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UWB: The Free Wireless Technology

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Abstract: The unlicensed UWB technology is changing our life's because of numerous advantages like high speed, high bandwidth, highly secure, low power consumption, low cost etc. To implement UWB technology the corresponding hardware should require additional features. In this paper complete description of UWB technology, its working operation and its characteristics is explained. The essential features required to design a UWB antenna is also explained here.
Keywords: UWB technology, UWB antenna.

I. INTRODUCTION

Since, the FCC has declared a bandwidth of 7.5GHz (3.1 - 10.6 GHz) designated as UWB (Ultra Wide Band) spectrum platform i.e. wireless communications for public uses [1]. The UWB technology is rapidly advancing as a short-range high-speed high-data rate wireless communication technology. UWB is a radio communication technology that uses very low energy pulses and transmits in a way that doesn't interfere with other traditional narrow bands and continuous carrier wave systems operating in the same frequency band. UWB is a very high-speed alternative to the existing wireless technologies such as WLAN, Hyper LAN etc.
This technology is an unlicensed service that can be used anywhere, anytime, by anyone without any subscription or payment. This technology has emerged as safest and most secure way of communication into our daily lives with almost negligible interference. But one can only take the benefits of UWB technology using corresponding compatible hardware. So, in this paper the essential feature of UWB technology and its compatible hardware is thoroughly explained.

I. UWB TECHNOLOGY : WORKING

UWB is defined as any wireless plan that occupies either a fractional bandwidth greater than 20% or more than 500 MHz of absolute bandwidth. UWB communications transmit signal without interfering with other traditional narrow bands operating in the same frequency band. Fig.1 displays the behavior between Emitted signal powers versus frequency. UWB signal is noise-like signal with low energy density; hence its detection is quite difficult. Additionally, the "noise-like" UWB signal has a particular shape compared to real noise signal (no shape). So, it is almost unfeasible for real noise signal to destroy the UWB pulse because interference would have to spread uniformly across the entire spectrum to obscure the pulse. UWB pulse behaves as a wideband noise source for other NB systems operating in that frequency range; but it doesn't affect them because of its low signal power.

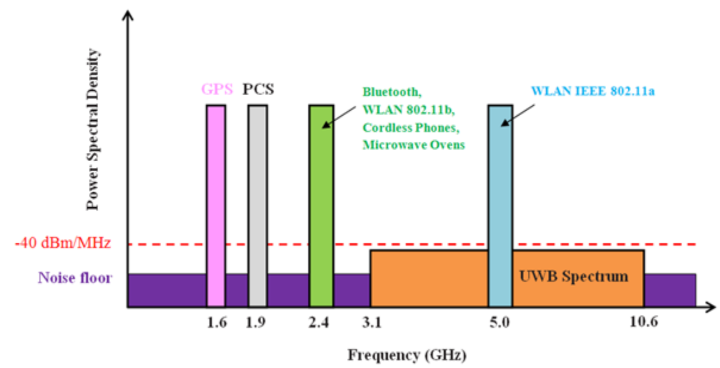

Fig. 1 Comparison of various communication standards

It only increases the SNR requirement of those systems. By using PN (Pseudo Random) codes UWB system can be made undetectable for hostile receivers and can be protected from jamming. Hence, UWB is possibly the most safe and secure means of signal transmission. The unique characteristics of UWB technology present a more powerful solution to wireless broadband than other technologies [1-5]. The UWB devices operate by employing a series of very short electrical pulses that result in very wideband transmission bandwidths. In addition, UWB signals can run at high speed and low power levels. It also enables various types of modulation scheme to be employed, including on–off keying, pulse-amplitude-modulation, pulse-position-modulation, phase-shift-keying, as well as different receiver types such as the energy detector, rake, and transmitted reference receivers. Another strong candidate for UWB is multicarrier modulation by using orthogonal frequency division multiplexing (OFDM).

II. UWB TECHNOLOGY CHARACTERISTICS

The unique characteristics of UWB technology are listed below:
1. **Capacity:** Since UWB has an ultra wide frequency bandwidth, so a huge capacity as high as hundreds of Mbps or even several Gbps can be obtained.

2. **Low power transmission:** UWB systems operate at extremely low power transmission levels. It divides the signal power across a huge frequency spectrum and the effect upon any frequency is below the acceptable noise floor. For example, 1 watt of power spread across 1GHz of spectrum results in only 1nW of power into each hertz band of frequency. Thus, UWB signals do not cause significant interference to other wireless systems.
3. **Fading Robustness**: It is channel fading resistant, due to the large number of resolvable multipath components. Wide band nature of the signal helps it in avoiding the problem of time varying amplitude fluctuations. It is also immune to Multipath Delays where various version of same signal appear at the receiver which have undergone a variety of diffraction, reflection, scattering effects as time delay introduced is generally more than the signal duration.
4. **Short Range:** Its normal range of operation is within 10m, so its power requirement is low and interference with other short range devices is less. It comes under WPAN protocol.
5. **Security Aspects**: UWB provides high level security and reliable communication.
6. **Low Cost:** UWB system has low cost and low complexity because it does not modulate and demodulate a complex carrier waveform, so it does not require components such as mixers, filters, amplifiers and local oscillators.
7. **Large Bandwidth:** The FCC allocated an absolute bandwidth more than 500 MHz up to 7.5 GHz which is about 20% up to 110% fractional bandwidth of the center frequency. This large bandwidth spectrum is available for high data rate communications as well as radar and safety applications.
8. **Very Short Duration Pulses:** Ultra-wideband pulses are typically of nanoseconds or picoseconds order. So UWB systems are often characterized as multipath immune or multipath resistant.
9. **Resolution:** High resolution localization, due to the very short pulse duration.
10. **Multiple accesses**: UWB technology provides multiple access capabilities, due to the wide bandwidth of transmission.
11. **Target Detection:** UWB antenna is used as target detection in RADAR.

All these unique features of UWB technology make it suitable for many different applications such as geo positioning, radar and sensor applications e.g. vehicular, marine, GPR, imaging, wall-imaging, sense-through-the-wall (STTW), surveillance systems etc.

III. UWB ANTENNA DESIGN CHALLENGES

UWB antennas exhibit very large bandwidth compared to general antennas [4-15]. There are two criteria available, for identifying when an antenna may be considered as UWB. A definition given by DARPA says that a UWB antenna has a fractional bandwidth greater than 0.25. Whereas, the United States Federal Communications Commission (FCC), places this bandwidth limit to 0.2. Additionally, the FCC provides an alternate definition whereby an UWB antenna may have a bandwidth greater than 500 MHz.

There are several known antenna topologies that are said to achieve broadband characteristics, such as the horn antenna, biconical antenna, helix antenna and bowtie antenna. All these antennas have been proven to have excellent broadband characteristics, but they are large, non-planar and physically obtrusive, therefore ruling them out as a possibility for use with small UWB integrated electronics. Another antenna design approach is to use frequency independent antenna which uses Babinet's Equivalence Principle of duality and complementarity for meeting the requirements of very wide impedance bandwidth. The Archimedian spiral antenna, logarithmic spiral antenna, fractal antenna are used for UWB operation because they possess small size, light weight and thin shape for portable devices.

The design of a UWB antenna is very difficult, because the fractional bandwidth is actually big, and antenna must cover multiple octave bandwidths in order to transmit pulses that are of the order of a nanosecond in duration. Since data may be contained in the shape of the UWB pulse, antenna pulse distortion must be kept to a minimum value. A non-dispersive characteristic in time and frequency domain provides narrow pulse duration to enhance a high data throughput. Antennas in the frequency domain are typically characterized by radiation pattern, directivity, impedance matching, and bandwidth.
The following are important challenges in designing UWB antennas.
1. UWB antenna must possess ultra wide frequency bandwidth.
2. The performance of a UWB antenna is required to be consistent over the entire operational band. Ideally, antenna radiation patterns, gains and impedance matching should be stable across the entire band. Sometimes, it is also demanded that the UWB antenna provides the band-rejected characteristic to coexist with other narrowband devices and services occupying the same operational band.
3. UWB antenna must possess directional or omni-directional radiation properties depending on the practical application. Omni-directional patterns are normally desirable in mobile and hand-held systems. For radar systems and other directional systems where high gain is desired, directional radiation characteristics are preferred.
4. UWB antenna needs to be small enough to be compatible to the UWB unit especially in mobile and portable devices. It is also highly desirable that the antenna's feature should be low profile and compatible for integration with PCB.
5. UWB antenna should be optimal for the performance of overall system. For example, the antenna should be designed such that the overall device (antenna and RF front end) complies with the mandatory power emission mask given by the FCC or other regulatory bodies.
6. UWB antenna is required to achieve good time domain characteristics. For the narrow band case, it is approximated

that an antenna has same performance over the entire bandwidth and the basic parameters, such as gain and return loss, have little variation across the operational band. In contrast, UWB systems often employ extremely short pulses for data transmission.

The UWB antenna design is the major dimension in the progress of UWB technology. The main challenge in UWB antenna design is achieving the wide impedance bandwidth while still maintaining high radiation efficiency. UWB antenna should be designed focusing on various parameters such as frequency of operation, substrate height, dielectric constant to be used. To cater to all these requirements the microstrip antenna has been gaining popularity. Owing to its narrow bandwidth, many solutions have been introduced, which offer the impedance bandwidth across the entire UWB range. Different techniques are applied for good impedance matching over the UWB range which includes different combination of specially designed patch or feed line with partial or optimized ground plane. UWB operation can be achieved by using either partial ground or CPW feed in different shapes of patch structures. By using different shapes of the patch, accommodate multimode surface current waves, which in turn lead to resonating at multiband frequencies and finally widen the impedance bandwidth.

IV. CONCLUSION

UWB communications is intended for short-range-cum-high-bandwidth communications by using a huge chunk of the radio spectrum. This unlicensed technology has been engaged into our daily lives with minimal interference. It is the safest and secure means of signal transmission.

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