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Comprehensive Analysis of BER and SNR in OFDM Systems

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ABSTRACT: The proliferation of mobile platforms has put lot of stress in terms of power limitations and Quality of Service being offered by OFDM systems. BER and SNR analysis plays an important and imperative role in understanding and improving the design of OFDM systems. In this paper we have presented a comprehensive analysis about BER and SNR for various scenarios which include different channels, different modulation techniques and carrier frequency offsets.

Keywords: OFDM, BER, SNR, Offsets, Quality of Service

I. LITERATURE REVIEW ON OFDM CONCEPTS

The OFDM transmission scheme seems to be a promising candidate for future broadband radio systems. That transmission scheme is currently deployed in the well known standard IEEE 802.16a/d [1]. The crucial part which determines the performance is thereby the combination of dynamic sub-carrier allocation, transmission power allotment, and adaptive modulation. Many communication systems require knowledge of the signal-to-noise ratio (SNR), with efficient signal detection and link adaptation as most prominent examples. Signal-to-Noise ratio (SNR) is an indicator commonly used to evaluate the quality of a communication link. More specifically, SNR knowledge enables wireless systems to improve propagation channel estimation and is a key decision parameter in adaptive processes such as dynamic reconfiguration of cognitive radios, adaptive modulation and coding (AMC) or adaptive power allocation. Frequency division multiplexing (FDM) extends the concept of single carrier modulation by using multiple sub carriers within the same single channel. The total data rate to be sent in the channel is divided between the various sub carriers [3]. An OFDM baseband signal is the sum of a number of orthogonal sub-carriers, each sub-carrier being independently modulated (for instance using QAM or PSK) by its own data. The orthogonality allows simultaneous transmission on a lot of sub-carriers in a tight frequency space without interference from each other. Thus, they are able to overlap without interfering. As a result, OFDM systems are able to maximize spectral efficiency without causing adjacent channel interference.BPSK is the simplest form of phase shift keying (PSK) A digital signal alternating between +1 and -1 (or 1 and 0) will create phase reversals, i.e. 180 degree phase shifts as the data shifts state. *QPSK* Higher order modulation schemes, such as QPSK, are often used in preference to BPSK when improved spectral efficiency is required [6]. QPSK uses four points on the constellation diagram. With four phases, QPSK can encode two bits per symbol. Quadrature Amplitude Modulation refers to QPSK with Amplitude Modulation. Basically, it is a mix of phase modulation and amplitude modulation. QAM phase modulates the carrier and also modulates the amplitude of the carrier [5] [8]

Additive White Gaussian Noise (AWGN) channel is a Channel Model used for analyzing modulation schemes used for transmission of radio OFDM Signal. In this Model the channel adds a white Gaussian noise to the OFDM signal which is passing through it. By this the signal gets two properties like the amplitude frequency response is flat which means that can signal pass through channel without any amplitude loss and having infinity bandwidth. Phase frequency response is linear, so that no phase distortion of frequency component occurs. *Rayleigh fading channel* is used when there is no direct path between transmitter and receiver [4]. If there is no line of site then the constructive and destructive nature of Multipath Signal in flat fading can be approximated by Rayleigh Distribution [7].

II. INTRODUCTION

Orthogonal frequency-division multiplexing (OFDM) is an efficient bandwidth signaling scheme for the wideband digital communications. One important difference between OFDM and frequency division multiplexing (FDM) is that, the individual carriers mutually overlaps in the OFDM spectrum. OFDM carriers exhibit orthogonality property based on a symbol interval if their spacing in frequency is exactly at the reciprocal of the symbol interval, which can be accomplished by utilizing the Discrete Fourier Transform (DFT) [1]. OFDM is a technique based on multicarrier communication. The basic approach of multicarrier communications is to divide the total available signal bandwidth into a number of subcarriers, and information is transmitted on each of the subcarriers. Unlike the conventional multicarrier communication scheme, in which spectrum of each subcarrier is non-overlapping and band pass filtering is used to extract the frequency of interest. The spectra of subcarriers overlap but individual subcarrier can be extracted by baseband processing. This overlapping property makes OFDM technique more spectral efficient than the conventional multicarrier communication scheme. With the development of modern digital signal processing technology, OFDM technique has become practical to implement and has been proposed as an efficient digital modulation scheme for applications ranging from modems, digital audio broadcast, to next-generation high-speed wireless data communications.

Orthogonal Frequency Division Multiplexing (OFDM) and Multiple-Input Multiple-Output (MIMO) are cutting edge physical layer technologies to be employed in fourth generation (4G) wireless cellular standards such as 3GPP Long Term Evolution (LTE/LTE-A), Worldwide Interoperability for Microwave Access (WiMAX) and high speed Wireless LAN standards. Such 4G cellular standards are expected to support data rates exceeding 100 Mbps through OFDMA, MIMO, dynamic carrier aggregation and thus enable a diverse number of applications in the wireless system such as broadcast/multicast video, on demand HDTV, high speed access to internet, interactive gaming amongst others. [10] At the same time there is an impressive effort towards fixed mobile convergence to enable smooth and effortless mobility across future Wireless LAN and cellular networks. Such factors are driving the wireless telecommunication system designers and operators to invest hugely in the development of OFDM compatible technologies and applications with the aim of tapping into the potentially vast revenue opportunity in futuristic 4G cellular network systems. High capacity and variable bit rate transmission information with high bandwidth efficiency are some of the requirements that the modern transceivers have to meet a variety of new high value added quality services to be delivered to the customers. A worldwide convergence has occurred for the use of Orthogonal Frequency Division Multiplexing (OFDM) as an emerging technology for high data rates. In particular, many wireless standards have adopted the OFDM technology as a mean to increase dramatically future wireless communications. The main reason behind OFDM's increased popularity is the desire for high speed wireless technologies and the increased demand for multimedia applications, which require higher data rates. Because in the wireless environment signals are usually impaired by fading and multipath delay spread phenomenon, traditional single carrier mobile communication systems do not perform well. In such channels, extreme fading of the signal amplitude occurs and Inter Symbol Interference (ISI) due to the frequency selectivity of the channel appears at the receiver side [2]. This leads to a high probability of errors and the system’s overall performance becomes very poor. Techniques like channel coding and adaptive equalization have been widely used as a solution to these problems. However, due to the inherent delay in the coding and equalization process and high cost of the hardware, it is quite difficult to use these techniques in systems operating at high bit rates.

In this proposed work we have presented an extensive analysis about the significance of BER (Bit Error Rate) and SNR (Signal to Noise Ratio) under various scenarios which include different channels and different modulation techniques. Carrier frequency offset (CFO) in orthogonal frequency- division multiplexing (OFDM) systems, which can induce the orthogonality loss among subcarriers resulting in significant performance degradation, is critical and to be estimated and compensated for. In this paper we have also studied the effect of CFO on AWGN channel and its subsequent impact on BER[9]. The advent of MIMO-OFDM systems the complexity in design and analysis of OFDM systems have reached another plane, the paper also presents the performance analysis of MIMO OFDM systems. We have presented a comprehensive analysis of performance of OFDM system considering different factors in regard to the BER and SNR of OFDM systems.

III. SIMULINK MODEL

To validate the research objectives a simulink model is developed for MIMO- OFDM system. The system has been developed using communication tool box available in MATLAB version 7.14 R2012.

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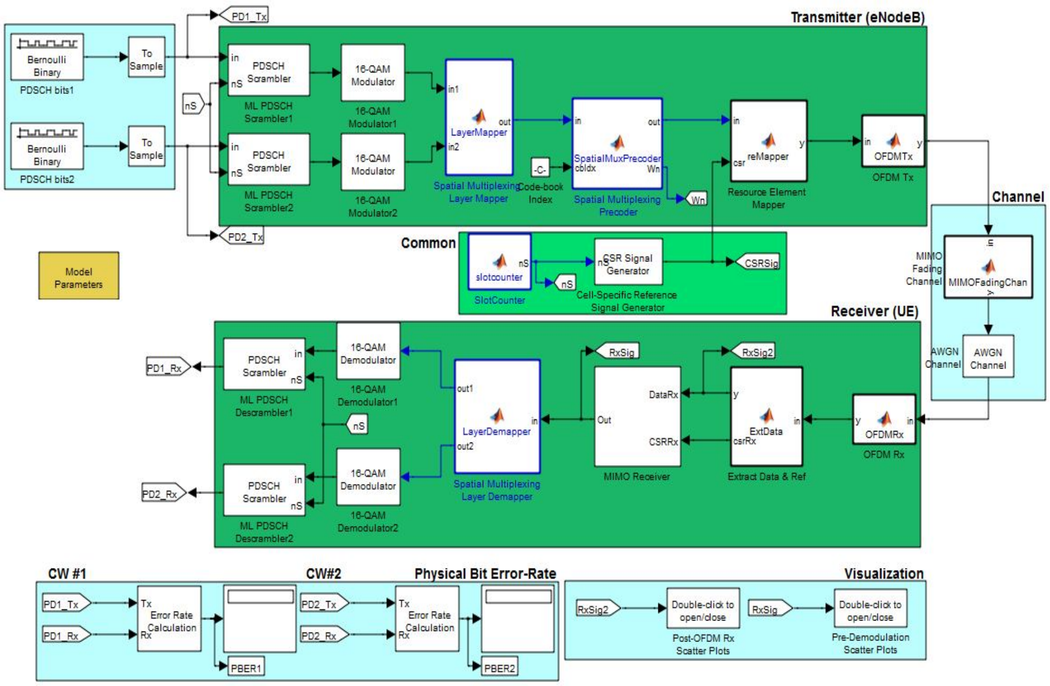

Fig.1. Snapshot of Simulink model used in the proposed work

The above model offers flexibility in selecting number of channels, channel bandwidth, type of channel etc. Apart from the above model text coding in MATLAB is also employed to validate the objectives of the proposed work in having a comprehensive study of performance of OFDM in regard to its BER and SNR performance measures.

IV. RESULTS

The below figure depicts an OFDM signal generated for the proposed work.

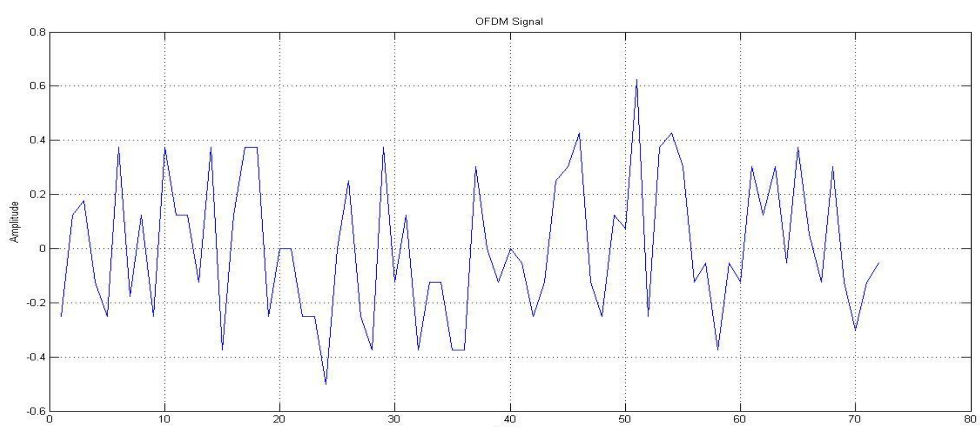

Fig.2. An OFDM Signal

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High power Amplification (HPA) induces distortion and subsequently affects BER and SNR, the below figure depicts an OFDM signal simulated for distortion after HPA.

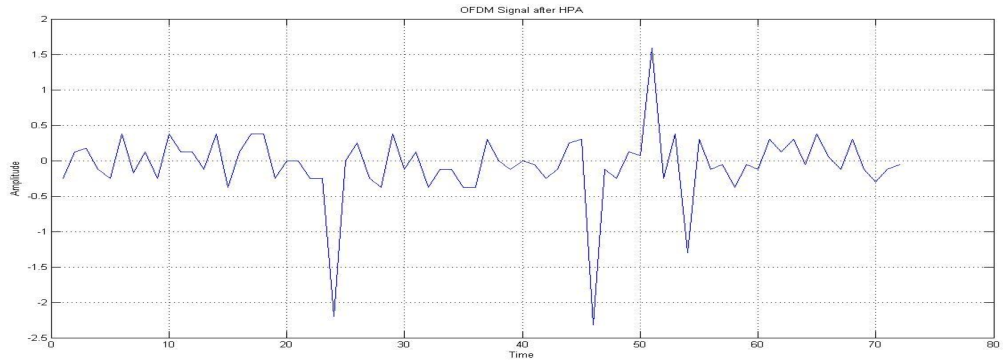

Fig.3. An OFDM Signal after HPA

The kind of modulation has a direct bearing on the performance and hence the variation between SNR and BER, the below figure depicts the variation for QAM type.

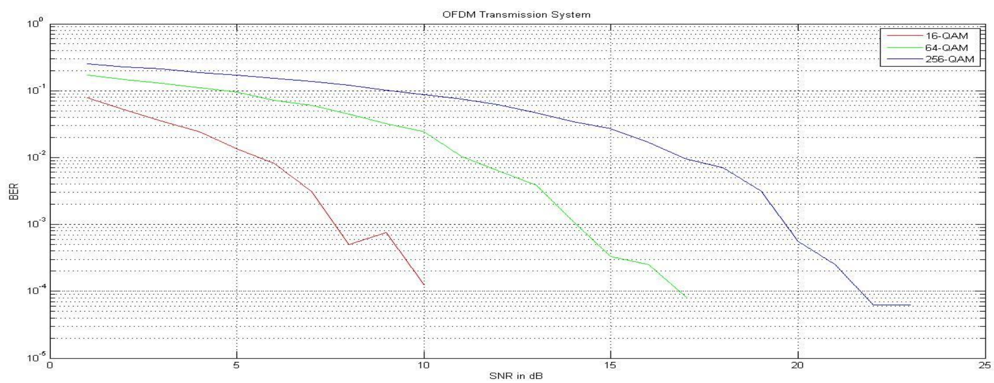

Fig.4. BER Compared with SNR for different levels of QAM

The type of channel also influences the performance of OFDM the below figure presents a comparative plot between Rayleigh and AWGN channels for BPSK type modulation.

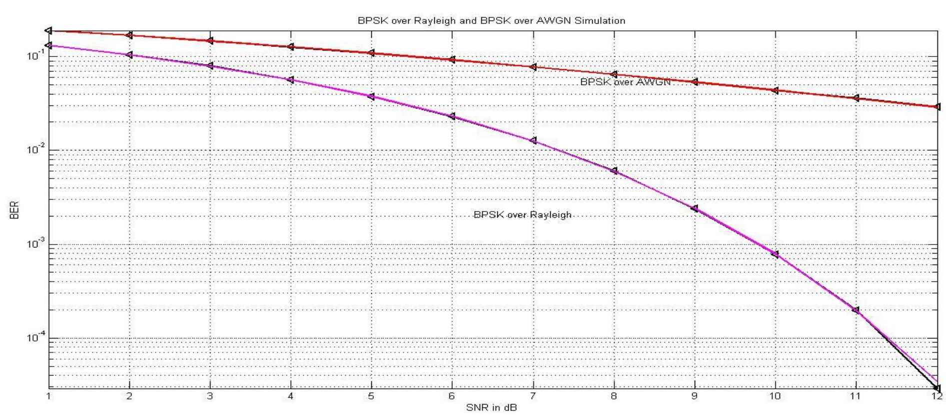

Fig.5. BER compared with SNR Plot for BPSK over AWGN and Rayleigh

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The relationship between SNR and BER is inversely proportional. An enhanced SNR indicates a reduce error rate and an improved performance. The below figures validates the above point in terms of different channels.

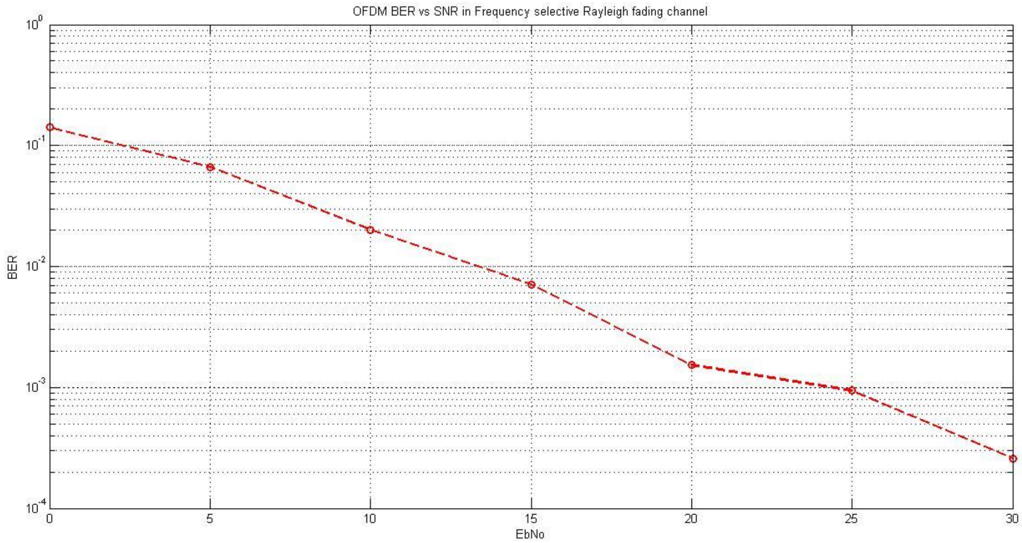

Fig.6. OFDM BER Compared with SNR in Selective Rayleigh Fading Channel

OFDM is extremely sensitive to synchronization errors, especially the carrier frequency offset (CFO), which is induced by oscillator discrepancies between the transmitter and receiver and/or Doppler shifts. As a result, CFO estimation for OFDM is an active area of research. The below figure depicts the BER sensitivity for CFO in an AWGN channel.

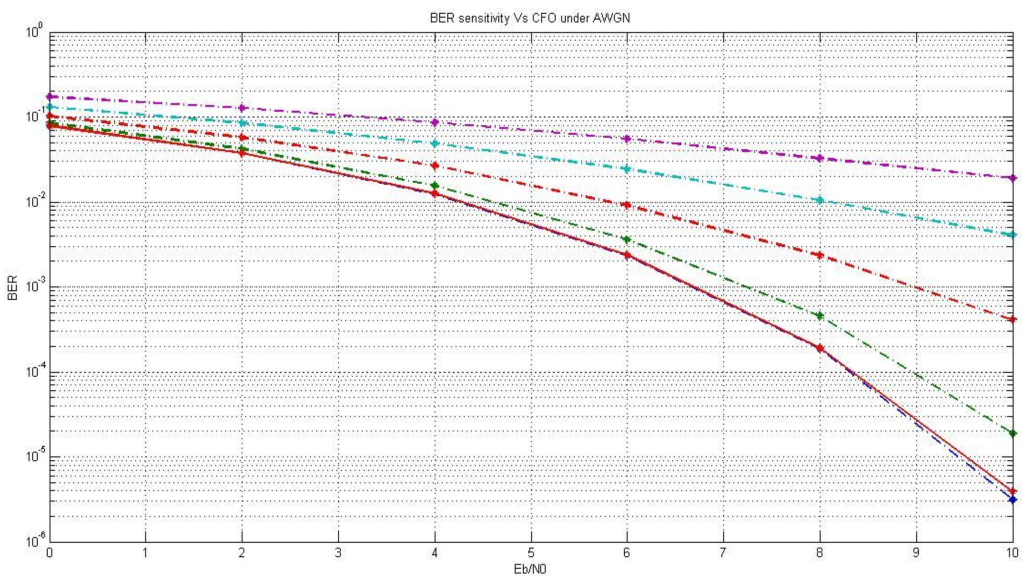

Fig.7. BER sensitivity for CFO in an AWGN channel.

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It can be observed that there is clear difference in comparison between two channels in terms of BER and SNR comparison for same modulation technique. With the advent of mobile platforms and other devices MIMO systems are becoming integral part of OFDM environment it is essential to analyze their performance as well. The below figures depict the signal power in the context of MIMO systems.

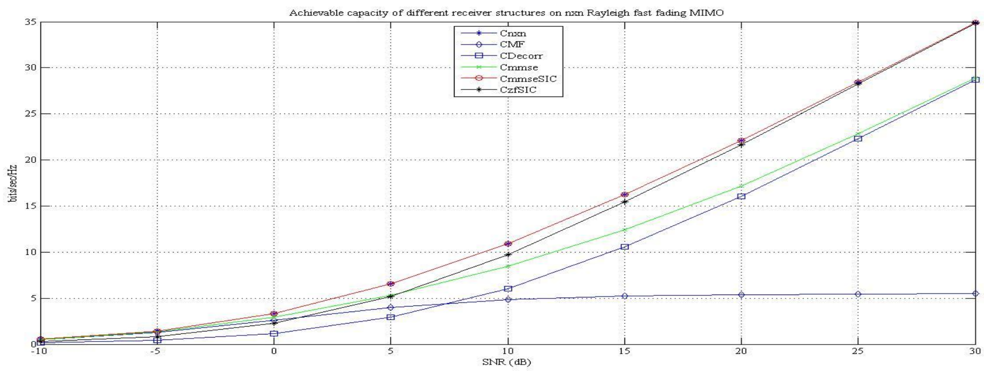

Fig.8. Capacity plot in comparison with SNR in a Rayleigh Fast Fading MIMO System

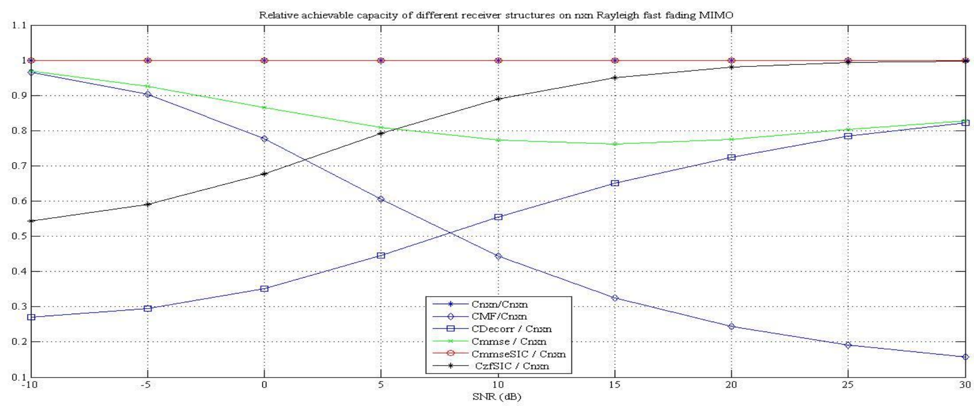

Fig.9. Relative Achievable capacity of different receiver structures in Rayleigh Fading MIMO

From the above discussions we can understand that the BER and SNR estimation pose a complex challenge due to multitude of reasons and complex interactions between different components of an OFDM system. The proliferation of MIMO systems adds to complexity of the environment.Understanding the performance measures of BER and SNR is very significant in better design of OFDM systems.

V. CONCLUSION

The portable and battery operated devices are getting integrated to most of the day to day applications. OFDM being chief player in these devices has to be updated and evolved continuously. This offers researchers ample opportunities and challenges alike in improving the performance of the OFDM systems. BER and SNR play a very crucial role in performance analysis. This paper brings out the complexity in BER and SNR analysis and their importance in development of better OFDM systems.

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BIOGRAPHY

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