DESIGN AND ANALYSIS OF MULTIBAND OFDM SYSTEM OVER ULTRA WIDE BAND CHANNELS

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) has recently been applied in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and its robustness to multi-path delay. UWB (Ultra Wide Band) OFDM communication was proposed for physical layer in the IEEE 802.15.3a standard which covers wideband communication in wireless personal area networks. The ultra-wide bandwidth offers pulses with very short duration that provides frequency diversity and multipath resolution. Ultra-wide band (UWB) channels raise new effects in the receiver, the amplitude fading statistics being different compared to the conventional narrow band wireless channels. This paper focuses on modelling and analysis of multiband OFDM for ultra-wide band channels, especially for simulation of personal area networks and also discusses the benefits, application potential and technical challenges in wideband communication.

Keywords: UWB; OFDM; multiband.

1. Introduction

High data-rate and reliable transmissions with bandwidth efficiency are the requirements for future wireless communication systems. Multi band orthogonal frequency-division multiplexing (MB-OFDM) based ultra wide band (UWB) communication technology has received considerable attention in recent years [1]–[3], primarily due to its ability to mitigate radio-frequency interference and multipath fading effects and to achieve substantial spectral efficiency at a relatively low cost. In 2002, the Federal Communications Commission (FCC) allowed UWB communication in the 3.1–10.6 GHz band having a –10 dB bandwidth greater than 500 MHz and a maximum equivalent isotropic radiated power spectral density of –41.3 dBm/MHz. UWB systems with fc > 2.5 GHz need to have a −10 dB bandwidth of at least 500 MHz, while those with fc < 2.5 GHz need to have a fractional bandwidth at least 0.20. Such systems rely on ultra-short waveforms that can be free of sine wave carriers and do not require IF processing. This has triggered a large amount of interest in this area due to the promise of unprecedented wireless data rates and precise positioning in a low-cost consumer radio. The UWB OFDM called Multiband OFDM (MB OFDM), has been preferred communication technique for physical layer in the IEEE 802.15.3a standard which covers wideband communication in Wireless Personal Area Networks (WPANs) [4] – [6] . This technology has been adopted to support high-speed short range wireless connectivity, e.g., the certified wireless universal serial bus (USB) that aims to offer data rates up to 480 Mb/s within 3 m is based on the MB-OFDM UWB technology [7].

Liano et al. [8] have reported the parameters of UWB channel model based on frequency domain approach with lognormal statistics. It was reported that the model can be used to derive more accurate channel models in both UWB system design and performance optimization. Earlier the performance of UWB channel in industrial environment was analyzed by Johan et al. [9]. The performance of proposed system has been analyzed for different UWB channel models for channel tracking.

2. System Model

The functional block diagram of the proposed Ultra Wide Band (UWB) Orthogonal Frequency Division Mutiplexing (OFDM) system is shown in Fig. 1. The input binary information is first grouped and mapped according to the modulation using signal mapper. The mapped signals are then converted in to parallel blocks for efficient high data rate communication. After the Inverse Fast Fourier Transform (IFFT), the sequence of guard interval is inserted between two consecutive blocks. For designing OFDM system, the length of the information block is assumed to be N, cyclic prefix length is L and the value of guard interval is zero. Then the length of the OFDM symbol is $N + L$. The parallel block of length $N + L$ is converted into serial sequence and passed through the frequency selective time varying fading channel with additive noise. The channel impulses are considered as a finite length vector h of length $1\times L+1$. Then the impulse response of the channel can be written as

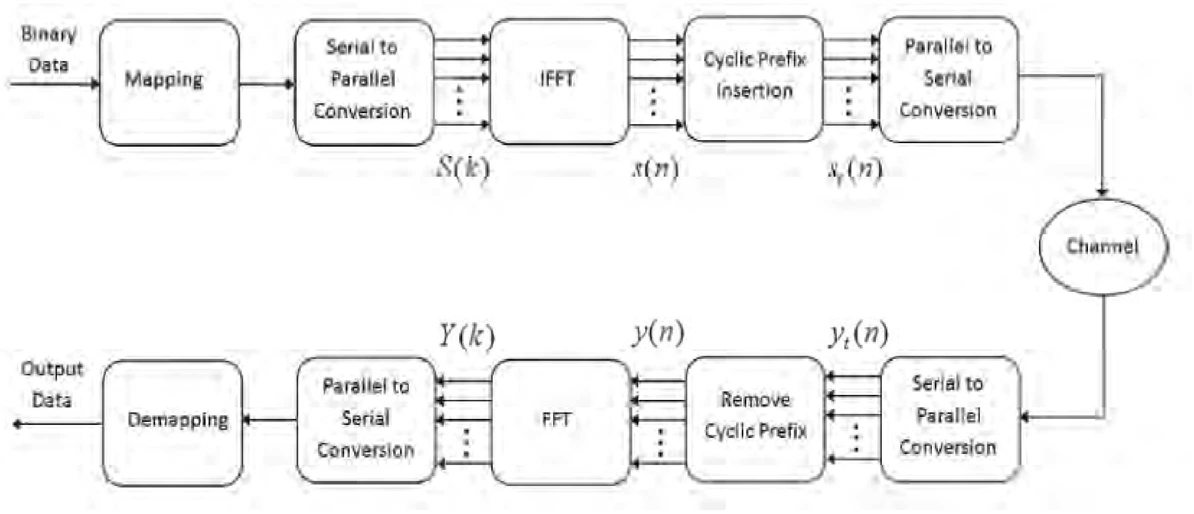


Fig.1. Block diagram of UWB OFDM system

$$h = [h_1\, h_2\ \dots\dots\dots .\, h_{L+1}]^T \tag{1}$$

where h_1, h_2, $h_3 \,.\,.\,.\,.\,.\,.\ h_{L+1}$ are the channel coefficients. The perfect synchronization between transmitter and receiver is assumed for developing the system model. The transmitted symbol $d_N(n)$ will pass through the frequency selective time varying fading channel with Additive White Gaussian Noise (AWGN). The received signal from the wireless channel can be expressed as

$$y(n) = \hat{H}\, F_N^H\, d_N\,(n) + \,\omega(n) \tag{2}$$

where $\hat{H}$ is the channel convolution matrix with the size of $(N + L) \times N$ and $\omega(n)$ is noise term [10]. The value of channel convolution matrix $\hat{H}$ can be estimated by converting the linear convolution into circular convolution matrix of size $N \times N$. While considering Zero Padded (ZP) OFDM, the entire linear convolution of each transmitted block with channel impulse response is preserved [11], [12].

The Channel matrix $\hat{H}$ with dimension $(N + L) \times (N)$ can be written as

$$\hat{H} = \begin{pmatrix} h_1 & h_2 & \dots\dots & h_{L+1} & 0 & \dots\dots & 0 \\ 0 & h_1 & \dots\dots & h_1 & h_{L+1} & \dots\dots & 0 \\ 0 & 0 & \dots\dots & 0 & h_1 & \dots\dots & h_{L+1} \end{pmatrix}^T \tag{3}$$

2.1. *UWB Channel model*

UWB channels influence new effects in the receiver as compared with narrow band wireless channels due to large bandwidth of operation. The mobile radio channel environment introduce severe multipath fading due to the combination of random delayed, reflected, scattered and diffracted signal components. The fading degrades the Carrier to signal Noise Ratio (CNR) and leading to higher Bit Error Rate (BER) in the link. The main purpose of the channel model is to evaluate the performance of the system in realistic environments. The most famous indoor channel model based on arrival of multipath components in UWB systems is Saleh-Valenzuela(S-V) approach. In this approach, the arrival of multipath components are grouped into two categories namely cluster arrival rate and ray arrival rate. The S-V model requires four parameters to describe indoor channel environments like cluster decay factor (Γ), ray decay factor (γ), cluster arrival rate (Λ) and ray arrival rate (λ). The impulse response of UWB channel can be written as,

$$h(t) = X \sum_{l=0}^{b} \sum_{k=0}^{K} \alpha_{k.l}\, \delta(t - T_l - \tau_{k,l}) \qquad (4)$$

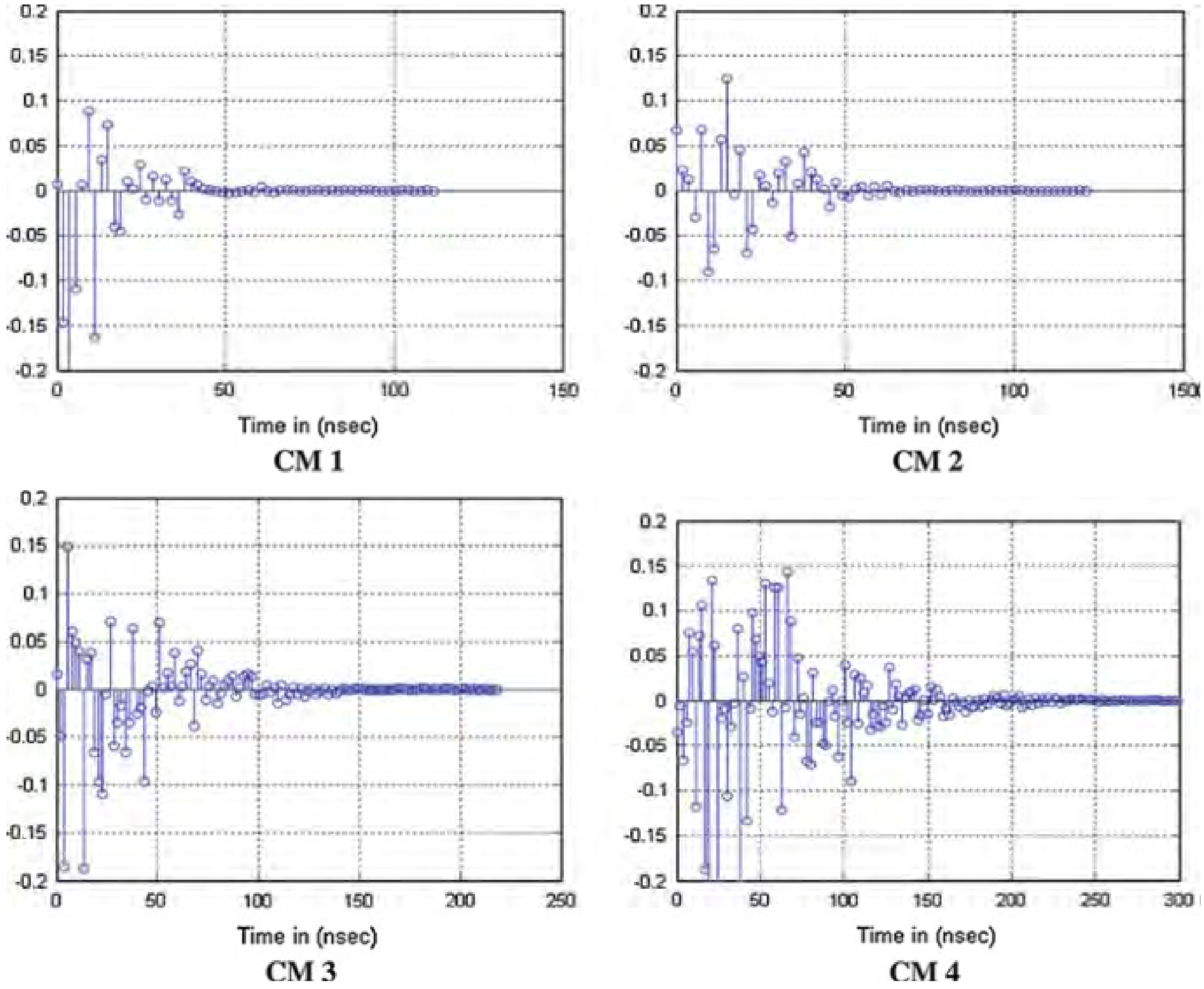
where b is the number of clusters, K is the number of multipath components within the cluster, $\alpha_{k.l}$ is multipath gain coefficient, T_l is Delay of lth cluster, $\tau_{k,l}$ is Delay of kth multipath component relative to the lth cluster arrival time and X is lognormal shadowing term. The characteristics of UWB channel environments considered for modelling and analysis is given in Table 1.

Table 1. UWB channel characteristics

Channel characteristics	**CM 1**	**CM 2**	**CM 1**	**CM 4**
Distance	(0–4) m	(0–4) m	(4–10) m	>10 m
(Non) line of sight	LOS	NLOS	NLOS	NLOS
Cluster arrival rate	0.02	0.4	0.0667	0.00667
Ray arrival rate	2.5	0.5	2.1	2.1
Cluster decay factor	7.1	5.5	14	24
Ray decay factor	4.3	6.7	7.9	12
σ_1(standard deviation for cluster)	3.4	3.4	3.4	3.4
σ_2(standard deviation for ray)	3.4	3.4	3.4	3.4
σ_x (standard deviation for lognormal	3	3	3	3

3. Simulation results

In this section, the performance of the proposed MB OFDM system for a UWB channel is analysed. The parameters for the different channel model (CM) are given in Table.1. The additive noise used in the simulation is based on a Gaussian distribution with a variance σ^2. The parameters of the OFDM are as in the IEEE 802.15.3a standard with a bandwidth of 528 MHz that is divided into 128 subcarriers and QPSK modulation is considered. To make subcarriers orthogonal in the presence of multipath, a guard interval length of 32 subcarrier is added. The UWB channel realizations are shown in Fig. 4. In order to assess the statistics of the modified channel realization 10,000 realizations are considered for channel model CM1, CM2, CM3 and CM4. The performance analysis of MB OFDM system over ultra wideband channel model is shown in Fig. 5. The BER of coherent BPSK modulation has been estimated for each SNR values considering the data rate 100 Mbps.



CM 1

CM 2

CM 3

CM 4

Fig. 4. Realization of UWB channels

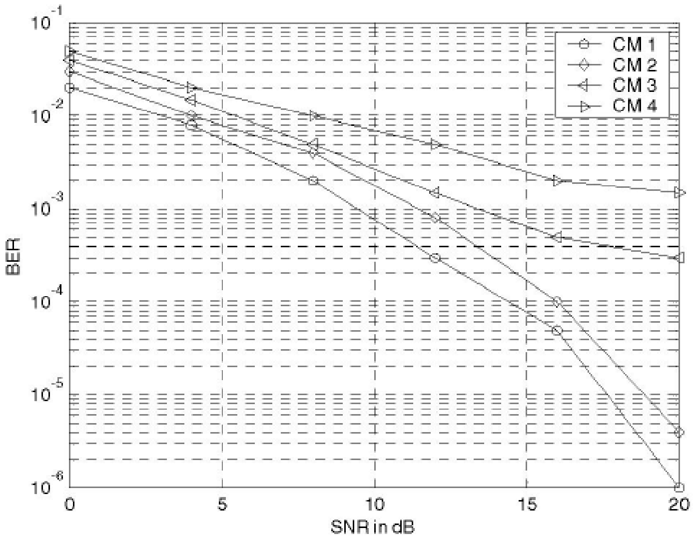


Fig. 5 BER analysis of UWB channel models

4. Conclusion

In this paper some of the key issues for design of multiband OFDM for UWB communications have been analyzed. We have shown that the UWB channel model developed under IEEE 802.15 is seen by OFDM systems in the frequency domain as Rayleigh fading with additional shadowing. The 528 MHz signal bandwidthchosen for Multiband OFDM essentially captures the diversity provided by the UWB channel. It is concluded that the proposed method is more suitable for large scale fading environments on rapid fading in high frequency long distance propagation.

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