

**IN FEBRUARY, THE FCC OPENED THE DOOR FOR ULTRAWIDE-BAND TRANSMISSIONS. AS VENDORS BEGIN TO REVEAL DETAILS OF THEIR FIRST SILICON, THE COMMUNICATIONS WORLD MAY NEVER BE THE SAME.**



# Ultrawideband: the next wireless panacea?

**U**WB (ultrawideband) differs from other RF technologies in that, instead of using a narrowband frequency carrier to transmit data, it sends pulses of energy across a spectrum of frequencies (Figure 1). The FCC (Federal Communications Commission) has defined that UWB transmissions fall within the frequencies of 3.1 to

10.6 GHz, with a minimum spectral width of 500 MHz, or 25% of the center frequency (3.5 to 4.5 GHz for a center frequency of 4 GHz). By dividing the power of the signal across a range of frequencies, the affect upon any frequency is below the acceptable noise floor for unintentional emitters that FCC Part 15 rules define. For example, 1W of power spread across 1 GHz of spectrum puts only 1 nW of power into each hertz band of frequency. A receiver collects the transmitted power across the spectrum to reconstruct the pulse. Thus, UWB can co-exist with other RF technologies, because it appears only as noise.

#### HOW DO YOU FIND THE SIGNAL?

Obviously, the pulses don't look like noise to a UWB receiver. You could call the pulse "shaped noise," because it is not flat but curves over the spectrum. Noise, in contrast, would look similar across a range of frequencies; in other words, it

would have no shape. For this reason, real noise, which may at times have the same intensity as the pulse, does not obliterate the pulse. Interference would have to spread uniformly across the entire spectrum to obscure the pulse. Interference in only part of the spectrum reduces the amount of overall signal that you can collect, but you can still recover enough of the pulse to restore or build the signal. Another important concept of UWB is that the signal is a function of time, not frequency. Frequency in UWB primarily determines propagation characteristics, such as the distance you can send a signal, because higher frequencies are more susceptible to fading, absorption, and other effects.

One of UWB's strengths is that vendors have targeted several applications for it right out of the chute. Because of its high data rate and range, UWB is particularly suited for transmitting multimedia data, such as for virtual PCs or multiple

*At a glance* ..... 52

*802.11 in trouble?* ..... 54

*For more information* ..... 56

portable HDTV monitors. Another key application is ranging. With a single receiver, you can determine the range of a transmitter; with three receivers you can use triangulation to determine position with a much higher degree of accuracy than a GPS (global positioning system). Examples of ranging products include proximity-detection devices, such as collision detectors in cars, and tracking devices, such as transmitters sewn into children's clothing. A third application class is radar and imaging. Because UWB uses a wide band of spectrum, the signal can more easily penetrate walls than can a narrowband frequency transmitter. Using ranging, a receiver can determine whether an object is moving. Real-world applications include rescue work, in which a UWB radar could detect a person's breathing beneath rubble.

Vendors use different methods to modulate data into the signal (Figure 2). In general, each method uses some form of PPM (pulse-position modulation), PAM (pulse-amplitude modulation), or a combination of both. PPM involves the placement of pulses in time. If you use a 1-nsec interval or window, for example, you can pulse as many as 1 billion times per second. If you group two consecutive windows, a pulse in the first window indicates a value of zero, and a pulse in the second window indicates a value of one. PPM4 uses four windows to define two bits, PPM8 uses eight windows to define four bits, and so on. You can also offset the pulse in time within a window, such as by 100 psec, to indicate a value of one. In another variation, OOK (on-off keying), the presence of a pulse indicates a value of one; no pulse indicates a value of zero. Multipath issues can make OOK challenging to use. PAM, on the other hand, defines values by changing the power of the pulse. PAM8, for example, uses eight levels of pulse amplitude to yield four bits.

One modulation scheme gaining wide acceptance is BPSK (binary-phase-shift keying), in which the phase of the signal (0 or 180°) determines bit value rather than position. Some vendors claim that BPSK offers a 3-dB advantage over PPM, because it maintains

**AT A GLANCE**

- ▶ UWB is appealing because it looks like noise to other RF technologies, supports multimedia data rates, and offers inherent data security.
- ▶ Proponents of UWB have yet to prove conclusively that, when properly implemented, it truly does appear as noise to other RF technologies.
- ▶ A UWB standard that supports interoperability between vendors and piconets between devices is still some way off.
- ▶ UWB has yet to undergo the scrutiny of the entire engineering community.

a lower peak power resulting in a higher average power.

Making the UWB signal appear as noise is actually a more complex process. For example, if you put out pulses at a regular interval, or PRF (pulse-repetition frequency), you could raise the noise floor on certain carriers and their harmonics. The signal needs to mimic white noise, which is random. Additionally, if you put pulses into more than a certain percentage of windows (some experts say more than 10%), your signal cannot generate enough pseudorandomness to appear as noise. (Note: One of the areas of contention in testing the effects of UWB on narrowband transmissions lies in whether the tests use PRF, thus making it appear that UWB is more disruptive than it would be if it were properly implemented.)

One method for boosting both signal integrity and security is to group several pulses into a code word to represent a

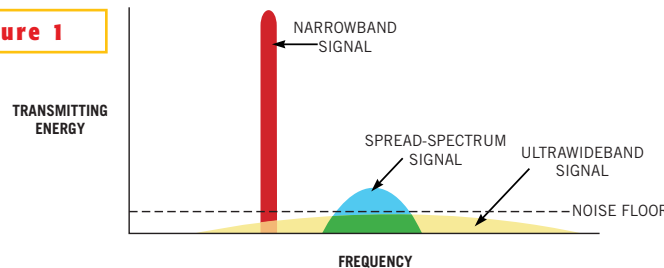
data value of one; the inverse of the code word represents zero. When the group of pulses appears, the receiver registers the value. Grouping several pulses per data bit increases the gain of the receiver. For example, if a receiver sees 9 bits of a 10-bit code, a reasonable possibility exists that an error occurred and that the code word was actually sent. Grouping pulses also makes it more difficult for someone without access to the code word to listen in on the transmission. Additionally, coded pulses can simultaneously support multiple users. To increase data integrity, the codes should be orthogonal; that is, two 10-bit codes should differ by more than one pulse to prevent confusion. Note that coding can be a dynamic characteristic, with the size of codes (number of pulses) increasing as distance increases, to boost the SNR. Certainly, you can implement other error-correction schemes to ensure signal integrity. Thus, overhead for error correction increases as the distance the signal travels—and the effects of fading—increase.

Power consumption depends greatly upon implementation, so UWB power quotes such as “uses one-eighth the power of 802.11” are suspect. True, UWB has a lower transmitting power than 802.11, because it sends short pulses instead of a continuous signal. Additionally, UWB can vary transmitting power based on the distance between nodes and access points. Most of these quotes, however, concern only transmitting power. Transmitting power is less important than total power, which includes the rest of the RF subsystem. UWB transmitting power is in the microwatts, but the chip set consumes milliwatts. Thus, IC power consumption more or less defines battery life, whereas transmitting-power control is more an issue of increasing the number of users in a space or adjusting for near-far differences, such as reducing power so that a closer device doesn't drown out a device that is farther away.

**THERE'S GOTTA BE A CATCH**

UWB isn't without difficulties. One technical challenge will be implementing accurate timing components, so correlated receivers can lock onto short

**Figure 1**



**Narrowband communications pack transmitting energy into a narrow spectrum. Ultrawideband communications spread transmitting energy across a wide spectrum of frequency, such that the energy in any frequency band is below the noise floor (courtesy XtremeSpectrum).**

pulses appearing randomly through time. Another challenge may be suppressing onboard microcontroller-unit noise; in narrowband systems, it's easier to remove such noise from the band than suppress it. Also, despite the theoretical advantages of reduced multipath inter-

ference—given the width of spectrum, you can often independently resolve multipath reflections rather than after they have combined destructively—multipath components could contain sufficient energy to warrant attention. There is also concern that narrowband trans-

missions can jam UWB receivers within the part of the spectrum that the narrowband transmission uses.

Not everyone views UWB as the wireless panacea. Supporters of narrowband-communications technologies offer strong resistance to UWB. At least one

## 802.11 IN TROUBLE?

A key question about UWB (ultrawideband) is whether it is complementary to technologies such as Bluetooth in the PAN (personal-area-network) space and 802.11 in the LAN (local-area-network) space. Most vendors say it is and that UWB fills the multimedia gap that 802.11 simply can't handle. Several of the larger vendors, most of whose UWB R&D efforts consist of watching the start-ups to see which ones they should buy, play UWB as "filling out their wireless portfolio." It almost seems as if vendors are trying to convince themselves that all of these technologies will coexist, so that they can sell lots of extra chips.

Vendors argue that each technology hits a "sweet spot," at which price and function perfectly match market needs and tolerances. Examples of such targeted devices are pop-up toasters and rice cookers. However, this argument fails to take into account whether consumers want a separate device for every sweet spot in their home. Some people eat a lot of toast. But for

most people, a toaster oven is more versatile and useful than a pop-up toaster. Vendors contend that the home of the future will have an 802.11 PC data network, a UWB link to an HDTV and stereo, and a Bluetooth PDA connection to a PC, just for starters. Certainly, the cost of the individual nodes will be optimal, but this model conveniently fails to account for all of the bridge devices between each of these networks, which increase the overall cost and number of boxes and significantly reduce ease of use. Will consumers be willing to pay slightly more per node but significantly less overall for a unified and single technology network? Put another way, if UWB can do the entire job, why not let it?

Supposedly, 802.11 has remarkable penetration into the market, and UWB, being late to the game, will be unable to compete with it. Yet, just how real is this penetration? Growth graphs show wonderful market numbers but reveal no detail about that growth (Figure A). For example, analysts often

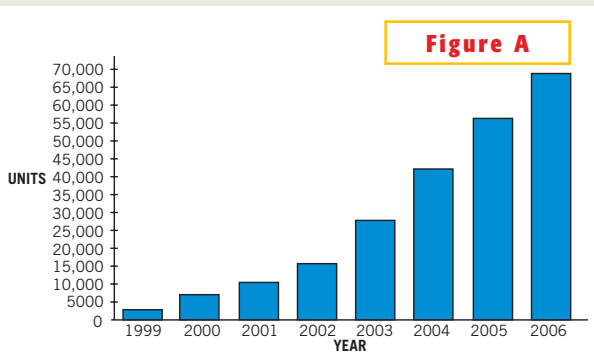
lump together 802.11a, 802.11b, and 802.11g figures. Because 802.11a and 802.11b are incompatible and often competing against each other, showing them as bolstering each other is misleading. The numbers also may fail to take into account the growth of other markets, such as 2.4-GHz phones, which sometimes cripple 802.11b networks. Security also affects the viability of a market. For example, 802.11 devices that cannot support security patches are obsolete and should be replaced, so you should not consider them part of the infrastructure. Security will also reduce effective bandwidth and, thus, appeal. Additionally, according to Gemma Paulo of Instat/MDR, WiFi (Wireless Fidelity, 802.11) has made only small gains into the corporate enterprise, which may recognize the usefulness of wireless for its few road warriors but questions the need for wireless for the employees stationed in cubicles. Prime WiFi applications are in fact verticals: education, health care, retail, and manufacturing. These areas are generally not considered to be horizontal corporate LANs. With the large volume of low-end WiFi equipment shipping to the business market, however, many believe that WiFi often manifests itself as a small rogue subnet, meaning that an employee who loves his or her wireless network at home installs one on company premises, often without the company's knowledge or permission.

The 802.11 standard also faces challenges in

multistory/vertical networks because it puts the onus of not interfering with the network on the user. Even if you don't install a 2.4-GHz phone, because you don't want it trashing your 802.11b network, your neighbor or the company upstairs might. With 802.11, you need to consider the amount of control the user has over the environment. UWB, on the other hand, doesn't yet appear to have these kinds of vulnerabilities. Additionally, many think that UWB will reach multigigabit data rates within the next five years.

Chances are, UWB and 802.11 will coexist in the near term, especially with the enthusiasm of larger chip vendors, who are pushing both technologies—UWB for short-range applications and 802.11 for longer range ones. In the long term, however, UWB promises to put 802.11 under a great deal of pressure. Economies of scale aside, UWB—unlike other RF technologies—does not require components such as mixers, filters, RF/IF converters, and local oscillators, because it does not modulate and demodulate a complex carrier waveform.

Therefore, UWB consumes less power, resulting in longer battery life and a shorter path to integrated CMOS. Additionally, the first incarnation of UWB promises to exceed the next generation of 802.11, meaning UWB has even more room to grow. To add another wrinkle, UWB is a physical-layer technology. Nothing says you can't run an 802.11 or Bluetooth MAC over UWB if protocol is really that important.



**The home-networking market promises to be a prime driver of RF technologies. Of all RF nodes, 802.11 is projected to dominate more than 90% of the market through 2006 (courtesy Instat/MDR).**

cell-phone vendor claims that UWB could lead to more dropped calls and even lower the number of calls that a network could handle. The NTIA (National Telecommunications Information Administration) claims to have shown that UWB could make it more difficult for GPS receivers to lock onto satellites. And NASA suggests that UWB could interfere with flight instruments on airplanes. UWB proponents suggest that such tests have looked at worst-case instead of typical-usage scenarios.

Thus, early developers of UWB have an incentive to develop and promote “good-neighbor” policies. Some feel that the FCC chose the 3.1- to 10.6-GHz range to prove that UWB has a negligible impact on narrowband systems in the higher frequencies. If all goes well, the FCC may loosen frequency restrictions, most significantly increasing UWB’s range. Others feel that the choice was political. Given that higher frequencies are more susceptible to absorption, forcing UWB to operate at higher frequencies limits its effective range, making it less of a threat to 802.11 and other technologies (see sidebar “802.11 in trouble?”).

One method of reducing narrowband interference is “notching” the spectrum that UWB uses, avoiding those parts of the spectrum that narrowband signals occupy. Notching offers an interesting trade-off. By giving up a notch of spectrum, the effective error rate for that spectrum becomes 100%, and no data is sent. However, the processing that might

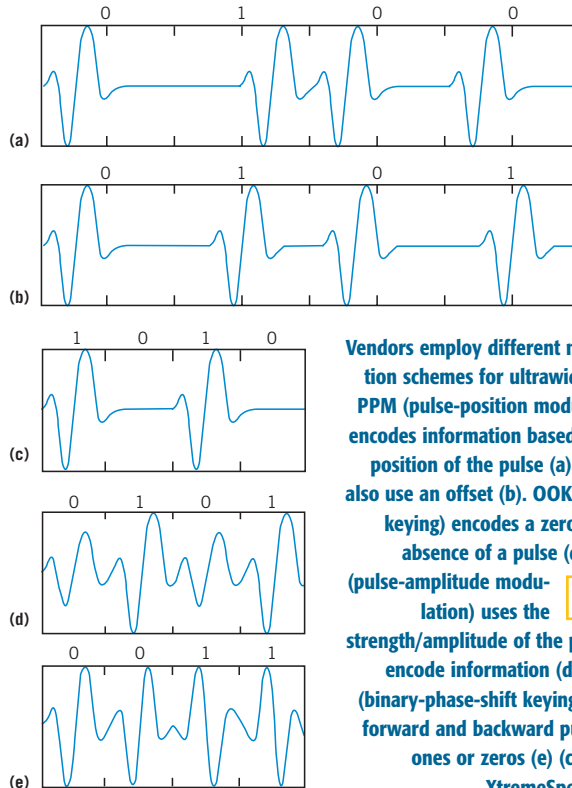
have been required to clean up the signal within that notch only to recover a portion of the available bandwidth may add more cost than the recovered bandwidth is worth. Notching makes particular sense in applications such as UWB/802.11a bridges, in which the proximity of the two radios makes minimizing interference difficult.

Still in the works is how multiple UWB devices will share bandwidth, as well as how multiple UWB networks of the PAN (personal-area-network) and LAN (local-area-network) variety will overlay each other. To some degree, each UWB device speaks its own language. Access points are based on timing, coding, characteristics of the modulation

scheme, and other factors. As such, independent UWB networks can coexist. However, depending on which modulation schemes are in use, an access point might be unable to distinguish which pulse came from which device or vice versa. Additionally, two devices could pulse in a complementary fashion that resembles a PRF over a series of pulses, exceeding the noise floor. There’s also the near-far problem to solve. In a near-far situation, the signal received from a device near an access point drowns out a signal from a device farther away; control of transmitting power allows the near device to “lower its voice,” so to speak. To make optimal use of the bandwidth, as well as support QOS (quality of service) and multimedia services, devices need to know about each

other and cooperate.

Several techniques for sharing bandwidth are under consideration. Timesharing requires no coordination between devices, because devices transmit using pseudorandom patterns. Collisions between devices and nonoptimal use of bandwidth are a regular part of timesharing, as is required synchronization between devices and the shared access point to establish timing and patterns. TDMA (time-division-multiple-access) schemes, which allocate dedicated time slots to each user, and CDMA (code-division-multiple-access) schemes, which assign codes and scrambles bits, are other candidates that more efficiently use bandwidth but require more processing and, thus, cost more.



**Vendors employ different modulation schemes for ultrawideband. PPM (pulse-position modulation) encodes information based on the position of the pulse (a); it may also use an offset (b). OOK (on-off keying) encodes a zero by the absence of a pulse (d). PAM (pulse-amplitude modulation) uses the strength/amplitude of the pulse to encode information (c). BPSK (binary-phase-shift keying) reads forward and backward pulses as ones or zeros (e) (courtesy XtremeSpectrum).**

**Figure 2**

**FOR MORE INFORMATION...**

For more information on products such as those discussed in this article, go to [www.edn.com/info](http://www.edn.com/info) and enter the reader service number. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

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Currently, none of these schemes has overwhelming support over the others.

**STANDARDS**

An important step in gaining acceptance for UWB will be the development of standards and careful design strategies with certification to ensure peaceful coexistence with narrowband technologies. The primary standard involving UWB is 802.15, which focuses on the wireless PAN. Other standards include 802.1 for Bluetooth, 802.3a for UWB, and 802.4 for ZigBee, another wireless standard. The QPSK-based 802.15.3 standard will share a MAC (media-access controller) with 802.3a. One goal of the group is to develop wireless distribution of video over short distances. The 802.3a standard will include piconet definitions, in which devices share the available aggregate bandwidth. Some experts expect a maximum of six piconets to be able to coexist in the same airspace. Another area ripe for standardization is the modulation scheme to ensure device and vendor interoperability. Interoperability is critical if UWB proponents hope to follow in the steps of 802.11, with its highly successful WiFi (Wireless Fidelity) interoperability branding campaign. However, given the youth of the industry, vendors can still probably count on selling both the access point and the node until one modulation technique gains critical mass.

The reality of UWB is beginning to come into focus. XtremeSpectrum, for example, is offering its Trinity chip set for sampling. (The company expects volume production to begin in the second quarter of 2003.) The \$19.95 chip set can transmit 100 Mbps across 10m using 200 mW. The company projects that the total bill of materials, including discrettes, antenna, and interface, will be \$21. Pulse Link promises a \$30 discrete radio by the end of 2003 that can transmit 400 Mbps as far as 10m and 8 Mbps as far as 500 ft (albeit at 50% error-correction overhead). The company hopes to spin an ASIC that can send 1 Gbps as far as 10m by next year. Optimistic projections place availability of first end-user products during Christmas 2003; perhaps more realistic minds say 2004, allowing time for a standard to be completed. Given the high entry price, UWB appears to be more suitable for higher end items than, say, a consumer-grade MP3 player. Obviously, prices will drop as volumes rise and

vendors move to single-chip CMOS implementations.

Note that UWB is not limited to RF applications. Work is already under way to demonstrate UWB over coax. Because coax is a shielded media, FCC spectral restrictions don't apply. Early results suggest maximum data rates of 2 Gbps over 1500 to 2000 ft of cable and through repeaters. If successful, UWB could ride over the existing infrastructure, boasting data rates of a few gigabits per second without interfering with legacy connections. Work with twisted pair shows 10 to 30 Mbps over as much as 20,000 ft. Twisted pair, however, is unshielded, so the wire turns into an antenna.

The floodgates of hype for UWB are about to break open, making it difficult to distinguish the realistic claims of vendors that actually have silicon from the exciting speculation of vendors who want to play in the market. The list of vendors actually developing UWB products today is small, as are the sizes of the companies on this list, and their applications are scattered.

Currently, the available information on UWB is limited to its wondrous advantages. This imbalance is due partially to the fact that the technology is only just becoming available to those in the engineering community with enough expertise to ferret out and discover UWB's vulnerabilities. These discoveries will come in time—unless, UWB really is the wireless panacea that some claim. □

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