Evaluation of Bit Error Rate Performance of Orthogonal Frequency Division Multiplexing System over multipath fading channel

Ojasvi bhatia, Manish Gupta, Yogesh Kumar Gupta

***Abstract*— Wireless communication is one of the most active areas of technology development and has become an ever-more important and prominent part of everyday life. Orthogonal Frequency Division Multiplexing System are better suited to the today's generation 3G networks and upcoming 4G and 5G networks in terms of bandwidth efficiency due to overlapping of frequency bands, high speed data transfer due to parallel data transfer, maintaining high quality of wireless link even under multipath conditions due to low symbol rate it minimizes ISI effects. The application of channel codes like convolution codes further reduces the Bit Error Rate and improves the link reliability. In this paper BER performance of OFDM systems has been evaluated with multipath Rayleigh fading channel and AWGN channel with different levels of M-QAM and M-PSK modulation schemes applied to OFDM subcarriers and results has been simulated using MATLAB.**

***Index Terms*—- *Bit* Error Rate; Signal to Noise Ratio; Intersymbol Interference, Additive White Gaussian Noise**

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is very similar to the well-known and used technique of Frequency Division Multiplexing (FDM). OFDM uses the principles of FDM to allow multiple messages to be sent over a single radio channel. It is however in a much more controlled manner, allowing an improved spectral efficiency. OFDM is different from FDM in several ways. In conventional broadcasting each radio station transmits on a different frequency, effectively using FDM to maintain a separation between the stations. There is however no coordination or synchronization between each of these stations. . All the sub carriers within the OFDM signal are time and frequency synchronized to each other, allowing the interference between sub carriers to be carefully controlled. These multiple sub carriers overlap in the frequency domain, but do not cause Inter-Carrier Interference (ICI) due to the orthogonal nature of the modulation. Typically with FDM the transmission signals need to have a large frequency guard-band between channels to prevent interference. This lowers the overall spectral efficiency. However with OFDM the orthogonal packing of the sub carriers greatly reduces this guard band, improving the spectral efficiency.

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In a single OFDM transmission all the subcarriers are synchronized to each other, restricting the transmission to digital modulation schemes. OFDM is symbol based, and can be thought of as a large number of low bit rate carriers transmitting in parallel [1]. All these carriers transmit in unison using synchronized time and frequency, forming a single block of spectrum. This is to ensure that the orthogonal nature of the structure is maintained. Since these multiple carriers form a single OFDM transmission, they are commonly referred to as 'sub carriers', with the term of 'carrier' reserved for describing the RF carrier mixing the signal from base band.

The basic idea of OFDM is to divide the available spectrum into several subcarriers. By making all sub channels narrowband; they almost experience flat fading, which makes equalization very simple. To obtain the high spectrum efficiency, the frequency responses of the sub channels are overlapping and orthogonal. This is just the reason why we named the technique as 'OFDM' [2].

II. Wireless Channel Modeling

Wireless communication is one of the most active areas of technology development and has become an ever-more important and prominent part of everyday life. Simulation of wireless channels accurately is very important for the design and performance evaluation of wireless communication systems and components [3]. Fading or loss of signals is a very important phenomenon that related to the Wireless Communications Field. That leads us to the fading models which try to describe the fading patterns in different environments and conditions.

Although no model can „perfectly" describe an environment, they strive to obtain as much precision as possible. The better a model can describe a fading environment, the better can it be compensated with other signals, so that, on the receiving end, the signal is error free or at least close to being error free. This would mean higher clarity of voice and higher accuracy of data transmitted over wireless medium. An important issue is in wireless application development is the selection of fading models.

Fading and Multipath

Fading refers to the distortion that a carrier-modulated telecommunication signal experiences over certain propagation media. In wireless systems, fading is due to multipath propagation and is sometimes referred to as multipath induced fading. To understand fading, it is essential to understand multipath. In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals' reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from terrestrial objects, such as mountains and buildings. The effects of multipath include constructive and destructive interference, and phase shifting of the signal. This distortion of signals caused by multipath is known as fading. In other words it can be said that in the real world, multipath occurs when there is more than one path available for radio signal propagation. The phenomenon of reflection, diffraction and scattering all give rise to additional radio propagation paths beyond the direct optical LOS [2] (Line of Sight) path between the radio transmitter and receiver

TYPES OF FADING

According to the effect of multipath, there are two types of fading

a). Large Scale Fading, In this type of fading, the received signal power varies gradually due to signal attenuation determined by the geometry of the path profile.

b). Small Scale Fading If the signal moves over a distance in the order of wavelength, in small scale fading leads to rapid fluctuation of the phase and amplitude of the signal.

Flat Fading If the bandwidth of the mobile channel is greater than the bandwidth of the transmitted channel, it causes flat fading. Flat fading is one in which all frequency components of a received radio signal vary in the same proportion simultaneously[8].

A. 2.4.1 *Types of small scale fading*

There are many models that describe the phenomenon of small scale fading. Out of these models, Rayleigh fading, Ricean fading and Nakagami fading models are most widely used.

a). *Rayleigh fading model*: The Rayleigh fading is primarily caused by mNultipath reception [6]. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal. It is a reasonable model for troposphere and ionospheres‟ signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading [7] is most applicable when there is no line of sight between the transmitter and receiver.

b). Ricean fading model: The Ricean fading model [6] is similar to the Rayleigh fading model, except that in Ricean fading, a strong dominant component is present. This dominant component is a stationary (non fading) signal and is commonly known as the LOS (Line of Sight Component).

c). Additive White Gaussian Noise Model: The simplest radio environment in which a wireless communications system or a local positioning system or proximity detector based on Time- of-flight will have to operate is the Additive-White Gaussian Noise (AWGN) [4] environment. Additive white Gaussian noise (AWGN) is the commonly used to transmit signal while signals travel from the channel and simulate background noise of channel. The mathematical expression in received signal $r(t) = s(t) + n(t)$ that passed through the AWGN channel where $s(t)$ is transmitted signal and $n(t)$ is background noise.

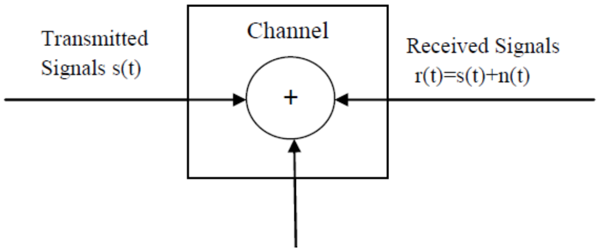

Fig 1: Block Diagram of AWGN

III. MODULATION OF OFDM SUB CARRIERS

Digital modulation schemes transform digital signals into waveform that are compatible with the nature of the communications channel. [3]One category uses a constant amplitude carrier and the other carries the information in phase or frequency variations (FSK, PSK). A major transition from the simple amplitude modulation (AM) and frequency modulation (FM) to digital techniques such as Quadrature Phase Shift Keying (QPSK), Frequency Shift Keying (FSK), Minimum Shift Keying (MSK) and Quadrate Amplitude Modulation (QAM).

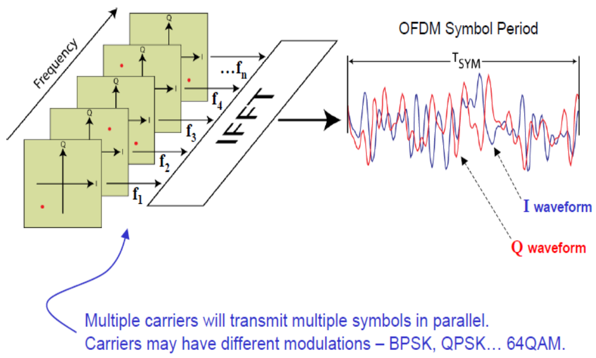

Fig 2. Generation of OFDM symbol

3.2 Bit Error Rate (BER)

The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted. BER= (Bits in Error) / (Total bits received).

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. The BER is the number of bit errors divided by the total number of transferred bits during a particular time interval. BER is a unit less performance measure, often expressed as a percentage. IEEE 802.11 standard has ability to sense the bit error rate (BER) of its link and implemented modulation to data rate and exchange to Forward Error Correction (FEC), which is used to set the BER as low error rate for data applications. [4]BER measurement is the number of bit error or destroys within a second during transmitting from source to destination

3.3 Signal to Noise Ratio (SNR)

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. It is an important parameter of the physical layer of Local Area Wireless Network (LAWN)[4]. Noise strength, in general, can include the noise in the environment and other unwanted signals (interference). BER is inversely related to SNR, that is high BER causes low SNR. High BER causes increases packet loss, increase in delay and decreases throughput. The exact relation between the SNR and the BER is not easy to determine in the multi channel environment. Signal to noise ratio (SNR) is an indicator commonly used to evaluate the quality of a communication link and measured in decibels and represented by Eq. (2).

SNR = 10 $\log_{10}$ (Signal Power / Noise Power) dB. --- (2)

3.4 E_b/N_0 (Energy per bit to Noise power spectral density ratio)

Eb/N0 is an important parameter in digital communication or data transmission. It is a normalized signal to-noise ratio (SNR) measure, also known as the "SNR per bit". It is specially useful when comparing the bit error rate (BER) performance of different digital modulation schemes without taking bandwidth into account. Eb/N0 is equal to the SNR divided by the "gross" link spectral efficiency in (bit/s)/Hz, where the bits in this context are transmitted data bits, inclusive of error correction information and other protocol overhead[5].
When forward error correction (FEC) is being discussed, Eb/N0 is routinely used to refer to the energy per information bit (i.e. the energy per bit net of FEC overhead bits); in this context, Es/N0 is generally used to relate actual transmitted power to noise.

IV. SIMULATION RESULTS

A comparative performance analysis of OFDM system based on IEEE 802.11a .WLAN standards has been done using MATLAB simulation software. The parameters used in simulation of OFDM are listed below[5].

NO. of bits per symbol	52
No. of symbols	10^5
FFT length	64
Modulation technique used	M-QAM M-PSK
Channel model	AWGN, RAYLEIGH

Table 1: Simulation Parameters for OFDM System

The simulation results are obtained using MATLAB codes. The performance analysis has been done to analyse comparative performance of OFDM system over multipath fading channel using various levels of (M = 2n) QAM, PSK digital modulation schemes, using channel equalization and forward error coding[6].

A. BER PERFORMANCE COMPARISON OF SINGLE CARRIER VERSUS OFDM SYSTEM ON AWGN CHANNEL

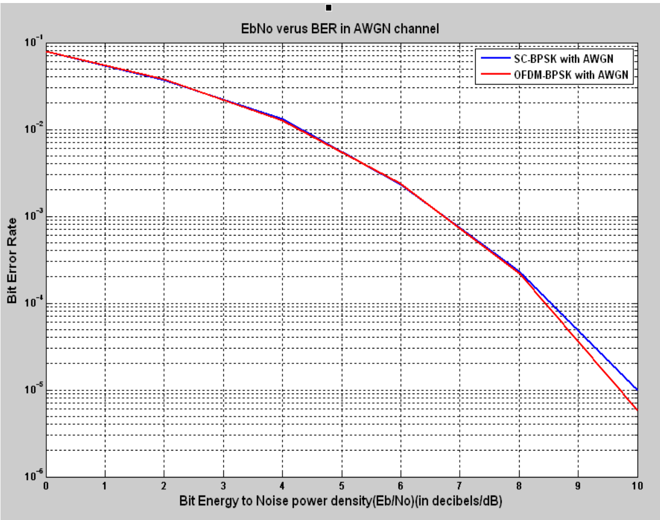

Fig 3. **:** BER Performance Comparison of Single Carrier versus OFDM System on AWGN channel

From the Simulation results it is observed that both Single Carrier and OFDM system shows similar BER performance in AWGN channel. In AWGN channel [2] OFDM system is similar to FDM system with same modulation and demodulation techniques used for SC system.
In the absence of multipath channel there is no any gain in EbNo at any BER for OFDM systems.

B. BER PERFORMANCE COMPARISON OF OFDM VERSUS SINGLE CARRIER SYSTEMS WITH MULTIPATH CHANNEL

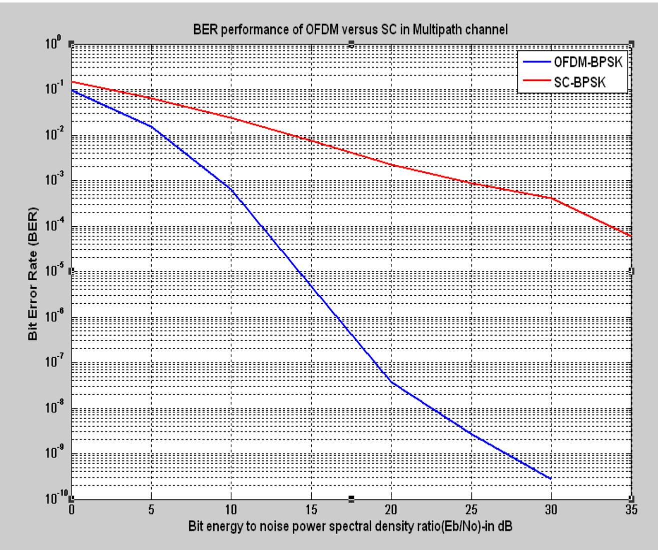

Fig4: BER performance of OFDM system in Rayleigh channel

In this the 'Bit Error Rate performance' of single carrier with BPSK modulation scheme is compared with OFDM with BPSK modulation scheme for each sub carrier[6].
The Simulation results obtained using MATLAB codes clearly shows OFDM system superior performance over Single Carrier system in multipath channel.
With increase in EbNo from 0 dB to 25db there is a large

difference in Bit Error Rates of SC-BPSK and OFDM-BPSK, fixing BER at 10^{-4} there is a gain of (32-12)dB = 20dB in EbNo for OFDM systems means OFDM system can achieve this Bit Error Rates with 20dB less EbN0. Spectral efficiency of OFDM system (60bitspersymbol) is also much higher than SC-BPSK (1 bit per symbol)

C. BIT ERROR RATE PERFORMANCE OF OFDM SUB-CARRIER MODULATION SCHEMES IN MULTIPATH CHANNEL

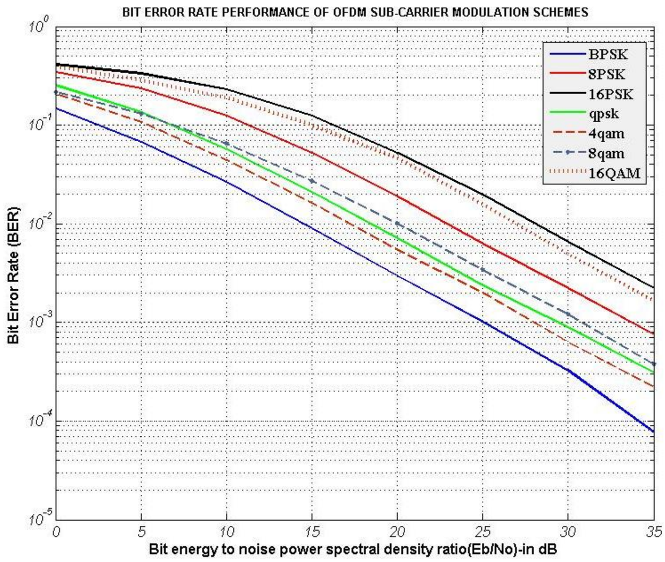

Fig 5: BER performance of OFDM sub-carrier modulation schems in multipath Rayleigh channel

The following simulation results obtained for different levels of M in M-Ary PSK and QAM schemes with Multipath channel shows that Bit Error Rate increases with increase in order of M. As BPSK (M=2) shows minimum BER but offers lowest data rate (1bit/symbol)[3].

Both M-PSK and M-QAM shows increase in BER with higher orders of M (>2) but M-QAM schemes shows slightly improved BER performance over M-PSK schemes. It is expected as M-PSK constellation points are more closely spaced than M-QAM which increases the probability of error.

It is self evident that higher data rates can be achieved at the expense of increase in BER but M-QAM schemes should be preferred over M-PSK schemes

V. CONCLUSION

These simulated results obtained using MATLAB shows superior performance of OFDM system over single carrier system under Multipath conditions. OFDM system has inherent equalization property because of low symbol rate modulation which increases the symbol duration more than or equal to channel delay spread and hence minimises the effect of Inter symbol interference (ISI)[7]. The effect of ISI on an OFDM signal can be further improved by the addition of a guard period to the start of each symbol. This guard period is a cyclic copy that extends the length of the symbol.

The future scope will be to further enhance the spectrum efficiency of OFDM system by applying spatial diversity schemes consisting of multiple input transmitters Antenna and Multiple output receivers Antennas (MIMO) over the same wireless channel. CDMA (Code Division Multiple Access) can be applied as a modulation scheme over OFDM sub carriers called Multi career CDMA which provides maximum bandwidth utilization with minimum interference.

REFERENCES

[1] Kuixi Chen; Jihua Lu; Bo Yang; Zhilun Li; Zibin Zhang, Performance analysis of an OFDM transmission system based on IEEE802.11a, Mobile Congress (GMC), 2011 Global Publication Date: 2011, IEEE Trans

[2] Abhishek Katariya, Amita Yadav, Neha Jain , Performance Elevation Criteria for OFDM under AWGN Fading Channel using IEEE 802.11a ,International Journal of Soft Computing and Engineering (IJSCE), ISSN: 2231-2307, Volume-1, Issue-3, July 2011

[3] Sanjeev Kumar, Swati Sharma , Error Probability of Different Modulation Schemes for OFDM based WLAN standard IEEE 802.11a, International Journal of Engineering (IJE), Volume: 4, Issue: 4-2011.

[4] Vineet Sharma , Anuraj Shrivastav , BER performance of OFDM-BPSK,-QPSK,- QAM over AWGN channel using forward Error correcting code , International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012, pp.1619-1624H. Poor,

[5] Jigisha N. Patel , Prof. (Mrs.) Upen D. Dalal, "A Comparative Performance Analysis of OFDM using MATLAB Simulation with M-PSK and M-QAM Mapping" , International Conference on Computational Intelligence and Multimedia Applications 2007B.

[6] M. A. Saeed, B. M. Ali, and M. H. Habaebi, "Performance evaluation of OFDM scenes over multipath fading channel", in *Asia-Pacic Conf. Commun." APCC*, Malaysia, 2003, pp. 415{419}

[7] T. Pollet, M. van Bladel, and M. Moeneclaey, "BER sensitivity of OFDM systems to carrier frequency offset and Wiener phase noise," *IEEE Trans. On Communications*, vol. 43, pp. 191-193, Feb.

[8] T.S Rapaport, Wireless Communications Principles and Practice 2nd Edition ,