Bit Error Rate Analysis of Multiband of CDM UWB System in UWB fading Channel

Sanjay M Gulhane, Athar Ravish Khan, and Umesh W Kaware

Abstract**—** Multiband orthogonal frequency division multiplexing (MB-OFDM) ultra wide band (UWB) system become promising technique for high data rate due to its large number of advantage over single band UWB system, but it suffer from coherent frequency diversity problem due to OFDM. In this paper we have proposed, multiband orthogonal frequency and code division multiplexing (MB-OFCDM) UWB system by introducing spreading to OFDM in order to provide frequency diversity. This paper presents the basic structure and operation of the MB-OFCDM system, and evaluates the bit error rate (BER) performance of MB-OFDM and MB-OFCDM system under UWB indoor multi-path channel model (IEEE 802.15.SG3a, 2003). It is observed that, MB-OFCDM system provides 2dB performance improvement as compared to MB-OFDM system in terms of BER.

Keywords**—** MB-OFDM, UWB, MB-OFCDM, UWB IEEE channel model.

I. Introduction

THE traditional design approach of single band ultra wide band (UWB) systems is based on a sequence of impulse like waveforms that occupies a very wide spectrum of 7.5 GHz. Although the impulse architectures offer relatively simple radio designs but it provides little flexibility in spectrum management. Moreover, building RF and analog circuits, as well as high-speed analog-to-digital converters, to process ultra-short pulse signal is a challenging problem. In addition, the digital complexity that is a high number of RAKE fingers needs to be quite large in order to capture sufficient multipath energy. In the multiband (MB) UWB approach, UWB frequency band is divided into several subbands, which allow the information to be processed over a much smaller bandwidth, thereby reducing overall design complexity as well as improving spectral flexibility. To capture the multipath energy efficiently, the orthogonal frequency division multiplexing (OFDM) technique has been used to modulate the information in each subband, and resulting system is referred as MB-OFDM UWB system. Multiband multicarrier approach that is MB-OFDM has drawn a lot of attention in high data rate wireless communications [1]. Although MB-OFDM is attractive for high data rate wireless communications, it does not have coherent frequency diversity. Combining OFDM with two-dimensional spreading an orthogonal frequency and code division multiplexing (OFCDM) modulation scheme has been used by Yiqing Zhou et.al [2], introducing spreading to OFDM to provide frequency diversity. Based on OFDM, OFCDM provides not only all advantages of OFDM, but also additional benefits by means of 2D spreading. In this paper the attempt has been made to introduce OFCDM modulation scheme in MB-OFDM and resulting system is referred as MB-OFCDM. Section II presents key point of MB-OFDM UWB system. Section III presents the basic structure and main functions of the MB-OFCDM system, section IV describe IEEE 802.15.3a.(TG3a) proposal for indoor UWB channel is describe and section V and VI presents the simulation results of BER analysis and conclusion respectively.

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II. Multiband OFDM UWB System

The MB-OFDM approach has been proposed by IEEE 802.15.3a [TG3a] in 2004 for wireless personal area networking (WPAN), and it has been approved as the UWB standard by the European Computer Manufacturers Association (ECMA) in December 2005. In the MB-OFDM proposal the entire band of 7.5GHz UWB signal is divided into 14 subbands of 528 MHz of bandwidth, and these subbands is divided into four band groups with three bands each, and one band group with two bands. Band group one, which is the three lowest frequency bands, is mandatory for all MB-OFDM compatible devices. In each 528MHz band OFDM with 128 subcarrier is used, which provide a set of orthogonal narrow band channels. Since the modulation/ demodulation of subcarriers can be realized by inverse fast Fourier transform (IFFT)/FFT, MB-OFDM is easy to implement. The overall system of MB-OFDM as shown in Fig 1, which provides a wireless communication with different data-rates of 53.3 to 480 Mbps. Information bits are processed by a convolution encoder and QPSK modulated. Cyclic prefix are appended to mitigate the effect of channel and guard samples are appended to allow for switching between the different bands. The time–frequency kernel is use to specify the center frequency for the transmission of each OFDM symbol. An example of one realization of a time– frequency code that is how the OFDM symbols are

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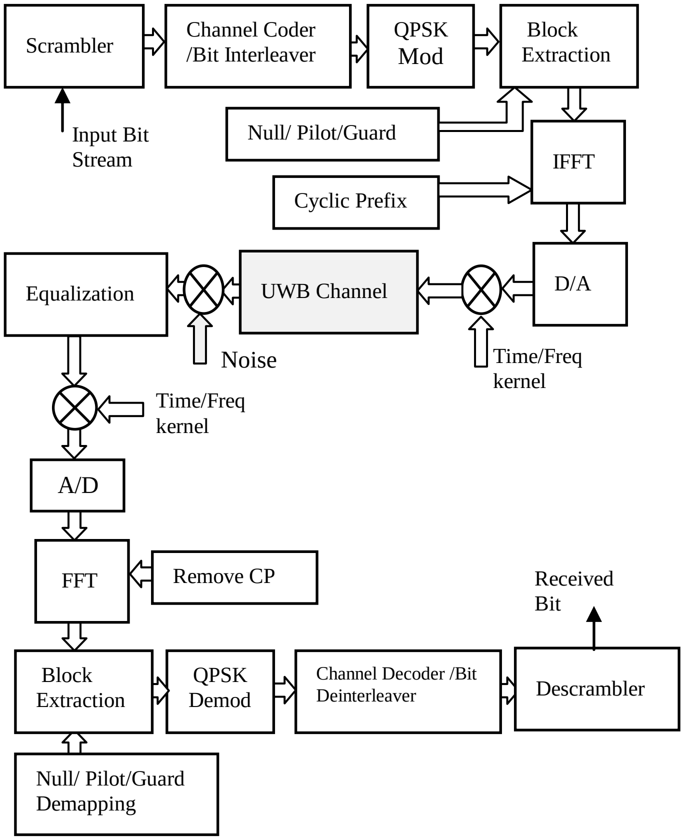

Fig. 1 Architecture of MB-OFDM UWB System

transmitted in a multiband OFDM is shown in Fig 2, for the time frequency code [1, 3, 2]. In MB-OFDM UWB transmission, the radio resource is divided into time frequency blocks. Each block occupies one symbol duration of 312.5nS and one subband of 528MHz with central frequency of 3432MHz, 3960MHz and 4488MHz for respective time-frequency block as per the code. MB-OFDM system can send one OFDM symbol in one symbol durations [3]. At the receiver by considering perfect channel estimation, the signals are demodulated and decoded by Viterbi decoder. Time frequency kernel with respective central frequency is used to recover the subbands.

III. MULTIBAND OFCDM UWB SYSTEM

The proposed architecture of MB-OFCDM is shown in Fig 3. In MB-OFCDM we are using 2D spreading using a spreading factor of $N = N_T \times N_F$, where N is the total spreading factor, N_T is time spreading factor and N_F is frequency spreading factor. The 2D spreading in OFCDM is different from the conventional spreading in CDMA, which expands the signal bandwidth. Instead, it is more like a coding scheme carrying the same data information in N_T time-frequency blocks. Thus, redundancy is introduced, and the information data rate is decreased. We deploy the similar OFCDM structure proposed by Yiqing Zhou et.al [2] in the multiband UWB system. Orthogonal variable spreading factor (OVSF) codes are used as the spreading codes in both the frequency and time domains. At the transmitter, information data streams are

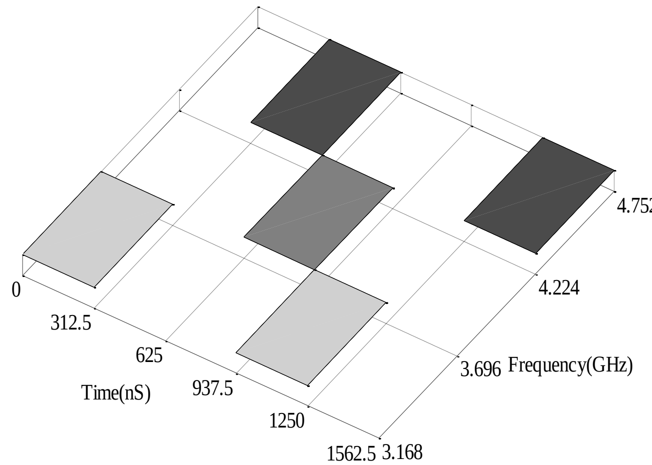

Fig. 2 MB-OFDM Transmission scheme

first serial-to-parallel converted, and then divided into multiple streams d_k, that are transmitted on multiple data code channels [2]. There are two spreading codes in frequency and four spreading codes in time domains. Hence, up to eight 2D code channels are available in the MB-OFCDM system, which can provide various data rates by assigning different numbers of code channels to a single user. When all the eight code channels are employed, MB-OFCDM can achieve the same data rate as that in MB-OFDM. On each data code channel, information bits are processed by a channel encoder and modulated by QPSK. Each modulated data symbol is 2D spread by a dedicated 2D code for the data code channel. Time domain spreading codes of length $N_F=4$, $\Omega_T=[C_1^t\{+1,-1,+1,-1\}, C_1^t\{+1,+1,+1,+1\}, C_3^t\{+1,+1,-1,-1\}, C_4^t\{+1,-1,-1,+1\}]$ and frequency domain spreading codes of length $N_T=2$, $\Omega_F=[C_1^f\{+1,-1\}, C_2^f\{+1,+1\}]$ are used for 2D spreading [6]. Out of eight dedicated 2D code channel, four code channel use the code set of $[\Omega_T, C_1^f]$ and remaining four code channels use the code set of $[\Omega_T, C_2^f]$. Hence 2D spreading factor 8 is achieved by using combination of time and frequency codes. Then all code channels are combined at the code multiplexer. After code multiplexing, the combined signal converted to a set of subcarriers. The 128 point IFFT is used as per timing parameters of TG3a. After performing the IFFT, a zero-padded suffix of length 32 is appended to the IFFT output and 5 samples of guard period are appended to allow for switching between the different bands. The final number of 165 sample per OFCDM symbol is obtained. After digital to analog conversion the time–frequency kernel is used to specify the center frequency for the transmission of each OFCDM symbol using time frequency code. Similarly as in MB-OFDM-UWB transmission, the radio resource is divided into time frequency blocks. Each block occupies one symbol duration of 312.5nS and one subband of 528MHz with central frequency of band gorup1 of TG3a proposal as per the code [1,3,2] for respective time-frequency block. MB-OFCDM system can send eight OFCDM symbol in one symbol durations, spread at different code sets. In the

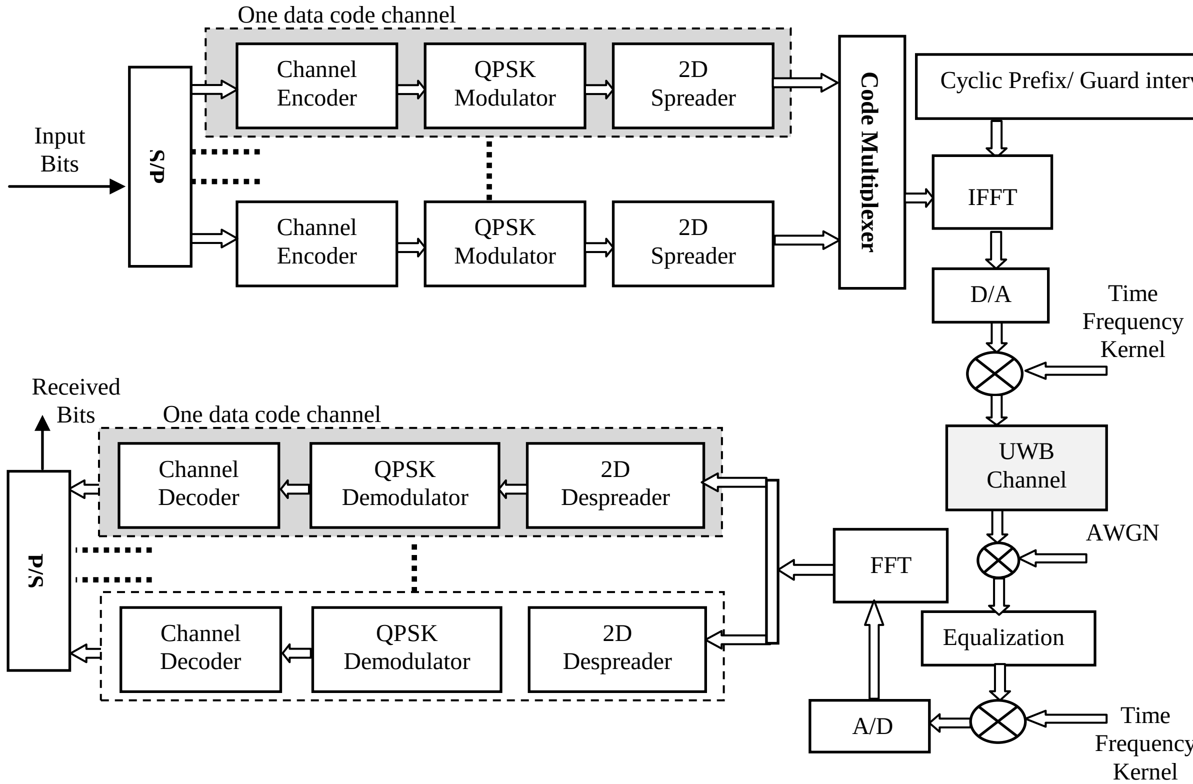

Fig. 3 Architecture of MB-OFCDM UWB System

receiver, signals are demodulated using time frequency kernel and reconstructed using analog to digital converter. The guard interval and zero padding are removed. After Fast Fourier Transform (FFT) data is given to data code channel, where the tones are obtained by 2D dispreading, QPSK demodulation and decoding. Figure 4 illustrates the transmission scheme of the MB-OFCDM-UWB system where eight coded OFDM symbols are transmitted in different subbands as per the time frequency code.

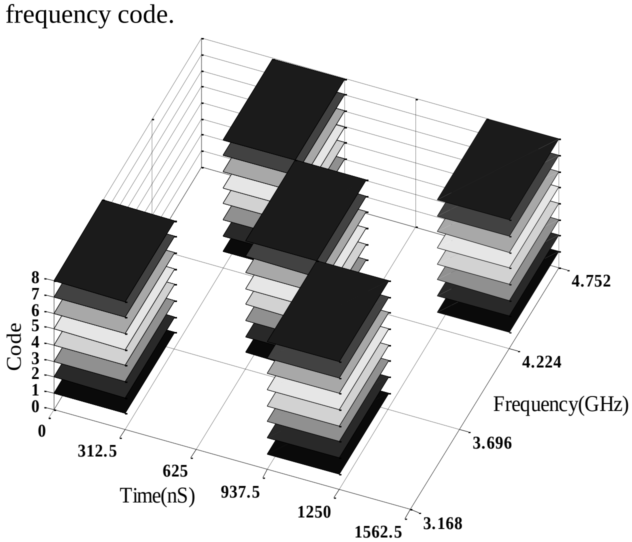

Fig. 4 MB-OFCDM Transmission scheme

IV. UWB IEEE Channel Model

Channel-Modelling sub-committee of study group IEEE 802.15.SGa [8] has published the final report regarding the UWB indoor multi-path channel model. This model is based on multipath contributions generated by the same pulse arrive at the receiver, grouped into cluster. The channel impulse response of the IEEE model is shown in Fig 5 and can be express as [7]

$$h(t) = X \sum_{n=1}^{N} \sum_{k=1}^{K(n)} \alpha_{nk}\, \delta(t - T_n - \tau_{nk}) \qquad (1)$$

where X is a lognormal distributed random variable representing the magnitude of channel gain.

$$X = 10^{\frac{g}{20}} \qquad (2)$$

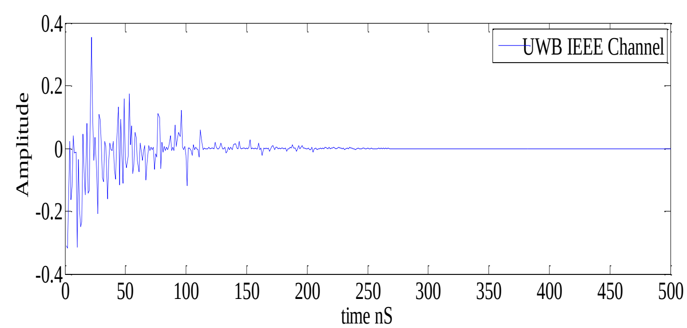

Fig. 5 Impulse response of UWB CM1 Channel

where g is Gaussian random variable with mean g_0 and variance σ_g^2, N is the observed number of clusters, $K(n)$ is the received number of multipath in the n^{th} cluster, α_{nk} is coefficients of the k^{th} path in the n^{th} cluster. T_n is the arrival time of the n^{th} cluster, τ_{nk} is the k^{th} path delay in the n^{th} cluster. The channel coefficient α_{nk} can be define as follows:

$$\alpha_{nk} = p_{nk}\beta_{nk} \tag{3}$$

where p_{nk} is a discrete random variable assuming ±1 with equal probability and β_{nk} is the log-normal distributed channel coefficient of multipath contribution, k belonging to cluster n. the β_{nk} term can thus be express as follows:

$$\beta_{nk} = 10^{\frac{x_{nk}}{20}} \tag{4}$$

where x_{nk} is assume to be Gaussian random variable.
According to the above definitions the channel model represented by the impulse response of (1) is fully characterized when the following parameter are defined [7]:

- The cluster average arrival rate Λ.
- The pulse average arrival rate λ.
- The power delay factor Γ for cluster.
- The power delay factor γ for pulse within a cluster.
- The standard deviation σ_ξ of the fluctuation of the channel coefficient for the clusters.
- The standard deviation σ_ζ of the fluctuation of the channel coefficient for pulse within each cluster.
- The standard deviation σ_g of the channel amplitude gain.

The value of parameters for LOS scenario is given in Table I [8].

V. Simulation and Results

MB-OFDM and MB-OFCDM UWB systems are simulated in MATLAB, under UWB indoor multi-path channel model (IEEE 802.15.SG3a, 2003). Simulation parameter used to evaluates the BER performance of both the systems are given in Table.2. The bit error rate curves with signal noise ratio (SNR) verses BER is shown in Fig .6 for IEEE UWB channel. MBOFDM and MB-OFCDM system with known channel information and perfect synchronization are considered. It is observed that performance of MB-OFCDM system is better than MB-OFDM UWB systems and the performance gap increases with increase in SNR.

Table I
Channel Parameter

Parameter	IEEE UWB Channel (CM1)
Λ(1/ns)	0.0233
λ (1/ns)	2.5
Γ	7.1
γ_{ch}	4.3
σ_ξ(dB)	3.3941
σ_ζ(dB)	3.3941
σ_g(dB)	3

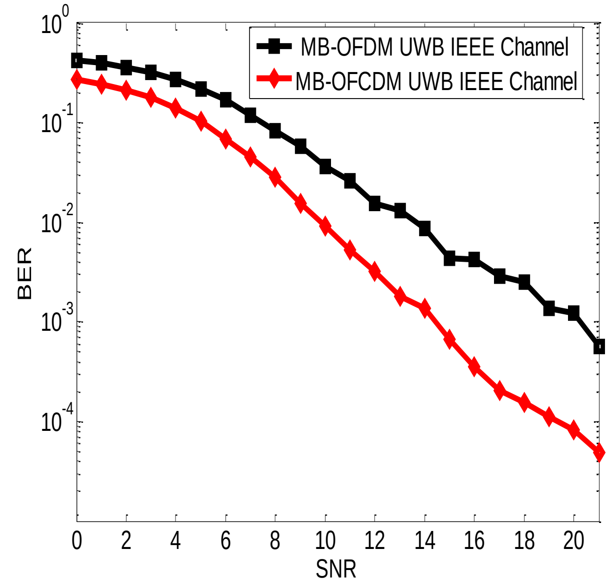

Fig. 6 BER Performance of both the system

Table II
Simulation Parameter

Parameter	MB-OFDM	MB-OFCDM
Number of OFDM subcarriers	128	128
Number of data subcarriers	100	128
Number of defined pilot subcarriers	12	--
Number of guard/Null subcarriers	10+6	--
Δf : Subcarrier frequency spacing	4.125 MHz	4.125 MHz
$T_{FFT:}$ IFFT/FFT period	242.42 ns (1/Δf)	242.42 ns (1/Δf)
T_{CP}: Cyclic prefix duration	60.61 ns	60.61 ns
T_{GI}: Guard interval duration	9.47 ns	9.47 ns
T_{SYM}: Symbol duration	312.5 ns	312.5 ns
Coding	convolution code with constraint length k = 7 and rate 1/3	convolution code with constraint length k = 7 and rate 1/3
Puncturing	Rate ½ puncturing matrix [1 0 1]	Rate ½ puncturing matrix [1 0 1]
Data Rate	320Mbps	320Mbps
Spreading factor	--	8
Time frequency code	[1,3,2]	[1,3,2]

VI. Conclusion

BER performance of MBOFDM UWB and MB-OFCDM UWB system has been observed in IEEE UWB channel, using a set of indoor channel parameters of channel model CM1 of TG3a IEEE proposal. Simulation results show that the MB-

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OFCDM-UWB system performs better than the MB-OFDM-UWB system. The performance gain of around 4 dB is observed at the bit error rate of 10^{-3}.

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