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Contents

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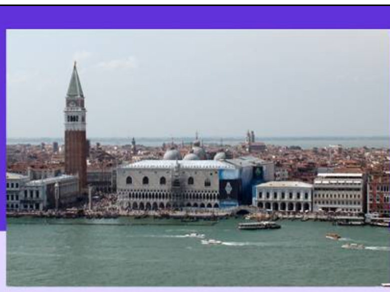

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Performance Measures of Ultra-Wideband Communication System

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Abstract: Ultra-Wideband (UWB) has the potential to become a viable and competitive wireless technology for short-range high rate Wireless personal area networks (WPANs) as well as lower-rate and low power causing low cost devices and networks. This paper discusses properties of Gaussian pulses and derivatives thereof used for UWB signalling. The power spectral density(PSD) of signals sent into channel appear as discrete components resembling spikes with amplitudes that could adversely interfere with established communication systems. In this, mathematical model for the analysis of PSD in the channel is introduced. PSD for Time Hopping UWB (TH-UWB) signals using PPM (Pulse Position Modulation) technique is derived and simulated in the MATLAB 7.0 environment. Results show that TH-UWB PPM is a potential candidate for the fourth generation broadband wireless networks. Finally, it is established that the introduction of randomness into transmitted signal has the effect of decreasing the amount of interference power.

Keywords: Ultra-Wideband, Spectral shaping, PSD, PPM, TH-UWB.

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1. Introduction

Ultra Wideband (UWB) technology is one possible solution for the short range Indoor communication applications. This technology has been introduced some decades ago but the applications have mostly been in ground penetrating radar systems. UWB systems spread the signal energy over the extremely large frequency band and make the power spectral density very low. An easy pulse waveform to generate UWB spectrum is a narrow Gaussian pulse and some of its modifications. The bandwidth of a Gaussian pulse is inversely proportional to the pulse width.

Due to the wide bandwidth of the UWB signal, the UWB energy will spread over the frequency bands allocated to the other radio systems, like GPS, cellular phones, broadcasting, etc. Currently, FCC in the USA is making regulations for UWB applications. In Europe, this regulatory work has also been started by CEPT and ETSI. During the regulatory work, some experimental field tests between the UWB transmitters and GPS receivers have been made [1-3]. Now-a-days, UWB spread spectrum techniques have recently attracted great scientific as well as commercial interest [4]. In this paper, time modulated implementation of UWB (TM-UWB) will be the considered. Rest of this paper is organised as follows: the underlying overview of UWB system is introduced in Section 2. In Section 3, a simulated system model is described, followed by the UWB system performance based on MATLAB simulation is discussed in Section 4. Section 5 provides a brief related research in this field. Finally, conclusion and future scope is outlined in Section 6.

2. Overview

The term UWB stands for Ultra-Wide Band, and it refers to a system or signal with an extremely large bandwidth. Originally, UWB signals are defined as signals having a fractional bandwidth of at least 0.25 or occupying at least 1.5 GHz spectrum. In recent literature [5], these two factors are modified to 0.20 and 0.5 GHz respectively.

2.1. Features of UWB System

The following are some features of the UWB systems [6].

● **Extremely low signal power spectral density:** Because of the low signal power and the available large bandwidths, UWB systems perform like spread spectrum systems. However, compared to the more common forms of spread spectrum system like Frequency Hopping and direct sequence system, UWB does not rely on a hopping sequence and spreading sequence respectively to generate wide bandwidth signals.

Compared to other narrowband communication systems, which operate in the bandwidth-limit regime, UWB works in the power limit regime. Therefore, UWB signal power in any single narrow frequency channel is very small and the interference to any other existing products like 802.11a terminals and 3G mobile phones can be ignored.

●**Robust to Multipath Interference:** UWB is robust to the effect of multipath interference. Because the signal bandwidth of UWB is much larger than the coherence bandwidth of the multipath channel, any frequency selective fading only affects a small portion of the signal spectrum for any channel realization. The capability to highly resolve multipath combined with the ability to penetrate through materials makes UWB technology valuable for high quality, fully mobile short-range indoor radio systems.

2.2. Applications

Typical applications of the UWB technology include through wall penetration, precise location, UWB radar and UWB sensor networks (IEEE802.15.4a). UWB is applicable in the above scenarios due to its popularity for multipath immunity, higher data throughput, better penetration, lower power consumption, and low probability of intercept and detection. High data rate UWB can enable wireless monitors, the efficient transfer of data from digital camcorders, wireless printing of digital pictures from a camera without the need for an intervening personal computer, and the transfer of files among cell phone handsets and other handheld devices like personal digital audio and video players[7].

2.3. Gaussian Monocycle

The basic element in UWB radio technology is the use of Gaussian monocycle [8] as shown in Fig. 1 below, in both time and frequency domains. The monocycle with a narrow pulse width produces a wide bandwidth signal. The monocycle's width determines the centre frequency and the bandwidth.

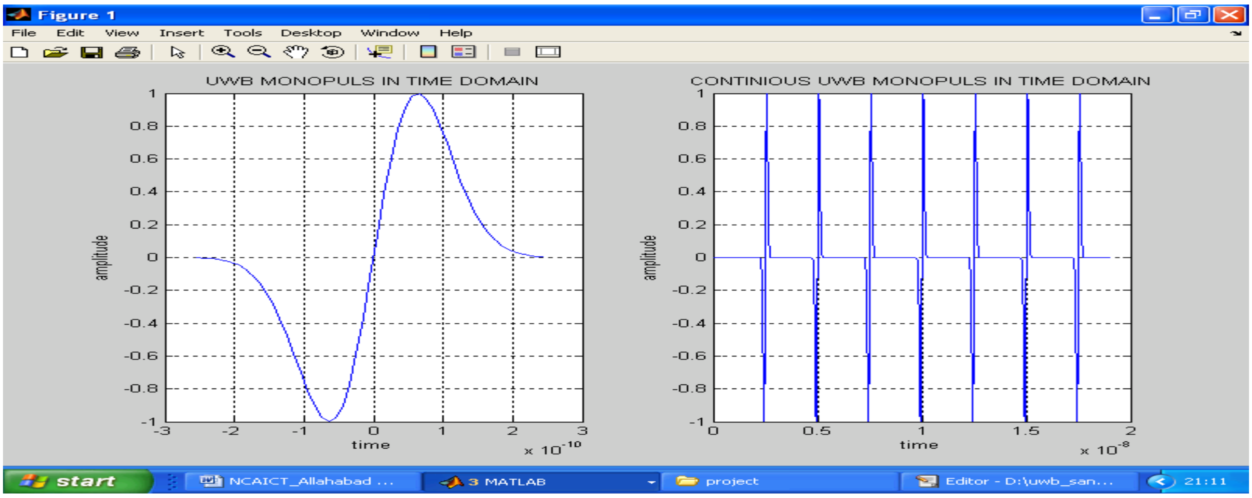

Fig. 1. Time Domain representation of UWB signals.

2.4. Monocycle Sequence

The monocycle itself contains no data; therefore a long sequence of monocycles termed a "pulse train" with data modulation is used for communication. A PN (pseudo-random) noise code can be used a channel code to add a time offset to each impulse as illustrated in Fig. 2.

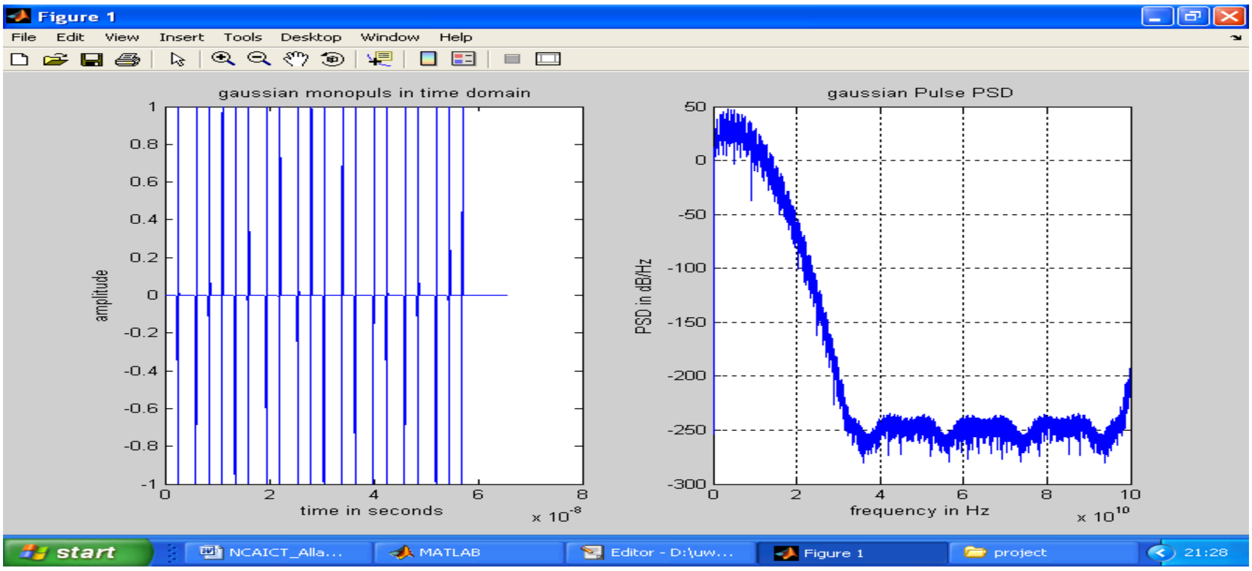

Fig. 2. Time Hopping Gaussian Pulse Train and Gaussian Power Spectral Density (PSD).

It can be seen that the monocycles in the time domain are transformed to energy spikes ("comb lines") at intervals in the frequency domain; therefore the power is spread among the comb lines. By shifting each monocycle's at a pseudo-random time interval, the pulses appear to be white background noise to users with a different PN code. PN coding can be used to eliminate energy spikes that would have interfered with conventional RF system at short range if pulses were placed uniformly in the time domain. This channel code also allow the data to be detected by the intended receiver, therefore data transmitted is more secure in hostile environment and also with less interference with multiple users [8]. The use of PN sequence in time hopping may theoretically imply that the system could have infinite number of unique users all on different PN channels.

2.5. UWB system using Time Hopping

Time hopping concept is generally imagined as, so called, impulse radio concept [9]. The idea of time hopping is part of the original proposal for UWB communications. Modulation of TH-UWB radio is achieved through shifting of pulses. The key motivations for using TH-UWB impulse radio are the ability to highly resolve multipath and the availability of technology to implement and generate UWB signals with low complexity. In both TH-UWB and DS-SS one information bit is spread over various monocycles and the required processing gain is achieved in reception.

2.6. The PPM-TH-UWB case

There are three concerns in terms of making selection of using PPM as the modulation technique instead of BPSK [10-11]. They are:

- Firstly, because the multipath channel is causal in time, PPM can utilize this feature very well to be tolerated with the reflective wireless channel and as well as good spectral properties;
- Secondly, since Philips is working on accurate timer implementation, which is important for building a real system, the problem of timing accuracy can be more or less solved [12];
- The third reason of choosing PPM is that it is also used by Time Domain Inc., one of the first companies who are working on commercial UWB products. Time Domain Inc. already made some successful UWB communication chipsets based on this modulation scheme, which indicates that PPM is acceptable as a mature modulation scheme.

3. UWB System Model

The basic signal model for TH-UWB using PPM (Pulse Position Modulation) is given by:

$$S_k(t)= \sum_j w(t - j\,T_f - c_j^{(k)}\,T_c - \delta d_n),$$

where $S_k(t)$ is the $k^{th.}$ Transmitted signal;
W(t) is the transmitted monocycle waveform;
T_f is the pulse repetition time or frame time;
J is the j^{th}. Monocycle that sits at the beginning of each frame;
Δ is the time shift that applies to the monocycle and such operation is defined when 1 is transmitted;
T_c is the additional time delay that associates with the time hopping code;
$c_j^{(k)}$ are time hopping code (periodic pseudorandom codes), and
d_n is the information data sequence.

In the initial simulation, a UWB mathematical model based on Gaussian pulse train in time and frequency domain with MATLAB using FFT(Fast Fourier Transform) were made, as shown in Fig. 1 and Fig. 2. The key findings of the TH-UWB system simulations with and without PPM are shown in Fig. 3 and Fig. 4.

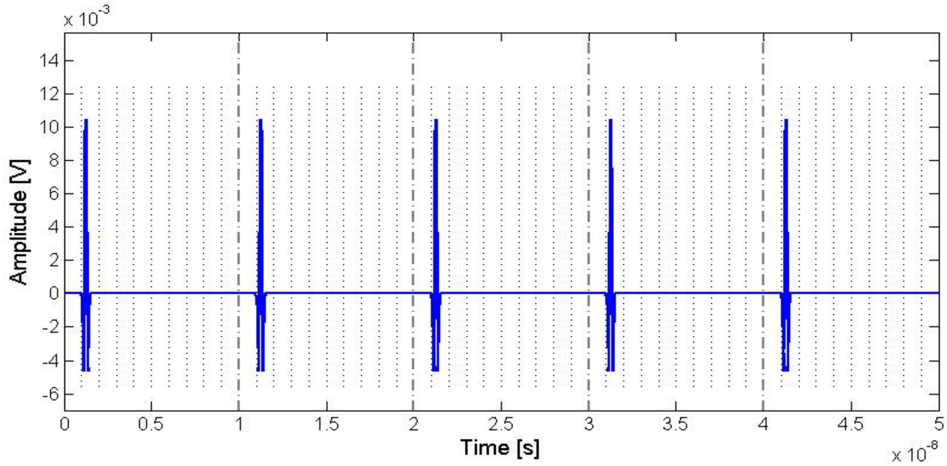

Fig. 3. TH-UWB with no PPM.

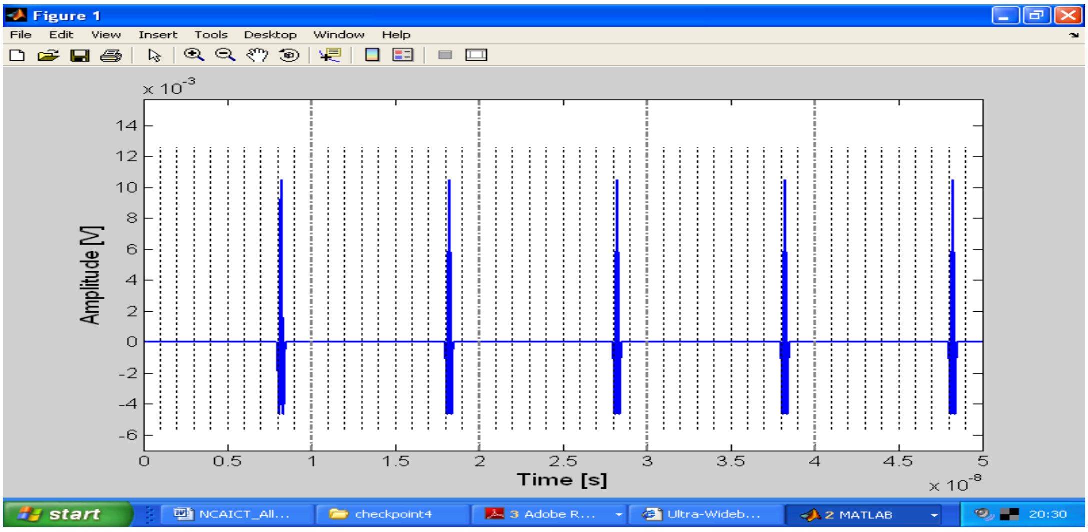

Fig. 4. TH_UWB with PPM.

4. UWB System Performance

Simulation using long sequence of Gaussian monocycles in a practical time scale with data modulation achieved by changing the pulse polarity was performed and the consequence on PSD of using time hopping technique in positioning the Gaussian monocycle in the pulse train was investigated. A time hopping Gaussian pulse train is illustrated in Fig. 3 and Fig. 4. The time axis is divided in to frames and during each time frame; only one slot is allowed to contain a Gaussian monocycle. The corresponding PSD of the sequence is shown in Fig. 5.

The particular time slot chosen for a given frame depends on the time hopping scheme employed. It can be seen that the use of long random sequence yields the smoothest PSD and produces a noise like signal. However, if the signal was to be transmitted over a communication link, this random sequence used had to be known on the receiver side in order to translate the signal back to useful information. This can be achieved by the use of long sequence random fix hopping, i.e. eventually a PN code which not only flattens the spectrum but provides a mean of channelization.

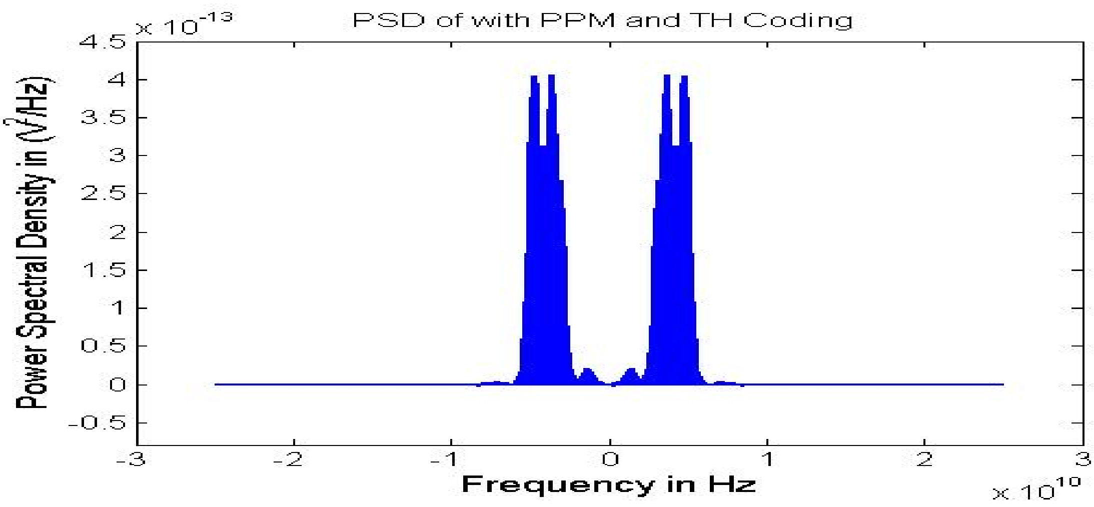

Fig. 5. PSD of PPM-TH-UWB system.

5. Related Work

The techniques for generating UWB signals have existed for more than three decades. Perhaps it is more readily known to the radar community within its time domain description as "base band carrier less short pulse" technique. A comprehensive reference of early works in this area can be found in [13]. In the late 90's, some research institutes and companies started to apply the knowledge of UWB (or Impulse radio) to the wireless communication area. Much work has been done so far and some early results have been achieved. The pulse shape that can be used in the UWB system is discussed in [14]. A new ultra wide band antenna is proposed by the authors for UWB applications in [15]. Modern UWB systems use other modulation techniques, such as Orthogonal Frequency Division Multiplexing (OFDM) [16-17], to occupy these extremely wide bandwidths. In addition, the use of multiple bands in combination with OFDM modulation can provide significant advantages to traditional UWB systems. The MultiBand OFDM approach allows for good coexistence with narrowband systems such as 802.11a, adaptation to different regulatory environments, future scalability and backward compatibility. This design allows the technology to comply with local regulations by dynamically turning off subbands and individual OFDM tones to comply with local rules of operation on allocated spectrum. More research in this field can also be obtained from [18-19].

6. Conclusion and Future Scope

In ultra wideband system design the pulse waveform and the pulse width are the main parameters in spectral allocation. The shape and location of the spectrum depends on the used pulse waveform. In UWB power spectral density of the transmission is small. The ultra-low PSD generated by random time hopping makes the signal appear as "white noise" to other radio frequency devices and therefore the already crowded spectrum can be re-utilised. In this way, UWB can be considered as a potential candidate for the high data rate communication. However, the in band interference of UWB signal using higher order derivatives of pulse may be thought of as future scope in this area.

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