UWB Communication Using BPSK Modulation

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***Abstract*—As the users of wireless devices including wireless home PCs and other devices have increased the bandwidth of the spectrum and the battery life became a challenging subject in the communication of wireless devices to enjoy the increased convenience of wireless connectivity. Ultra-Wide Band (UWB) is a technology which transmits data with high bandwidth, using a very low power spectral density. Because of low power consumption, UWB signals are not harmful to the health of human, and it is a good candidate for communication of devices in wireless personal area networks (WPAN). In this paper, we show that how the UWB technology signal carries the big amount of data using very low power, and also we compared the status of UWB signal during carrying the high amount of data while the data rate is on different scales. In this work, we simulated the transmitter and receiver for UWB communication using the Binary Phase Shift Keying (BPSK) modulation technique which shifts the phase of the signal by 180 degrees. The simulation results are presented and compared.**

KEYWORDS—-Communication systems, UWB, BPSK, WPAN.

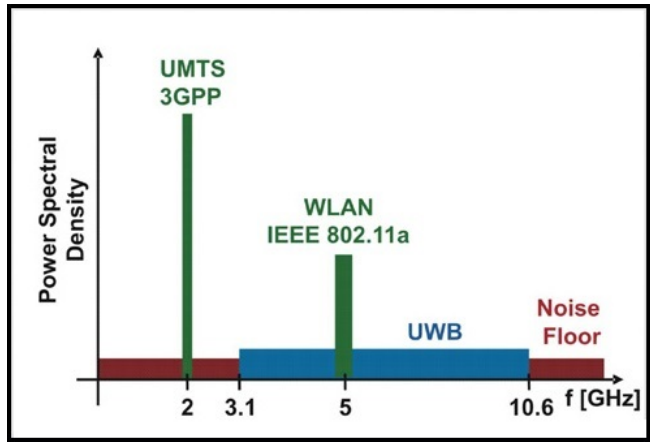

Fig. 1. UWB spectrum

I. Introduction

Ultra-wide band (UWB) technology is a promising solution for high-capacity wireless communications systems. As can be seen in Fig. 1, UWB radios uses frequency range from 3.1 GHz to 10.6 GHz a band more than 7 GHz wide. Each radio channel can have a bandwidth of more than 500 MHz, depending on its center frequency [1]. UWB communication systems are usually classified as any communication system whose instantaneous bandwidth is many times greater than the minimum bandwidth required to deliver information. The excess bandwidth is a defining characteristic of UWB [2]. As the peripheral devices are freeing their spaces for wireless devices the UWB technology plays an important role in Wireless Personal Area Networks (WPAN), especially for connecting the devices which are placed around 10 meters. The consumers will soon demand it for their video recording and storage devices, for real-time audio and video streaming, interactive gaming, and Video conference services as digital media becomes more predominate in the home. Many technologies used in the digital home (As defined by the Digital Living Network Alliance (DLNA), the term digital home refers to a home network of consumer electronics (CE), mobile and PC devices that cooperate transparently, delivering simple, seamless interoperability that enhances and enriches user experiences.), such as digital video and audio streaming, require high-bandwidth connections to communicate. Considering the number of devices used throughout the digital home, the bandwidth demand for wireless connectivity among these devices became very large indeed.

The wireless networking technologies developed for wirelessly connecting PCs, such as Wi-Fi and Bluetooth Technology, are not optimized for multiple high-bandwidth usage models of the digital home. Although data rates can reach 54 Mbps for Wi-Fi, for example, the technology has limitations in a consumer electronics environment, including power consumption and bandwidth [1]. When it comes to connecting multiple CE devices in a short-range network, or WPAN, a wireless technology needs to support multiple high data rate streams, consume very little power, and maintain low cost, while sometimes fitting into a very small physical package, such as PDA or cell phone. The emerging UWB wireless technology and silicon developed for UWB applications offer a compelling solution [1]. This paper provides an overview of ultra-wideband communications, starting with its history and applications. Next, related works are mentioned the discussion turns to the comparison of UWB with narrowband technologies. In this paper, the different modulation techniques are explained and the BPSK modulation technique is used in simulated transceiver. We show how the UWB technology signal carries the big amount of data using very low power, and also, the status of UWB signal during carrying the high amount of data while the bandwidth of the radio is on different scales is compared, the simulation results are presented and compared in the last section.

II. Related Works

UWB was first employed by Guglielmo Marconi in 1901 to transmit Morse code sequences across the Atlantic Ocean using spark gap radio transmitters [3]. However, the benefit of a large bandwidth and the capability of implementing multiuser systems provided by electromagnetic pulses were never considered at that time. Approximately fifty years after Marconi, modern pulse-based transmission gained momentum in military applications in the form of impulse radars. Some of the pioneers of modern UWB communications in the United States from the late 1960s are Henning Harmuth of Catholic University of America and Gerald Ross and K. W. Robins of Sperry Rand Corporation. From the 1960s to the 1990s, this technology was restricted to military and Department of Defense (DoD) applications under classified programs such as highly secure communications. However, the recent advancement in microprocessing and fast switching in semiconductor technology has made UWB ready for commercial applications. Therefore, it is more appropriate to consider UWB as a new name for a long-existing technology [4].

In [5] the performances of time hopping (TH) pulse position modulation (PPM) and BPSK modulation schemes are accurately compared in terms of the bit error rate (BER). It is shown that the BPSK system outperforms the binary PPM system for all values of SNR. In [6] three different modulation schemes for two different UWB pulses- Gaussian second derivative and wavelet based monocycle pulse are considered for performance evaluation, the author compared the performance in the presence of Additive white Gaussian noise (AWGN) and Rayleigh fading channel, and shows that the BER performance of BPSK modulation scheme is better in AWGN channel as compared to PPM and on-off keying (OOK) modulation techniques.

III. UWB transceiver and comparison with Narrow Band

On February the 14th 2002, the Federal Communication Commission (FCC) in the US has approved the use of the very controversial UWB technology for commercial applications [7]. UWB differs substantially from conventional narrowband radio frequency (RF) and spread spectrum (SS) technologies, such as Bluetooth Technology and WiFi 802.11a/b/g/n/ac technologies. The UWB transmitter works by sending billions of pulses with a duration of nanoseconds across a very wide spectrum of frequency several GHz in bandwidth. An example of UWB pulse is shown in Fig. 2(a), and the frequency domain of UWB is shown in Fig. 2(b). The corresponding receiver then translates the pulses into data by listening for a familiar pulse sequence sent by the transmitter. UWBs combination of larger spectrum, lower power, and pulsed data, improves speed and reduces interference with other wireless spectra. In the United States, the FCC has mandated that UWB radio transmissions can legally operate in the range

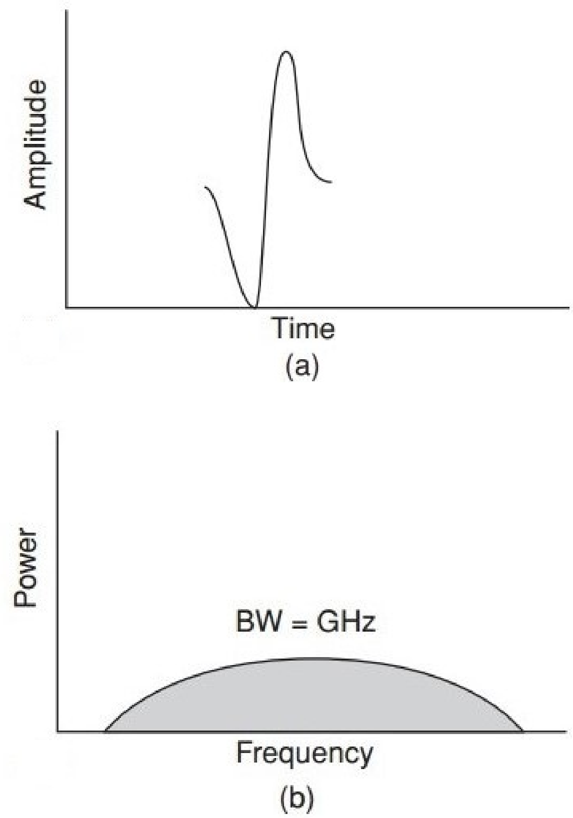

Fig. 2. A UWB pulse in (a) the time domain and (b) the frequency domain.

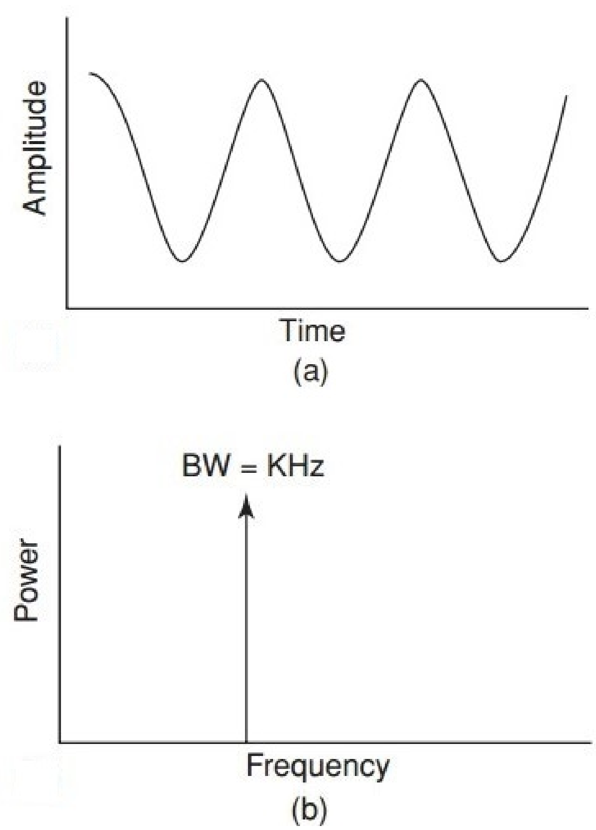

Fig. 3. A narrowband signal (a) the time domain and (b)the frequency domain.

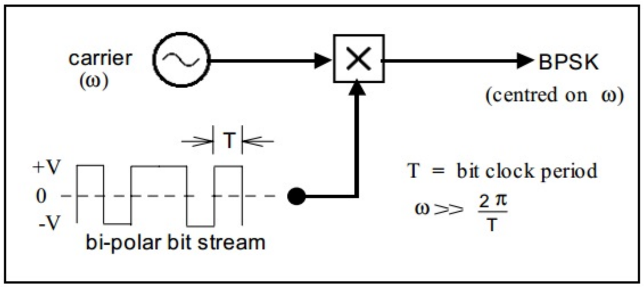

Fig. 4. Generation of BPSK

from 3.1 GHz up to 10.6 GHz, at a limited transmit power of 41dBm/MHz. The result is dramatic short-range channel capacity and limited interference [8]. UWB communications are fundamentally different from all other communication techniques because it employs extremely narrow RF pulses with a duration of nanoseconds, which are generated from the UWB pulse generator, to communicate between transmitters and receivers. A narrow band signal is shown in Fig. 3(a) and the frequency domain of narrow band signal is shown in Fig. 3(b).

Beside the mentioned benefits of the UWB technology, the interference is another factor that makes the UWB technology more interactive. UWB technology is very low power consumption comparing with narrow band and wide band technologies in this reason it doesn't interfere with another signal, by using the Orthogonal Frequency Division Multiplexing (OFDM) the interference of other signals is eliminated. Utilizing short-duration pulses as the building blocks for communications directly generates a very wide bandwidth. 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 [9].

IV. Modulation techniques of UWB

Information can be encoded in a UWB signal in a variety of methods. The most popular modulation schemes developed to date for UWB are PPM, which the simplicity and synchronization of transmitter-receiver are the features of this technique, pulse-amplitude modulation (PAM) has simple receiver and transmitter designs but it is sensitive to noise. OOK, its implementation is simple but like PAM it is sensitive to noise [10], and the BPSK modulation technique is a technique which has the simplest system design and optimum power efficiency [11]. As the data is carried in the polarity of the pulses in BPSK modulation technique, the data symbol 1 is indicated in the phase value of zero degrees, and the data symbol 0 is indicated in the phase value of 180 degrees [12]. In this work we simulate a UWB transmitter and receiver using BPSK modulation scheme which shifts the phase of signal by 180 degrees. as can be seen in Fig. 4, the BPSK signal is generated by shifting the phase of the carrier by 180 degree. The captured graphs of transmitted data, unfiltered received

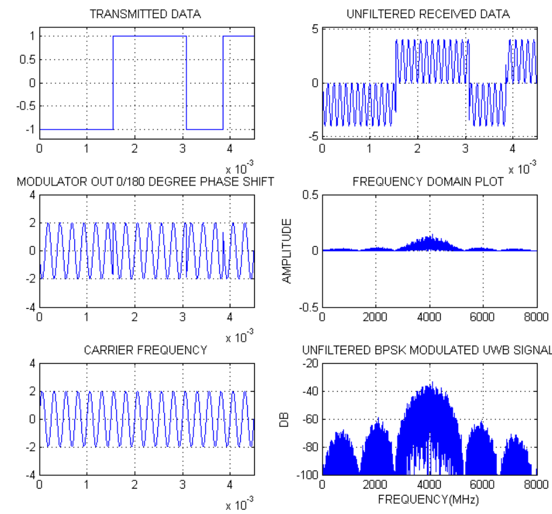

Fig. 5. UWB link state when the data rate is set to 1.3 Gbps

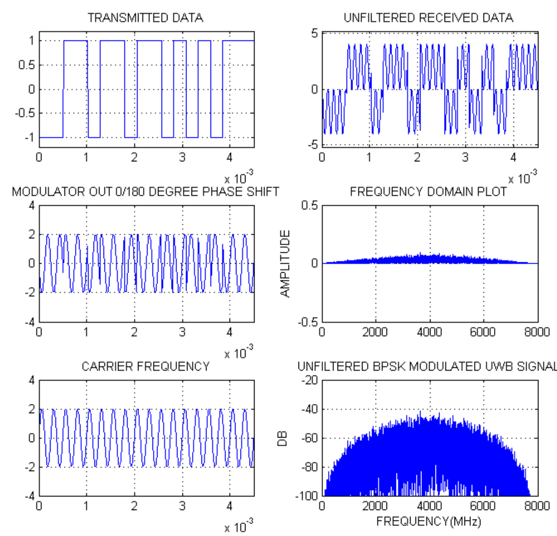

Fig. 6. UWB link state when the data rate is set to 3.9 Gbps

data, carrier frequency, modulated signal and carrier frequency are presented in simulation results section.

V. Methodology and Simulation Results

We have simulated the UWB transmitter and receiver by generating random data symbols and carrier wave (sine wave) which BPSK modulate them to construct a BPSK UWB transmitter. The bellow formula is used to generate unmodulated frequency carrier.

$$f_{car1} = a.sin(2\Pi f_c t) \quad (1)$$

In the equation (1), f_{car1} is the unmodulated frequency carrier, a is the amplitude of the wave, and the rest of the formula is the equation of sine wave. The unmodulated carrier frequency is shown in Figs. 5 and 6 by the name of carrier frequency.

The f_{car1} is multiplied by generated random binary symbols $s1$ (data) to generate modulated BPSK carrier (f_{car2}).

$$f_{car2} = f_{car1}.s1 \tag{2}$$

At this point in the transmitter a bandpass filter would be added to meet FCC UWB spectral mask of -41.25 dBm/MHz equivalent isotropically radiated power (EIRP). f_{car2} is shown in Figs. 5 and 6 by the name of unfiltered BPSK modulated UWB signal.

The fast fourier transform (FFT) of f_{car2} is taken to represent the signal in frequency domain. The frequency domain is shown in Figs. 5 and 6 under the name of frequency domain.

The receiver demodulates the BPSK UWB signal and the filtered data is recovered. Our system operates in the 3.1-10.6 GHz UWB band (at data rates up to 3.9 Gbps) by changing frequency carrier and the bandwidth (Data rate) can be changed. In the simulation, we set the value of carrier frequency to 4 GHz and run the simulation with data data rates 1.3 Gbps and 3.9 Gbps which the results show that in case of 3.9 Gbps data rate the signal capacity occupied completely.

The FCC has mandated that UWB radio transmissions can legally operate in the range from 3.1 GHz up to 10.6 GHz, at a limited transmit power of -41dBm/MHz. Our simulation shows the results of an UWB system with 4 GHz bandwidth and data rate of 1.3 Gbps as shown in Fig. 5. Also we have tested the system by changing the data rate to 3.9 Gbps the results show that in a UWB system with bandwidth of 4 GHz and data rate ranges of 3.9 Gbps the UWB signal is completely occupied as shown in Fig. 6.

It is to mention that in our system we can change the bandwidth of the system up to 7.5 GHz and also the data rate can be changed by reconfiguring the parameters in simulation.

VI. Conclusion

UWB is the leading technology for freeing people from the wires, enabling wireless connection of multiple devices for transmission of high definition video, audio, and other high bandwidth data. In this paper the UWB technology is overviewed with its history and applications, then UWB technology is compared with other wireless technology such as narrow band wireless technology. In the last section, the results of simulations are presented which was generated by a simulated design of UWB transmitter and receiver using BPSK modulation technique.

It would be nice to do this in real time with multipath, and other parameters, but we did with what we had. And also, the QPSK modulation can be used to increase the data rate of the system.

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