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ANALYSIS OF MULTI-CARRIER CODE DIVISION MULTIPLE ACCESS SYSTEM UNDER CLIPPING NOISE IN DIFFERENT CHANNELS

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ABSTRACT

Multi Carrier Code Division Multiple Access (MC-CDMA), a promising technology for the 4G communication systems is considered in this paper. The foremost limitation of such system is the Multiple Access Interference (MAI) which is due to frequency-selective fading, near-far effect, frequency offset, and nonlinear power amplification. The performance of MC-CDMA under such scenario is poor . The Bit Error Rate (BER) performance is analyzed under clipping noise in a variety of channels, such as AWGN, Rayleigh fading and Rician channel as a function of Signal-to-Noise Ratio.

Indexing terms/Keywords

MC-CDMA, OFDM, CDMA Clipping Noise, AWGN, Rayleigh channel, Ricianchannel

Academic Discipline And Sub-Disciplines

Electronics and Communication Engineering- Wireless Communication

SUBJECT CLASSIFICATION

Code Division Multiple access Method

TYPE (METHOD/APPROACH)

Analysis and Comparative study

1. INTRODUCTION

Wireless communications is an emerging field, which has seen enormous growth in the last several years. The spectacular growth of video, voice and data communication over the Internet, and the equally rapid pervasion of mobile telephony, justifies great expectations for mobile multimedia. Due to this growth of multimedia communication, the users demanded high date rate communication systems in wireless environment where the spectral resource is scarce. To fulfill the requirements new technologies like Code Division Multiple Access and Orthogonal Frequency Division Multiplexing (OFDM) are few promising systems for the 4G communication standards.

While present communication systems are primarily designed for one specific application, such as speech on a mobile telephone or high-rate data in a wireless local area network (WLAN), the next generation of WBMCS will integrate various functions and applications. Supporting such large data rates with sufficient robustness to radio channel impairments, requires careful selection of a transmission technique. One of the most promising techniques for achieving high data rate transmission in mobile environment is Multi-Carrier Code Division Multiple Access (MC-CDMA) technique. In this paper, besides the implementation of MC-CDMA system, we also focus on its performance in a variety of channels, such as additive white Gaussian noise (AWGN), the Rayleigh fading and the Rician fading channel.

The paper is organized as follows. Section II explains the principles of MC-CDMA, CDMA concepts and the concepts of OFDM. Section III explains the implementation of MCCDMA systems; section IV discusses the clipping noise effects; section V discusses the system performance of the three channel models. Section VI discusses about the simulation results and in section VII draws the conclusion.

2. PRINCIPLES OF MC-CDMA

The combination of OFDM-CDMA (MC-CDMA) [1] is a useful technique for 4g systems where we need variable data rates as well as provide reliable communication systems. A MC-CDMA system basically applies the OFDM type of transmission to a Direct Sequence (DS)-CDMA signal. In conventional DS-CDMA each user symbol is transmitted in the form of sequential chips each of which is narrow in time and hence wide in bandwidth. In contrast to this, in MC-CDMA due to the FFT transform along with OFDM, the chips are longer in time duration and hence narrow in bandwidth. The multiple chips for a data symbol are not sequential but instead transmitted in parallel over many sub-carriers. An interesting feature of MC-CDMA is that the modulation and demodulation can be easily implemented using simple FFT and IFFT operators.

2.1.Concepts of CDMA

Code Division Multiple Access (CDMA) is digital cellular technology that uses spread spectrum technique [3]. All the channels use the full available spectrum. Individual conversations are encoded with a pseudo-random digital sequence. In CDMA each user is assigned a unique code sequence. The receiver, knowing the code sequences of the user, decodes a received signal after reception and recovers the original data. This is possible since the cross correlations between the code of the desired user and the codes of the other users are small. Since the bandwidth of the code signal is chosen to be much larger than the bandwidth of the information-bearing signal, the encoding process spreads the spectrum of the signal. The spectral spreading of the transmitted signal gives CDMA its multiple access capability.

2.2.Concepts of OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier transmission technique [4], which divide the available spectrum into many carriers, each one being modulated by a low rate data stream. OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels, which are then allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another , preventing interference between the closely spaced carriers. Coded OFDM (COFDM) is analogous to OFDM expect that forward error correction is applied to the signal before transmission. This is to overcome errors in transmission due to the lost carriers from frequency selective fading, channel noise and other propagation effects.

3. IMPLEMENTATION OF MC-CDMA SYSTEM

In Multi-Carrier CDMA the signal is spread before being converted into a parallel data stream, which is then transmitted over multiple carriers. If the processing gain is equal to the number of carriers then this system modulates all the carriers with the same data bit, but with a phase shift on each carrier determined by the spreading code.

This multi-carrier modulation can also implemented using an inverse FFT. The block diagram of the MC-CDMA system is shown in the above Fig 1

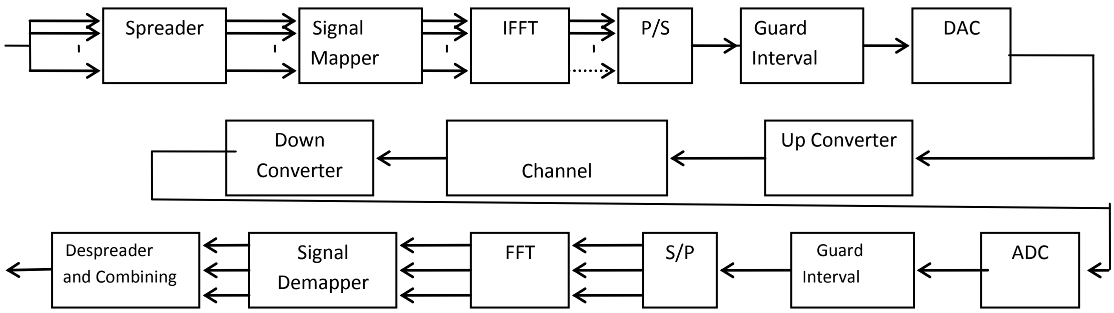


Fig 1. Block diagram of MC-CDMA transceiver.

The serial data stream is mapped to data symbols with phase and amplitude modulation scheme and the resulting symbol is divided into a vector of N data symbols resulting parallel data symbols. The IFFT of the data symbols are computed and cyclic prefix is introduced as a guard interval whose length should exceed the maximum excess delay of the multipath radio channel. Due to the cyclic prefix the transmitted signal becomes periodic and the effect of time dispersive multipath channel becomes equivalent to a cyclic convolution discarding the guard interval at the receiver. Due to the properties of the cyclic convolution, the channel is limited to the multiplication of the transfer function, the Fourier transform of the channel impulse response. At the receiver side the reverse operation of the transmitter has been performed. The guard period is removed and then FFT of each symbol has been determined to find the original transmitted spectrum. By using the code sequences used at the spreading block of transmitter has been used at the dispreading block of the receiver to obtain the original signal which was transmitted. The transmitted signal is given by

$$S(t) = \sum_{m=-\infty}^{\infty} \sum_{n=0}^{N-1} D_m C_n e^{j2\Pi(f_c+F/T_b)t} p(t-nT_s) \quad (1)$$

where

n represents the time index.

D_m represents the spreading code of the m^{th} user

T_s represents the symbol duration

C_m represents the transmitted data symbol of the n^{th} subchannel

p represents the no. of input symbol of one MCCDMA symbol for each user

In the MCCDMA receiver, after down conversion and removal of guard interval, the received data is converted in to a parallel symbol stream using a serial to parallel converter. Also the m-subcarrier component corresponding to the received data are detected with FFT and then multiplexed with the gain to combine the energy of the received signal scattered in the frequency domain. Finally after interleaving and dispreading the received data can be recovered. The received signal can be written as

$$r(t) = \rho_n \sum_{m=-\infty}^{\infty} \sum_{n=0}^{N-1} D_m C_n e^{j2\Pi(f_c + F/T_b)t} p(t - nT_s) \tag{2}$$

4. CLIPPING NOISE EFFECTS IN MC-CDMA

The OFDM uses High Power Amplifiers(HPA) which are usually non linear for achieving high efficiency. This amplifiers however does not have equal gain throughout the frequency range. This leads to clipping of few symbols and usually called as clipping noise [7]. This makes OFDM to suffer from spectral spreading and In-Band distortion. This clipping noise reduces spectral efficiency and BER performance. One of the solution is using Golay Sequences for small number of users and Walsh Hadamard sequences for high number of users [8].

The modeling of the clipping effect on the OFDM signal is shown in [8]for a distorting system with characteristics denoted as f(x). Let x(k) be the discrete OFDM signal in time domain which follows the complex Normal distribution with equal variance Px/2.. When this signal is passed through a clipping amplifier, the resultant will be of two components. One component will the signal itself and the other is the distorted component. This can be easily verified by the Bussgang Theorem and shown in[8].

$$X_{clip}(k) = \alpha X(k) + n_d(k) \tag{3}$$

Alpha depends on the P_x and *f(x)*. The clipped signal is

$$X_{clip}(k) = \{X(k)\} when \mid X(k) < A \mid \tag{4}$$

$$X_{clip}(k) = A^{\arg(X(k))} when \mid X(k) \geq A \mid \tag{5}$$

The Input power BackOff (IBO) for such systems is given by

$$IBO = \frac{A^2}{P_x} \tag{6}$$

This IBO is given usually in decibels and variation of the IBO changes the performance analysis in terms of BER .

5. SYSTEM PERFORMANCE

To analyze the system performance, we consider three channel models, such as AWGN, Rayleigh fading and Rician fading channel.

AWGN channel

This channel is assumed to corrupt the signal by the addition of white Gaussian noise n(t) which denotes a sample function of the additive white Gaussian noise (AWGN) process [3] with zero mean and two sided power spectral density.

$$\Phi_n(f) = 0.5\, N_0 \text{ W/Hz.} \tag{7}$$

Rayleigh fading channel

Depending on the surrounding environment, a transmitted radio signal usually, propagates through several different paths before it reaches the receiver. If there is no line-of-sight between the transmitter and the receiver the attenuation coefficients corresponding to different paths are often assumed to be independent and identically distributed in which path gain has uniformely distributed phase and Rayleigh distributed magnitude [6]. In this channel, the transfer function assumed for the m^{th} user can be represented as

$$H_m(f_c + F/T_b) = \rho_{m,i} e^{j\theta_{m,i}} \tag{8}$$

where

$\rho_{m,i}$ and $\theta_{m,i}$ represents the random magnitude and phase of the channel of the user at the frequency f_c.

The random magnitude is assumed to be independent and identically distributed (iid) Rayleigh random variables in the interval for all users and subcarriers where the Rayleigh distribution is

$$f(\rho_{m,i}) = \frac{\rho_{m,i}}{\sigma_{m,i}^2} e^{\frac{-\rho_{m,i}^2}{2\sigma_{m,i}^2}} \tag{9}$$

Rician fading channel

The model behind the Rician fading is same as Rayleigh fading except that in Rician fading a strong dominant component is present. This dominant component can be for instance LOS.

Refined Rician models also consider

- That the dominant wave can be a phasor sum of two or more dominant signals, e.g. the line-of-sight, plus ground reflection. This combined signal is then mostly treated as a deterministic process.
- That the dominant wave can also be subject to shadow attenuation. This is a popular assumption in the modeling of satellite channels.

Besides the dominant component, the mobile antenna receives a large number of reflected and scattered waves.as there is line of sight component , the maganitude factor $\rho_{m,i}$ for i = 0,1,2…N-1 assume to have the following Rician distribution which is given by

$$f(\rho_{m,i}) = \frac{\rho_{m,i}}{\sigma^2_{m,i}} e^{\frac{\rho^2_{m,i}+b_0^2}{2\sigma^2_{m,i}}} I_0\left(\frac{b_0\rho_{m,i}}{\sigma^2_{m,i}}\right) \qquad (10)$$

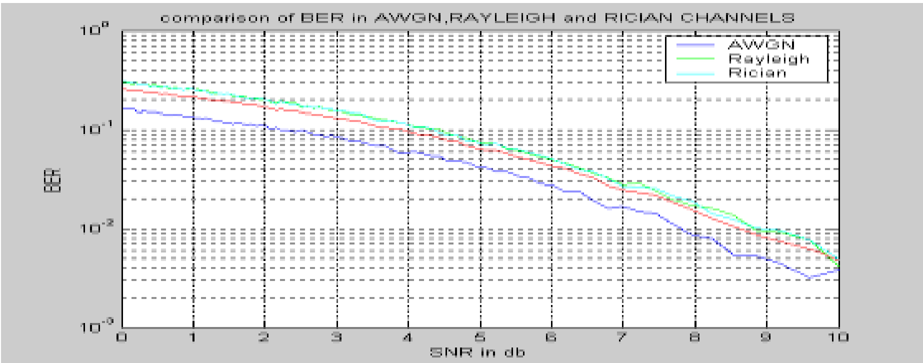
where b is the line of sight component and I_0 is the ordered modified Bessel function which is given by

$$I_0(x) = \frac{\sum_{k=0}^{\infty}(x/2)^{2k}}{k\iota\Gamma(k+1)} \quad \text{for } x \geq 0 \qquad (11)$$

6. SIMULATION RESULTS

The simulation is done using MATLAB for the performance of the multicarrier code division multiple access system in a variety of channels, such as AWGN, Rayleigh fading and Rician fading channel, as a function of signal-to-noise ratio (SNR = T_b/N_0). Assuming that each interference signal has a local-mean power equal to the local-mean power of the desired signal and then the number of sub-carriers (N=128) and number of users (M=32) are fixed. Here, the BER of AWGN channel only depends on SNR, and outperforms other channels.

In Rician fading channel, the performance is improved, as the K-factor is increased. This is because K-factor means the power of the LOS component. When K-factor is zero, the performance of Rician fading channel is same as that of Rayleigh fading channel due to absence of LOS path.



7. CONCLUSION

In this paper, we summarize multiple access technique based on a combination of Code Division Multiple Access (CDMA) and multi-carrier modulation (OFDM), and then discuss MC-CDMA. In MC-CDMA, a data symbol is converted into M parallel branches and the bits on each branch are transmitted on orthogonal carriers. This system can easily transmit and receive signals using the Fast Fourier Transform (FFT) and solves the Inter Carrier Interference (ICI) problem.

The performance of this system under clipping noise in AWGN, Rayleigh fading and Rician fading channel is analyzed . By simulation result, BER in AWGN channel outperforms other channels as SNR is increased. The performance of Rician fading channel is better than that of Rayleigh fading channel, because of the LOS path. BER depends on the number of users and sub-carriers in Rayleigh fading and Rician fading channel. The performance is degraded by the number of users and improved by number of sub-carriers.

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