Emerging Wireless Technologies

Ultra Wideband Communications

Foreword: The Public Safety Wireless Network (PSWN) Program is conducting an ongoing assessment of advancements in the wireless communications industry. The scope of this assessment is to identify emerging wireless services and technologies for potential public safety use in the near future and beyond. This document is the fourth in a series of studies on emerging wireless technologies. This particular document concentrates on ultra wideband (UWB) communications, their applications, and their impact on the public safety community.

Overview

Ultra wideband (UWB) technology can be defined as any wireless transmission scheme occupying a bandwidth of more than 1.5 gigahertz (GHz). The Federal Communications Commission (FCC) is currently working on setting emissions limits allowing deployment of UWB communications systems on an unlicensed basis following the Part 15.209 rules for radiated emissions of intentional radiators. (Note: Part 15.209 contains the rules governing the radiated emissions from devices such as desktop computers.) This rule change would allow UWB-enabled devices to operate with existing narrowband systems using the same spectrum. Overlaying spectrum on existing bands is currently not allowed. This overlay method will result in much more efficient use of the available spectrum. These recent actions by the FCC give commercial vendors a unique opportunity to develop equipment that could potentially take advantage of the vast amount of usable spectrum that exists in the wireless space. Further, these actions could drive development of high data rate applications now being conceived throughout the wireless industry.

Introduction to UWB Technology

UWB technology has been around since the 1980s, but has been used primarily for radar-based applications. However, recent developments in high-speed switching technology are making UWB technology more attractive for low-cost consumer communications applications. Commercial entities, such as Intel and IBM, are currently working on internally funded research projects whose intent is to further explore the potential benefits and future challenges associated with extending UWB technology into the high-rate communications arena. The FCC has not made a final ruling on the future of UWB technology, but it is currently working on setting emissions limits that would allow deployment of UWB communications systems on an unlicensed basis.

What is Ultra Wideband?

UWB radio is a revolutionary communications mechanism that uses high-frequency microwave pulses for transmitting digital data over a wide spectrum of frequency bands with very low power intensity. It can transmit data at very high rates (for wireless local area network applications) and very low rates (for telemetry applications). Within the power limit allowed under the current FCC regulations, UWB radios can carry large amounts of data over a short distance, at very low power. In addition, it has the

ability to carry signals through doors and other obstacles that tend to reflect signals at more limited bandwidths and at higher power levels. At higher power levels, UWB signals can travel significantly greater ranges.

Instead of transmitting traditional sine wave signals, UWB radio broadcasts digital pulses timed very precisely on a signal across a very wide spectrum. The transmitter and receiver must be coordinated to send and receive pulses with an accuracy of trillionths of a second. Very high-resolution radars and precision (sub-centimeter) radio location systems can also use UWB technology.

The effect of transmitting high speed pulses instead of sine waves gives UWB transmissions a degree of immunity to multipath fading. Multipath fading is the constructive and destructive interference created by multiple reflections of the same signal being received simultaneously. This favorable multipath fading capability makes UWB technology well suited for applications in environments that would otherwise suffer from multipath fading with sine wave transmissions.

UWB devices work inside the same increasingly crowded radio frequencies that many other systems use. They send out short electromagnetic pulses that last half a billionth of a second, followed by pauses that are perhaps 200 times that length. By spreading the pulses over a wide area of the spectrum (roughly 1 GHz), the devices use extremely low power and little total bandwidth. Many supporters of UWB technology envision applications such as home security and personal-area networks that activate home appliances when the user nears them. Police and fire departments are already trying out devices that can detect people behind walls.

Government and Industry Interest in UWB Technology

The government and commercial industry are expressing great interest in UWB technology. For example, two main UWB applications of interest are the transmission of large amounts of voice and data at very high speeds requiring very little power, and radars capable of penetrating walls and providing detailed views from "behind" the wall. In addition, the ability to define the precise location of hidden objects to within 1 inch is of interest to military, law enforcement, and rescue agencies. In response, the FCC approved limited productions of UWB radars for police and rescue workers.

With these new applications, the wireless industry is interested in UWB technology's potential to—

- ***End spectrum congestion.*** The wireless industry is currently experiencing limited spectrum availability. To compound this problem, the wireless industry is seeking room in the already congested spectrum to introduce next-generation services. Competition is high for the limited available spectrum, as is the cost for licensing. Users of UWB devices operating in a single channel do not need a license.
- ***Eliminate interference from signals reflecting off buildings or walls and congested cell sites.*** According to one estimate, with this technology in place, more than 20,000 people can use UWB cell phones in the same square block without interference. UWB devices would be virtually immune to interference because UWB signals can penetrate walls and other obstructions, eliminating a major source of multipath interference.

- ***Provide secure transmissions.*** UWB devices transmit millions of coded pulses per second at emissions below the noise floor and across an ultra wide bandwidth using receiver/transmitter pairs communicating with a unique timing code. These transmissions have a very low radio frequency signature, providing intrinsically secure transmissions with low probability of detection and low probability of interception.
- ***Reduce power consumption dramatically.*** One vendor, Time Domain, has developed a chip that consumes only 0.05 milliwatts of power compared with the hundreds of milliwatts used by today's cell phones. This reduced power consumption leads to longer battery life.

Major Participants in UWB Research

For a company to participate in the production and retailing of UWB devices, it must obtain permission from the FCC and National Telecommunication and Information Administration (NTIA). Recently, U.S. Radar Inc., Time Domain, and Zircon Corporation collectively petitioned the FCC for a waiver of Part 15 of the Commission rules. The FCC and NTIA responded favorably. These waiver requests were beneficial to the FCC and NTIA because they alerted the FCC of the vast potential of UWB technology. With a waiver, these companies can develop and manufacture UWB-enabled products and devices in response to market demand, albeit with certain FCC limitations.

After careful consideration, the NTIA, in coordination with the Interdepartment Radio Advisory Committee (IRAC) granted U.S. Radar Inc., Time Domain, and Zircon Corporation waivers to assess UWB devices. NTIA also granted this request to help both the FCC and the NTIA assess the overall value of the UWB devices.

With waivers granted, UWB companies were eager to begin developing products using UWB technology. For example, U.S. Radar Inc. specializes in ground-penetrating UWB technology. It is currently investigating UWB technologies that will assist law enforcement and public agencies in detecting buried bodies. Likewise, Zircon Corporation, which is best known for its Stud Sensor tool, is working on a similar device that lets construction engineers detect steel girders and other metal objects inside concrete. Time Domain develops UWB chips, called PulsON. Its product is RadarVision, a device firefighters can use to detect the location of people in burning buildings, or police can use to find criminals in hiding.

FCC Regulatory and Standard Issues

FCC is in the process of determining the feasibility of UWB transmissions. Due to the wideband nature of UWB emissions, UWB transmissions could interfere with other licensed bands in the frequency domain if left unregulated. The FCC must walk a fine line. It must satisfy the need for more efficient methods of using available spectrum (as represented by UWB devices), while not causing potential interference for those currently using the spectrum (as represented by users holding licenses in certain frequency bands). In general, the FCC is interested in making the most of the available spectrum, as well as trying to foster competition among different technologies.

In May of 2000, the FCC issued a Notice of Proposed Rule Making (NPRM) that solicited feedback from the industry on specific rule changes that could allow UWB emitters under the Part 15 rules. Industry demonstrated significant interest in the rule-making process by filing more than 500

comments since the first Notice of Inquiry (NOI).

Figure 1 below shows how the current NPRM would limit UWB transmitted power spectral density[1] (PSD) for frequencies greater than 2 GHz. Under the NPRM, UWB devices can transmit at powers no greater than -41 decibels/megahertz (dBm/MHz) at any frequency higher than 2 GHz. The PSD of UWB transmissions are extremely small. In comparison, the PSD of UWB transmissions are less than the electrical noise generated and emitted by a common hair dryer.

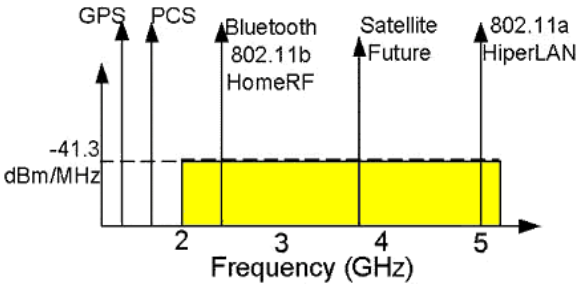

Figure 1: Power spectral density limits in the current FCC NPRM

Other UWB Challenges

FCC restrictions are only one limiting factor to the acceptance of UWB technology. To develop approaches for coexistence within operational scenarios important for the industry, further coordination through standards participation will be necessary. For example, if UWB is to be used as a personal area network (PAN) technology in close proximity to an IEEE 802.11a[2] local area network (LAN), then developers must design the UWB system to coexist openly with the LAN. This can only be achieved through industry involvement and standards participation, as well as careful designs.

The National Telecommunications and Information Administration (NTIA) has conducted testing of UWB transmissions. The studies were to investigate the interference effects that UWB signals may have with the Global Positioning System (GPS) already in existence. The results of the NTIA study have concluded that there are some interference effects between UWB and GPS transmissions. This conclusion is bounded by the fact that it would take a large number of UWB devices transmitting all at once to fully disrupt a GPS receiver's lock with a satellite.

Ultra Wideband Applications

According to a Time Domain executive, if and when the FCC makes a final ruling, UWB technology can enable a number of remarkable uses. What is significant about this technology is that it has positioning, radar, and radio capabilities all rolled into one. For example, Time Domain is developing chips for a golf product called Caddy—a device that precisely measures the distance from tee to hole. This ability to determine precise ranging can be applied to law enforcement activities such as hostage standoff situations.

In addition, home security and home entertainment systems could become wireless using UWB technology. To be specific, one company is investigating a home security bubble that can detect the difference between an insect, a small pet, and person that could be an intruder. It could also detect one's pending arrival home (thanks to a small identification card that is worn, perhaps, on a belt) and open the garage door as the driver pulls in. The transparent feature of this technology might detect an intruder in the garage and forewarn the homeowner in his/her car, while trapping the person by keeping the door closed. In

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[1] *Power spectral density—For a specified bandwidth of radiation consisting of a continuous frequency spectrum, the total power in the specified bandwidth divided by the specified bandwidth*

[2] *For more information on IEEE 802.11a, please refer to the third installment in this series, "Emerging Wireless Technologies: High-Speed Wireless LANs and Internet Protocols of Tomorrow"*

the same way, home entertainment systems could become wireless using ultra wideband technology. Time Domain has developed a prototype that users can carry with them throughout their homes to transmit preferred programming to televisions. The televisions could recognize the user and automatically turn on his/her favorite channels.

Furthermore, UWB will have to coexist with many other legacy technologies. One of UWB technology's characteristics is that it is not capable of transmission over long distances. As a result, it is not expected to replace existing cellular/personal communications services (PCS) technologies, but will complement them by providing a bandwidth option inside buildings and homes. When a cell phone user enters an UWB-equipped building, that user's phone connection might switch automatically from the cellular tower to a UWB transmitter attached to a private branch exchange (PBX) system. With this technology in place, wireless communication can make more efficient use of the finite radio channels.

These are only a few innovative illustrations of ultra wideband's potential. There are many more practical applications of UWB technology of interest to the military/government and to commercial entities, as shown below in Figure 2.

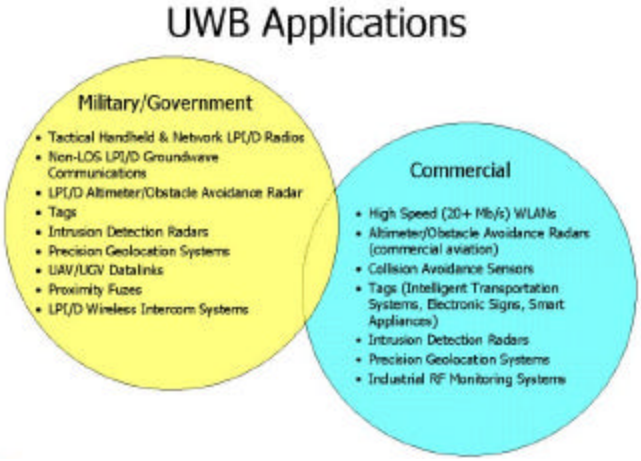

Figure 2

Impacts on Public Safety

UWB devices will greatly benefit the public safety community. It's ability to "see through" concrete and other debris will be extremely helpful in search and rescue operations.

Because location can be determined through walls to within inches or less, vendors are developing applications for firefighters. Portable (possibly ladder-mounted) UWB devices could be placed outside a burning building, while firefighters wear very small, transmitter devices. These small devices would allow the ladder mounted radio to accurately pinpoint the position of firefighters from outside of the burning building. This combination would allow for navigation and communications inside a smoke-filled building where there is little or no visibility.

Some key characteristics of UWB technology is that UWB signals are transmitted with very low power, and at a very fast rate. These characteristics make UWB signal very hard to detect and intercept. Low probability of interception (LPI) and low probability of detection (LPD) characteristics of UWB signals would make it an attractive alternative for tactical operations communications.

These are just a few UWB applications that would help the public safety community. By working with UWB developers, public safety agencies could suggest mission-specific applications that could become reality.

Conclusion and Future Challenges

In this article, the following topics were discussed: the promise of UWB technology, FCC regulation issues, participating organizations, and applications in high-data

rate, short- to medium-range communications. The benefits of UWB applications include potential low-cost implementations, low-power consumption applications, high throughput afforded by the wide bandwidth, accurate position location that could be combined with communications capabilities, and favorable multipath fading capabilities because of the nature of the short impulse.

However, there are still challenges in making this technology live up to its full potential. The regulatory process is still in motion. Several companies in the wireless market are involved in helping the FCC identify emission limits favorable to UWB systems. These limits allow the systems to be competitive within the marketplace, while, at the same time, prohibiting them from causing an unacceptable level of interference for other wireless services sharing the same frequency band. FCC regulators are in the beginning phase of assessing the usability of the UWB technology, and it is anticipated that standardization will be needed in the future to help make this technology widely available in the consumer market.

This article has also identified some unique applications that will help UWB technology developers make the best use of this newly available spectrum. One main recipient of this innovative technology will be the public safety community. If the FCC rules support the continued development of UWB technology, the decision could drive the development of high data rate applications now being conceived throughout the wireless industry.

Postscript: The purpose of this article is to further educate the reader regarding advancements in ultra wideband technology and its impacts to public safety. In upcoming articles, other developments in emerging wireless technologies (e.g., E911, wireless priority access) will be presented.

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