Ultra-wideband (also **UWB**, and **ultra-wide-band**, **ultra-wide band**, etc.) may be used to refer to any radio technology having bandwidth larger than 500 MHz or 20% of the center frequency, according to Federal Communications Commission (FCC). This article discusses meaning of Ultra-wideband in the field of radio communications.

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. A February 14, 2002 Report and Order by the FCC [1] authorizes the unlicensed use of UWB in **3.1–10.6 GHz**. This is intended to provide an efficient use of scarce radio bandwidth while enabling both high data rate *personal-area network* (PAN) wireless connectivity as well as longer-range, low data rate applications as well as radar and imaging systems. More than four dozen devices have been certified under the FCC UWB rules, the vast majority of which are radar, imaging or positioning systems. Deliberations in the International Telecommunication Union Radiocommunication Sector (ITU-R) have resulted in a Report and Recommendation on UWB in November of 2005. National jurisdictions around the globe are expected to act on national regulations for UWB very soon.

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 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.

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.

A significant difference between traditional radio transmissions and UWB radio transmissions is that traditional transmissions transmit information by varying the power/frequency/and or phase of a sinusoidal wave. UWB transmissions can transmit information by generating radio energy at specific time instants and occupying large bandwidth thus enabling a pulse-position or time-modulation. But also information can be imparted (modulated) on UWB signals (pulses) by encoding the polarity the pulse, by the amplitude of the pulse, and/or also 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, supporting forward error correction encoded data rates in excess of 675 Mbps. Such a pulse-based UWB method using burst of pulses is the basis of the IEEE 802.15.4a 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 to a high resolution. With a two-way time transfer technique distances can be measured to high resolution as well as to high accuracy by compensating for local clock drifts and inaccuracies.

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 inter-pulse interference for fast pulse system which can be mitigated by coding techniques.

Technical discussion

One performance measure of a radio in applications like communication, positioning, location, tracking, 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 (Shannon told us what, but not how!) 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 (AWGN). Thus channel capacity increases linearly by increasing bandwidth of the channel to the maximum value available, or equivalently in a fixed channel bandwdith by increasing the signal power exponentially. By virtue of the huge bandwidths inherent to UWB systems, the huge channel capacities can be achieved without invoking higher order modulations that need very high SNR to operate.

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

Channelization (sharing the channel with other other links) is a complex problem subject to many practical variables. Typically two UWB links can sharing 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 (FEC) technology, as demonstrated recently in some very high data rate UWB pulsed systems, like LDPC (Low Density Parity Coding), perhaps in combination with Reed-Solomon codes, can provide channel performance approaching the Shannon limit. 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.

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 multipath generated copies of the original pulse to improve performance on receiver. Other UWB systems use channel equalization techniques to achieve the same purpose. Narrowband receivers can use similar techniques, but are limited due to the poorer resolution capabilities of narrowband systems.

There has been much concern over the interference of narrow band signals and UWB signals that share the same spectrum. The subject was extensively covered in the proceedings that led to the adoption of the FCC rules in the US, and also in the 6 meetings relating to UWB of the ITU-R that led to the ITU-R Report and Recommendations on UWB technology.

Applications

Due to the extremely low emission levels currently allowed by regulatory agencies, UWB systems tend to be short-range and indoors. 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 aggragating 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.

UWB is also used in "see-through-the-wall" precision radar imaging technology, precision positioning and tracking (using distance measurements between radios), and precision time-of-arrival-based localization approaches. [1] It exhibits excellent efficiency with a spatial capacity of approximately 10,000,000,000,000 bit/s/m².

UWB is a possible technology for use in personal area networks and appears in IEEE 802.15.4a draft PAN standard.