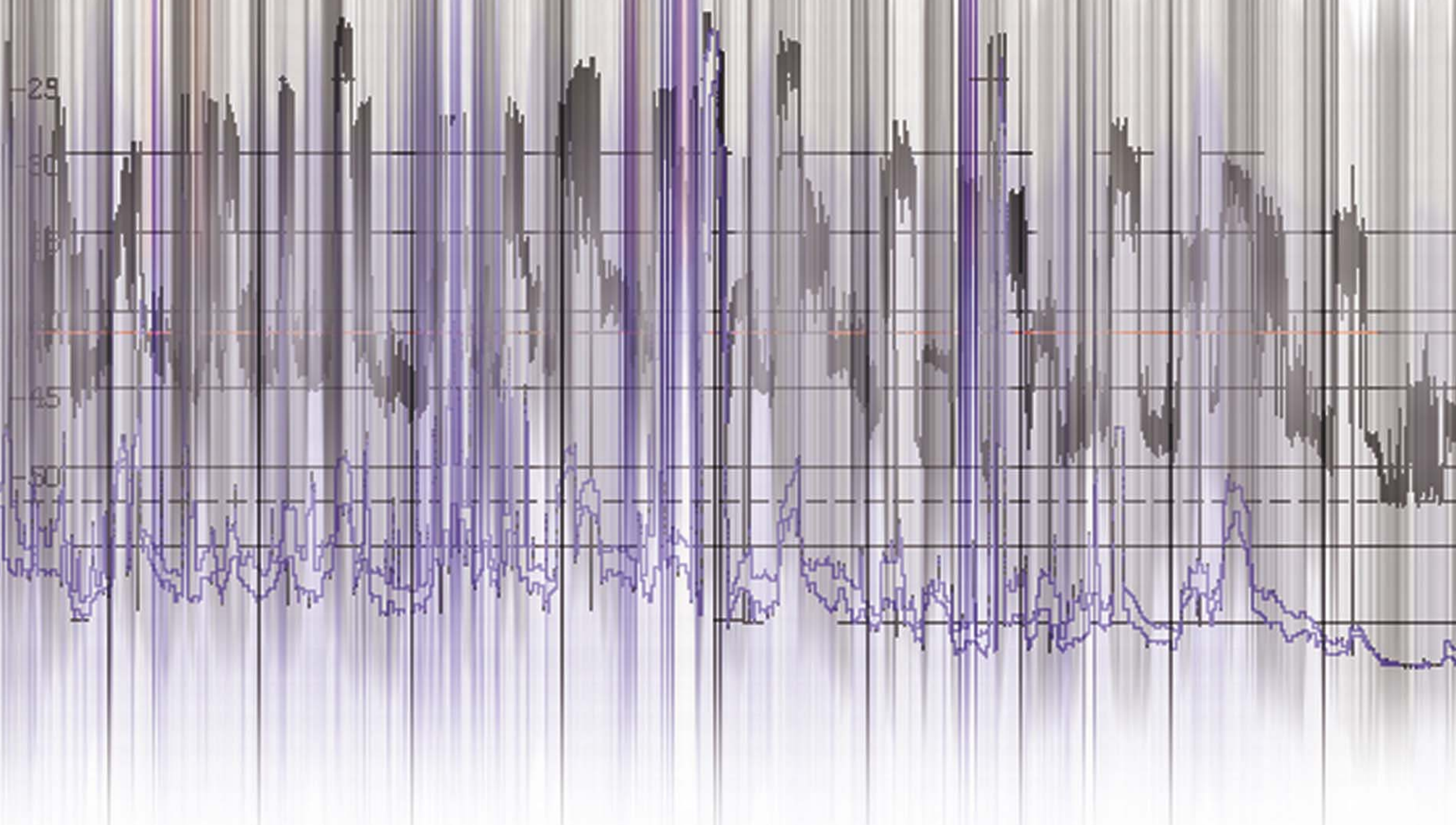

BY DAN STRASSBERG • CONTRIBUTING TECHNICAL EDITOR

Testing UWB: Don't try this at home!

ULTRAWIDEBAND WIRELESS COMMUNICATION MAY BE THE WAVE OF THE FUTURE, BUT ENGINEERS WHO LACK SOLID RF-TEST EXPERTISE WILL NEED ASSISTANCE FROM AN EXPERIENCED TEST LAB TO ESTABLISH UWB-PRODUCT COMPLIANCE WITH FCC SPECS.

If many of the best-known electronics companies—and a large number of smaller start-ups—get their way, UWB (ultrawideband), the new, short-range, ultrahigh-speed wireless-communication technology, will soon transform communication among computers and peripherals and among consumer-electronic devices—at least in the United States. What's more, Japan appears close behind. Meanwhile, Europe seems to be taking a wait-and-see position on UWB.

In the United States, the FCC (Federal Communications Commission) has allocated a 7.5-GHz-wide swath of spectrum—3.1 to 10.6 GHz—to UWB. If you haven't yet read about the technology, your reaction may be, "How can it do that? Other services are already using most of that spectrum." The answer is that UWB, by design, sends signals at such low average power (−41.3 dBm/MHz) and in such short bursts that the signals appear as low-level noise to the receivers for the other services. Those receivers have enough noise immunity to be unperturbed by the UWB transmissions.

Two industry groups support competing and incompatible forms of UWB. The WiMedia Alliance, of which the MBOA (Multiband OFDM Alliance) recently became part, primarily supports MB-OFDM (multiband orthogonal frequency-division multiplexing); the UWB Forum supports DS (direct-sequence)-UWB, which some—but *not* Forum members—call impulse radio. Both groups are rumored to also support—or at least to be considering support of—a low-cost, lower speed, low-power version of impulse radio, whose key application may be a future version of ZigBee, the wireless-sensor standard.

Both groups' Web sites list large numbers of member companies, but, of the two, the WiMedia Alliance includes more merchant IC manufacturers, including the all-important Intel, and a technology that many—albeit, not UWB Forum members—call more ele-

AT A GLANCE

- UWB (ultrawideband) radio, a shared-spectrum wireless technology, has the potential to transmit data at gigabit-per-second rates over distances of tens of meters without interfering with existing services with which it shares the spectrum.

- The IEEE has not yet reached consensus on a UWB standard, so developers of products that use UWB technology must choose between fundamentally incompatible approaches, each of which claims advantages over the other.

- MB-OFDM (multiband orthogonal frequency-division multiplexing) has broader support among IC makers; DS (direct-sequence)-UWB development is further along.

- Testing products that incorporate UWB technology requires great familiarity with multigigahertz RF measurements and the instruments used to make them.

gant and more readily scalable to higher data rates. The Forum says, however, that its DS-UWB technology uses less power to achieve equivalent range—a key attribute in battery-powered-system applications—and is both inherently simpler, thus less costly, and closer to market readiness than is the Alliance's computationally intensive MB-OFDM. The Alliance disagrees on several counts. As Jason Ellis, senior manager of business development and marketing at Alliance member Staccato Communications, puts it, "Real MB-OFDM devices cost substantially less and use less power." However, a Forum spokesman insists that the DS-UWB parts perform more required UWB functions than do the MB-OFDM parts that Alliance members are using for comparison and that if comparable parts of both types existed, the DS-UWB parts would cost less and use less power.

DIFFICULT DECISION

Early adopters of UWB will, therefore, need to choose between the two major approaches, and, in choosing, they will have to decide whether they think the Alliance's lead in industry popularity trumps the Forum's lead in developing its technology. At one time, the UWB Forum had proposed a CSM (common signaling mode), which would allow MB-OFDM and DS-UWB systems to communicate with each other at low data rates. The WiMedia Alliance has declared the CSM idea dead, but Forum members say that CSM can't and won't die unless one of the two technologies disappears, because, without it, neither type of system can detect the presence of nearby systems of the other type. The result, they insist, will be interference that may prevent either type of system from working satisfactorily.

For a wireless technology, UWB can be blazingly fast. According to Alliance members, early MB-OFDM-based products will permit data rates as high as 480 Mbps at a 3m distance and 110 Mbps at 10m. In a few years, these folks say, speeds should reach 1 Gbps at perhaps as much as 20m. Unfortunately, when quoting these performance figures, the Alliance members sidestepped the issue of BER (bit-error rate) or PER (packet-error rate). Without that information, the data rates are not particularly meaningful.

Alliance members assert that the 10^{-12} error rates of which Forum members speak represent overkill in the area of the UWB market that many in the Alliance consider the most lucrative—consumer multimedia applications. Nevertheless, Freescale Semiconductor, the Forum's principal merchant-IC-manufacturer member, was first to announce an agreement to supply UWB devices to a major consumer-electronics manufacturer (Haier). Freescale was also first to deliver fully operational UWB silicon (with a raw data rate of 114 Mbps at 20m) and expects late this

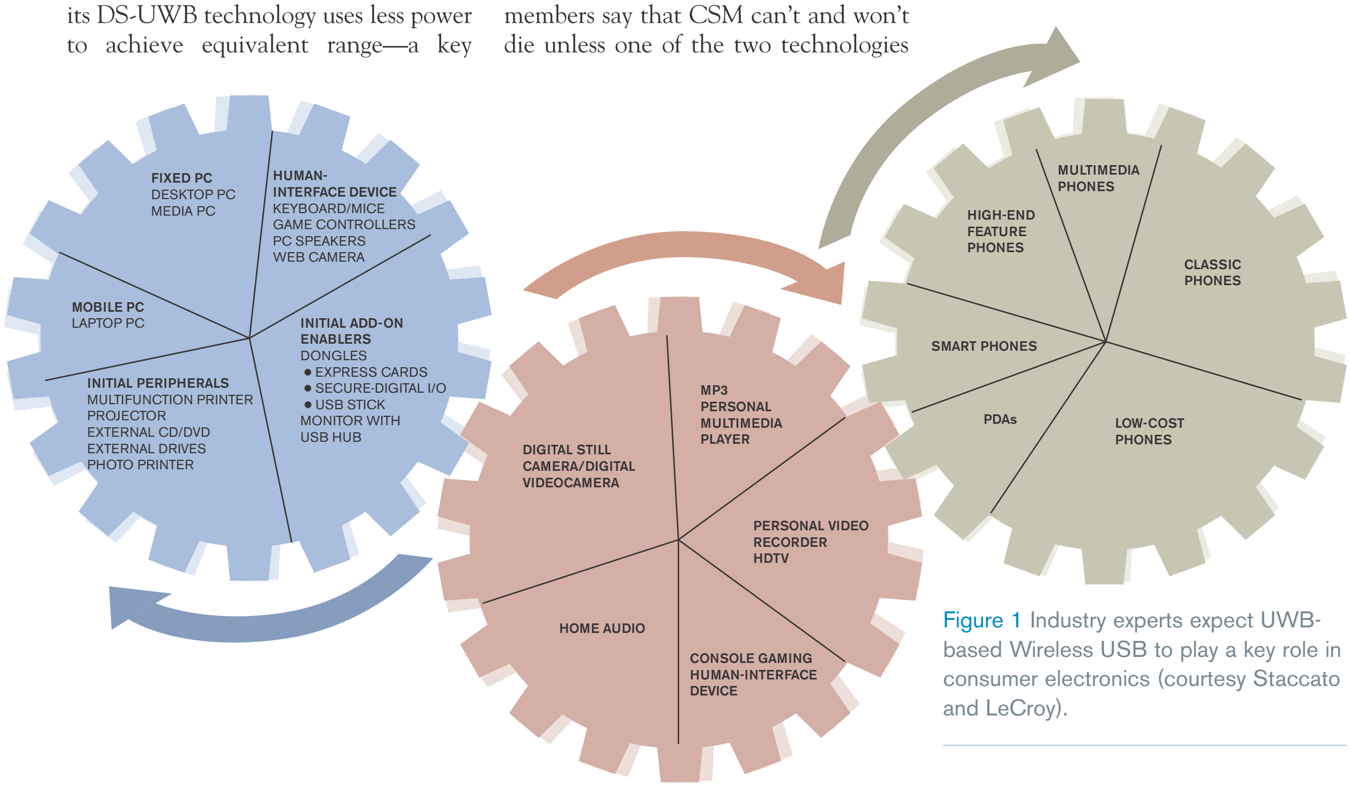

Figure 1 Industry experts expect UWB-based Wireless USB to play a key role in consumer electronics (courtesy Staccato and LeCroy).

year or early next to announce parts almost six times as fast. The company also questions whether 16-QAM (16-level quadrature-amplitude modulation), which the Alliance recently specified for data rates greater than 200 Mbps, can really achieve 10m range and still meet the FCC's −41.3-dBm/MHz radiated-power limit, because, says a Freescale spokesman, "16-QAM takes approximately 4 dB more power per bit to go the same distance as DS-UWB's bipolar- and quadrature phase-shift keying."

How the UWB market divides among several segments will determine the kinds of products chip and module manufacturers emphasize (see **sidebar** "UWB drives to commercialize"). A key UWB application is almost certain to be WUSB, a wireless version of the Universal Serial Bus, whose wired embodiments truly dominate connections between peripheral devices and PCs. Industry watchers seem to agree, however, that growth of USB for peripheral interconnection has slowed and that sales of USB components—ICs, for example—for home-multimedia applications now exceed sales of such components for use in PCs and peripherals. This trend is like-

UWB DRIVES TO COMMERCIALIZE

By Roberto Aiello, Staccato Communications

The stars must be in proper alignment for any new technology to come to market, and, for UWB (ultrawideband) communication, the key items are international standards, market pull, and the availability of commercially viable products. All these elements are lining up, and consumer products will feature high-speed wireless connectivity for the 2006 holiday season.

For wireless communications, regulatory agencies must define the first piece, spectrum allocation, before organizations can establish standards. On Feb 14, 2002, the FCC (Federal Communications Commission) issued a Report and Order allocating 7.5 GHz of unlicensed spectrum for UWB devices operating in the 3.1- to 10.6-GHz frequency band. This move legitimized the technology and fueled the urgency to understand the customer requirements and to have the technology mature within an open-industry-standards forum. Outside the United States, worldwide regulatory agencies are in varying stages of developing regulations and, in most industrialized countries, should soon issue rulings.

The standards activities began within an IEEE committee, and, in an effort to accelerate and streamline standardization, the MultiBand Coalition formed in September 2002. The coalition later became the MultiBand OFDM (orthogonal-frequency-division-multiplexing) Alliance and this year merged with the WiMedia Alliance to become an open industry association for promoting and enabling the rapid adoption, regulation, standardization, and multivendor interoperability of UWB. WiMedia-based UWB specifications target use in wireless personal-area networks that operate at speeds as high as 480 Mbps and provide low-power multimedia capabilities for consumer, mobile, and automotive markets. Emphasizing peaceful coexistence with other wireless services, WiMedia's UWB common platform operates with application stacks that the Wireless-USB Promoter Group, the 1394 Trade Association's Wireless Working Group, and the Bluetooth-SIG developed. IEEE and Ecma-International standards committees are currently reviewing the platform specs.

MARKET PULL

WiMedia UWB technology, which will debut as Certified Wireless USB, is fulfilling a market need by enabling popular, high-performance wired approaches to evolve into wireless approaches. Developers are designing the technology, which extends to support Wireless IEEE 1394, Internet protocol over UWB, and next-generation Bluetooth, into computers, peripherals, home-entertainment equipment, mobile phones, and other consumer-electronic devices. Through UWB, these products will rid themselves of unsightly rats' nests of cabling.

As with any technology en route to market, price is a key concern; multivendor interoperability, form factor, and performance are also important. With the history of Bluetooth and WiFi (Wireless Fidelity) as benchmarks, vendors know that, to achieve mass-market adoption of their products, designers must implement them in all-CMOS semiconductors. Besides low cost, the all-CMOS approach provides outstanding performance in small packages, thanks to high levels of integration.

Staccato Communications and other UWB-semiconductor companies have recently entered the final stage of launching a technology: compliance and interoperability testing. Things are looking good: The developers of Certified Wireless USB built on established compliance programs that have enabled more than 2.5 billion USB connections. We are well on the way to seeing UWB-based products late in 2006.

AUTHOR'S BIOGRAPHY

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ly to accelerate in WUSB; although there is little probability of a rush to substitute printers that use WUSB for units having wired connections, observers expect WUSB and a UWB version of IEEE 1394 (FireWire) to rapidly supplant wired connections among components of large-screen high-definition-TV systems (**Figure 1**).

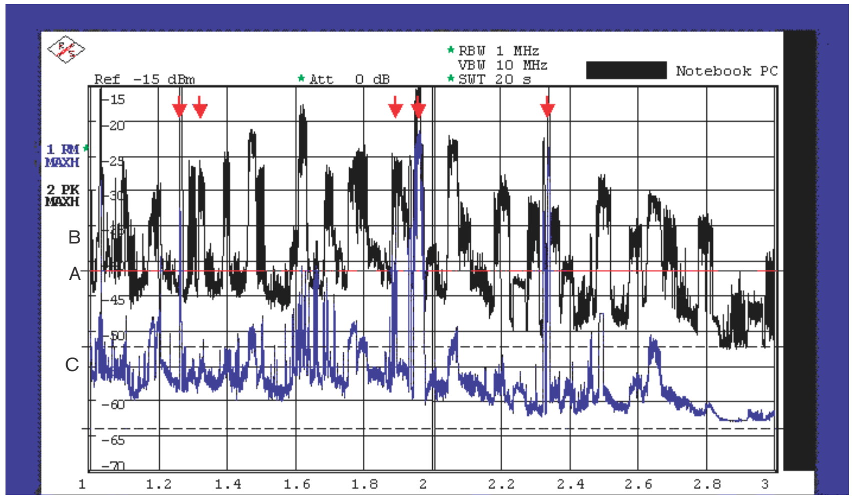
DOUBTERS AND DETRACTORS

UWB, like any other technology that is new and unproven in commercial applications, has doubters and detractors. In this case, many detractors fear that UWB will interfere with the other services whose spectrum it shares. UWB raises barely a whisper of concern, however, compared with another currently trendy shared-spectrum communication technology, BPL (broadband over power lines—see **sidebar** "BPL: the uninvited guest").

In a move to pre-empt problems, UWB-system architects have removed from the range of frequencies that UWB occupies the area in the vicinity of 5 GHz, which is home to several of the newer forms of wireless networks, such as IEEE 802.11a, g, and n, whose narrowband signals might otherwise cause interference to UWB signals. In addition, to avoid interference with the GPS (global positioning system), the FCC not only restricts UWB to frequencies well above those that GPS uses, but also demands stringent testing of UWB products and systems for out-of-band emissions at or near GPS frequencies.

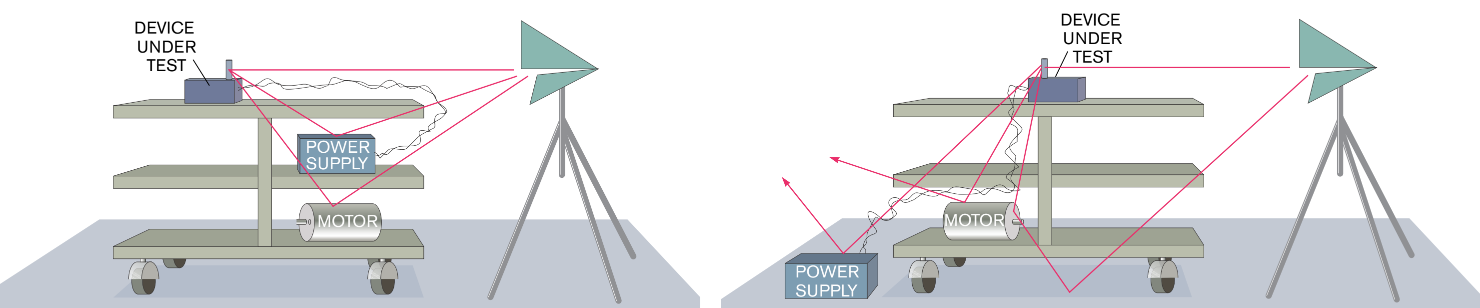
The feeling in the UWB community is that the FCC has gone overboard in restricting the field strength of UWB emissions, even though, in some other technologies, such as BPL, the commission appears to have yielded to political pressures and ignored—or at least downplayed—legitimate concerns about interference to established services.

Currently, however, limits that UWB developers regard as excessively strict on EMI (electromagnetic-interference) emissions from UWB transmissions make compliance measurements more difficult, expensive, and time-consuming than the developers feel they need to be and can sometimes even make meaningful measurements impossible. Moreover, the limits are often far below FCC limits on and actual emissions from portions of the equipment under test that are unre-



NOTES:
RBW=RESOLUTION BANDWIDTH.
VBW=VERTICAL BANDWIDTH.
SWT=SWEEP TIME.

Figure 2 Unintentional emissions from common products that have no UWB capabilities exceed the FCC UWB-emissions limit of −41.3 dBm/MHz (Trace A, red). Even though intentional UWB emissions are limited to 3.1 to 10.6 GHz, the limit also applies to out-of-band emissions, such as those shown, from a popular notebook PC. Trace B (black) shows the peak emissions. Trace C (blue) shows the rms emissions. The blue-trace peaks rise well above the FCC limit–particularly in the GPS bands denoted by the red arrows. The peaks were present even when the PC was off, albeit still connected to ac power (courtesy Freescale).



(a) (b)

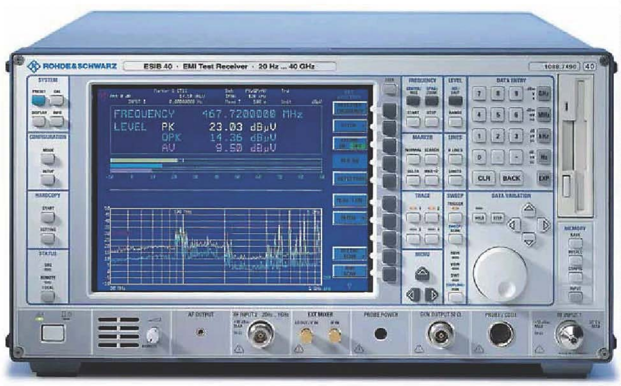
Figure 3 The physical arrangement of test equipment can render UWB-emissions measurements meaningless. Reflections from the device under test, its power supply, and a motor result in unstable readings (a). Rearranging these components solves the problem (b) (courtesy Freescale).

lated to UWB. These emissions—for example, from PC power supplies and processor ICs—are present whether or not UWB is in use and can so completely dwarf those from UWB that, when UWB is activated, its contribution is undetectable (**Figure 2**).

BIG DIFFERENCES

DS-UWB and MB-OFDM differ profoundly. DS-UWB is sometimes referred to as a zero-carrier system because some implementations do not use conventional modulation of a sinusoidal carrier. The bandwidth can exceed 25% of the signal's center frequency, however. For example, signals that occupy a frequency range of 3.1 to 4.9 GHz have a center frequency of 4 GHz and a bandwidth of 1.8 GHz, which is 45% of the center frequency. In this type of UWB, the signals can be on for a few nanoseconds or, in some cases, even less than 1 nsec and can be off for considerably longer periods.

MB-OFDM is not a zero-carrier system; it uses a large number of carriers. Because attempting to continuously use the full 1.8 GHz would enormously increase the design complexity and might increase the power requirements beyond acceptable limits, the WiMedia Alliance system divides the 3.1- to 4.9-GHz spectrum into three bands, each slightly wider than 500 MHz, and periodically switches the signal among the bands. Each band contains 128 OFDM carriers, each of which is modulated either by QPSK (quadrature-phase-shift keying), which transmits two bits per symbol, or at higher data rates, by 16-QAM, which transmits four bits per symbol. The OFDM carriers are *not* subcarriers, however; there is no main carrier.



EMI (electromagnetic-interference) test receivers, such as this unit from Rohde and Schwarz, are among several specialized classes of instruments that play major roles in the testing of products that implement UWB.

The ensemble of modulated carriers occupies one of the 500-MHz-wide bands for 250 nsec. Then, after a short delay, it switches to one of the other two 500-MHz-wide bands for another 250 nsec. Then, after another short delay, it switches to the third 500-MHz-wide band for another 250 nsec. The process repeats approximately every microsecond. A key reason for occupying three 500-MHz-wide bands, each for less than one-third of the time, instead of continuously occupying just one 500-MHz band, is to hold down the average energy radiated in any one band—and, hence, across the entire 1.8 GHz—to comply with the FCC radiation limits. According to the UWB Forum, however, the band-switching approach raises by 6 dB the ratio of peak-to-average signal, preventing operation at the FCC's maximum permitted level, thereby reducing the range.

The reason for using only the lowest one-fourth of the allocated 3.1- to 10.6-GHz spectrum is to stay in a frequency range that is compatible with current, well-understood, cost-effective CMOS-

BPL: THE UNINVITED GUEST

Any technology that moves into the spectrum space that other communication services already occupy is bound to create consternation among users. A case in point is BPL (broadband over power lines). Unlike short-range, wireless UWB (ultrawideband), which users generally consider to be a well-mannered guest, BPL is a medium-range wired technology, whose critics insist that its key shortcoming is an inability to confine its signals to the power lines over which they are supposed to travel. BPL's appeal is its use of ac-power wiring, which is virtually everywhere that people are. Unfortunately, the power wiring is also BPL's potential undoing.

Power lines are meant to convey ac at 50 or 60 Hz–not signals at the higher frequencies that BPL uses. When they travel over power lines that weren't designed to carry them, those frequencies too readily escape into the air, where they can become uninvited interlopers in many forms of wireless communication and can cause myriad problems.

Power-line communication has existed in various forms for three decades or so but has achieved only limited success. Every few years, someone resurrects the idea, promising even higher data rates, at which the technology then fails anew when facing real-world conditions. Often, the problem is unreliable data transmission–a consequence of power lines' uncontrolled high-frequency characteristics, which change continually with variations in the ac load. Although major companies–most recently, Google (www.google.com)–have invested heavily in BPL, cynical critics offer the tongue-in-cheek suggestion that power-line communication should adopt the slogan "the technology of tomorrow–now and forever."

IC-fabrication technology. As IC manufacturers develop faster processes, the Alliance expects UWB to occupy nearly all of the allotted 7.5-GHz-wide spectrum.

WHAT TO TEST

"In testing a new-product design that incorporates UWB, four major areas require attention: conformance to regulatory requirements, performance, interoperability, and fairness," says Yoram Solomon, mobile-connectivity-solutions director for strategic marketing and industry relations at Texas Instruments (see **sidebar** "Ensuring fair sharing of the UWB channel"). At this stage of UWB's evolution, you must regard all of the areas as challenging. Many of the required measurements are inherently difficult, and developers haven't yet had the opportunity to learn through their own and others' experience most of the lessons they need to learn about what to do and what to avoid (**Figure 3**).

Only those who have access to a properly equipped compliance laboratory and who have significant knowledge and experience in RF measurements and the use of sophisticated RF-measurement instruments should attempt to make the FCC-required compliance measurements. In the absence of those prerequisites, opportunities abound to spend weeks of precious time and huge sums of money on meaningless measurements. Also, because you usually won't find out until much later that the measurements were meaningless, you risk basing costly, yet inappropriate decisions on them.

Mike Violette, chief executive officer of Washington Laboratories Ltd, an FCC-listed test lab in Gaithersburg, MD, makes the following comments: "There are about 170 FCC-listed labs in the United States and half-again as many overseas." You can get the full list from the FCC Directory of Test Labs. "There is no particular designation for labs that are allowed to do UWB testing; any listed lab that has the right equipment and know-how can do it," says Violette.

NOT CHEAP

"One critical aspect of doing the testing is that the necessary equipment isn't cheap," Violette says. "The biggest issue is the available RBW [resolution bandwidth]. One of the UWB tests requires measuring 'power in a 50-MHz band.' To properly do this test, you need a receiver

ENSURING FAIR SHARING OF THE UWB CHANNEL

By Yoram Solomon, Texas Instruments

The WiMedia UWB (ultra-wideband) approach comprises the PHY (physical) and MAC (media-access-control) layers. For applications above those layers, including Wireless USB, Wireless 1394, Wireless Internet protocol, and Bluetooth, the MAC provides access to the air medium through the PHY. Without a fairness policy, the MAC could grant an application access to the radio channel for as long as the application asks. Such unlimited access could, however, cause a serious problem. Several WiMedia links may be active within the same area, and all active links may simultaneously seek access to the radio channel. Because the UWB allocation offers a wide radio spectrum per channel, few channels are available to the links. Without the fairness policy, no device will likely get the desired channel access, and the resulting interference among channels will render all channels useless.

The fairness policy is a set of rules, typically implemented in firmware and running within the MAC. Those rules use the MAC services and ask for fair, effective, and efficient access to the medium. The policy takes into consideration the types of devices seeking access to the medium. Some devices and their links require isochronous access with guaranteed bandwidths and predictable service intervals for streaming multimedia. Other applications may require bulk transfers with low latency. Still others require low power consumption and mobility. The fairness policy's role is to ensure that the applications get the best possible aggregate access to the air channel in accordance with their special requirements.

The policy is also protocol-agnostic. Many protocols, such as those mentioned, can reside on this policy. The fairness policy uses the MAC services through built-in function calls–not according to the type of protocol. The function calls it uses depend on the type of service the application protocol requests and the current usage of the radio channel that the receiver detects. The fairness policy thus optimizes the applications' shared use of the radio channel.

WiMedia developed the MAC as it was developing the fairness policy. When developing this policy, WiMedia's technologists considered the ability to test each of the rules for compliance. Thus, vendors can test every WiMedia-compliant device for fairness-policy compliance. Such testing simulates or emulates an environment with multiple WiMedia devices seeking access to the radio channel while the device under test receives information to transmit. This approach enables testing of the behavior of the device and its adherence to the entire set of rules.

AUTHOR'S BIOGRAPHY

Yoram Solomon is the mobile-connectivity-solutions director for strategic marketing and industry relations at Texas Instruments. He serves on the Bluetooth special-interest group and the WiMedia board of directors and has served as a director of the WiFi Alliance.

or spectrum analyzer with a 50-MHz RBW. To my knowledge, only two units, one from Rhode and Schwarz and one from Agilent, provide both the required resolution and the dynamic range. They are costly and somewhat finicky, too."

John McCorkle, chief technologist of Freescale Semiconductor's UWB Organization, says, "Even with the proper instruments, it is easy to take too few measurements or to allow too little averaging time for rms measurements. To keep from missing narrowband spikes within bands of interest, measurements need to be spaced at 0.4 times RBW-frequency intervals. To obtain accurate rms readings, the detector should dwell at each frequency for 1 msec. If you sweep the frequency instead of changing it in steps, you must set the sweep speed to meet the 1-msec averaging-time requirement. Taken together, the frequency-interval and averaging-time requirements impose a not-insignificant minimum on the time required to perform a UWB emissions test."

Washington Labs' Violette adds, "The other critical aspect of the measurement is that achieving the necessary sensitivity in the GPS bands requires painstaking technique and a very-low-noise measurement path. Also, to get the signal level above the noise, you must place the measurement antenna unusually close to the unit under test. The limits are absolutely too conservative in the GPS bands—something like 30 dB below the general-emissions limits for other FCC-regulated devices, such as computers and other unintentional emitters."

ANOTHER VIEW

At press time, Peter Cain, an expert on UWB testing at Agilent and the author of an application note on the subject (**Reference 1**), commented, "FCC testing isn't the only issue. Regulatory testing is always a subset of the RF testing that a new radio design requires. Regardless of the technology, antenna-based testing always requires attention to detail; the same principles apply to UWB as apply to other [radio] technologies.

"I agree, though, that the levels tested for UWB are low and that you must exercise care to isolate signals not related to the UWB transmitter itself. Building low-noise amplifiers into spectrum analyzers is one way instrument manufacturers can remove the uncertainty of users trying to improvise noise-reduction techniques. Still, how low the emissions have to be depends on more than the other users of the band and the regulatory requirements. Placing the UWB transmitter or receiver near any other radio device or digital device with 'rich' emissions also has an impact. You can, however, desensitize either radio's receiver if the noise floor or out-of-band rejection isn't good enough.

"Before you go to the expense of booking a test at any test house, you should use the wide capabilities of your spectrum analyzer to understand what the device [under test] is doing. The FCC may have chosen certain ways of doing things, but that shouldn't prevent you from working in advance on ways to more quickly identify problems. If you expect your UWB device to be used near any other radio, it is very important to know how the two will interact.

"To overcome long measurement times, you can make the narrow-bandwidth and wide-span measurements with FFT-based techniques instead of swept-frequency ones. Using a 1-kHz RBW automatically guarantees a 1-msec measurement time because the measurement-time window has to be at least several milliseconds. With regard to the 50-MHz RBW requirement, I note that Wisair has just successfully gotten a device through FCC certification without using a 50-MHz RBW filter."

A MATTER OF PROTOCOL

James Wright, director of marketing at LeCroy's Protocol Solutions Group (formerly, CATC), says, "Protocol testing is [yet another] nontrivial area of UWB testing. WUSB will offer more variations and more operating modes than its wired counterparts and will require highly sophisticated protocol-test instruments." LeCroy's initial protocol-test offerings focus on Certified WUSB, a version of WUSB specified by the USB-IF (USB Implementers' Forum). Though the UWB Forum proposed a DS-UWB-based version of WUSB, the USB-IF based Certified WUSB V1.0 on MB-OFDM. Although this development didn't please the UWB Forum, the group still believes that DS-UWB will play an important role in WUSB's future.

Another piece of the UWB-testing puzzle is interoperability testing. The quickest way for developers of UWB products to determine whether their products exhibit interoperability problems is through "unplugfests"—the wireless equivalents of the "plugfests" that organizations responsible for wired protocols have used to great advantage. The events, which have good credibility with special-interest groups and manufacturers alike, bring together for hands-on trials developers of products that are supposed to communicate and work harmoniously with each other. When they detect problems, the developers try to find solutions, and it is not uncommon for competitors to assist one another. Although the WiMedia Alliance hasn't yet announced any unplugfest plans, some members expect that early in 2006 and maybe even sooner, the organization will hold its first such event. It almost certainly won't be the last. EDN

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+ In his editorial, "Branding the invisible," *EDN Europe* Editor Graham Prophet also takes a look at UWB. Read what Graham has to say at www.edn.com/article/CA484535.

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