Multicarrier CDMA with OFDM as Data Enhancement Technique and BER Analysis

P.R. Srilakshmi and B.A. Sapna

Abstract--- *To achieve high data rate Multi-Carrier Code Division Multiple Access (MC-CDMA) is a suitable choice for next generation wireless communication system. MCCDMA is the combination of CDMA and OFDM schemes along with receiver diversity including cyclic prefix and zero padding, resulting into getting the advantages of all of these schemes. Capacity improvement is one of the major issues in designing of wireless communication system. In wireless communication system capacity planning greatly depends on performance criteria called bit error rate (BER). This study investigates the BER performance of MCCDMA system over Rayleigh fading channel for different length of spreading code such as OVSF code. Various performance enhancements are done by using receiver diversity and rate matching is done using OVSF and cyclic prefix for N-point IFFT based OFDM implementation. Diversity used in the receiver is EGC (Equal gain Combining) and MRC (maximal ratio combining). Performance Analysis of the OFDM-CDMA for different spreading code length is carried out.* E_b/N_o *Vs BER plot for 64 point FFT based OFDM is also plotted for noise model like Rayleigh fading etc.*

Index Terms--- *MC-CDMA, CDMA, OFDM, OVSF Code, Cyclic Prefix, Zero Padding, Receiver Diversity (MRC), BER*

I. Introduction

IMPLEMENTATION of MC-CDMA system with W-H codes and OFDM transmission technology for enhanced data rate of 2mbps and reduction in multiple access interference receiver diversity can be implemented to reduce fading effect and provide better data rate. Wireless communication is the fastest growing segment of the communications industry. As such, it has captured the attention of the media and the imagination of the public. The first wireless networks were developed in the pre-industrial age. These systems transmitted information over line- of-sight distances using smoke signals, torch signaling, flashing mirrors etc. Early radio systems transmitted analog signals. Today most radio systems transmit digital signals composed of binary bits, where the bits are directly obtained from a data signal or by digitizing an analog signal.

Wireless communication networks have become much more important than any one when cellular concept was first developed. The rapid growth in cellular telephone subscribers indicates that wireless communication is a robust, viable noise and data transport mechanism.

In single carrier CDMA system, it deals with the assignment of multiple users to a shared communication source. In this system multiple access among users is made possible by assigning different users, different sets of non-overlapping Fourier coefficients. This is achieved at the transmitter by inserting (IFFT) silent Fourier coefficients and removing them on the receiver side after the FFT. Multicarrier modulation is implemented digitally. ISI may be completely removed by MC-CDMA with OFDM transmission scheme. Cyclic prefixing (CP) is employed in order to mitigate the effects of the loss of orthogonality caused by amplitude and phase distortion introduced by the transmission channel. Although the CP is an elegant and easy solution, it leads to a loss of inefficiency in the data throughput. This gives us a reason to introduce other multicarrier modulation techniques such as FMT that do not need the use of the CP. MC-CDMA is the combination of CDMA and OFDM, therefore we can get the advantages of both the schemes. In MC-CDMA scheme each data symbol is spreaded in frequency domain and transmitted on different subcarrier which is helpful in eliminating frequency selective fading and show significant improvement in BER performance. MC-CDMA is a well developing promising technique for next generation wireless communication system. Orthogonal Variable Spreading code Factor (OVSF) is an implementation of code division multiple access where before each signal is transmitted, the signal is spread, over a wide spectrum range through the use of a users code. These codes are derived from an OVSF code tree, and each user is given a different, unique code. An OVSF code tree is a complete binary tree that reflects the construction of Hadamard matrices.

In MC-CDMA, Orthogonal Variable Spreading factor codes can be used to allow multi rate communication while maintaining the orthogonality among the users with different data rate. Channel used is based on Rayleigh function. Rayleigh distribution is a continuous probability distribution. The Rayleigh Probability density function is

$$f\left(\frac{x}{\sigma}\right) = \frac{x \exp\left(\frac{-x^2}{2\sigma^2}\right)}{\sigma^2}$$

II. Proposed System Model

A. Transmitter Model

Simulation model of MC-CDMA Transmitter is shown in fig1. It consist of a modulator, CDMA Spreading using OVSF(Orthogonal Variable Spreading code Factor) codes,

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serial to parallel convertor, cyclic prefix and Zero padding, IFFT block etc. QPSK modulation is undergoing and the modulated signal is spreaded using OVSF Code which is based on OVSF code tree and is developed by using a recursive algorithm. A serial to parallel conversion is undergone and this parallel data is provided with cyclic prefix and Zero padding in order to prevent the loss of data. Inverse FFT is implemented to convert data from frequency domain to time domain .since channel used is time dependent These parallel subcarriers are orthogonal to each other and can be generated by using Inverse Fast Fourier transform (IFFT). After this cyclic prefix is used as a guard interval to minimize the effect of inter carrier interference (ICI). Now parallel to serial converter (P/S) converts parallel data into serial data stream and transmit over channel.

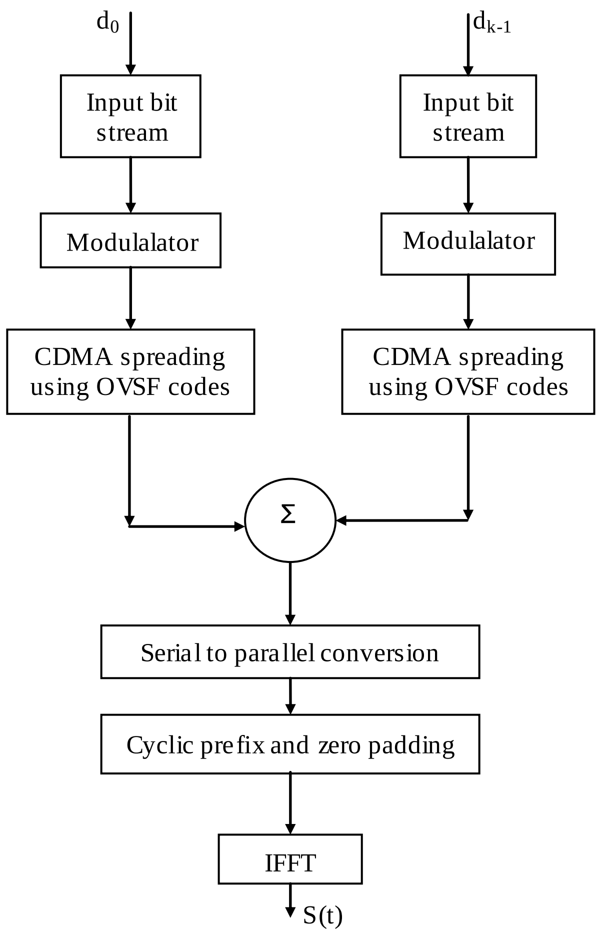

Fig.1: MC-CDMA Transmitter Model

B. Receiver Model

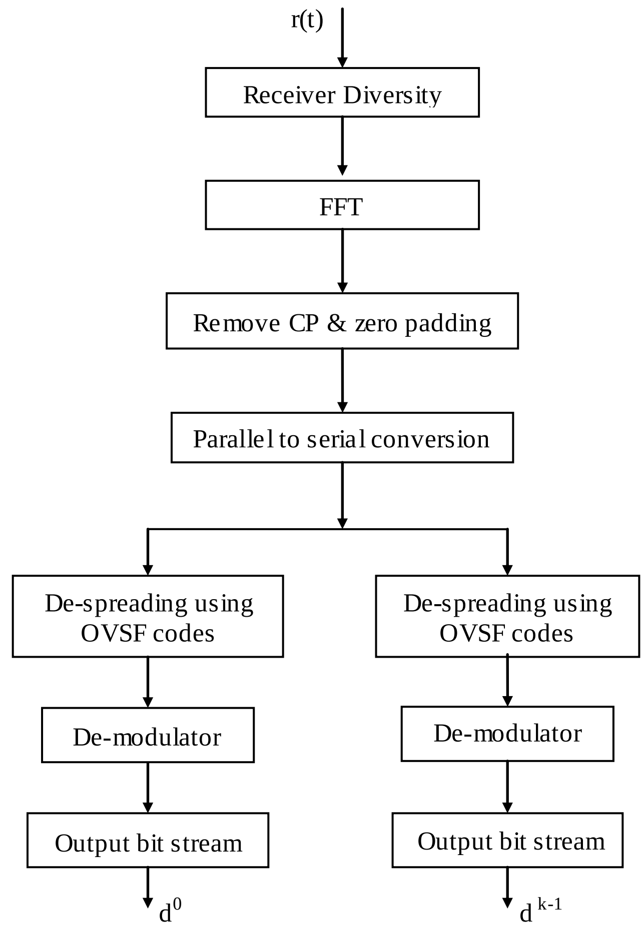

Fig.2: MC-CDMA Transmitter Model

Block diagram for Receiver Model of MC-CDMA is shown in the fig.2. The received signal is given by

$$r(t)=\sum_{i=-\infty}^{+\infty} \sum_{k=1}^{k} \sqrt{2P_k} \sum_{n=1}^{N_c} \beta_{k,n}(t) d_k(i) P_{T_b}(t - iT_b) a_k(n) \cos(w_n t + \theta_{k,n}) + \eta(t)$$

Where η *(t)* is the Additive White Gaussian Noise (AWGN) with psd of $N_0/2$ and α_{kn} is the channel phase . At receiver, convert serial data into parallel by serial to parallel converter (S/P) then remove the cyclic prefix and zero padding and take the Fast Fourier Transform (FFT) of received signal. After that dispread and demodulate the users signal. The output of demodulator passes through a channel decoder. To reduce ISI, MC-CDMA system has introduced where it divide bit streams into many sub streams and pass through sub channel to reduce ISI.

The multicarrier CDMA scheme is categorized mainly in to two groups. One spreads the original data stream using the given spreading code and then modulates a different subcarrier with each chip (that is, spreading operation in frequency domain) and other spreads the serial to parallel converted data streams using a given spreading code such as OVSF code and then modulates a different subcarrier with each of a data stream.

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Fig.2 consist of a Receiver diversity ,Fast Fourier Transform(FFT),removal of cyclic prefix (CP), parallel to serial convertor, CDMA de-spreading using OVSF code, de-interleaver, de-modulator. Diversity techniques that mitigate the effect of multipath fading are called micro diversity. Diversity to mitigate the effect of shadowing from buildings and objects is called macro diversity. Macro diversity is generally implemented by combining signals received by several base stations or access points. This requires coordination among the different base stations or access points. Such coordination is implemented as a part of the networking protocols in infrastructure based wireless networks.

There are many ways of achieving independent fading paths in a wireless system. One method to use multiple transmit or receive antennas, also called as antenna array, where the elements of the array are separated in distance. This type of diversity is referred as space diversity. The kind of receiver diversity used here is maximal ratio combining and equal gain combining. MRC requires knowledge of the time varying SNR on each branch, which can be very difficult to measure. A simpler technique is equal gain combining, which co-phases the signals on each branch and then combines them with equal weighting ,$\alpha_i=e^{-\theta i}$. The SNR of the combiner output, assuming equal noise PSD N_0 in each branch, is given by

$$\gamma\sum=1/N_0M\,(\sum_i r_i)^2$$

Also the channel model used in the proposed system is Rayleigh fading channel. The simplest probabilistic model for the channel filter taps is based on the assumption that there are a large number of statistically independent reflected and scattered paths with random amplitudes in the delay window corresponding to a single tap. The phase of the i^{th} path is $2\pi f_c t$ modulo2π.

The channel impulse parameter is exponentially distributed with density

$$1/\sigma_i^2 \exp\{-x/\ \sigma_i^2\},\ x\geq 0$$

This model, which is called Rayleigh fading channel, is quite reasonable for scattering mechanisms where there are many reflectors, but is adopted primarily for its simplicity in typical cellular situations with a relatively small number of reflectors. The word Rayleigh is almost universally used for this model, but the assumption is that the tap gains are circularly symmetric complex Gaussian random variables.

III. Spreading Code for Rate Matching

Spreading will convert narrowband signal to a wideband signal to suppress the self interference by multipath effect. Various types of spreading codes are studied, they are Walsh-Hadamard (W-H) code, Pseudo Noise (PN) spreading code, Gold code, Golay code are used to spread the user data. These codes can be distinguished each other from their correlation properties, orthogonality property and peak average to power ratio (PAPR).

Since W-H code is orthogonal code its performance is good among the above said spreading code. To minimize the MAI each users spreading code should be orthogonal. In synchronous downlink for MAI reduction W-H code can be used. In uplink PN code is used as spreading code because due to distortion spreading codes orthogonality gets lost. Also PN sequences are provided in FHSS system. In view of correlation property Gold code is suitable option than any other codes for asynchronous transmission. W-H code and Gold code can be used in WCDMA standard. Orthogonal Variable spreading code Factor (OVSF) codes have better orthogonality than W-H codes. This OVSF codes are based on OVSF code tree which in turn depend on a recursive algorithm.

In the data channelization technology, orthogonal variable spreading factor (OVSF) code can distinguish the different data tunnels and promise the orthogonality for different customer tunnels. This results in a major drawback of OVSF codes, called blocking property as in fig 4. It may have significant impact on the bandwidth utilization of systems. Different data through put are made available to same user by allocating different OVSF code under the same code tree. This is the basic rate matching principle. This process may be implemented using OVSF code tree. Different user provided with different OVSF code.

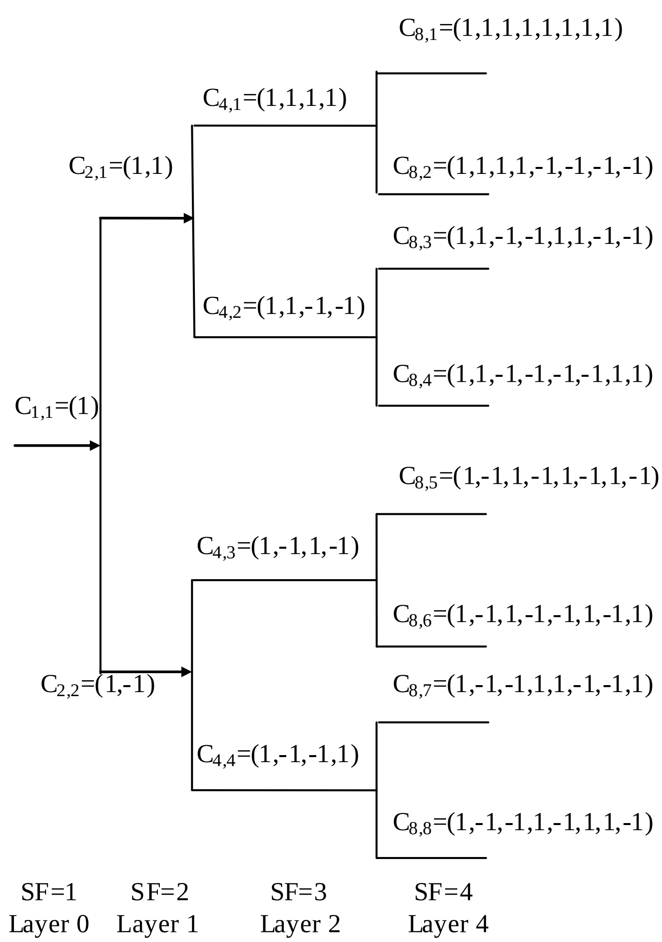

Fig 3: code tree representation for OVSF code

Recursive algorithm:

$C_1(0) = 1$

$$C_N(i) = \{ C_{2N}(2i-1) = (C_N(i), C_N(i))$$
$$C_{2N}(2i) = (C_N(i), -C_N(i))$$

Fig :3 illustrates a family of channelization codes ranging from a spreading factor of 1(on the left hand side) to a spreading factor of 8(on right hand side).This family of channelization codes is referred to as the OVSF code tree. The creation of OVSF code tree can be defined with the following simple recursive algorithm. From fig: 3, we start at the bottom of the tree with a value of 1. This corresponds to a channelization code with a spreading factor of 1(not spread).

To move to the code of length 2 chip, we create two new branches on the tree. The algorithm for deciding the codes for these new branches can be summarized as follows:

1. Moving up a branch repeat the parent node sequence twice.
2. Moving down a branch repeat the parent node sequence twice, but inverting the second sequence.

From this we end up with two codes of length 2.By recursively applying this algorithm we can build four codes of length 4 and then codes of length 8.

IV. SIMULATION RESULTS

Proposed design of MC-CDMA transmitter and receiver as described in section II has been simulated using MATLAB Version 7.10 R2010a. It shows results for MC-CDMA with OFDM along with receiver diversity, different types of receiver diversity are tried in the system. Results shows that MC-CDMA with maximal ratio combining will provide better results than Equal gain combining.MC-CDMA with spreading code as both W-H codes and OVSF codes are tried. Results shows that MC-CDMA with receiver diversity and OVSF code provide better results. Fig 9 shows Rate matching using OVSF codes. Bandwidth used is 3.84MHz and variable data rate of 480kbps and 960kbps is tried and plotted.

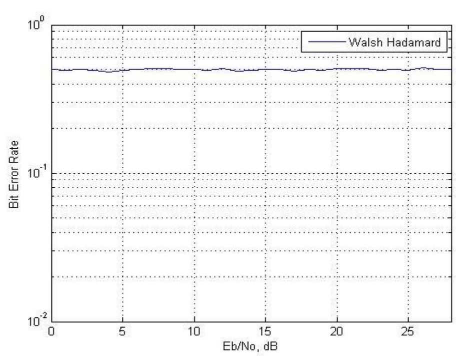

Fig 4: MC-CDMA with OFDM without Receiver Diversity

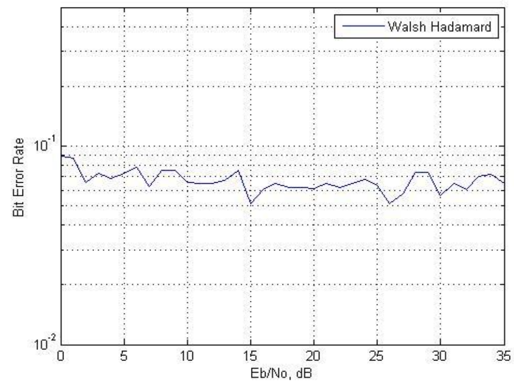

Fig 5: MC-CDMA with OFDM and receiver diversity as maximal ratio combining with BPSK modulation

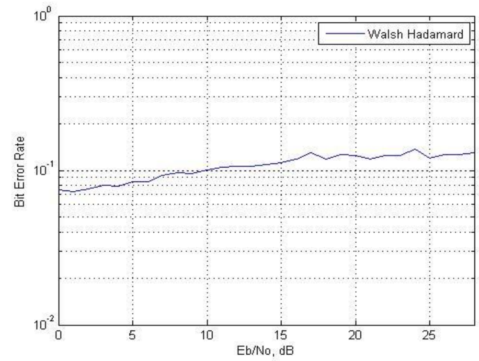

Fig 6: MC-CDMA with OFDM and receiver diversity as equal gain combining with BPSK modulation

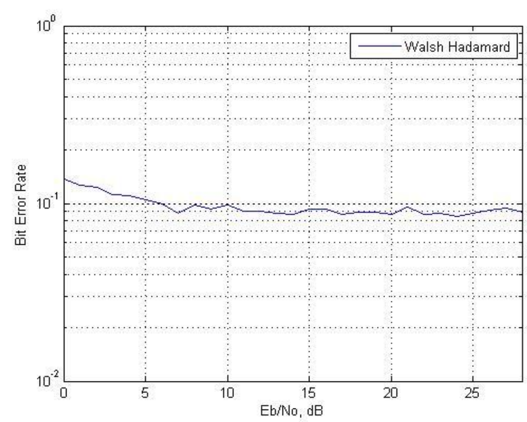

Fig 7: MC-CDMA with OFDM and receiver diversity as maximal ratio combining with QPSK modulation.

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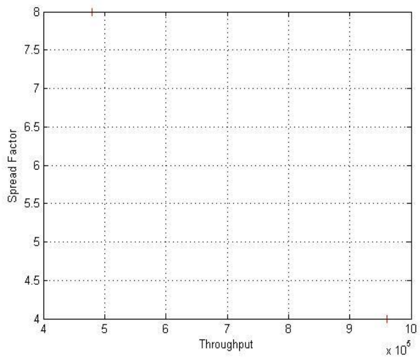

Fig 8: Rate Matching using OVSF Codes

V. DISCUSSION AND CONCLUSION

The performance of the MC-CDMA system with OFDM is analyzed. The system includes receiver diversity technique which mitigates the effect of fading thus improving the BER performance. A comparison study of BER performance analysis for different receiver diversity and modulation techniques is done. System replaces W-H codes with OVSF code. Performance analysis will be better for system with receiver diversity and OVSF code.

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