BER Analysis of MIMO-OFDM System Using Various Modulation Schemes

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***Abstract*—Multiple transmit and receive can be used to form multiple input multiple-output (MIMO) channels to increase the capacity and data rate. The key advantage of employing multiple antennas is to get reliable performance through diversity and the achievable higher data rate through spatial multiplexing. In MIMO system, information can be transmitted and received from multiple antennas simultaneously since the fading for each link between a pair of transmit and receive antennas can usually be considered to be sovereign, so the probability that the information is detected precisely is higher. Fading of the signal can be diminished by different diversity techniques, where the signal is transmitted through multiple independent fading paths in terms of the time, frequency or space and combined constructively at the receiver. In this paper, Bit Error Rate (BER) of MIMO-OFDM system using various modulation schemes has been analyzed .**

Keywords: BER, MIMO, OFDM

I. INTRODUCTION

Multiple-Input Multiple-Output (MIMO) systems have changed wireless communications technology with the potential gains in capacity when multiple antennas at both transmitter and receiver ends of a communications systems are used. Fresh techniques were essential to grasp these gains in existing and new systems which account for the extra spatial dimension. MIMO technology has been adopted in multiple wireless standards, including Wi-Fi, WiMAX and suggested for future systems. Orthogonal frequency division multiplexing (OFDM) is an efficient technique to diminish ISI. OFDM [1] is a frequency division multiplexing (FDM) scheme utilized as a digital multicarrier modulation method [2]. In other words OFDM is frequency division multiplexing of multi-carriers those are orthogonal to each other means they are placed precisely at the nulls in the modulation spectra of each other. This makes OFDM [3] spectrally more efficient. In OFDM data is divided into a number of parallel data streams or sub-channels, one for every sub carriers which are orthogonal to each other though they overlap spectrally. Every sub-carrier is modulated with a conventional modulation scheme at a low symbol rate maintaining entire data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

In today's development MIMO is very practical and beneficial with the combination of OFDM system. Utilizing the flexibility of MIMO systems in order to have high data rates is an especially smart research topic for future development scheme designs and their applications. Multiple-input multiple-output (MIMO) systems tender much larger channel capacity over traditional single-input single-output (SISO) systems. Lately, many transmit beam forming algorithms have been developed to utilize the high capacity in the MIMO systems [4][5]. Additionally, in MIMO systems, after selecting the group of users with the currently utmost possible rates are determined by a packet scheduler in each time-slot, they are needed to be assigned to the transmitter's antennas in a way that the maximum throughput in the system can be achieved. Diversity techniques like space-time coding have received attention due to their capability to offer higher spectral efficiency than conventional systems [6]. When these techniques are applied in a frequency-selective channel, a space-time equalizer is needed at the receiver to reimburse for the inter symbol interference (ISI). MIMO systems now comprise of a chief research area in telecommunications. It is also being considered as the one of the technologies that have a possibility to resolve the restricted access of traffic capacity in the forthcoming broadband wireless Internet access networks such as Universal Mobile Telephone Services(UMTS) and beyond Antenna selection has been recommended for enhanced performance in correlated fading [7][8]. Assuming that the number of RF chains is lesser than the number of antennas, the antenna selection algorithms decide the most favorable subset of transmit and receive antennas based on minimum error rate. The dimension of the active subsets of transmit and receive antennas is fixed by the number of RF chains, Per-antenna rate control which is equivalent to the power allocation, is applied to uncorrelated fading channels in [9], there it is shown that per-antenna rate control at the fading rate almost achieves capacity. Though, adaptation at the fading rate may be tricky to achieve in practice owing to inaccuracies in channel estimates and feedback delays. The remaining of this paper is organized as follows. MIMO and OFDM is discussed in Part II. In Part III model description and observations is done .In Part IV brief conclusion is given. Finally references are given.

II. MIMO SYSTEM AND OFDM

Conventionally, multiple antennas (at one side of the wireless link) have been used to carry out interference cancellation and to realize diversity and array gain in the course of coherent combining. The use of multiple antennas at both sides of the link bids an additional fundamental gain, known as spatial multiplexing gain, which results in raised spectral efficiency. Spatial multiplexing yields a linear capacity boost as compared to systems with a single antenna at one or both sides of the link, at no additional power or bandwidth spending [10–11]. The corresponding gain is accessible if the propagation channel exhibits affluent scattering and can be realized by the synchronized transmission of independent data streams in the same frequency band. The receiver exploits dissimilarities in the spatial signatures brought by the MIMO channel onto the multiplexed data streams to separate the different signals, thus realizing a capacity gain.

Diversity results in improved link reliability by rendering the channel "less fading" and by escalating the sturdiness to co-channel interference. Diversity gain is achieved by transmitting the data signal over multiple independently fading dimensions in time, space, and frequency and by performing appropriate combining in the receiver. Spatial diversity is mainly attractive as compared to time or frequency diversity, because it does not tempt an expenditure in transmission time or bandwidth, respectively. Space-time coding [12] understands spatial diversity gain in systems with multiple transmit antennas with no requirement of channel knowledge at the transmitter. Multiple antennas can be used at one or both sides of the wireless link to cancel or lessen co-channel interference, and therefore improve cellular system capacity. MIMO technology will largely be used in broadband systems that show frequency-selective fading and, therefore, intersymbol interference (ISI). OFDM modulation turns the frequency-selective channel into a set of parallel flat fading channels and is an attractive way of coping with ISI. The basic principle that lie behind OFDM is the introduction of a guard interval, known as cyclic prefix (CP), which is basically a copy of the last part of the OFDM symbol, and need to be long enough to house the delay spread of the channel [13]. The employment of the CP converts the action of the channel on the transmitted signal from a linear convolution into a cyclic convolution, so that the resulting overall transfer function can be diagonalised by the use of an IFFT at the transmitter and an FFT at the receiver end. As a result, the overall frequency-selective channel is converted into a set of parallel flat fading channels, which in turn radically simplifies the equalization job. On the other hand, as the CP carries redundant information, it invites a loss in spectral efficiency, which is usually kept at a maximum of 25 percent. OFDM has tighter synchronization requirements than single-carrier (SC) modulation and direct-sequence spread spectrum (DSSS), is more vulnerable to phase noise, and suffers from a larger peak-to-average power ratio. Multiple access and broadcasting is basically different in systems with multi-antenna terminals and base stations compared to systems with single-antenna terminals base stations or both. The fundamental reason is that realizing spatial- multiplexing gain needs the users to bump in signal space. This favors collision-based multiple-access schemes like code division multiple-access (CDMA) over orthogonal multiple-access schemes such as frequency division multiple access (FDMA) or time division multiple-access (TDMA).

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a calculated time interval. BER is a unit less performance measure, frequently expressed in the form of percentage. The bit error probability is the expectation value of the BER. The BER can be considered as an estimated guess of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors. Calculating the bit error rate assists to choose the appropriate forward error correction codes. Given that most such codes only bit-flips, but not bit – insertions or bit detection, the hamming distance metric is the suitable way to compute the number of bit errors. The BER may be enhanced by choosing strong signal strength by choosing a slow and robust modulation scheme or line coding scheme, and also by applying channel coding schemes such as redundant forward error correction codes.

III. Model Description & Observations

For simulation of MIMO-OFDM, the system was modeled using Orthogonal Space Time Block Coding (OSTBC) technique which proposes spatial diversity gain to attain higher data rates. The OSTBC technique is an smart scheme as it can results in the full spatial diversity order and have symbol-wise maximum-likelihood (ML) decoding. The employ of Orthogonal Space-Time Block Codes (OSTBC) to achieve diversity gains in a multiple-input multiple-output (MIMO) communication system using OFDM is established. The simulation creates a random binary signal, modulates it by means of a phase shift keying (PSK) technique, and then encodes the waveform using a rate orthogonal space-time block code for transmission over the fading channel. The fading channel models six independent links, owing to the three transmit by two receive antennae configuration as single-path Rayleigh fading processes. The simulation attaches white Gaussian noise at the receiver. Then, it combines the signals from both receive antennas into a single stream for demodulation. For this combining process, the model assumes perfect knowledge of the channel gains at the receiver. For an IFFT transformation, a cyclic prefix (CP) is added to the signals and gets transmitted through the channel. At the receiver, the CP is removed if present and afterward the FFT is applied to reconstruct the signal. The FFT length considered for these simulations is 64. Total 128 subcarriers have been taken. OFDM symbol rate is 7.5 Ksps and the symbol period is 10^{-3}s. The system is designed for transmission of data over three transmit antennas and two receive antennas (3 x 2) using independent Rayleigh fading per link. Simulations were done using MATLAB to evaluate the performance of the system. The simulation compares the demodulated data with the original transmitted data, computing the bit error rate. The results have been compared for the BER performance as a function of signal to noise ratio (Eb/N0) using BPSK, its higher order and QAM modulation. In case of BPSK modulation, to have BER = 10^{-5}, MIMO OFDM requires 15 dB of Eb/No, while theoretical value of SNR required is 13 dB for achieving BER of 10^{-5}. On dealing with QPSK, high SNR is required to achieve BER of even 10^{-4}. Also, it has been observed that 8-PSK performs very badly and achieved only 10^{-3} at 20 dB. Alternatively, with QAM for both the simulated systems, the SNR requirement is almost same to the BPSK scheme. It is clear from all the simulated modulation schemes as shown in Figures 1-4 that BPSK has better BER performance as compared to its higher orders with low power penalty over Rayleigh Fading channel. The following graphs illustrate the performance of MIMO based OFDM as compared to their theoretical counterparts. For the theoretical results, the E_bN_o is scaled by the diversity order (four in this case).

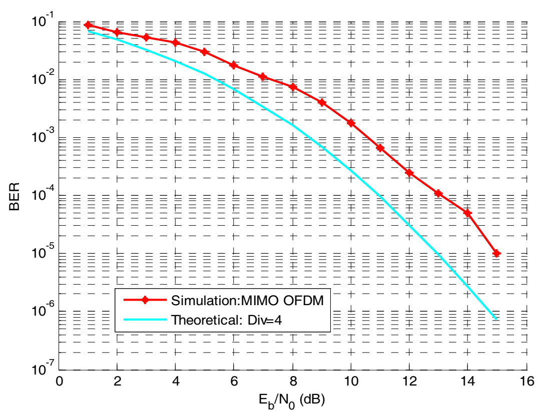

Fig. 1 Measured BER for OSTBC over 3 x 2 Rayleigh Fading Channel using BPSK

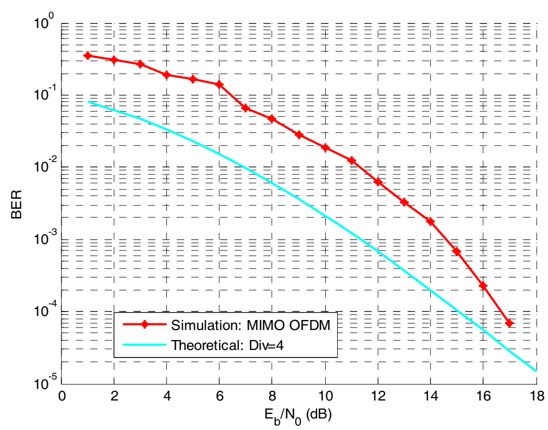

Fig. 2 Measured BER for OSTBC over 3 x 2 Rayleigh Fading Channel using QPSK

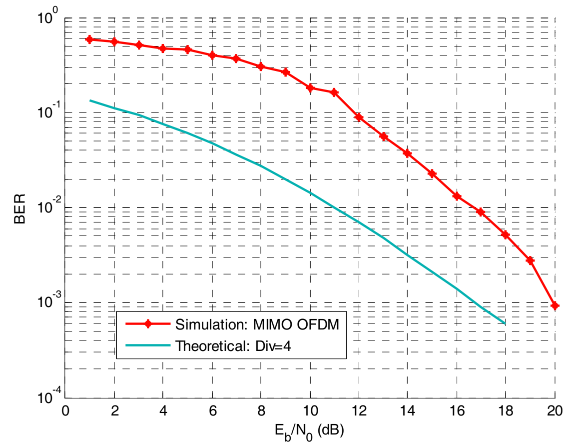

Fig. 3 Measured BER for OSTBC over 3 x 2 Rayleigh Fading Channel using 8-PSK

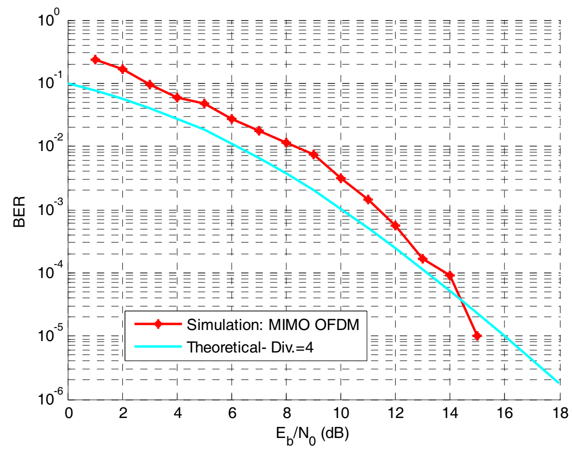

Fig. 4 Measured BER for OSTBC over 3 x 2 Rayleigh Fading Channel using QAM

IV. Conclusion

This work presents the performance of MIMO - OFDM system using various modulations techniques over Rayleigh fading channel. For higher orders of PSK schemes more SNR requirement is reported to target an acceptable BER over the simulated channel. Further, QAM requests fewer SNR as compared to PSK to achieve a suitable BER and is approximately same as that of BPSK. Lower order modulation schemes can be considered, but this is at the disbursement of data throughput. It is essential to balance all the available factors to realize a satisfactory bit error rate. Generally all the requirements are not achievable and some trade-offs are necessary.

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