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PERFORMANCE COMPARISON BETWEEN MC-CDMA AND DS-CDMA SYSTEMS FOR AWGN AND RAYLEIGH FADING CHANNEL

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Abstract- **The latest technology in cellular mobile communication systems has become more demanding for better quality of service. It requires broad bandwidth for huge data transfer. In this paper, we compare the performance of Direct Sequence Code Division Multiple Access (DS-CDMA) and Multi-Carrier Code Division Multiple Access (MC-CDMA) which are the major contenders for the next generation wireless signaling techniques. Code Division Multiple Access (CDMA) is a multiple access technique in which several transmitters can send information simultaneously over a single communication channel. Walsh-Hadamard (W-H) Code is chosen for spreading, which reduces Multiple Access Interference (MAI) due to its orthogonal property. Minimum mean square equalization (MMSE) and Matched filter detection is assumed for both DS-CDMA and MC-CDMA. The comparative study of Bit Error Rate (BER) performance over different modulation techniques is done and their performances are compared for BER and Eb/N0.**

Index Terms- ***BER*****, CDMA, DS-CDMA, MC-CDMA, OFDM, W-H Code.**

I. INTRODUCTION

In recent years Orthogonal Frequency Division Multiplexing (OFDM) and CDMA systems have gained attention due to their use in high speed wireless communication. Both OFDM and CDMA have different features, for example, the former is a completely immune to multipath fading effects, and the later has multi-user capability. OFDM-CDMA to combine these features, so that we can achieve higher data rates for multiple users simultaneously. OFDM is a digital multi-carrier modulation scheme that transmits high data rate stream by several low rate data stream. Orthogonal sub-carriers are used to carry data on parallel channels. OFDM needs accurate frequency synchronization and its sub-carriers are not orthogonal due to frequency deviation. Frequency deviation between transmitter and receiver oscillator cause Carrier Frequency Offset (CFO). CFO causes Inter-carrier Interference. It has the noises like amplitude variation and Peak to average power ratio. OFDM requires very accurate frequency synchronization between the transmitter and the receiver; with frequency deviation the sub-carriers will no longer be orthogonal, causing Inter-Carrier Interference (ICI) (i.e, cross-talk between the sub-carriers). Frequency offsets are typically caused by mismatched transmitter and receiver oscillators, or by Doppler shift due to movement.

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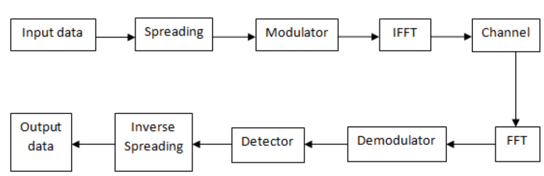

Fig. 1 Block diagram of CDMA system

CDMA is one of several methods of multiplexing wireless users. In CDMA, users are multiplexed by distinct codes rather than by orthogonal frequency bands, as in Frequency Division Multiple Access (FDMA), or by orthogonal time slots, as in Time Division Multiple Access (TDMA).

II. LITERATURE REVIEW

Multicarrier signaling technique is applied in [1] to a DS-CDMA system, where a data sequence is multiplied by a spreading sequence modulates multiple carriers, rather than a single carrier. To prevent self-interference they use band-limited spreading waveforms, and system performance over a frequency selective Rayleigh channel in the presence of partial band interference are evaluated; also compare system performance with that of a single-carrier RAKE system. The narrowband interference suppression capability of this multicarrier system is useful to reject the interference from a narrowband signal to a CDMA signal.

In [2], the overview of multiple access schemes such as MC-CDMA, DS-CDMA, and multi-tone CDMA (MT-CDMA) and discussion of advantages and disadvantages with a normal DS-CDMA scheme. Simulation results are shown that the MC-CDMA scheme with MMSEC is a promising protocol in a 2-path frequency selective slow Rayleigh fading channel.

MC-DS-CDMA can adapt the transmission rates by changing both time and frequency spreading factors. In [3], an analytical method is proposed to evaluate the effects of the power control element and the complete Multiple Access Interference (MAI) on the multi-rate MC-DS-CDMA system. A larger power control can make the frequency-domain spreading gain is usually better than that with a larger time-domain spreading gain.

In [4], the effects of long spreading sequences and Carrier Frequency Offset (CFO) on the performance of asynchronous MS-DS-CDMA systems with correlated fading among sub channels were investigated. An expression for approximate BEP was obtained based on Gaussian and local-mean approximation. The derived analytic results for MC-DS-CDMA by appropriate modifications with by means of numerical simulations; they demonstrated that ICI can be mitigated by using optimum combining and by assigning a common random spreading sequence over all subcarriers of a given user.

[5], investigates the trade-off between diversity and channel estimation and channel estimation errors for asynchronous MC-CDMA and MC-DS-CDMA. Both systems perform pilot-symbol aided channel estimation maximal ratio combining at the receiver, where the weighting coefficients are determined by the channel estimated at each sub-carrier. The bit error rates of the two systems for different information rates, number of users and number of pilot symbols used in each channel estimate is compared.

In [6], gives the most suitable technique for implementing 4G communication systems. The modems of OFDM, MC-CDMA and OFCDM have been redesigned and performance is analyzed in terms of probability of error. The results reveal that OFCDM provides the lowest BER for given SNR and the selection of a higher spreading factor for frequency-domain spreading led to an increase in the BER, when the channel chosen to be highly frequency-selective and a higher spreading factor for time-domain spreading led to an increase in the requirement for the number of subcarriers.

The principal goal of [7] is designing and testing the performance of source and channel coding and decoding circuits are implemented for CDMA Transceiver using extremely simple circuit concept as transmitter and receiver hardware of cellular communication system is implemented for CDMA scheme. It also describes the modulation and demodulation circuits for CDMA. Transceiver is realized by VHDL codes and testing the same for a wide range of input conditions.

In [8], an improved MC-CDMA system using Frequent Domain Differential Detection (MC-FDDD-CDMA) for low SNR links is proposed. They are analyzed the system performance of BER under the fast fading HF channel, with synchronization errors, including frequent offset and timing offset. The results show that the synchronization errors reduce the desired signal amplitude, and introduce Inter-Carrier Interference, which limits the system BER performance.

They improved a system, which can effectively reduce the CPE and considerably promote the BER performance under the low SNR HF channels. In [9], they designed the CDMA transmitter and receiver and they are tested using and arbitrary and receiver and they are tested using an arbitrary chosen data stream. A comparison has been done between the transmitted and received data and satisfactory results have been achieved.

Increasing the number of bits is possible to reach the standard rates specified for CDMA. [10], analyzes the performance of BER under Rayleigh fading channel conditions of MC-CDMA in presence of AWGN (Additive White Gaussian Noise) using BPSK modulation for different number of subcarrier, different number of users using MATLAB program, and comparison between simulated results, which shows the reduction in BER performance.

[11], implements the MC-CDMA system and derive the comparison of BER Vs Eb/N0 for MC-CDMA communication system using variable number of bits with QPSK and BPSK modulation on Rayleigh channel and Additive White Gaussian Noise. Simulation result of BER Vs Eb/N0 with

QPSK modulation shows that as BER performance decreases, Eb/N0 increases. The received MIMO MC-CDMA signals will never be corrupted because copy of same signals are transmitted over all subcarriers and error or overlapping of signals will never take place because of orthogonal property.

Wavelet packet waveform set is the set of waveform generated from a full binary wavelet packet tree which is used as the modulation waveform in a MC-CDMA system. [12], presents a design of conventional MC-CDMA and wavelet packets based MC-CDMA and their comparison on the basis of performance matrices. BER Comparative analysis of MC-CDMA system with wavelet packet based MC-CDMA system using different modulation techniques is presented. Wavelet packet based MC-CDMA system using BPSK modulation is quite satisfactory as compared to other modulation techniques in AWGN channel.

In this paper, we compare the performance of DS-CDMA and MC-CDMA for different modulation techniques such as BPSK, QPSK and their performances are compared for BER and Eb/N0.

III. SYSTEM MODEL

A. MC-CDMA

MC-CDMA is the combination of frequency domain spreading of data and OFDM schemes, combines the advantages of both the schemes. The narrow bandwidth message is multiplied by a large bandwidth signal that is a pseudo random noise code. Users in a CDMA system use the same frequency band and transmit simultaneously. The transmitted signal is recovered by correlating the received signal with the PN code used by the transmitter. Spreading codes are pseudo-orthogonal codes.

MC-CDMA systems are more sensitive to the carrier frequency offset than single-carrier systems. Carrier frequency offset removes the orthogonality among subcarriers in MC-CDMA systems and degrades the system performance seriously.

(i) MC-CDMA Transmitter

MC-CDMA scheme transmits the same symbol in parallel through several subcarriers. The OFDM transmits different code of the user in the frequency domain. Data stream from each user is divided in to several low rate parallel data stream. The input data is multiplied by the spreading code. The MC-CDMA transmitter spreads the original data stream over different subcarriers using a given spreading code in frequency domain. We can use the W-H codes as an optimum orthogonal set, because we do not have to pay attention to the auto-correlation characteristics of the spreading codes.

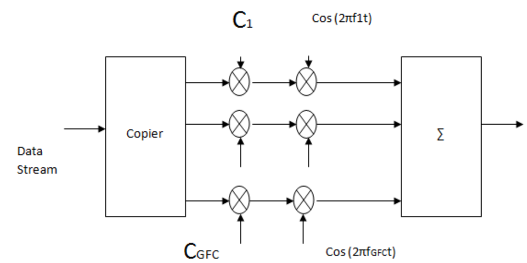

Fig. 2 MC-CDMA Transmitter

The OFDM system with the CDMA system converts the symbols to time domain samples by Inverse Fast Fourier Transform (IFFT) and assigns a sub-carrier for each symbol. Then the sub-carriers are multiplexed to form as a serial stream. Before the transmission of the serial data stream, it is converted to blocks and each block is separated by a guard frame. The total number of sub-carriers are modulated in baseband by an IFFT and converted back in to serial data. A cyclic prefix is inserted between the symbols which are a repeat of the end of the symbols at beginning, to reduce ISI and ICI caused by multipath fading. The cyclic prefix length is chosen such that it is greater than the delay spread of the channel. In MC-CDMA transmission, it is essential to have frequency non selective fading over each sub-carrier.

(ii) MC-CDMA Receiver

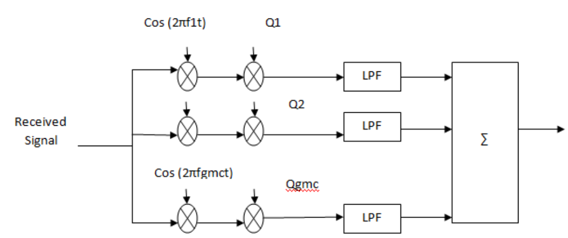

Fig. 3 MC-CDMA Receiver

Then, the cyclic prefix is removed and the samples are serial to parallel converted to obtain the m-subcarriers components. The m-subcarriers are demodulated by a Fast Fourier Transform (FFT) and multiplied by the gain to combine the received signal energy scattered in the frequency domain.

B. DS-CDMA

DS-CDMA is the combination of time domain spreading of data and OFDM schemes, combines the advantages of both the schemes. Sequence to be transmitted is spread in the time domain and transmitted by multiple sub-carriers. Pseudo-noise sequence is used as the spreading code.

(i) DS-CDMA Transmitter

DS-CDMA scheme transmits the time domain data signal through sub-carriers. The DS-CDMA transmitter spreads the original data stream using a given spreading code in time domain. Instead of PN sequence we may use the W-H code as an optimum orthogonal set. The spreading signal is modulated by either BPSK or QPSK modulation and transmitted through channel.

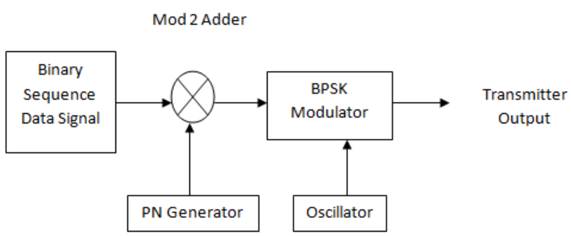

Fig. 4 DS-CDMA Transmitter

(ii) DS-CDMA Receiver

Received signal is the modulated form of spreading signal. The received signal is demodulated and de-spread using the reverse form of transmitter.

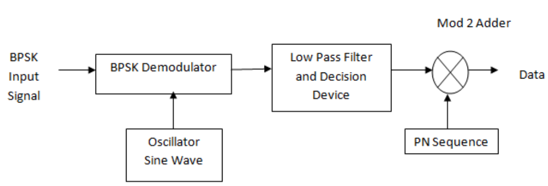

Fig. 5 DS-CDMA Receiver

In Direct Sequence Spread Spectrum transmission, the user data signal is multiplied by a code sequence, as binary sequences are used. The duration of an element in the code is the “chip time”. The ratio between the user symbol time and the chip time is called the spread factor.

IV. MODULATION TECHNIQUES

In telecommunications, modulation is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside a signal that can be physically transmitted. Modulation of a sine waveform is used to transform a baseband message signal in to a pass band signal.

A device that performs modulation is known as a modulator and a device that performs the inverse operation of modulation is known as a demodulator. The aim of digital modulation is to transfer a digital bit stream over an analog band pass channel, for example over the public switched telephone network or over a limited radio frequency band.

(a) Binary Phase Shift Keying (BPSK)

BPSK also called as 2PSK, is the simplest form of Phase Shift Keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned. This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision.

In the presence of an arbitrary phase shift introduced by the communications channel, the demodulator is unable to tell which constellation point. As a result, the data is often differentially encoded prior to modulation. BPSK is functionally equivalent to 2-QAM modulation.

(b) Quadrature Phase Shift Keying (QPSK)

Sometimes this is known as quaternary PSK, Quadriphase PSK, 4-PSK or 4QAM. QPSK uses four points on the constellation diagram, equi-spaced around a circle. With four phased, QPSK can encode two bits per symbol.

The mathematical analysis shows that QPSK can be used either to double the data rate compared with a BPSK system while maintaining the same bandwidth of the signal, or to maintain the data-rate of BPSK but halving the bandwidth needed. In the latter case, the BER of QPSK is exactly the same as the BER of BPSK.

Given that radio communication channels are allocated by agencies such as the Federal Communication Commission giving a prescribed bandwidth, the advantage of QPSK over BPSK becomes evident: QPSK transmits twice the data rate in given bandwidth compared to BPSK, at the same BER.

V. SPREADING CODE

Spreading will convert narrowband signal to wideband signal to suppress the self interference by multipath effect. Various types of spreading codes, like W-H code, Pseudo Noise (PN) spreading code, Gold code and Golay code are used to spread the user data. These codes can be distinguished by their correlation properties, orthogonal and peak average to power ratio (PAPR). Since W-H code is orthogonal code its performance is good among the above spreading code. To minimize the MAI, spreading code should be orthogonal. In uplink PN code is used because due to distortion spreading codes orthogonal gets lost. For a stream of digits as 0 and 1, have the following two properties, such as balance property and independence.

The Walsh-Hadamard codes are generated with set of $N=2^n$ codes. Orthogonality property shows cross-correlation between any two W-H codes of the same set is zero. W-H code spreading, is used for all users of the same channel which are synchronized in time.

VI. PERFORMANCE ANALYSIS

(i) BIT ERROR RATE

The bit error rate or bit error ratio (BER) is defined as the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure. The bit error probability is the expectation value of the BER. The BER can be considered as an approximate estimate of the bit error probability.

BER measure requires a transmitter, a receiver and a channel. Generate long sequence of random bits, which is the input to the transmitter.

BER as function of the Eb/N0 is given by:

$$BER = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right) \qquad (1)$$

(ii) SNR

SNR is the Signal to Noise Ratio, is defined as the ratio of signal power to the noise power. It measures the relationship between the strength of an information signal and the random fluctuations on amplitude, phase and frequency on that signal as noise.

For digital signals, SNR is defined as the amount of energy in the signal per bit of information carried by the signal.

SNR=Signal Power/Noise Power (2)

VII. SIMULATION RESULT

The user bits are randomly generated and the comparison is performed between MC-CDMA and DS-CDMA. Simulation of BER Vs SNR with BPSK modulation of MC-CDMA shows that as BER performance decreases, the bit energy to noise ratio, Eb/N0 increases. We have noticed that BER for MC-CDMA BPSK shows low value compared to all other techniques.

BER for MC-CDMA with BPSK for 2 users

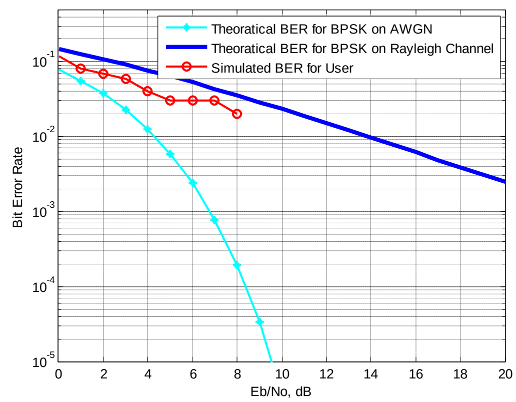

Fig. 6 USER1 BER FOR MC-CDMA BPSK

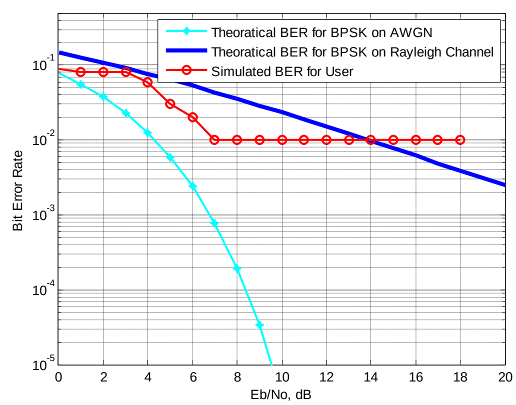

Fig. 7 USER2 BER FOR MC-CDMA BPSK

BER for MC-CDMA with QPSK for 2 users

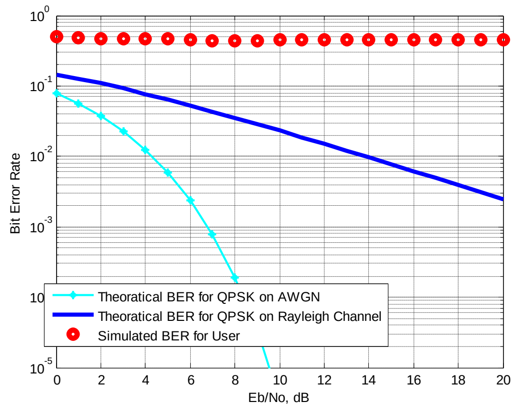

Fig. 8 USER1 BER FOR MC-CDMA QPSK

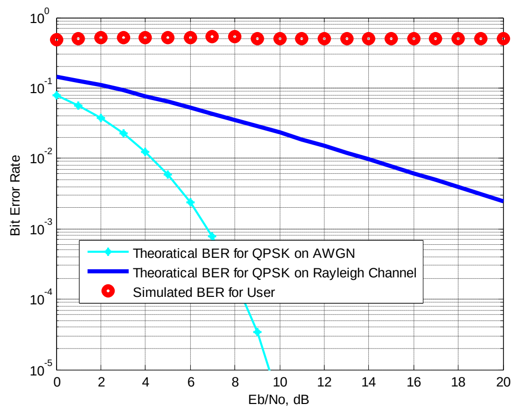

Fig. 9 USER2 BER FOR MC-CDMA QPSK

BER for DS-CDMA with BPSK for 2 users

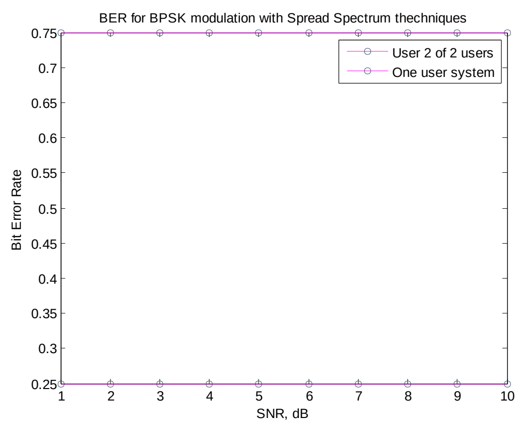

Fig. 10 BER FOR DS-CDMA BPSK

VIII. CONCLUSION

This paper compare the BER between MC-CDMA and DS-CDMA for high speed data communication and tried to study the BER Vs Eb/N0 performance for both communication system using variable number of bits with BPSK and QPSK modulations on Additive White Gaussian Noise, and data is generated randomly. In tabulation, we consider the number of users 2 with the number of sub-carriers 4, and number of users 4 with number of sub-carriers 4, which shows MC-CDMA with BPSK shows better performance compared to all other methods. Thus the performance of MC-CDMA with BPSK is better than the QPSK modulation technique based on simulation results.

Table 1

MC-CDMA with BPSK Modulation

SNR Range (dB)	BER for AWGN		BER for Rayleigh Channel		Number of users=2, Number of sub-carriers=4		Number of users=4, Number of sub-carriers=4	
	Min	Max	Min	Max	Min	Max	Min	Max
0-9	3.3627e^-5	0.0786	0.0288	0.1464	0	0.1400	0	0.1500
0-19	1.0011e^-36	0.0786	0.0031	0.1464	0	0.1900	0	0.2100
0-29	0	0.0786	3.1443e^-4	0.1464	0	0.1000	0	0.2100
0-39	0	0.0786	3.1470e^-5	0.1464	0	0.1300	0	0.2300
0-49	0	0.0786	3.1473e^-6	0.1464	0	0.18	0	0.27

Table 2

MC-CDMA with QPSK Modulation

SNR Range (dB)	BER for AWGN		BER for Rayleigh Channel		Number of users=2,Number of sub-carriers=4		Number of users=4, Number of sub-carriers=4	
	Min	Max	Min	Max	Min	Max	Min	Max

0-9	3.3627e^-5	0.0786	0.0288	0.1464	0.1900	0.2500	0.2000	0.2500
0-19	1.0011e^-36	0.0786	0.0031	0.1464	0.2300	0.2500	0.1900	0.3100
0-29	0	0.0786	3.1443e^-4	0.1464	0.2100	0.2500	0.1900	0.2700
0-39	0	0.0786	3.1470e^-5	0.1464	0.1400	0.2500	0.1800	0.2800
0-49	0	0.0786	3.1473e^-6	0.1464	0.2000	0.2400	0.1700	0.234

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