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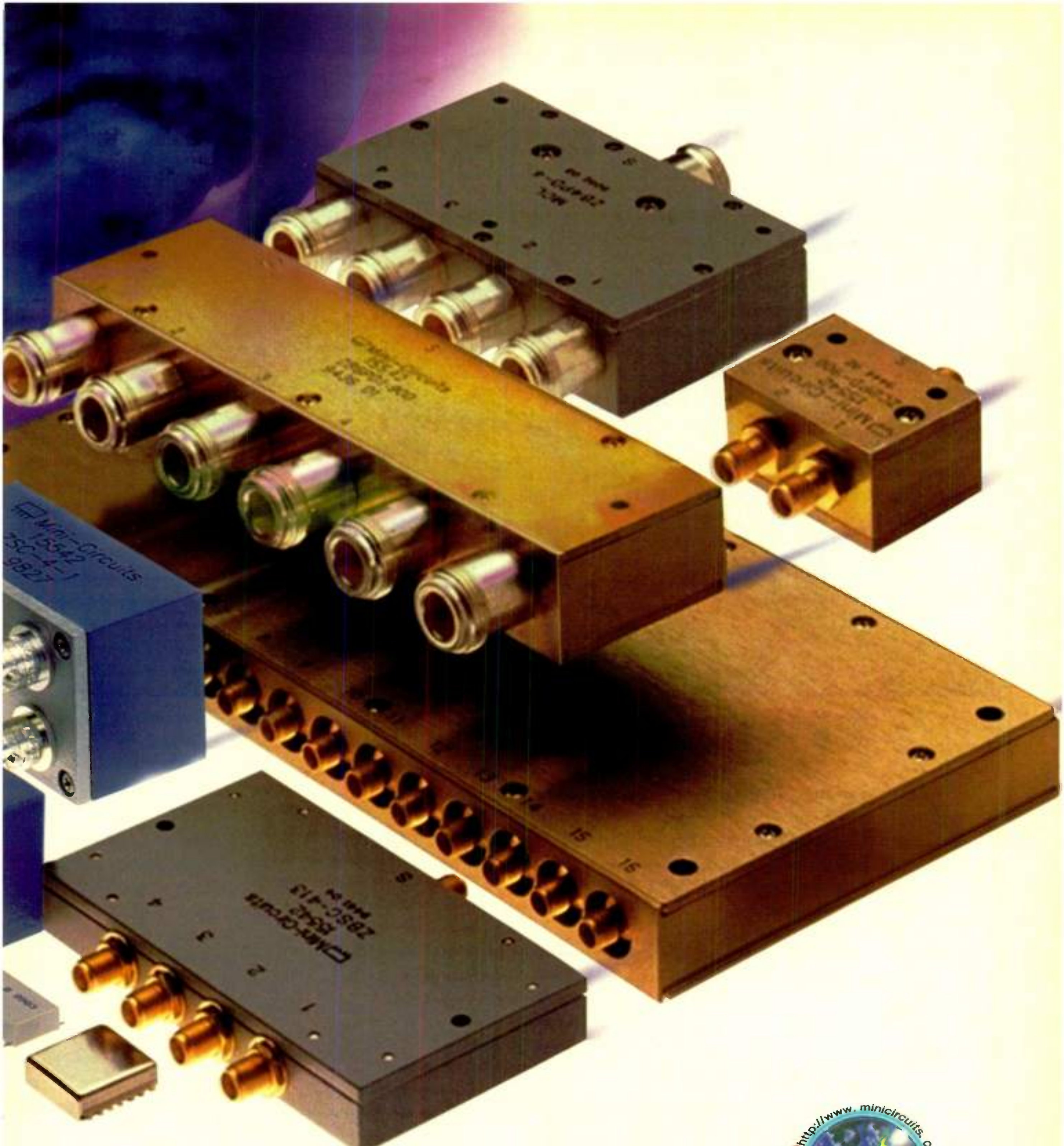
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FEATURES

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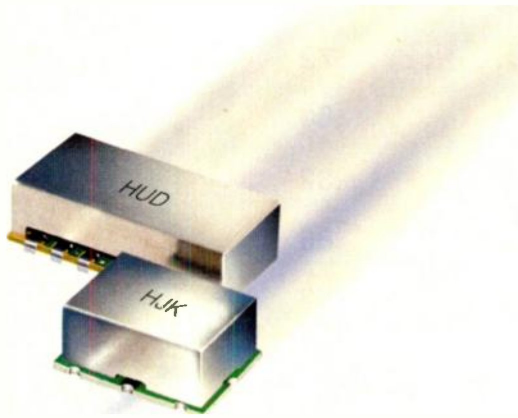

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** HJK-3H	140-180	0.5-20	16	37	8.0	44	44	16.95
HJK-9H	818-853	40-100	17	33	6.7	35	31	16.95
HJK-19H	1850-1910	70-130	17	34	7.7	28	22	16.95
HJK-21H	1850-1910	180-300	17	36	7.6	28	25	16.95
** HUD-3H	140-180	0.5-20	16	37	8.1	47	45	15.95
** HUD-19SH	1819-1910	50-200	19	38	7.5	38	36	19.95

*Units protected under U.S. patents 5,416,043 and 5,600,169.
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RF editorial

Did the Grinch steal 3G?

By Roger Lesser
Editor
rlesser@intertec.com

Every Celluser in Cellville liked wireless a lot.
More data and other goodies — anything hot!
But the Grinch of 3G sat in his tower of tech,
"They'll never get it, that's my bet."

The Grinch liked 2G really a lot.
"2G has 80% of what 3G's got."
He looked for chips and clocks that made 3G work,
"The technology's somewhere," he said with a smirk.

He read about what the ITU had wrought,
"It's too late for anyone" is what he thought.
"3G will be here soon," the poohbaas said.
"But, it's too late," snarled the Grinch from his bed.

The 3G products were starting to grow,
But the Grinch noted, "It's really too slow."
"They promised it all, they promised a lot,
the wait has been long, longer than not."

The Grinch smiled and looked up with a grin,
"If they bypass 3G, would it be a wireless sin?"
Cellusers in Cellville are an educated group.
Would they greet 3G with a moan or a whoop?

The Grinch used his 2G with pride and with joy.
"If 3G were here would it become just a toy?
I have what I have and I like it for sure,
and I don't think that 3G is all that pure."

So, down to Cellville the Grinch he did glide,
His 3G feelings he could not hide.
The Cellusers in Cellville saw him come down with a thud,
And heard him yell, "Is 3G a dud?"

They looked at him between their boxes and clocks,
And yawned at 3G as they pulled on their sox.
"3G is too late, its promise is hallow."
They agreed with the Grinch (a hard pill to swallow).

So, there is no 3G in Cellville today.
It may come, but who can say?
The Grinch is happy in his wireless way,
"I'll wait for 4G, come what may."

Dear readers, thanks for your time.
I promise not to do another column in rhyme.
A Cat in the Hat is not for me,
So, an editor is what I guess I'll be.

Thanks for the inspiration Ted Geisel

Roger

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Established 1978

Editorial offices
5680 Greenwood Plaza Blvd., Suite 100
Greenwood Village, CO 80111 • 720-489-3100; Fax 720-489-3253;
e-mail *rfdesign@intertec.com* • Web site **www.rfdesign.com**

Editor . . . . . Roger Lesser
Technology Editor . . . . . Ernest Worthman
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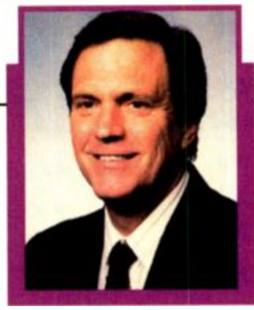
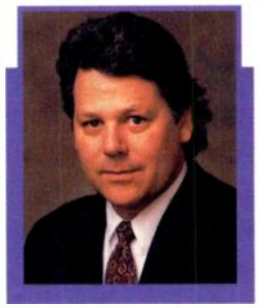
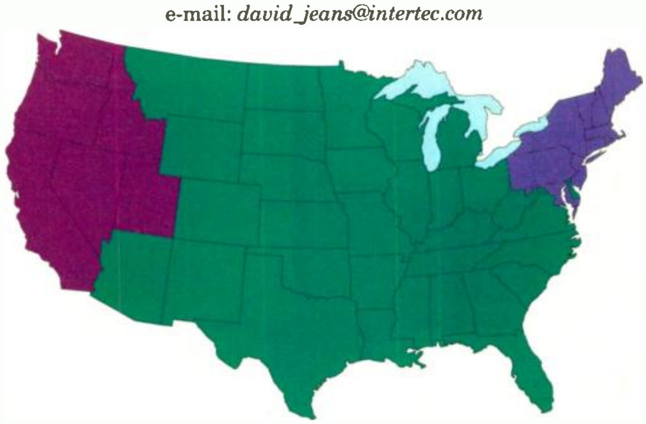


PHIL COOK
Marketing Manager- West
2121 Alton Parkway, Suite 200 • Irvine, CA 92606
Tel. 949-838-2165 • Fax: 949-252-0556
e-mail: *phil_cook@intertec.com*

CORY BUDAJ
Marketing Manager- Central
5680 Greenwood Plaza Blvd., Suite 100 • Greenwood Village, CO 80111
Tel. 720-489-3201 • Fax: 720-489-3253
e-mail: *cory_budaj@intertec.com*



DAVID JEANS
Marketing Manager- East
5680 Greenwood Plaza Blvd., Suite 100 • Greenwood Village, CO 80111
Tel. 720-489-3108 • Fax: 720-489-3253
e-mail: *david_jeans@intertec.com*



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Classifieds: Dawn Rhoden
9800 Metcalf Ave.
Overland Park, KS 66212-2215
Tel. 913-967-1861; Fax: 913-967-1735
e-mail: *dawn_rhoden@intertec.com*

Europe: Stephen Bell
P.O. Box 98, Worcester Park, Surrey, KT4 8WB, United Kingdom
Tel. +44.208.286.8889; Fax: +44.181.286.8898; e-mail: *stephenbell@email.msn.com*

Israel: Asa Talbar
Talbar Media
Tel. +972.3.562.9565;
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23–25 **49th International Relay Conference** – Oak Brook, IL – Information: Web site: **www.ec-central.org**

30–3 **Global Summit 2001** – *Orlando* – Information: Web site: **www.tdma-edge.org**

MAY

1–3 **IEEE Radar Conference** – *Atlanta* – Information: Tel.404.385.3502; Web site: **www.conted.gatech.edu**

22–24 **Eastec 2001** – *West Springfield, MA* – Information: Tel. 800.733.4763.

22–24 **International Microwave Symposium: IEEE-MTTS** – *Phoenix* – Information: Web site: **www.nonlintec.com**

JUNE

3–7 **Supercomm** – *Atlanta* – Information: Web site: **www.supercomm2001.com**

5–7 **Sensors Expo 2001** – *Chicago* – Information: Tel. 203.882.1300 x 181. Web site: **www.sensorsexpo.com**

6–8 **2001 IEEE International Frequency Control Symposium/ Exhibition** – *Seattle* – Information: Web site: **www.ieee-uffc.org/fc**

24–27 **WCA Annual Conference** – *Boston* – Information: Wireless Communication Alliance (WCA). Tel. 202.452.7823.

JULY

9–12 **Embedded Systems Conference** – *Chicago* – Information: Web site: **www.embedded.com/esc**

AUGUST

13–17 **IEEE-EMC Symposium** – *Montreal* – Information: Web site: **www.ieee.org.**

SEPTEMBER

4–7 **Embedded Systems Conference** – *Boston* – Information: Web site: **www.embedded.com/esc**

OCTOBER

1–4 **Communications Design Conference** – *San Jose* – Information: Web site: **www.CommDesignConference.com**

2–4 **Sensors Expo Fall** – Philadelphia – Information: Web site: **www.sensorsexpo.com**

RF courses

ALEXANDER RESOURCES – *3G Wireless: Promises and Realities* – April 30–May 1, Orlando; *Making Money in the U.S. Wireless Internet Market* – July 10–11. Information: Jeff Stone, Alexander Resources,15851 N. Dallas Pkwy, Addison,TX 75001; Tel. 972.818.8225; Fax: 972.818.6366; e-mail: *jstone@alexanderresources.com*.

BESSER ASSOCIATES – *3G Made Simple* – May 14; *RF and Wireless Made Simple* – May 15–16; *RF and Wireless Made Simple II* – May 17–18; *Advanced Wireless and Microwave Techniques* – Feb. 12–16; *Bluetooth: Operation and Use* – May 10–11; Mountain View, CA. Information: Besser Associates, 201 San Antonio Circle Building E, Suite 280, Mountain View, CA 94040; Tel. 650-949-3300; Fax: 650-949-4400; e-mail: *info@bessercourse.com*; Web site: **www.bessercourse.com**

R.A. WOOD ASSOCIATES – *Introductory RF and Microwaves* – April 19–25; *RF and Microwave Receiver Design* – April 19–20; *RF Power Amplifiers, Classes A Through SS: How the Circuits Operate, How to Design Them, and When to Use Each* – April 19–20, Baltimore, MD. Information: R.A. Wood Associates, 1001 Broad St. Ste. 450, Utica, NY 13501; Tel. 315.735.4217; Fax 315.735.4328; e-mail: *RAWood@rawood.com;* Web site: **www.rawood.com**

UCLA – *Digital Signal Processing: Theory, Algorithms, and Implementation* – April 9-13; *Communication Systems Using Digital Signal Processing* – May 14-18; *Introduction to Data Compression* – May 30-June 1; *Digital Signal Processing: Theory, Algorithms, and Implementation* – August 13-17; *Bluetooth: Technology, Applications, and Performance* – Aug. 20–22, Los Angeles, Information: Information Systems and Technical Management Short Courses. Tel. 310.825.3344; e-mail: *mhenness@unex.ucla.edu*; Web site: **www.uclaextenstion.org/shortcourses**

UNIVERSITY OF MISSOURI-ROLLA – *Grounding and Shielding Electronic Systems* – April 19, Columbus, OH; June 19–20, Boston; August 8–9, Toronto; *Circuit Board Layout to Reduce Noise Emission and Susceptibility* – April 19, Columbus, OH; June 21, Boston; August 10, Toronto; September 19, Denver. Information: Web site: **www.umr.edu/-conted>**

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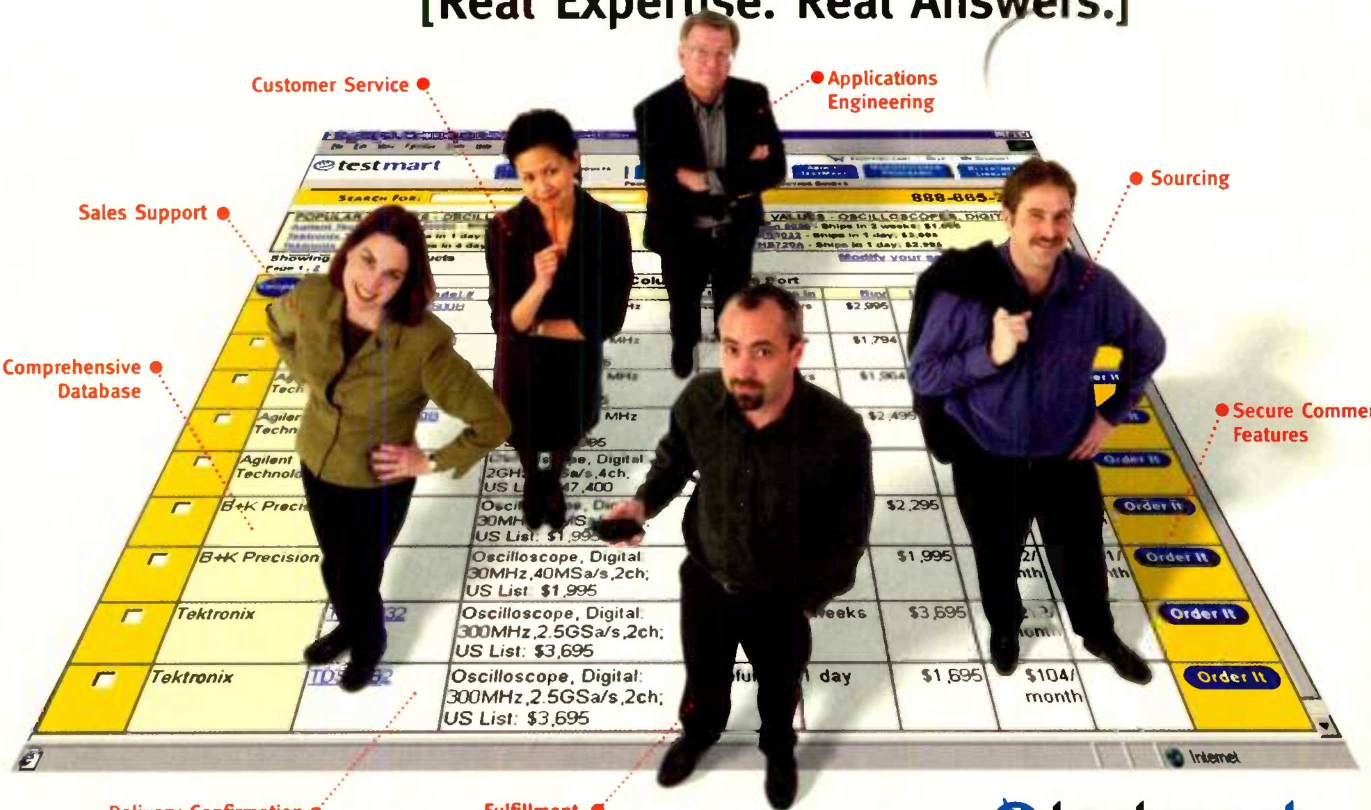

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Ultra wide band and the Federal Communications Commission

by Delaney M. DiStefano

With a new administration in town and a new chairman on the bench, it has been rather quiet at the FCC. Meanwhile, America waits to learn what this administration's focus will be. Something that has been brewing for a while, however, just got a little closer to fruition.

Last May the FCC published a notice of proposed rule making (NPRM) in which it proposed, and requested comments on, feasible ways to regulate ultra wide band (UWB) technology and products. Because a portion of this new UWB technology will most likely operate in the restricted government bands, the National Telecommunications and Information Administration (NTIA) and the Associated Institute for Telecommunication Sciences were recruited to research the effect of UWB devices on federal radio systems. NTIA's reports were recently published and are currently going through the notice and comment period.

UWB devices are proposed to be regulated under Part 15 of the FCC's rules regarding unlicensed devices. The current rules regarding intentional radiators are insufficient to deal with the novel concepts of UWB. Under Part 15, intentional radiators are only permitted to operate under a set of strict emission limits, which preclude operation in certain restricted bands and in television broadcast bands.

UWB devices, on the other hand, may operate in restricted bands and television broadcast bands. Part 15 emission measurement procedures were designed to govern the use of narrowband transmitters. By its very name, UWB operates on very wide bands that would be difficult to measure under the current scheme.

The greatest obstacle faced by these devices is the fact that they do operate in restricted bands. Therefore, NTIA and the FCC want to make sure that the devices will not cause harmful interference to federal equipment operating between 400 MHz and 6.0 GHz; especially GPS equipment.

What is ultra wide band?

UWB devices are intended to operate on already occupied spectrum without causing harmful interference. UWB devices have low spectral power density and in general use very short carrierless pulses over a wide swath of spectrum usually exceeding 1 GHz. The FCC has not yet accepted a definition of UWB for regulatory purposes. However, in the NPRM, the FCC stated that its proposed definition for UWB devices is, "any device where the fractional bandwidth is greater than 0.25 or occupies 1.5 GHz or more of spectrum."

UWB devices can reportedly see images of objects buried underground or imbedded in walls. UWB devices can be used to measure distances or locations of objects. UWB can also be used for short-range high-speed data.

The greatest attribute of UWB devices is spectrum efficiency. The ability to operate in already encumbered spectrum without causing harmful interference to existing users is a highly desirable trait within the crowded radio spectrum. Clearly, with UWB's touted potential-there are many parties interested in the outcome of this rule making.

What now?

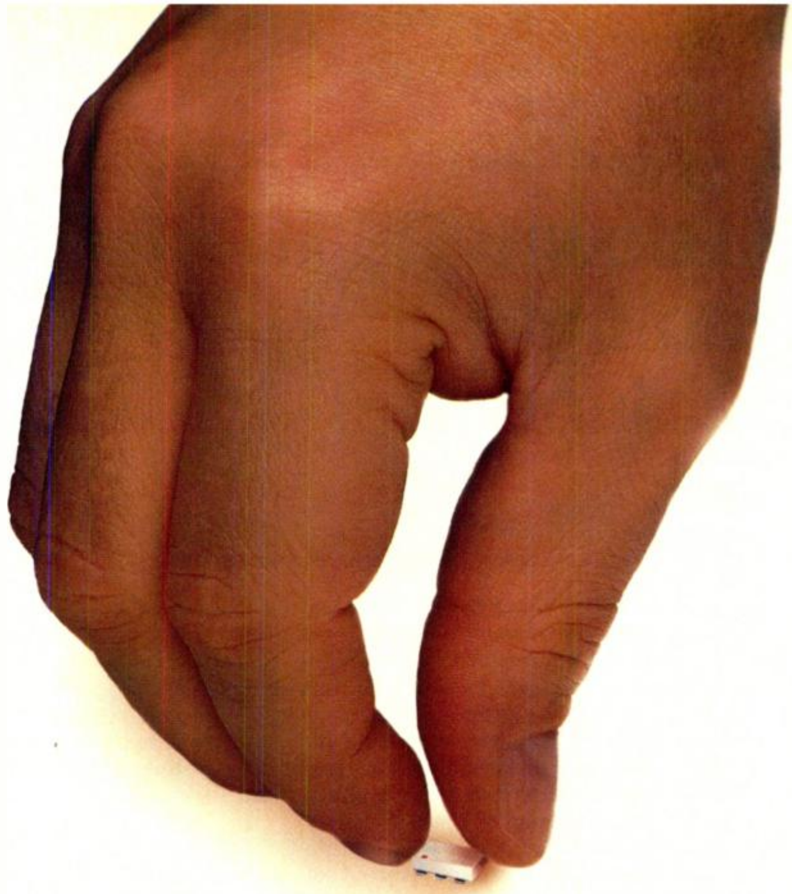
Through conversations with an FCC employee working on this matter, I have found out that the FCC has the daunting task of sifting through all of the comments on its own NPRM and the comments to NTIA's reports. The FCC will use this wealth of information to adjust the permissible parameters in which UWB devices will be permitted to operate; parameters such as unit pulse rate and average and peak emission levels.

The FCC and NTIA must also come into agreement over permissible parameters because it is mainly the federal government's spectrum that will be used after all. Anticipating timely "negotiations" between NTIA and the FCC, the FCC has set an ambitious timeline and hopes to go to the report-and-order phase this summer.

It would not be surprising if going to the report-and-order phase takes longer than hoped. Nor would it be surprising if the FCC decides to be conservative in its rules. It may take some time and a few rule waivers before any truly liberal rules (and subsequent waivers) are enacted. But no one really knows until the pen is put to paper and the rules are written.

RF

Delaney M. DiStefano is a senior associate with the law firm of Schwaninger & Associates, P.C. Ms. DiStefano is a member of the New York State and District of Columbia Bars and an active member of the Federal Communications Bar Association. Ms. DiStefano's primary practice is in wireless telecommunications and she is a veteran of several FCC auctions.



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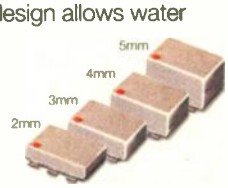

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A scroll down technology lane

By Megan Alderton
Associate Editor
megan_alderton@intertec.com

It's time to ride the rocket of the new millennium folks; after all, 2001 is here.

And though most of us weren't around to welcome the 1900s, I think we can safely say that a lot has changed since then. Granted, we aren't riding around in hovering automobiles and taking moon-cruises (yet), but a retrospective into the last 100 years should be enough to remind us of how much our inventive minds can change the human lifestyle over a relatively short period of time.

After attending the Bluetooth Developer's Conference in San Jose last December, my mind started jogging down the timeline of technology. I thought about the things that I remember seeing for the first time and that I take for granted now. Like when my family first got a VCR (the first movie we rented was Footloose), it changed our lives (the VCR I mean). Or take the cordless telephone (that took teenage life to a whole new level).

Speaking of a whole new level, those things are ancient history thanks to the emergence of cell phones and DVD players. But that's just the thing about technology — ancient history is so relative that it is really only a matter of patient history. Something new and improved will come along eventually; you just have to wait for it. Just look at the red carpet the last 100 years has unrolled before us:

Just 100 years ago Guglielmo Marconi received the first transatlantic radio signals using syntonised (tuned) receivers and transmitters. In 1906, Lee DeForest developed the vacuum tube triode and the first amplifier was constructed. Three years later, the first successful radio broadcast was made in, appropriately, San Jose, CA.

Jumping ahead to the roaring 20s, Philips introduced its first radio set, Western Union sent the first electronically transmitted photograph, and the first electronic TV picture was transmitted.

The first digital computer could add and subtract using binary code. It came along in 1939. Today's computer makes that look like the abacus. OK, maybe I'm easily impressed, but this all blows me away. What's more is that it never stops.

I'm sure that many of you are frustrated with the recent slows in the semiconductor industry and other sectors, but think of how many ups and downs the industry has seen since its infancy. Without the downs, the ups don't mean a thing. Let's just keep hoping that the slow-down is just a blister on the toe of the industry. You see it coming, and it hurts like crazy to put your shoes on after it pops, but once it does, it heals so fast you hardly remember it was ever there.

Megan

LBS revenues to grow to $40.7 billion in 2006

The nascent location-based services (LBS) industry is about to see tremendous growth, according to a new study from Allied Business Intelligence (ABI), Oyster Bay, NY. The report, *Location-Based Services: A Strategic Analysis of Wireless Technologies, Markets and Trends*, indicates that world LBS revenues will grow from about $1 billion in 2000 to more than $40 billion in 2006, representing a compound annual average growth rate of 81%.

Many factors will contribute to the growth, ABI said. Despite the obvious U.S. Enhanced-911 mandate, which calls for U.S. wireless carriers to begin selling automatic location identification (ALI)-capable handsets by the end of 2001, carriers are also looking for new revenue streams and newer ways to deliver compelling services to promote customer loyalty and reduce churn.

Most carriers have already stated their plan to pursue either network or handset-based location fixing technologies in their networks. Several companies are wrapping up initial LBS and location-relevant wireless advertising test-markets and have reported positive results. However, possible threats toward the development of the LBS industry lie in concerns over privacy issues and unsolicited wireless advertising. ABI's study shows that this should not be a major concern for subscribers because the carriers, application and content developers, and infrastructure providers have invested millions in the research and development of LBS.

DARPA prepares for electronic warfare contracts

A U.S. electronic warfare program is moving into the development phase as the Defense Advanced Research Projects Agency (DARPA), a Pentagon research agency, prepares to award contracts to develop key technologies.

Known as WolfPack, the program intends to develop a ground-based electronic warfare system that could jam communications and radar emitters operating at frequencies ranging from 20 MHz to 2.5 GHz. The system must also be designed, however, to avoid disrupting non-threatening military and commercial communications.

Corrections:

Following are corrections to articles in the August and September 2000 issues of RF Design:

- The August 2000 article, *Understanding Piezoelectric Quartz Crystals*, by Louis Bradshaw, omitted the following information about the author:

Louis Bradshaw attended Texas Technological College in Lubbock, TX, for more than two years and has more than 25 years of experience in the quartz crystal industry. He has held positions in engineering, quality documentation, and manufacturing at Fox Electronics in Fort Meyers, FL. Bradshaw can be reached at 1.888/GET.2.FOX; or by e-mail at *louisb@foxonline.com*.

- In the September 2000 article, *Interactive Direct-Coupled Filter Design*, by Thomas Cuthbert, Equation 1 was repeated as Equation 2. The correct Equation 2 on page 26 is as follows:

$$Q_k = g_k \times Q_{BW},\ k = 1,2, \ldots, N.$$

RF Design apologizes for any inconvenience this may have caused.

HOT WEB SITE

Engineering computation available online

Waterloo Maple's Web site now offers Maple-enabled solutions. These solutions allow engineers as well as students, architects, robotics designers, and other non-engineers to perform complex calculations interactively using only a browser. No additional software or plug-ins are needed to obtain the results. The current Maple-enabled solutions include calculations for chemical analysis, electronic simulation, machine design, and mathematical analysis. All solutions feature an easy-to-use interface and are driven by Maple's intelligent analytical algorithms. Next-generation elements will include advanced symbolic solutions that allow flexible management of unknown design parameters, and solution disclosure mechanisms that present the actual steps used to derive the solution.

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DARPA is now seeking industry proposals for the third phase of the WolfPack program. It plans to select as many as three teams to define alternative approaches to making the WolfPack operational concept work.

The deadline set for industry proposals was March 19. Raytheon, Rockwell Collins and BAE Systems were among potential bidders.

The $40 million WolfPack program is a result of military planners' beliefs that future battlefields will have no borders, interspersing military forces with civilians. If this happens, U.S. military will no longer be able to use blanket jamming techniques to neutralize enemy emitters.

The WolfPack program aims to develop technologies for RF "spectrum dominance" against advanced communications and radar systems. Technology development will focus on new antenna designs; low-power, wideband signal collection and processing capabilities; network architectures that do not rely on base stations; routing algorithms; and distributed algorithms used to detect, locate and identify RF emissions.

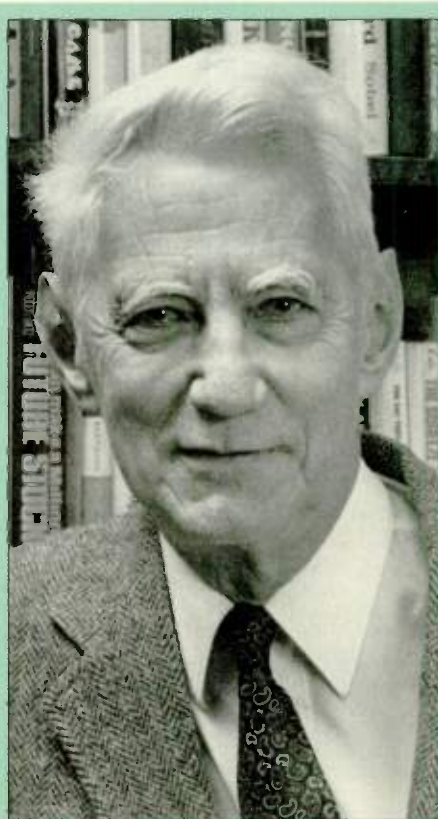
Father of information theory dies at 84

Claude Elwood Shannon, the mathematician who laid the foundation for modern information theory, died in February at age 84.

Shannon worked at Bell Labs in the 1940s where he figured out the upper limits on communication rates. His contributions helped to define the engineering limits faced first in telephone channels, then in optical communications and wireless.

Shannon published his landmark *A Mathematical Theory of Communication* in 1948. It was in this pioneering paper that he established the foundations of information theory in which his framework and terminology remain standard. Another of his works, *Communication Theory of Secrecy Systems*, is credited with transforming cryptography from an art to a science.

Shannon joined Bell Labs in 1941 and remained affiliated with the company until 1972. He became a visiting professor at MIT in 1956, a permanent faculty member in 1958, and a professor emeritus in 1978.



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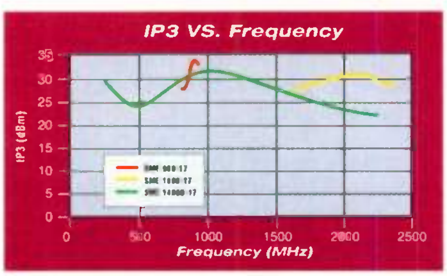

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SME 1400B-10	1-2200	1-2200	1-2000	+10	+6	+19	6.5	30
SME 1400B-13	1-2200	1-2200	1-2000	+13	+9	+22	6.5	30
SME 1400B-17	1-2200	1-2200	1-2000	+17	+13	+27	6.5	30
SME 1900-17	1600-2400	1400-2390	10-250	+17	+14	+29	7.4	26

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OFDM takes a step towards standardization

The OFDM Forum, an association organized to promote a single standard for high-speed wireless communications, today announced the signing of a reciprocal membership agreement with the Continental Automated Buildings Association (CABA). This agreement expands the OFDM Forum's vision of working towards a single, compatible global standard for OFDM technology by working with CABA to establish the future direction of home and building automation. "We are very pleased to welcome CABA to the OFDM Forum," said Lee Warren, Business Development Vice President for Wi-LAN Inc. and Chairperson of the OFDM Forum. "As well, we are excited about the opportunity of becoming an active member of CABA. We feel the association fits well with our goals, specifically in the WLAN, WPAN and HMM working group, and believe this win-win situation will be pivotal to establishing future wireless standards for the North American home and building industry."

Manufacturers endorse new wireless-data specification

Nokia, Motorola, Ericsson, Siemens and others have banded together to endorse a next-generation delivery protocol for cellular phones and other devices. The companies will support and develop products based the Extensible Hyper Text Markup Language (XHTML). XHTML is an evolution to the Wireless Application Protocol (WAP), a much-maligned software delivery system that failed in its promises to bring wireless-data services and content over a range of portable devices. In addition to handset manufacturers, a number of mobile operators have also announced support for XHTML: Vodafone, Orange, Radiolinja, Sonera, DNA, Telenor, Netcom, T-Mobil, TIM, RadioMobil, and EuroTel Praha. The move comes in the wake of industry concerns that the wireless industry is in need of a shot in the arm and that concerted efforts by the industry would help to fend off further fears that the industry is showing weakness in inter-industry cooperation.

BUSINESS BRIEFS

Zeevo qualifies baseband, associated software for Bluetooth — Zeevo Santa Clara, CA, formerly known as TelenComm, has attained Bluetooth qualification for its Bluetooth baseband, link manager, and associated software. The products are now included on the Bluetooth Qualified Product List (BQPL).

Microchip Technology attains USB compliancy on PICmicro microcontrollers — Microchip Technology's, Chandler, AZ, family of one-time programmable (OTP) devices supporting the Universal Serial Bus (USB) 1.1 low-speed interface are USB-IF compliant.

NEC to spin off Microwave and Optical Semiconductor Division — NEC, Santa Clara, CA, intends to spin off its Compound Semiconductor Device Division (CSDD) into a new company, effective October 2001. CSDD designs and manufactures a range of silicon and GaAs RF and microwave semiconductor devices as well as optical semiconductors.

National Semiconductor chooses 3DSP Technology for next-generation chips — National Semiconductor, Irvine, CA, has selected 3DSP, Irvine, CA, as a key development partner. In designing a new architecture for low power and configurable system-on-a-chip (SoC) products, National will incorporate a 3DSP DSP core, and will use HiFI – the 3DSP design environment for DSP intellectual property (IP) SoC – to tailor to the SP-X DSP core to meet third-generation (3G) wireless requirements.

Andrew completes Brazil acquisition — Andrew, Orland Park, IL, acquired the remaining 30% equity in its Andrew Industria e Comercio Ltda and Andrew Comercio e Servicos Ltda subsidiaries in January. The transaction amount has not been disclosed. Andrew originally acquired 51% of both companies in 1995 and raised its interest to 70% in 1997.

Zucotto Wireless, RealChip Communications partner for chip design, turnkey management — Zucotto Wireless, Sunnyvale, CA, and RealChip Communications, Sunnyvale, CA, have joined in a multi-chip design agreement to manage the production and delivery of the Xpresso Java native processor. RealChip will act as a liason between Zucotto and various intellectual property suppliers, manufacturers, and EDA tool suppliers, as well as the fab for the Xpresso semiconductor, United Microelectronics Corporation (UMC).

Classwave Wireless announces strategic partnership with Starwood Hotels and Resorts — Classwave Wireless, Toronto, and Starwood Hotels and Resorts worldwide have entered a strategic partnership. Under terms of the agreement, Classwave will implement a suite of wireless services which will be available for hotel guests using Bluetooth devices including wireless registration, e-mail, and Internet access.

Samsung selects Silicon Laboratories' GSM RF synthesizer technology — Samsung Electronics, Korea, has chosen Silicon Labs' Si4133G RF synthesizer for use in the company's newest GSM cellular handsets. The Si4133G meets Samsung's mobile phone technology and reduced size requirements with its synthesizer integration.

STRENGTH

REPUTATION

Smart antennas for multiple sectorization in CDMA cell sites

Smart and flexible antenna hardware provides a step in the right direction for spectrum efficiency, channel loading and reliability.

By Ji-Hae Yea

Data is the buzzword du jour on the lips of just about everyone in the wireless industry. And certainly ample reason exists to believe that non-voice traffic will play an increasingly large role in defining the technology, business opportunities and challenges of the wireless future.

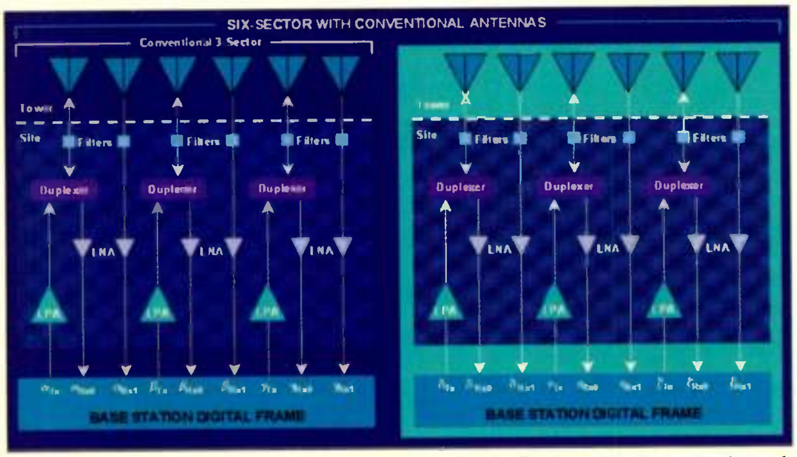

Figure 1: Conventional six-sector deployments require duplicating virtually every piece of base-station equipment.

What is often overlooked in the enthusiasm to gaze over the data horizon, however, is that growth in voice subscriber numbers and minutes of use shows little sign of slowing. While the impact of the data explosion on carriers' networks remains largely hypothetical, the challenge of providing sufficient network capacity to handle current (mainly voice) traffic is already a daunting reality for many operators. Whether one focuses on the impending demands of data traffic or the needs of more than 60 million current CDMA subscribers in the here and now, the issue of how to increase network capacity in a cost-effective, scalable manner is pivotal.

Among other approaches to this problem, six-sector cells and smart antennas are two ideas that have generated a great deal of interest among network operators. Smart antenna technology can facilitate the successful implementation of six-sector in CDMA networks.

Six-sector theory and practice

In theory, increasing the number of sectors in a CDMA cell is a good way to increase its capacity. Everything else being equal, a six-sector cell should offer double the capacity of a three-sector cell with a similar coverage footprint.

Unfortunately, everything else is not equal. As the number of sectors increases, the total area of the softer handoff zones between sectors increases, which in turn increases the "handoff overhead" of the cell. And because mobiles in softer handoff require downlink transmit power from more than one sector at a time, handoff overhead exacts a direct cost in terms of cell capacity.

Similarly, the more sectors there are, the greater the likelihood of pilot pollution. As the number of strong pilots in any locale increases, the noise floor rises with a direct and negative impact on capacity. Thus, while increasing the sectorization of a cell increases capacity in some ways, it decreases it in others. In practice, cells with more than three sectors have generally not offered anywhere near the expected capacity payoff.

Implementing six-sector with conventional antennas has typically entailed serious challenges. The sheer number of separate antennas required for a six-sector deployment means that the physical installation and alignment processes are painstaking and expensive. Iterative tower climbs are the order of the day in optimizing a conventional six-sector site, and that's only after the ever-more-difficult zoning battles have been waged and won.

The smart antenna six-sector solution

Smart antenna systems make six-sector a practical proposition. They do so in three principal ways: by reducing handoff overhead, by easing the implementation burden and by facilitating successful optimization.

The size of the softer handoff zones between sectors in a CDMA cell is a function of the rolloff characteristics of the antennas employed. The sharper the main-lobe rolloff, the smaller the areas of overlap between sectors where mobiles will be in softer handoff. The software-defined sector patterns produced by the phased-array panel antennas of a smart antenna system display much sharper rolloff than do conventional antennas—so much sharper that the handoff overhead of a six-sector cell equipped with smart antennas can be roughly com-

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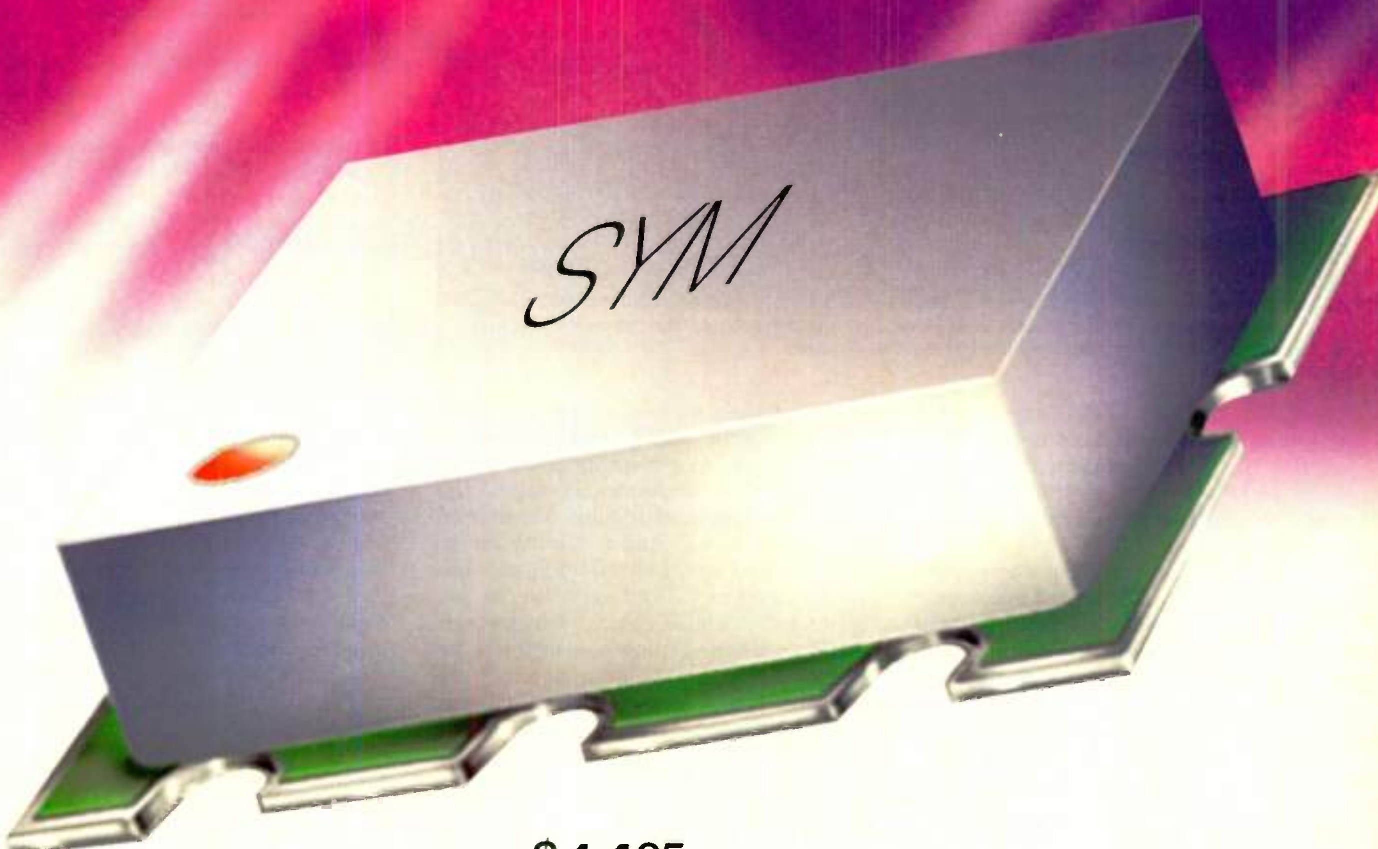

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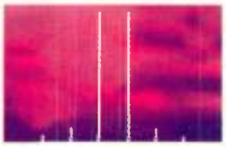

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SYM-10DH	800 -1000	31	45	29	7.6	17.80
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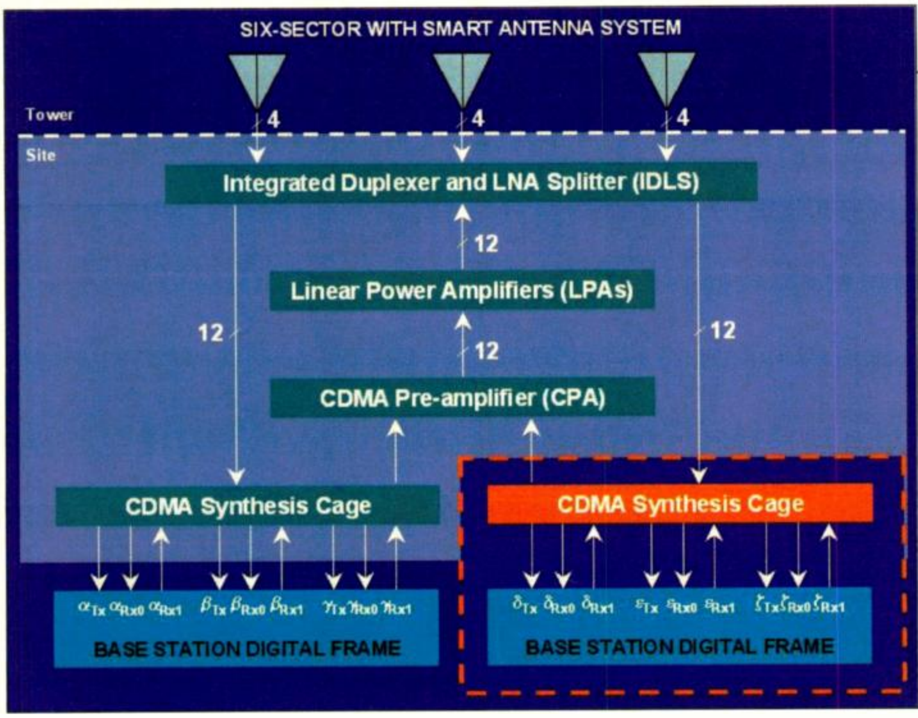

Figure 2. Smart antenna system enables three-, four-, five- and six-sector configurations without any additional antennas, power amplifiers, duplexers, filters or cables.

parable to that of a typical three-sector site with conventional antennas. This means that the theoretical capacity gains offered by the additional sectors can actually be practically realized with smart antennas.

Smart antenna systems ease the implementation burden of six-sector deployments by reducing the number of antennas required on the tower. With conventional antennas, six-sector can require as many as 18 precisely aligned antennas for the site to operate properly. With a smart antenna system, as few as three antennas do the job, regardless of whether the site is configured for three, four, five or six sectors.

Smart antenna systems can significantly reduce the amount of additional equipment necessary to implement six-sector. Of course, six-sector requires two base station radios, but with conventional antennas, it also requires twice the power amplifiers, duplexers, filters and cabling compared to three-sector. Because a smart antenna system manages the RF signal flow from the base stations all the way to the antennas, no additional amplifiers, duplexers, filters or cabling is required. This results in significant cost savings. Figures 1 and 2 illustrate the reduction in equipment that a smart antenna system makes possible.

Finally, smart antennas make six-sector optimization easier. Through remote software control, network engineers can manipulate the gain and phase of each individual narrow beam comprising the smart antenna pattern. This "sculpts" the coverage footprint to manage pilot pollution and control the location of handoff regions. Compared with the precision and flexibility inherent in smart antenna systems, conventional antennas afford only the crudest control over these critical parameters. Smart antennas allow six-sector to be successfully deployed in sites where optimization issues would prevent it with conventional antennas.

Case study

The recent commercial deployment of a CDMA smart antenna system in multi-sector configurations was implemented in a case study. Examining the deployment illustrates many of the advantages smart antennas have to offer. The deployment had four objectives:

- To demonstrate the ease and cost-effectiveness of deploying multi-sector with smart antennas.
- To significantly increase the capacity of the cell over the three-sector baseline, and to quantify this increase.
- To maintain or enhance quality of service relative to the three-sector baseline, not only in the case-study cell but in neighboring cells.
- To demonstrate the unique ability afforded by smart antennas to reconfigure a cell from four- to five- to six-sector through software control.

The cell where the deployment occurred is a busy suburban site in the network of a major U.S. cellular operator. The site was originally configured in three-sector using conventional antennas and a Nortel Networks CDMA Metro Cell base station.

The site was configured with two CDMA carriers. Rather than employing a hashing algorithm to allocate traffic between the two carriers, the operator implemented an overflow algorithm that directs traffic to the second carrier (F2) only when the first (F1) reaches its capacity limit. This feature provided a convenient method for measuring the capacity improvement provided by the smart antenna deployment.

Baseline switch statistics showed that traffic was distributed relatively equally among the three original sectors of the cell, with the alpha, beta and gamma sectors carrying on average 32%, 39% and 29% of the total load, respectively. As each sector of a perfectly balanced cell would carry 33.3% of the load, the "peak load" in the beta sector can be expressed as being about 117% of "ideal." This figure represents more balanced loading than is often observed in commercial CDMA cell sites. Experience in using smart antennas to generate custom sector patterns (to balance traffic loading in three-sector sites) suggests that load balancing renders significant capacity benefits when peak loading is greater than 120%. Cells like this one, in which the absolute traffic load is high and evenly distributed, are ideal candidates for the six-sector solution.

Prior to system installation, the RF footprint of the cell was determined empirically with CDMA drive-test equipment. Figure 3 shows the plot of the strongest serving pilot PN offset for the baseline configuration. Subsequently, a smart antenna system was installed, and commercial traffic was cut over to the system initially in a three-sector configuration that duplicated the sector orientation and coverage of the baseline configuration. Then, after installation of a second Metro Cell base station, the site was taken to six-sector. Before and after ERP plots of the two configurations are shown in Figure 4. The footprint of the six-sector pattern was also verified through drive-testing; the six-sector strongest serving pilot PN offset plot is shown in Figure 5.

Four- and five-sector configurations were also implemented and measured in commercial service. All sectorization changes after the initial cut-over to the

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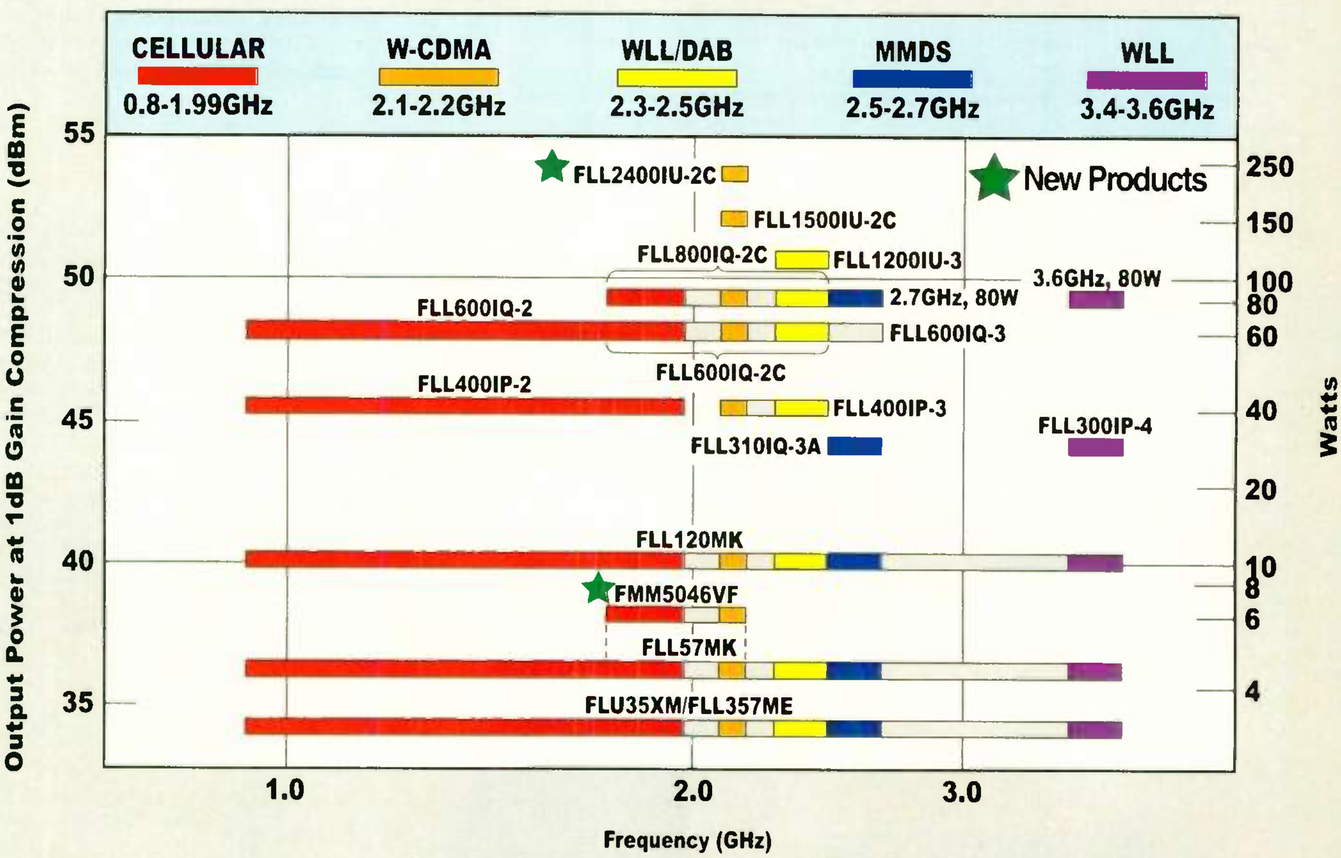

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smart antenna system were implemented through remote software control of the beamwidth, azimuth pointing angle and per-beam gain of the synthesized antenna patterns. No physical changes to the antenna tower were required.

Measuring capacity gain

Measuring the capacity of a CDMA cell site is not straightforward. Therefore, it is typically difficult to quantify the precise capacity improvement attributable to a configuration change. However, the way the operator of this network implemented F2 provides a convenient means of estimating capacity gain in this instance.

Users are assigned to F2 only after traffic on F1 causes the base station to exceed an operator-established threshold of 67% of maximum transmit power. Thus, any call completions on F2 can be considered as having been blocked on F1. The probability of a call being blocked can be expressed as the grade of service (GOS), which can be calculated for this cell from switch statistics by:

$$GOS = \frac{T_{F2}}{T_{F1} + T_{F2}} \quad (1)$$

where TF1 and TF2 are the number of call completions over a given time on F1 and F2, respectively. For any given level of traffic, therefore, a low GOS indicates that F1 is carrying most traffic and that relatively little blocking would be present if F2 were absent; a high GOS indicates that a high level of blocking would occur without F2.

To assess the efficiency of the cell under different sectorization schemes, the observed GOS can be plotted against call completions. An efficiency curve can then be computed using the Erlang B model that best fits the observed data. The general Erlang B model is given by:

$$GOS = \frac{\frac{A^C}{C!}}{\sum_{k=0}^{C} \frac{A^k}{k!}} \quad (2)$$

where C is the number of trunked channels offered by a trunked radio system and A is the total offered traffic

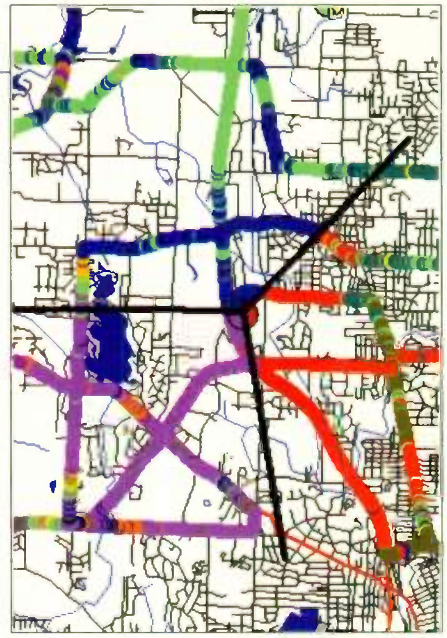

Figure 3. Plot of strongest serving pilot PN for the three-sector baseline configuration.

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Low Cost Power Splitters

Introduction

Ever expanding applications of RF and Microwaves for Wireless and Cable applications have revived the development efforts of components at these frequencies. There is a continuing demand to reduce the cost and increase the performance and quality at the same time. Mini-Circuits is working to satisfy these goals and has introduced a new splitter series to satisfy the demands of the market. These splitters are designed to need only commercially available low-cost off-the-shelf chip resistors and capacitors as external components, and are designed for automated manufacturing to achieve low overall cost.

What Constitutes a Power Splitter

Fig 1 is the block schematic of a two-way power splitter. It consists of a divider section, a matching section, a resistor R1 and a capacitor C1. The function of the divider section is, as the name implies, to divide the input signal into two parts. The matching section together with capacitor C1 performs wide-band matching at all ports. Resistor R1 helps provide wide-band isolation between the two RF output ports. The matching and divider sections form the heart of the splitter. They are realized using magnetic cores. The matching and divider sections are integrated into a single unit, and are herein afterwards called the splitter. The next section describes the splitter.

Construction of the "TCP" device

TCP-series splitters use one magnetic core transmission line transformer for power division and another similar transformer for matching. The transformers share a common structure, for compactness. The base of the device is plastic with embedded leads, which makes the construction very rugged. The leads are solder plated for excellent solderability. All connections from the transformers to the header are made by welding. This helps to ensure preciseness of the assembly, with resulting high performance repeatability, as well as preventing any disconnection during reflow.

Performance of the Splitter

Mini-Circuits has introduced three splitters covering the frequency range of 5 to 2500 MHz. TCP-2-10 and TCP-2-25 are designed for 50 ohm, and TCP-2-10-75 is for 75 ohm characteristic impedance. ***Fig 2*** is a typical photo of the splitters and ***Table 1*** gives the specifications. ***Fig 3*** shows the insertion loss of TCP-2-10. The insertion loss of the splitter is typically 0.5 dB above the 3 dB split over the band. ***Fig 4*** shows the isolation vs. frequency, which is typically 25dB over the band. ***Fig 5*** shows VSWR vs. frequency at all three ports, which is typically 1.1:1. Circuit board layout plays an important part in the performance of the splitter. In order to minimize parasitic effects, suggested layouts as shown in ***Fig 6*** should be used.

The external components, resistor and capacitor should be of 0805 size. The capacitor should be of NPO type with a nominal value of 1.5pF. The chip resistor should have a nominal value of 100, 150, and 475 ohms for TCP-2-10, TCP-2-10-75, and TCP-2-25 respectively.

Conclusion

Three power splitters have been introduced to operate over 5-2500 MHz. Due to all-welded connections the splitters are very rugged. The product has been designed to be fabricated in automated set-ups which helps lower the cost. Further cost reduction is obtained by designing the unit to work with a low-cost off-the-shelf chip resistor and capacitor used as external components.

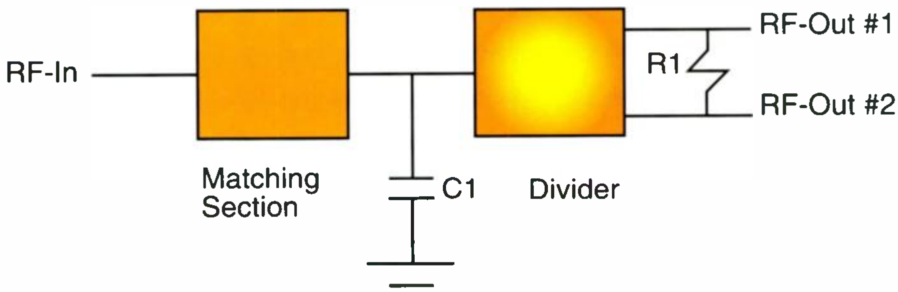

Fig. 1 Block Schematic of a Power Splitter

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ELECTRICAL SPECIFICATIONS Table 1

MODEL NO.	FREQ. RANGE (MHz)	ISOLATION (dB) L Typ. Min.	M❖ Typ. Min.	U Typ. Min.	INSERTION LOSS (dB) ABOVE 3.0 (dB) L Typ. Max.	M❖ Typ. Max.	U Typ. Max.	PHASE UNBALANCE (Deg.) L Max.	M❖ Max.	U Max.	AMPLITUDE UNBALANCE (dB) L Max.	M❖ Max.	U Max.	Price $ ea. Qty. (10-49)
TCP-2-10	5-1000	25 17	25 16	21 16	0.3 0.9	0.5 0.9	0.5 1.4	4	4	6	0.6	0.6	0.3	3.95
■TCP-2-10-75	5-1000	24 14	29 19	30 16	0.3 1.4	0.3 0.9	0.6 1.3	6	4	3	1.2	0.6	0.5	4.95
TCP-2-25	200-2500		18 10			0.6 1.3			6			0.8		4.95

❖ When only specification for M range given, specification applies to entire frequency range.

■ Denotes 75 ohm model L=low range [f_L to 10 f_L] M=mid range [10f_L to f_U/2] U=upper range [f_U/2 to f_U]

Fig. 2

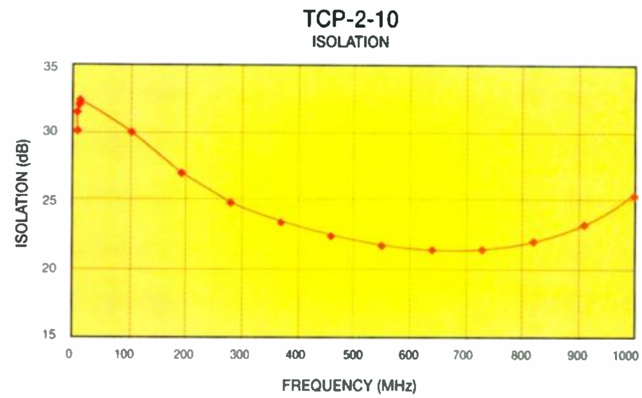

Fig. 4

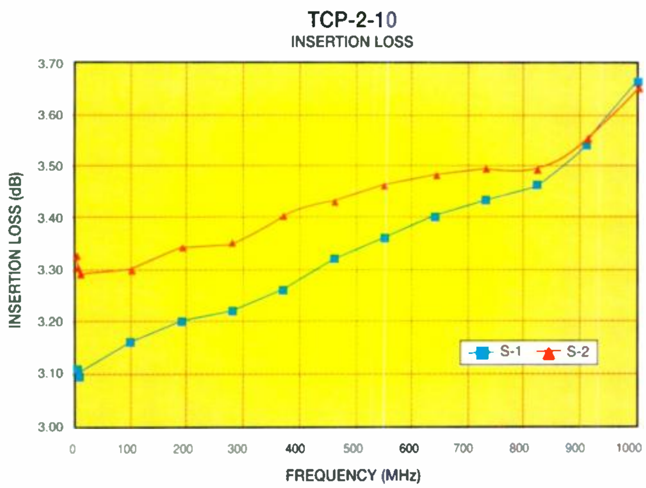

Fig. 3

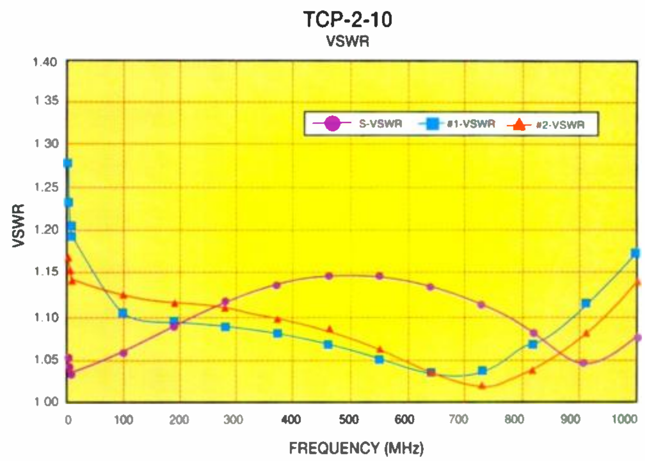

Fig. 5

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POWER SPLITTERS

Typical Performance Data For TCP-2-10

Frequency (MHz)	Insertion Loss (dB) S-1	Insertion Loss (dB) S-2	Amplitude Unbalance (dB)	Isolation (dB)	Phase Unbalance (dB)	VSWR S	VSWR 1	VSWR 2
5.00	3.10	3.33	0.23	30.15	0.98	1.05	1.28	1.17
7.00	3.10	3.30	0.20	31.40	0.82	1.04	1.23	1.15
10.00	3.10	3.29	0.19	32.26	0.60	1.04	1.20	1.14
100.00	3.16	3.30	0.14	30.00	0.15	1.06	1.10	1.12
190.00	3.20	3.34	0.14	27.03	0.45	1.09	1.09	1.12
370.00	3.26	3.40	0.13	23.32	0.88	1.14	1.06	1.10
550.00	3.36	3.46	0.10	21.68	1.23	1.15	1.05	1.06
730.00	3.43	3.49	0.06	21.37	1.41	1.11	1.04	1.02
910.00	3.54	3.55	0.01	23.06	1.63	1.05	1.11	1.08
1000.00	3.66	3.65	0.01	25.28	1.74	1.07	1.17	1.14

Typical Performance Data For TCP-2-10-75

Frequency (MHz)	Insertion Loss (dB) S-1	Insertion Loss (dB) S-2	Amplitude Unbalance (dB)	Isolation (dB)	Phase Unbalance (deg.)	VSWR S	VSWR 1	VSWR 2
5.00	3.13	3.50	0.37	24.98	0.43	1.04	1.17	1.38
10.00	3.12	3.38	0.26	27.65	0.22	1.02	1.15	1.26
100.00	3.16	3.38	0.22	28.67	0.07	1.04	1.14	1.20
300.00	3.25	3.38	0.14	27.92	0.24	1.14	1.20	1.18
500.00	3.32	3.27	0.04	29.42	0.56	1.20	1.20	1.16
700.00	3.41	3.27	0.14	29.83	0.68	1.22	1.30	1.19
800.00	3.46	3.32	0.15	27.04	0.70	1.22	1.31	1.22
900.00	3.54	3.40	0.14	24.10	0.66	1.21	1.30	1.23
950.00	3.63	3.46	0.16	22.90	0.63	1.21	1.32	1.23
1000.00	3.64	3.52	0.11	21.81	0.56	1.20	1.35	1.23

Typical Performance Data For TCP-2-25

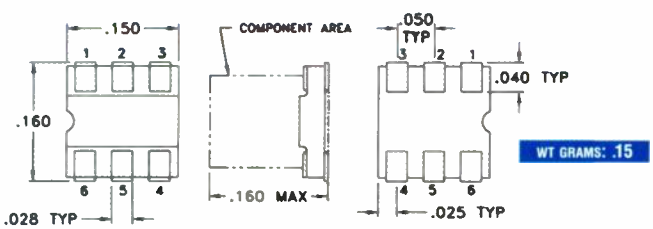
Frequency (MHz)	Insertion Loss (dB) S-1	Insertion Loss (dB) S-2	Amplitude Unbalance (dB)	Isolation (dB)	Phase Unbalance (deg.)	VSWR S	VSWR 1	VSWR 2
200.00	3.56	3.54	0.01	16.61	0.32	1.96	1.54	1.53
346.67	3.59	3.56	0.03	17.48	0.54	1.94	1.55	1.54
640.00	3.70	3.61	0.08	18.59	0.87	1.90	1.62	1.68
1080.00	3.73	3.54	0.19	20.91	1.22	1.85	1.68	1.60
1373.33	3.78	3.52	0.26	22.17	1.46	1.77	1.73	1.62
1520.00	3.74	3.45	0.29	22.38	1.52	1.73	1.73	1.63
1813.33	3.75	3.39	0.35	21.59	1.72	1.57	1.77	1.63
2106.67	3.78	3.39	0.39	19.71	1.96	1.44	1.81	1.67
2400.00	3.78	3.38	0.40	17.51	2.42	1.23	1.90	1.75
2523.08	3.83	3.44	0.39	16.64	2.60	1.19	1.88	1.74

PIN CONFIGURATIONS	TCP-2-10	TCP-2-10-75	TCP-2-25
SUM PORT	6	6	6,5,2
PORT 1	3	3	3
PORT 2	4	4	4
GROUND	1	1	1
SHORT	2,5	2,5	-
RESISTOR:	100Ω 3,4	150Ω 3,4	475Ω 3,4
CAPACITOR 1.5pF	2 To GND / 5 To GND	5 To GND	-

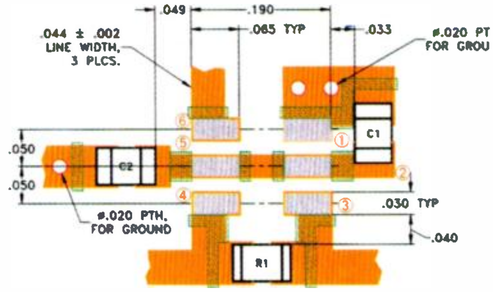
Operating Temperature -20°C to 85°C, Storage Temperature, -55°C to 100°C

CASE STYLE DRAWINGS & DIMENSIONS (INCH)

CASE STYLE DB714



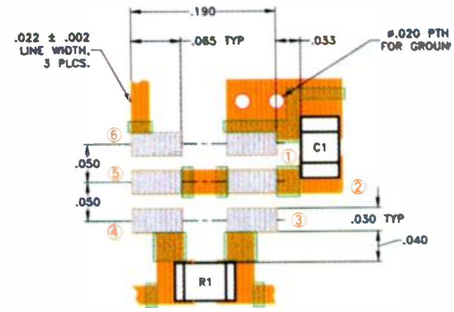
SUGGESTED PCB LAYOUT FOR TCP-2-10



RESISTOR R1: 100 Ohm, 0805 SIZE
CAPACITORS C1 & C2: 1.5 pF, 0805 SIZE

RECOMMENDED MATERIAL: ROGERS RO4350, DIELECTRIC THICKNESS: .020 ± .002
COPPER: 1 OZ. EACH SIDE

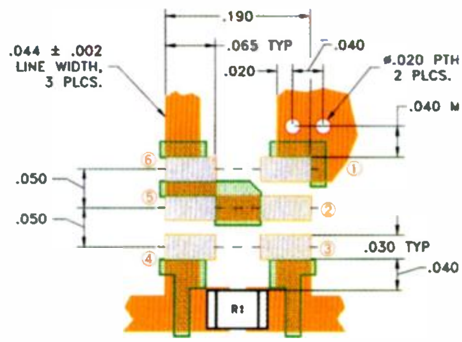
SUGGESTED PCB LAYOUT FOR TCP-2-10-75



RESISTOR R1: 150 Ohm, 0805 SIZE
CAPACITOR C1: 1.5 pF, 0805 SIZE

RECOMMENDED MATERIAL: ROGERS RO4350, DIELECTRIC THICKNESS: .030 ± .002
COPPER: 1 OZ. EACH SIDE

SUGGESTED PCB LAYOUT FOR TCP-2-25

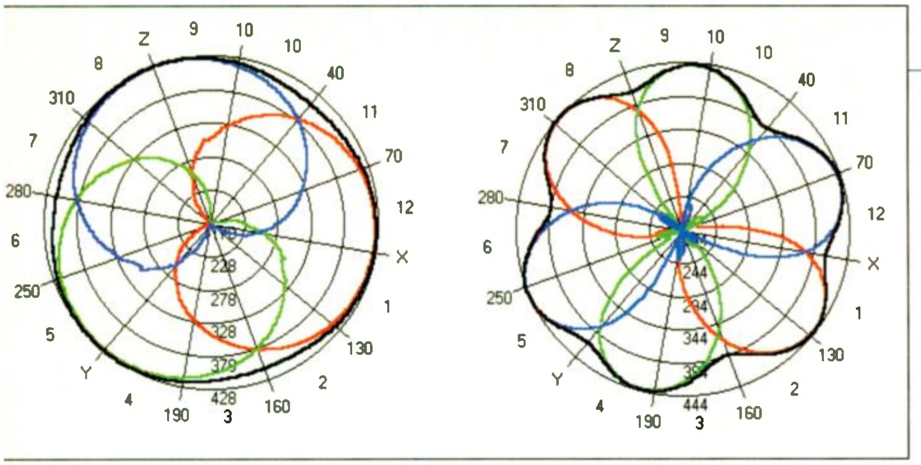


RESISTOR R1: 475 ± 1% Ohm, 0805 SIZE

RECOMMENDED MATERIAL: ROGERS RO4350, DIELECTRI THICKNESS: .020 ± .0015
COPPER: 1/2 OZ. EACH SI

DENOTES METALLIZATION
DENOTES SOLDER MASK
DENOTES METALLIZATION FOR DEVICE SOLDERING

Fig. 6



'igure 4. ERP plots comparing antenna patterns of the three-sector baseline configuration (left) and the SpotLight 2000 six-sector configuration (right).

Figure 5. Plot of strongest-serving pilot PN for the SpotLight 2000 six-sector configuration.

n Erlangs. In determining the best-fit curve, the value of C is chosen to minimize the squared error between the observed GOS at a given level of traffic and the predicted GOS from the model for the same level of traffic. Offered traffic, A, is taken to be the number of call completions in a given hour (TF1 + TF2) multiplied by a constant representing assumed average call duration.

The Erlang B model does assume a fixed-trunk air interface, and CDMA does not strictly meet this criterion either. This is because the number of available channel elements varies with the forward-link power requirements and the handoff state of the mobiles being served. However, over time, there is an average number of "available" channel elements, and thus the Erlang B model still provides a good approximation of GOS for a CDMA cell.

Capacity results

The results of the analysis are presented in Figures 6 and 7. Figure 6 shows the best-fit Erlang B curves relating GOS to offered traffic for the baseline three-sector and smart antenna six-sector configurations using data from the 4 p.m to 5 p.m. busy hour. It is appropriate to concentrate on the busy hour because this is when any capacity gains afforded by six-sector will be most valuable to the network operator — in terms of network efficiency and revenue. Data were collected over 15 consecutive days for the baseline configuration and over 12 consecutive days for the six-sector configuration.

Figure 6 shows that the smart antenna six-sector configuration resulted in a significant rightward shift in the best-fit curve. This indicates that, at a given GOS, the six-sector cell was carrying more offered traffic. Figure 7 presents the magnitude of this increase at various grades of service. At a reasonable 2% GOS (i.e., a 2% access failure rate), the smart antenna system in six-sector increases capacity by 73.6%.

This significant increase in cell capacity can be attributed to the control of handoff overhead. Figure 8 compares Ec/I0 plots for the baseline three-sector configuration with conventional antennas and the smart antenna six-sector configuration. The size of the inter-sector softer handoff regions—and thus the amount of handoff overhead—is indicated by the darker shaded areas. By inspection, the amount of handoff overhead appears roughly equivalent between the two configurations. In fact, as measured by the ratio of Walsh-code Erlangs to primary Erlangs, handoff overhead increased less than 7% in moving from the three-sector baseline to the six-sector configuration (1.86 to 1.99), despite the 100% increase in the number of handoff zones. This means that, in contrast to the conventional six-sector case, scarcely any of the capacity gains of a six-sector deployment facilitated by smart antennas are squandered on unproductive overhead; they are instead available to carry revenue-producing traffic.

Quality of service

The main purpose of the six-sector deployment was to provide increased site capacity. Metawave's smart antenna system delivered on that promise. But capacity gain in any single cell would not be worthwhile if it came at

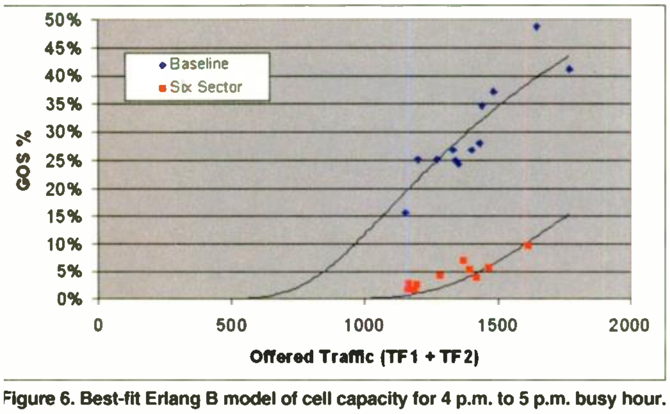


Figure 6. Best-fit Erlang B model of cell capacity for 4 p.m. to 5 p.m. busy hour.

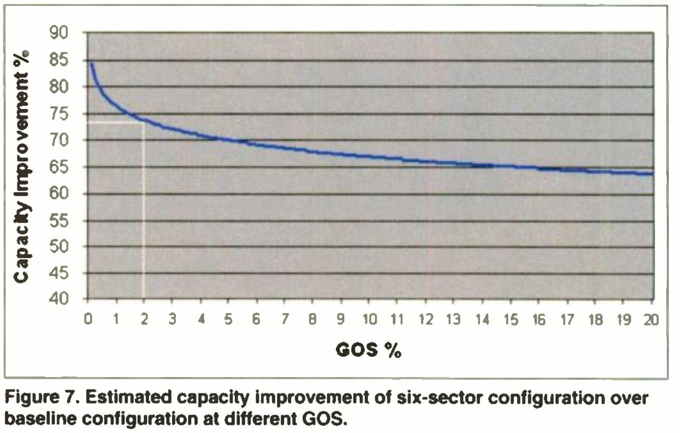
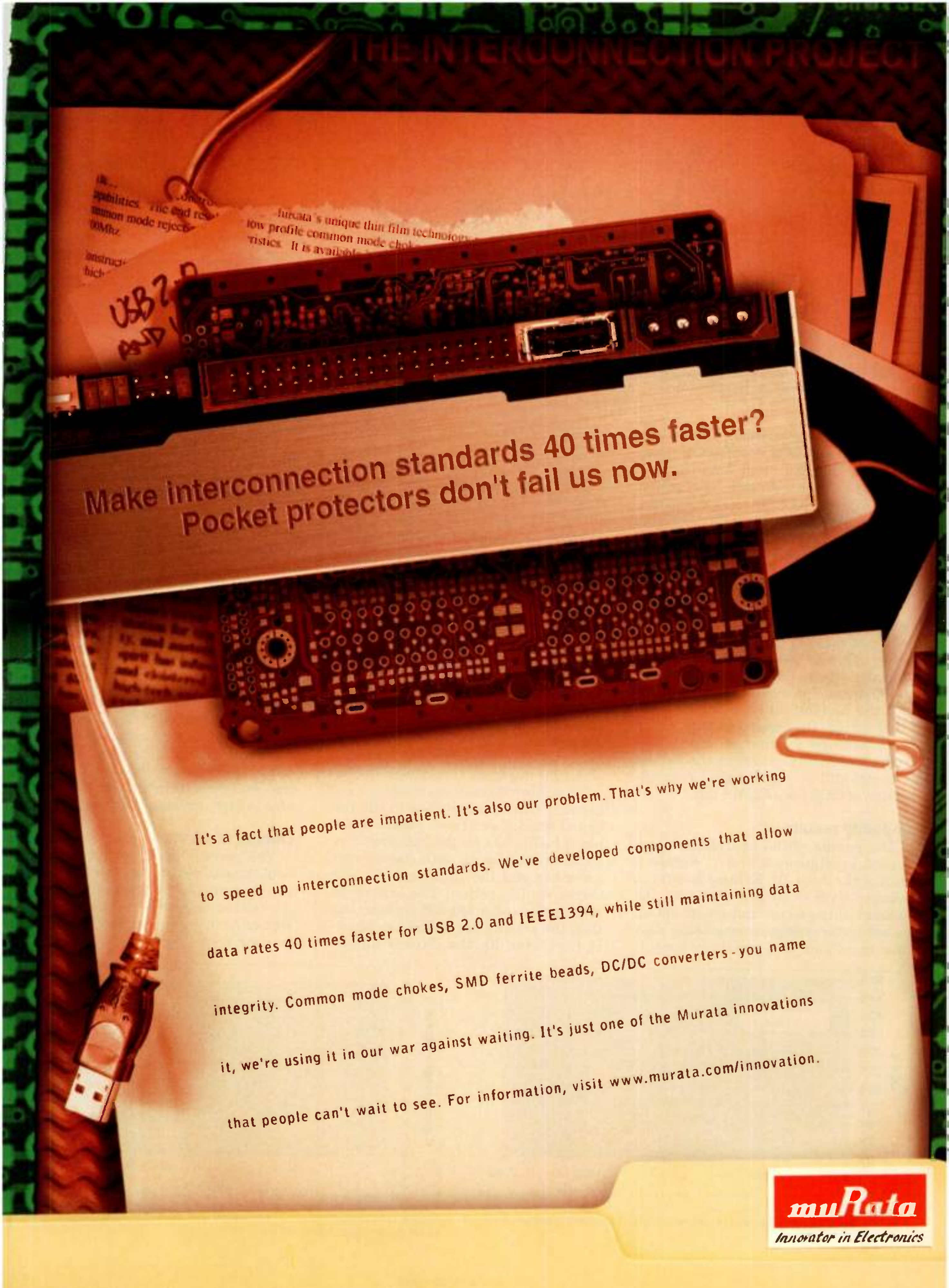


Figure 7. Estimated capacity improvement of six-sector configuration over baseline configuration at different GOS.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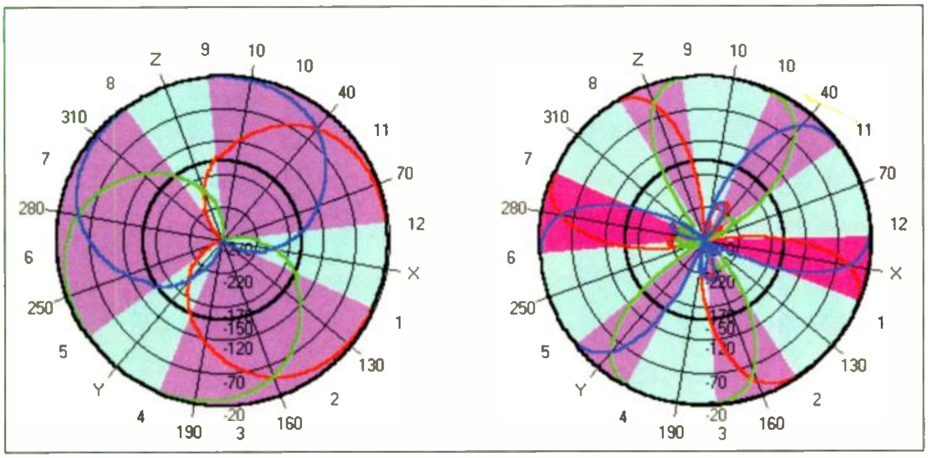

Figure 8. Ec/I0 plots of the baseline three-sector configuration (left) and the new six-sector configuration (right) reveal similar total handoff overhead

the expense of quality of service (QoS) in the cell itself or in neighboring cells. The case study results show that, overall, the smart antenna deployment maintained, and in some ways actually enhanced, the performance of the study cell and its neighbors.

To make meaningful QoS comparisons, it is necessary to establish that the levels of carried traffic before and after the implementation of the smart antenna system are roughly comparable. The switch data on call completions presented in Table 1 demonstrate that this was the case; both in the study cell and its neighbors.

cell	Baseline, 3-sector	New, 6-sector
Study cell	15,197	15,977
Neighbor A	4,369	5,151
Neighbor B	2,617	2,719
Neighbor C	3,859	3,566
Neighbor D	1,662	2,035

Table 1. Levels of total carried traffic in the baseline three-sector and new six-sector configurations, comparing average daily call completions.

Typically, six-sector deployments using conventional antennas suffer QoS problems due to excess pilot pollution. In areas where a dominant server does not exist because of pilot pollution, one would expect significant problems with dropped calls and access failures. As Table 2 shows, the smart antenna six-sector deployment belied these expectations. The dropped call rate fell by between 10% and 55% in every cell in the cluster. With regard to access failures, three cells experienced slight increases (of between roughly 1% and 7%), while two others experienced decreases of almost 20%. On balance, the smart antenna system in six-sector delivered enhanced QoS along with greater capacity.

cell	3-sector	6-sector	3-sector	6-sector
Study cell	1.35	1.21	1.14	0.95
Neighbor A	1.51	1.33	1.66	1.77
Neighbor B	2.33	1.06	1.10	1.11
Neighbor C	1.65	1.45	1.50	1.22
Neighbor D	1.87	1.53	1.00	1.01

Table 2. QoS metrics for baseline three-sector and new six-sector configurations.

Easy reconfiguration

A final goal of the deployment was to demonstrate the flexibility of smart antenna systems in reconfiguring a site from one sectorization scheme to another through software control. Flexible smart antenna technology makes it practical for an operator to take a three-sector antenna site to a four-, five-, or six-sector site and back again as traffic and RF demands change. As an example of the real-world uses of this feature, imagine implementing a three-sector smart antenna solution to balance traffic loading in a highly imbalanced cell. A year later, after a new shopping mall, freeway and housing development have appeared within the footprint of the cell, one might conclude that the heavy loading across all three sectors indicated a six-sector solution. And a year after that, one might decide to take the site back to four sectors to help manage pilot pollution arising from a new neighboring off-load site. Smart antennas can provide the flexibility to make such changes with minimal base-station equipment changes and with no changes whatsoever to the antennas on the tower.

As a demonstration of this flexibility, the study site was operated for five days each in four- and five-sector configurations. The estimated capacity increases, dropped call rates and blocking rates for these two configurations relative to the baseline three-sector configuration are presented in Table 3.

Because the goal of this deployment, relative to the four- and five-sector configurations, was to demonstrate how smart antennas enable easy, software-controlled sectorization changes, neither configuration was optimized in any systematic way. Both the four- and five-sector configurations feature beamwidths large enough to provide real scope for traffic load balancing using the smart antenna system's ability to adjust beamwidth and orientation, as in the well-proven three-sector case. One could expect this effort to produce

Configuration	Estimated capacity increase @2%GOS (%)	Average daily dropped call rate (%)	Average daily access failure rate (%)
Baseline	**N/A**	**1.35**	**1.14**
Four-sector	**48.7**	**1.22**	**1.03**
Five-sector	**53.7**	**1.45**	**1.04**

Table 3. Estimated capacity increases and QoS metrics form new four- and five-sector configurations relative to baseline three-sector configuration.

incremental capacity gains beyond those reported in Table 3, as those gains resulted entirely from the increased number of sectors.

The results

The results of this deployment provide conclusive validation of the use of smart antennas to facilitate multiple sectorization schemes in CDMA cells. The sharp sector rolloff characteristics of such systems' software-defined, multi-beam antennas produce in practice the substantial capacity benefits that four-, five- and six-sector configurations have long promised in theory. In addition, the precision and flexibility of smart antennas allow operators to successfully negotiate the challenges of optimization in a way that conventional antennas do not.

No single sectorization scheme will prove optimal for every capacity-constrained CDMA cell. In many instances, the apparent capacity problem stems less from an absolute shortage of site capacity than from the uneven distribution of traffic among sectors. In such cases, using smart antennas to balance traffic loading by customizing sector size and orientation can "unlock" capacity that is sitting idle in under-utilized sectors. This can boost site capacity by as much as 50%, (as demonstrated by commercial three-sector deployments) without exacerbating problems of pilot pollution or neighbor list planning.

However, in cells where the traffic load is well-balanced among the three sectors — and balanced at an unacceptably high level — a six-sector configuration facilitated by smart antennas can create new capacity. In intermediate cases, smart antennas can both create additional sectors for greater capacity and distribute traffic more evenly across those sectors to boost site efficiency.

As subscriber numbers continue to soar, and as the predicted demand for data traffic begins to materialize, CDMA network operators will need to use all available tools and strategies to meet the attendant capacity challenges. Smart antennas will certainly be among the most flexible and cost-effective of those tools, and using such systems to facilitate flexible, multiple sectorization schemes will likely be among the most promising strategies.

RF

About the author

Ji-Hae Yea is currently senior RF network Engineer at Metawave Communications. Yea has led numerous projects on smart antenna field trials and deployments and is a member of multiple project core teams for smart antenna system design and product development. His current areas of interest include algorithm development, wireless position location and performance analysis for wireless voice and high-speed data systems. He holds a Bachelor of Science in Electronics from Dankook University, Korea, and a Master of Science in Electrical Engineering from the University of Washington. He can be reached at 888.638.2928 or through the company's Web site at: **www.metawave.com.**


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Interfacing E– and E²–PROM memory with digital signal processors

As more digital-based features and functions get crammed into wireless products, DSPs and support hardware take center stage.

By Iantha Scheiwe and Felicia Benavidez

Today's 2 and 2.5G wireless devices offer a relatively full plate of features and functions. Tomorrow's 3G will extract an even higher price in terms of digital technology and storage memory for their pervasive feature set.

To support this feature-hungry environment, digital signal processors and their support memory are becoming mainstream. Erasable programmable read-only memory (EPROM) and electrically erasable programmable read-only memory (EEPROM), along with latest generation DSPs, promise to field the ball.

The fundamentals

An EPROM is a read-only memory chip that can be reprogrammed using a special ultraviolet device. The chips are packaged with a clear plastic cover so that the chip can be exposed to the light and be erased for reprogramming.

An EEPROM, or E²PROM, can be erased and reprogrammed in a similar fashion. EEPROMs do not require any special packaging or reprogramming devices. They are reprogrammed by simply applying an electrical current to the memory chips (as opposed to having to use UV light) and then writing new instructions to the device.

Digital signal processor (DSP) hardware engineers can fully utilize a processor's resources and generate an optimized memory design by interfacing their DSPs to one or more of these devices in their designs. EPROM and EEPROM memories are not fast access devices, especially in the realm of DSP applications. Even the fastest EPROM or EEPROM memories require that a DSP core running at 100 MHz generate wait states.

Both types of memory devices have address stability requirements, and any interface with a DSP will require multiple wait states. This article will explain EPROM and EEPROM memory capabilities and typical applications (some will be manufacturer and device specific). Although some of the technical terms may vary from one DSP vendor to another, the same EPROM interface methods will apply regardless of vendor.

EPROM and EEPROM memories

The only distinction between the two types of memories is the means by which a user or a vendor in an application erases the memory prior to reprogramming. Designers interface both devices identically in DSP applications and the two devices, if otherwise identical, are interchangeable. The terms EPROM and EEPROM are interchangeable in theory and for the discussions herein.

Either memory device is available in an assortment of packaging and capacity ranges. The most widely available memory is 8-bit, but 16-bit and 32-bit memories are also available. Designers can also multiply bit rates by using multiple devices in parallel, e.g., three 8-bit devices to achieve 24-bit performance. Commercially available device memory capacities also vary widely, from 2 kB to 4 MB or more to fit nearly every design need. The primary purpose of EPROM memory is to provide non-volatile storage for critical startup programs and data. Although their access speed has increased in recent years, the current highest-speed EPROM memories can be accessed at 70 MHz. Most are considerably slower.

Interface issues

With a DSP core running at 100 MHz, one wait state equals 10 ns (time is the inverse of speed). The interface between the two devices must fit the system timing requirements so both devices are compatible. The designer will have to program wait states into the DSP because EPROMs cannot drive the data bus in one clock cycle. For even the fastest EPROMs, the DSP will incur a wait state penalty that can vary anywhere from 1 to 20, or more wait states.

Because the EPROM is a slower device in most design applications, the designer seeks to minimize the content of the EPROM. By downloading modestly sized programs or data stored in the EPROM to the DSP's internal random access memory (RAM), the application will achieve optimum performance much more quickly (since the data in the DSP's internal RAM runs at the same speed as the DSP). Thus, in most design interfaces with DSPs, designers will try to avoid large memory EPROM devices. In DSP applications, EPROMs are most frequently used when the system has to boot after a reset. Routine maintenance, program

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ERA-1SM	DC-8000	11.8	12.0	4.3	26.0	40	1.42
ERA-21SM	DC-8000	13.2	12.6	4.7	26.0	40	1.57
ERA-2SM	DC-6000	15.2	13.0	4.0	26.0	40	1.57
ERA-33SM	DC-3000	17.4	13.5	3.9	28.5	40	1.72
ERA-3SM	DC-3000	18.7	12.5	3.5	25.0	35	1.72
ERA-6SM	DC-4000	12.2	▲17.9	▲4.5	▲36.0	70	3.90
ERA-4SM	DC-4000	13.4	▲17.3	▲4.2	▲34.0	65	3.90
ERA-51SM	DC-4000	16.1	▲18.1	▲4.1	▲33.0	65	3.90
ERA-5SM	DC-4000	18.5	▲18.4	▲4.3	▲32.5	65	3.90
ERA-50SM	DC-1500	•18.3	▲17.2	▲3.5	▲32.5	60	2.95

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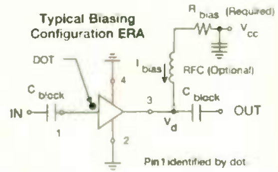
Typical Biasing Configuration ERA



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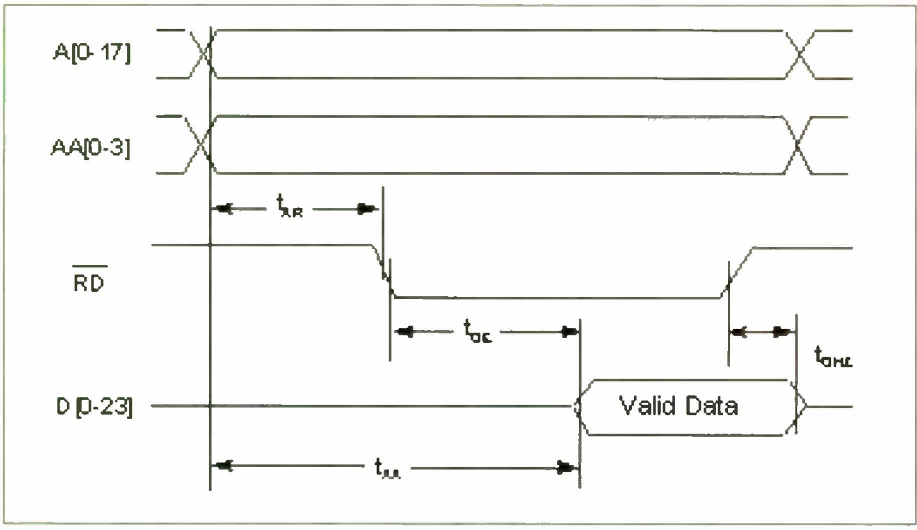

Figure 1. External memory bus asynchronous read timing.

upgrades, or power failure can also cause a reset to occur.

In terms of the operation of the DSP, the EPROM only functions to boot the DSP. When the DSP boots after reset, it needs to know what to do. A common way of telling it what to do is with an external EPROM. The DSP accesses the non-volatile EPROM at boot since the DSP's static RAM (SRAM) is volatile and cannot retain its contents if power is lost. As a result of any reset and boot, the DSP's RAM program control will be lost. Although using external EPROM to boot the DSP is common, the designer can select other approaches such as flash memory or booting from a host.

In some applications, the system may also require permanent data or tables, a second use of EPROMs with a DSP. Remember, while the DSP is a high-speed device, the EPROM is not. For this reason, EPROM usage is limited in DSP applications to functions that are not time-critical, such as boot sequences. The DSP can access the required data or tables at boot time without incurring a performance penalty, as would be the case if the EPROM had to be accessed as a routine processing step. EPROMs are used because they are non-volatile, cheap and have small footprints (depending on capacity). These are the attributes that make them a good choice for boot applications. Slow speed relative to the DSP is the reason why the EPROM performs no active functions during regular DSP system operation.

In some systems, a hardware device other than the DSP may require and/or cause a reset. This action will also cause the DSP to reset, which in turn triggers access to the EPROM. The particular trigger depends on the reset mode in the design. The reset mode lines in the design define whether the system triggers access to the EPROM to reset. Once the access to the EPROM is triggered, the following signal lines define the interface between the EPROM and the DSP. These signals are common to DSP interfaces with EPROMs:

- *Read data enable* – An active low-output signal that is asserted during an external memory or peripheral read access.
- *Write data enable* – Same as above for write access.
- *Address bus* – Address lines that allow the DSP to directly address 256 Kwords of external memory or peripherals. These active high-output signals are asserted only during external memory or peripheral read or write accesses. These signal lines maintain state when external memory spaces are not being accessed.
- *Address attribute (AA)* – (This chip select may be named differently by DSP vendors, but the function will be identical.) When the four AA attribute signals are selected they can function as chip selects or additional address lines. When the *row address strobe* option is selected for these signal lines they can function as row address strobe lines for dynamic RAM (DRAM) interfacing.

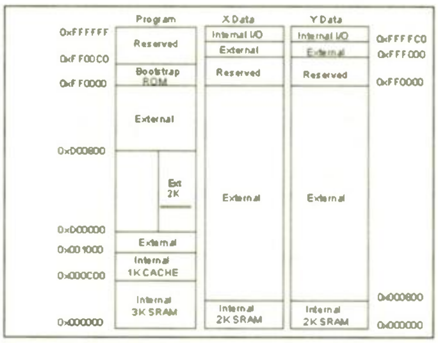

Figure 2. EEPROM memory map layout.

Programs stored in the EPROM's non-volatile memory storage can be read and run indirectly as 8-bit data. Either a program or direct memory access (DMA) can access the EPROM and pack and store the data into the DSP's program memory. After every three accesses, the DSP packs the three 8-bit transmissions into 24-bit words for storage into program RAM. An alternative to packing three transmissions from one 8-bit device is to arrange three 8-bit EPROMs as a 24-bit bank and get 24-bit data in each transmission. This method takes the most advantage of a particular manufacturer's 24-bit word architecture, but requires additional board space and system cost. After the data loading is complete, the DSP turns program control over to the newly loaded program.

This program, called the overlay loader, can then load additional data (under dynamic memory access (DMA) or program control) from the EPROM(s) into program, X data, or Y data spaces for later execution or use)[1]. Although not commonly done, after the DSP has booted and is ready to run, the overlay loader program can access the same EPROM for additional saved blocks of data or tables. In this way, the remainder of the data loading may be done at a higher clock speed.

An application

One application of this method can load a small program that sets a phase lock loop (PLL) at a higher frequency. The PLL initially runs at the input clock speed of the system's on-board oscillator. This speed is usually slower than the full capability of the DSP. A high-speed oscillator is not used here because it can cause signal interference on the board. By using a slower clock, the designer can use the PLL to multiply the slower oscillator to meet the maximum clock speeds of the DSP. To speed up the boot process, it is advantageous to start the PLL with a small program so that the remainder of the boot program can utilize the DSP's maximum clock speed. This is especially useful if there are many boot instructions because most applications have to boot within a limited amount of time.

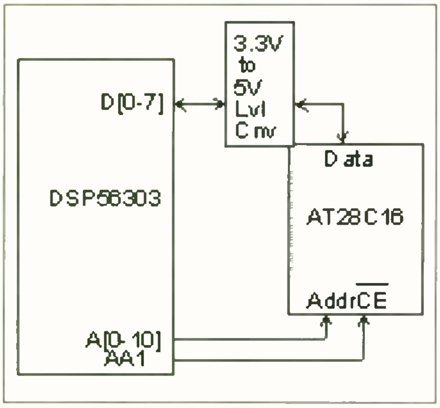

Figure 3. Schematic of the voltage converter.

It's all about the boot

Boot times are defined by the individual end-use requirements of each application. In cell phones, for instance, the design can tolerate a boot time of only a few seconds. Most cell phone users are too impatient to wait longer. In another instance, when a base station boots, there's normally a large amount of data and many channels of voice that also require a large amount of data. A base station may receive a reset command during a power failure, when another component fails, or as a result of human error. Similarly, a reset command may be generated when the base station requires servicing or an upgrade. Finally, the system will have to be reset after the installation of new hardware or other new devices. The boot time requirements will vary standard-by-standard and application-by-application. The memory capacity of each EPROM depends on the non-volatile memory requirements for the particular system to reset and boot.

The reset table (Table 1) is for a typical DSP from a major manufacturer. Any DSP will have a reset table proprietary to its vendor. In this particular device series, there is a reset mode that sends the DSP to fetch instructions from 8-byte wide devices. This mode, Mode 9, is the one that is used for EPROM boot. A DSP typically has many other reset modes, so the designer must look to find an appropriate mode to use.

Some types of EPROMs can be upgraded or reprogrammed remotely while the DSP is still running because the EPROM is only used at start-up. During development this feature is particularly convenient because it allows for fast test-program-retest development cycles.

Mode	Description
0	Bypasses the bootstrap ROM. This device starts fetching instructions
at	
	$C00000
1	Reserved
2	Reserved
3	Reserved
4	Reserved
5	Reserved
6	Reserved
7	Reserved
8	Bypasses the bootstrap ROM. This device starts fetching instructions
at	
	$C00800
9	Bootstrap from Byte-wide memory (EPROM)
A	Bootstrap through SCI
B	Reserved
C	HI08 bootstrap in ISA/DSPxxx mode (DSP specific)
D	HI08 bootstrap in HC11 non-multiplexed mode (DSP specific)
E	HI08 bootstrap in 8051 multiplexed mode (DSP specific)
F	HI08 bootstrap in HC11 MC68302 bus mode (DSP specific)

Table 1. DSP operating and reset modes (16-bit DSP).

Interfacing the DSP and EPROM

The designer sets the core speed of the DSP from one of several possible sources. All memory interface timings are derived from the period of the DSP core clock. For example, if the DSP core clock frequency is 100 MHz, then the memory interface timing is based on a 10 ns clock cycle time.

In most applications, the designer wants the PLL to run as quickly as possible for optimum program execution. The designer sets the clock and PLL speeds in the PLL control register. This optimized speed will vary with the designer's choice of DSP. Note that these timing requirements are affected by various factors, including the use of a PLL and the PLL's external frequency source. These factors can cause the clock cycle to vary from 10 ns.

Unlike synchronous devices, asynchronous EPROMs don't use an external clock as reference for any action. However, it's always important to perform a timing analysis for the interface to assure compatibility between the memory and the DSP. Figure 2 visually shows the flow of signals interacting between the DSP and the memory device for the READ timing. The *write* timing chart is identical except that the *valid data* on *read* is not driven by EPROM, but by the DSP for *write*.

DSP PLL and clock generation

The designer configures the DSP PLL and clock generation in the PLL control (PCTL) register to set the core speed of the DSP for optimum processor and memory performance. The PCTL register performs three sub-functions:

•*Frequency predivider* — This frequency pre-divider has a programmable division factor of 1 to 16. The designer can pre-divide the input clock frequency before passing it to the PLL loop frequency multiplier. The division factor is the binary value plus one.

•*PLL Loop frequency multiplier* — This sub-function multiplies the clock frequency output from the predivider by the voltage-controlled oscillator (VCO). The multiplication factor is the binary value plus one.

•*Frequency low-power divider (LPD)* — The LPD divides the output frequency of the VCO before it is used by the DSP core. The frequency LPD can be programmed with a division factor range from one to 128. The EPROM can download a program to the LPD that reprograms the LPD without losing the lock. For the clock to be valid, the PLL must be locked.

The designer can use combinations of these sub-functions to divide and multiply frequencies for optimum DSP performance.

The operating frequency of the DSP is set in the PCTL register as follows:

$$F_{CORE} = \frac{F_{EXTAL} \bullet MF}{PDF \bullet DF}$$

where:

FCORE is the DSP core frequency.
FEXTAL is the external input frequency source.
PDF is the predivider factor.
MF is the PLL multiplication factor.
DF is the division factor.

The remaining key factors in designing the interface between the EPROM

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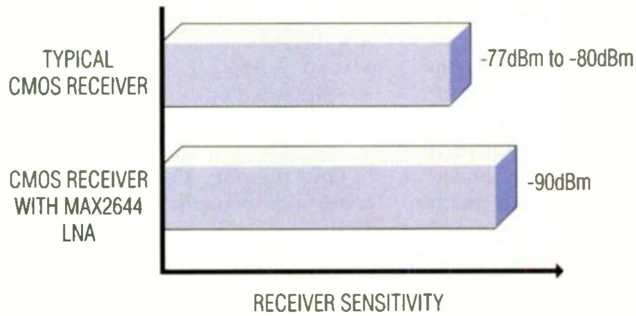

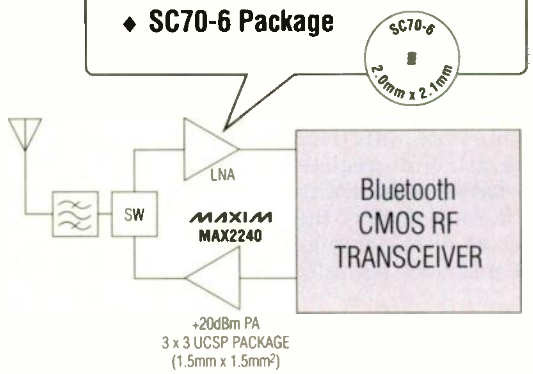

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NEW	MAX2644	2450	16	2.0	-3	Yes	Bluetooth, 802.11, HomeRF™, WCDMA, satellite radio, MMDS
NEW	MAX2654	1575	15	1.5	-7	—	GPS
NEW	MAX2655	1575	14	1.7	+3	Yes	GPS in cellular phones
NEW	MAX2656	1960	13.5	1.9	+1.5	Yes	PCS, DCS, WLL

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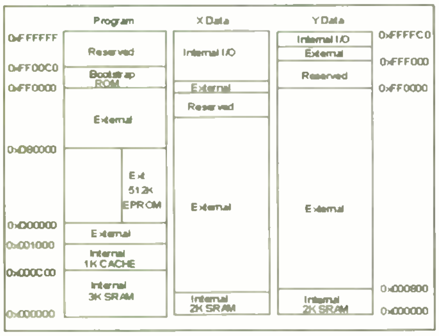

Figure 4. DSP boot memory map.

and the DSP are the bus control register and the address attribute control registers. The bus control register defines how many wait states are necessary for the DSP to interface with the EPROM. The address attribute register determines the behavior of the address attributes (AAs). In some devices, the AA signals can act as either chip selects or additional address signals. Every

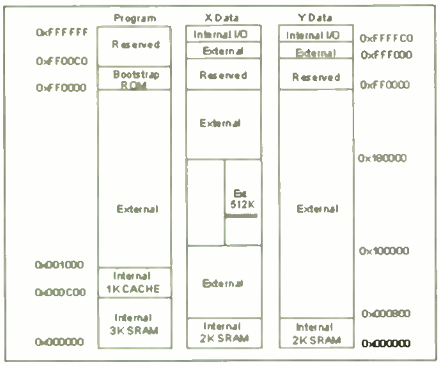

Figure 5. DSP overlay memory map layout.

designer using a DSP, regardless of vendor, will have to program the wait states and how the chip select will operate.

One last factor in the interface is that the memory device and the DSP may have different voltages. In this example, an EEPROM is connected as diagrammed in the memory map layout in Figure 2. In this example, the program in the EEPROM can be loaded into the DSP at boot time and run. The running program on the DSP can then save an updated version of the program back into the EEPROM for later use. Used with this particular device, the 5.0 V EEPROM does not match the 3.3 V DSP and requires the use of a level converter. Using a level converter allows the designer to match the voltage levels as shown below in Figure 3. This situation is fairly common in many DSP designs and can be solved in similar fashion.

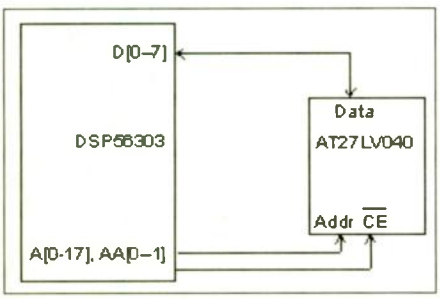

Figure 6. DSP block diagram.

Summary

If a designer requires a non-volatile memory for the boot program in a DSP application, an EPROM is a common selection. EPROM devices come in a wide range of sizes and memory capacities. The DSP typically runs at a much higher frequency than the memory device. Therefore, the designer will have to program wait states into the DSP because the EPROM cannot drive the data bus in one clock cycle.

The program(s) stored in the EPROM can be read and run indirectly as 8-bit data, then packed and stored into DSP program memory. After every three accesses, the DSP packs the three 8-bit transmissions into 24-bit words for storage into program RAM. A common alternative is for three memory devices to send 8-bits each per access, meeting the DSP's need for 24-bit words.

Although not commonly used, the overlay loader can access the same EPROM(s) after the DSP has booted and download additional data or tables at a higher clock speed. One implementation of this method is to load a small program at boot that sets the PLL at a higher frequency.

RF

1. This pertains to this manufacturers particular device. Other devices may organize their memory differently.

Implementation example

In this example, a 512 K x 8-bit boot with X data space program overlay is interfacing the EPROM and the DSP.

A program loaded in the EPROM will load into the DSP at boot time and run. The booted program can then load additional programs and data from the EPROM into the DSP using overlay techniques (see Figures 4, 5 and 6).

- DSP speed: 80 MHz
- Input frequency source: 4.0 MHz crystal
- EPROM access time: 150 ns
- Wait states: 12
- Voltages: DSP and memory devices are 3.3 V

One memory device comprises the 8-bit wide boot bus. During reset, the DSP boot code loads bytes from the EPROM, packs them into 24-bit words, and stores them into Program RAM. The first word read from the EPROM indicates the number of words to load. The second word from the EPROM contains the starting load address for the packed data. The starting load address is also the address that gains program control after the program is loaded.

About the authors

Iantha E. Scheiwe is currently a senior application developer working for Motorola's Semiconductor Products Sector. Prior to her current position, she worked with an SPS software research team investigating SIMD DSP architectures. She graduated from Valparaiso University in 1996 with a B.S. in computer engineering.

Felicia L. Benavidez works in Motorola's Wireless Infrastructure Systems Division where she works with customers to integrate Motorola's MSC8100 and DSP56300 families of DSPs in infrastructure applications. Benavidez graduated with a B.S. in electrical engineering from New Mexico State University.

Bringing wireless to the battlefield

How do you bring wireless communications to the battlefield? Simple. You wear it.

By Joseph Fjelstad and John Murray, Ph.D.

With a goal toward the design of a system enabling the 21st century U.S. soldier to become a more effective instrument of war, recent advances in the US Army's Land Warrior program have focused on providing soldiers with up-to-date technology for wireless communication, navigation and information interchange. The Land Warrior system will make rapid deployable light forces more effective on the future battlefield, providing enhancements of lethality, survivability, mobility and sustainability.

The Land Warrior may not look like much, but offers everything a handset and mobile computer have to offer. Can you spot the mouse?

Targeting vastly increased situational awareness for dismounted infantry soldiers, an integrated system of rapid mobile digital and voice connectivity has been developed by product engineering and analysis firm Pacific Consultants, Mountain View, CA.

Two years ago, the U.S. Government Accounting Office (GAO) noted that the project was "over budget, behind schedule and needed more oversight." The Land Warrior program, started in the early 90s, regularly received widespread negative national front-page newspaper coverage for lack of progress in achieving the program objectives.

Putting Land Warrior on the fast track

A paradigmatic turn-around began in October of 1999 when U.S. Army management, under the direction of Colonel Bruce Jette, took the initiative to treat the project as a "fast track Silicon Valley project," utilizing new product innovations and commercial-off-the-shelf (COTS) components to develop working prototypes of a wearable computer, voice-over IP radio and the software package needed to control the system. Implementing such an innovative COTS approach was a direct alternative to traditional methods of military procurement and program development.

A goal of the program was to keep costs under control by leveraging the rapid advances taking place in the commercial research and development arena; most notably in the area of wireless communication. This wasn't easy. "One of the stiffest challenges we faced involved taking available commercial standard applications and re-deploying them into military standard applications," said Pacific Consultants CEO Dr. Hugh Duffy.

Pacific Consultants provided overall systems integration of Land Warrior components including the computer/radio, global positioning system and a weapon with thermal imaging capability for detection of hidden targets. Also provided was a laser range finder and a video sight that allows soldiers to accurately aim and shoot around corners or obstacles without exposing themselves to enemy warfare. This latter feature is especially desirable in urban warfare, where soldiers are continually encountering walls, stairs, doorways and fences.

The wearable computer

The Land Warrior wearable computer system is centered around two commercially available data handling platforms – the Land Warrior computer running Windows 2000 on PC 104 hardware and the Land Warrior communications-navigation (CommNav) unit, using Windows CE running on an Intel Strongarm

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MBA-12	+7	0.8-2.5	5.95	MBA-18MH	+13	1.6-3.2	7.95
MBA-26	+7	2.2-2.7	5.95	MBA-25MH	+13	2.0-3.0	7.95
MBA-591	+7	2.8-5.9	6.95	MBA-35MH	+13	3.0-4.0	7.95
MBA-671	+7	2.4-6.7	8.95	MBA-9H	+17	0.8-1.0	9.95
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processor. This CommNav unit contains a GPS receiver and dead reckoning positioning module (DRM), as well as a wireless LAN PC card. It also includes DSP hardware for handling audio communications.

Mobile data on the battlefield

Faced with an accelerated timeline, the software engineering process consisted of two parallel, spiral development programs. A series of rapid prototyping and user interface mock-up cycles were valuable in gathering user requirements and validating design choices via user juries. In tandem with this, a more comprehensive production software development process has been used, integrating participatory design and extensive user involvement in all phases of the project.

The earlier verion of the Land Warrior system (top) had a number of exposed cables. The current version (bottom) is more compact with the use of flex circuitry.

Land Warrior-equipped soldiers have the capability to originate and disseminate a variety of asynchronous data messages, including operational orders, intelligence information, logistics reports and tactical fire support requests. A rapid call for medical assistance can also be issued. The Land Warrior mapping component provides the capability to show current position information for each member of the platoon. The system automatically generates and transmits regular GPS-based position update messages, so that Land Warrior users can be constantly updated with each other's current location. "Knowing the positions of fellow platoon members minute-by-minute, especially in relation to the enemy's location, provides a tremendous strategic advantage," said Pacific Consultants' President Dr. Bret Herscher.

Map overlays can be edited to add targets, route plans, rally points, mined areas and a wide range of other geolocated points of interest – these can then be transmitted to all platoon members or a selected group of recipients. A video-mode data server provides the user with overlaid text and graphics when the system is used for displaying real-time video from the weapon-mounted sights. The system includes a still-image handling facility for saving, annotating, and transmitting video scenes that are captured using the weapon sights. The Land Warrior application also incorporates a simple hypertext browser, which soldiers use to access various operations

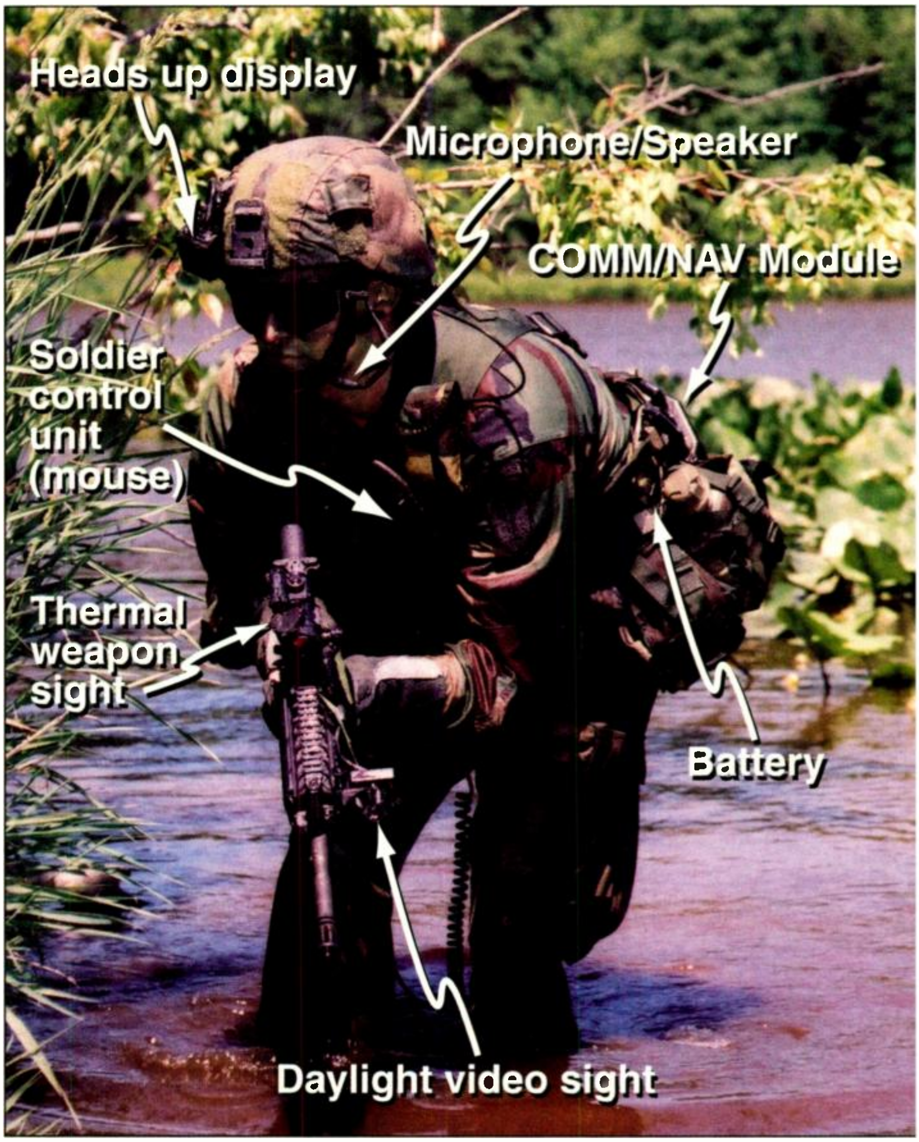
manuals, training texts, and other HTML-based reference material.

Networking the system

The Land Warrior wireless communication system involves an infrastructureless mobile network, a form of peer-to-peer interaction over a wireless LAN that is sometimes characterized as an ad-hoc network. Since each node is mobile, it needs to connect to the network dynamically and in an arbitrary fashion. Each participating node will act as a router when forwarding data packets on behalf of other nodes on the network. They will also take part in connection discovery and route maintenance to other nodes on the network. Sub-nets can form when a larger group of nodes sub-divides into two or more smaller groups that are separated by distance or poor RF propagation circumstances.

This data network uses standard IEEE 802.11 wireless LAN communications protocols. An innovative multicast group IP addressing scheme is used to map individual duty positions within the platoon to their virtual location on the wireless LAN. "This is one of the vast improvements in situational awareness that the Land Warrior system delivers,' said Herscher. "No longer are soldiers reduced to communication via shouts, yells and hand signals, which have a propensity towards giving away a soldier's position to the enemy."

The addressing scheme obviates the need to closely couple a soldier's LW system (and hence its assigned IP address) with his assigned role in the platoon. Voice-over-IP is used for audio communication within the Land Warrior network. A pool of virtual channels is available for normal audio use, with one additional channel being set aside for emergency calling purposes.



The soldier of the 21st Century must be able to win the tactical communications war. Land Warrior is part of the U.S Army's effort to bring advanced technology to the battlefield. The Army is also developing similar programs for airborne and armor forces.

The intrinsic mobile characteristics of the U.S. Army's military operations suggest that the future battlefield will require a variety of wireless data communication networks. The Land Warrior system will eventually participate in extensive networks linking command and control centers, logistic posts, ground vehicles, aircraft and other equipment and facilities. It is expected to form the lowest echelon in the Tactical Internet hierarchy. Thus, a reliable gateway between the internal LW wireless LAN and the rest of the military communications network is required. To this end, as part of the proof-of-concept development activity, the platoon radio-telegraph operator (RTO) was equipped with a Single Channel Ground and Airborne Radio System-Advanced System Improvement Program (SINCGARS ASIP) military radio in addition to his LW system.

The frequency-hopping ASIP radio provides standard military voice and data communications capability. The data network access component of the radio connects to a serial port on the proof-of-concept Land Warrior computer. This link enables the RTO to send and receive certain operational orders and situational awareness data to and from the battle command center. Additional software was provided to drive this radio. Thus, the RTO's Land Warrior system forms the gateway between the two networks.

The Land Warrior's CommNav software, which runs on the Windows CE platform, provides the bridge between the primary Land Warrior application and the wireless LAN. It also handles the GPS and DRM positioning data. It is designed to run independently of the main application, so that the CommNav unit can continue to function autonomously should the PC104 computer fail. This means an individual soldier can still communicate by voice and continue his position update transmissions, in the absence of the Windows 2000 system. Another feature of

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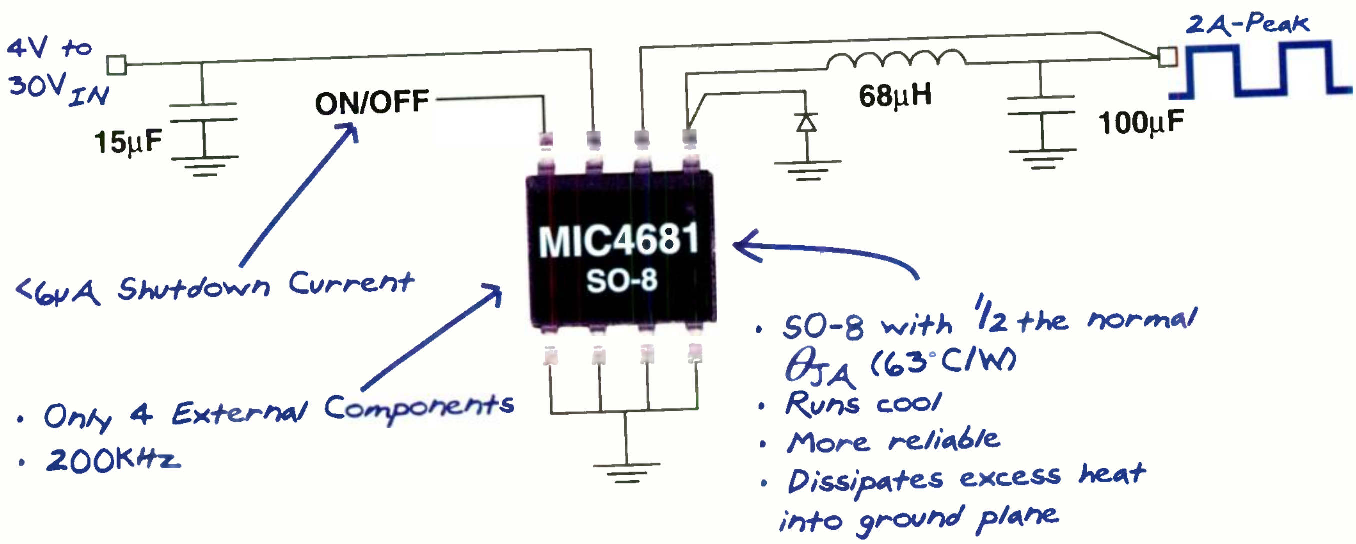

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the computer is its inertial navigation module, supporting the GPS in terrain that satellite signals can't reach, in urban streets between tall structures or in rural areas with dense tree canopies.

The primary Land Warrior peripheral components are attached to the soldier's Personal Area Network (PAN) which, in the proof-of-concept systems, used standard CAN 2.0b technology. The components mounted on the soldier's weapon include a laser rangefinder and digital compass, a daylight video sight, a thermal sighting unit and a mouse device. The PAN also links to the head-mounted display controller and an additional chest-mounted mouse control. In addition, it can be used to attach bio-sensors or other peripheral devices to the Land Warrior system.

Flex circuitry

The refocusing effort for the Land Warrior program brought flex circuitry application development to center stage. The Pacific Consultants' effort on flex circuitry was led by Joseph Fjelstad. With earlier versions of the Land Warrior system containing interconnected discrete cables, soldiers had complained that the bulky circuitry wasn't easily constrained- this resulted in soldiers regularly becoming snagged by trees, shrub branches and limbs in field trials. Along with this bulk came additional weight for already overburdened soldiers.

The current flex circuitry concept for the Land Warrior that was developed and executed was one where most of the various cables were integrated into a single flexible circuit that was patterned to follow the contours of the modular lightweight load-carrying equipment (MOLLE) or vest that holds the system components. In use, the flexible circuit wraps around the shoulders of the soldier and is invisible as it is sewn into the vest's fabric.

Along with eliminating the problem of snagging, this flexible circuit variation provided significant weight savings. The final cable with connectors weighed in at just 80 grams compared with the 680 grams of the original cables, resulting in an 88% weight reduction.

With all of the improvements both already designed and implemented, plus those planned for future versions of the Land Warrior, the anticipated cost of outfitting each soldier is targeted to be on the order of $15,000 to $20,000, nearly $70,000 less than the original $85,000 estimate provided by previous military contractors. In the future, it is anticipated that modified versions of the Land Warrior software product will be deployed on other hardware platforms, for various simulation and gaming purposes. Utilization of these approaches to user training and engagement with the system will be carefully studied in the coming months.

Version 1.0 of the Land Warrior system is currently under development. This version is slated to be a manufacturable system with numerous added features learned from the Army's experience with the 0.6 development system. The Army expects to eventually outfit 41,000 soldiers with the system, beginning in 2003.

RF

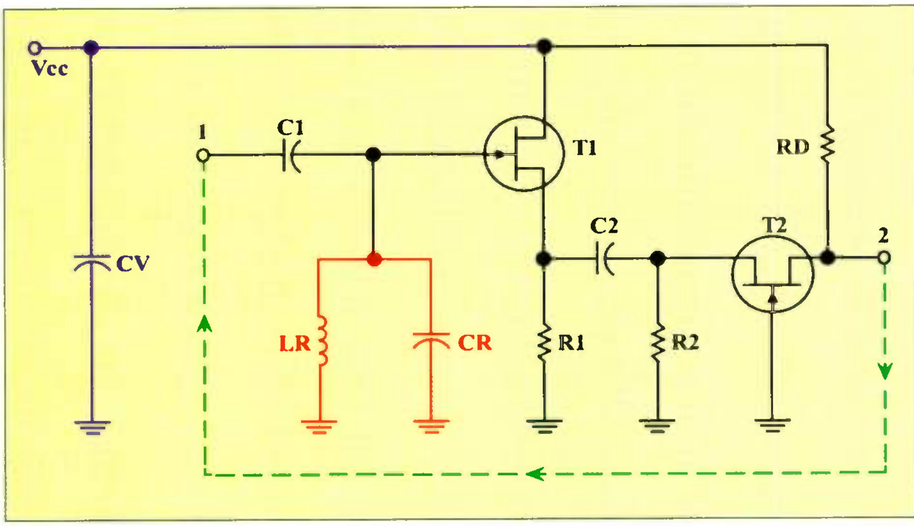

Figure 1. A frequency-selective (LR, CR) two-stage amplifier circuit.

to the first amplifier stage, the input impedance of this second stage is low, and the output impedance is high. So, there is an impedance match to the output port and the input port of the first stage as well. For this reason, the influence of the JFET's impedances on the loaded Q of the resonant circuit is low. By connecting the two stages via the coupling capacitors (C_1 and C_2) the loop is closed and the two-stage amplifier operates as an oscillator with a frequency determined mainly by the value of the resonant circuit capacitor and that of the resonant circuit coil.

The principle of the oscillator is similar to the well- known Franklin oscillator[2]. However, in contrast to the Franklin oscillator, the parallel tuned circuit is not isolated from the two-stage amplifier by means of small capacitors, but rather by impedance matching. Therefore, the loop gain is higher, and the output signal is suited for low impedance loads.

The basic circuit

Some simplifications can be carried out, leading to the basic circuit of the source-coupled JFET oscillator for a fixed frequency as shown in Figure 2.

Only one coupling capacitor (C_F) is necessary to separate the different DC voltages between the gate and the drain of the two JFETs. The two source resistors are replaced with only one resistor (R_S), leading to a galvanic coupling of both the JFETs. The frequency of operation (F) can be easily estimated by the well-known expression:

$$F = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

where L is the value of the inductance of the resonant coil (LR) and C is the sum of the capacities of the resonant capacitor (C_R), a part of the T_1 JFET's input capacitance and a fraction of the feedback capacitor. The oscillator circuit shown in Figure 2 can be built with common lumped circuit elements, leading to small physical dimensions. The values of the specific elements depend on the types of the transistors in use, the frequency range and the bias voltage. The output signal is gathered from the two galvanic- coupled source electrodes via the coupling capacitor (C_O). The impedance at this point is relatively low, so a common 50Ω load can be directly connected to the oscillator. An additional buffer amplifier is not necessary for proper operation.

The test circuit

To investigate the electrical characteristics of this oscillator circuit, a number of VCOs were built at the different operating frequency bands. One universal circuit was used, changing only values of the relevant circuit elements according to the different frequency bands. The modified and extended circuit of the design is shown in Figure 3.

Two inexpensive GaAs FETs were used as the active devices (T_1, T_2). The drain resistor (R_D) has a fixed value of 470Ω for all frequencies. Due to the fact that the JFETs used in the test circuit tend to oscillate at undesired frequencies, this resistor may be shunted by an additional capacitor (C_D), if necessary.

In this particular circuit, an operating point-dependent parasitic oscillation is observed in the 6 GHz region. This is caused by the small internal reactive elements of the JFETs, such as bonding wire inductances and case capacitances. This parasitic oscillation can mix with the desired frequency's harmonics and result in spurious modes looming in the desired frequency band. The shunt capacitor reduces the amplitude of the oscillator's harmonics and suppresses the generation of spurious modes. The value of the shunt capacitor depends on the desired fre-

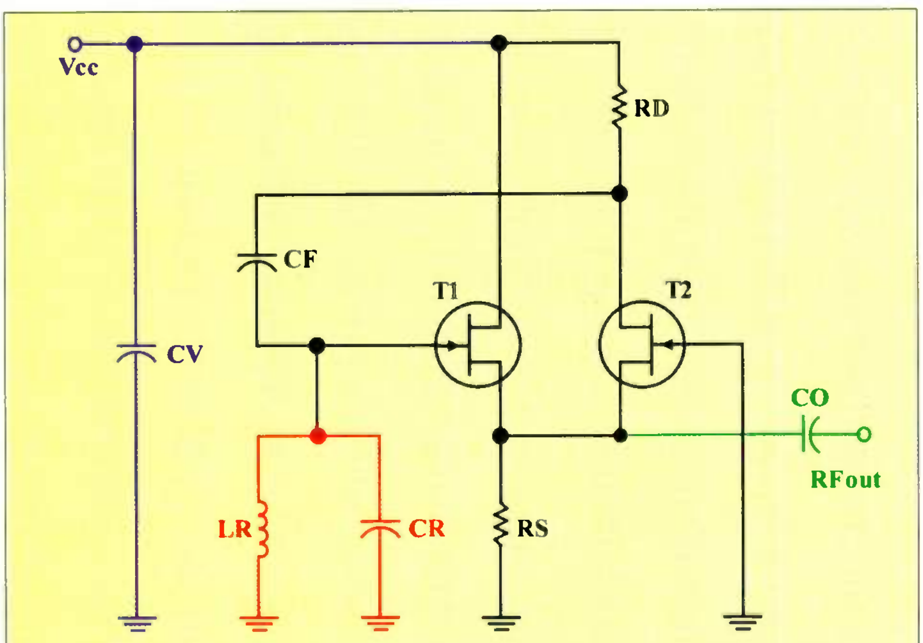

Figure 2.The basic circuit of the source-coupled JFET oscillator.

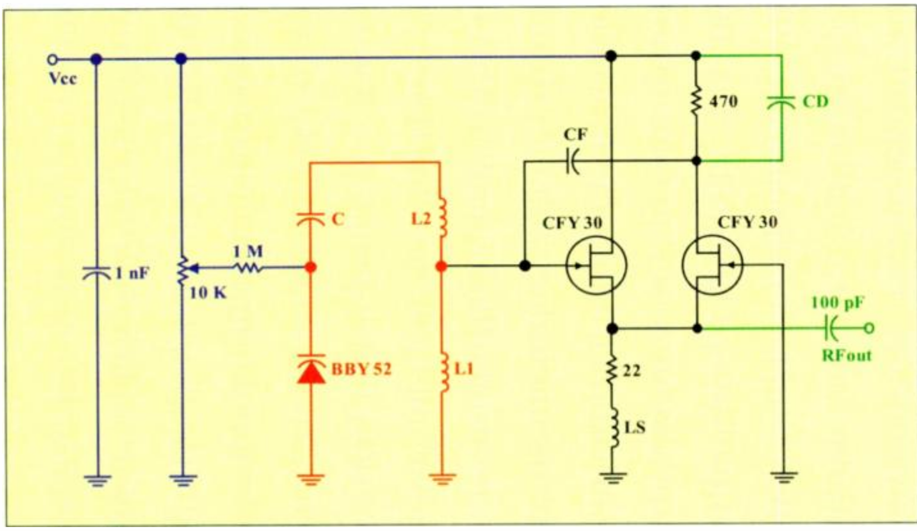

Figure 3. The investigated VCO circuit.

quency range and is about twice the value of the feedback capacitor. If the shunt capacitor is required, attention should be paid to the fact that both the feedback capacitor and the shunt capacitor are connected in series to ground. And the series capacitance of these two capacitors is directly connected, in parallel, to the resonant coil. Thus, the value of this series capacitance must be added to the value of the resonant circuit capacitor when calculating the resonant frequency.

The source resistor regulates the operating point of the respective JFETs, and it determines the generated output power of the oscillator circuit. To achieve a high output signal at a low supply voltage, the source resistor is substituted by a series connection of a fixed 22Ω resistor and a source coil with a frequency-matched inductance value. This increases the DC current via the JFETs and, in turn, increases the amplification factor of both transistors. For higher supply voltage values or less output signal, the source resistor should have values in the range of 47Ω to 200Ω. The source coil can be omitted if the source resistor has a value of 47Ω or more.

For frequencies higher than 2 GHz, the input impedance of the first JFET must be taken into account. Therefore, the resonant circuit coil consists of a series connection of two coils (L_1, L_2). At these higher frequencies, the coils form a tapped coil, reducing the JFETs capacitive input load. For lower frequencies, the additional coil is not necessary and can be shunted by a jumper.

To tune the frequency of the generated signal, a capacitive- (C) coupled varactor diode was used in the tuned circuit to allow voltage tuning. The varactor diode is biased via a potentiometer (10 kΩ) and a resistor (1 MΩ). The tuning range of the VCO depends on the degree of capacitive coupling between the resonant circuit and the varactor diode.

A higher value of the coupling capacitor will allow a larger tuning variation, but will pull down the center frequency. Referring to Figure 3, the tuning voltage can be varied only between zero and the supply voltage (V_{cc}). Therefore, the tuning range depends on the amount of the supply voltage. For values of the supply voltage (V_{cc}) of 3 VDC or less, the tuning range of the capacitance of the varactor diode is low. For lower frequencies, the varactor type should be substituted by a more suitable one.

The oscillator has been developed using the same layout of the printed circuit for signal frequencies from 20 MHz to 3.2 GHz. Some typical element values for the specific frequency bands are given in Table 1 (see page XX). The oscillator of this test circuit is primarily intended to serve as a VCO in a low-voltage, small-band PLL circuit. The tuning range can be small, but must be larger than the thermal frequency drift of the oscillator. For further purpose, this oscillator should be readapted.

The 20 MHz oscillator

In this case, the tuning capacitance of the varactor diode is about 2 pF and is too small for the short wave region. To increase the capacitance, four varactor diodes were used and connected in parallel. An oscillator was built for the 20 MHz region with a resonant circuit consisting of a 940 nH coil (L_1) and an 82 pF capacitor (C) in series to the four varactor diodes. The additional coil (L_2) is not necessary, and is therefore replaced by a shunt. A 100 pF shunt capacitor (C_D) and a 56 pF feedback capacitor(C_F) were used. There is already a series capacitance of about 36 pF in parallel with the resonant circuit coil, which reduces the capacitance variation because of the small capacitance of the varactor diodes. Therefore, the tuning range is relatively small. Spurious modes could not be observed within this tuning range.

The value of the coupling capacitor is too low for a short wave signal at a 50Ω load. Hence, the output power is only 8.7 dBm at a supply voltage of 2.0 VDC. The oscillator operates well in the voltage region from 1.5 VDC to 2.5 VDC, but becomes unstable at higher voltage values. This frequency range seems to be the lower border of the test circuit. For lower frequencies, the topology of the oscillator circuit must be improved.

The 50 MHz oscillator

Two varactor diodes connected in parallel are used as the voltage- controlled capacitor for the 50 MHz oscillator. They are connected via a 56 pF series capacitor to the 470 nH resonant circuit coil. Both the 22 pF feedback capacitor and the 47 pF shunt capacitor add a constant capacitance of about 15 pF to the resonant circuit capacitor. The additional coil is bridged. The supply voltage can be varied from 1.5 VDC to 3.5 VDC without any electrical problems. At a voltage value of 2.0 VDC, the oscillator produces an output signal of 10.0 dBm. No spurious modes could be detected. This oscillator works without any problems.

The 145 MHz oscillator

A simple VCO was built for the frequency range from 144 MHz to 146 MHz. The resonant circuit coil has a value of 136 nH. Two parallel varactor diodes are connected via a 12 pF capacitor to the coil. The 10 pF shunt capacitor and the 4.7 pF feedback capacitor form an additional parallel capacitance of about 3.2 pF. For this frequency and above, the parasitic capacitances of the soldering pads and the input capacitance of the JFET will have have an influence on the signal frequency. The additional coil is bridged in this circuit as well. As before, the supply voltage can be varied from 1.5 VDC to 3.5 VDC. At a voltage value of 2.0 VDC, the oscillator produces an output signal of 10.3 dBm. No spurious modes could be detected. Although the oscillator of this

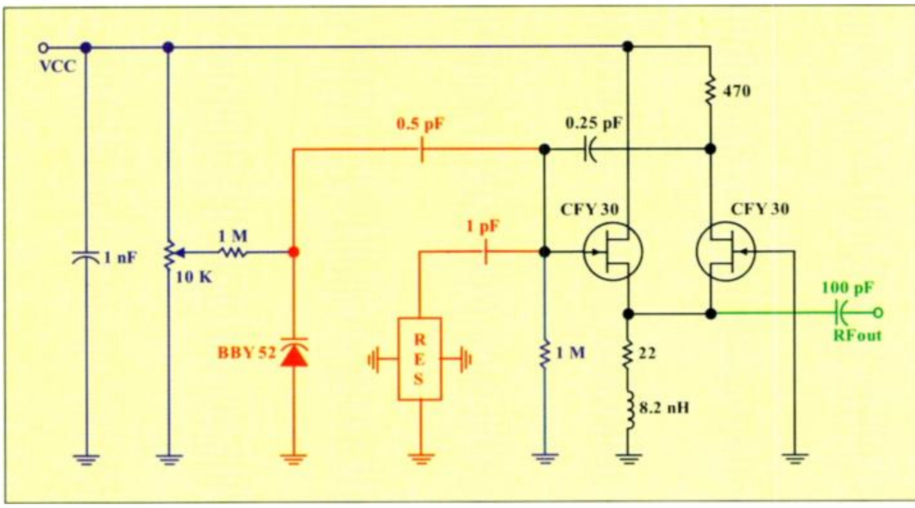

Figure 4. The microwave VCO circuit using a coaxial ceramic resonator.

test circuit is primarily intended to serve as a VCO in a low-voltage, small-band PLL circuit, it can operate as a stand-alone emitter supplied by a 1.5 VDC button cell. Modulation via the tuning voltage is also possible.

The 230 MHz oscillator

For the sake of completion, a 230 MHz VCO was also built. A 68 nH resonant circuit coil is shunt by two series 2.2 pF feedback capacitors and 5.6 pF shunt capacitor. A varactor diode is connected to the resonant circuit coil via a 6.8 pF capacitor. Coil L_2 is bridged in this circuit. As before, the supply voltage can be varied from 1.5 VDC to 3.5 VDC. At a voltage of 2.0 VDC, the oscillator produces an output signal of 9.8 dBm. No spurious modes could be detected. This oscillator also works well, having only a slightly larger frequency drift due to thermal influence.

The 430 MHz oscillator

A number of VCOs were built for the frequency range of 400 MHz to 460 MHz. The best results are obtained with the element values given in Table 1. The resonant circuit coil has a value of 33 nH. The varactor diode is connected via a 3.3 pF capacitor to the resonant circuit coil. The 2.2 pF shunt capacitor and the 1.0 pF feedback capacitor form an additional parallel capacitance of about 0.7 pF. Coil L_2 is still not necessary at this frequency.

The supply voltage was varied from 0.7 VDC to 4.5 VDC. The oscillator starts generating an RF signal at a supply voltage of about 0.7 VDC. At 1.0 VDC, there is already an output signal of typically 0 dBm. At a voltage value of 2.0 VDC, the oscillator requires a supply current of 26.5 mA and produces an output signal of 10.7 dBm. To further explore the limits of the circuit under test, the supply voltage is boosted up to 4.5 VDC. At this voltage, the oscillator requires a supply current of 42 mA and the output signal exceeds 16 dBm. This oscillator's frequency can be varied between 408 MHz and 457 MHz.

Some thermal problems were observed at this high value of supply voltage. Both transistors were soldered on the printed circuit board without any heat sinks. Without such heat sinks, thermal heating caused a significant frequency drift and a reduction of output power. To avoid overheating and operate in the stable area circuit, a maximum supply voltage of 3.0 VDC is recommended.

This design precipitates some interfering spurious modes with supply voltages between 1.5 VDC to 2.8 VDC. Therefore, the shunt capacitor is required to reduce the amplitude of the spurious modes and should not be omitted.

The 870 MHz oscillator

The next VCO was built for the frequency range of 860 MHz to 880 MHz. In this design, the resonant circuit coil has a value of 10 nH. The varactor diode is connected via a 2.7 pF capacitor to the coil. A shunt capacitor is not required for this frequency. For the feedback capacitor, a 0.5 pF feedback (C_F) is used. Coil L_2's position is bridged and not used.

At the voltage level of 2.0 VDC, the oscillator produces an output signal of 10.1 dBm. No spurious modes could be detected. This oscillator also is stable, but a significant frequency drift due to thermal influence is noted.

The 920 MHz oscillator

As can be seen from Table 1, the only difference between the circuit element values of both the 870 MHz and the 920 MHz oscillator is the value of the capacitor connecting the varactor diode to the resonant circuit coil. A capacitance value of 1.8 pF is used instead of 2.7 pF. The supply voltage can be varied from 1.0 VDC to 3.0 VDC. At a voltage value of 2.0 VDC, the oscillator produces an output signal of 9.9 dBm. No spurious modes could be detected.

The 2.45 GHz oscillator

Some VCOs were built around a center frequency of about 2.45 GHz. The element values for the best results are given in Table 1. The resonant circuit coil consists of a series connection of two coils. L_1 has a value of 2.7 nH and L_2 has a value of 4.7 nH. Both coils form a single tapped coil in the resonant circuit. For the microwave oscillators, the high-frequency SMD inductors were used because of the increased Q. The varactor diode is connected via a 3.3 pF capacitor to the tapped resonant circuit coil. The 0.25 pF feedback capacitor is created by two series capacitors with a value of 0.5 pF each. The supply voltage can be varied from 1.0 VDC to 4.0 VDC. At a voltage of 2.5 VDC the oscillator has a tuning range of about 50 MHz and produces an output signal of 6.7 dBm. No spurious modes could be detected. As with previous models, a frequency drift exists due to thermal influence. Additionally, the phase noise at this frequency range does not allow small- band applications.

The 3.2 GHz oscillator

To explore the SMD limits of this type of VCO, an oscillator was built for the 3.2 GHz region on common FR4 substrate. Some difficulties arose because only specific discrete element values were available for SMD elements. In this case, the parasitics could not be neglected. Even the SMD pads parasitic capacitances to ground had to be taken into account. A tapped resonant coil was used consisting of two coils. Coil L_1 has a value of 1.35 nH and coil L_2 has a value of 2.7 nH. To obtain the 1.35 nH value, two 2.7 nH coils were connected in parallel. A 2.2 pF capacitor is connected in series to the varactor diode as well as a 0.25 pF feedback capacitor. The 0.25 pF feedback capacitor is built by serially connecting two 0.5 pF capacitors.

The supply voltage can be varied from 1.0 VDC to 4.0 VDC without any electrical problems. At a voltage value of 3.0 V, the oscillator produces an out-

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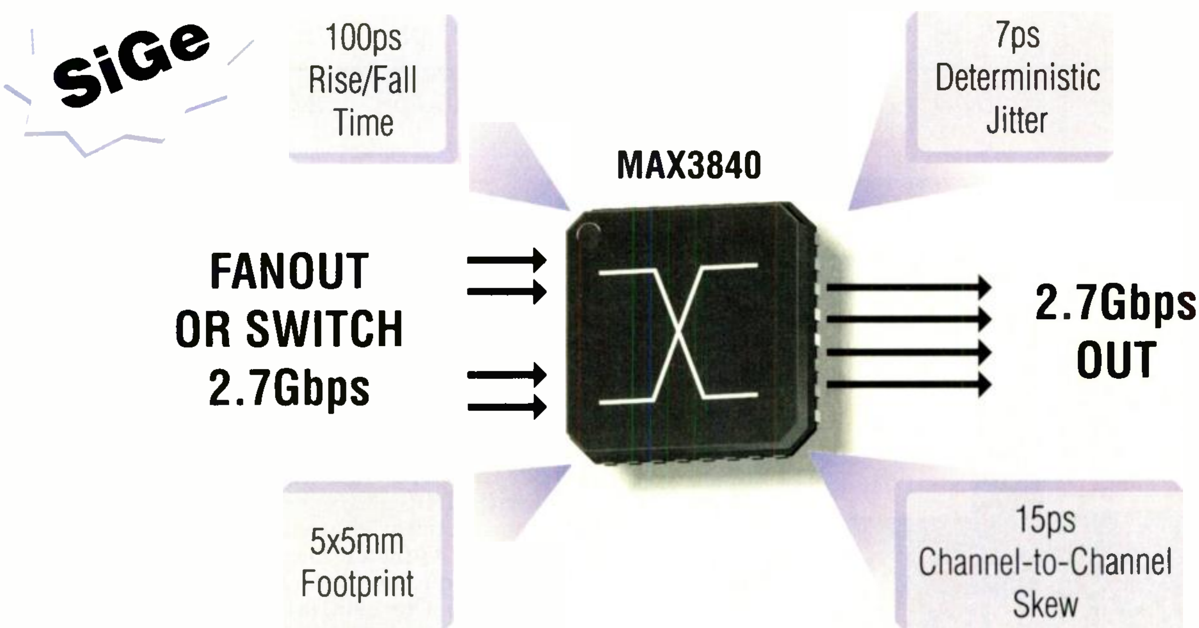

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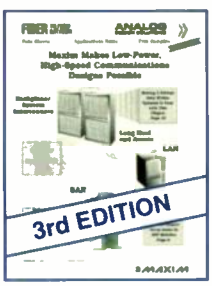

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Freq.	C	L_1	L_2	L_S	C_F	C_D	V_{cc}	P_{out}
3.2 GHz	2.2 pF	1.35 nH	2.7 nH	8.2 nH	0.25 pF	n/a	3.0 VDC	6.4 dBm
2.45 GHz	3.3 pF	2.7 nH	4.7 nH	8.2 nH	0.25 pF	n/a	2.5 VDC	6.7 dbM
920 MHz	1.8 pF	10 nH	n/a	18 nH	0.5 pF	n/a	2.0 VDC	9.9 dBm
870 MHz	2.7 pF	10 nH	n/a	18 nH	0.5 pF	n/a	2.0 VDC	10.1 dBm
430 MHz	3.3 pF	33 nH	n/a	39 nH	1.0 pF	2.2 pF	2.0 VDC	10.7 dBm
230 MHz	6.8 pF	68 nH	n/a	68 nH	2.2 pF	5.6 pF	2.0 VDC	9.8 dBm
145 MHz	12 pF	136 nH	n/a	136 nH	4.7 pF	10 pF	2.0 VDC	10.3 dBm
50 MHz	56 pF	470 nH	n/a	470 nH	22 pF	47 pF	2.0 VDC	10.0 dBm
20 MHz	82 pF	940 nH	n/a	940 nH	56 pF	100 pF	2.0 VDC	8.7 dBm

Table 1. Typical element values for the specific frequency bands.

modes could be detected. This frequency range seems to be the upper limit of the test circuit. For higher frequencies, the topology of the oscillator circuit must be improved.

Improving phase noise and stability

The only frequency-determining circuit of the oscillator is the resonant circuit at the gate electrode of the first transistor (T_1). Due to the losses of SMD elements, and of the transistor itself (both rise with increasing frequency), the circuit quality is too small to ensure a low frequency drift at frequencies above 1.5 GHz. To improve the electrical characteristics at microwave frequencies, a high Q-factor coaxial ceramic resonator was used as the frequency-determining element. A slight modification to the oscillator circuit leads to good results. The modified circuit of a 2.45 GHz oscillator is shown in Figure 4. The coaxial ceramic resonator does not exceed the dimensions 3 mm x 3 mm x 6 mm and has an intrinsic resonant frequency of 2.9 GHz. It is coupled via a capacitor with a relative high value of 1 pF, to the gate of the first transistor. This capacitor is necessary to pretune the frequency range of the oscillator, but disables the proper biasing of the first transistor. Therefore, an additional 1 MΩ resistor has to be connected from this gate to ground.

A capacitively coupled varactor diode is used to tune the frequency of the generated signal. The value of the coupling capacitor is 0.5 pF. This value is too high. Other values were not available during the test. Thus, the varactor diode is not coupled straight to the coaxial ceramic resonator[5], but is coupled, in parallel, to the input capacitance of the first transistor. This ensures the intended tuning range and does not further impair the loaded Q of the coaxial ceramic resonator. The phase noise of the improved oscillator is small enough to allow frequency shift keying (FSK) with a 50 kHz frequency nc346 series

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NC5115	50 GHz – 75 GHz	WR-15
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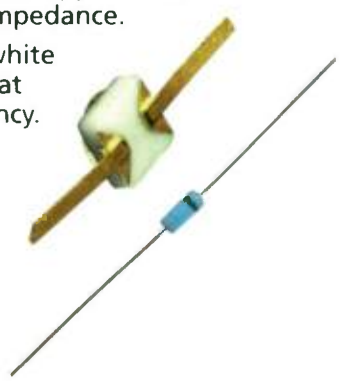

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NC401	100 MHz – 18 GHz
NC406C	18 GHz – 110 GHz

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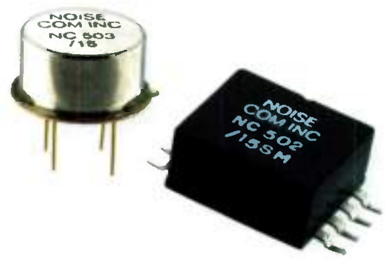

NC500 SERIES Standard Models		
MODEL	FREQUENCY RANGE	OUTPUT ENR
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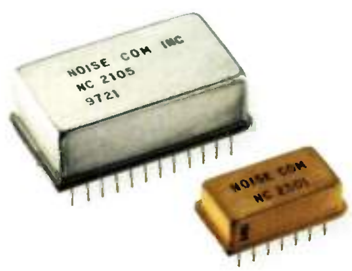
NC503/15	0.2 MHz – 2 GHz	31 dB
NC506/15	0.2 MHz – 5 GHz	31 dB
NC513/15	0.2 MHz – 2 GHz	51 dB

Broadband Amplified Noise Modules

- Designed for circuit board mounting.
- Provide a high-level noise output.
- Available in 24- and 14-pin packages.

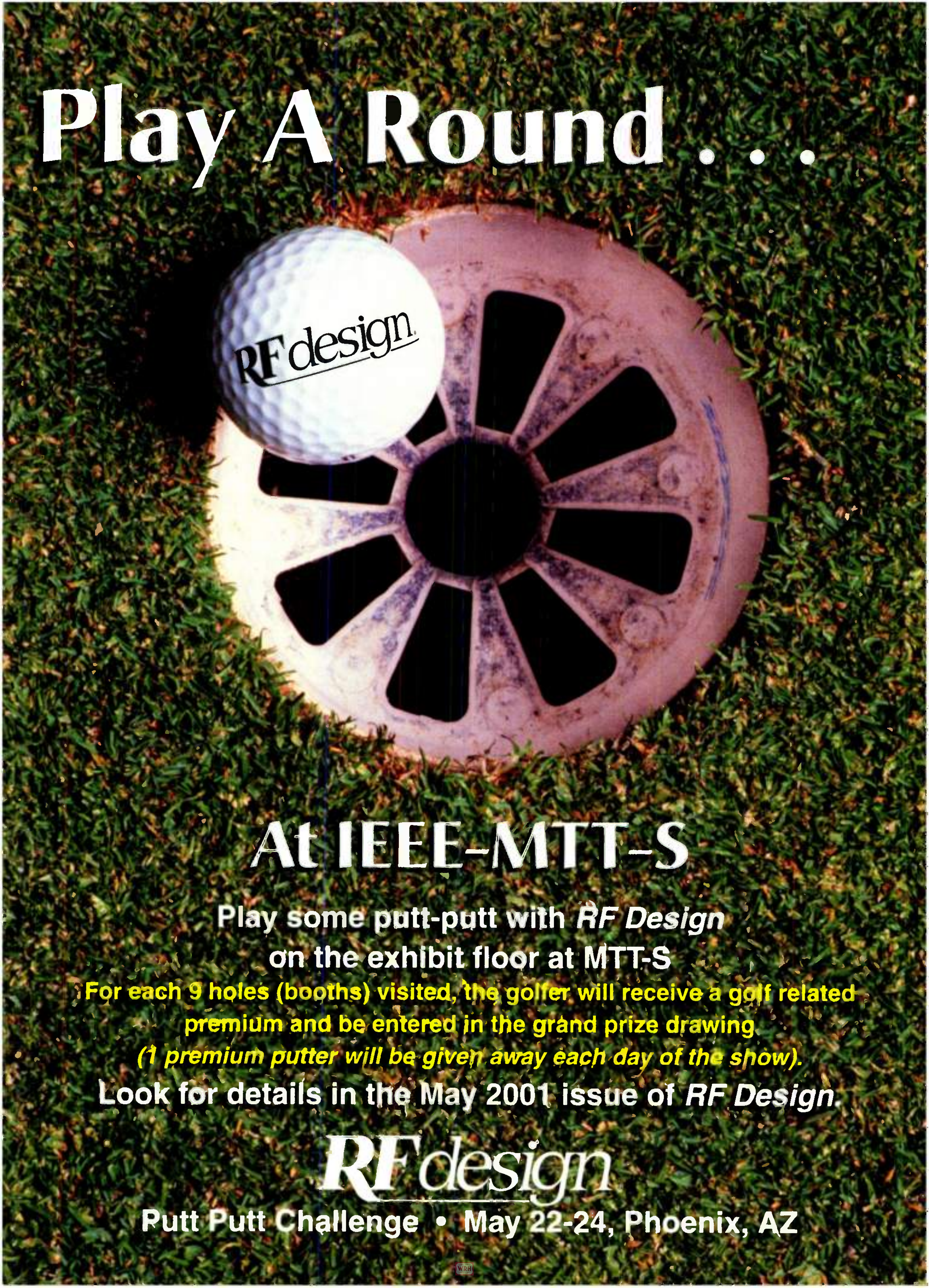


NC2000 SERIES Standard Models		
MODEL	FREQUENCY RANGE	OUTPUT
NC2101	100 Hz – 20 kHz	0.15 Vrms
NC2105	500 Hz – 10 MHz	0.15 Vrms
NC2201	1 MHz – 100 MHz	+5 dBm
NC2601	1 MHz – 2 GHz	-5 dBm

Broadband Noise Generators

- Designed for easy operation.
- Feature dedicated control and programming keys; large 4 x 20 LCD display.
- Output power control, filter setting, and attenuator step size for noise and signal performed from front panel, or remotely using IEEE-488 interface.

UFX7000 SERIES Standard Models		
MODEL	FREQUENCY RANGE	OUTPUT POWER
UFX7107	100 Hz – 100 MHz	+13 dBm
UFX7108	100 Hz – 500 MHz	+10 dBm
UFX7112	1 MHz – 2 GHz	+0 dBm
UFX7218	2 GHz – 18 GHz	-20 dBm
UFX7911	5 MHz – 1 GHz	+30 dBm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RF design
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Play some putt-putt with RF Design
on the exhibit floor at MTT-S
For each 9 holes (booths) visited, the golfer will receive a golf related premium and be entered in the grand prize drawing
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Look for details in the May 2001 issue of RF Design.
RF design
Putt Putt Challenge • May 22-24, Phoenix, AZ

lator is 2.8 dBm at a supply voltage of 2.0 V.

Conclusion

An easily designed oscillator principle has been employed in the design of direct frequency VCOs. The use of common SMD components is investigated for a number of frequency ranges. The oscillator is primarily intended to serve as a VCO in low-voltage, small-band PLL circuits. In this application, the exact frequency will be tuned by the PLL circuit. Therefore, a raw estimate of the resonant frequency can be determined by a single formula. These experiments suggest that a consistent oscillator design principle can simplify a number of RF design problems.

RF

About the authors

Bettina Koster is a research engineer at the Allgemeine und Theoretische Elektrotechnik (ATE), Bismarckstrasse 81, Duisburg University, D-47048 Duisburg, Germany and currently working towards the Dr. Ing. degree. She can be reached by e-mail at *bettina.koster@uni-duisburg.de* or by telephone at +49 (0) 203 379 2812.

Dr. Peter Waldow is president of the Institute of Mobile and Satellite Telecommunication (IMST), D-47475 Kamp-Lintfort, Germany. He is currently on leave to Duisburg University as head of ATE. He can be reached by e-mail at *waldow@uni-duisburg.de*.

Dr. Ingo Wolff is founder of the ATE and president of the IMST. Presently he is rector of Duisburg University. He can be reached by e-mail at *i.wolff@uni-duisburg.de*

The authors would like to thank Murata for providing samples of coaxial ceramic resonators. We also wish to thank Rutronik Elektronische Bauelemente GmbH for providing samples of high frequency, SMD inductors of the TDK NLU Series for use in this experiement.

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3G IS HERE!
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The program manager gets a complete view of the project at hand, including the immediate effects of changes.
The DSP designer gets bit-true simulation and a direct path to TI C5x/C6x DSP implementation.
The systems architect can build his working simulation with easy to use functional blocks—then hand off to DSP and RF designers.
The RF designer can design with distortion-true system blocks, then move directly to Xpedion simulation tools.
INFO/CARD 62

On The Web

PCB design guide available on Web

Trompeter Electronics' new *Printed Circuit Board Design Guide* offers tutorial-style information on RF signals and how to manage them, along with a selection of coax connector products for effective transport of high-frequency signals on and off a PCB. The guide is available for direct download at the company's Web site.
Trompeter Electronics
INFO/CARD 115

Site resource for communications test

Anritsu's new Web site is a resource for engineers looking for communications test solutions and optical and microwave components and devices. The site also provides information on the company's other product lines, including network solutions and industrial automation. Engineers working on data communications, fiber optic, microwave/RF, telecommunications, and wireless systems will find detailed specifications on test and measurement products. Among those detailed are BERTS, cable and antenna analyzers, VNAs, fault management systems, power meters, and radio communications analyzers. Also listed on the Web site is Anritsu's line of components and devices.
Anritsu
INFO/CARD 116

Catalog offers broad line of rectangular connectors

Harting's latest release, *The Heavy Duty Han Connector Catalog*, is a source for signal and power connection solutions in robotics, metal forming, plastics, semiconductor, telecommunications, automotive, rail, pulp and paper, textile and other industries. The catalog has an easy-to-read format for selection of industry-standard multi-pin connectors and offers an extensive line of rectangular connector technology.
Harting
INFO/CARD 117

Brochure highlights product capabilities

A new brochure highlighting the product capabilities of Tyco Electronics is now available. The 26-page brochure reviews the products available from Tyco Electronics and describes the industries the company serves. Each page of the brochure is dedicated to the products suitable for a specific industry. Other product-centric pages are dedicated to interconnection systems, application tooling, terminal blocks, printed circuit boards, circuit protection, relays, switches, electronic modules, fiber optics, wireless products, battery packs, wire harnessing protection, wire and cable products and touchscreens. A directory of worldwide Tyco Electronics phone numbers is also included.
Tyco Electronics
INFO/CARD 118

Third-party handbook features support vendors

Microchip Technology's *Third Party Guide* features third-party development support suppliers for Microchip's PICmicro family of RISC microcontrollers, serial EEPROMS and microperipheral products. The 2001 edition features more than 110 companies worldwide who manufacture accessories, assemblers, compilers, real-time operating systems, emulators, linkers, programmers, simulators and software that directly support Microchip's PICmicro microcontrollers and memory products. The guide features a cross-reference matrix that provides the selection of third-party tools and the Microchip products they support, and also provides third-party location information.
Microchip Technology
INFO/CARD 119

Coaxial connector catalog provides specification data

The Microwave Coaxial Connector Catalog, from Dynawave, provides specification data for electrical, mechanical and environmental parameters, along with material and finish information for the connector body, spring, center contact, insulator and O' Ring. Detailed schematics are provided for the connectors, jacks, plugs, adapters, interconnects, and accessories. The catalog also includes an index that cross-references part numbers to the page they appear on. Products listed in the catalog include the Dynamate Blind-Mate connector, Dynacon interconnects and Dynaseal cable assemblies for MIC component packaging.
Dynawave
INFO/CARD 120

Broadband brochure features DC blocking

Dielectric Laboratories announces its new *Ultra Broadband DC Blocking Capacitor* brochure. Featured in this brochure are the Opti-Cap and Milli-Cap broadband solutions, as well as 0603- and 0805-size broadband DC blocks. The Opti-Cap takes advantage of Milli-Cap characteristics such as the 0502 footprint, high Q, very low series inductance and combines it with high value capacitance for coverage from DC to light (12 KHz to 40+ GHz). While the DC blocking capabilities are the key feature, the overall size of .055" 2 with an 0502 footprint, combined with single step assembly makes this useful for fiber optic applications such as OC-192 and OC-768. The Opti-Cap is designed for conductive epoxy attachment to the board. The Milli-Cap provides broadband width resonance-free performance with low loss and high series resonance. This product covers the bands applicable to digital radios, LMDS, SONET, filters and test equipment. The technology uses single layer capacitors in a surface mount package that allows for coverage in frequencies of 20 MHz to 40+ GHz depending on product selected.
Dielectric Laboratories
INFO/CARD 121

Create component catalogs for electronic exchange

Parts Planner 2000, from Wireless Valley Communications, is a utility for creating, maintaining, and distributing electronic catalogs of RF distribution system components and their characteristics within SitePlanner 2000 and on the Web. Parts Planner makes it possible to create a comprehensive catalog of components that can be exchanged and viewed electronically. Wireless communication systems designers can import catalogs into SitePlanner 2000 and use components directly in RF designs. Features of the software include: vendor parts lists in shipping version of SitePlanner 2000 for one year; capability to fully model any type of RF distribution component; an easy interface; performance simulation; support for RF, optical, baseband and other media; and XML file format.

Wireless Valley Communications
INFO/CARD 122

New .DXF CAD import modules

Remcom has just released its new 3D solids and layered CAD import modules for importing Autocad .DXF files and .SAT solid objects into its XFDTD electromagnetics software. Complicated objects described either as 3D solids or layers can be imported into XFDTD and automatically meshed. The Layered CAD import module allows extrusion so 2.5D objects can be imported, while the 3D Solids Importer meshes any collection of 3D solids. By eliminating the need to draw objects in XFDTD, this capability will enable end-users working with CAD software to use XFDTD more efficiently and save substantial time.

Remcom
INFO/CARD 123

Programs offer frequency conversion analysis

R.A. Wood Associates announces updates to two RF design products: SpurFinder 2.1 and TunerHelper 1.1.4. Both programs offer capability to analyze a frequency conversion process for either a receiver or transmitter. The programs work for down conversions and up conversions. SpurFinder helps a designer evaluate various frequency conversion schemes. The program draws a mixer spur chart, showing the output frequencies of all mixer-spurious products for a given range of input frequencies. The latest version includes the new Slider Bar, which lets the user slide a cursor across the input frequency range, and a table displays the output mixer spurious products and their frequencies in real time. Tuner Helper allows the designer to analyze in detail a specific mixer conversion scheme. The user can determine and specify input pre-selection filter requirements, mixer spurious and leakage requirements, and output post selection filter requirements.

R.A. Wood Associates
INFO/CARD 124

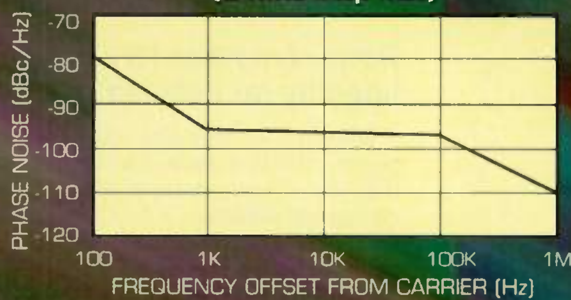
LOW COST FAST SWITCHING SYNTHESIZERS

- **Operating Bands From 1 – 15 GHz**
- **Ideal for Wireless Applications**

OPTIONS

- 12 Volt Operation
- Optimized Bandwidth/Tuning Speed Combination

TYPICAL PHASE NOISE AT 2 GHz (2 MHz Step Size)



SPECIFICATIONS

MODEL	SLS SERIES
Frequency	1–15 GHz
Frequency step size	200 kHz to 10 MHz
Tuning range	Up to half octave
Switching speed	500 µs*
Output power	10 dBm min.
Output power variation	±2 dB min.
In band spurs	70 dBc min.
Harmonics	20 dBc
Phase noise	See graph
Reference	Internal or external
External reference Frequency Input power	 5/10 MHz 3 dBm ±3 dB
Frequency control	BCD or binary
DC power requirement	+15 or +12 volts, 200 mA 5.2 volts, 500 mA
Operating temperature	-10 to +60°C
Size	5" x 6.5" x 0.6"

* Acquire time depends on step size (low as 25 µs).

3 YEAR WARRANTY

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INFO/CARD 50

WRH

MTT-S Product Preview

A look ahead to the newest products to be presented at MTT-S.

GPRS power amplifier module meets Class 12 profile

The ECM007, from EiC, is a fully matched dual-band GSM/DCS1800 power amplifier module that meets or exceeds the demanding GPRS Class 12 operating profile. This power amplifier module is designed using EiC's proprietary InGaP HBT process and, together with a low thermal resistance IC design, allows for GRPS Class 12 performance that requires up to a 50% duty cycle operation. The ECM007 provides a minimum output power of 34.5 dBm in Class IV GSM operation and provides band select and analog power control features.

EiC
INFO/CARD 125
Booth # 315

Power amplifier RFICs deliver linearity for cellular/PCS/3G

Stanford Microdevices introduces its SPA Series of power amplifier radio-frequency integrated circuits (RFICs). These products offer cellular, PCS and 3G equipment designers a new in a single integrated circuit. The amplifiers are intended for the most demanding wireless network system requirements. These devices cover the 850 MHz, 1950 MHz and 2150 MHz frequency bands and serve as driver amplifiers for base station and repeater applications. Housed in standard surface-mount SOIC8 plastic packages with backside metallization, the amplifiers provide the exceptional linearity demanded by advanced network modulation standards.

Stanford Microdevices
INFO/CARD 126
Booth #445

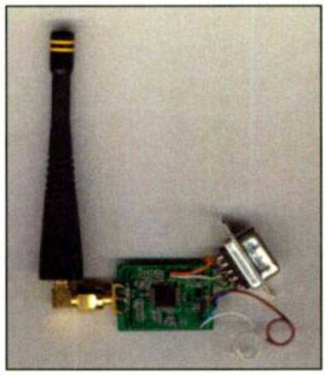
Low-profile xtals encapsulated in an SMD quartz envelope

Interquip's new line of miniature crystals utilized technonolgy that encapsulates the quartz crystal resonator element in an SMD envelope. This technology allows quartz crystals from 3.58 to 80 MHz to achieve a height profile of 1.0 mm or less.

Interquip
INFO/CARD 175

FM/FSK transmitter IC operates in 26 MHz band

The NT2800 is a complete, fully integrated, single-chip, FM/FSK transmitter IC that will operate in any 26 MHz band from 800 – 1000 MHz, on a 2.7 to 3.3 VDC supply. The device integrates on an on-chip VCO, phase-locked loop, and reference oscillator. The NT2800 accepts either analog or data as input to the modulator (direct modulation). Tuning is accomplished via a three-wire serial interface. Power output is +1.5 dBm. Packaging is a 16-pin QSOP.



Numa Technologies
INFO/CARD 127

ATE systems for wireless RFIC provide new test choices

Credence System's RFx is a mixed-signal test system for cost-sensitive, high-volume production testing of RF/wireless devices for low cost-of-ownership. This full mixed signal system design provides test engineers new technology test choices for comprehensive RF device testing. The RFx is designed specifically for testing devices used in wireless, cellular, and personal communications.

Credence Systems
INFO/CARD 128
Booth #245

Stock invar waveguide for RF filters

H. Rollet maintains a stock of copper, bronze, invar and aluminum waveguides at its new distribution base in New Hampshire, and through its California distributor A-Alpha Waveguide. In copper, bronze and aluminum, the sizes covered range from WR22 through WR650, while invar is held in the common sizes for RF Filters WR28, WR42, WR51, WR62, WR75, WR90,WR112, WR137 & WR159. Non-standard waveguides are available from H. Rollet in the UK.

H. Rollet
INFO/CARD 129
Booth # 2215

Avnet and Philips:
PeRFect Partners

Completing its line-up of RF discrete semiconductors, Philips introduces for the first time a new range of PIN diodes developed for use as RF switches and attenuators. Targeted for a variety of RF wireless designs, including phone and satellite applications, the new devices feature high isolation between a phone's transmitter and receiver, low insertion loss and low distortion, enabling designers to create smaller, lighter and lower-cost mobile products.

PHILIPS

With the addition of PIN diodes to their RF discrete portfolio, Philips now offers a one-stop shop for RF devices, including power-amplifier modules, RF MMICs, varicap diodes and RF wideband transistors.

Avnet complements Philips' technology with a dedicated business group for RF & Microwave products and wireless field and design expertise cultivated through 25 years of assisting customers at every stage of the design cycle.

To request a free PIN diodes Designer's Sample Kit containing a selection of new RF PIN diodes, a CD ROM diskette with datasheets, application notes, and S-parameters, please visit: **www.em.avnet.com/rfm/pindiodes.html** or call **1-800-261-9602, ext. 352.**

PIN Diodes

TYPE	Case	Config.	Limits		Rd (W)typ		Cd (pF)typ	
			V_R(V)	I_F(mA)	@.5mA	@10mA	@0V	@20v
BAP50-03	SOD323	Single	50	50	25	3	0.45	0.3@5V
BAP50-04	SOT23	Series	50	50	25	3	0.45	0.3@5V
BAP50-05	SOT23	CC	50	50	25	3	0.45	0.3@5V
BAP64-02	SOD523	Single	200	100	20	2	0.52	0.23
BAP64-03	SOD323	Single	200	100	20	2	0.52	0.23
BAP64-04	SOT23	Series	200	100	20	2	0.52	0.23
BAP64-04W	SOT323	Series	200	100	20	2	0.52	0.23
BAP64-05	SOT23	CC	200	100	20	2	0.52	0.23
BAP64-05W	SOT323	CC	200	100	20	2	0.52	0.23
BAP64-06	SOT23	CA	200	100	20	2	0.52	0.23
BAP51-02	SOD523	Single	60	60	5.5	1.5	0.4	0.2@5V
BAP51-03	SOD323	Single	60	60	5.5	1.5	0.4	0.2@5V
BAP51-05W	SOT323	CC	60	60	5.5	1.5	0.4	0.2@5V
BAP65-02	SOD523	Single	30	100	-	0.56	0.65	0.375
BAP65-03	SOD323	Single	30	100	-	0.56	0.65	0.375

Types in bold are included in this kit.

AVNET®
electronics marketing

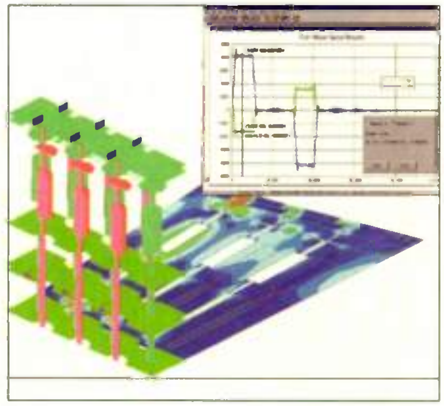
240 W high-power GaAs FET for L-band applications

A new high-power GaAs FET with an output of 240 W for use in the 2.1 to 2.2 GHz frequency range is available from Fujitsu Compound Semiconductor. The FLL2400IU-2C employs a push-pull design that offers ease of matching, greater consistency, and a broader bandwidth for high-power amplifiers. This product is used for solid-state, base-station, power amplifiers for W-CDMA and IMT 2000 communications systems applications. The device uses an enhanced GaAs power field-effect transistor process that uses a gold gate (Au) metallization process.

Fujitsu Compound Semiconductor
INFO/CARD 130
Booth # 1224

Full-wave spice attacks high-speed digital

Ansoft announces version 8.0 of the Ansoft High-Frequency Structure Simulator (Ansoft HFSS). HFSS is a full-wave finite element electromagnetic (EM) simulator that enables engineers to design three-dimensional (3D) high-frequency structures such as connectors, IC packages, and antennas found in cellular telephones, broadband communications systems, and microwave circuits.



Ansoft
INFO/CARD 131
Booth # 1521

Power meter for accurate CW measurement

Krytar's new RF/microwave power meter was developed specifically for engineers needing to accurately measure CW or swept RF and microwave power in the field or in the lab. Auto-ranging linearity is ±0.05 db. Accurate CW power measurement range is –30 to +20 dBm (useable to –39 dBm). The unit provides a DC output voltage of –3.9 to +2.0 volts, which is equivalent to power input of –39 to +20

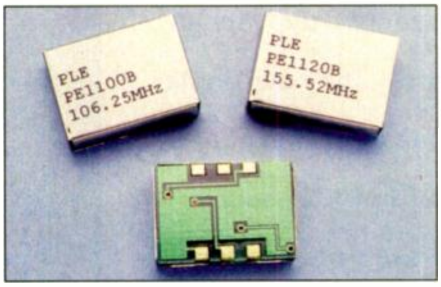
dBm (allows low-cost swept scalar measurements). Optional RS232 serial port or IEEE-488 interface bus is available.
Krytar
INFO/CARD 132
Booth # 517

MC-card connectors for use in cellular devices

RF Connectors has added two new special application connectors to its line of subminiature coaxial connectors. Designed for use in cellular devices where board and chassis space is limited, these right-angle connectors mate with PCB and card-mounted jacks. The RMC-610-A connector is available for RG-178/U and the RMC-6010-B is designed for use with RG-174/U, RG-188/U and RG-316/U cables. Bodies are of nickel-plated, machined brass, and contacts are gold-plated BeCu. The insulation is teflon.
RF Connectors
INFO/CARD 133
Booth # 3011

PECL oscillators with differential output

Pletronics announces a line of differential PECL output oscillators.



Available frequencies are from 10.0 MHz to 170.0 MHz. The PE1100BV series offers a true crystal design for ultra low jitter (3pS RMS maximum for >70.0 MHz). The parts have an input voltage (Vcc) of 3.3 volts ±50 PPM over the operating temperature range of 0 – 80°C. The packaging is an industry standard footprint six-pad layout.
Pletronics
INFO/CARD 134
Booth # 3620

Distortion measurement test set offers broad applications

L-3 Communications' Celerity Systems division introduces the CS29010 integrated distortion measurement test set. The set has broad applications for a variety of wide-band, complex, mixed-signal design and development for components, sub-systems and systems, all in a single box. The system is suitable for the test and measurement requirements of cellular, PCS, satellite, LMDS, wireless data, and all communications or data link systems operating in complex multi-channel and multi-signal environments. This modular system features wide bandwidth (45 MHz @ 12 bits bandwidth) high performance arbitrary waveform generation, radio frequency up/down conversion and wideband recording capability with deep memory (4 GB RAM) all through a 600 Pentium III processor with a Windows NT operating system.
Celerity Systems
INFO/CARD 135
Booth # 3214

RF product of the month

TC2000 SoC

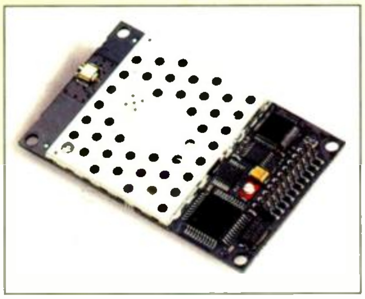
Zeevo's new system-on-a-chip (SoC) solution includes RF, analog, digital baseband, and memory functionality in one mixed-signal CMOS device. The TC2000 is designed to minimize required external components to provide a full system solution. The chip provides a platform that makes implementation easier for integrated Bluetooth silicon devices and technology. The device includes all hardware and software (stack profiles), offers a development environment and includes reference designs as well. The TC2000's features include high sensitivity (measured at the antenna, after the filter), excellent noise tolerance, a standard CPU, and all advanced Bluetooth features. Zeevo also provides a proprietary Turbo Mode that increases throughput two to four times. The TC2000 meets or exceeds Bluetooth small size and low power consumption requirements. Packaged in a low-temperature, co-fired ceramic (LTCC) package to control noise, the TC2000 has RF components (including filters and shield but excluding the antenna) integrated around the chip in the package. There is a single-pin RF interface so customers can mount it just like a regular component, effectively making it a "digital-looking" chip. The IP is re-usable and scalable across the fast-growing communications markets, providing longevity and obsolescence-proof products. Its technical features include a frequency range of 2.4 - 2.4835 GHz for ISM band applications: personal computers, PDA, PC accessories, LAN access points, printers, gaming devices. It is built on a 0.18um CMOS process and includes all necessary RF, CPU, and radio subsystems.

Zeevo
INFO/CARD 136

RF, analog, baseband, and memory functionality in one mixed-signal CMOS device

2.4 GHz spread spectrum transceiver

AeroComm announces the release of a line of LX 2.4 GHz frequency-hopping spread spectrum (FHSS) transceivers. LX transceivers are agency-approved, ready-to-use modules designed for rapid integration into larger volume OEM products. Five versions of transceivers and two repeater models are available. Manufacturers can choose short-range, low-power versions for battery-powered or piconet applications, and higher-power radios coupled with repeaters for miles of range. With RF data rates up to 244 Kb/s, and 3 mW for local uses (within 50 feet), it reaches 150mW for miles of longer range applications. LX transceivers are available with integral strip dipole antennas for applications not permitting external antennas. Radios with antenna connectors are also available for use with a variety of agency external antennas.



Aerocom
INFO/CARD 138

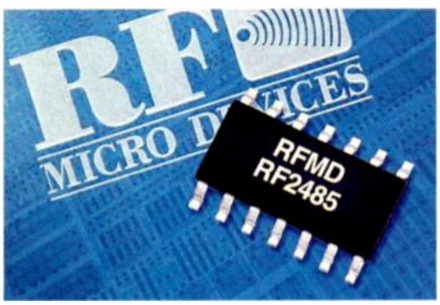
Multifunction RFIC

Hittite Microwave introduces a multifunction RFIC component, the HMC310MS8G. The device incorporates a power amplifier and low-noise amplifier with a transmit/receive switch. The device is designed for applications in the 2.4 GHz ISM band including HomeRF, Bluetooth, and low-power wireless local area network (WLAN) radios. It offers 14 dB of gain and +6 dBm P1dB in the transmit mode. Its 14 dB of gain is rated with an overall noise figure of 2.7 dB when in receive mode. This low-current, transceiver requires no external circuitry to operate the amplifier power down features and is available in the industry standard MSOP8G package.

Hittite Microwave
INFO/CARD 139

Five-watt attenuators for DC to 18 GHz

RF Micro Devices announces the RF2485 quadrature modulator for terrestrial trunked radio (TETRA) systems. Designed for TETRA use in the 200 to 600 MHz band, the RF2485 features a broadband noise floor of –149 dBm/Hz typical at 5 MHz offset along with ACPR of –48 dBc typical at 25 kHz. The device operates from a single 5VDC power supply and contains all of the required components to implement the modulation function. Included are differential amplifiers for the baseband inputs, a 90 degree hybrid phase splitter, limiting LO amplifiers, two balanced mixers, a combining amplifier and an output RF amplifier which will drive a 50Ω load.



Typical applications for the RF2485 include digital and spread spectrum systems; GMSK, QPSK, DQPSK and QAM modulation; private mobile radio and TETRA systems; AM, SSB, DSB modulation and image-reject up-converters.
RF Micro Devices
INFO/CARD 140

Ultra low current downconverter

M/A-COM announces a low-cost, highly linear IC downconverter for use in cellular band, CDMA handsets and other battery-operated RF systems. This device integrates a switched LNA, mixer, and several buffer amplifiers in a miniature 4 mm WLF package. The IC features an on-board LNA and bypass switch for gain control, a mixer with LO buffer and RF input amplifier, and single-ended and differential mixer output buffers. Based on enhancement-depletion gallium arsenide (ElD) MESFET technology, the IC draws lower current than typical SiGe ICs, which typically draw 25 mA or more. The small size, low cost, linearity, and low current draw make this IC a candidate for lightweight, battery-operated, handsets and portable systems. The MD59-0043 operates with an RF output frequency between 800 and 900 MHz. The device has a low noise figure, 2.3 dB, very low current draw, 20 mA (16 mA in low gain mode), a conversion gain of 28 dB, and an input IP3 of –10 dBm, typically. The device requires an LO signal of –6 dBm.
M/A-COM
INFO/CARD 141

EMI/RFI flexible conduit

The RF9600 is now available on the new MURS frequencies. These five VHF channels are available for use by almost anyone and no license is required. The Mt.JRS radio modem is capable of 9600 baud, has error correction, robust reliability, and comes pre-programmed with all

2W & 5W DC to 18GHz ATTENUATORS

from $29.95 ea. (1-49)

Rugged Stainless Steel Construction, High Repeatability, Miniature Size, Low Cost, and Off-The-Shelf Availability are some of the features that make Mini-Circuits "BW" family of precision fixed attenuators stand above the crowd! This extremely broad band DC to 18GHz series is available in 5 watt Type-N and 2&5 watt SMA coaxial designs, each containing 15 models with nominal attenuation values from 1 to 40dB. Built tough to handle 125 watts maximum peak power, these high performance attenuators exhibit excellent temperature stability, 1.15:1 VSWR typical, and cover a wealth of applications including impedance matching, reducing power levels when testing higher power amplifiers, wide band matching during intermodulation measurements, and providing a 2W or 5W termination load for power amplifiers. Call Mini-Circuits today and capture this next generation of performance and value!

Mini-Circuits...we're redefining what VALUE is all about!

MODELS (Add Prefix BW-)

2W SMA	5W SMA	5W Type-N	Attenuation (dB) Nominal	Accuracy*
$29.95	$44.95	$54.95		
S1W2	S1W5	N1W5	1	±0.40
S2W2	S2W5	N2W5	2	±0.40
S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	±0.60
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	±0.60
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	±0.60
S30W2	S30W5	N30W5	30	±0.85
S40W2	S40W5	N40W5	40	±0.85

*At 25°C includes power and frequency variations up to 12.4GHz. Above 12.4GHz add 0.5dB typ. to accuracy.

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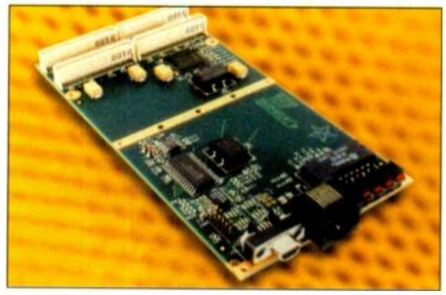
five frequencies. Each station may have its own ID code to ensure that it responds to commands. Units will work well with many commercial weather stations, as well as the less-expensive home variety. Neulink radio modems are available on VHF, UHF, and 2.4 GHz frequencies.
RF Neulink
INFO/CARD 142

Three-volt TX/RX RS-232 serial devices

Intersil introduces a new family of VDC RS-232 transmitters-receivers that operate as the serial interface port for such portable battery-operated appliances as cellular phones, digital cameras, personal digital assistants and palmtops. The JCL32xx RS-232 devices are five-driver, three-receiver transceivers that support data rates of 250 kbps, and are fully compatible with 3.3 VDC-only systems, mixed 3.3 VDC and 5.OVDC systems, and 5.O VDC-only systems. The new devices offer 15 kV electrostatic discharge (ESD) circuit protection to protect the exposed RS-232 pins from ESD damage. The 3V family of products requires 0.3 mA of supply current during normal operation. The devices feature manual, automatic and enhanced automatic power-down features that reduce standby supply current. These features can shut down the on-chip power supply and simultaneously disable the transmitter outputs that also result in a reduction of standby current. Automatic power-down function activates when an RS-232 cable is disconnected or when the peripheral driving the device powers down. The device powers up immediately after detecting a valid RS-232 level on any receiver input, such as when the cable is reconnected.
Intersil
INFO/CARD 143

PMC-based DSP I/O card

A high-performance, integrated PMC-based 110 card has been announced by Ixthos. The PMC ENET-1 card includes



integrated I/O and DSP hardware and software solutions for wireless digital radio/programmable software receivers, semiconductor fabrication and test equipment, sonar/imaging, telecommunications and networking, as well as high-speed serial interconnect fabric and networking. The card provides Ethernet and serial ports on a single PMC card for use in 3.3 VDC or 5.0 VDC PCI signaling environments. A flexible stacking option allows for another PMC module to be "piggybacked" onto the ENET-1 during development.
Ixthos
INFO/CARD 144

Economize.

At prices as low as 29¢ each*, Stanford Microdevices' affordable SGA series gain blocks present a cost-effective solution to designers with high-volume requirements in wireless data products and thousands of general-purpose applications up to 5 GHz.

SOT-363 Package

And, the SGA series' economy goes beyond price. The units' low-voltage operation and low DC current requirement make them ideal for today's vast range of wireless devices requiring power-efficient performance.

The broadband units also offer exceptional IP3 performance and superior linearity for the power consumed.

Part Number	Bandwidth (GHz)	Gain @ 1 GHz (dB)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	Noise Figure (dB)	Vd (V)	Id (mA)
Low Voltage Gain Blocks								
SGA-0163	DC-4.5	13	12	-2	+9	4.7	2.1	8
SGA-0363	DC-5.0	20	17	+2	+14	3.0	2.5	11
High Reverse Isolation Gain Blocks								
SGA-1163	DC-6.0	12	11	-3	+8	3.1	4.6	12
SGA-1263	DC-4.0	16	15	-8	+3	2.7	2.8	8
General Purpose Gain Blocks								
SGA-2163	DC-5.0	10	10	+7	+21	4.2	2.2	20
SGA-2263	DC-3.5	15	14	+8	+20	3.2	2.2	20
SGA-2363	DC-2.8	17	16	+8	+19	2.9	2.7	20
SGA-2463	DC-2.0	20	17	+9	+20	2.7	2.7	20

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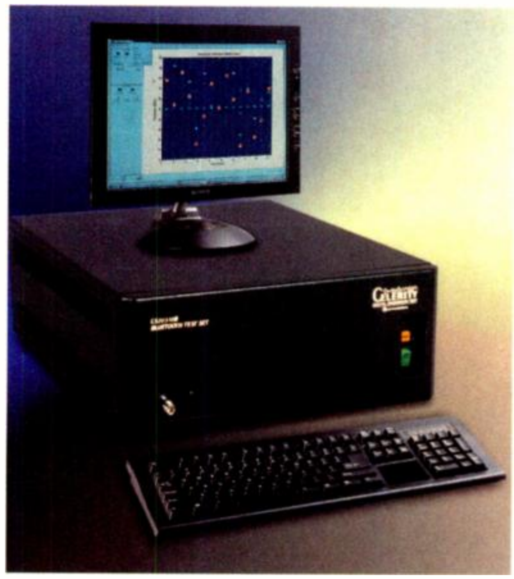
INFO/CARD 25

Multifunction, multi-platform Bluetooth RF Test Set

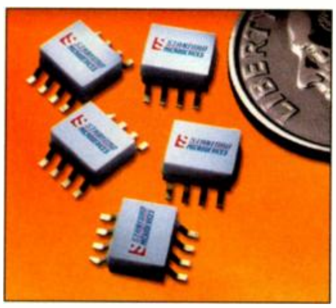


Celerity introduces the CS20310 Bluetooth RF Test Set. This test instrument records, analyzes and generates Bluetooth signals over full 83.5 MHz bandwidth. It is also capable of digitally generating up to 12,800 hops at 1,600 hops/sec in the 2.4 GHz band with full control of all RF parameters for receiver RF compliance testing. A broadband downconverter and high-performance 300 MS/s ADC captures all of the hops in time, preserving complete time, frequency, modulation, and transient information of the Bluetooth signals. High-speed digital analysis routines process the stored data, providing detailed RF parameter data essential for fully characterizing Bluetooth RF transmitters. In addition, each hop can be demodulated to provide the baseband data, allowing protocol analysis using third party protocol analyzer software The CS20310B utilizes a modular, open platform that allows easy upgrades for additional features such as deeper memory, additional recorder/generator channels, and wider bandwidths. The Windows NT environment can be integrated with popular simulation, analysis, and desktop publishing tools

Celerity Digital Broadband Test
INFO/CARD 158

Low-noise amplifier for 2G and 3G

Stanford Microdevices introduces the SLX-2043, a pHEMT-based low-noise amplifier module for 2G/3G wireless applications. The

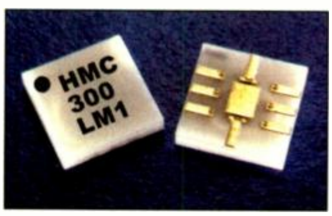


module is designed for amplification of W-CDMA, CDMA, GSM-EDGE/EGSM, and TDMA/TDMA-EDGE signals in base-station receiver applications from 1.7 GHz to 2.5 GHz. The device offers a typical noise figure of 1.1 dB, a typical output intercept of 34 dBm and 15 dB of gain. The LNA offers input and output matching without external matching components and is unconditionally stable. It operates from a single 4V supply.

Stanford Microdevices
INFO/CARD 159

SMT medium-power amplifier

The HMC300LM1 is a broadband SMT medium-power amplifier that operates between 25.5 and 33.5 GHz. A 0.25um power pHEMT process is used to achieve efficient gain and output power performance. High volume surface-mount re-flow assembly techniques may be used to mount the amplifier to the end user's PCB. The LM1 package eliminates the need for wire bonding or die attach mounting. The amplifier provides 15 dB of gain and +24 dBm of saturated output power across various microwave radio bands. This millimeter wave amplifier requires no external RF matching components and minimal DC bypass com-

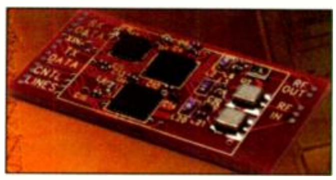


ponents. The amplifier operates from a +6 V Vdd and a –0.35 Vgg gate bias.

Hittite Microwave
INFO/CARD 160

Miniature GSM/GPRS transceiver

Silicon Labs introduces the Aero GSM transceiver chipset. The chipset provides a complete RF front end for dual- and triple-band GSM digital cellular handsets. The highly integrated three-chip

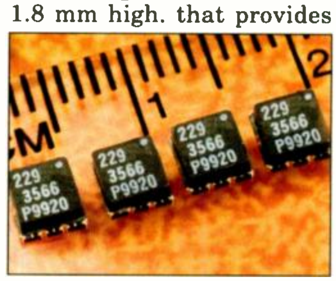


solution eliminates the IF SAW filter, external low noise amplifiers (LNA) for three bands, transmit and RF VCOs, and more than 60 other discrete components. The transceiver provides a universal analog baseband interface that is software-programmable and allows handset designers to implement the product with any supplier's baseband subsystem. The unit is also compliant with General Packet Radio Services' (GPRS) Class 12 requirements, supporting high data rate communication for Internet-enabled wireless terminals.

Silicon Laboratories
INFO/CARD 161

Miniature W-CDMA power amplifier

Celeritek announces a new W-CDMA power amplifier for wireless data transmission at 3.5 Ghz. The part is manufactured in a miniature, 4mm square, leadless chip carrier package. The CMM3566-LC is a linear power amplifier intended for use in subscriber units and base stations that operate in the 3.45 to 3.50 GHz frequency range. Typical features include operation at 7.0 VDC, 30 dB gain at operating output, +24 dBm linear output power (W-CDMA). The device is packaged in an LCC-8 package measuring 4 mm x 4 mm x 1.8 mm high. that provides



excellent electrical stability. The device requires minimal external circuitry for bias and matching.

Celeritek
INFO/CARD 162

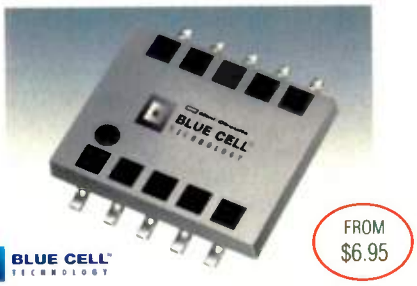
NEW PRODUCTS

NO. 80

RF/IF MICROWAVE COMPONENTS

2 TO 1100MHz RF TRANSFORMER FOR IMPEDANCE MATCHING

Designed for impedance matching applications, Mini-Circuits low cost TC4-11 RF transformer provides 4:1 impedance ratio (50 ohms primary, 12.5 ohms secondary) in the broad 2 to 1100MHz band. Referenced to midband loss, users can expect 1dB insertion loss in the 5 to 700MHz range and 2dB loss bandwide. This leadless surface mount transformer is housed in an open style aqueous washable package with ceramic base. Absolute maximum RF input power is 0.25W.



BLUE CELL TECHNOLOGY

1900 TO 2400MHz 90° HYBRID IS ULTRA-THIN 0.050" SOLUTION

Mini-Circuits 1900 to 2400MHz broadband QBA-24 is a 2way-90° power splitter developed with high 21dB typical isolation and low 0.54dB insertion loss (typ, avg. of coupled outputs less 3dB). As a splitter, these patented Blue Cell™ hybrid's are capable of handling 20W (max.) power input and are housed in a low profile 0.050" ceramic package with solder plated leads for good heat dissipation and excellent solderability. Available off-the-shelf.

FEATURED PRODUCT

DC TO 8GHz MMIC AMPLIFIER HAS HIGH RELIABILITY

The GAL-21 is a newly developed monolithic surface mount amplifier from Mini-Circuits for the broad DC to 8GHz band. When operated at 2GHz/25°C, the unit typically delivers high 13.1dB gain (±0.6dB flat) and maximum output power of 12.6dBm typical (at 1dB comp.). These low cost 50 ohm amplifiers are housed in an industry standard SOT-89 package for excellent heat dissipation and display low 128°C/W (typ, θjc) thermal resistance. Available from stock.

1500 TO 3600MHz SM MIXER SUPPRESSES INTERMODULATION

This level 17 (LO) SYM-36H surface mount frequency mixer from Mini-Circuits targets PCS and ISM applications within 1500 to 3600MHz. Typically at center band, the mixer exhibits high 25dBm IP3 and low 6.3dB conversion loss. Bandwide, L-R isolation is 30dB, and L-I isolation is 34dB typical. Ruggedly constructed in a low cost plastic package with solder plated leads and covered by a 5 year Ultra-Rel® reliability guarantee.

1350 TO 2000MHz VCO WORKS FROM 12V SUPPLY

Mini-Circuits new ROS-2000 voltage controlled oscillator features 1350MHz to 2000MHz broad band linear tuning from a miniature 0.5"x0.5"x0.18" industry standard surface mount package. The VCO delivers low -100dBc/Hz SSB phase noise typical at 10kHz offset, good 30-50MHz/V typical tuning sensitivity, and 0.5 to 20V minimum to maximum tuning voltage. Typical power output is +7dBm with output suitable for LO drive to mixers. Affordably priced.

13dB "DO-IT-YOURSELF" COUPLER DELIVERS COST SAVINGS

The patented TCD-13-4 from Mini-Circuits needs only a commercially available 50 ohm external chip resistor, and a complete 5 to 1000MHz directional coupler is realized. Designed to lower costs through automated manufacturing, this rugged coupler provides 13.0dB±0.5dB nominal coupling (±0.6dB max. flatness) with 0.7dB mainline loss and 18dB directivity typical midband. The 50/75 ohm "do-it-yourself" TCD family contains 9 units with 9 to 20dB coupling for 5 to 1000MHz.

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AMPLIFIERS

Amplifier supports Bluetooth applications

The RF2472 is a SiGe low-noise amplifier for use in Bluetooth and cell phone applications. The amp offers a low noise figure of 1.5 dB and more than 14 dB of gain in the 2.4 GHz ISM band The device is characterized at 1.9 GHz operation and is suited for PCS handset applications as well as Bluetooth. It draws 6 mA from a 3 VDC supply and offers a powerdown mode, reducing its current consumption to under 1 mA.
RF Micro Devices
INFO/CARD 163

Low-noise HBT amplifiers

Alpha Industries' four new broadband HBT amplifiers exhibit low noise and high linearity performance. They are suited for applications in cellular and PCS base stations; cable systems as return path amplifiers, line amplifiers and tuners; in wireless LAN (Bluetooth, 802.11x, home RF and WIFI) and Hyperlan systems. The complete family of HBT amplifiers is designed as cascadeable 50Ω gain blocks, and all four amplifiers are available in industry-standard tape-and-reel packages. The GBH112 provides 13 dB of small signal gain with 8 GHz of bandwidth. It has a P1dB of 12.5 dBm at 2 GHz and IP3 of 25 dBm. The amp is available in plastic, micro-X and the smaller SC-88 package. The GBH114 operates from DC to 8 GHz with 15 dB of gain and a 3 dB bandwidth of 6 GHz.
Alpha Industries
INFO/CARD 164

TEST EQUIPMENT

WLAN receiver for 802.11b networks

The Grasshopper hand-held wireless receiver is designed for sweeping and optimizing local area networks. The instrument measures coverage for direct sequence networks that operate on the IEEE 802.11b standard. The receiver detects and differentiates from narrowband multipath interferences such as microwave


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ovens and frequency hopping systems. It includes a built-in display, keypad, antenna, rugged carrying case and two removable battery packs for true portability.
Berkeley Varitronics Systems
INFO/CARD 165

Amplifier test system integrates analysis capability

Anritsu has enhanced its ME7840A power amplifier test system with additional measurement capability. The instrument can now conduct ACPR, IMD, PAE, compression, harmonics and S-parameter measurements with a single connection. The new capabilities complement the test set's existing features, including the ability to conduct swept frequency and swept power measurements. The instrument combines the Scorpion vector network measurement system, the Scorpion PA Navigator user interface and a test set.
Anritsu
INFO/CARD 166

PASSIVE COMPONENTS

E-core transformers for switch-mode apps

The series 6655, 6656, 6657 and 6658 PC-mount ferrite E-core transformers are for use in switch-mode power supply applications. They range in size from 0.750" X 0.868" X 0.625" to 1.620" X 1.350" X 1.130". Transformers are constructed using a UL-approved nylon bobbin and can be supplied in horizontal or vertical mount configurations. The ferrite material allows use of the transformers over the 10 kHz to 250 kHz frequency range. Cores can be gapped for flyback applications or to provide tighter inductance tolerances. Full mechanical specifications are available in PDF format at the API Delevan Web site, **www.delevan.com**, along with a design worksheet for the designer to fill out the electrical specifications required.
API Delevan
INFO/CARD 167

High Q factor chip inductors

The KQ 0402 surface-mount inductor is designed with a high Q factor and high self-resonant frequency suitable for high-frequency applications. It features a flat top design. The 1.1 mm X 0.5 mm inductor is suitable for high-speed pick-and-place components and automatic machine insertion. The KQ series offers tolerances of ±2%, ±5%, ±10% and ±20% with a nominal inductance range of 1.8 nH to 10 mH. The quality factor range is 16 to 65 with a self-resonant frequency range of 90 to 6,000 MHz. The inductors are suitable for reflow soldering. The series is available in sizes 0402, 0603, 0805 and 1008.
KOA Speer Electronics
INFO/CARD 168

SEMICONDUCTORS

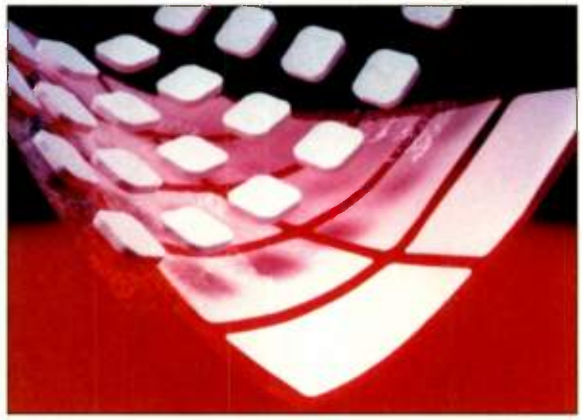
RFIC switch for DBS receivers

The UPG183GR 4 X 2 GaAs switch is designed for use in LNB downconversion

Continued on page 104

Wireless Symposium product wrap

Wireless Symposium introduced a number of new and noteworthy products. Here are some of the highlights.



Thermally conductive PCB/heat sink gap filler

W. L. Gore's Polarchip thermal interface material is a highly compressible, thermally conductive material designed for filling the undesirable air gaps between heat generating devices on printed circuit boards, heat sinks, heat spreaders, and metal chassis. The material is suitable for gap-filling applications where the thickness of the gap is large or variable due to irregular surfaces. A variety of pressure-sensitive adhesives are available and can be laminated to one side of the thermal interface to facilitate attachment.

W. L. Gore & Associates
INFO/CARD 148

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INFO/CARD 35

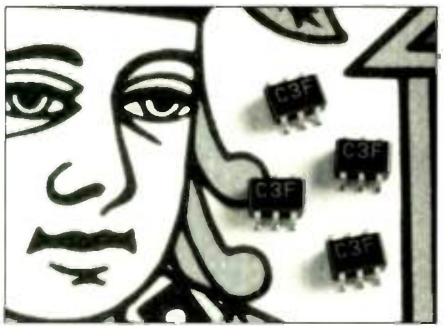
Extended frequency range VCXO

Valpey Fisher presented an improved VF194IVF294 tri-state VCXO with an extended frequency range of 1.5 to 160 MHz. Applications for the device include xDSL, SONET/SDH, digital video, HDTV, cellular base stations, ISDN, and wireless LANs. The device is housed in a standard 6-pin LCC footprint and offers ±25 ppm stability, with ±100 ppm pullability. Both 5 VDC and 3.3 VDC devices are available.

Valpey Fisher
INFO/CARD 149

RFIC driver amplifier for mobile communications

California Eastern Labs has added a medium-power amplifier to its line of NEC Silicon RFICs. The UPCS1S2TB has an upper operating frequency of 2.9 GHz at 3 dB bandwidth. Designed to drive two-stage PAs, the device offers 30 dB of isolation to minimize a PA's loading effects. At 2.5 GHz the device offers +8.0 dBm of output power and a typical power gain of 20.5 dBm. The device is housed in a miniature six-pin SOT-363 package and is available on tape and reel for high volume automated assembly.



CEL
INFO/CARD 150

Single positive supply voltage pHEMT

Agilent Technologies previewed a true small-signal E-pHEMT device; the first in a family of high-gain, highly linear and low-noise transistors. The ATF-54143 is designed for cellular/PCS base stations, multi-channel multipoint distribution systems, and other applications in the 450 MHz to 6.0 GHz fre-

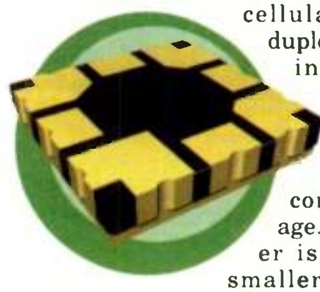
quency range. Typical performance at 2.0 GHz is 0.55 dB noise figure, +36 dBm output intercept point and 17.4 dB associated gain. Operation is from a single +3 VDC supply at 60 mA current.
Agilent Technologies
INFO/CARD 151

TDMA/GSM dual-band amplifier/mixer

RFMD debuted its RF2492 dual-band LNA/mixer for the emerging TDMA/GSM handset market. The device is a complete receiver front end with dual IF outputs that can interface to two independent IF SAW filters. Multiple gain options are provided and an integrated frequency doubler is included in the LO circuit providing both high- and low-band LO signals. It features 24 dB of cascaded gain, and a 2.9 dB noise figure draws 30 mA of supply current, adjustable LNA bias current and IIP3 and differential LO buffer outputs.
RF Micro Devices
INFO/CARD 152

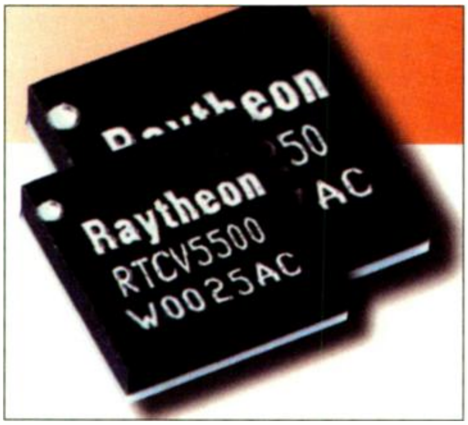
Miniature cellular duplexer for cellular phones

Sawtek offered pre-production release of a miniature 5 mm x 5 mm cellular RF SAW duplexer supporting CDMA, TDMA and AMPS architectures in a compact package.This duplexer is about 75% smaller than first-generation SAW duplexers and more than 95% smaller than ceramic duplexers. The device offers increased receiver sensitivity in CDMA, TDMA and analog cellular phones through reduced insertion loss and increased spurious rejection.



Sawtek
INFO/CARD 153

High-speed 5 GHz wireless chipset



Raytheon presented a 54 Mb/s radio chipset, called Tondelayo, based on the IEEE 802.11(a) standard for high-speed wireless networks in the 5 GHz UNII bands. The chipset includes a power amplifier/switch module, RF, IF and baseband component chips. The device uses C-OFDM modulation in a flexible low-risk design approach. It also includes CardBus and PCI reference designs and a robust suite of drivers. The design provides a cost-effective solution across all three 5.0 GHz UNII bands.

Raytheon
INFO/CARD 154

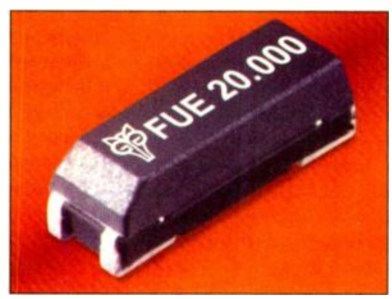
Bluetooth antennas offer high gain

Centurion Wireless Technologies displayed two antennas for Bluetooth applications. The BlueChip antenna is an internal antenna that offers high gain (>2.0 dBi) and wide bandwidth. It features PCB surface mount in vertical or horizontal positions and can be delivered in tape-and-reel packaging. The MicroBlue antenna features 0.03" thickness, and provides 3 dBi gain. The MicroBlue is customizable for high-volume embedded applications in either board- or cable-mount configurations. Both units cover a frequency range from 2.4 to 2.5 GHz and are omnidirectional along the azimuth plane.

Centurion
INFO/CARD 155

Compact crystal for portable and wireless apps

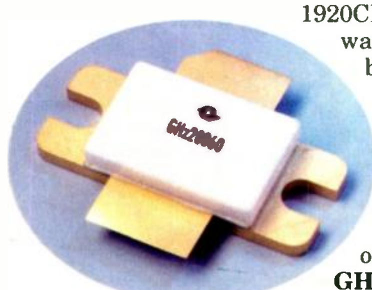
Fox Electronics introduced a new crystal that provides a cost-effective alternative for portable, wireless and other applications with space and budget constraints. It measures just 13.4 mm x 5.08 mm. The crystal offers a frequency range of 3.579545 MHz to 66.6667 MHz, a frequency tolerance of ±50 PPM, a frequency stability of ±80 PPM or less depending on frequency, and an operating temperature from –20°C to +70°C. The SMD crystal is encased in a plastic package and can be furnished in standard tape-and-reel packaging.



Fox Electronics
INFO/CARD 156

Bipolar 20060 Transistor for Wireless Base Stations

GHz Technology announced the release of the GHz20060, its newest transistor for linear wireless communication systems. The GHz20060 is a simplified version of GHz Technology's double input matched wider bandwidth 1920CD60. The GHz20060 is a 60-watt (PEP), 26-volt, Class AB bipolar transistor for use in the 1800 to 2000 MHz frequency range. It has a minimum power gain of 9 dB. The transistor is designed for linear wireless base station applications. Samples of the part are available now.



GHz Technology
INFO/CARD 157

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in DBS receiver applications. The switch provides four independent IF input channels that can be internally switched to one of two output channels. The frequency range is 950 to 2,150 MHz, and insertion loss is 7 dB at 50Ω typical per channel. The switch offers a 26.5 dB isolation and comes in a 16-pin HTSSOP package.
California Eastern Laboratories
INFO/CARD 169

FEC chips support wireless Internet access

The 2 kb Astro LE forward error correction chip operates at standard channel rates up to 35 Mb/s. A 4 kbit chip was also developed to provide additional coding gain for less cost-sensitive applications. The chips are to be designed into modems for use in high-speed wireless Internet access applications including point-to-multipoint terrestrial and satellite connections. The chips incorporate Advanced Hardware Architectures' TPC technology, delivering as much as 3 dB of additional coding gain.
Advanced Hardware Architectures
INFO/CARD 170

SIGNAL SOURCES

Commercial PLL

Vari-L is offering the Model PLL400-915 PLL that generates frequencies from 902 to 928 MHz in 200 kHz steps. The unit typically requires 19 mA of current from a 5.0 VDC supply voltage. Typical phase noise at 0.5 kHz offset is –84 dBc/Hz and the typical phase noise at 100 kHz offset is –131 dBc/Hz. Phase detector spurious suppression is typically –82 dBc. Typical output power is 4.0 dBm. Second harmonic suppression is typically –13 dBc and third harmonic suppression is typically –27 dBc. The unit is housed in a .60" x .60" x .13" surface mount, pick- and-place/reflow compatible package.
Vari-L
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Compact 3.3 VDC OCXO functions as TO-8

MTI-Milliren introduces a 3.3 VDC OCXO. With a frequency range from 4.8 MHz to 100 MHz, these devices easily achieve the necessary performance characteristics normally associated with larger designs by using a full-size TO-8 (HC-37) quartz housing. Features include a thermal stability of 2.0 E^{-08} over a 100°C temperature range, warm up time of less than 5 minutes, and power consumption of 1.0 W at +25°C. Phase noise at 1 Hz offset is –85 dBc/Hz with a noise floor of –150 dBc/Hz (at 10 MHz). Devices are delivered in hermetic 16-pin DIP or surface-mount packages, or can be modified with footprint adapter boards.
MTI-Milliren
INFO/CARD 172

TCXO has digital compensation

The new QED 110-AH/BH SMT DTCXO is digitally compensated to achieve a stability of ±0.4 ppm over its operating temperature range ofIt is designed for use in test equipment, man-pack and handset military radios.
TEMEX Electronics
INFO/CARD 174

GLOSSARY OF TERMS USED IN THIS ISSUE OF RF DESIGN

2G – second generation of wireless communications systems
3G – third generation
A/D – analog-to-digital
AC – alternating current
ACPR – adjacent–channel power ratio
ADC – analog–to–digital converter
AGC – automatic gain control
AMPS – advanced mobile phone system
AODV – ad-hoc on demand distance vector
ASIC – application–specific integrated circuit
ASK – amplifier shift keying
ASP – application service provider
ATM – asynchronous transfer mode
AWGN – additive white gaussian noise
BPSK – binary phase shift keying
CCRR – co–channel rejection ratio
CDMA – code–division multiple access
CDPD – cellular digital packet data
CGI – common gateway interface
CMOS – complementary metal-oxide semiconductor
CMRR – common-mode rejection ratio
CW – continuous wave
DC – direct current
DCS – distributed communications system or digital cellular system
DDS – direct digital synthesis
DECT – digital european cordless telephone
DSP – digital signal processor
DUT – device under test
EEPROM – electrically erasable programmable read-only memory
EM – electromagnetic
EMC – electromagnetic compatibility
EMI – electromagnetic interference
ESD – electrostatic discharge
ETSI : european telecommunications standards institute
FCC – federal communications commission
FDD – frequency division duplex
FEM – finite-element method
FET – field-effect transistor
FHSS – frequency-hopping, spread spectrum
FIFO – first-in, first-out
FIR – finite impulse response
FSK – frequency shift keying
GaAs – gallium arsenide
GaN – gallium nitride
GFSK – gaussian filtered frequency shift keying
GMSK – gaussian minimum shift keying
GPIB – general-purpose interface bus
GPRS – general packet radio service
GPS – global positioning system
GSM – global system for mobile communications
HBT – heterojunction bipolar transistor
HDR – high data rate
HEMT – high electron mobility transistor
HSCSD – high–speed circuit-switched data
HTTP – hypertext transfer protocol
I and Q – in–phase and quadrature
I/O – input/output
IC – integrated circuit
IF – intermediate frequency
IM – intermodulation
IMD – intermodulation distortion
InP – indium phosphide
IP – internet protocol
IR – infrared
ISM – industrial, scientific, and medical
JSP – java server pages
LAN – local area network
LDMOS – laterally diffused metal oxide silicon
LMDS – local multipoint distribution service
LNA – low–noise amplifier
LO – local oscillator
LOS – line of sight
LPF – low–pass filter
LSI – large scale integration
LTCC – low–temperature co–fired ceramic
MDS – multipoint distribution systems
MMAC – million multiply accumulate operations
MMDS – multichannel multipoint distribution service
MMIC – monolithic microwave integrated circuit
MOSFET – metal–oxide semiconductor field–effect transistor
MOU – minutes of use
MSPS – million samples per second
NRZ – non–return to zero
NTC – negative temperature coefficient
OEM – original equipment manufacturer
PA – power amplifier
PAR – peak-to-average ratio
PCB – printed circuit board
PCS – personal communications system
PDA – personal digital assistant
PDC – pacific digital cellular
PECL – positive emitter-coupled logic
PHEMT – pseudomorphic high-electron-mobility transistor
PIM – personal information management
PLL – phase–locked loop
PPM – parts per million
PSK – phase shift keying
QPSK – quadrature phase shift keying
RFI – radio frequency interference
RFIC – radio frequency integrated circuit
ROM – read–only memory
SDH – synchronous digital hierarchy
SMA – standardization management activity
SMD – short message delivery
SMR –specialized mobile radio
SMS – short messaging service
SMT – surface–mount technology or surface–mount toroidal
SNR – signal–to–noise ratio
SOIC – small-outline integrated circuit
SONET – synchronous optical network
SPDT – single–pole double–throw
SSPA – solid state power amplifiers
TCP – transmission control protocol
TDD – time division duplex
TDMA – time–division multiple access
TETRA – trans european trunked radio
TTL – transistor –transistor logic
TXCO – temperature–compensated crystal oscillator
UART – universal asynchronous receiver transmitter
UDP – user datagram protocol
UMTS – universal mobile telecommunications service
UTRA – UMTS terrestrial radio access
VCO – voltage-controlled oscillator
VCXO – voltage–controlled crystal oscillator
VOFDM – vector orthogonal frequency division multiplexing
VSAT – very small aperture terminal (satellite service)
VSWR – voltage standing wave ratio
WAP – wireless application protocol
W–CDMA – wideband code–division multiple access
WLAN – wireless local area network
XDSL – another name for an ISDN BRI channel

RF literature and product showcase

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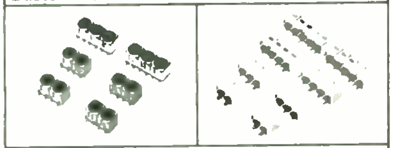

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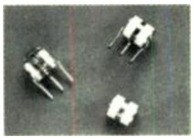

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● Attenuation Frequency Flatness:	
±0.30 dB @ 10dB	±1 50 dB @ 40dB
±0 80 dB @ 20dB	±1 60 dB @ 60 dB
● Transfer Function Accuracy:	
0 - 10 dB @ ±0.25 dB Max	30 - 50 dB @ ±1.0 dB Max
10 - 30 dB @ ±0. 50 dB Max	50 - 60 dB @ ±1.5 dB Max
● Switching Time:	500 nS Max
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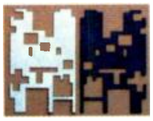

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Gee-whiz, or Gee was...

by Ernest Worthman
technology editor
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I start this column with a question as to why, when I try to talk mobile-to-mobile with a close friend, the conversation never gets finished. The reason is that I never seem to get a clear, continuous, noise-free transmission. The call either gets dropped, it is so noisy I can't hear, or the digital dropout makes it sound like a staccato conversation. And, while I'm probably exaggerating a bit, it happens EVERY TIME. I'm quite annoyed with it.

Not exactly news — OK, so this isn't news. I'm using it as a springboard into this month's column because I think it has some relevance.

I've been watching (and not without some heart palpitations, mind you) the current dismal performance of the traditionally strong semiconductor and related industries. I have resisted orating any number of knee-jerk reasons that so many are quick to offer, including explanations of why we're heading for a recession, or why the new president doesn't have the nation's confidence.

Enough time has gone by that I believe the current state of stagnation within what I sometimes call the "gadgetry" industries (computer, electronic entertainment, information and intercommunications) that constantly create new gizmos, features and options is a wake-up call. I believe that we are seeing the beginning of technological overload. I believe that the consumer is getting overwhelmed and inundated with wonderful technological options with little real functionality.

Been there, done that — Even I, one of the original technological junkies who spends way too much time watching the Discovery Channel, am getting a bit bored with the feverish pace of incessant technological diarrhea. I've tried most of it, and use almost none of it. And this isn't just the wireless communications industry. The computer industry is just as stoic. I have finally realized that I just don't need to be running an Intel P4 at 1.4 GHz, when my paltry little 1.0 GHz AMD does the job nicely.

I'm not alone — I opened this column with the example of poor mobile-to-mobile communications because of a friend of mine. Actually, he is the one who got me off on this tangent. All he wants is a mobile phone system that is reliable. No wonder he isn't rushing out to get the latest Web-enabled wireless phone. He's thinking if this is the best that voice can offer, why even try the wireless Internet?

And he's not the only one. I've seen headlines saying that 3G phones are just gadgetry (October 2000, *eWeek*) and heard rumors that the wireless Web infrastructure is way too slow to support complex multimedia and high-speed data (same source). From March's *PC World*, Editor Stephen Mans writes, "New PCs equal new hassles." His position is that it's just getting to be too much of a hassle to upgrade a computer under the Windows environment, and users just don't need the incremental increase in performance brought on by the potential headache of upgrading. And Intel has expressed concerns that the investment required for a 3G infrastructure buildout will bankrupt the wireless industry. Furthermore, when news like Ericsson's departure from the handset market is announced, one has to wonder.

It's personal — Recall that I mentioned in an earlier column the difficulty my favorite editor, Roger, had with trying to access the Internet on his new Sprint Web phone. He's told me since then that he's done a few basic Web inquiries, but far from the hype that abounds in commercials and promotions — and it's still slow! He isn't in a hurry to get the next-generation wireless communicator (whatever they choose to call it) either.

Lately, for me, the Internet has been losing its glamour as well. I've had more than my share of dead sites, broken links, and porno sites connected to seemingly innocent sites. I'm sick of dealing with idiotic Internet mail-order companies that are impossible to contact by telephone or fax when their site hiccups and you can't communicate with them on an order. I'll never order motorcycle parts through an Internet e-business again.

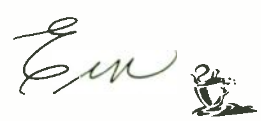
Additionally, the bombardment of pop-up ads, offers too good to refuse and tons of unrelated material that one has to wade through when using the Internet is starting to wear thin. Certainly, the bloom has fallen off of my rose.

I've started going back to physically browsing the brick-and-mortar Media Plays and Virgin Superstores for my DVDs, Barnes and Noble for my books and magazines, and the Supr' Softwares for my computer applications. I like being able to take stuff back if I need to. And I like the touchy-feely 3D environment that allows me to have a cup of coffee by a fireplace while reading the latest issue of *Cats* magazine.

Maybe I'm wrong, and the industry pundits are right when they say this slowdown is only temporary, or they blame it on the "recession," or the lack of a killer 3G application, or the regular delays in Bluetooth, WAP and other enabling platforms.

Maybe I'm wrong when I say the public has had enough of missed debut dates and underperforming products...maybe. After all, I did buy Iridium stock at just over $6 a share.

But, I also bought ITT stock at $24 a share about a year ago.



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