BER Performance in MIMO-OFDM System using Variation in CP through the M-QAM Modulation Technique

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Abstract- *Because of the rapid growth of digital communication in recent years, high data rate modulation scheme is one of the important criteria besides good error coding. However, the implementation of high data rate modulation techniques that have good bandwidth efficiency in W-CDMA cellular communication requires perfect modulators, demodulators, filter and transmission path that are difficult to achieve in mobile environment, due to its resistance to ISI. Modulation schemes which are capable of delivering more bits per symbol are more immune to errors caused by noise and interference in the channel. Moreover, errors can be easily produced as the number of users is increased and the mobile terminal is subjected to mobility. A multiple-input multiple-output (MIMO) communication System combined with the Quadrature Amplitude modulation (QAM) and orthogonal frequency division multiplexing (OFDM) modulation technique can achieve reliable high data rate transmission over broadband wireless channels .The performance analysis of these modulation schemes are carried out in terms of Bit Error Rate (BER) versus Signal to Noise Ratio (SNR) in AWGN and Multipath Rayleigh Fading channel .The transmission of signal from base station to mobile station using M-ary Quadrature Amplitude modulation (QAM) modulation scheme is consider in WCDMA system. In this paper, the channel estimation & BER performance of a MIMO-OFDM are evaluated on the basis of error reduction and better system designing using popular IFFT/FFT & 16-QAM modulation formats. The final performance of the system with different parameters is tested by using MATLAB code word.*

Keywords- BER, IFFT/FFT, MIMO-OFDM, M-QAM, SNR

I. INTRODUCTION

Orthogonal frequency-division multiplexing (OFDM) is a well known method for high-data-rate wireless transmission. OFDM may be combined with multiple antennas at both the access point and mobile terminal to increase diversity gain and enhance system capacity on a time-varying multipath fading channel, resulting in a multiple-input multiple-output OFDM system. It converts a frequency-selective channel into a parallel collection of frequency flat sub channels, which makes the receiver simple [1]. Multiple antennas can be used at the transmitter and receiver, now widely termed as a MIMO system[2].

Recently OFDM was selected as the high performance local area network transmission technique. A method to reduce the ISI is to increase the number of subcarriers by reducing the bandwidth of each sub channel while keeping the total bandwidth constant [3]. The ISI can instead be eliminated by adding a guard interval at the cost of power loss and bandwidth expansion [4]. These OFDM systems have been employed in military applications since 1967’s, [5,6]. Simplified model implementations were studied by Peled [7] in 1980.Most recent advances in OFDM transmission were presented in the impressive state of art collection of works edited by Fazel and Fettweis [8]. Recent research efforts have focused on solving a set of inherent difficulties regarding OFDM, namely peak-to-mean power ratio, time and frequency synchronization, and on mitigating the effects of the frequency selective fading channels. The main objective of this paper is to present an analysis for channel estimation & BER estimation against different challenges of wireless communication system and avoid Inter Symbol Interference (ISI) & Inter Carrier Interference (ICI). It also minimize transmission power required (translates to SNR), and minimize bandwidth (frequency spectrum) used. MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP Long Term Evolution, WiMAX and HSPA+ [9].

II. MIMO

The high growth and demand of Multimedia application services and growth of contents of wireless application lead to increasing interest to high speed communication. Multiple input and multi output (MIMO) system are today considered as one of most important research area of wireless communication. In the case of MIMO system capacity increase and BER reduces. Channel capacity is defined as the maximum rate at which data can be transmitted with small error probability [10].

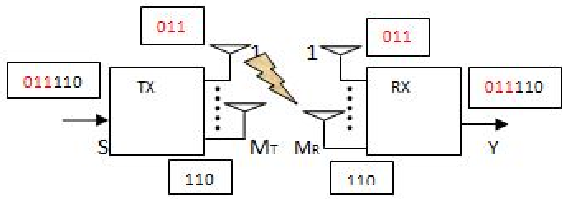

Fig. 1: Block diagram of a MIMO system.

From the above diagram MIMO systems use multiple antennas in the transmitter and receiver sides. The signals are sent by transmitter antennas are received by the receiver antennas and then combined, in order to achieve a reduction of error or a increasing of capacity of the system. Mathematically, if a signal Sj(t) is transmitted from the j_{th} transmitted antenna, the signal receive at the i_{th} receive antenna. The input output relation is given by,

$$y_i(t) = \sum_{j=1}^{M_T} h_{i,j}\, S_j(t), i=1,2,\ldots\ldots M_R \quad (1)$$

Here we take MT transmit and MR receive antennas with input data stream is S and output data stream is Y. MIMO has higher capacity as compare to other system. The MIMO capacity is given by,

$$C = M_t M_r B \log_2(1 + S/N) \quad (2)$$

Where C is known as capacity, B is known as bandwidth, S/N is known as signal to noise ratio. MT is the number of antennas used at the transmitter side & MR is the number of antennas used at receiver side.

III. OFDM

OFDM (Orthogonal Frequency Division Multiplexing) is becoming a very popular multi-carrier modulation technique for transmission of signals over wireless channels. OFDM divides the high-rate stream into parallel lower rate data (N number) and hence prolongs the symbol duration, thus helping to eliminate Inter Symbol Interference (ISI). It also allows the bandwidth of subcarriers to overlap without Inter Carrier Interference (ICI) as long as the modulated carriers areorthogonal. OFDM therefore is considered as an efficient modulation technique for broadband access in a very dispersive environment. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL Internet access, wireless networks,power-line networks, and 4G mobile communications [11].

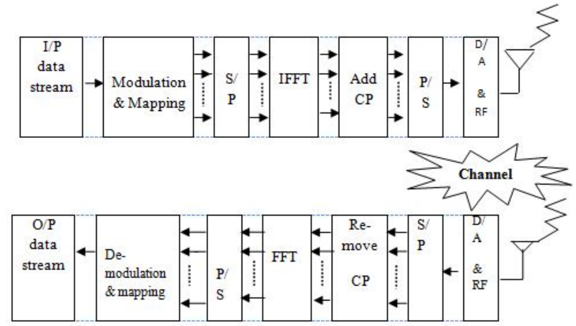

Fig. 2: Block diagram of an OFDM system.

1. First main component of OFDM is FFT/ IFFT witch modulates a block of input QAM values onto a number of subcarriers. In the receiver, subcarriers are demodulated by FFT, which perform reverse operation of IFFT. In practice, IFFT can be made by using FFT. Therefore same hardware will be used for the both which reduces the complexity of communication system.
2. Second important feature of OFDM system is coding and interleaving. Some successive subcarriers in the OFDM system may suffer from deep fading, in which the received SNR is below the required SNR level. In order to deal with the burst symbol errors, it may be essential to use of FEC (Forward Error Correction) codes. The FEC codes can make error corrections only as far as the errors are within the error-Correcting capability, but they may fail with burst symbol errors. Due to this code average errors convert into random errors, for which interleaving techniques are used.
3. The third key principle is the introduction of a cyclic prefix and zero padding as a Guard Interval to reduce interference between the symbols [12].

IV. COMBATING ISI WITH GUARD PERIOD

A. ISI

To optimize the performance of an OFDM link, time and frequency synchronization between the transmitter and receiver is of absolute importance. This is achieved by using known pilot tones embedded in the OFDM signal or attach fine frequency timing tracking algorithms within the OFDM signal's cyclic extension (guard Period/ Interval). To prevent ISI, the individual blocks are separated by guard intervals wherein the blocks are periodically extended. In addition, once the incoming signal is split into the respective transmission sub-carriers, a guard interval is added between each symbol. Each symbol consists of useful symbol duration, Ts and a guard interval, Δt, in which, part of the time, and a signal of Ts is cyclically repeated. This is shown in Fig. 3 As long as the multi path propagation delays do not exceed the duration of the interval, no inter-symbol interference occurs and no channel equalization is required. For a delay spread that is longer than the effective guard period/ Interval, the BER (Bit Error Rate) rises rapidly due to the inter-symbol interference. The maximum BER that will occur is when the delay spread is very long as this will result in strong inter-symbol interference.

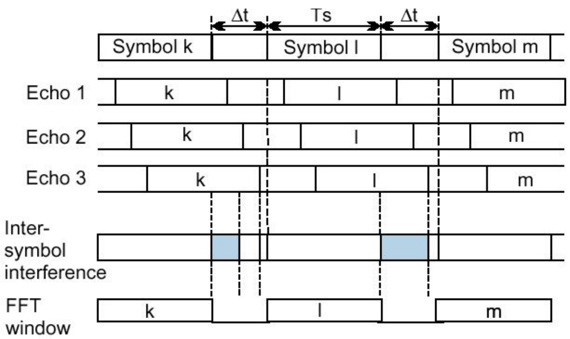

Fig.3 Combating ISI using a guard interval/ Period

In a practical system the length of the guard period can be chosen depending on the required multipath delay spread immunity required.The Guard Period In OFDM System can be inserted in two different ways. One way is the zero padding (ZP) i.e. pads the guard interval with zeros. The other way is the cyclic extension of the OFDM symbol (for some continuity) by insertion of CP (cyclic prefix) or CS (cyclic suffix). CP is to extend the OFDM symbol by copying the last samples of the OFDM symbol into its front.

B. Cyclic Prefix

Let TG denote the length of CP in terms of samples. Then, the extended OFDM symbols now have the duration of Tsym=Tsub+TG. Figure 4(a) shows two consecutive OFDM symbols, each of which has the CP of length TG, while illustrating the OFDM symbol of length Tsym=Tsub +TG.
Figure 4(b) shows the ISI effects of a multipath channel on some subcarriers of the OFDM symbol. It can be seen from this figure that if the length of the guard interval (CP) is set longer than or equal to the maximum delay of a multipath channel, the ISI effect of an OFDM symbol (plotted in a dotted line) on the next symbol is confined within the guard interval so that it may not affect the FFT of the next OFDM symbol, taken for the duration of Tsub. This implies that the guard interval longer than the maximum delay of the multipath channel allows for maintaining the orthogonality among the subcarriers. As the continuity of each delayed subcarrier has been warranted by the CP, its orthogonality with all other subcarriers is maintained over Tsub, such that:

$$1/T_{sub}\int_0^{T_{sub}} e^{j2\pi f_k(t-t_0)}\, e^{j2\pi f_i(t-t_0)}\,dt = 0 \qquad (3)$$

for the first OFDM signal that arrives with a delay of t0, and

$$1/T_{sub}\int_0^{T_{sub}} e^{j2\pi f_k(t-t_0)}\, e^{j2\pi f_i(t-t_0-T_s)}\,dt = 0 \quad (4)$$

for the second OFDM signal that arrives with a delay of t0 +Ts.

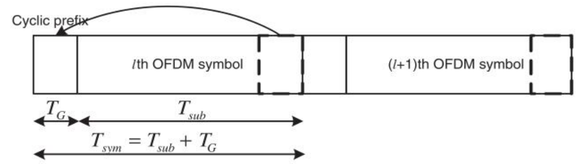

Fig. 4(a) OFDM symbol with CP

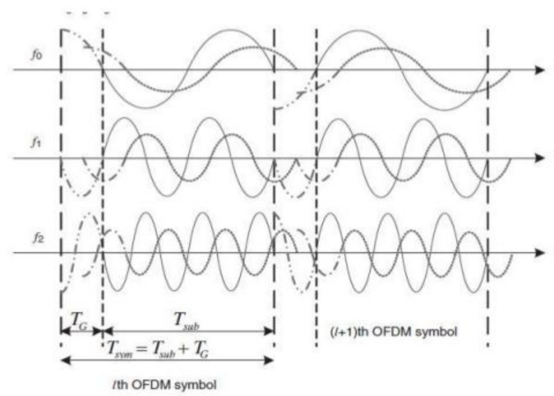

Fig. 4(b) ISI Effect of a multipath channel for each sub-carrier

C. BER OF OFDM SYSTEM

The analytical BER expressions for M-ary QAM signaling in AWGN and Rayleigh channels are respectively given by equation (5) & equation (6) as:

$$P_e=\frac{2(M-1)}{M\log_2 M}\, Q\left(\sqrt{\frac{6E_b \log_2 M}{N_0(M^2-1)}}\right) \qquad (5)$$

$$P_e=\frac{M-1}{M\log_2 M}\, Q\left(1-\sqrt{\frac{3\gamma \log_2 M/(M^2-1)}{3\gamma \log_2 M/(M^2-1)+1}}\right) \qquad (6)$$

Where, γ and M denote Eb/N0 and the modulation order, respectively, while Q(x)[13] is the standard Q-function defined as:

$$Q(x)=\frac{1}{\sqrt{2\pi}}\int_x^{\infty} e^{-t^2/2}\,dt \quad (7)$$

Note that if Nused subcarriers out of total N (FFT size) subcarriers (except Nvc=N/N_{used} virtual subcarriers) are used for carrying data, the time-domain SNR, SNRt [13], differs from the frequency-domain SNR, SNRf , as follows:

$$SNR_t = SNR_f + 10\log N_{used}/N[db] \quad (8)$$

D. Modulation Technique

In BPSK modulation the phase of carrier is modulated according to the modulating signal. It has one fixed phase when the data is at one level, the phase is different by 180 degree. At the receiver side exact signal is recovered by the help of demodulation technique [14].By allowing the amplitude to vary with the phase, a new modulation scheme called Quadrature amplitude modulation (QAM), which is both an analog and digital modulation technique. It conveys two analog message signals, or two digital bit streams, by modulating the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation technique or amplitude modulation (AM) analog modulation technique. The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. MIMO uses square constellations namely, quadrature phase-shift keying (QPSK, also known as 4QAM), 16QAM, and 64QAM schemes for transmission. 4, 16 and 64 indicate the number of constellation points in the QAM schemes respectively. In QAM, the constellation points are arranged in a square grid with equal vertical and horizontal spacing. The 16-QAM,64-QAM constellation diagram are given in figure 4(a), 4(b) & 4(c) respectively [15].

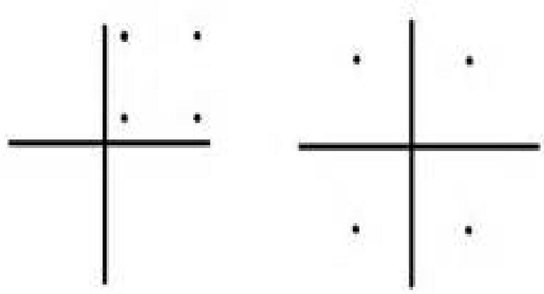

Fig.4(a) QAM constellation diagram for 4-QAM

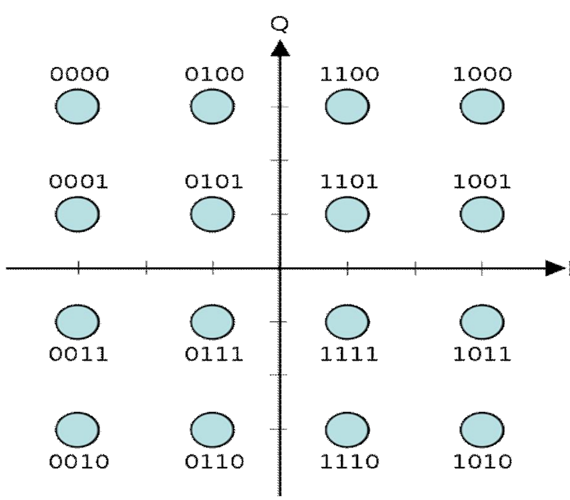

Fig.4(c) QAM constellation diagram for 16-QAM

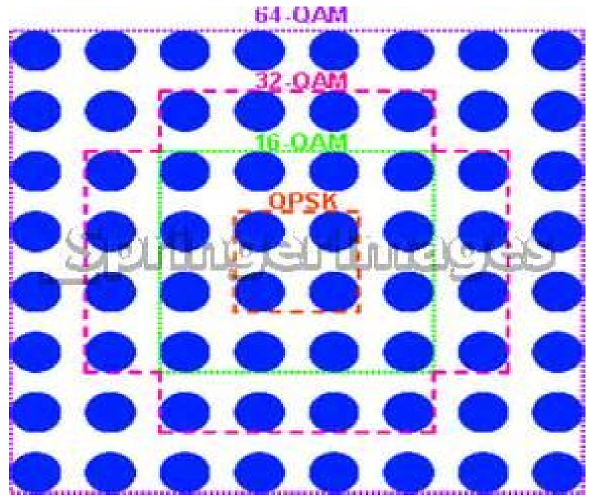

Fig.4(b) QAM constellation diagram for 64-QAM

V. RESULT

The effect of Guard period insertion has been evaluated by comparing the simulation result obtained by plotting Bit Error Rate (BER) against the Signal to Noise Ratio (SNR) for different way & value of Guard Period Insertion in the MIMIO OFDM System.

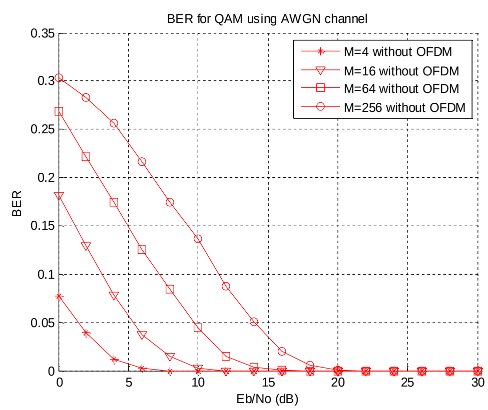

Fig.6(a) Bit error probability curve for QAM Without OFDM

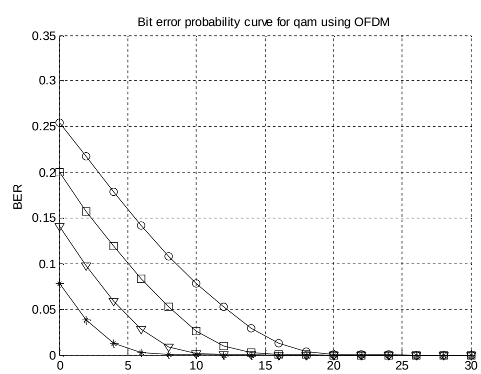

Fig.6(b) Bit error probability curve for QAM With OFDM

COMPARISON

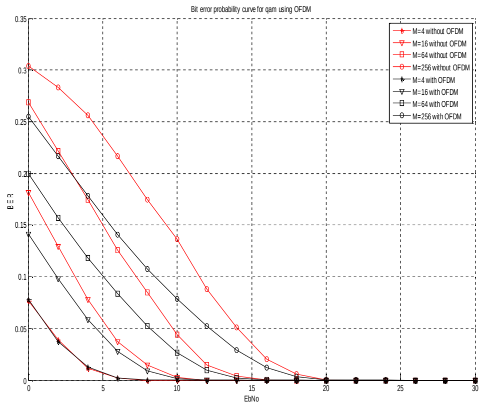

Fig.6(c) Bit error probability curve for QAM With and Without OFDM

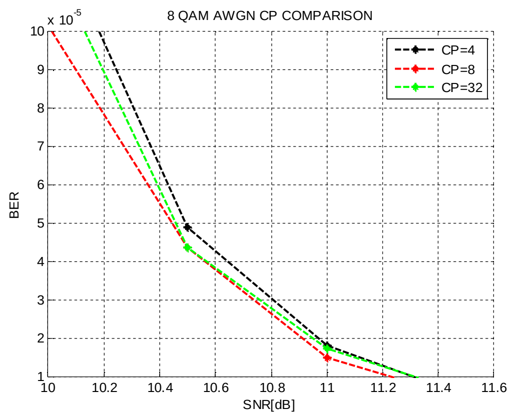

Fig.6(d) Bit error probability curve for QAM With variation in CP

Fig.6 shows comparison of QAM modulation scheme for different modulation index(M) values under AWGN channel with and without OFDM.In system with OFDM BER performance is improved (BER is decreased) as compared to system without OFDM. It is clear that the BER performance in an AWGN channel is consistent with the analytical results. This is true regardless of how long GP is,because there is no multipath delay in the AWGN channel.

VI. CONCLUSION

Thus the above study & result reveals the fact the Guard Period, which also know n as "Guard Interval if properly taken can optimize the Inter-Symbol Interference to the extent that it can be neglected for the test purpose.

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