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PERFORMANCE EVALUATION OF ULTRA WIDEBAND IMPULSE RADIO SYSTEM

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ABSTRACT

Ultra Wideband Technology for commercial communication application is a recent innovation. The short range wireless systems have recently gained a lot of attention to provide multimedia communication and to run high speed applications around a user centric concept in so called Wireless Personal Area Network (WPAN). UWB technology presents itself as a good candidate for the physical layer of WPAN.

In this thesis, a comparative performance analysis of the direct-sequence spread spectrum (DS-SS) for Pulse Position Modulation (PPM) and Pulse Amplitude Modulation (PAM) schemes carried out. The simulation results show that the bit error rate (BER) performance of the DS-SS PAM outperforms the DS-SS PPM systems. Further, study is carried out for selection of transmission pulse to meet the FCC specified frequency mask for indoor applications. The work is extended to cover the link budget analysis for UWB systems also.

The present work can be extended in future to cover the realistic channel models for various applications such as sensor networks, WPAN and multipath etc. Channel coding can also be a promising research direction.

KEYWORD:- USB, IR,

INTRODUCTION

Ultra wideband impulse radio (UWB-IR) is built on a long history of technological advancement in the field of wireless communication. Since the invention of first wireless telephone system by Marconi, a steep growth is seen in wireless services. The number of cellular phone users has increased dramatically. With the rapid proliferation of wireless communication service in past decades the wireless technology also has grown enormously.

UWB-IR is a most recent technology in wireless communication. It has received great attention in both academia and industry for application in wireless communication. However, it is a deeply rooted as wireless communication itself.

UWB-IR is a fast emerging technology with uniquely attractive features inviting major advances in wireless communication, networking radar, imaging and positioning system.

Wireless Sensor Networks can be defined as systems composed of several autonomous nodes linked together by a dedicated wireless link [1]. The nodes architecture may include a microprocessor, several sensor and actuator modules and also a radio communication module on a single board. WSNs support a large range of applications: monitoring, local area control, factory and house automation and tactical applications [1-3]. The case study presented in this paper studies a local area protection system. It is a kind of remote detection and identification application, in which sensor nodes are densely scattered in the protected area to detect or sense intrusion events, generated by intruder nodes presence in their vicinity, in order to report it to a base station for analysis. This can be used to reinforce homeland or military troop's security in a tactical application. The intrinsic constraints when setting up such systems are power efficiency, reliability, latency, simplicity, and small size [1-3]. IR-UWB is a good candidate to satisfy the mentioned constraints because of its interesting characteristics which are low radiated power, simple circuitry, localization ability, high multipath resolution and multiuser access capabilities using Time Hopping (TH) [4-5].

The Federal communication Commission (FCC) has allocated 7.5 GHz of the spectrum for unlicensed devices in the 3.1 to 10.6 GHz frequency band. A spectrum for unlicensed use of UWB system is defined as any radio system that has a 10 dB bandwidth larger than 25 percent of its center frequency, or has a 10-dB bandwidth equal to or larger than 1.5 GHz if center frequency is greater than 6 GHz .

The goal of this paper is to analyze and propose an efficient WSN architecture based on IR-UWB and validate it using engineering simulation. As an alternative MACPHY, layer for 802.15.4a based WSN, several IR-UWB MAC-PHY models have been proposed [6-11]. These models can be divided into two categories: the first one insists on the PHY layer characterization [6-8]. The second one integrates this characterization into the network simulator [9-12]. None of them uses the real pulse propagation delay. Instead, they use a uniformly distributed random value to approximate it. This can be tolerated for the first type of models as they aim to provide a Bit Error Rate versus Signal and Interference to Noise Ratio (BER/SINR) depending on the number of active users. However, when modeling at the network simulator, such approximation can be avoided, as the pulse propagation delay and the number of active users is available. Indeed, the second type of model does not completely meet the WSN simulation requirements as it does not include sensing and sensor channel models. This paper presents an overview of a new developed simulation platform for IR-UWB that takes into account the previous mentioned aspects. It also presents a comprehensive performance evaluation of WSNs that has been conducted using this platform. The performance evaluation compares distributed MAC protocol for IR-UWB to 802.15.4 Uncoordinated Access. The network performance is evaluated using a detection and identification application and also Constant Bit Rate (CBR) traffic. CBR is included for comparison purposes as it is mainly the used model to simulate WSN traffic. Channel model based on measurements and utilizing low power ultra-short pulses of width 10ns and center frequency 1.5GHz in medium-size, two storey building. In this model he assumes that, multipath components are also assumed to be Poisson distributed with rate ʌ. Within each cluster, the arrival of the multipath component is also assumed to be Poisson distributed with rate $\lambda > ʌ$. In this modeling, the channel impulse response. Multiple access is achieved in impulse radio through timely sharing the channel .from [8], time hopping sequence must have a distinct time shift pattern assigned to each user in order to eliminate catastrophic collisions, i) Uniform Pulse Train Spacing: A pulse train of the form $\mathrm{s(t)} = \sum_{\mathrm{j}=-\infty}^{\infty} \omega(\mathrm{t} - \mathrm{jT_f})$ consist of monocycle pulses spaced $\mathrm{T_f}$ seconds apart in time. The frame or pulse repetition time typically may be a hundred to a thousand times the monocycle width, resulting in a signal with a very low duty cycle.

GENERATION OF DS UWB SIGNALS

Direct Sequence Spread Spectrum (DS-SS) is a well known digital modulation method. We will review its basic principles here, with particular focus on its extension to UWB.

Signals with an ultra wide bandwidth can be generated by first coding the binary sequence to be transmitted with a pseudorandom or PN binary-valued sequence, and then amplitude modulating a train of short pulses. In more detail, the DS-UWB signal can be generated as follows: Given the binary sequence to be transmitted $b = (\dots, b_0\ b_1 \dots, b_k, b_{k+1} \dots,)$; generated at a rate of $R_b = 1/T_b$ bits/s, a first system repeats each bits Ns times and generates a binary sequence $(\dots, b_0, b_0 \dots b_0, b_1, b_1, \dots b_1, b_k, b_k, \dots, b_{k,} b_{k+1}, b_{k+1} \dots, b_{k+1}) = a^*$ at a rate of $R_b = N_s/T_b = 1/T_s$ bits/s. As in this scheme this system is introduce redundancy and is a $(N_s\ , 1)$ code repetition coder. A second system transforms the a^* sequence into a positive and negative-valued sequence $a = (\dots, a_0, a_1 \dots, a_j, a_{j+1} \dots,)$, i.e.:$(a_j = 2a_j^* - 1,\ -\infty < j > +\infty)$.

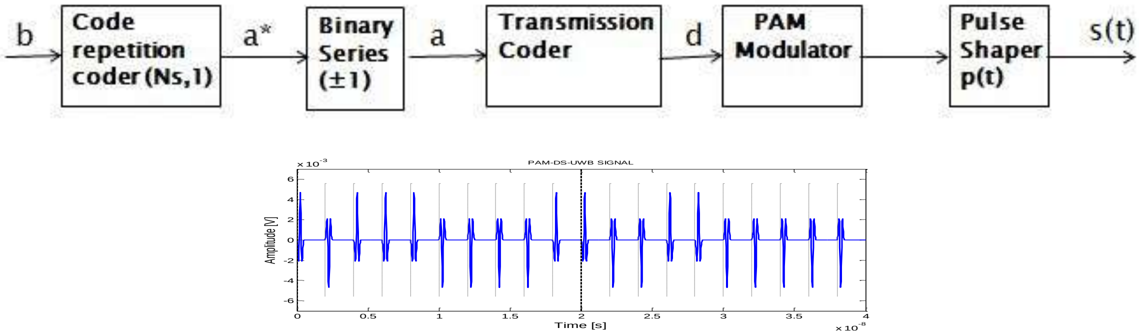

Figure 1 : Transmission scheme for PPM-DS UWB signal

Pulse Shaper in UWB-IR

The choice of the impulse response of the pulse shaper filter is crucial since it affects the PSD of the transmitted signal, in this section we will analyzed the effect of pulse width variation and differentiation on pulse shape. We then investigate the effect of combining different waveform to form a pulse that complies with power limitations set by emission masks of UWB. The pulse shape that can be generated in the easiest way by a pulse generator actually has a bell shape such as Gaussian pulse □(□) can be described by the following expression:

$$p(t) = \pm 1/\sqrt{2\pi\sigma^2}\ \ e^{-\left(\frac{t^2}{2\sigma^2}\right)} = \pm\sqrt{2}/\alpha\ \ e^{-\frac{2\pi t^2}{\sigma^2}}$$

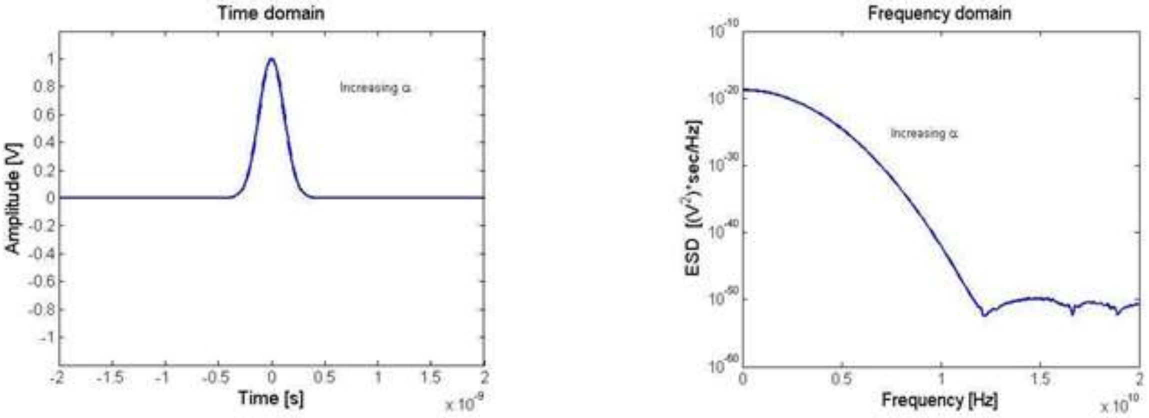

Figure 2: The Gaussian pulse: (left) waveform, and (right) corresponding unilateral ESD

New Pulse Shape Satisfying FCC Masks

In the time domain, the higher order derivatives of the Gaussian pulse resemble sinusoids modulated by a Gaussian pulse shaped envelop. As the order of the derivative increases, the number of zero crossing is increases; more zero crossing in the same pulse width corresponds to a higher "carrier" frequency sinusoid modulated by an equivalent Gaussian envelope. These observations lead to considering higher order derivatives of the Gaussian pulse as candidates for UWB transmission. Specifically, by choosing the order of the derivative and a suitable pulse width, we can find a pulse that satisfies the FCC's mask. In this section, we drive the spectrum of the higher order derivatives of the Gaussian pulse and, then choose a pulse shape that meets the emission requirements.

SIMULATION PLATFORM OVERVIEW

We developed a WSN simulator based on IR-UWB in our previous work [13]. The platform development is based on a hardware prototype [5]. It mainly focuses on the IR-UWB PHY and MAC layer accuracy modeling. The PHY layer behavior is modeled by taking into account the pulse collision according to the pulse propagation delay. Slotted and UnSlotted MAC protocols for IR-UWB are modeled. A remote detection and identification application is also included.

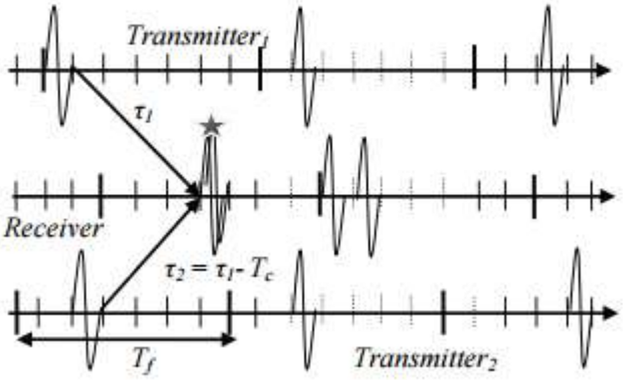

Figure 3: Collision illustration

IR-UWB signals are transmitted in form of very short pulses with low duty cycle (figure 1). The medium is divided into frames and each frame is shared in Nh chips. The frame and chip duration are Tf and Tc, respectively. The transmitted symbol can be repeated following a pseudo random sequence to avoid catastrophic collision under multiuser access conditions [7-8]. Using the Time Hopping Binary Pulse Amplitude Modulation (THBPAM) scheme for example, the kth user transmitted signal s ( )t k tx ( ) can be expressed as.

$$s_{tx}^{(k)}(t) = \sum^{+\infty} \sqrt{E_{tx}}\, x_{tx}\left(t - j.T_f - c_j^k.T_c\right)$$

where E_{tx} is the transmitted pulse energy; $x_{tx}(t)$ denotes the basic pulse shape and represents the j^{th} component of the pseudo random Time Hopping Sequence. The received signal r(t) when only one user is present can be expressed as

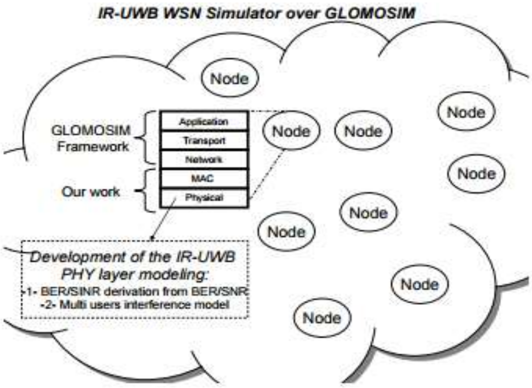

Figure 4: Simulation Methodology Overview

PERFORMANCE EVALUATION

The PSD limitation defined by emission masks determines the maximum allowed transmitted power. Given the allowed power, we will now evaluate, under rather simplified hypotheses, the maximum distance over which propagation can occur when a predetermined probability of error must be guaranteed at the receiver, at a given data rate. Decision at the receiver is based on the observation of a received energy E over a finite time interval, which is composed of mainly two terms: a signal term E_r and a noise term E_{noise}. The noise term may include several independent noise sources such as thermal noise, multi-user interference, and so on, that is.

Table 3.1 Simulation parameter

Specification	Values
Sampling Frequency	50e9
Average pulse repetition period	2e-9
Transmitting antenna gain	1
Receiving antenna gain	1
System margin	5 rdB
Order of the derivative	5
Noise figure	7 dB

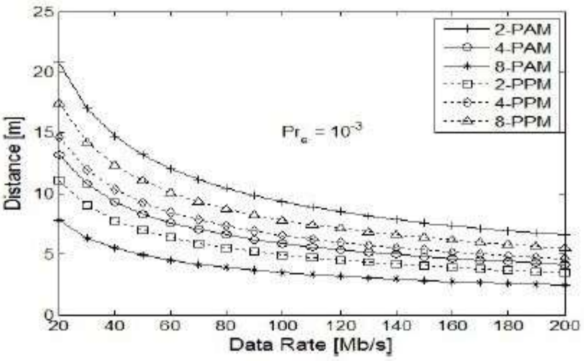

Figure 5 shows that the PAM is outperform the PPM over a distance of 10 meter. As we increase the values of M we can seen that the performance is increased for PPM .while the opposite is also true for M-PAM signals.

The purpose of this chapter is to investigate how the above models translate in the case of communications systems using IR-UWB. IR-UWB incorporates peculiar features that need to be taken into account for a comprehensive analysis of system design. We first take perfect synchronization between transmitter and receiver, and proceed to give a detailed analysis of receiver structures for different IR-UWB modulation formats, and in particular DS-UWB. The IR-UWB transmitted signal is ideally composed of a sequence of pulses that do not overlap in time. Each pulse is confined within a specific time interval, and the pulse itself has finite duration. While ISI among pulses belonging to the same transmission is ideally absent in the transmitted signal, it might not be so after the signal has traveled through a real channel. Pulses might in fact be delayed by different amounts, and replicas of pulses due to multiple paths might cause ISI. Moreover, in the case of the presence of several users transmitting over the same channel, pulses originating in other transmission links may collide with pulses belonging to a reference transmission, giving rise to an interference noise called Multi-user interference (MUI).

At the receiver, the reference signal, indicated as a useful signal, is corrupted by mainly two additive noise components. The first is thermal noise generated in the receiver antenna and the receiver circuitry. The second is MUI due to the presence of multiple users in the system. The problem of receiver design thus states as follows:

finding a good, when possible optimal, way for extracting the useful signal from the received signal. Solving the general problem is a complicated task leading to complex receiver structures and requiring good modeling for the noise components. While it is well-known that thermal noise is well represented by a White Gaussian random process, MUI noise characteristics depend on the number of users in the system, that is, the number and features of the interferes. The problem of optimal receiver design is greatly simplified under the absence of ISI an MUI.

CONCLUSION

We have calculated the distance between transmitter -receiver and data rate for DS-PAM and DS-PPM system, and in chapter 4 we have calculayed the probability of error for DS-PAM and DS-PPM system. It is shown that result obtained using multi-path free AWGN channel.

Our comparison results of the presence of Direct-Sequence UWB system for the multipath free AWGN channel,as measured by the probability of error, shows that PAM systems outperforms the PPM systems for all values of SNR.

In addition our simulation results show that the system using fifth order pulse performance better than the lower order pulse used system. so pulse selection in UWB is important from the probability of error point of view.

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