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Kevin Phillips
University of North Florida

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Kevin Phillips

Faculty Sponsor: Dr. Susan Vasana, Assistant Professor of Electrical Engineering

Abstract

Following FCC approval of Ultra-Wide Band (UWB) radio rules for commercial applications in 2002, a UWB radio physical layer standard is currently under development within the IEEE 802 LAN/MAN Standard Committee. Although the UWB transmitter and UWB band are spelled out by the FCC, neither UWB signal forms nor modulation schemes are defined by the regulations [1]. This paper illustrates two types of impulse UWB radio modulation systems and their simulation performance. They are direct sequence UWB (DS-UWB) and time modulated (TM- UWB) or so called time hopping UWB (TH-UWB). Unique ways of coding and positioning the impulses, as in Transmitted-Reference Delay (TRD) modulation and Pulse-Position Modulation (PPM), can result in the simple UWB radio architectures. Systems of TRD for DS-UWB and PPM for TH-UWB are simulated under the same data and under the same AWGN channel conditions. TRD-DS-UWB system presents superior performance over PPM- TH-UWB system, which is shown in the comparison chart of the paper. The simulation was verified with ideal calculated performance for TRD modulation. The UWB applications are also discussed.

Key Words

Ultra Wideband (UWB), Direct Sequence UWB (DS-UWB), Time Hopping UWB (TH-UWB), Transmitted-Reference Delay (TRD) Modulation and Pulse-Position Modulation (PPM).

Introduction

Ultra-wideband (UWB) is a revolutionary wireless technology poised to find use in a broad range of consumer, enterprise, industrial and public safety applications [2]. First developed for military radar, UWB was authorized for commercial use by a ground breaking ruling of the US FCC in 2002. Unlike conventional wireless systems, which use narrowband modulated carrier waves to transmit information, DS-UWB transmits data by pulses generated at very high rates: in excess of 1 billion pulses per second [2].

An UWB signal is defined as a signal that has a bandwidth larger than 500MHz. It can coexist with other systems in the same frequency range due to its large spreading factor and low power spectral density. UWB technology can be implemented in applications such as short-range high-speed data transmission and also precise location tracking. It can also be used in upcoming applications such as wireless office networks, and applications that require a fast data transfers. The primary commercial application is wireless multimedia personal area networks (PAN). These networks will connect consumer electronics (CE), PCs, and

mobile communications devices in the home and office.

One main benefit in using UWB is shown that the frequency range can be shared with other types of systems. Also compared to narrow band systems, UWB uses significantly less RF power. The drawback is that UWB is susceptible to interference from other high power systems that operate over the UWB band that is being used. Hence, choosing a modulation scheme which gives good receiving sensitivity for the UWB signals is important.

UWB radio physical layer standard is currently under development within the IEEE 802 LAN/MAN Standard Committee in Task Group 802.15.3a. Although the UWB transmitter and UWB bandwidth restriction are defined, neither UWB signals nor modulation schemes are defined by the regulations [1]. Thus two very good solutions have emerged from the standards work (DS-UWB and MB-OFDM) to vie for the standards. DS-UWB achieves its UWB bandwidth from the short impulses that comprise the DS "chips" while MB-OFDM achieves its UWB bandwidth form the aggregation of narrow band carriers. We concern ourselves here with UWB systems that achieve their UWB bandwidth from short impulses. This paper includes the simulation and performance comparison of two types of UWB modulation systems, i.e. Transmitted-Reference Delay (TRD) modulation for a variant of DS-UWB (not the system proposed in 802.15.3a) and Pulse -Position Modulation (PPM) for TH-UWB systems. The simulation is performed in Coware's Signal Processing Workstation (SPW).

TRD Modulation for DS-UWB

Among various proposed UWB systems, direct sequence ultra-wideband (DS-UWB) takes maximum advantage of what UWB has to offer. By using the widest possible bandwidth to produce the shortest possible pulses, DS-UWB supports robust, high rate links in high multipath and offers precise spatial resolution for location detection. By generating continuous smooth white noise at the lowest levels relative to alternative approaches, DS-UWB is the preferred technology in terms of minimizing the potential to cause interference [2].

An impulse radio (IR) is a system that implements UWB technology. An IR transmits very short pulses with low duty cycles as coded data. The transmitted information can be coded on a train of pulses in a variety of ways. Positions or polarities of the pulses can be coded on different levels [3].

Impulses can be sent with the information encoded differentially [1] and [4]. A method of transmitting and receiving impulses that can easily implement a rake receiver is Transmitted Reference Modulation (TRD). The method employs differentially encoded impulses sent at a precise spacing D (D is the data bit/chip interval). The data value of the pulse is referenced to the polarity of the previously sent pulses. The system is shown in the simplified block diagram of Figure 1. The transmitter sends pulses separated by a delay D that are differentially encoded using pulse polarity. The pulses, including propagation induced multipath replicas,

are received and detected using a self-correlator with one input fed directly and another input delayed by D. Long sequences of differentially encoded pulses may be sent in the same manner. The receiver resembles a conventional DPSK receiver [1].

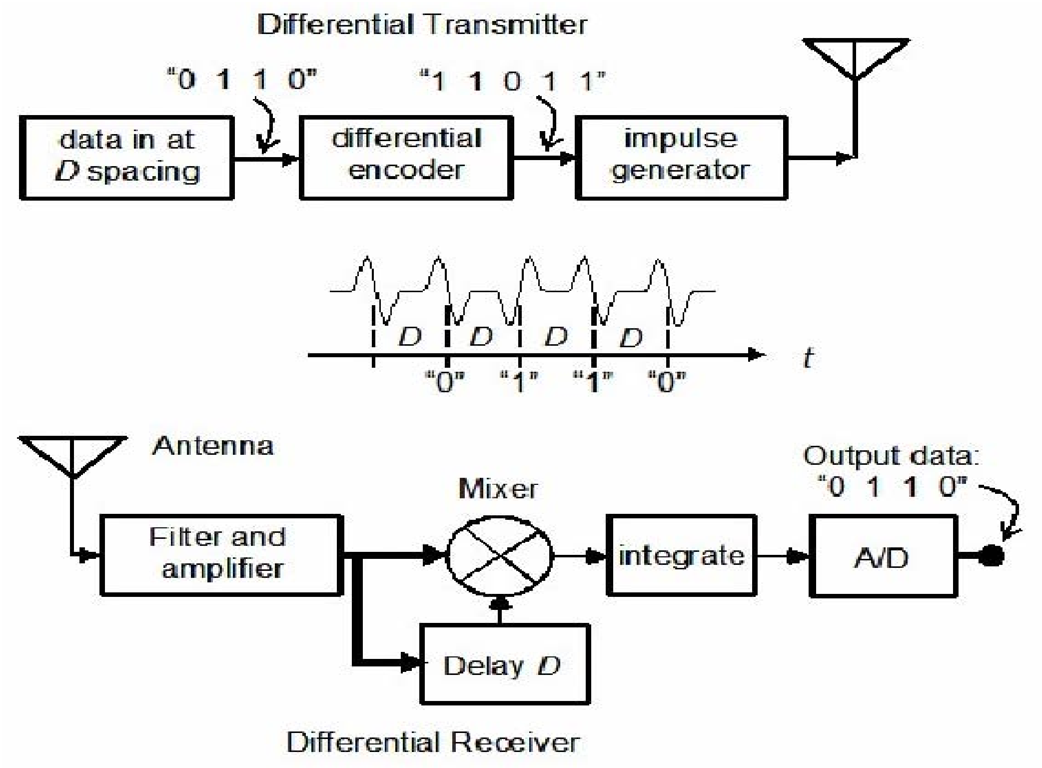


Figure 1. A TRD-UWB Transmitter and Receiver.

The DS-UWB system with TRD modulation scheme is simulated on the Coware SPW (Signal Processing Workstation). In the simulation system the DS-UWB baseband waveform with bipolar signaling is sampled at 16 samples per symbol. The reference pulse shape defined for the DS-UWB proposal is a root-raised cosine (RRC) pulse with 30% excess bandwidth [5]. The simulation performance is presented in section IV of this paper.

PPM for TH-UWB or TM-UWB

TRD modulation in section 2 is one way to modulate the IR signal. Pulse position modulation (PPM) is considered as another modulation scheme. To prevent collisions among different users and provide strength against multiple access interference each information symbol is represented by a sequence of pulses. The positions of pulses in a sequence are determined by a random time hopping (TH) sequence specific to each user. This research paper defines an UWB signal and a simple receiver. An introduction of an impulse radio is made to explain a time – hopping pulse position modulation (TH-PPM) scheme. Results are shown gained from

simulation software along with findings and conclusion.

In the UWB system, long sequences of pulsed are used with TH – PPM for communication. TH modulation causes a distribution of low power in the frequency domain. This causes the UWB signal to resemble noise in the frequency domain. The advantage causes the UWB to be less detectable, and resistant to jamming. Another advantage allows sharing of the frequency range the UWB signal operates in. The drawback is that the UWB signal is susceptible to interference from other in-band systems [6] and [7].

The transmitter is built to show how data can be transmitted using a PPM scheme. An impulse train is implemented and a delay is set to delay a pulse one half of a cycle or no delay at all. This only shows a transmitter in its simplest form. There could be four different delays in this sequence: one, two, three, and four quarter cycles. AWGN noise is added to resemble a channel for the signal to pass through.

2-ary PPM is simulated as the block diagram of Figure 2. A clock is added to show how the signal can be coded. When the clock strikes and it does not hear a signal until one cycle later that pulse can be coded as a zero. Otherwise when the clock strikes and the receiver will hear a pulse it can be recovered as a one. Although this is simplified it shows how PPM can be used to code information and transmit.

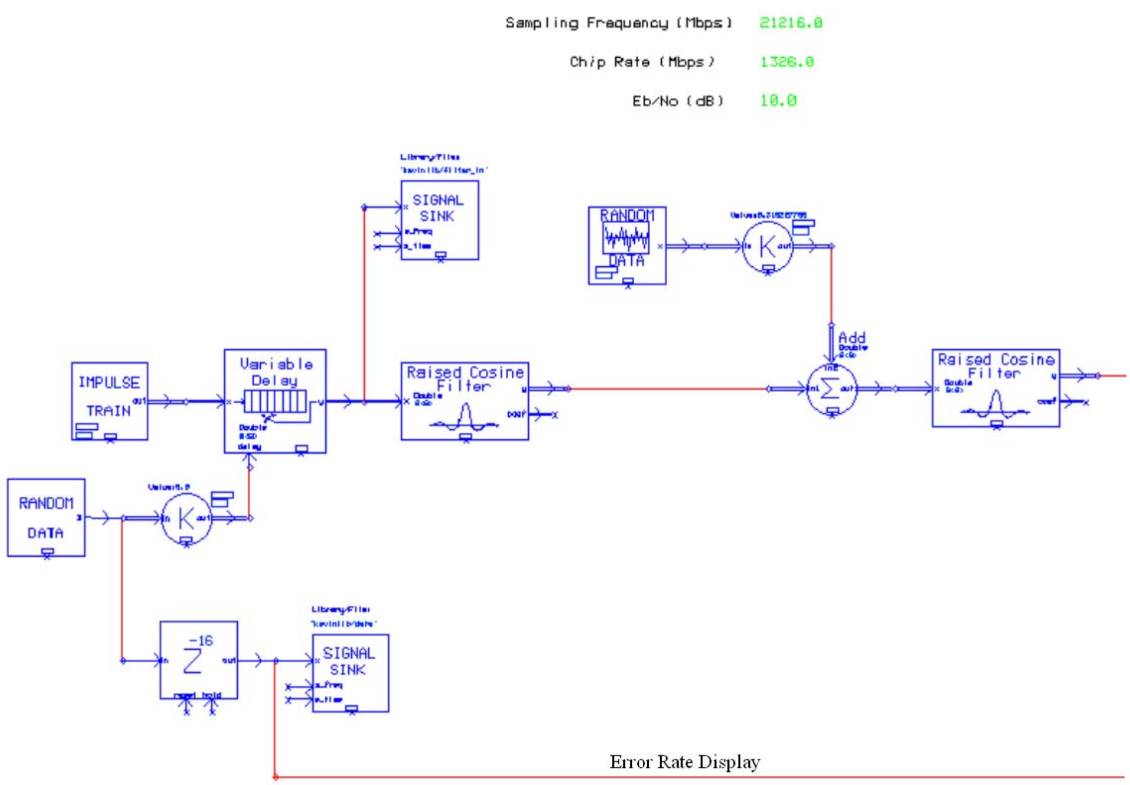


Figure 2. Simulation System – PPM Transmitter.

The signal will be sampled with the frame clock where the TH sequence will be implemented to distinguish between different users. When the user is identified the signal will finish the correlation process through integration and a decision that is made after correlation. The demodulated data is then recovered. Figure 3 shows a block diagram of a demodulator and detector part of the receiver built using SPW. This simple receiver is what we came up during the simulation.

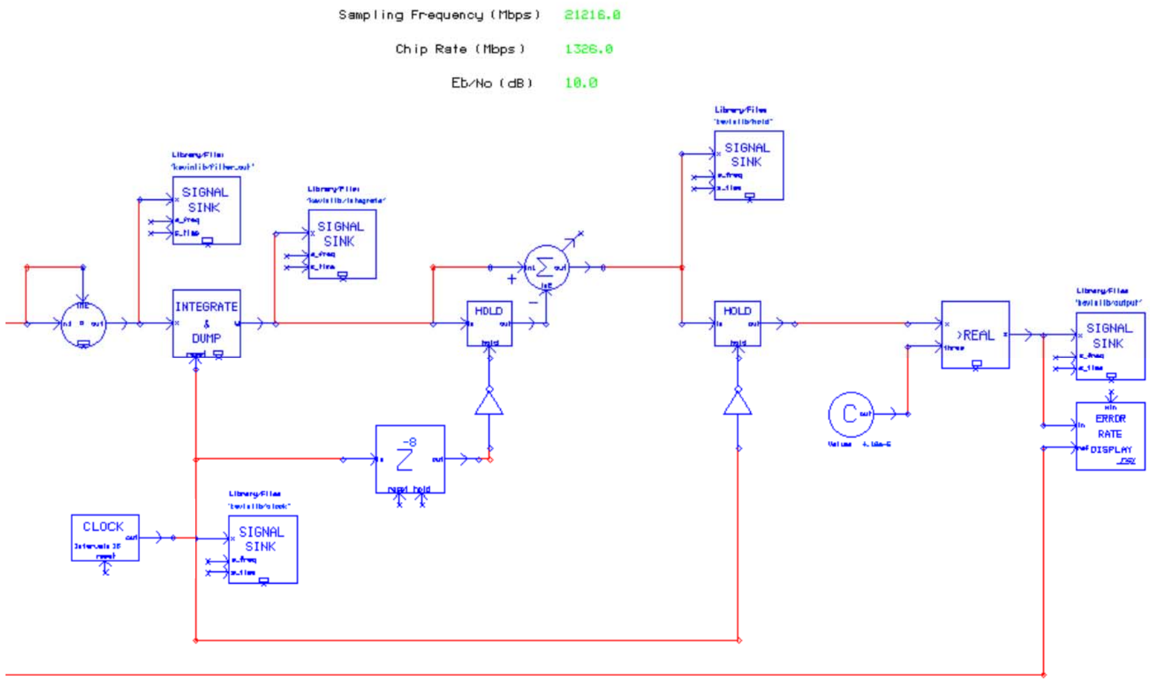
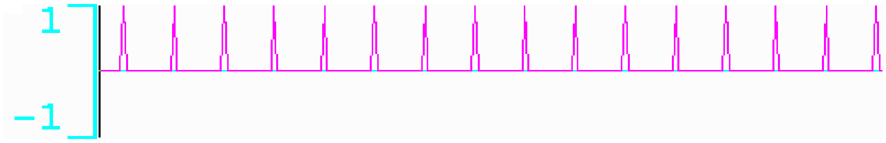


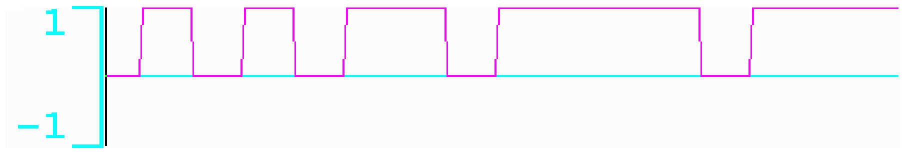
Figure 3. Simulation System – PPM Receiver.

This receiver shows only one finger of a correlation receiver. More can be added to accumulate more power or as multiple users are added. This receiver accepts the signal after transmitting through an AWGN channel.

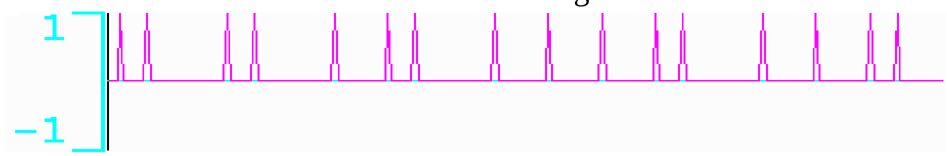
The filtered received signal is squared by a square-law device before integrator. The integrated signal clearly shows the PPM scheme that has been coded. Each position a pulse has been shifted the integration changes. The delta detection which is similar to the method illustrated in reference paper [5] and [6] is used here. The information coded in pulse position is converted to a level coded signal. After this waveform is retrieved it can be compare to a threshold to recover the original data. The simulation signals are shown in Figure 4.



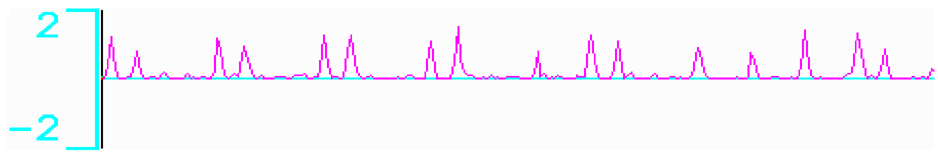
The Clock Signal



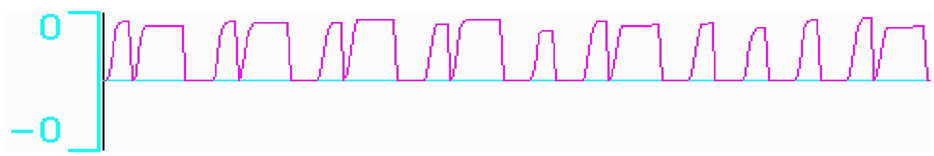
The Information Signal



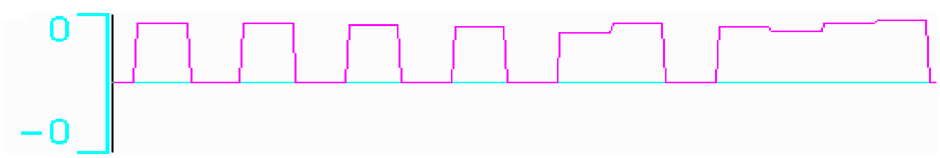
The PPM Modulated Signal



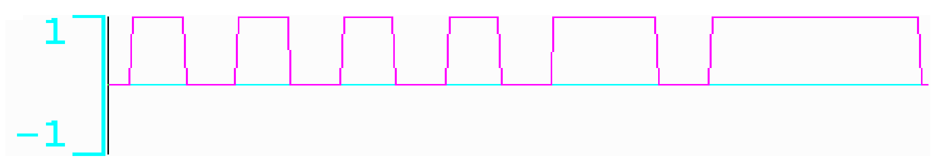
The Received Noisy Signal



The Integrated Signal



The Correlated Signal



The Detected Signal with Delay

Figure 4. PPM-UWB Simulation Signals.

System Performance Comparison

Two types of impulse UWB radio modulation systems are simulated. Both of them are unique ways of coding and positioning the impulses, results in the simple UWB radio architectures. Transmitted-Reference Delay (TRD) modulation system for DS-UWB and Pulse-Position Modulation (PPM) system for TH-UWB are simulated under the same data and sampling rates (16 samples per chip) and under the same AWGN channel conditions. The pulse shape is raised-cosine filtered. Both receivers use correlators implemented as integrator-and–dump. Ideal clock synchronization was assumed in the simulation. Self-correlator was used to demodulate TRD signals. The square-law and delta-detection method, such as in [8] and [9], was used for PPM signal detection. The simulation results are plotted as bit-error-rate (BER) vs. E_b/N_0 (dB) in Figure 5. The plot shows that TRD-DS-UWB system presents superior performance over PPM- TH-UWB system, about 4 dB gain at 0.1% bit-error-rate (BER). The simple PPM receiver presented in this paper gives better performance when signal-to-noise ratio is low, but “flat out” at the lower BER.

The ideal TRD performance from calculation in [1] is plotted with simulation performance of TRD in Figure 6. We can see how the simulation performance close to the ideal theoretic performance, where the pulse shape filter may degrade the performance a little. This comparison gives us the confidence in our simulation data.

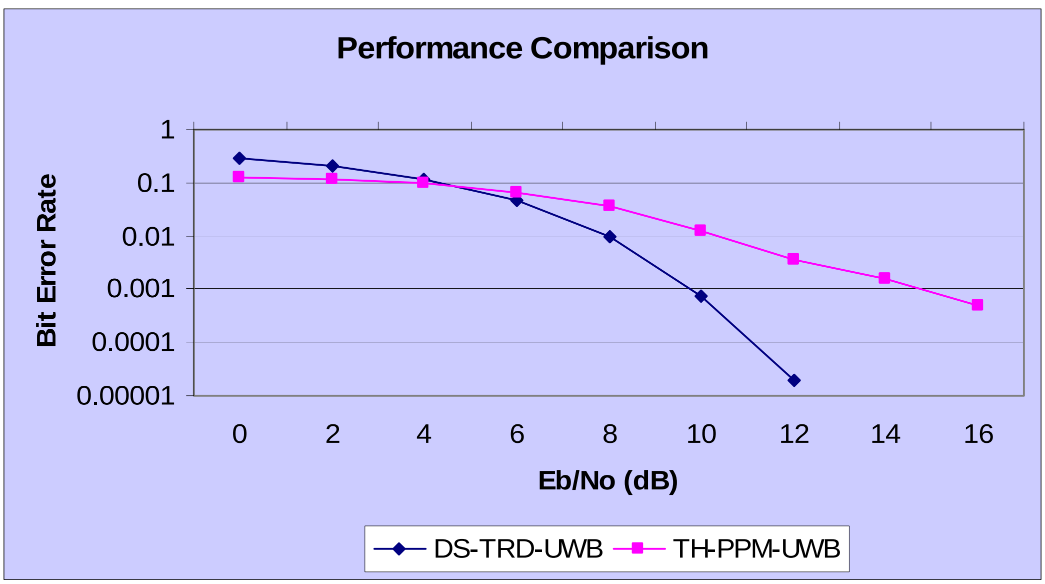


Figure 5. Bit-Error-Rate Performance Comparison.

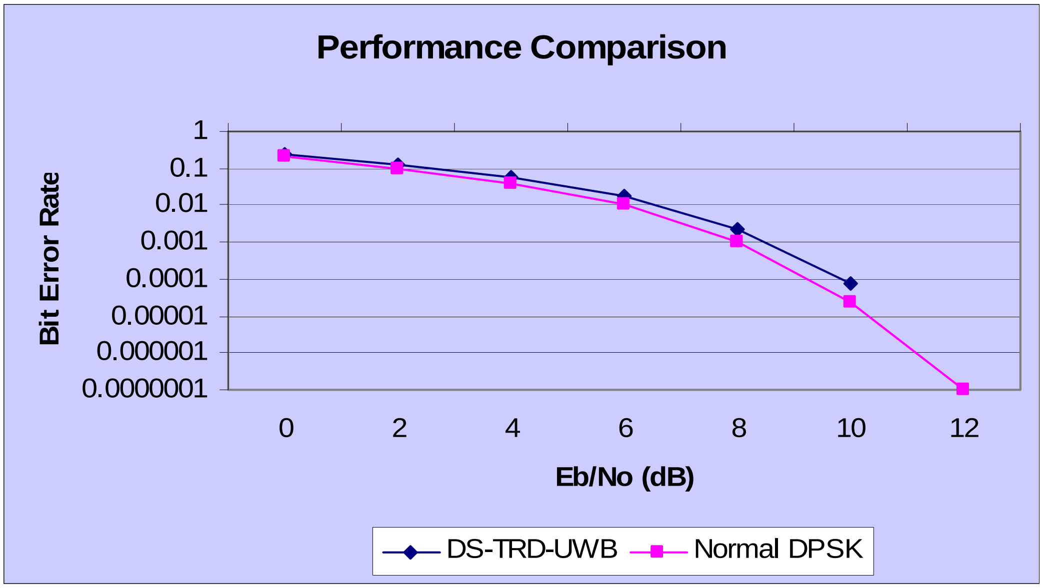


Figure 6. Simulation and Ideal TRD Performance Comparison.

Conclusion

Since the US Federal Communications Commissions (FCC) approved the use of ultra wide band (UWB) technology in 2002, communication systems that use UWB signal have drawn considerable attention. An UWB signal is defined as a signal that has a bandwidth larger than 500MHz and an EIRP lower than -41.3 dBm/MHz in the 3.1 to 10.6 GHz UWB band. UWB can coexist with other systems in the same frequency range due to its large spreading factor and low power spectral density. UWB technology can be implemented in applications such as short-range high-speed data transmission and also precise location tracking. It can also be used in upcoming applications such as wireless office networks, and applications that require a fast data rate. Also this type of system will need to operate in an area where there will be little interference from other systems preferable in a small radius where data can be transmitted over short distances in a multiple access environment.

Impulse radio is a form of UWB signaling for low power short-range communication systems. There are considerable findings from research of the DS-UWB and TH-PPM modulation schemes used by impulse UWB radios. A DS-UWB (but not differentially encoded like the system studied here) is the one of the most commonly used signal modes. That 802.15.3a proposal has further chosen to incorporated in the Common Signaling Mode (CSM). CSM, see [10], is a signaling technique designed to allow different classes of devices (MB-OFDM and DS-UWB) to communicate with each other in order to coordinate their actions and interoperate within the same wireless network. The TH-PPM, also called TM-UWB (Time Modulated UWB), was implemented by Time Domain Corp. in their Radar-vision and P200 series of products.

This paper illustrates two types of impulse UWB radio modulation systems and their simulation

performance. Unique ways of coding and positioning the impulses, as in Transmitted-Reference Delay (TRD) modulation and Pulse-Position Modulation (PPM), can result in the simple UWB radio architectures. Systems of TRD for DS-UWB and PPM for TH-UWB are simulated under the same data and sampling rates and under the same AWGN channel conditions. The paper shows that TRD-DS-UWB system presents superior performance over PPM- TH-UWB system, about 4 dB gain at 0.1% bit-error-rate (BER). Simulation is verified by comparing TRD simulation results with its theoretic performance.

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Biography

Susan Vasana received her B.S.E.E. degree from Shanghai Jiaotong University, Shanghai, China and her M.S. degree from Tongi University, Shanghai, China. She graduated from Queen’s University, Kingston, Canada with the Ph.D. in electrical and computer engineering in 1994. Dr. Vasana is an assistant professor in electrical engineering at University of North Florida (UNF), Jacksonville, Florida. Her current research topics include MIMO wireless communications and ultra-wideband communications. Prior to joining UNF, she had worded for Motorola Inc. as a system design engineer doing research and development of wireless products (1994-2002). She is the inventor of seven Motorola patents. She was an Assistant Professor at Tongji University, Shanghai, China (1986-1989); She also worked at the National Institute of Scientific Research (INRS), Montreal, Canada (1994).