Ultra-wideband

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Ultra-wideband (aka UWB, ultra-wide band, ultraband, etc.) is a radio technology that can be used at very low energy levels for short-range high-bandwidth communications by using a large portion of the radio spectrum. UWB has traditional applications in non-cooperative radar imaging. Most recent applications target sensor data collection, precision locating and tracking applications. [citation needed]

UWB communications transmit in a way that doesn't interfere largely with other more traditional narrowband and continuous carrier wave uses in the same frequency band. However first studies show that the rise of noise level by a number of UWB transmitters puts a burden on existing communications services. This may be hard to bear for traditional systems designs and may affect the stability of such existing systems. [citation needed]

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Overview

Ultra-Wideband (UWB) is a technology for transmitting information spread over a large bandwidth (>500 MHz) that should, in theory and under the right circumstances, be able to share spectrum with other users. Regulatory settings of FCC are intended to provide an efficient use of scarce radio bandwidth while enabling both high data rate "personal area network" (PAN) wireless connectivity and longer-range, low data rate applications as well as radar and imaging systems.

Ultra Wideband was traditionally accepted as pulse radio, but the FCC and ITU-R now define UWB in terms of a transmission from an antenna for which the emitted signal bandwidth exceeds the lesser of 500 MHz or 20% of the center frequency. Thus, pulse-based systems—wherein each transmitted pulse instantaneously occupies the UWB bandwidth, or an aggregation of at least 500 MHz worth of narrow band carriers, for example in orthogonal frequency-division multiplexing (OFDM) fashion—can gain access to the UWB spectrum under the rules. Pulse repetition rates may be either low or very high. Pulse-based UWB radars and imaging systems tend to use low repetition rates, typically in the range of 1 to 100 megapulses per second. On the other hand, communications systems favor high repetition rates, typically in the range of 1 to 2 giga-pulses per second, thus enabling short-range gigabit-per-second communications systems. Each pulse in
a pulse-based UWB system occupies the entire UWB bandwidth, thus reaping the benefits of relative immunity to multipath fading (but not to intersymbol interference), unlike carrier-based systems that are subject to both deep fades and intersymbol interference. [citation needed]

**Concept**

A significant difference between traditional radio transmissions and UWB radio transmissions is that traditional systems transmit information by varying the power level, frequency, and/or phase of a sinusoidal wave. UWB transmissions transmit information by generating radio energy at specific time instants and occupying large bandwidth thus enabling a pulse-position or time-modulation. The information can also be imparted (modulated) on UWB signals (pulses) by encoding the polarity of the pulse, the amplitude of the pulse, and/or by using orthogonal pulses. UWB pulses can be sent sporadically at relatively low pulse rates to support time/position modulation, but can also be sent at rates up to the inverse of the UWB pulse bandwidth. Pulse-UWB systems have been demonstrated at channel pulse rates in excess of 1.3 giga-pulses per second using a continuous stream of UWB pulses (Continuous Pulse UWB or "C-UWB"), supporting forward error correction encoded data rates in excess of 675 Mbit/s. [1] Such a pulse-based UWB method using bursts of pulses is the basis of the IEEE 802.15.4a (http://www.ieee802.org/15/pub/TG4a.html) draft standard and working group, which has proposed UWB as an alternative PHY layer.

One of the valuable aspects of UWB radio technology is the ability for a UWB radio system to determine "time of flight" of the direct path of the radio transmission between the transmitter and receiver at various frequencies. This helps to overcome multi path propagation, as at least some of the frequencies pass on radio line of sight. With a cooperative symmetric two-way metering technique distances can be measured to high resolution as well as to high accuracy by compensating for local clock drifts and stochastic inaccuracies. [citation needed]

Another valuable aspect of pulse-based UWB is that the pulses are very short in space (less than 60 cm for a 500 MHz wide pulse, less than 23 cm for a 1.3 GHz bandwidth pulse), so most signal reflections do not overlap the original pulse, and thus the traditional multipath fading of narrow band signals does not exist. However, there still is multipath propagation and inter-pulse interference for fast pulse systems which have to be mitigated by coding techniques. [citation needed]

**Uses**

The UWB characteristics are very well suited to short-distance applications. A representative case is for PC Peripherals; see Wireless USB (implemented on top of UWB).

**Regulation**

Ultra-Wideband (UWB) may be used to refer to any radio technology having bandwidth exceeding the lesser of 500 MHz or 20% of the arithmetic center frequency, according to Federal Communications Commission (FCC). A February 14, 2002 Report and Order by the FCC [2] authorizes the unlicensed use of UWB in the range of 3.1 to 10.6 GHz. The FCC power spectral density emission limit for UWB emitters operating in the UWB band is -41.3 dBm/MHz. This is the same limit that applies to unintentional emitters in the UWB band, the so called Part 15 limit. However, the emission limit for UWB emitters can be significantly lower (as low as -75 dBm/MHz) in other segments of the spectrum.

More than four dozen devices have been certified under the FCC UWB rules, the vast majority of which are radar, imaging or locating systems[citation needed].

There has been much concern over the interference of narrow band signals and UWB signals that share the same spectrum; traditionally the only radio technology that operated using pulses was spark-gap transmitters, which were banned due to excessive interference. However, UWB is much lower power. The subject was extensively covered in the proceedings that led to the adoption of the FCC rules in the US, and also in the meetings relating to UWB of the ITU-R that led to the ITU-R Report and Recommendations on UWB technology. In particular, many common pieces of equipment emit impulsive noise (notably hair dryers) and the argument was successfully made that the noise floor would not be raised excessively by wider deployment of wideband transmitters of low power.

Theoretical discussion

One performance measure of a radio in applications like communication, locating, tracking, and radar, is the channel capacity for a given bandwidth and signaling format. Channel capacity is the theoretical maximum possible number of bits per second of information that can be conveyed through one or more links in an area. According to the Shannon–Hartley theorem, channel capacity of a properly encoded signal is proportional to the bandwidth of the channel and to the logarithm of signal-to-noise ratio (SNR)—assuming the noise is additive white Gaussian noise. Thus channel capacity increases linearly by increasing bandwidth of the channel to the maximum value available, or equivalently in a fixed channel bandwidth by increasing the signal power exponentially. By virtue of the huge bandwidths inherent to UWB systems, huge channel capacities could be achieved in principle (given sufficient SNR) without invoking higher order modulations that need very high SNR to operate.

Ideally, the receiver signal detector should match with the transmitted signal in bandwidth, signal shape and time. Any mismatch results in loss of margin for the UWB radio link.

Channelization (sharing the channel with other links) is a complex problem subject to many practical variables. Typically two UWB links can share the same spectrum by using orthogonal time-hopping codes for pulse-position (time-modulated) systems, or orthogonal pulses and orthogonal codes for fast-pulse based systems.

Current forward error correction technology, as demonstrated recently in some very high data rate UWB pulsed systems (like Low density parity check code) can — perhaps in combination with Reed–Solomon error correction — provide channel performance very closely approaching the Shannon limit (See Shannon–Hartley theorem). When stealth is required, some UWB formats (mainly pulse-based) can fairly easily be made to look like nothing more than a slight rise in background noise to any receiver that is unaware of the signal’s complex pattern.[citation needed]

Multipath (distortion of a signal because it takes many different paths to the receiver) is an enemy of narrow-band radio. It causes fading where wave interference is destructive. Some UWB systems use "rake" receiver techniques to recover multi path generated copies of the original pulse to improve performance of the receiver. Other UWB systems use channel equalization techniques to achieve the same purpose. Narrow band receivers can use similar techniques, but are limited due to the poorer resolution capabilities of narrow band systems.

Multiple antenna technologies

- Distributed MIMO: To increase the transmission range, this scheme exploits distributed antennas among different nodes.
- Multiple antenna: Multiple antenna schemes such as MIMO have been used to increase the system throughput and the reception reliability. Since UWB has almost impulse-like channel response, the
Combination with multiple antenna techniques is preferable as well. Coupling MIMO spatial multiplexing with UWB's already high throughput gives the possibility of short-range networks with multi-gigabit rates.

Applications

Due to the extremely low emission levels currently allowed by regulatory agencies, UWB systems tend to be short-range and indoors applications. However, due to the short duration of the UWB pulses, it is easier to engineer extremely high data rates, and data rate can be readily traded for range by simply aggregating pulse energy per data bit using either simple integration or by coding techniques. Conventional OFDM technology can also be used subject to the minimum bandwidth requirement of the regulations. High data rate UWB can enable wireless monitors, the efficient transfer of data from digital camcorders, wireless printing of digital pictures from a camera without the need for an intervening personal computer, and the transfer of files among cell phone handsets and other handheld devices like personal digital audio and video players. [citation needed]

UWB is used as a part of location systems and real time location systems. The precision capabilities combined with the very low power makes it ideal for certain radio frequency sensitive environments such as hospitals and healthcare. Another benefit of UWB is the short broadcast time which enables implementers of the technology to install orders of magnitude more transmitter tags in an environment relative to competitive technologies. U.S.-based Parco Merged Media Corporation was the first systems developer to deploy a commercial version of this system in a Washington, DC hospital.[citation needed]

UWB is also used in "see-through-the-wall" precision radar imaging technology[4], precision locating and tracking (using distance measurements between radios), and precision time-of-arrival-based localization approaches. [5] It exhibits excellent efficiency with a spatial capacity of approximately $10^{13}$ bit/s/m². [citation needed]

UWB has been a proposed technology for use in personal area networks and appeared in the IEEE 802.15.3a draft PAN standard. However, after several years of deadlock, the IEEE 802.15.3a task group[6] was dissolved[7] in 2006. The work was completed by the WiMedia Alliance and the USB Implementer Forum. Slow progress in UWB standards development, high cost of initial implementations and performance significantly lower than initially expected are some of the reasons for the limited success of UWB in consumer products, which caused several UWB vendors to cease operations during 2008 and 2009[8].

See also

- Narrowband
- Wideband
- Broadband
- Bluetooth
- Channel Coding
- Network
- DASH7
- DAA
- Energy harvesting
- FM-UWB
- IEEE 802.15
- MIIM
- Modulation Methods
- Real-time locating
- Spark-gap transmitter
- Spread spectrum
- TransferJet
- Wideband
- Wireless USB
- ZigBee
- WiMedia Alliance
- Wireless FireWire
- Orthogonal frequency-division multiplexing (OFDM)
- Phase-shift keying (PSK)
- Pulse-position modulation (PPM)

References
External links

Standardization

- IEEE 802.15.4a Includes a C-UWB physical layer, may be obtained from [1] (http://www.ieee.org)
- Standard ECMA-368 High Rate Ultra Wideband PHY and MAC Standard (http://www.ecma-international.org/publications/standards/Ecma-368.htm)

Regulations

- Use of MIMO techniques for UWB (http://www.mprg.org/research/UWB/uwb_MIMO.html)

Resources

- Numerous useful links and resources regarding Ultra-Wideband and UWB testbeds (http://wcsp.eng.usf.edu/UWB_links.html) – WCSP Group – University of South Florida (USF)
- The Ultra-Wideband Radio Laboratory at the University of Southern California (http://ultra.usc.edu/)
- DGPS + UWB (http://uc.gpsworld.com/gpsuc/Personal+Navigation/DGPS---UWB/ArticleStandard/Article/detail/585104)


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