Performance Analysis of UWB System

Asawari K.Chinchanikar[*], **Dr. R. S. Kawitkar**[**]

[*]Electronics & Telecommunication, Cusrow Wadia Institute of Technology, India
[**]Electronics & Telecommunication, Sinhgad College of Engineering, India

Abstract- *M*B-OFDM UWB communication technology use orthogonal UWB pulse sequence and multiple sub channels to achieve reliable high data rate transmission and spectral efficiency. In this paper, we followed the standard proposal IEEE 802.12.3a to implement the MB-OFDM UWB system in Matlab simulink. We analyzed the system performance in the multipath fading channel, using S-V channel model. We evaluated the bit error rate for LOS & NLOS channels. We used fixed-point simulation platform which is constructed according to MB-OFDM scheme proposed by MB-OFDM Alliance and the compensation scheme is based on phase compensation.

Index Terms- Convolutional encoder, MB-OFDM system, UWB, Viterbi decoder.

I. INTRODUCTION

The proliferation of wireless communication devices in our lives shows no sign of stagnation. The ever growing demand for higher quality media and faster content delivery where we work, live, and play drives the quest for higher data rates in communication networks. To meet this demand for capacity in the wireless personal area network (WPAN) space, the IEEE 802.15.3a task group has set out to define a very high data rate alternate physical layer for IEEE 802.15.3, the current high data rate WPAN standard. The IEEE 802.15.3a task group is currently in the process of reviewing proposals presented by a variety of companies. All of the current proposed physical layers employ ultra wideband (UWB) communication.

Multiband-OFDM (MB-OFDM) [1] is one of the promising candidates for PHY layer of short-range high data-rate UWB communications. It combines Orthogonal Frequency Division Multiplexing (OFDM) with the above multi-band approach enabling UWB transmission to inherit all the strength of OFDM technique which has already been proven for wireless communications (ADSL, DVB, 802.11, 802.16., etc.). For these reasons MB-OFDM was proposed as the PHY layer technology for UWB communication as part of IEEE 802.15.3a standardization process for Wireless Personal Area Network (WPAN) communications.

In this paper, Section 1gives the introduction of the topic, section 2 gives base band implementation of MB-OFDM UWB system, section 3 discusses UWB (IEEE 802.15.3a) channel model. and section 4 discusses channel estimation and compensation ,section 5 covers the performance analysis of UWB system.

II. BASEBAND IMPLEMENTATION OF THE MB-OFDM UWB SYSTEM

A multi-band OFDM system [2] divides the available bandwidth into smaller non-overlapping sub-bands such that the bandwidth of a single subband is still greater than 500MHz (FCC requirement for a UWB system). The system is denoted as an 'UWB-OFDM' system because OFDM operates over a very wide bandwidth, much larger than the bandwidth of conventional OFDM systems. OFDM symbols are transmitted using one of the sub-bands in a particular time-slot. The sub-band selection at each time-slot is determined by a Time-Frequency Code (TFC). The TFC is used not only to provide frequency diversity in the system but also to distinguish between multiple users.

The proposed UWB system[3] utilizes five sub band groups formed with three frequency bands (called a band group) and TFC to interleave and spread coded data over three frequency bands. Four such band groups with three bands each and one band group with two bands are defined within the UWB spectrum mask (Figure. 1). There are also four three-band TFCs and two two-band TFCs, which, when combined with the appropriate band groups provide the capability to define eighteen separate logical channels or independent piconets. Devices operating in band group #1 (the three lowest frequency bands) are selected for the mandatory mode. Figure 2 gives an example of a TFC, where the available bandwidth of 1.584GHz (3.168-4.752 GHz) is divided into three sub-bands of 528MHz each.

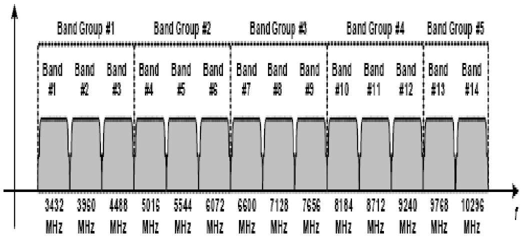

Figure 1: UWB Spectrum Division into Band Groups and sub-bands

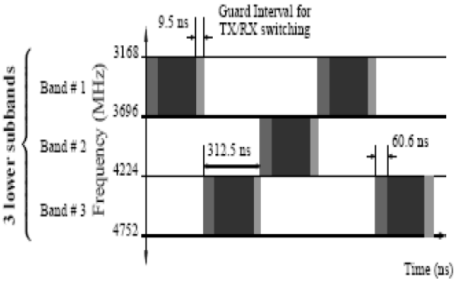

Figure 2: Example of Time-Frequency Code in MB-OFDM system

Figure 3 illustrates the transmitter and the receiver of the MB-OFDM UWB [4] system. They consist of two parts: baseband and radio frequency (RF). The baseband of the transmitter consists of a convolutional encoder which serves to add patterns of redundancy to the data in order to improve the SNR for more accurate decoding at the receiver . The system supports five different coding rates: 1/3, 11/32, 1/2, 5/8, and 3/4. Puncturing is a procedure for omitting some encoded bits at the transmitter and inserting a dummy ”zero” metric into the received sequence at the receiver in the place of the omitted bits. The purpose of the bit interleaver is to provide robustness against burst errors [3]. The bit interleaving operates through two stages, a symbol interleaving followed by a tone interleaving.a bit-interleaver. The fourth block in the baseband of the UWB transmitter is the constellation mapper, in which OFDM subcarriers are modulated using QPSK modulation. An input binary sequence is now converted into a complex-valued sequence according to Gray-coded constellation mapping .

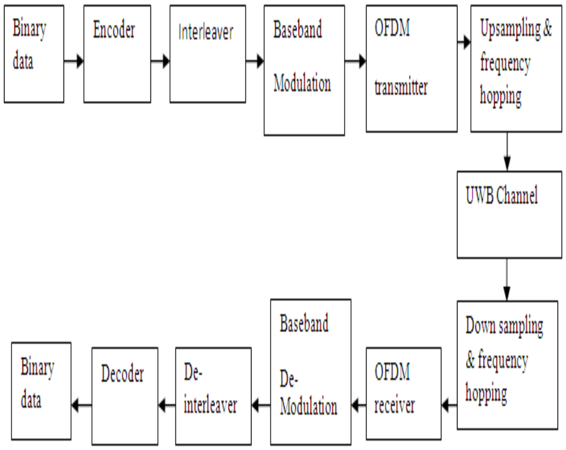

Figure 3: MB-OFDM system

The sequence in series is now converted to parallel, and the pilots, guards, and nulls are also inserted to the OFDM symbols before IFFT is taken. Each OFDM symbol contains 128 subcarriers. The duration for the OFDM symbol is TS = 242.42 nsec. After that, the cyclic prefix used to eliminate the ISI is pre-appended to the OFDM symbol and the guard interval used to ensure a smooth transition between two adjacent OFDM symbols is appended. The duration of the cyclic prefix is TC = 60.61 nsec, equivalently to 32 subcarriers. The duration of the guard interval is TG = 9.47 nsec, equivalently to 5 subcarriers. In the RF implementation the signal is up sampled and transmitted through the UWB antenna. The baseband of the receiver, in general, consists of similar blocks of the baseband in the transmitter but in the reverse order.

The system parameters for MB-OFDM UWB system are listed in table 1.

TABLE I: MB-OFDM UWB system parameters

Parameter	Value
Total bandwidth	528 MHz
N_{SD}: Number of data subcarriers	100
N_{DSP}: Number of defined pilot carriers	12
N_{SUP}: Number of undefined pilot carriers	10
N_{ST}: Number of total subcarriers used	122(=N_{SD}+N_{SDP}+N_{SUP})
Subcarrier frequency spacing	4.125MHz(528MHz/128)
T_{FFT}: IFFT/FFT period	242.42ns
T_{CP}: Cyclic prefix duration	60.61ns(=32/528MHZ)
T_{GI}: Guard interval duration	9.47ns(=5/528MHz)
T_{SYM}: Symbol interval parameter	312.5ns(T_{CP}+T_{FFT}+T_{GI})value
Data rates	53.3,55,80,106.7,110,160, 200,320,400,480MBits/s

III. UWB CHANNEL MODEL

The modified Saleh-Valenzuela (S-V) model[5]-[6]-[7] was adopted as a reference UWB channel model by the IEEE 802.15.3. The modelling of UWB channels is based on the measurement of indoor propagation environment, as the main commercial applications will be indoor communications. The main distinguishing features of UWB propagation channel are its extremely multipath-rich profile and non-Rayleigh fading amplitude characteristics.

The modelling of UWB propagation channel is fully based on the proposed IEEE 802.15.3a Standard Model . The S-V multipath model is given by equation 1

$$hi\,(t) = \sum_{l=0}^{L-1}\sum_{K=0}^{K\,l-1} \alpha_{k,l}\,\delta(t - T_l - \tau_{k,l}) \quad \dots (1)$$

where ,
L = number of clusters;
K = number of multipath components (number of rays) in the l^{th} cluster;
$\alpha_{k,l}$= Multipath gain coefficient of k^{th} ray in l^{th} cluster;
T_l arrival time of the first ray of the l^{th}cluster, ,
$\tau_{k,l}$ delay of the k^{th} ray within the l^{th} cluster relative to the first path arrival time, Tl;

Note that by definition, we have $\tau_{0,1}$= 0and we set T_0=0. The cluster and rays form a Poisson arrival process with distributions given by equation 2, equation 3.

$$P(T_l/T_{l-1})= \Lambda\exp[-\Lambda(T_l-T_{l-1})],\ l>o \qquad ...(2)$$
$$P(\tau_{k,l}/\tau_{(k-1),l})=\lambda\exp[-\lambda(\tau_{k,l}-\tau_{(k-1),l})],\ \ k>0 \qquad ...(3)$$

Where
Λ = cluster arrival rate;
λ = ray arrival rate.

The parameters of proposed model are listed the table II

TABLE II:UWB channel model parameters

Model parameters	CM1 LOS (0-4m)	CM2 NLOS (0-4m)	CM3 NLOS (4-10m)	CM4
Λ[1/nsec]	0.0233	0.4	0.0667	0.0667
λ[1/nsec]	2.5	0.5	2.1	2.1
T	7.1	5.5	14.00	24.00
τ	4.3	6.7	7.9	12
$\sigma 1$ [dB]	3.4	3.4	3.4	3.4
$\sigma 2$ [dB]	3.4	3.4	3.4	3.4
σx [dB]	3	3	3	3

IV. CHANNEL ESTIMATE AND COMPENSATION

The channel estimate and compensation [8] used in the simulation is discussed here only because all other parts of the receiver are the inverse function compared to transmitter expect digital baseband processing, The equalizer used in conventional wireless systems are compensate in time domain which require high hardware cost. Channel estimation of OFDM system works in frequency domain which using accumulator and simple circuits to do the channel estimate. UWB channel is flat frequency selective channel but the channel impulse response assumed does not change during frame period. The basic ideas of frequency estimation is that compared two received long preambing sequence(R_{0LTS} and R_{1LTS}) with known training sequence (L_{LTS}) , calculating difference of amplitude and phase, compensate every OFDM symbols in the frame based on this info. The process is described as：

$$R_{RLTS}=(R_{OLTS} + R_{1LTS})/2 \qquad ...(4)$$
$$\hat{H} = R_{RLTS} / L_{LTS} \qquad ...(5)$$
$$\check{R}= R/\hat{H} \qquad ...(6)$$

Where R : the received OFDM signal vector
L_{LTS} : known training sequence;
$\hat{H}$: estimated channel impulse response;
$\check{R}$: corrected receive OFDM signal vector.

Channel estimation can be divided into two parts: the estimate for subcarrier’s phase and power. The power error can compensate by rectify constellation; the phase by get R_{RLTS} ’s conjugate complex in accordance with L_{LTS} plus a complex multiplication to compensate channel distortion. Based on above analyze, channel estimate is divided into two parts: phase error estimate and power rectify of subcarriers.

In our simulation, only phase compensation is chosen because our scheme avoids division with a complex divisor and ensures that the magnitude of the division output has a small dynamic range. The structure of compensation is illustrated in figure 4.

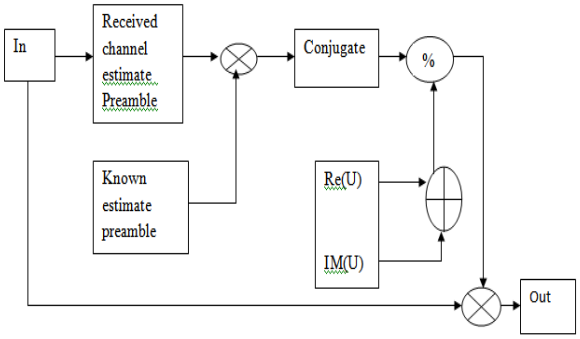

Figure 4: Phase compensation scheme

V. RESULTS

As OFDM symbols are transmitted using one of the sub-bands in a particular time-slot. The sub-band selection at each time-slot is determined by a TFC. Here the simulation results are carried out for TFC 1 in the band group1which is mandatory (figure 5). The band is split into 3 sub-bands each with bandwidth of 528MHz, and in the spectrogram plot. One can see how the time-frequency interleaving is achieved by only using one of the 528MHz sub-bands at a time. In the spectrogram, the x-axis represents time, the y-axis represents frequency, and the color indicates the power of the signal at that particular time and frequency with the red colors indicating high power, and blue colors indicating low power.

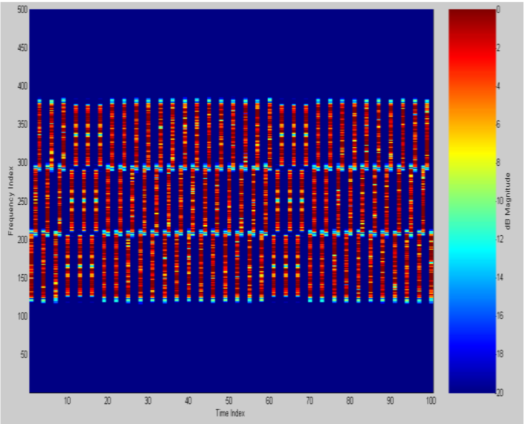

Figure 5: Spectrogram for TFC1 in band group 1

We set the channel SNR to a high value (i.e. 60 dB) and we get two scopes from the UWB simulation, first the power spectrum of the baseband equivalent received signal over all three sub-bands(figure 6), and second, the signal constellation after channel phase estimation and compensation(figure 7). The DC null in the power spectrum is from the OFDM transmission, but the rest of the spectrum approximately follows the frequency-selective fading characteristic of the multipath channel.

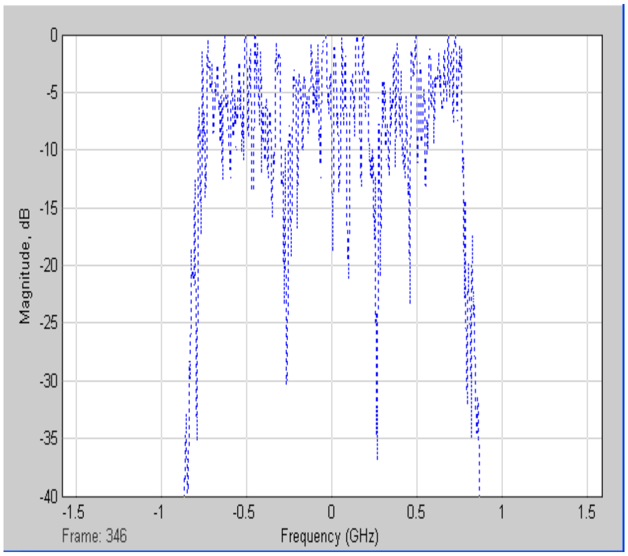

Figure 6: The power spectrum of the baseband equivalent received signal, over all three sub-bands

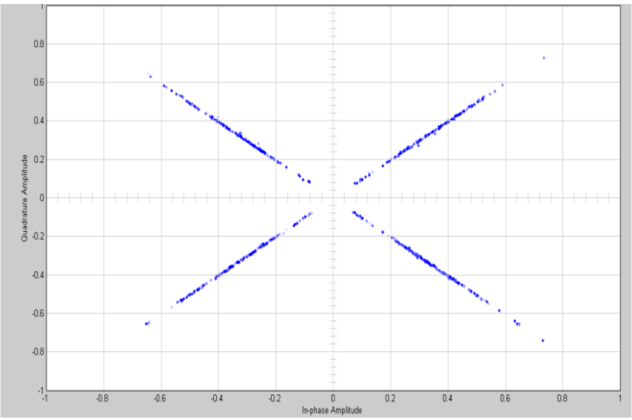

Figure 7: The signal constellation after channel phase estimation and compensation.

The results for BER for different taken S/N ration are taken for four UWB channels [fig. 8]. The IEEE 802.15.3a Standard Model defined four different measurement environments, namely CM1, CM2, CM3 and CM4.

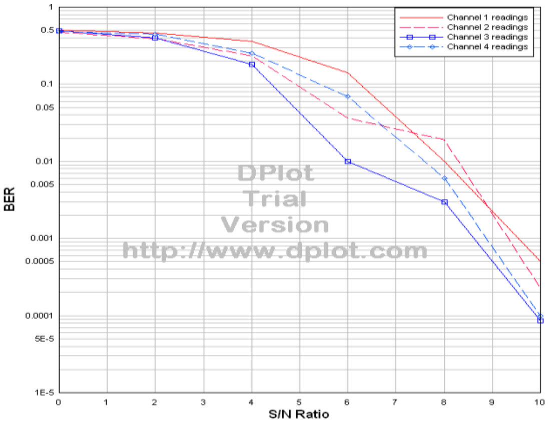

Figure 8: BER v/s S/N for four UWB channels

Figure 9 gives the probability of error as a function of SNR for different bit rates. As word length is 8 bits, the system barely work normally; while word length increase to 10 bits, the system's BER decrease notability; the performance of system is improved if we go for higher word lengths like 10 bits , 12 bits and 16 bits. The word length of digital baseband is a significant factor in system design and the performance of system will be affected if it not properly chosen.

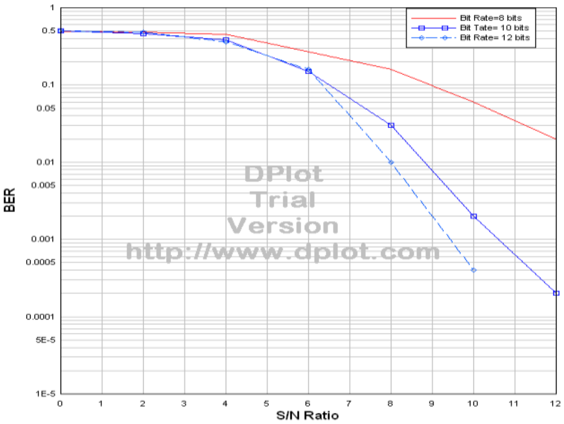

Figure 9: S/N ratio for various channels

VI. CONCLUSION

The work in this paper includes the baseband implementation and performance analysis of the MB-OFDM UWB system. Since UWB transmission technology is the future technology which promises to fulfill the demand of high transmission data rates, understanding the architecture and the performance of the UWB system is important. The implementation and the performance analysis help us to achieve it. The baseband implementation of the MB-OFDM UWB system follows the standard proposal IEEE 802.15.3a in a straightforward manner.

We analyzed the performance of the system according to IEEE 802.15.3a channel standard, which consists of four different channel models for LOS and NLOS conditions.

In this paper, UWB fixed-point simulation platform for MB-OFDM system is constructed, based on this platform, the performance degradation of fixed for digital baseband receiver and Viterbi decoder is analyzed. The result of simulation show that for fixed-point realization, receiver's digital baseband and viterbi decoder use 12 bit can fulfill the requirement. Through the implementation and the performance analysis, we have obtained a good understanding about the architecture and the performance of the MB-OFDM UWB system. The understanding would help us improving the system in the future.

The future scope of the project is implementation of the system using ECMA-368 standard which is based on the concept of beacon group. It has two types of TFCs i.e. Time-Frequency Interleaving (TFI) and Fixed Frequency interleaving (FFI) and forms 30 logical channels.

REFERENCES

[1] A. Batra, J. Balakrishnan and A. Dabak, “Multi-band OFDM: a new approach for UWB”, *Internat. Symp. on Circuits Systems*, May 2004.

[2] A. Batra, J. Balakrishnan, A. Dabakand et al., “Multi-Band-OFDM Physical Layer Proposal for IEEE 802.15 Task Group 3a”, *IEEE* P802.15-03/268r3, March 2004.

[3] S. Sadough, A. Mahmood1, E. Jaffrot, Pierre Duhamel,” Performance Evaluation of MB-OFDM based UWB System”, *Journal of Iranian Association of Electrical and Electronics Engineers* - Vol.4- No.1- Spring and summer 2007.

[4] A. Batra, J. Balakrishnan and A. Dabak, “Multi-band OFDM: a new approach for UWB”, *Internat. Symp. on Circuits Systems*, May 2004.

[5] A. Saleh and R. Valenzuela, “A Statistical Model for Indoor Multi-path Propagation”, *IEEE JSAC*, Vol. SAC-5, pp. 128-137, Feb. 1987.

[6] A. Batra, J. Balakrishnan, G. R. Aiello, J. R. Foerster and A. Dabak, “Design of a Multi-Band OFDM system for realistic UWB channel environments”, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 52, Issue 9, pp. 2123-2138, 2004.

[7] Ch. Sasmita Das, Bikramaditya Das, Susmita Das, Member, IEEE,” Efficacy of Multiband OFDM Approach in High Data Rate Ultra WideBand WPAN Physical Layer Standard using Realistic Channel Models”, *International Journal of Computer Applications* (0975 – 8887) Volume 2 – No.2, May 2010

[8] Yuqiang Zhang, Junhui Zhao,” Performance Simulation of Fixed-Point for MB-OFDM UWB system”,*IEEE* 2005.

AUTHORS

First Author – Asawari Chinchanikar, B.E. E & TC, Lecturer, Cusrow Wadia Institute of Technology, Pune. ,asawari_c@gmail.com

Second Author – Dr. R. S. Kawitkar,B.E.(Electronics), M.S. Electronics, Ph.D. Electronics, MBA(HRM) , Professor, Sinhgad college of Engineering, Pune. rskawitkar@rediffmail.com