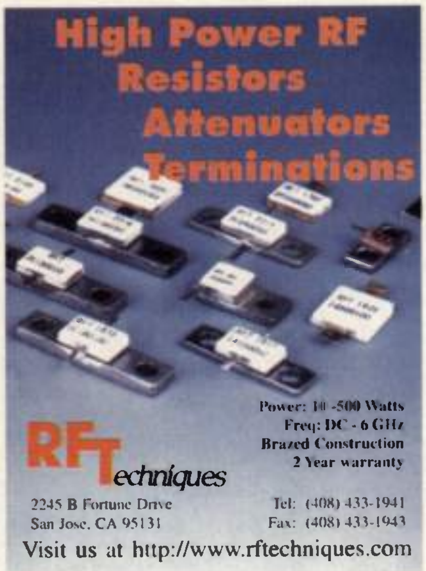

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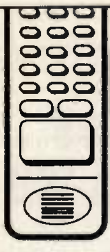

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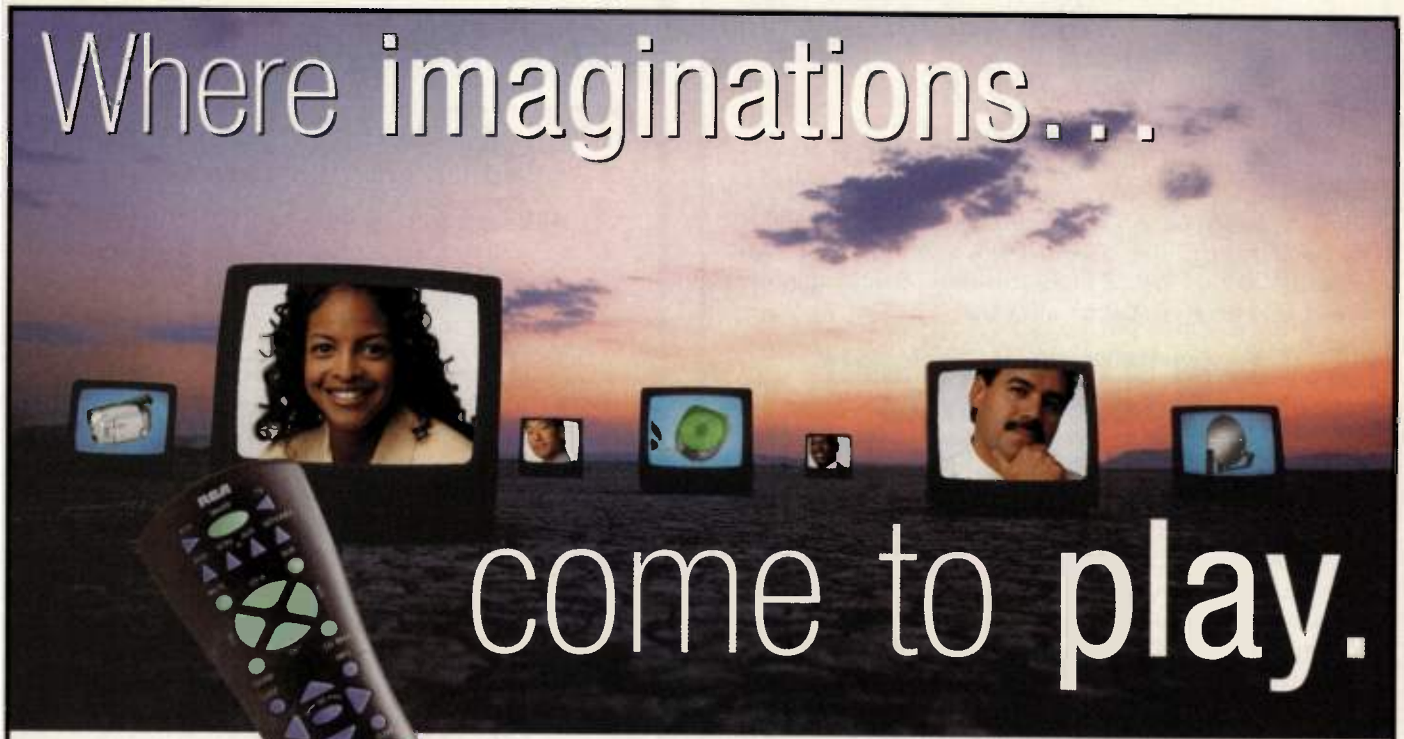
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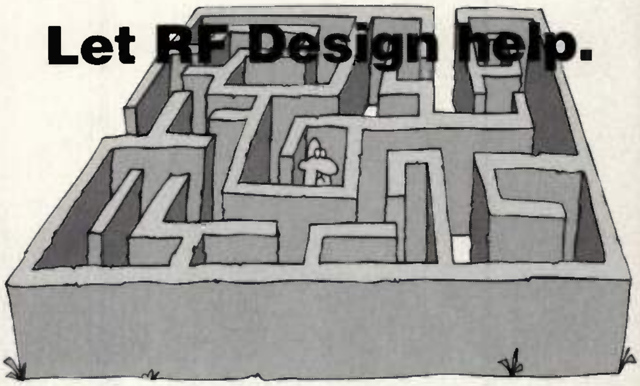

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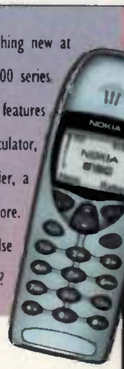

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Does IEEE really get it?

by Ernest Worthman

I love it when I find a topic that drives to the heart of a subject. Such was the case with a column I had written a couple of months ago about voice mail purgatory.

I got more mail from that one column, than all of my earlier columns combined. Before I move on to this month's "rant", I want to tip my hat to those of you that took the time to share your thoughts with me. Hearing from you is really what it's all about. Look for examples of the responses I received on **RF Design Online**.

Now, this month I want to comment about an organization that many of us are either part of or, at least, aware of—the Institute of Electrical and Electronics Engineers (IEEE).

Lately, there have been a couple of long-term issues about this organization that have been bugging me and I want to see if some of you share my thoughts.

For 19 years, I've been a member of the IEEE. For an organization that is so full of educated, dedicated professionals, its functionality leaves a lot to be desired. It seems to me that the IEEE has a lot of the trouble in organization.

At the last MTT-S in Anaheim, I received advanced registeration as an exhibitor. When I arrived in Anaheim, I went to the registration booth to try to correct the registration from exhibitor to a press registration. After I told them who I was, the attendee registration people sent me to the exhibitor's registration booth. I repeated the story. They sent me back to attendee registration (At this point, picture a tennis ball). Finally, guess who fixed the problem. Not the IEEE, rather the magazine that co-sponsored the show. A magazine representative was in the back of registration dealing with other issues, when she overhead the frustrating conversation I was having with an IEEE person, and in a heartbeat, fixed it.

Just one example of a bad experience? One of the technologies we follow very closely is intelligent transportation. With that in mind, we attempted to attend the Vehicular Technology Conference (VTC) held in Houston. Going to the IEEE Web site for information on who to contact, we eventually found our way to the VTC Web site. After e-mailing and calling every individual on the conference committee list (we worked our way up the food chain) over a period of two months (with no response), the conference chair finally contacted our editor, Roger Lesser. Even then it took weeks to receive an answer to the request. Too little, too late.

Our editorial director, Don Bishop, has had similar experiences. In fact, his experiences led him to write a letter to the board of directors, questioning their association with the press, in light of their complaints that they are not getting adequate press coverage.

Every time the race for officers comes up, predictably, the candidates tell us that the organization needs to be more responsive to its members. Well, although I'm press, I'm a member. In the past I've complained on a member platform, to the IEEE about some of their third-party service providers. Did I ever get a reply? Never! Did they investigate it, not to my knowledge.

I'm not intimating that the IEEE is a organization of bumblers— quite th opposite. I believe the IEEE to be a most professional, dedicated, avant garde, on the cutting edge of technolog association. What I am stating is tha its administration is out of touch wit its members, and perhaps, reality. As a member, I've never thought their ser vices to be stellar. As press, it's eve worse. I mean, who passes up fre press? The IEEE for one.

I'd be interested in what you, ou readers, feel about the IEEE. Please e mail me with your thoughts.

Ernest Worthman is RF Design's technology 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 or though the letters to the editor on the RF Design Web site, www.rfdesign.com.

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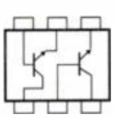

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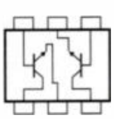

Part Number	Description	Q1 Spec	Q2 Spec
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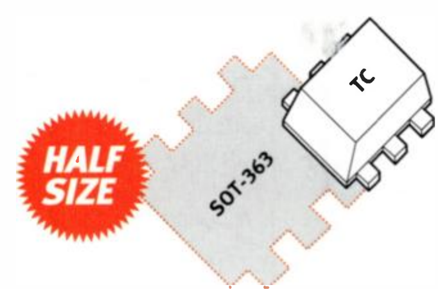

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