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Performance Analysis of BER Improvement for Multi Carrier CDMA System

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Abstract*— Multi-carrier code division multiple access is an attractive choice for high speed wireless communication as it mitigates the problem of inter symbol interference and also exploits frequency diversity. In order to support multiple users with high speed data communications, the MC-CDMA technique is used to address these challenges. The work in this paper derives simulation result through MATLAB code of average bit error rate versus bit energy to noise ratio of Multicarrier Code Division Multiple Access systems using various pilot symbol estimation and detection techniques which are used for both uplink & downlink MC-CDMA systems i.e. MRC and MMSE. We simulate different equalization technique used in communication and compare the result and on the basis of that we will conclude that which technique will be best suited for future generation wireless communication. All the simulation is carried out on MATLAB tool.

***Index Terms*— BER, Eb/No, MCCDMA, MMSE, MRC.**

I. INTRODUCTION

Wireless communication is generally considered to be a branch of telecommunications. It encompasses various types of fixed, mobile, and portable two-way radios, cellular telephones, personal digital assistants, and wireless networking. MC-CDMA is a combination of OFDM and code division techniques [10, 12]. Several techniques have been proposed. The three most popular proposals are multicarrier MC- CDMA, multicarrier modulation with direct sequence DS- CDMA, and multi-tone MT-CDMA [6-9]. In this thesis, we concentrate on MC-CDMA, a novel digital modulation and multi access scheme and a very promising technique for 4th generation cellular mobile radio systems. MC-CDMA allows high-capacity networks and robustness in frequency selective channels.

MC-CDMA: The combination of multicarrier transmission and CDMA can be achieved in different ways. Consequently, the multiplexing CDMA designs fall in two categories: First one is Frequency Domain Spreading in which MC-CDMA combines the multicarrier transmission with the frequency domain spreading, i.e., the original data stream from a user is spread with this user's specific spreading code in the frequency domain but not in the time domain. In other words, each symbol is transmitted simultaneously in a number of subcarriers, but multiplied by corresponding chips of the spreading code for every subcarrier . Another one is Time Domain Spreading termed as MC -DS-CDMA scheme which spreads the original user data stream in the time domain. The user data stream is first serial to parallel converted into N_c (the number of sub carriers) sub streams, each of which is time-spread and transmitted in an individual sub carrier. In other words, a block of N_c symbols are transmitted simultaneously. The value of N_c can be chosen according to the system design requirement. However, it is commonly assumed to be equal to the length of spreading code N which will also make the comparison with MC-CDMA easier .All the symbols are spread in the time domain using the same spreading code for a particular user. It is clear that this scheme achieves time domain diversity but no frequency domain diversity for each individual data symbols [1]. The sub carriers satisfy the same orthogonally condition as that of MC-CDMA. This scheme is suitable for uplink transmission since it is easy for the establishment of quasi-synchronization between different users.

II. CHANNEL ESTIMATION TECHNIQUE

Channel estimation in wired systems is straightforward, channel is estimated at startup, and since channel remains the same, therefore no need to estimate it continuously. Hence, in this thesis, we concentrate on channel estimation, regarding wireless MC-CDMA systems only. There are mainly two problems in the design of channel estimators for the wireless systems [3, 5]. The first problem is concerned with the choice of how the pilot information should be transmitted. Pilot symbols along with the data symbols can be transmitted in a number of ways, and different patterns yields different performances. The second problem is the design of an interpolation filter with both low complexity and good performance. These two problems are interconnected, since the performance of the interpolator depends on how pilot information is transmitted.

III. PILOT SYMBOL ASSISTED MODULATION

Channel estimation usually needs some kind of pilot information as a point of reference. Channel estimates are often achieved by multiplexing known symbols, so called, pilot symbols into the data sequence, and this technique is called Pilot Symbol Assisted Modulation (PSAM). This method relies upon the insertion of known phasors into the stream of useful information symbols for the purpose of channel sounding. These pilot symbols allow the receiver to extract channel attenuations and phase rotation estimates for each received symbol, facilitating the compensation of fading envelope and phase. A fading channel requires constant tracking, so pilot information has to be transmitted more or less continuously. Decision directed channel estimation can also be used, but even in these types of schemes pilot information has to be transmitted regularly to mitigate error propagation. Pilot symbols are transmitted at certain

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locations of the OFDM frequency time lattice, instead of data, and in it was addressed how you choose those locations.

IV. BLOCK-TYPE PILOT CHANNEL ESTIMATION

For block type arrangements, channel at pilot tones can be estimated by using MMSE estimation, and assumes that channel remains the same for the entire block. So in block type estimation, we first estimate the channel, and then use the same estimates within the entire block. MMSE estimation has been shown to yield 10-12dB gain in signal to noise ratio (SNR) over other estimation for the same mean square error of channel estimation. A low rank approximation is applied to linear MMSE by using the frequency correlations of the channel to eliminate the major drawback of MMSE, namely complexity.

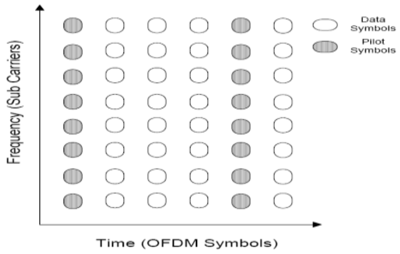

Fig. 1 Block Pilot Patterns

For the case of block-type pilot channel estimation

$$\hat{h}_{mmse} = R_{hh}\,(R_{hh} + \sigma_n^2 (pp^H)^{-1})^{-1}\hat{p}$$

In the following, we assume, without loss of generality, that the variances of the channel attenuations in h are normalized to unity, i.e. E $\{|h_k|^2\} = 1$. The MMSE estimator defined in Equation is of considerable complexity, since a matrix inversion is needed every time the training data in p changes. The complexity of this estimator can be reduced by averaging over the transmitted data i.e., we replace the term $(pp^H)^{-1}$ in Equation with its expectation $E\{(pp^H)^{-1}\}$. Assuming the same signal constellation on all tones and equal probability on all constellation points, We have $E\{(pp^H)^{-1}\} = E\{|\ 1\ /\ pk\ |^2\}I$, where I is the identity matrix. Defining the average signal-to-noise ratio as

$$SNR = E\,\{|p_k|^2\}/\sigma_n^2$$

We obtain a simplified estimator,

$$\hat{h}_{mmse} = R_{hh}\,(R_{hh} + (\beta/SNR)I)^{-1}\hat{p}$$

Where,

$$\beta = E\,\{|p_k|^2\}\ E\,\{|1/p_k|^2\}$$

is a constant depending on the signal constellation.

V. COMB-TYPE PILOT CHANNEL ESTIMATION

Comb type pilot tone estimation, has been introduced to satisfy the need for equalizing when the channel changes even in one OFDM block. The comb-type pilot channel estimation consists of algorithms to estimate the channel at pilot frequencies and to interpolate the channel. In comb-type channel estimation, which is also called pilot symbol aided channel estimation, we periodically insert pilot tones in the OFDM blocks and transmit them along with the data. Since we know the frequency response of the channel at the pilot inserted sub-carriers, we can obtain the whole channel frequency response by using an interpolation method.

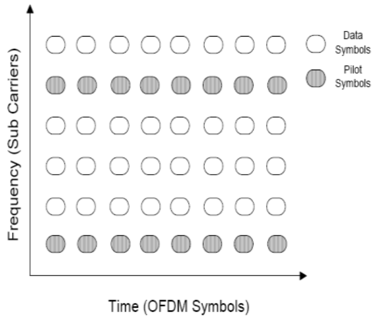

Fig. 2 Comb Pilot Patterns

If h_i is a Rayleigh distributed random variable, then h_i^2 is a chi-squared random variable with two degrees of freedom. The pdf of γ_i is

$$P(\gamma_i) = [1/(E_b/N_o)]e^{-\gamma_i/(E_b/N_o)}$$

Since the effective bit energy to noise ratio γ is the sum of N such random variables, the pdf of γ is a chi-square random variable with 2N degrees of freedom. BER computation in AWGN, with bit energy to noise ratio of E_b/N_o the bit error rate for BPSK in AWGN is derived as

$$P_b = \frac{1}{2}\,erfc(\sqrt{E_b/N_o})$$

Given that the effective bit energy to noise ratio with maximal ratio combining is γ, the total bit error rate is the integral of the conditional BER and given as

$$P_e = \int_0^{\infty} \frac{1}{2}\,\mathrm{erfc}(\sqrt{\gamma})\,p(\gamma)\,d\gamma =$$

$$\int_0^{\infty} \frac{1}{2}\,\mathrm{erfc}(\sqrt{\gamma})\,\frac{1}{(N-1)!\,(E_b/N_o)^N}\,\gamma^{N-1}e^{\frac{-\gamma}{(E_b/N_o)}}\,d\gamma.$$

This equation reduces to

$$P_e = p^N \sum_{k=0}^{N-1} (N-1+k)(1-p)^k$$

Where,

$$p = \frac{1}{2} - \frac{1}{2}\left(1 + \frac{1}{E_b/N_o}\right)^{-1/2}$$

A. SIMULATION AND RESULT

Bit error rate with Eb/No simulation of MMSE equalization technique of Block-type Pilot Channel Estimation is generated in Fig. 3

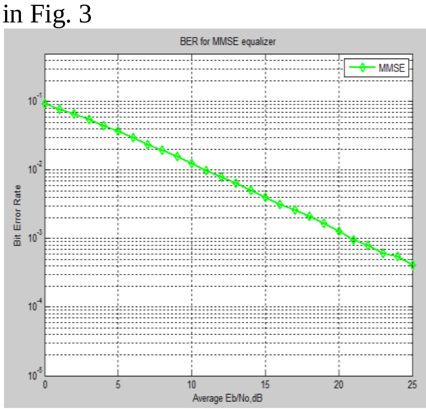

Fig. 3 MMSE Bit Error Rate

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Bit error rate with Eb/No simulation of MRC equalization technique of Comb-type Pilot Channel Estimation is generated in Fig. 4 which shows that simulated output is better than calculated output

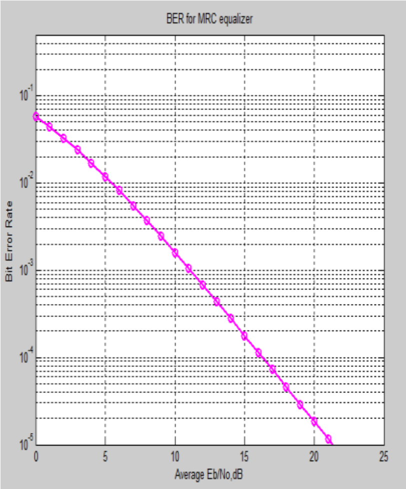

Fig. 4 MRC Bit Error Rate

Comparison of BER for BPSK Modulation with MMSE and MRC Equalizer for Rayleigh Channel using MATLAB code is simulated and output of the simulation is shown in Fig .5

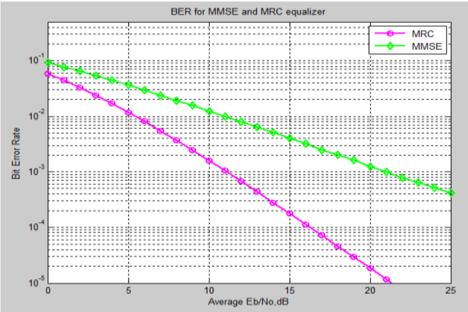

Fig. 5 BER for MMSE and MRC Equalizer

On Comparison it can be seen that the **Minimum Mean Square Error** equalizer results in around 3dB of improvement. The results show that the comb-type estimation schemes outperform block-type schemes, which is because the channel changes so fast that there are even changes for adjacent symbols.

VI. CONCLUSION

After analyzing the result from the simulated plots we concluded the comb-type estimation schemes outperform block-type schemes, as MRC equalization technique is 3dB better than MMSE equalization technique which is because the channel changes so fast that there are even changes for adjacent symbols.

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