www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 4 Issue 1 January 2015, Page No. 10166-10171

Analysis and Simulation of Orthogonal UWB Pulse for Modulation Scheme and Transmission

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Abstract: ***A promising coherent Impulse-Radio Ultra-Wideband (IR-UWB) communication system with one relay. IR-UWB communications attracted significant attention as a strong candidate solution for short-range high data-rate applications. UWB is a modulation and data transmission method which has potential to change the wireless picture entirely in future. The non-orthogonal cooperation in narrow-band wireless networks often requires deploying distributed space-time codes with joint encoding of several symbols at the source and relays; in addition, it requires joint decoding of these symbols at the destination. But the proposed non-orthogonal cooperation scheme realized within one symbol duration. This means the proposed strategy is adapted to the structure of the Pulse Position Modulation (PPM) that constitutes the most popular modulation scheme associated with UWB transmissions. This strategy also proposes a simple and efficient power allocation strategy that further boosts the performance of the proposed cooperation strategy. This paper illustrates various pulses using Gaussian monocycle and doublet.***

Keywords: Ultra-wideband, UWB, PPM, cooperation, relay, diversity, power allocation, decode-and-forward, DF, performance analysis, cooperative diversity, correlated noise.

1. Introduction

The world of ultra-wideband (UWB) has changed dramatically in very recent history. A substantial change occurred in February 2002, when the FCC (2002a, b) issued a ruling that UWB could be used for data communications as well as for radar and safety applications. UWB is not necessarily entirely new in either the concept or the signal-processing techniques used, we believe the current (and for the foreseeable future) emphasis on low power, low interference and low regulation makes the use of UWB an attractive option for current and future wireless applications.

The ability to move between the very high data rate - short link distance and the very low data rate - longer link distance applications is one of the enormous potentials of UWB. The very low transmit power available invariably means low energy, multiple, UWB pulses must be combined to carry 1 bit of information. This simply means, trading data rate for link distance can be as simple as increasing the number of pulses used to carry one bit. The more pulses per bit, lower the data rate, and greater the achievable transmission distance.

1.1 Ultra Wideband Overview

Historically, UWB radar systems were developed mainly as a military tool because they could "see through" trees and beneath ground surfaces. However, recently, UWB technology has been focused on consumer electronics and communications. Ideal targets for UWB systems are low cost, low power, high data rates, precise positioning capability and extremely low interference.

UWB technology differentiates from conventional narrowband wireless transmission technology – instead of broadcasting on separate frequencies; UWB spreads signals across a very wide range of frequencies.

The typical sinusoidal radio wave is replaced by trains of pulses at hundreds of millions of pulses / per second. The very low power and wide bandwidth makes UWB transmissions appear as background noise.

1.2 A Note on Terminology

The name ultra wideband is an extremely general term to describe a particular technology. Many people feel other names, such as pulse communications, may be more suitable and descriptive. However, UWB is the by which most people refer to ultra wideband technology. The question then arises as to how to spell UWB. Is it "ultrawideband", "ultra wide band", "ultrawide band" or "ultra wideband"? In this text, ultra wideband will be used quite arbitrarily. Our reasoning is that the term wideband communication has become very common in recent years and is one that most people are familiar with. To show that UWB uses an even larger bandwidth the extra-large "ultra" is prefixed; however, we use ultra wideband because both "ultrawideband" and "ultra-wideband" seem unwieldy.

1.3 Advantages of UWB

UWB has a number of advantages that make it attractive for consumer communications applications. Particularly, UWB systems

- Comprise of potentially low complexity and low cost;
- Consists noise-like signal;

- Resistant to jamming and severe multipath;
- Very good time domain resolution which is useful in location and tracking applications.

2. Literature Survey

This is basically based on Ultra Wide band system and their characteristics and generation of the UWB in monocycle and Doublet. In this report we are introducing the benefits of the UWB and comparison of the spectral allocation for different wireless radio system, survey of UWB waveforms, division of different modulation methods for UWB communication and types of Receiver used for UWB, Comparison of performance of UWB with the others in the sense that it provides the means to do what has not been possible before, be that the use of high data rates, smaller, lower powered devices, ground penetration radars, through-wall radar imaging or, indeed, some other new application. However, UWB is, rather, a new engineering technology in that no new physical properties have been discovered. However, the dominant method of wireless communication today is based on sinusoidal waves. The sinusoidal electromagnetic waves are so universal in radio communications that many people are not aware that the first communication systems were in fact pulse-based. This is a paradigm shift for today's engineers from sinusoids to pulses that require the most shifts in focus.
The existing UWB cooperation techniques can be classified into two broad categories.

2.1 Orthogonal Techniques

Here cooperation is performed over two distinct time slots where in the first slot the message is transmitted from the source to the relays (and in some cases to the destination) and in the second slot the message is retransmitted from the relays to the destination. Despite their good error performance and simplicity, such schemes are characterized by a data rate reduction where cooperative systems transmit at half the rate of their equivalent non-cooperative systems. For example, in [11] the symbol duration is doubled (compared to non-cooperative systems) where the first half of this duration is completely dedicated to the communication between the source and the relay while the second half is dedicated to the relay- destination link system resources is highly penalizing and constitutes a major drawback that renders these simplistic orthogonal schemes not suitable for real life applications.

2.2 Non-Orthogonal Techniques

The second category corresponds to non-orthogonal co-operation strategies, where appropriate encoding schemes render these cooperative systems capable of transmitting at the same data rate as non-cooperative systems. In particular, all transmissions (whether from the source or the relays) occur in the same TDMA time slot. In such systems, the TDMA slots allocated to the relays are not used for transmitting the information of the source, thus the relays can assist the source even if they have their own data to communicate.

2.3 UWB Generation on Monocycle and Doublet Pulse

The pulse generator which we propose is a generator that delivers very short monocycle pulses of the order 244 ps. These pulses will be used in the ultra wide band system block transmitter. The standard of generation is to represent the monocycle pulse as a mathematical function consisting of a sum in terms of hyperbolic tangent. These will be achieved through the property in the transfer function of the transistors differential pair. We now analyze the theory, based on two approaches demonstrate the approximation between the hyperbolic tangent and the transfer function of the MOS differential pair. The transfer functions presented in are nonlinear functions; they are used to obtain signals with specific forms. For example, conversion of a triangular signal into a sinusoidal signal is the best known of the transfer function of the bipolar transistors differential pair. This transfer function was also used by J. F. M. Gerrits and J. R. Farserotu to propose a mathematical function representing the momentum of the second derivative of Gaussians used in some ultra wide band systems receiving pulse. For us, we propose another function mathematical generating the Gaussian monocycle pulse, and thereafter, a circuit to generate a mathematical function, but this time using MOS transistors differential pairs.

3. Generation of the Pulses

3.1 Monocycle Pulse

We propose and simulate a simple method for generating UWB monocycle pulses based on Cross-Gain Modulation (XGM) in a optical amplifier (OA) as shown in Fig. 1. In this system an optical Gaussian pulse (pump) and a Continuous Wave (CW) (probe) are applied to the optical amplifier. The cross-gain modulation (XGM) in the Optical Amplifier (OA), a pair of polarity-reversed optical Gaussian pulses is generated at the output of the SOA. These two polarity-reversed optical pulses are then time delayed by two cascaded FBGs to introduce a time-delay difference. When the physical spacing between the two FBGs and their reflectivities are properly designed, a monocycle pulse with the required design parameters is generated.

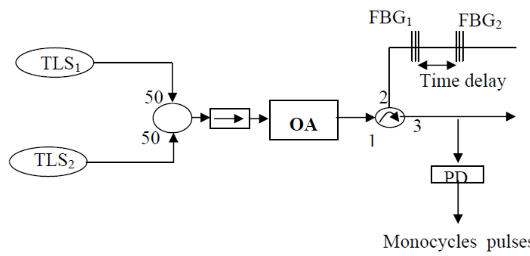

Figure 1: Monocycle Pulse Generation System

The basic idea of this approach is to generate a pair of polarity-reversed pulses at different wavelengths with an appropriate time delay difference between the pulses. The material gain spectrum of an OA is homogeneously broadened therefore the cross gain modulation (XGM) effect in an OA is used to generate the polarity-reversed pulses.

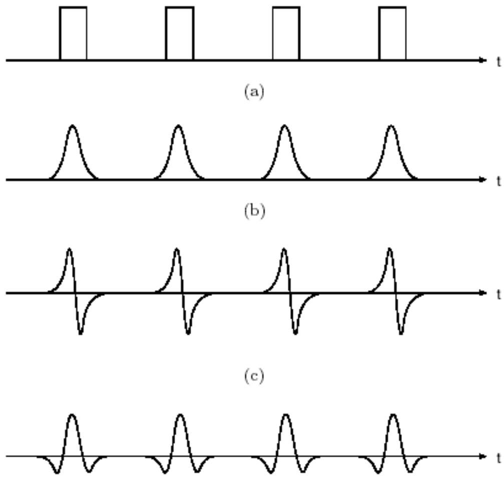

Figure 2: Details of the pulses generated in a typical UWB communication system: (a) square pulse train; (b) Gaussian-like pulses; (c) first-derivative pulses; (d) received Gaussian doublets.

3.2 Mathematical Equations

Gaussian monocycle or doublet pulse can be generated by implementing the first- or the second-order derivative of a Gaussian pulse where the zero-mean Gauss function is described by Equation (1), where σ is the standard deviation:

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-x^2/2\sigma^2} \quad (1)$$

Where, G(x) is Gaussian waveforms because their mathematical definition is similar to the Gauss function. A *Gaussian pulse* which is the basis of these Gaussian waveforms are represented by the following Equation

$$y_{g1}(t) = K_1 e^{-(t/\tau)^2} \quad (2)$$

Where, y_{g1} is the basis of the Gaussian pulse, $-\infty < t < \infty$, τ is the time-scaling factor, and K1 is a constant. More waveforms can be created by a sort of high-pass filtering of this Gaussian pulse. This filtering acts in a manner similar to taking the derivative of Equation (2). For example, the first derivative of a Gaussian pulse, a Gaussian monocycle, has the form:

$$y_{g2}(t) = K_2 \frac{-2t}{\tau^2} e^{-(t/\tau)^2} \quad (3)$$

Where: y_{g2} is the first derivative of a Gaussian pulse, $-\infty < t < \infty$, τ is the time-scaling factor and K_2 is a constant. The Gaussian monocycle has a single zero crossing. Further derivatives yield additional zero crossings, one additional zero crossing for each additional derivative. If the τ value is fixed, by taking an additional derivative, the fractional bandwidth decreases, whereas the center frequency increases. A Gaussian doublet is the second derivative of Equation (3).

$$y_{g3}(t) = K_3 \frac{-2}{\tau^2} \left(1 - \frac{2t^2}{\tau^2}\right) e^{-(t/\tau)^2} \quad (4)$$

Where, y_{g3} is second derivative of a Gaussian pulse, $-\infty < t < \infty$, τ is the time-scaling factor and K_3 is a constant.

3.3 Doublet *Pulse*

If the input signal to the three-tap microwave delay-line filter is a Gaussian monocycle, a Gaussian doublet can be generated. This will be illustrated in fig. where the monocycle pulses was generated and entering to the photonic delay- line filter the output wave (doublet) taken at the BPD.

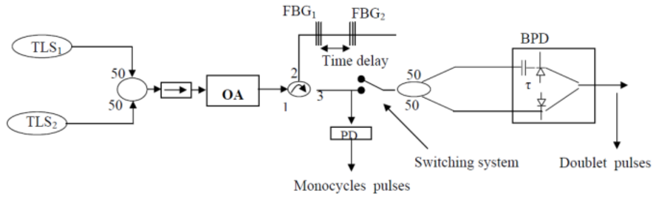

Figure 3: The completed switchable new system to produce the monocycles and doublet Gaussian pulse.

The system shown in Fig. 3. was simulated with two parts one for monocycle and for doublet. Two CW tunable laser sources, TLS1 and TLS2, serve as the pump and the probe respectively, are used in the system. The output of TLS1 is pulsed laser source with Gaussian shape. Then a CW probe from TLS2 and the pulsed optical sequence are applied to the OA via a 3 dB coupler. At the OA, the intensity of the probe light is modulated by the pump pulse because of the XGM. A pulse with a shape similar to the pump pulse but with a reversed polarity is generated at the probe wavelength are shown in Fig. To obtain a UWB monocycle, a time delay difference between the two polarity-reversed pulses needs to be introduced.

It is realized in the numerical experimental system by using two uniform FBGs (FBG1 and FBG2). The central wavelengths of FBG1 and FBG2 are chosen to be identical to the wavelengths of the probe and the pump.

The time-delayed pulses are then detected at PD photo detector, and thus a UWB monocycle pulse is generated, and the simulation was performed where, FBG1 and FBG2 are kept between physical spacing of in 3.5mm, which corresponds to a time-delay difference of 35 ps. Both FBGs are 1 mm long.

The central reflection wavelengths of FBG1 and FBG2 are 1549.21 and 1552.63 nm, with 3 dB bandwidths of 0.55 and 0.87 nm. These bandwidths of FBG are wide enough that no considerable distortions to the pump or probe pulses are generated. Fig shows the XGM where a strong pump light will reduce the gain of OA, and causes to modulation of a weak CW probe light.

4. UWB Transmitter

A general UWB transmitter block diagam is shown in Figure. First, meaningful data are generated by applications that are quite separate from the physical layer transmitter. Applications might be an e-mail client or a web browser on a personal computer, a calendar application on a personal digital assistant (PDA), or the digital stream of data from a DVD player. From the perspective of the physical layer the data may be anything at all. This part of the wireless device is often called the 'back end'. This terminology is not immediately apparent, but it is common to refer to it as from the receiver's point of view.

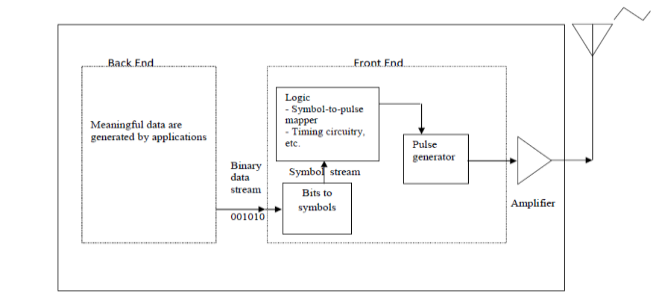

Figure 4: UWB Transmitter

This binary information stream is then passed to the 'front end', which is the part of the transmitter which we are concerned about.

If higher modulation schemes are to be used the binary information should be mapped from bits to symbols, with each symbol representing multiple bits. These symbols are then mapped to an analog pulse shape. Pulse shapes are generated by the pulse generator. Precise timing circuitry is required to send the pulses out at intervals which are meaningful.

If PPM is employed the timing must be even more precise, usually less than one pulse width. Pulses can then be optionally amplified before being passed to the transmitter.

In general though, to meet power spectral requirements, a large gain is typically not needed and may be omitted. Although this is an extremely simplistic transmitter model, which omits any forward error-correcting scheme, it serves the purpose to show that UWB transmitters can be quite simple. This is to be compared with other wireless transmitters, such as OFDM.

5. UWB Receiver

A general UWB receiver block diagram is shown in Fig. 5. The receiver performs the opposite operation of the transmitter to recover the data and pass the data to whatever 'back end' application may require it. There is a major difference between the transmitter and the receiver that the receiver will almost certainly have an amplifier to boost the signal power of the extremely weak signals received. A general UWB receiver block diagram is:

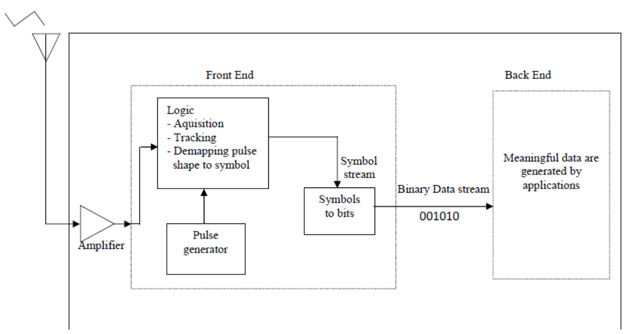

Figure 5: A general UWB Receiver Block diagram

It performs the functions of *detection* or *acquisition* to locate the required pulses amongst the other signals and then to continue *tracking* these pulses to compensate for any mismatch between the clocks of the transmitter and the receiver. Communication requires both the transmission and reception of signals. We have mostly concentrated on the wireless transmission side up to this moment. We will now focus on the detection of pulses, that is, the acquisition and tracking of the pulse trains.

6. PPM

Pulse Position Modulation, sometimes known as pulse phase modulation is used for digital signal transition. It is used in fibre optics and IR (infrared) remote controls where there is a lack of interference. This technique uses pulses of the same breath and height but is displaced in time from some base position according to the amplitude of the signal at the time of sampling.

The Pulse Position Modulation (PPM) is a modulation technique designed to achieve the goals like simple transmitter and receiver circuitry, constant bandwidth, noise performance and the power efficiency and constant transmitter power. The amplitude of the pulse in Pulse Position Modulation is kept constant as in the case of the FM and PWM to avoid noise interference. Unlike the PWM, in order to achieve constant transmitter power, the pulse width is kept constant. The modulation is done by varying the position of the pulse from the mean position according to the variations in the amplitude of the modulating signal.

The Pulse Position Modulation (PPM) can be actually easily generated from a PWM waveform which has been modulated according to the input signal waveform. A demodulation of PPM can be done both synchronously and asynchronously. PPM synchronous demodulation is complex as it requires synchronization of the receiver with the transmitter. During asynchronous PPM demodulation technique, comparatively less quality can be achieved, but with an advantage of very simple circuit for demodulation. This article discusses how to demodulate the PPM waves using the simplest possible method.

6.1 PPM Generation

The PPM required for this project is generated from a PWM wave which is modulated with the message signal. This message signal is a pure sine waveform generated using the Wien Bridge Oscillator (WBO). A ramp signal is generated with the help of a RC charging circuit and a comparator IC. Additional comparator IC which is fed with ramp signal as one of its input and the message signal as other can produce a PWM wave at its output. The PPM wave is generated using PWM wave using a mono-stable multi-vibrator. PWM generation circuit is explained in below block diagram:

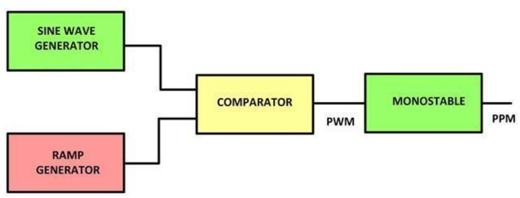

Figure 6: PPM generation

A sine wave generator circuit is used in this project which is based on the Wien Bridge Oscillator (WBO) circuit. This WBO circuit can produce distortion less sinusoidal sweep at its output. The circuit is designed in such a way that both the amplitude and frequency of the oscillator can be adjusted using potentiometers. A waveform of frequency 1 KH_z is produced by adjusting sine wave generator.

The Ramp generator used in this circuit is designed with an op-amp and an RC charging circuit. This RC charging circuit is connected to the output of the op-amp and the voltage across the capacitor is connected to one of the input of the op-amp. The variable pin of a potential divider is connected to another input of the op-amp the variable pin of a potential divider is connected to which divides the voltage from the output of the op-amp.
Features:

- PPM Modulation using Timer IC
- Message signal with three different frequency
- On Board carrier signal
- On-board message signal with variable amplitude
- PAM Demodulation using Low Pass Filter
- Amplifier using Op-Amp
- Internal Power Supply +5V , +12V/ 500 mA
- Number of test point to study the PPM system
- A block diagram with user friendly front panel

6.2 Working of PPM

In PPM, data are transmitted with short pulses. All of these pulses have both the same width and amplitude. The delay between each pulse is the parameter that changes. Here is an example of a PPM signal:

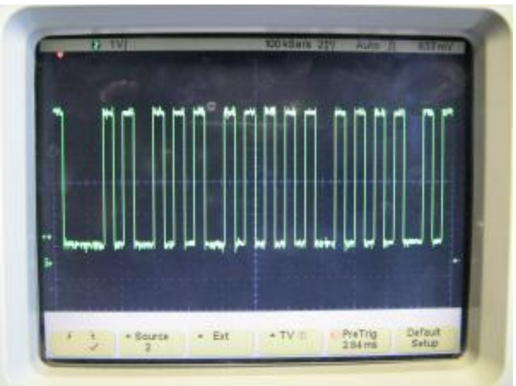

Figure 7: PPM encoded signal captured from a TV remote control

It is obvious that the signal has similar pulses (in terms of amplitude and width), but still the duration between them differs. I will start with the digital PPM to explain how exactly this method works.

7. Results

We have simulated in matlab and results are compared .An AWGN channel is considered as channel model hence multipath gathering effects are not considered.

In the first step a simple Gaussian monocycle and Gaussian doublet are generated along with it's a spectrum.

The fig shows generated Gaussian monocycle and Gaussian doublet with their frequency plots which justify the name Ultra wideband because of their wide band structure.

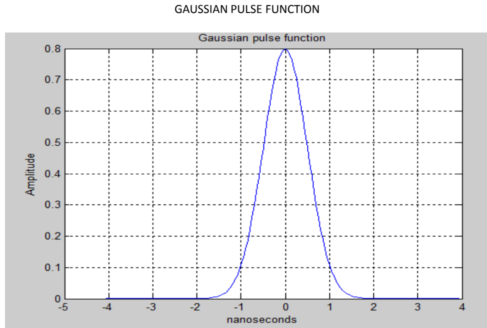

Figure 8: Gaussian pulse function

After generating the optical monocycle pulses by using the optical amplifier the doublet Gaussian pulses can be generated according to equation (3). The second -order derivative of Gaussian pulses can be approximated by the first- or the second-order difference. It is known that the a second-order difference can be realized using a three-tap microwave delay-line filter with coefficients of (1, -2, 1)

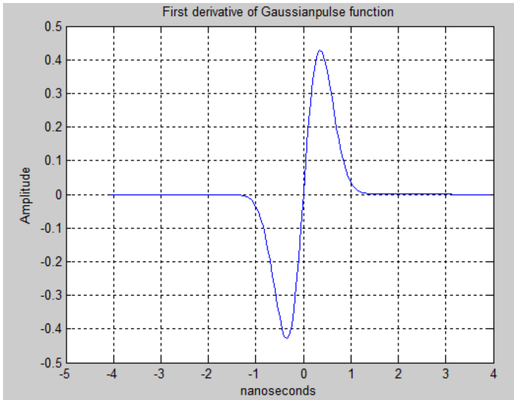

Figure 9: First derivative of Gaussian pulse function

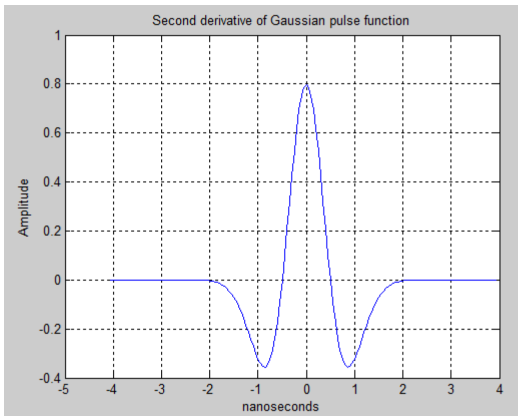

Figure 10: Second derivative of Gaussian pulse function

In the first step a simple Gaussian monocycle and Gaussian doublet I generated along with its a spectrum. The fig shows generated Gaussian monocycle and Gaussian doublet with their frequency plots which justify the name Ultra wideband because of their wide band structure.

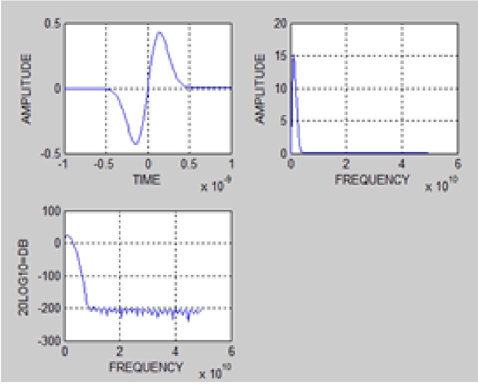

Figure 11: Gaussian monocycle and spectrum

In the second step a simple UWB transmitter and receiver scheme is implemented using BPSK scheme .the experimental results shown in below

Fig. 12. (a) shows the transmitted data .fig Fig. 12. (c) shows the sinusoidal carrier signal. Fig. 12. (b) shows modulated output for the scheme. Fig. 12. (d) shows the received data prior to the filter. Fig. 12. (e) and (f) shows the frequency spectrum for the scheme

The BPSK modulated received signal .the spectral mask for UWB indoor applications is -41.3dbm/Mh_z . Fig. 12. (f) shows exactly the same where spectral mask is around -41dbm/mhz.

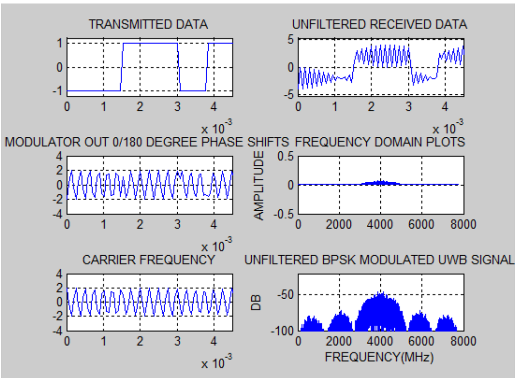

Figure 12: A simple UWB BPSK transmitter receiver scheme

8. Conclusion

- A general model to analyze the PSD of UWB signals was developed to investigate the transmission performance of data-modulated monocycle signals.
- The PSD of a monocycle-based UWB signal with OOK, BPM and PPM schemes was calculated.
- Two pulses have to be well separated by at least channel spread, resulting in the reduced data rate .by transmitting pulses with the time delays greater than the maximum expected multipath delay, unwanted reflections can be avoided at the receiver this is inherently in sufficient and places limit on the maximum speed of the data transmission for the given modulation system the distance required between multipath decreases with pulse width.

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