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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 6 (2): 267-270, 2007
ISSN 1812-5638

Performance Analysis of MC-CDMA for Wide Band Channels

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Abstract: Fourth Generation wireless communication demands a better multiple access technique for reducing the Multiple Access Interference (MAI) and Inter Symbol Interference (ISI) and to improve the bit error rate performance. MC-CDMA is the best candidate that would satisfy the demands of 4G wireless systems. MC-CDMA does not require more rake figers and it shows better performance than OFDM at low signal power in Ultra Wide Band (UWB) channel. UWB uses bandwidth above 20% of center frequency which severely suffers from frequency selective fading. This study analyses the performance of Orthogonal Frequency Division Multiplexing (OFDM) and Direct Sequence (DS) CDMA systems. The simulation results shows that the MC-CDMA performs well interms of BER comparatively with other techniques in wide band channel. UWB Saleh-Valenzulea channel model proposed by intel is used in the simulation for analyzing the performance of MC-CDMA systems.

Key words: MC-CDMA, UWB, OFDM, RAKE Fingers

INTRODUCTION

In recent years, ultra-wide band communication has received great interest from both research community and industry. Several GHz of bandwidth has been authorized for license free communication by the Federal Communication Commission (FCC) in United States (Molisch, 2003; Gui and Nag, 1999). FCC has mandated that the UWB radio transmission is lies between 3.1 and 10.6 GHz with a minimum instantaneous bandwidth of 500 MHZ or a fractional bandwidth of more than 20% (Foserter, 2002). The fractional bandwidth is the ratio of-10 dB bandwidth of the signal and the carrier frequency (f_c). UWB systems with f_c>2.5 GHz need to have a-10 dB bandwidth of at least 500 MHZ, while those with f_c <2.5 GHz need to have a fractional bandwidth at least 0.20 (Saleh and Valenzuela, 1987). MC-CDMA is capable of exploiting frequency diversity in an explicit manner, since the energy of the symbol is spread over several sub-carriers (Hara and Prasad, 1997a), more over MC-CDMA is simpler than DS-CDMA and shows better performance in terms of BER (Viterbi, 1995). This research deals with the performance of MC-CDMA in Saleh-Valenzulea model. The channel characteristic of the model is proposed by Intel. Four Channel Models are compared and analyzed.

MC-CDMA SYSTEM MODEL

Multicarrier Code-division Multiple Access (MCCDMA) is a promising approach to the challenge of providing high data rate wireless communication. It represents the fusion of two distinct techniques (Hara and Prasad, 1997b). The first is Orthogonal Frequency-division Multiplexing (OFDM), which addresses the intersymbol interference problem arising in channels where the signal bandwidth exceeds the coherence bandwidth of the fading process (Wang and Giannakis, 2000). The idea in OFDM is to divide the available bandwidth into a large number of small orthogonal bands or subcarriers, each much smaller that the coherence bandwidth and thus exposed only to frequency-flat fading (Bingham, 1990). A central feature of OFDM is that it can take advantage of the Fast Fourier Transform (FFT) to translate the signal from the frequency to the time domain and vice versa. The second ingredient is CDMA, which has become a prominent multiple-access technique in mobile wireless systems (Forester, 2002). In its direct-sequence form, however, CDMA suffers in the face of frequency-selective fading, particularly in the downlink where orthogonal spreading codes are typically employed. The orthogonality is destroyed by the channel, which renders the codes mutually interfering (Bingham, 1990).

The basic idea of CDMA is to maintain a sense of orthogonality among the users in order to eliminate the MAI. This is done by employing orthogonal spreading codes to spread the data sequence. In MC-CDMA these spreading codes are defined in the frequency domain. Pseudo orthogonal codes can be used instead of orthogonal codes, thus increasing the number of users that can be accommodated. But pseudo orthogonal codes can increase MAI since the spreading codes are not fully orthogonal.

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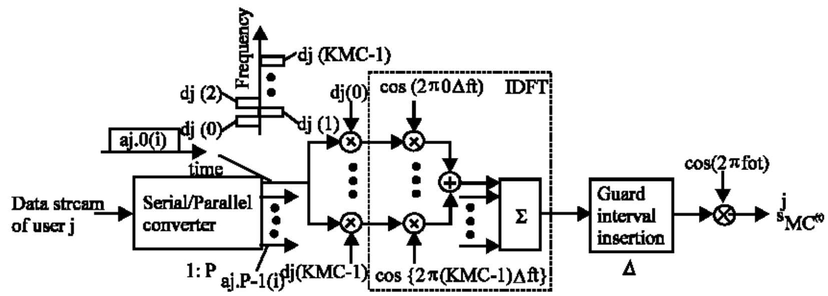

Fig. 1: MC-CDMA transmitter

Figure 1 shows the MC-CDMA transmitter for the jth user with CBPSK format. The input information sequence is first converted into P parallel data sequences aj,0 (i), a j,1 (I),.......a j,p^{-1} (i) and then each Serial/Parallel converter output is multiplied with the spreading code with length K_{MC} All the data in total $N = P \times K_{MC}$ (corresponding to the total number of subcarriers) are modulated in base band by the Inverse Discrete Fourier Transform (IDFT) and converted back into serial data. The guard interval is inserted between symbols to avoid intersymbol interference (Gui and Nag, 1999) caused by multipath fading and finally the signal is transmitted after Radio Frequency (RF) upconversion. The complex equivalent low-pass transmitted signal is written as:

$$S^{j}_{MC}(t) = \sum_{i=-\infty}^{+\infty} \sum_{P=0}^{P-1} \sum_{m=0}^{KMC^{-1}} a\, j, p^{(i)} d\, j^{(m)} \quad (1)$$
$$P_s\left(t - iT'_s\right)_e^{j2\pi(Pm+P)\Delta f'(t-iT'_s)}$$

Where $\{d_j(_0).d_j(_1)..........d_j(K_{MC}{}^{-1})\}$ is the sampling code with length K_{MC}, $T`_s$ is the symbol duration, $\Delta f'$ is minimum subcarrer separation and the $p_s(t)$ is the rectangular symbol.

UWB CHANNEL MODEL

A reliable channel model which captures the important characteristics of the channel is a vital prerequisite for system design the accurate design of channel model is a significant issue in UWB systems. The most famous multipath UWB indoor channel models are tap-delay line Rayleigh fading model (Hara and Prasad, 1997a), Saleh-Valenzulea (1987) model and Δ-K model. Recently Intel proposed a modified S-V model for UWB communication. The large bandwidth of UWB channels may raise new effects in the receiver compared to narrow band wireless channels. For example, only few a multipath components are overlap within each resolvable delay bin, so that the central limit theorem is not applicable and amplitude fading statistics are different. Sometimes, there can be delay bins into which no Multipath Components (MPC) fall and thus are empty (Foserter, 2002). The arrival time of multipath components of a wide band signal is same as the S-V model approach. The S-V channel measurement shows that the multipath components are arriving in a cluster form. Since UWB signals can be up to 7.5 GHz wide (Batra *et al*., 2003), the MPC are separated by 133 ps and it can be individually resolved at the receiver (Yang and Giannak, 2004). The different paths of such wide band signal can rise to several multipath components, all of which will be part of one cluster.

The amplitude statistics in S-V model are based on Rayleigh distribution, the power of which is controlled by the cluster and ray decay factor (Forester, 2002). The S-V characteristics of the UWB channel proposed by intel is depicted in Table 1.

However recent measurements in UWB channel show that amplitudes do not follow Rayleigh distribution rather it follows lognormal distribution. The impulse response of UWB channel can be written as:

Table 1: S-V channel characteristics proposed by intel

Target channel characteristics	CM 1LOS (0-4 m)	CM 2NLOS (0-4 m)	CM 3NLOS (4-10 m)	CM 4XNLOS
Mean excess delay	5.05	10.38	14.18	21
RMS delay	5.28	8.03	14.28	25
Model characteristics				
Λ(1/nsec)	0.0233	0.4	0.0667	0.0667
λ (1/nsec)	2.5	0.5	2.1	2.1
Γ	7.1	5.5	14.00	24.00
γ	4.3	6.7	7.9	12
σ_1	3.3941	3.3941	3.3941	3.3941
σ_2	3	3.00	3.00	3

$$h(t) = X\sum_{l=0}^{L-1}\sum_{k=0}^{K-1} \alpha_{k,l}\,\delta(t - T_l - \tau_{k,l}) \qquad (2)$$

Where $\alpha_{k,l}$ is the multipath gain coefficient of kth ray related to lth cluster. T_l is the delay or arrival time of first path of lth cluster. $\tau_{k,l}$ is the delay of kth path within the lth cluster relative to T_l. X is the lognormal shadowing term. The ray arrival and cluster arrival distribution time are given by:

$$p\,(T_l/T_{l-1}) = \Lambda \exp\,[-\Lambda\,(T_l - T_{l-1})] \quad l>0 \qquad (3)$$

$$p\,(\tau_k/\tau_{k-1}) = \lambda \exp\,[-\lambda\,(\tau_k - \tau_{k-1})] \quad l>0 \qquad (4)$$

SIMULATION RESULTS

In order to demonstrate the simulation results, we assume the following:

No. of users	:	1
Channel Model	:	S-V Channel
Bandwidth	:	528Mbps (OFDM), 1.58 GHz (MC-CDMA)
Data Rate	:	160 Mbps (OFDM), 96 Mbps (MC-CDMA)
Modulation	:	QPSK
Rake finger	:	16 (Ds-CDMA)
Spreading Code length	:	24 (DS-CDMA) 20 (MC-CDMA)
FFT size	:	128 (OFDM), 256 (MC-CDMA)
Data tone	:	100 (OFDM), 200 (MC-CDMA)
Guard Interval	:	70.075ns(OFDM), 54.0936ns (MC-CDMA)
Symbol Interval	:	312.5ns (OFDM), 208.33ns (MC-CDMA)

The graph shows BER performance of DS-CDMA/OFDM/MC-CDMA system at all different channel profiles. The simulations are developed at different data rate mentioned above and the comparing the band width of MC-CDMA and DS-CDMA in Fig. 2, which spreads the original data by spreading code, the bandwidth of OFDM system is less wider. UWB system is not restricted by bandwidth. DS-CDMA system uses 16 rake fingers to catch multipath components and OFDM uses time spreading and frequency spreading. The results from the figures shows that MC-CDMA outperforms in Fig. 3, because MC-CDMA system can effectively combine the received signal energy scattered in the receiver structure. DS-CDMA on the other hand using more number of rake fingers can give equal performance as that of MC-CDMA in Fig. 4, but the entire system becomes more complex. MC-CDMA can solve the power problem of OFDM because the MC-CDMA data is spread by spreading the code before modulation.

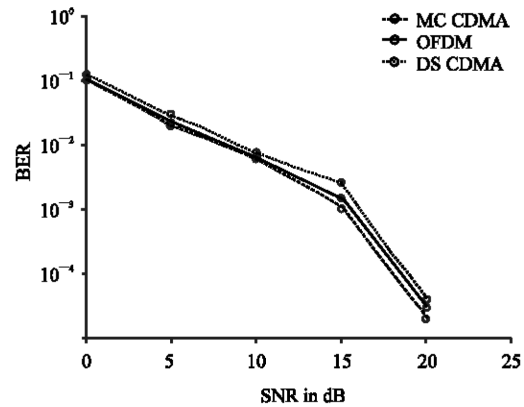

Fig. 2: Performance of DS-CDMA/OFDM/MC-CDMA at AWGN

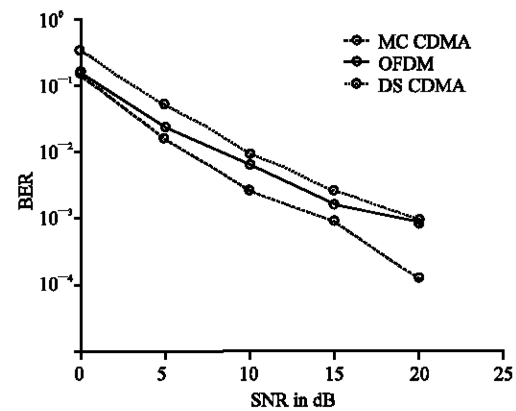

Fig. 3: Performance of DS-CDMA/OFDM/MC-CDMA at CH (1)

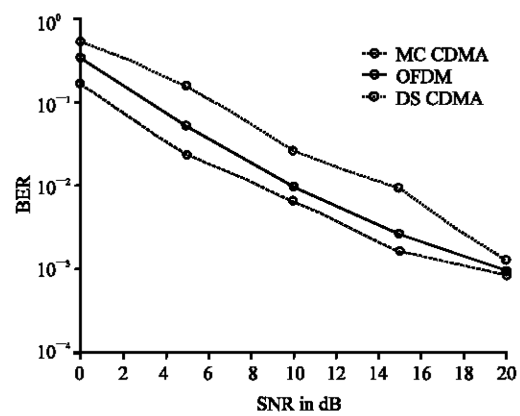

Fig. 4: Performance of DS-CDMA/OFDM/MC-CDMA at CH (4)

CONCLUSION

In this study the performance of MC-CDMA in UWB channel is compared with DS-CDMA and OFDM system. UWB saleh-valenzulea channel model is proposed by intel is used in the simulation for analyzing the performance of MC-CDMA system. The results shows that by using more number of rake fingers DS-CDMA can perform better than OFDM, but the complexity sharply increases, accordingly. MC-CDMA can perform better than OFDM, but the complexity sharply increases, accordingly. MC-CDMA is almost equal to DS-CDMA in terms of required bandwidth and it is slightly complex than OFDM systems. However the MC-CDMA system shows good performance at every channel than other systems. The performance of the MC-CDMA system can be further improved by employing dynamic sub-channel allocation and adaptive modulation techniques.

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