PERFORMANCE ENHANCEMENT OF DS-UWB SHORT RANGE COMMUNICATION SYSTEM USING EQUALIZATION TECHNIQUES

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PERFORMANCE ENHANCEMENT OF DS-UWB SHORT RANGE COMMUNICATION SYSTEM USING EQUALIZATION TECHNIQUES

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CERTIFICATE

This is to certify that the thesis entitled "**PERFORMANCE ENHANCEMENT OF   DS-UWB SHORT RANGE COMMUNICATION SYSTEM USING EQUALIZATION TECHNIQUES**" by **Ashish Kumar Nayak (211EE1120)**, submitted to the National Institute of Technology, Rourkela for the Degree of Master of Technology is a record of bonafide research work, carried out by him in the Department of Electrical Engineering under my supervision. I believe that the thesis fulfils part of the requirements for the award of Master of Technology. The results embodied in the thesis have not been submitted for the award of any other degree.

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DATE   **Ashish Kumar Nayak**

ABSTRACT

UWB is a major research area in the field of wireless communication. The IEEE 802.15.3a has been assigned the job of standardizing it. It is being considered as a breakthrough technology capable enough to revolutionize short range wireless communication. Ultra wideband communication as its name implies has large absolute bandwidth greater than 500 MHz and operating frequency band is 3.1 GHz- 10.6GHz. It is a rapidly growing technology that plays a very promising role in modern age wireless communication. It finds application in various sectors, for example in medical application to observe the status of patient using wireless health monitoring of life sustaining systems. In vehicular technology it can be used for obstacle avoidance and fast data transmission, and in military application as radar for detection behind walls and other blockages. Since it is based on short pulse carrier less transmission so hardware implementation becomes less complex and cheap. Thesis work has been done to study the BPSK modulation based DS-UWB communication system. Direct sequence spread spectrum (DSSS) technique along with UWB signal and two types of equalization techniques has been incorporated to mitigate the multipath fading effect associated with S-V indoor channel. Rake receiver has been used to utilize the energy of various delayed multipath components to improve the performance of the system. In short range communication process, indoor channel model or UWB channel model has been studied with different transmitter receiver separation, using some fundamental parameters of channel. Inter symbol interference (ISI) is a major problem in frequency selective fading channels, to overcome this problem, RAKE-MMSE equalizer and single carrier frequency domain equalizer (SC-FDE) have been incorporated. Thesis comprises of the system performance study and design done by using the above said equalization techniques for DS-UWB communications system.

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LIST OF ABBREVIATIONS

Abbreviations	Description
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
CIR	Channel Impulse Response
DS-UWB	Direct Sequence Ultra Wideband
EIRP	Effective Isotropic Radiated Power
FCC	Federal Communications Commission
FEC	Forward Error Correction
GPS	Global Positioning System
IBI	Inter Block Interference
IR	Impulse Response
LOS	Line of Sight
LTE	Long Term Evolution
MMSE	Minimum Mean Square Error
NLOS	Non Line of Sight
OOK	On-Off Keying
PAM	Pulse Amplitude Modulation
PDP	Power Delay Profile
PPM	Pulse Position Modulation
QOS	Quality of Service
SC-FDE	Single Carrier Frequency Domain Equalizer
S–V	Saleh and Valenzuela model
WPAN	Wireless Personal Area Network

Chapter 1

INTRODUCTION

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INTRODUCTION

1.1 Introduction

Wireless communication technology provides tremendous opportunities in short range. Short range communication is also achieved using wired cables like LAN cable, optical cable etc. Those wired communication has limitations like their cost of installation are high and hardware implementation is bit complex, even though they provide high data rate transmission. According to the Ultra-Wide Band (UWB) technology, it offers high data transmission rates which are well advance than currently deployed technologies like IEEE 802.11a, b, and Wi-Max. Extremely large bandwidth along with lower power spectral density makes UWB a prominent wireless technology and that's why it is receiving attention in various sectors. Bluetooth, Wireless PAN are some existing short range communication techniques, they have restrictions in their bandwidth and rate of data transmission. Ultra-wideband (UWB) is an emerging technology for short-range communications. UWB propagation based on short duration impulses, which gives it a large bandwidth and hence high data rates [7] and [19].

According to FCC UWB has an emission level of below -41dBm/MHz. This makes it ideal for certain radio frequency sensitive environments such as hospitals and healthcare.

DS-UWB is often referred to as zero carrier technology which operates by sending low power Gaussian shaped pulses. Which are coherently received the signal at the receiver. In general the system operates using Gaussian pulses and the transmissions spread out over a wide bandwidth, typically order of hundreds of MHz or even several GHz. Typically a DS-UWB transmitter transmit the data less than 75 nanowatts per MHz [3, 19]. This is very small when compared to 802.11 transmissions that may be between 25 and 100 mw, and Bluetooth that may be anywhere between 1 mw and 1 w [3]. This very low spectral density of DS-UWB transmissions do not cause harmful interference to other radio transmissions like traditional carrier based techniques and other existing narrow band techniques. According to the FCC's

spectral mask graph UWB band is likely to be more sensitive to interference such as the Global Positioning System (GPS). Also it can be possible to reduce the UWB transmission power density levels even further when there is no noticeable interference.

There are several ways in which DS-UWB transmissions can be modulated to enable data transmission. According to the limitation on the power density of FCC's rule, modulation process must be applied in an efficient manner. It must provide the optimum error performance for a given level of energy per bit. The choice of modulation also affects the UWB transmission spectrum, and this must be taken into consideration to ensure that the spectral density limits are not exceeded.

Two of the most popular forms of modulation used for DS-UWB are pulse position modulation (PPM), and binary phase shift keying (BPSK). These provide the best performance in terms of modulation efficiency and spectral performance and BPSK modulation is low-complexity and easy to implementation [21] and [23]. Although DS-UWB (Direct sequence ultra wideband) is a new technology operating using a totally different approach to the traditional carrier based transmissions. That is normally used for high data rate and security purpose. UWB with its carrier free technology offers the possibility of very high data rate transmissions using very low power [3]. As such, it is a technology that cannot be ignored, and one which will certainly take a significant section of the market. For application purposes, it is used as a part of localization systems and real time tracking systems, radar technology and in the telemedicine sector. The indoor channel for short range communication is particularly dynamic due to multipath propagation and ISI effect. These types of effect produce a strong negative impact on the bit error rate of any modulation techniques [15]. So dynamic link and robust error correction like equalization process and diversity scheme will give more advantage in data transmission.

1.2 Motivation

The data rate demand for personal area network is increasing day by day. Existing technologies like Bluetooth, Zigbee, and Wi-Fi are either too slow or obsolete to satisfy this demand or they consume more power. UWB is an ultimate solution and a strong candidate to satisfy these demands. This is what motivated us to design and simulate the DS-UWB short range communication.

1.3 Thesis Objectives

Project work is to improve the performance of DS-UWB short range communication system by using equalization techniques, so the objectives are:

1. To study the DS-UWB communication system along with the Saleh-Valenzuela channel and applying the considered equalization techniques which are RAKE-MMSE equalizer and SC-FD equalizer.

2. To compare the outcomes of both equalization techniques on the basis of BER performance.

1.4 Literature Survey

The term ultra-wideband was coined in 1989 by the U.S Department of Defence. By the end of 1989, UWB techniques, and many implementation approaches had been developed for a wide range of application, such as radar, communications, automobile collision avoidance, telemedicine, and positioning system etc [3]. UWB has many benefits, including high data rate, availability of low-cost installation, low transmit power and low interference. The approval of UWB technology made by federal communication commission (FFC) of the united states in 2002. That has been reserved the unlicensed free band between 3.1GHz to 10.6 GHz (7.5 GHz) for indoor UWB wireless communication systems [19] and [20].

In UWB, there is no need of spectrally efficient and these narrow pulses have very low power in any particular band. So interference is minimised. For high data rate short range transmission, direct sequence based ultra-wideband (DS-UWB) systems are a strong contender for consumer market applications. Due to the large transmission bandwidth, DS-UWB employs a train of highly duty cycle pulses. Whose polarities follow pseudorandom code sequences. Single band UWB systems have the advantage of low installation cost and secure transmission of data [3] and [7].

The DS-UWB modulation is implemented by simply direct modulation of a sequence of impulse like wave form and PN sequence. That occupies a bandwidth of several GHz [7]. Two of the most popular forms of modulation used for DS UWB are pulse position modulation (PPM),

and binary phase shift keying (BPSK). These provide the best performance in terms of modulation efficiency and spectral performance. In this type of modulation technique signal is transmitted continuously and there is no low duty cycle in case of the impulse radio [21].

The goal of the statistical channel model helps to analyse the indoor channel model, which is known as Saleh-Valenzuela channel model. UWB channel model has many advance characteristics over the propagation channel where UWB devices are operating in order to implement the efficiency of the modulation techniques. Which can describes the data rate and performance of any short range communications system. The basic parameters to consider in a channel model are power delay profile, cluster arrival rate, ray arrival rate and decay factor etc. Saleh-Valenzuela channel has five primary parameter. These five primary parameters are used to derive the statistical channel model of the indoor propagation [4] and [10]. These are characterised by four different distances, and according to types of channel model we can observe the performance of the different modulation techniques performance.

Basically Rake receiver is a diversity technique. Diversity usually employed to reduce the depth and duration of fades that employed at the receiver side [7] and [15]. Rake receiver works by correlating the received signal with the source signal or reference signal. The Rake receiver is known as a technique that can effectively combine the signal of different paths with different delays. Number of the fingers in Rake Receiver is also significant in designing of rake receivers as it decides the complexity of the circuit. In this paper, a robust MMSE Rake receiver scheme is presented with equalizer [6] and [8]. From which, it can be enhanced the quality of service using that type of dynamic link.

SC-DF equalization technique is a low complexity and less cost of equalization process. Single carrier frequency domain equalization technology is an important component of physical layer technology for broadband wireless access system, which can effectively avoid the lack of great complexity for single-carrier time domain equalization and also gives better performance than time domain equalization process [6] and [9]. In SC-FDE cyclic prefix insertion process provides great mitigation technique in distorted channel environment.

1.5 Thesis Outline

Thesis consists of five chapters which are organized as follows:

Chapter 1: Introduction

Chapter 1 gives the overview of the complete project. It explains the background of the project work and objective of the thesis. It also contains the literature survey and thesis outline.

Chapter 2: UWB Short Range Communication System

Chapter 2 gives the detailed explanation about the UWB short range communication. It consists of definition, regulation and application of UWB systems. Different UWB pulse shapes and modulation techniques are explained. S-V indoor channel model is also explained in detail which has been used as transmission channel in this project work.

Chapter 3: Description of DS-UWB

This chapter explain in detail the DS-UWB, it gives in detail Direct Sequence Spread Spectrum technique along with its benefits and application. It elaborates the Rake receiver which is used at the receiving end, and the considered equalization techniques are explained in detail.

Chapter4: **Design of DS-UWB System for Short Range Communication**

This chapter consist of block diagrams and mathematical illustrations of the considered DS-UWB system. Model structure of RAKE receiver and equalization techniques has also been explained with the help of block diagrams.

Chapter 5: Conclusion

It includes the conclusion and future work of this thesis, the references and appendix are included at the end of the thesis.

Chapter 2

UWB SHORT RANGE COMMUNICATION SYSTEM

CHAPTER 2

ULTRA WIDEBAND SHORT RANGE COMMUNICATION SYSTEM

2.1 Introduction

The hunger for a higher data rate has shifted the level from 2.5G to 3G to LTE. With each evolution new techniques developed which provides higher data rates. With passage of time the demand for data rate grows and these techniques become obsolete. The recent demand in the wireless communication requires the devices being able to transfer data at speed of Gbps. This is why UWB comes into existence**.**

The high data rates provided by UWB systems will allow applications such as video broadcasting and video teleconferencing with very high Quality of Service . In this chapter we are describing the uses of UWB short range communication, by which we can predict the scenario and useful applications . It will show how in the day to day life short range communication is useful. The UWB has emission cap specified by the FCC and it is describe very unique properties and hence less harmful for human body. UWB systems are less complex and lower in cost which advantageous from the user point of views.

When we are considering data communication, modulation techniques play a key role. Several types of modulation schemes are presented in this chapter and also the generation of some UWB pulses like Gaussian mono-pulse, Gaussian doublet pulse is described. As increasing the order of the Gaussian pulse shape the detection error probability will be reduced [7].

The channel model contained four primary parameter through which we can be derived four types of channel model such as CM1, CM2, CM3 and CM4. These four channel models are described for different distance. UWB system has numerous applications and benefits the user and the new in the modern day techniques and data rate are communications.

2.2 UWB Short range communication

Modern developments in narrowband pulse generation and high-speed switching technology has prompted a fresh look at UWB signal generation for various types of purposes i.e., high-speed, short-range networking for a variety of potential low-power, low-cost multimedia transport applications in home and enterprise environments. The UWB link can function as cable replacement for a typical scenario providing wireless data connectivity between a host such as a Desktop PC and a peripheral device such as mouse or keyboard that requires range from a relatively low order (100 Kb/s) to high order (100 Mb/s) [12] and [20]. In term of bit rate, UWB reaps the benefits of a broad spectrum. According to the formula

$$c = w.\log_2(1 + SNR) \qquad (2.1)$$

Where c = capacity, w = bandwidth, and SNR = Signal to noise ratio, it is easier to increase the bit rate (capacity) by increasing the bandwidth instead of the power, given the linear –versus- logarithmic relationship. For this reason communication process prefer to increase the system bandwidth instead of the power to achieve higher bit rates. This means that systems that use the UWB spectrum can be designed to achieve high bit rate better than narrow bandwidth systems [3].
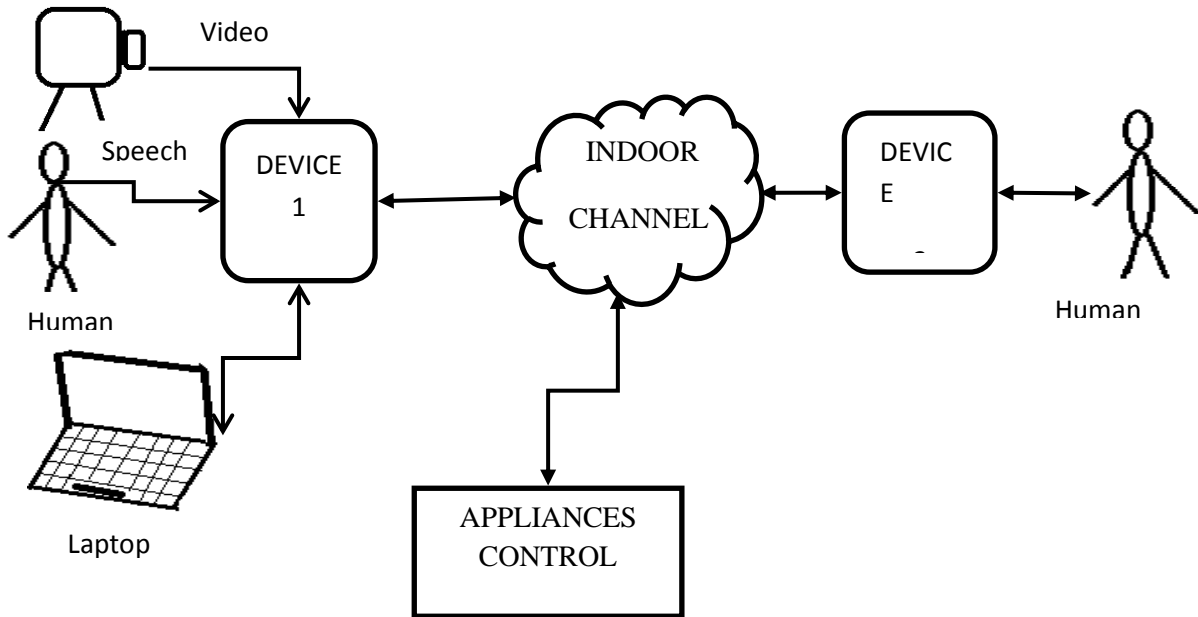

Fig 2.1 Architecture of UWB short range communication system

The above Architecture provides a robust wireless backbone for high speed communication. Which describes the data transmission like videos, speech, local area networking, medical application etc., can be possible using UWB technology. Because that has many advantages over the wired cable data transmission and other licence free spectrum technology.

2.3 Definition of UWB

The UWB technology has been referred to as baseband, carrier free transmission of short impulse of up to nanosecond duration. According to the FCC, an UWB signal is one that occupies more than 20percent of the center frequency or a minimum of 500 MHz of spectrum and that allocated unlicensed radio spectrum from 3.1 GHz to 10.6 GHz [3]. The allowable power emission level is -41.3 dBm/MHz that is standardized by FFC's rules.

The formula proposed by the FCC for calculating fractional bandwidth is

$$\frac{2(f_H - f_L)}{(f_H + f_L)} \approx \frac{W}{f_c}$$

(2.2)

Where f_H is the upper frequency level of the -10 dB emission point and f_L is the lower frequency level of the -10 dB emission point [3]. W was the absolute bandwidth and the centre frequency of the transmission was defined as the average of the upper and lower -10 dB points, i.e., $(f_H + f_L)/2$. According to FCC's rule UWB signals must meet the spectrum mask, that shown in Fig. 2.2. The band that is allocated to UWB is already being used by certain narrow band systems. 0.96 GHz to 1.61 GHz or 0.65 GHz band is used by the GPS (Global positioning system) [22]. Hence for UWB signal should strictly abide by the UWB mask.
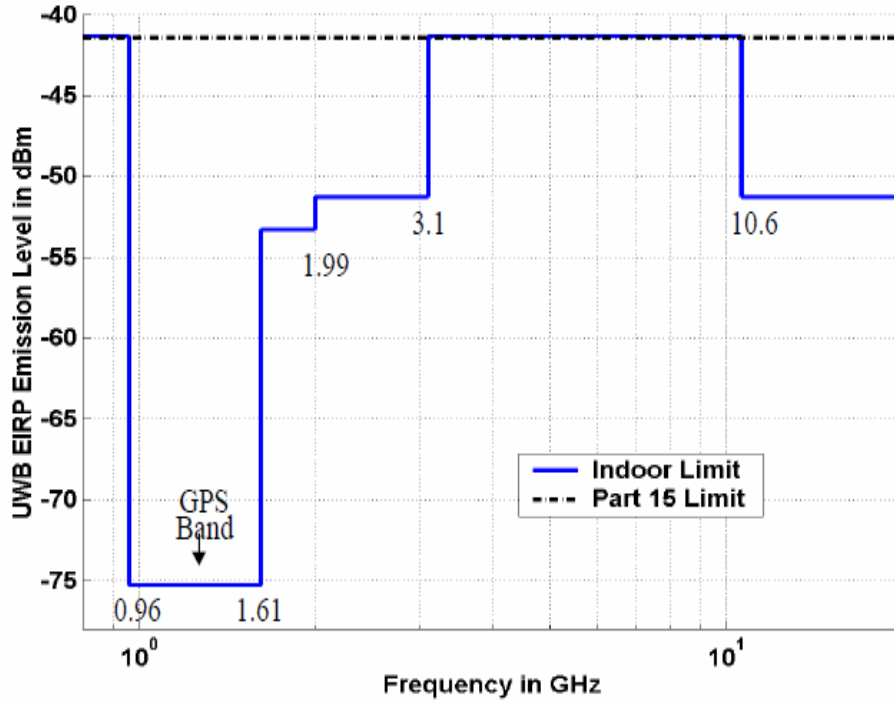
Fig. 2.2 UWB emission limit for indoor systems. [21]

The above figure represents the emission mask of the indoor UWB system. The emission power of UWB devices should be below -41.3dBm/MHz from 0Hz - 0.96GHz, below -75.1dBm/MHz from 0.96GHz-1.61GHz, below-53dBm/MHz from 1.61GHz to 1.99GHz, below -51.3dBm/MHz from 1.99 GHz to 3.1emission limits are defined as the effective isotropic radiated power (EIRP) in terms of mille-watt per 1 MHz bandwidth [7].

2.3.1 Ultra Wide Band Pulses generation

UWB Technology is based on Single-band systems employing carrier free communications. The single-band UWB system is implemented by direct modulation of a sequence of impulse like waveforms. Those waveforms occupy a bandwidth of several GHz. Generally, the pulse duration is on the order of nanoseconds [book]. The single-band UWB is also known as impulse radio.

Pulse shapes that are commonly used in UWB systems is Gaussian pulse and its higher-order derivatives also can be used for transmission purpose. A Gaussian pulse is modelled as

$$\overline{w}(t) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left[-\frac{1}{2}(\frac{t-\mu}{\sigma})^2\right] \tag{2.3}$$

Where μ is denotes the location of the pulse centre.

σ is a parameter that determines the pulse width.

The baseband pulses used by UWB signals have very short time duration in the range of a few hundred picoseconds. These signals have frequency response from nearly zero hertz to a few GHz. As there is no standardization yet, the shape of the signal is not restricted, but its characteristics are restricted by the FCC mask.

A good candidate shape for the UWB signal is the second derivative of a Gaussian pulse, which is mathematically defined as [4]:

$$w(t) = \frac{1}{\sqrt{2\pi}\sigma}\left[1-(\frac{t-\mu}{\sigma})^2\right]\exp\left[-\frac{1}{2}(\frac{t-\mu}{\sigma})^2\right] \tag{2.4}$$

Pulse duration is $T_w = 7\sigma$ and pulse centre is at $\mu = 3.5\sigma$

UWB Gaussian doublet pulse illustrated in fig. 2.3
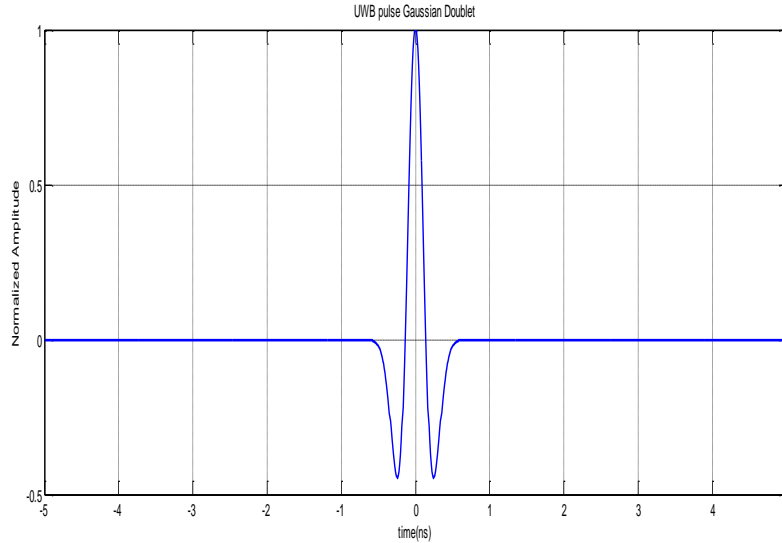
Fig. 2.3 UWB Gaussian Doublet Pulse

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2.3.2 Pulse Modulation

There is various baseband modulation schemes that have been studied. Modulation types are pulse position modulation (PPM), phase shift keying (PSK), pulse amplitude modulation (PAM), On/Off keying (OOK). PPM and BPSK are good candidates for UWB due to the fact that from the theory point of view they have a better bit energy performance than PAM or OOK [21].

2.3.2.1 Pulse Position Modulation:

PPM is one of the most popular modulation techniques in UWB literature. With PPM, the information is carried in the fine time shift of the pulse. The M-ary PPM signal can be modelled as

$$\overline{x}(t) = \sum_{k=-\infty}^{\infty} w(t - kT_f - m(k)T_d)$$

(2.5)

Where $m(k) \in \{0,1,......M-1\}$ is the kth M-ary symbol and T_d is the modulation delay, which provides a pulse time shift to represent each M-ary symbol, especially monocycles conveying information $m(k)$ is sifted by delay of $m(k)T_d$ seconds. PPM signal illustrated in fig. 2.4

Fig.2.4 PPM Signal

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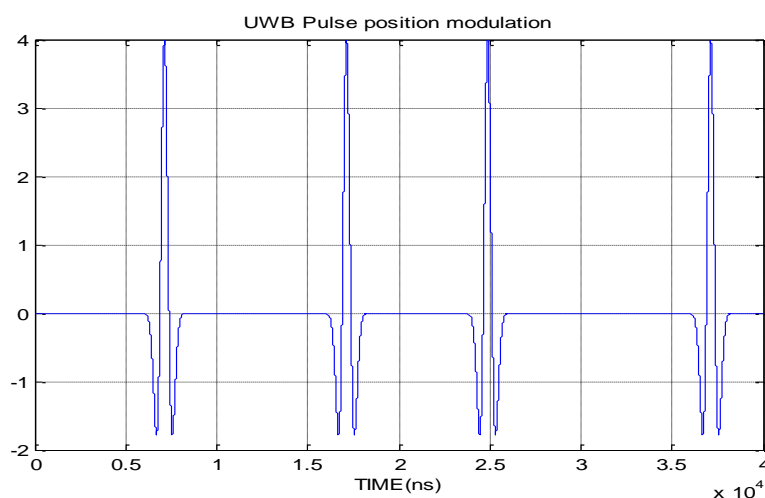
2.3.2.2 Bi-Phase Shift Keying

This modulation is also called antipodal and consists in changing the polarity of the transmitted pulses according to the incoming data as shown in the figure (2.5)

For example, a pulse has positive polarity if the information bit is 1, whereas it has negative polarity if the information bit is 0. A BPSK signal can be modelled as

$$\bar{x}(t) = \sum_{\infty}^{\infty} d(k)w(t - kT_f)$$

(2.6)

PSK signal illustrated in fig .2.5
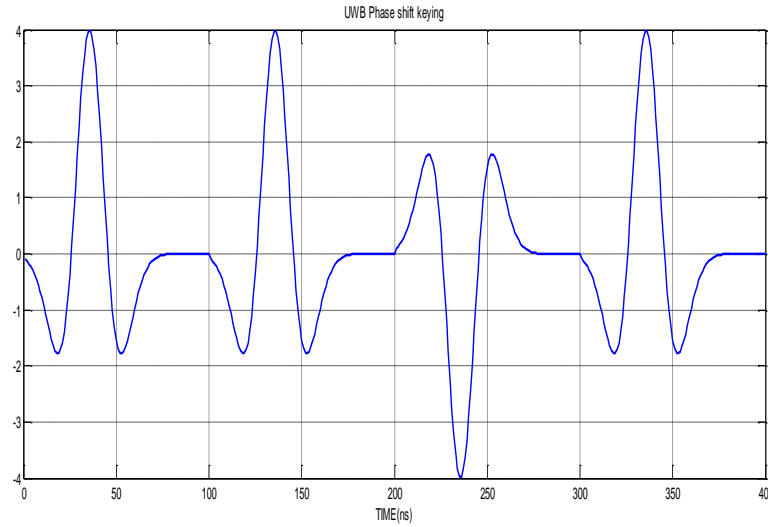
Fig.2.5 PSK Signal

2.3.3.3 PULSE Amplitude Modulation

The information in a PAM signal is conveyed in the amplitude of pulses, specially an M-ary PAM signal compares a sequence of modulated pulse with M different amplitude levels. The PAM signal can be modelled as

$$\bar{x}(t) = \sum_{\infty}^{\infty} a_m(k)w(t - kT_f)$$

(2.7)

Where $a_m(k)$ is the amplitude of the kth pulse, which depends on the M-ary information symbol $m \in \{,1,.............M-1\}$ .PAM signal illustrated in fig. 2.6
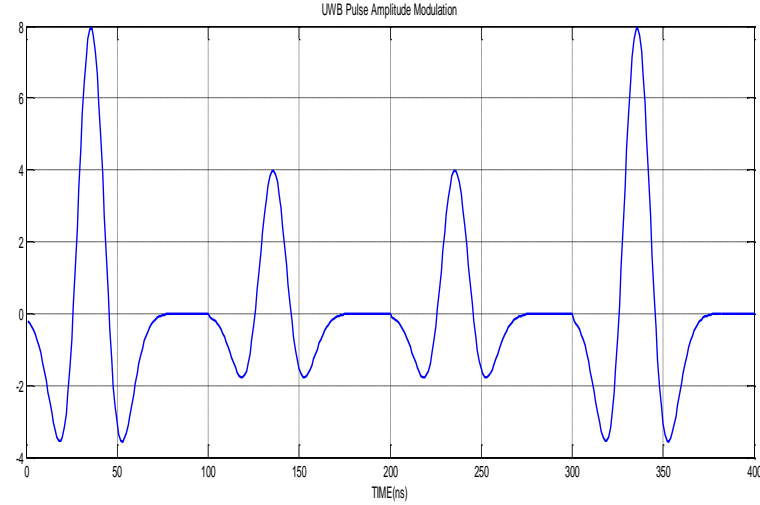
Fig.2.6 PAM signal

2.3.3.4 On-Off Keying Modulation

OOK is a special case of PAM with binary symbol $m \in \{0,1\}$ and pulse amplitude $a_m(k) = m(k)$. In other word, a pulse is transmitted if the information bit is 1; while it is absent if the information bit is 0. An OOK signal can be modelled as

$$\bar{x}(t) = \sum_{\infty}^{\infty} m(k)w(t - kT_f)$$

(2.8)

OOK signal illustrated in fig.2.7

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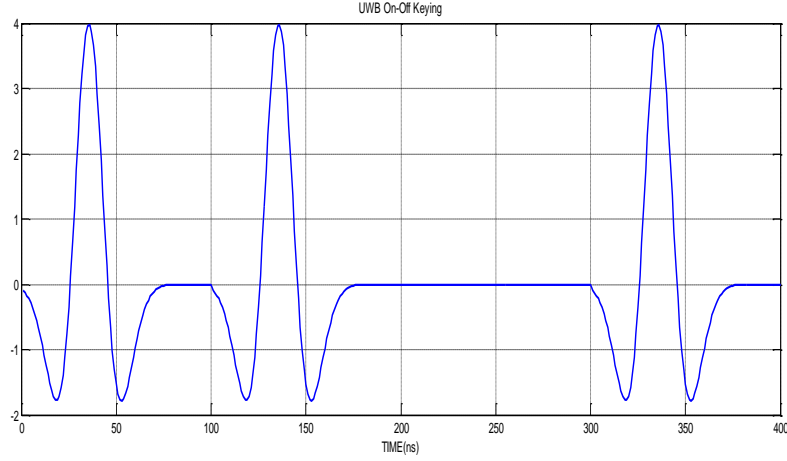
Fig.2.7 OOK Signal

2.4 UWB channel Modelling

The channel models used in this paper are the model proposed by IEEE 802.15.3a Study Group [10].The Saleh-Valenzuela (S-V) model was introduced for a wideband indoor channel. In the channel model multipath arrivals are grouped into two categories. One is cluster arrival and another is ray arrival within a cluster. This model contains four main parameters, using these four parameter the cluster arrival rate and the ray arrival rate within a cluster, the cluster decay factor are derived for short range channel model. The impulse response of the S-V model is modelled by

$$h(t) = \sum_{c=0}^{C} \sum_{l=0}^{L} \alpha(c,l)\delta(t - T_c - \tau_{c,l})$$

(2.9)

Where, $\alpha(c,l)$ denotes the gain of the *l*th multipath component in the cth cluster

C is the total number of clusters

L is the total number of rays within each cluster

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$\tau_{c,l}$ is the delay of the lth path in the cth cluster and that is relative to the cluster arrival time. By definition we have $\tau_{c,0} = 0$. The cluster and path arrivals within each cluster are modelled by Poisson processes:

$$PT_c(T_c | T_{c-1}) = \lambda \exp\left[-\Lambda(T_c - T_{c-1})\right], c > 0, \quad c > 0;$$ (2.10)

$$P\tau_{c,l}(\tau_{c,l} | \tau_{c,l-1}) = \lambda \exp\left[-\Lambda(T_{c,l} - T_{c,l-1})\right], l > 0$$ (2.11)

Where Λ is the cluster arrival rate and λ (where $\lambda > \Lambda$) is the ray arrival rate (i.e., the arrival rate of path within each cluster). The path amplitude $|\alpha(c,l)|$ follows the Rayleigh distribution, whereas the phase $\angle \alpha(c,l)$ is distributed uniformly over $[0, 2\pi)$, Specifically the multipath gain coefficient $\alpha(c,l)$ is modelled as a zero-mean complex Gaussian random variable with variance

$$\Omega_{c,l} = E\left[|\alpha(C,L)|^2\right] = \Omega_{0,0} \exp(-\frac{T_c}{\Gamma} - \frac{\tau_{c,l}}{\Upsilon})$$ (2.12)

Where, $\Omega_{0,0}$ is the mean energy of the first path of the first cluster

Γ is the decay of the total cluster power with delay as well as the cluster decay of each cluster. According to the channel model theory, these four main parameters can be changed for different environments [7].

TABLE 2.1 UWB CHANNEL MODEL CHARACTERISTICS [7, 10]

Model characteristics	CM1	CM2	CM3	CM4
Mean excess delay(nsec) (P_{10dB})	5.0	9.9	15.9	30.1
RMS delay(nsec)(τ_{rms})	5	8	15	25
N P_{10dB}	12.5	15.3	24.9	41.2
NP (85%)	20.8	33.9	64.7	123.3
Channel energy mean	-0.4	-0.5	0.0	0.3
Channel energy std(dB)	2.9	3.1	3.1	2.7
Model Parameter				
$\Lambda[1/ns]$ **(Cluster arrival rate)**	0.0233	0.4	0.0667	0.0667
$\lambda[1/ns]$ **(Ray arrival rate)**	2.5	0.5	2.1	2.1
Γ **(Cluster decay factor)**	7.1	5.5	14	24
γ **(Ray decay factor)**	4.3	6.7	7.9	12
$\sigma_1(dB)$	3.3941	3.3941	3.3941	3.3941
$\sigma_2(dB)$	3.3941	3.3941	3.3941	3.3941
$\sigma_x(dB)$	3	3	3	3

TABLE 2.2 CHANNEL MODELS PARAMETERS TO FOUR DIFFERENT USAGE SCENARIOS.

CHANNEL MODELS(CMs)	DISTANCE(METER)	PATH
CM1	0-4	LOS
CM2	0-4	NLOS
CM3	4-10	NLOS
CM4	More than 10	EXTREME-NLOS

The above table shows that S-V channel characterise by the different distance. According to the distance channel impulse response varies, also with the channel parameter.

2.5 Advantages of UWB Systems

UWB waveform is the pulse of short time duration, and contains some unique properties. In communication system, UWB pulses can be used to provide very high data rate performance in multi-user domain. These short duration waveforms are relatively immune to multi-path fading effects compared to narrow band systems as observed in mobile and in-door environments. As a result, UWB systems are capable more than 1Gb/s, that is well suited for high-speed wireless applications. The same UWB device can provide speeds much higher than that of current communication networks, to very low speed and low power applications. This provides flexibility according to the demand.

As we know bandwidth is inversely related to pulse duration, so that the spectral bandwidth of these waveforms can be made quite large and has low power spectral density. This low energy density is translated into a low probability of detection RF signature. So it produces minimal

interference to adjacent systems and delivers minimal RF health hazards, which is a significant benefit for both defence sector and commercial applications.

2.6 Applications of UWB in short range

UWB pulses provide a better range resolution, human tracking and positioning measurement within a building. UWB is limited by regulations limiting the power levels which is a tiny fraction of other radio technologies, hence it has health benefits and can adapt to sensitive environments, such as hospitals and airports [3] etc.

2.7 Summary

In this chapter, advantage and requirement of the short range communication explains by considering different aspects. Different kind of Modulation process of the UWB technology is described using mathematical model and also represents the figure of the different modulation techniques. Indoor channel characteristics explains using different channel model. It explains the advantages and applications of the UWB technology.

Chapter 3

DESCRIPTION OF DS-UWB SYSTEM

CHAPTER 3

DESCRIPTION OF DS-UWB

3.1 Introduction

DS-UWB uses a combination of a single-carrier spread-spectrum design and wide coherent bandwidth. The UWB Forum and IEEE 802.15.3a are organizations focused on UWB design and applications. They are also assigned the work of standardizing the UWB and its models and other security mechanism to enable robust communications. The DS-UWB provides low fading, optimal interference characteristics, inherent frequency diversity and precision ranging capabilities [3]. DS-UWB transmits the data by pulses of energy generated at very high data rates, in excess of 1 billion pulses per second. A fixed UWB chip rate in conjunction with variable-length spreading code words enables this scalable support
 [24]. DS-UWB provides four key advantages over legacy wireless technologies: viz high quality service, high data rates that scale to 1Gbit/sec or more, lower cost, and longer battery life. These attributes mean DS-UWB is well suited to be the physical layer for WPANs. Spread spectrum technique is not only combats multipath fading but also exploits the delayed multipath components to improve the performance of the system using diversity techniques. Rake receiver is one of the diversity techniques that can be used in frequency selective fading to improve the performance of the system.

3.2 Direct-Sequence UWB

DS-UWB uses an orthogonal code to spread the message signal and enable multiple accesses. This method has the advantage that the available B.W and time remain unsplitted. The narrow pulses have very low power in any particular band so interference can be minimized. Through this huge bandwidth, the hunger for high bit rates can never be satisfied, and no matter how wide the spectrum is, if we don't send enough pulses per second, we cannot get enough bits per second. This need for higher bit rate led to the development of the Direct-sequence UWB.

Eventually, if we send pulses at a high enough pulse rate then we end up sending them in every available chipping slot, and that is the principle of a DS-UWB scheme [3, 7].

In practice when binary signalling, is used binary phase-shift keying (BPSK) is preferred. It is used in DS-UWB, antipodal signals are used for the ones and zeros, (the PN sequence used for binary zero is the negative of the sequence used for binary one) because antipodal signals are the optimal signals to be used for binary signalling, in terms of giving the lowest bit error rate for a given signal to noise ratio (SNR) [3].

DS-UWB is similar to the direct sequence spread spectrum where the entire frequency band is used to transmit the data by spreading the data using pseudo random codes of different length. In DS-UWB standard, two bands are considered for operation. The occupies lower band is 1.75 GHz of spectrum from 3.1 GHz to 4.85 GHz and the higher band occupies 3.5 GHz of spectrum from 6.2 GHz to 9.7 GHz [18]. Aim of DS-UWB system is to utilize the unique properties of UWB over the large available bandwidth of two frequency bands. At the same time multiple access capabilities can be explored offered by standard CDMA techniques. The DS-UWB system is different from those conventional spread spectrum techniques in the sense that it uses the orthogonal properties of the spreading codes to eliminate the interference from adjacent piconets [18]. Based on direct sequence spreading, impulses are used. So different data rates can be achieved through spreading sequences of different lengths.

Table 3.1 provides the different data rates using BPSK in the lower operating band. It can be observed that using a code length of L=12 a data rate of 55 Mbps can be achieved. Also a code length of L=1 (FFC rate 1) a data rate of 1320 Mbps can be achieved [24].

TABLE.3.1 AVAILABLE DATA RATE USING BPSK IN THE LOWER OPERATING BAND [24]

Data Rate	FEC Rate	Code length	Bits per symbol	Symbol Rate
55 Mbps	½	L=12	1	$F_{chip}/12$
110 Mbps	½	L=6	1	$F_{chip}/6$
220 Mbps	½	L=3	1	$F_{chip}/3$
500 Mbps	¾	L=2	1	$F_{chip}/2$
600 Mbps	1	L=2	1	$F_{chip}/2$
1000 Mbps	¾	L=1	1	F_{chip}
1320 Mbps	1	L=1	1	F_{chip}

As we can note from the data in table that as we increase the code length of the PN-sequence the data rate is reduced. But a higher data rate , though achieved using a lower code length will minimize the user capacity of the UWB system Hence a proper trade off should be consider. A code rate of length 6 or 3 can be preferred in indoor communication environment. Since maximum number of users communicating will be less.

3.3 RAKE Receiver

Diversity technique is a powerful communication receiver technique that provides wireless link improvement at relatively low cost [15]. Diversity concept can be explained simply. If one radio path undergoes a deep fade, another independent may have a strong signal. After adding the all multipath signal at Rake receiver gives strong energy of the transmitted signal.

These days RAKE receivers are in widespread use, especially in CDMA systems which employ spread spectrum techniques. In RAKE receiver time diversity technique is used. Time diversity repeatedly transmits the information at time spacing that exceed the coherence time of the channel, so that multiple reception of the signal will be received with independent fading conditions [7, 15]. IR-UWB systems produce pulses that are quite short duration, in the order of

nanoseconds, which leads to the assumption that all multipath components will be non-overlapping. This means that IR UWB systems can in principle take advantage of multipath propagation by combining a large number of different and independent replicas of the same transmitted signal to form a stronger version of the incoming signal [15].
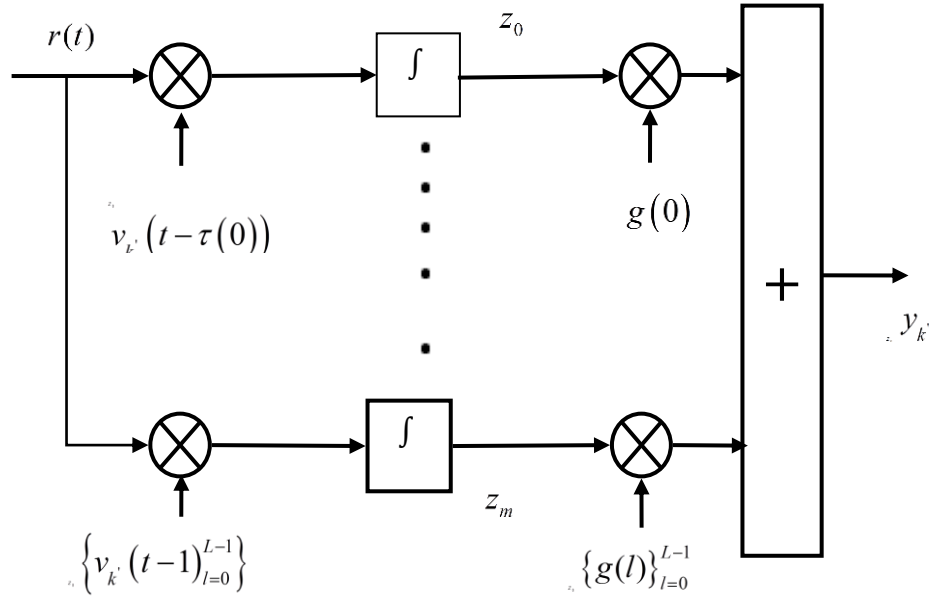
Fig3.1 Rake receiver with reference signal $\left\{v_k\left(t-1\right)_{l=0}^{L-1}\right\}$ [7].

Above figure shows that Rake receiver is collecting bunch of fingers, through which multipath rays is detected by the time delayed reference signal   in every fingers and coherently

adds multiple rays that increase the collected signal energy. .The signal received at the receiver is correlated with delayed versions of the reference pulse $\{v_k(t-1)_{l=0}^{L-1}\}$ is multiplied by the tap weights $\{g(l)\}_{l=0}^{L-1}$ and finally combined linearly.

 The reference pulse is the

$$v_{k'}(t) = \sum_{n_c'=0}^{N_C} c(n_c')w(t - k'T_f - n_c'T_c)$$

(3.1)

22

The output of correlator is given by

$$y_{k'} = \int_{-\infty}^{\infty} v_{k'}(t)r(t)dt$$

(3.2)

This has the advantage that only the intended receiver can demodulate it. The weighting coefficients are based on the power or the SNR (Signal- to-Noise Ratio) from each correlator output [15]

(i)   If the power or SNR is small out of a particular correlator, it will be assigned a small weighting factor

(ii)   If maximal-ratio combining is used, following can be written for

$$Z' = \sum_{l=0}^{L-1} g(l)Z_l$$

(3.3)

The weighting coefficients, l are normalized to the output signal power of the correlator

$$g(l) = \frac{Z_l^2}{\sum_{l=0}^{L-1} Z_l^2}$$

(3.4)

The weight coefficients $g(l)$ are normalized to the output signal power of the correlator in such a way that the coefficients sum to unity, as describe above equation (3.4). There are many ways to generate the weighting coefficients due to Multiple Access Interference the Rake fingers with strong multipath amplitudes will not necessarily provide strong output after correlation [15]. Choosing weighting coefficients based on the actual outputs of the correlator yields to better Rake performance. The UWB receiver is typically a homodyne cross-correlation is based on architecture. That utilises a direct RF-baseband conversion. If the number of fingers increases the resolvable multipath components form a stronger version of the incoming signal but in the design process hardware complexity increase, also cost of the component gradually increases. From the channel point of view the entire multipath component depends on the channel power delay profile of that channel model [3] and [10].

3.4 Equalizer Techniques

The term equalization can be used to describe any signal processing operation that minimizes ISI. Because of non-ideal characteristics of channel, inter symbol interference (ISI) occurs and equalization is used to eliminate the ISI. Equalization is achieved to reduce the effects of the channel distortion. Equalization process mainly is done in time domain and frequency domain [15].In frequency domain equation is

$$H_{eq}(f)F^*(-f) = 1 \qquad\qquad (3.5)$$

$H_{eq}(f)$ is the Fourier transforms of the impulse response of the equalizer $h_{eq}(t)$.

$f(t)$ is the combined complex baseband impulse response of the transmitter, channel and RF section of the receiver.

$F^*(f)$ is the Fourier transforms of $f(t)$.

Above equation indicates that an equalizer is actually an inverse filter of the channel.

For a time varying channel, an adaptive equalizer is designed to track the channel variation so that equation (3.5) can be satisfied. First a known, fixed length training sequence is sent by the transmitter so that the receiver's equalizer may adapt to a proper setting for minimum bit error rate (BER) detection. A more sophisticated reception with an equalizer before the correlator would be required for very high data rate [8] and [15].

UWB short range system operates in multipath channels where the effect of the multipath varies dynamically on the basis of the applications and the environment conditions [21] and [22]. Typically NLOS channel environments at distances of 4m to 10m have an RMS delay spread of 14 ns, while the worst case channel environments such as channel model 4 in S-V channel have an RMS delay spread of 25ns [3]. When the data rate is relatively high, the received signal contains ISI and the Rake receiver to maximize the signal power cannot effectively suppress the ISI. The performance of a single carrier system in a highly dispersive UWB channel is limited by two effects (A large number of Rake fingers is needed to capture multipath energy sufficiently and the time dispersive nature of the channel causes inter-symbol interference). The effect of ISI can be mitigated by the use of an equalizer, but this performance gain comes at the cost

additional computational complexity [3], [7] and [19]. If the channel is frequency selective, the equalizer enhances the frequency component with small amplitude and attenuates the strong frequencies in the received frequency response. For time varying channel, an adaptive equalizer is needed to track the channel variation. The frequency domain equalization techniques can offer better tradeoff between complexity and performance compared to the time domain equalization techniques for DS-UWB system.

In wideband communications, inter symbol interference (ISI) caused by multipath propagation can significantly degrade the system performance. For single carrier system, Rake receiver is one effective way to exploit time diversity. Better performance can achieved with more receiving branches. But complexity of rake receiver increase rake receiver linearly with increasing the number of branches.

DS-UWB communication systems are operated in dense multipath environments. In the dense multipath environment low complexity of equalization, better performance can be achieved by using single-carrier frequency domain equalizer (SC-FDE) systems with a cyclic prefix. DS-UWB is considered as frequency domain equalization for modulation with Gaussian monocycles, spreading sequence and a cyclic prefix. Cyclic prefix is used to avoid inter block interference (IBI), also used as guard interval. As the duration of cyclic prefix is longer than channel impulse response [5] and [6]. The same block can be transmitted more than once to increase the received signal to noise or one symbol in a block is repeated several times. Where data is transmitted by block wise in the time domain. That has been proved to have similar complexity as OFDM. In the overall system first spreading is used to collect the gain in frequency diversity and the block spreading employing a short orthogonal code is utilized to avoid IBI and ISI effect.

In other word, minimum mean square error (MMSE) criterion purpose MMSE-Rake receiver, which determines the Rake receiver weight co-efficients based on MMSE criterion to improve the performance of the receiver. The MMSE receiver is not ISI free. The provides receiver structure reduces intense multipath destruction and severe inter-symbol interference (ISI) by using a combine adaptive Rake and equalizer structure referred to as the MMSE (minimum mean square) algorithm.Adaptive MMSE design methods are commonly used in

practical systems[6] and [8]. Maximizing SNR is equivalent to minimize the energy of the component of the channel impulse response that causes ISI [12], [15] and [18].

3.5 Summary

This chapter explains the advantage of DS-UWB in short range communication and also describes the basic properties of DS-UWB system. Diversity technique represents along with Rake Receiver using time diversity techniques, that is used for improve the dynamic link quality at the receiver side. Equalization based of mitigation of ISI also encounter in improve the performance.

Chapter 4

DESIGN OF DS-UWB SYSTEM FOR SHORT RANGE COMMUNICATION

CHAPTER 4

DESIGN OF DS-UWB SYSTEM FOR SHORT RANGE COMMUNICATION

4.1 Introduction

In this chapter, BPSK modulation presents for single-band DS-UWB for single user. First of all in UWB transmission process, Gaussian pulse is taken as transmitting signal .Because UWB pulse has many advantage over any other pulse shape wave form. Such as signal power, pulse duration etc. That pulses are very familiar with the different application.

4.2 System model and Mathematical Representation

DS-UWB employs a train of high duty cycle pulses whose polarities follow pseudorandom code sequences [7]. The Gaussian BPSK symbols $d(k)$ are spread by a sequence of monocycles and Modulated with chip pulse $\{c(n_c)w(t-kT_f-n_cT_c)\}_{n_c}^{N_c-1}$, whose polarities are determined by the spreading sequence $\{c(n_c)\}_{n_c=0}^{N_c-1}$ and the second derivative of the Gaussian pulse

$$w(t) = \frac{1}{\sqrt{2\pi}\sigma}\left[1-(\frac{t-\mu}{\sigma})^2\right]\exp\left[-\frac{1}{2}(\frac{t-\mu}{\sigma})^2\right] \tag{4.1}$$

So combination of the Gaussian pulse, BPSK signal and PN sequence forms continuous transmitted data stream X (t). That can be written as

$$X(t) = \sum_{k=-\infty}^{\infty} d(k) \sum_{n_c}^{N_C-1} c(n_c)w(t-kT_f-n_cT_c) \tag{4.2}$$

$$C(t) = \sum_{n_c}^{N_C-1} c(n_c)w(t - kT_f - n_cT_c) \tag{4.3}$$

Where, $d(k) \in \{-1,1\}$ is modulated binary data and $p(t)$ is the UWB pulse with symbol duration $T_s = N_cT_c$, N_c represent spreading code of length and T_c is the chip duration.

$d(k) = -1$ When the data bit is 0 and $d(k) = 1$ when data bit is 1 $\quad \{C(n_c)\}_{n_c=0}^{N_C-1} \in \{1,-1\}$

Represents the pseudorandom code or spreading sequence. The transmitted signal transmit through the frequency selective channel, the channel model followed by

$$h(t) = \sum_{l=0}^{L-1} \alpha(l)\delta(t - \tau(l)) \tag{4.4}$$

$$\tilde{h}(t) = X(t) \otimes h(t) \tag{4.5}$$

Where, $\alpha(l)$ represents the multipath Gain coefficients.

L denote the number of resolvable path.

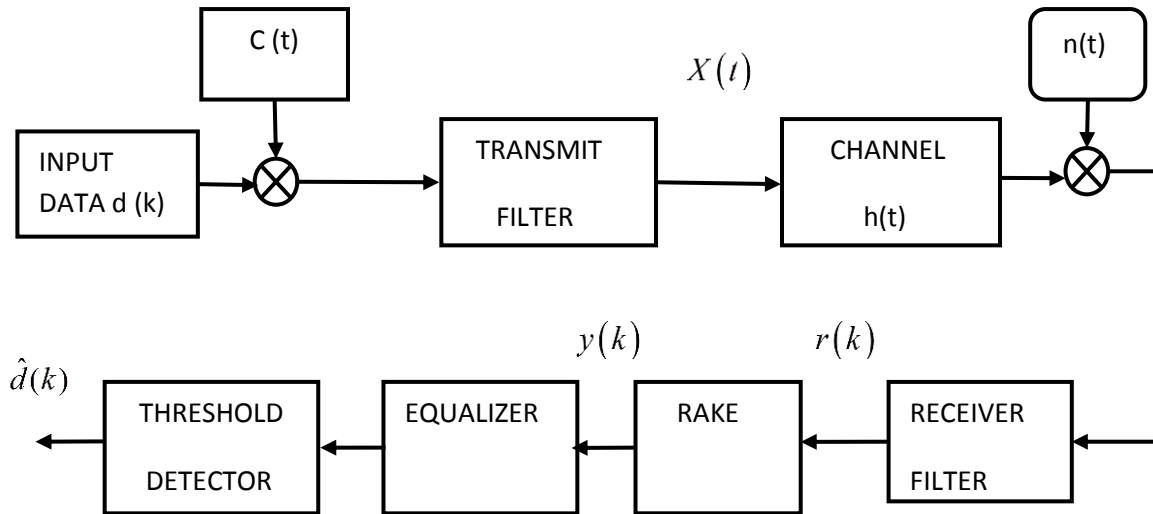$\tau(l)$ Represents the path delays relative to the delay of the first arrival path.

Fig.4.1 Block diagram of DS-UWB system [18].

Where $p(-t)$ represents the receiver matched filter and $n(t)$ is the additive white Gaussian noise (AWGN) with zero mean and variance $N_0 / 2$. Also $m(t) = p(t) * p(-t)$ and $\tilde{n}(t) = n(t) * p(-t)$. Combining the channel impulse response (CIR) with the transmitter pulse shape and the matched filter, can be represented as

$$\tilde{h}(t) = p(t) * h(t) * p(-t) \tag{4.6}$$

The output of the receiver filter is sampled at each Rake finger [8]. Since a UWB signal has a very wide bandwidth, a Rake receiver combining all the paths of the incoming signal is practically not able to done. This kind of Rake receiver is usually named an Arake receiver.

1.) SINGLE CARRIER FREQUENCY DOMAIN EQUALIZER

A cyclic-prefixed single carrier frequency domain equalizer (SC-FDE) transmission over UWB channels is illustrated in fig.4.2. A block of signals $(k), (0 \leq k \leq N-1)$, is transmitted with length N. acyclic prefix (CP) is inserted between blocks to mitigate interlock interference (IBI). As long as the duration of CP is longer than that of CIR ,IBI effect can be ignored. For simplicity reason, we will assume here in our mathematical derivations that $p(t) = \delta(t)$.Assuming perfect time synchronization and CIR is

$$h = \left[h(0), h(1), ..., h(L) \right]^T \tag{4.7}$$

As in equation $\qquad h(t) = \sum_{l=0}^{L} h_l \delta(t - \tau_l) \tag{4.8}$

Parameter L is the total number of paths in the channel.

The block received signal y can be expressed in a matrix form as

$$y = \overline{H}.d + n \qquad (4.9)$$

$$\text{Where, } d = \left[d(0), d(1), \ldots, d(N-1)\right]^T \qquad (4.10)$$

$\tilde{H}$ is the circulant Toepllitz matrix with the first column being h zero padding to length N yielding to vector $\tilde{h}.n$ is a $N \times 1$ vector of white Gaussian noise samples with the variance $\sigma_n^2 = {N_0}/{2}$. The frequency domain received signal Y can be expressed as

$$Y = F.y = A.d + F.n \qquad (4.11)$$

Where F is the discrete Fourier transform (DFT) matrix and $F_{l,k} = \left(\dfrac{1}{\sqrt{N}}\right).\exp\left(-j.\left(2.\dfrac{\pi}{N}\right).l.k\right), 0 \le l, k \le N-1$, Matrix Λ is a diagonal matrix, with its (k,k)th entry denoted as H_k, where H_k is the kth coefficient of the channel frequency response and $H_k = \displaystyle\sum_{l=0}^{L} h(l).\exp\left(-j.\dfrac{2\pi}{N}.k.l\right)$.

This is equivalent to $H = \sqrt{N}.F.\tilde{h}$

Where, $H = \left[H_0, H_1, \ldots H_{N-1}\right]^T$. The purpose of frequency-domain equalization (FDE) is to eliminate inter symbol interference (ISI) within individual transmission blocks. The frequency domain equalization taps are given by $C_k = \dfrac{H_k^*}{\left|H_k\right|^2 + \sigma_n^2 / \sigma_d^2}$ in order to perform frequency-domain channel equalization, the estimation of the channel coefficients, H_k

k=0, 1 …N-1, are required. After DFE and IDFT, the received signal z becomes

$$Z = F^H.C.Y \tag{4.12}$$

$$Z = F^H.C.\Lambda.d + F^H.C.F.n \tag{4.13}$$

Where C is the $N \times N$ diagonal element as the frequency-domain equalizer taps. Signal detection is performing in time domain.
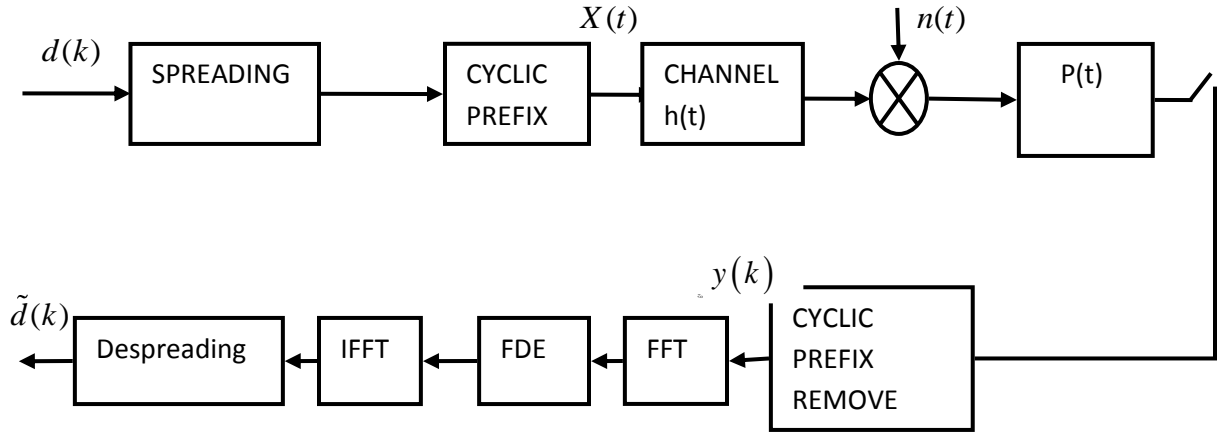

Fig.4.2 Model of the single carrier Frequency domain equalizer system [5].

2.) RAKE MMSE EQUALIZER

In practical scenario channel characteristics does not know properly .so using training sequence at the receiving end provides the channel estimation .Through the help of the channel estimation we can minimise the ISI at the receiver, this type of equalizer is composed of a Rake combine with L fingers to collect signal energy and mitigate ISI and other interference. The adaptive rake structure attempts to utilize multipath diversity in the same style as the rake receiver on each finger. The weight coefficients of the L taps for the MMSE filter are chosen as to minimize the MSE between the desired output and the received output at each finger.

The weight vector $\hat{\beta}$ contains all of the filter co-efficient and the receiver

vector= $\left[r_1[n], r_2[n], ...r_L[n] \right]$ contains all of the filter input samples. Assuming perfect synchronization between the transmitter and the receiver, the l th correlation output $r_L[n]$

$(l=1,2,3,.....L)$ for the n th desired data symbol . The output $I[n]$ of the Rake receiver system and update equation are follows

$$I[n] = r\left[\hat{\beta} \right] \tag{4.14}$$

$$e[n]^n = I[n] - d[n] \tag{4.15}$$

$$(\beta)^{n+1} = (\beta)^n + \frac{(r^H)e[n]^n}{|r^n|^2} \tag{4.16}$$

As with MMSE receiver the filters are only received to compute an output and perform coefficient updates at symbol rate. Due to the tremendous high data rate and longer multipath delay spread as CM3 and CM4, the Rake receiver cannot always overcome the resulting ISI. In the MMSE Rake equalizer receiver, the equalizer is used to mitigate residual interference. In this process, it is assuming that the n th data bit is being detected the MMSE criterion is to
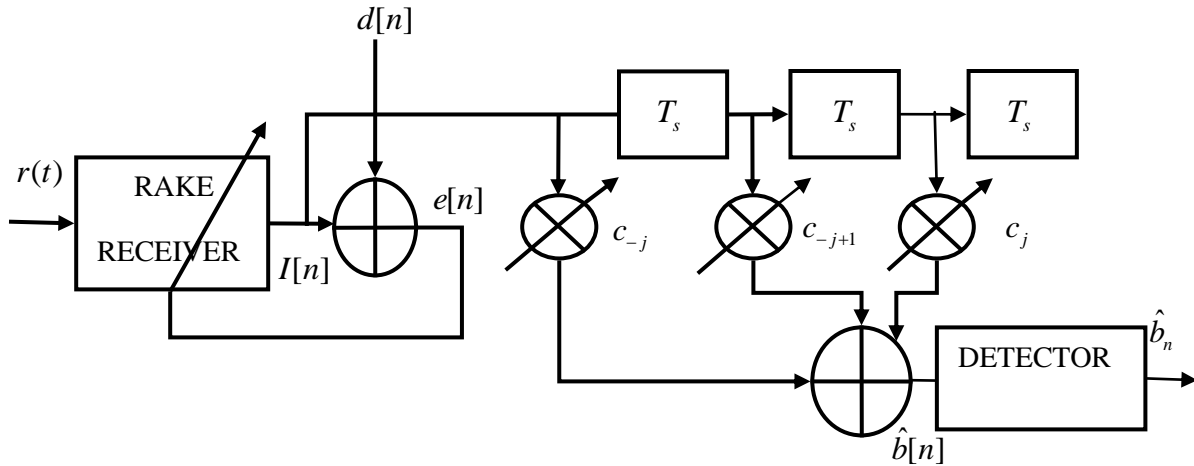

Fig4.3 The structure of the MMSE Rake-Equalizer Receiver Model [8]

Minimize, $E\left[\left|b_n - \hat{b}_n[n]\right|^2\right]$.

Let the number of tap equation is $\left\{c_{-j}, \ldots\ldots c_j\right\}$.

Then the equalizer output is $\hat{b}[n] = \sum_{j=-J}^{J} c_j I[n-j]$ (4.17)

To optimize performance, the equalizer coefficients, $c = \left[c_{-j}, \ldots\ldots, c_j\right]$ are chosen to minimize the MSE

of its output, that $\hat{c} = \arg\min E\left[\left|b_n - \hat{b}[n]\right|^2\right]$

$$\hat{c} = \arg\min E\left[\left|b_n - \hat{b}[n]\right|^2\right]$$ (4.18)

SUMMARY:

This chapter explains working mechanism of the system model of DS-UWB system, Rake MMSE Equalizer and SC-FD equalizer. Mathematical model is given for the process. It is enhanced performance in the short range communication process.

Chapter 5

SIMULATIONS, RESULTS AND OBSERVATION

CHAPTER 5

RESULTS AND DISCUSSION

5. Results and discussion

Channel model 3 and channel model 4 has the characteristic of longer delay spread [Table 2.1] and gain is decayed faster in CM3 and CM4 because of long path as compare to the channel model 1 and channel model 2. So we have taken more disturbance and fading channel model in our simulation to analyze the performance in dense medium. As we know high data rate requires smaller symbol period, if symbol period is less than the multipath delay spread then ISI occurs. Due to extremely high data rate and longer multipath delay spread as CM3 and CM4, the Rake receiver cannot always overcome the resulting ISI.Because Rake receiver accumulate signal energy of multipath component, but do not mitigate the ISI associated with receiver. In this simulation process we have considered 6 multipaths component, so 6 Rake fingers are taken into consideration.

To reduce the ISI effect, we step out to advance MMSE technique. Rake MMSE has error minimisation property which is done by comparing Rake received signal and training data signal. It adjusted the received according to the training signal using MMSE technique at each of the fingers. The received signal at the Rake MMSE receiver further processed in the MMSE equalizer. This equalizer is used to mitigate residual interference. So 10 number of equalizer taps are used in our simulation process. This minimises the attenuation or ISI of the received signal. Figure 5.1 shows that performance of Rake, Rake MMSE and SC-FD equalizers in CM3 channel. It can be observed that the performance of Rake MMSE is better than Rake receiver.

Amongst the three techniques, SC-DF equalizer is showing the best result in this graph. In SC-DF equalizer data is sent block by block. Each block contains certain number of samples which are transmitted by adding cyclic prefix in each block. The cyclic prefix work as guard interval between the symbols or block, which minimises the inter block interference (IBI) and

also it eliminates ISI within individual transmission block. This is very superior technique to eliminate ISI in the received signal. Table 5.1 shows that the BER at the different SNR level.
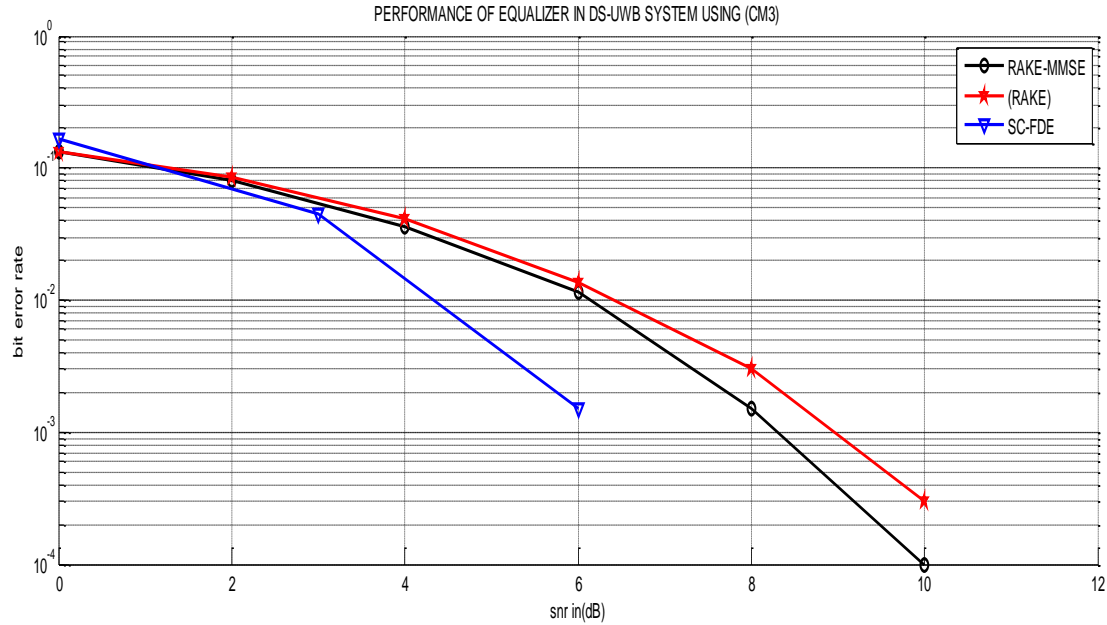

Fig 5.1 Performance of the techniques in Channel model 3 using 6 bits of PN sequence.

TABLE 5.1

PERFORMANCE OF THE TECHNIQUES FOR DS-UWB BPSK SYSTEM

FOR 6 BITS OF PN SEQUENCE IN CHANNEL MODEL 3

SNR IN (dB) / BER	2dB	6dB	8dB
RAKE	0.0861	0.0137	0.0030
RAKE MMSE	0.0732	0.0086	0.0017
SC-FDE	0.0640	0.0015	0.0000

Fig 5.2 shows the performance of the three techniques in CM4 channel. It can be seen that the performance of the three techniques degrades slowly as compared to the previous graph 5.1. This is because the channel model 4 uses more than 10m distance between transmitter and receiver and has the power delay profile of 25ns.This power delay profile is more compared to CM 3 which is 14ns. Power delay profile (PDP) of an indoor channel model shows that more the PDP higher the fading effect. Also PDP is defined as the measure of average combined signal power of time delayed multipath components. So CM4 are showing degraded version of the CM3. In this graph SC-FD equalizer is showing better performance, it is because IBI and ISI occurrence are very less in the equalizer.Table 5.2 shows that BER at different SNR in CM4.
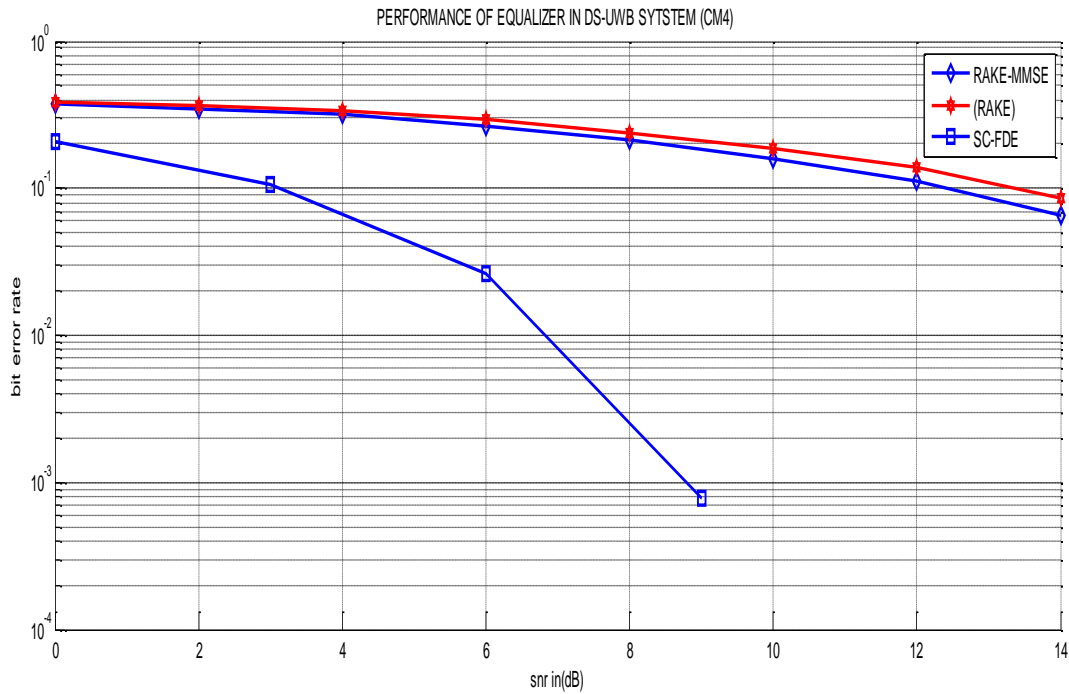

Fig. 5.2 Performance of the techniques in Channel model 4 using 6bits of PN sequence.

TABLE 5.2

PERFORMANCE OF THE TECHNIQUES FOR DS-UWB BPSK SYSTEM

OF 6 BITS OF PN SEQUENCE IN CHANNEL MODEL 4

SNR IN (dB) / BER	2dB	6dB	9dB
RAKE	0.3637	0.2885	0.2101
RAKE MMSE	0.3456	0.0265	0.1816
SC-FDE	0.1171	7.813E-05	0.0000

It can be seen in fig 5.3 performance is improved due to increase in the PN sequence length. Because more number of PN sequences gives better performance. Because higher the processing gain of the direct sequence spread spectrum waveform is more resistance to the interfernce. 12bits of PN sequence gives more processing gain as compare to 6 bits of PN sequence [Table 3.1]. We can analyse performance by comparing with the fig 5.1. But SC-FD is showing better as compared to others because of less ISI due to the block by block transmission and adding cyclic prefix. Table 5.3 shows the BER at different SNR in CM3.
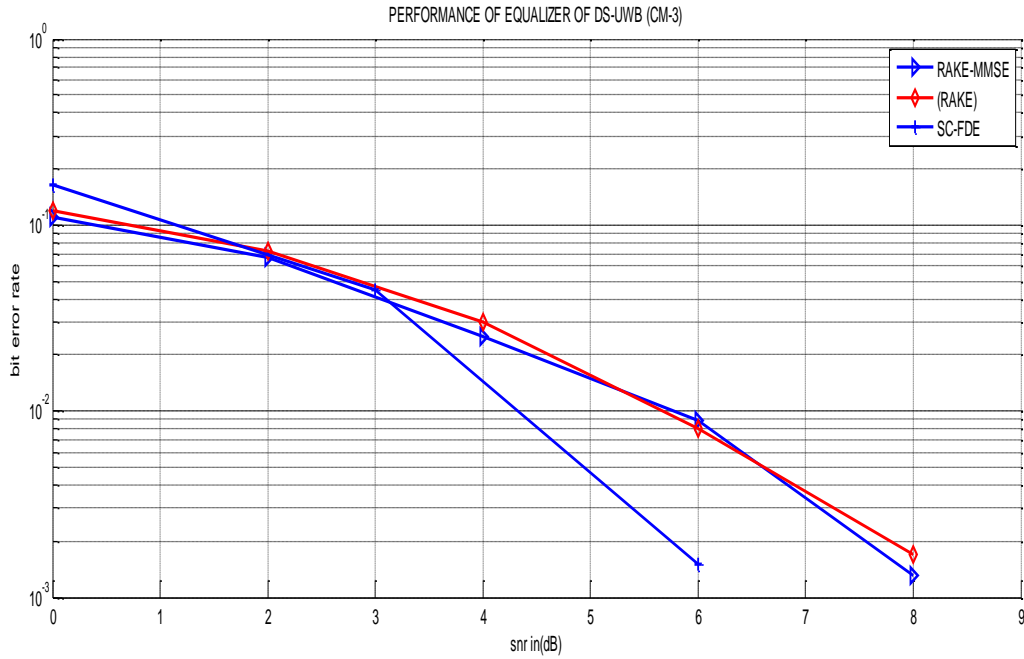
Fig. 5.3 Performance of the techniques in Channel model 3 using 12 bits of PN sequence.

TABLE 5.3

PERFORMANCE OF THE TECHNIQUES FOR DS-UWB BPSK SYSTEM

OF 12 BITS OF PN SEQUENCE IN CHANNEL MODEL 3

SNR IN(dB) BER	2dB	6dB	8dB
RAKE	0.0726	0.0089	0.0017
RAKE MMSE	0.0690	0.0081	0.0013
SC-FDE	0.0664	0.0015	0.0000

Fig 5.4 shows that the bit error rate performance in the CM4 is getting litle distorted due long distance of the channel between transmitter and receiver. Also that CM4 has more power delay

profile .So more disturbance is created in the collecting the multipath signal streangth at the receiver side.That's why less signal power prediction gives us low BER performance.According to the fig 5.4 and table 5.4, it shows that only SC-DF equalizer gives better performance in both CM3 and CM4 NLOS ptath and noisy environment.
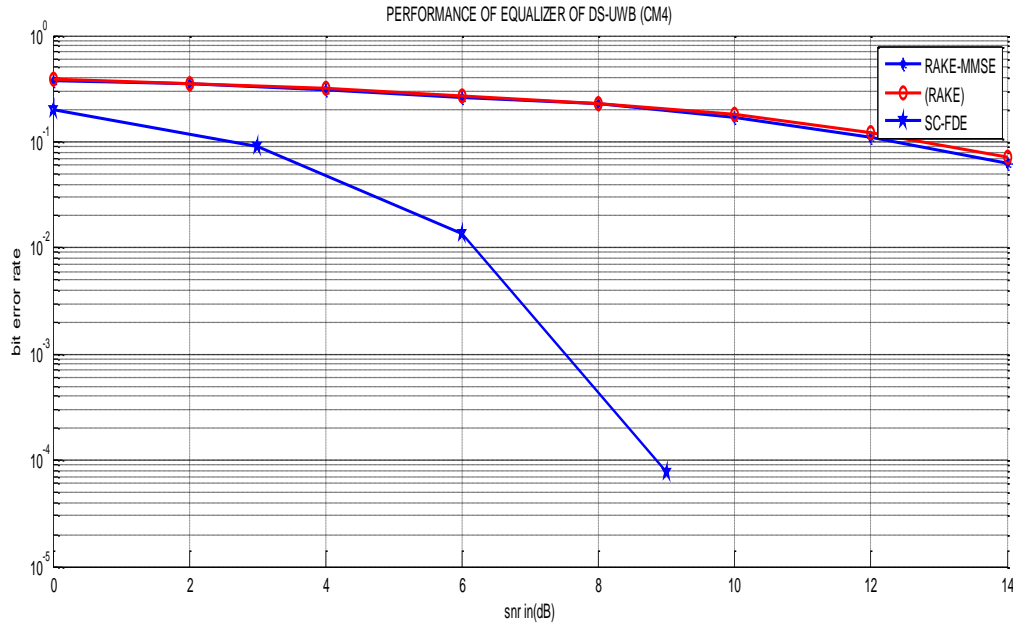

Fig. 5.4 Performance of the techniques in Channel model 4 using 12 bits of PN sequence.

TABLE 5.4

PERFORMANCE OF THE TECHNIQUES FOR DS-UWB BPSK SYSTEM

OF 12 BITS OF PN SEQUENCE IN CHANNEL MODEL 4

SNR IN(dB) / BER	2dB	6dB	8dB
RAKE	0.3573	0.2730	0.2302
RAKE MMSE	0.3494	0.2620	0.2260
SC-FDE	0.1171	0.0136	0.0004

The equalizer technique plays a major part in the system performance .From the above result we can say that, equalizer using Single carrier frequency domain equalizer always results the in better performance i.e., lower bit error rate in different environment.

Chapter 6

CONCLUSION AND FUTURE WORK

CHAPTER 6

CONCLUSION AND SCOPE OF FUTURE WORK

Conclusion

In this thesis we designed and simulated a variety of DS-UWB system for short range communication. The systems have also been compared with PN sequence of different lengths. SC-DFE based system can be a method of choice since it performs better than Rake MMSE and only Rake techniques. Similarly a trade-off between different code lengths may be chosen for higher data rate along with secure and versatile communication. The thesis provided some vital aspects of DS-UWB system design.

Future Work

A variety of applications have been proposed for implementation in the near future. The useful applications include personal data communication, medical applications, military applications etc. These findings may be highly useful for future DS-UWB system design and implementation purposes. The future work in this area may involve hardware design of the proposed system and testing it under real life conditions.

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REFERENCES

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