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ULTRA WIDEBAND PULSE GENERATION USING MULTIPLE ACCESS MODULATION SCHEMES

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ABSTRACT

An Ultra-wideband (UWB) employs very narrow pulses, of the order of a few nano-seconds, in order to provide high data rate communications .These narrow pulses spread the energy over a wide frequency band, and hence the name ultra-wideband (also called Impulse radio). In this paper, we will discuss the basic techniques of UWB pulse modulation and transmission design considerations using Time Hopping and Direct Sequence multiple assess modulation techniques using MATLAB Simulations .

KEYWORDS: UWB, PAM, PPM, PPM-TH, PAM-DS

INTRODUCTION

UWB transmission is a signal, that occupies a bandwidth of greater than 500 MHz or having a fractional bandwidth larger than 20% as compared to narrowband signal which typically have a fractional bandwidth less than 1% .As per FCC regulations, UWB systems having the central frequency fc >2.5 GHz need to have a –10 dB bandwidth of at least 500 MHz, while UWB systems with fc <2.5 GHz need to have fractional bandwidth at least 0.2 .

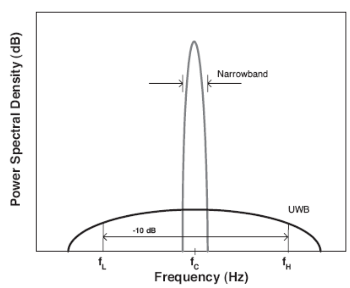

Fig.1.UWB bandwidth

PULSE GENERATION

Impulse Radio is one of the popular choices for UWB transmission. Since it does not use a sinusoidal carrier to the signal to a higher frequency but instead communicates with a baseband signal composed of sub nanosecond pulses and because of the very short duration of the pulses, the UWB spectrum signal will be several gigahertz's wide. One of the most Popular Pulse Shape of UWB communication system is the gaussian pulse or a derivative of the gaussian pulse due to its mathematical convenience and ease of generation. The Gaussian pulse is defined as

$$p(t) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{(t-\mu)^2}{2\sigma^2}} \quad -\infty < t < \infty \quad (1)$$

Where σ is the standard deviation of the Gaussian pulse, and μ is the location in time for the midpoint of the Gaussian pulse in seconds [4][5].

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Modulation Techniques

A. PPM Modulation

In PPM modulation, each pulse is sent in advance or delayed to a regular time scale. A binary communication system can be established with a forward or backward shift of the pulse in time.

The data is encoded by adding an extra time shift '' δshift'' to the impulse as shown in the Fig. The binary PPM signal is defined as

$$s(t) = \sum_{k=-\infty}^{\infty} a_k \; p\left(t - kT_f \pm \delta_{shift}\right)$$

where the data modulation is done by small shifts in the pulse position δshift, p(t) is the UWB pulse and T_f is the frame duration.

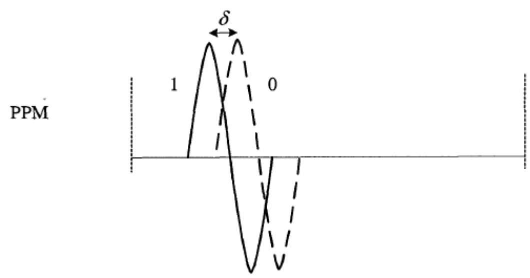

Fig.2. PPM Modulation

B. PAM Modulation

The second data modulation scheme is pulse amplitude modulation (PAM), which is based on encoding the data in the amplitude of the impulses. The PAM modulated signal can be written as: $s(t) = \sum_{k=-\infty}^{\infty} a_k \; p(t - kT_f)$ where ak is the amplitude of the pulse p(t) and T_f is the frame duration. Fig.3. illustrates a PAM modulated signal.

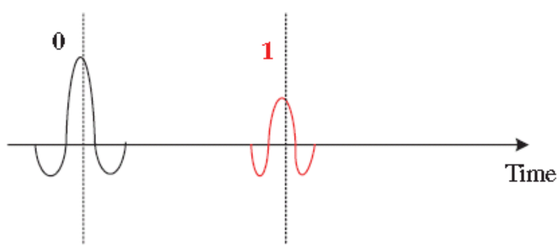

Fig.3. PAM Modulation

C. Bi-phase modulation (BPM)

In Bi-phase modulation (BPM) we invert the pulse, to create a pulse having opposite phase. This is known as. Bi-phase is therefore antipodal and in a purely additive whit Gaussian noise (AWGN) channel has error performance identical to binary phase shift keying (BPSK).

The BPM signal can be expressed as:

$$s(t) = \sum_{k=-\infty}^{\infty} a_k \; p(t - kT_f), \text{with } a_k = 1, -1$$

Where p(t) is the pulse shape and Tf is the duration of time frame.

BPM is a form of PAM modulation. Specifically, when in the binary PAM modulationa_k 's have symetric antipodal amplitudes this modulation reverts to the BPM modulation.

In the Bi-phase modulation negative pulse is represents as "0" and a positive pulse represents as "1".

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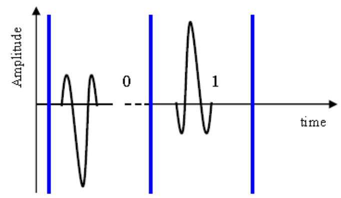


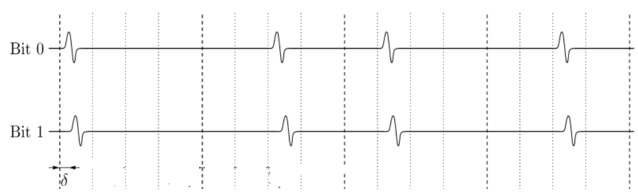
Fig.4. Bi-phase Modulation.

Multiple Access Modulation techniques

In order to minimize the potential interference from UWB transmissions and provide multiple access capability, a randomizing technique is applied to the transmitted signal. This results in the spectrum of the ultra wide band signal signal close to like as noise. The two main randomizing techniques used for single band UWB systems are time-hopping (TH) and direct-sequence (DS) and these techniques can be used in conjunction with all the modulation techniques described earlier.

A. Multiple Access Time Hopping(TH)

This technique is variation of traditional time division multiple access (TDMA). In traditional TDMA a frame is divided into N time slots and allowing N users to share a single link. Each user is assigned a time slot and can transmits in the same time slot each frame. Time hopping technique adds a variation to this by changing the time slot from frame to frame according to the user's code. Also when it is used with UWB more than one pulse is used to represent the data symbol. In the time hopping , each impulse position is determined by a pseudo-random (PR) code. In this way, more energy is allocated to a symbol and transmission range is increased. Also the different users are distinguished by their unique time hopping code and can transmit the signal at the same time.



δ = Pulse position shift

Fig.5.Time hopping Pulses while representing bits.

B. Multiple Access Direct Sequence

Direct Sequence (DS) is another multiple access technique that is popular in UWB community. DS-UWB is similar in principle to more traditional DS-SS systems such as cellular CDMA (code division multiple access). It employs sequences of UWB pulses in which every user is distinguished by its specific PR code sequence which performs pseudo random inversions(PR) of the UWB pulse train. A data bit is then used to modulate these UWB pulses. The resultant signal will be a continuous transmission of ultra wide band pulses and their number depends on the pulse length and the bit rate of the system.

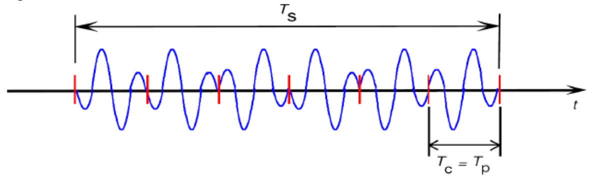


Fig.6. Direct sequence Pulses

At the transmitter information symbol to be transmitted is first spread with a pseudo random or PN sequence and then amplitude modulated with short pulses and on the receiver side the information is firstly dispread using the same pseudo random sequence used at time of spreading. This system of communication is called DS-UWB.

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UWB TRANSMITER DESIGN MODEL

In this paper we will consider the design considerations of UWB transmitter using Pulse Position Modulation Time Hopping (PPM-TH) and Pulse Amplitude Modulation Direct Sequence (PAM-DS) multiple access modulation schemes

A. PPM-TH-UWB Transmitter

One of common technique for UWB modulation pulse position modulation (PPM). In Pulse position modulation each pulse is sent earlier or can be delayed to the regular time scale. Therefore according to the bits of data, the pulse can be delayed. PPM is useful because of its simplicity and the delay can be controlled easily. In UWB, a very fine resolution in time is required to modulate the pulses. The peaks of the spectra of Gaussian pulse and PPM can result in interference with other operating radio frequency systems so the the signal must be time shifted with the help of pseudo random codes.

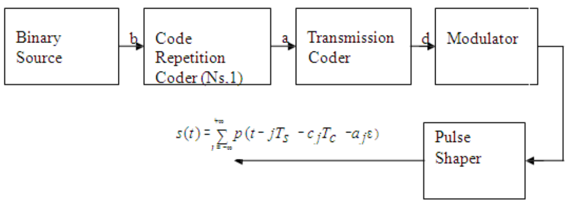

Fig.7. PPM-TH-UWB Transmitter

The binary source generates the bits to be transmitted at rate $R_b = 1/T_b$ .given to code repetition coder which introduces redundancy and acts as channel coder. It repeats the bits generated by the binary source Ns times so the bits are now generated at the rate $R_{cb} = \frac{N_s}{T_b}$b=a.The transmission coder generates a PN(pseudo random code) with a period N_p and applies this code to the repeated bits generating a new sequence of bits

$d_j = c_j T_c + a_j \varepsilon$ (2)

Where, T_c is the chip time
c_j is the pseudo random code
The shift generated by PPM the modulator is $a_j\varepsilon$
The pulse shaper generates a pulse with impulse response p(t) such that the output of the pulse shaper filter is non-overlapping pulses . The Gaussian derivative pulse is used for this purpose.
The signal at the output of the PPM-TH-UWB transmitter is represented as
$s(t) = \sum_{j=-\infty}^{+\infty} p(t - jT_s - c_j T_c - a_j \varepsilon)$ (3)
Where, $c_j T_c$ = time dither introduced by the TH code,
$a_j\varepsilon$ = time shift introduced by the PPM modulator,
One bit duration $T_b = T_s N_s$
This signal s (t) is transmitted by the UWB transmitter over the channel and received at the receiver end.

The above described model is created using MATLAB software and the transmitted signal is generated using PPM-TH multiple access modulation scheme using the following parameters (Pow=30,fc=50e9,numbits=3,Ts=3e9,Ns=5,Tc=1e-9,Ns=5,Tc=1e-9,Np=5,Tm=0.5e-9,and dPPM=0.5e-9).
Where Pow = Average transmitted power (dBm), fc = sampling frequency , numbits = number of bits generated by the source ,Ts = frame time, pulserepetition period , Ns = number of pulses per bit ,Tc = chip time, Np = periodicity of the Time Hopping code, Tm = pulse duration , dPPM= time shift introduced .

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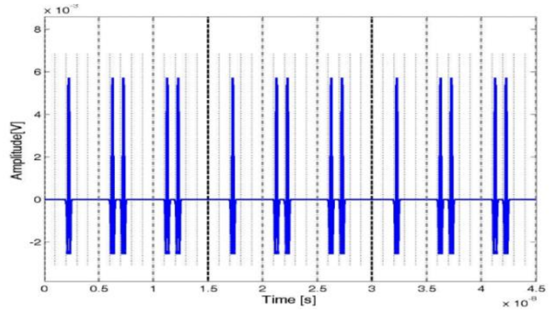
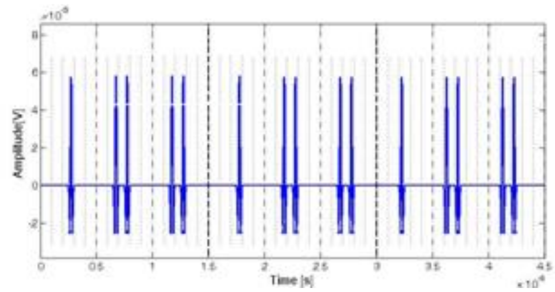


Bit 1 1 0

Fig.8. UWB PPM-TH before

modulation



Bit 1 1 0

Fig.9.UWB PPM-TH after modulation

B. DS-UWB Transmitter

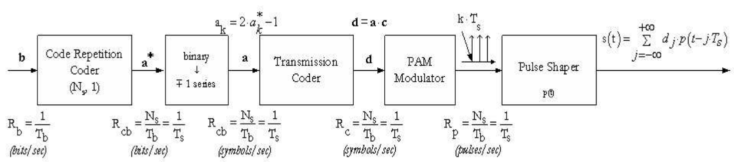


Fig.10.UWB DS-UWB Transmitter

UWB signals can also be generated in a Direct-Sequence Spread-Spectrum fashion by first coding the binary sequence to be transmitted with a PN binary-valued sequence, and then by amplitude modulating a train of short pulses. A binary sequence is generated at the same rate, R_b= $1/T_b$, and the first part of the system is a repetition coder which repeats each bit Ns times and generates a new binary bit sequence a at a rate of Rcb = N_s/T_b = $1/T_s$ bits/s. Redundancy is also introduced in this way.

The next step is the binary series part of the system where the sequence a+ is transformed into a which is composed of binary antipodal symbols (±1). code c consisting of (±1)'s and with period N_p to the sequence a. A new sequence d=a*c is generated, consisting of dj = ajcj .

Sequence d then enters the PAM-modulator where a s Dirac pulses sequence positioned at jT_s is generated at a rate R_p = N_s/T_b = $1/T_s$. The train of pulses enters the pulse shaper and shaper has the same function as in TH-UWB so that the output of the pulse shaper filter is non-overlapping. The signal at the output of the PAM-DS transmitter is represented as

$$s(t) = \sum_{j=-\infty}^{+\infty} d_j\, p(t - jT_S) \quad (4)$$

The above described model is created using MATLAB software and the transmitted signal is generated using PAM-DS multiple access modulation scheme using the following parameters

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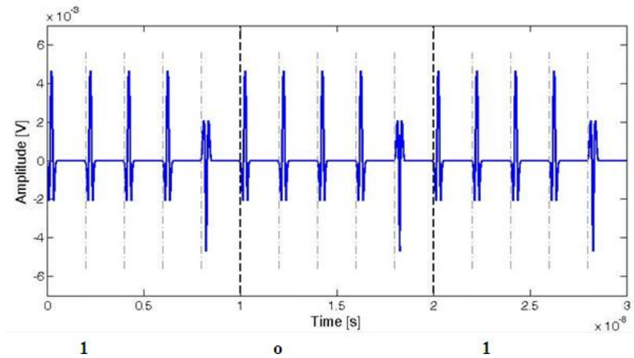

Fig.11. UWB PAM-DS before modulation

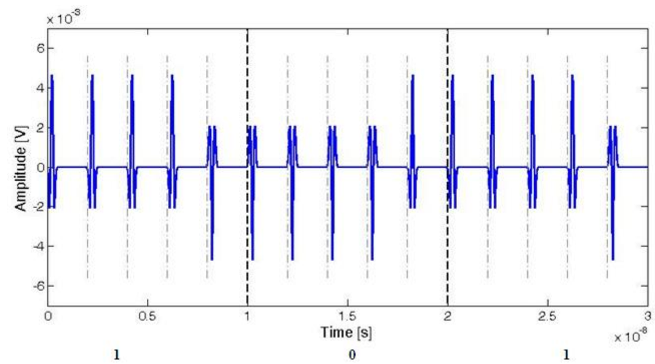

Fig.12. UWB PAM-DS after modulation

(Pow=30,fc=50e9,numbits=3,Ts=3e9,Ns=5,Tc=1e-9,Ns=5,Tc=1e-9,Np=5,Tm=0.5e-9).
Where Pow = Average transmitted power (dBm),fc = sampling frequency, numbits = number of bits generated by the source ,Ts= frame time, pulse repetition period, Ns = number of pulses per bit, Tc = chip time, Np= periodicity of the Time Hopping code, Tm = pulse duration [s]

CONCLUSION

In this paper all the basics of UWB modulation and multiple access modulation techniques are explained and we have generated the UWB transmitter model using both Pulse position modulation time hopping multiple access and Pulse amplitude direct sequence multiple access modulation scheme and generated the pulses before and after the modulations. Also the PN codes used for transmission pulse generation can also act as code division multiple access codes such that different users will have different codes and by using the pulses with this code duration, they will act as noise for users with different PN codes which can be utilized as a signal to be sent over the channel to obtain optimal results.

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