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BER Performance Analysis of M-QAM OFDM over a Multipath Rayleigh Channel with AWGN

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Abstract- OFDM largely used in modern digital communication system to achieve high data rate transmission and bandwidth efficiency, is also very effective in dealing with multipath Rayleigh fading. High data rate translates into low bit error rate and this is always the goal of every communication engineer. In this paper, the bit error rate performance analysis of OFDM on M-QAM modulation over a multipath Rayleigh Channel has been achieved. The model design and simulation was done using Simulink. The results obtained showed that for lower values of Eb/No between 5 - 15db, the BER decreases as the M-ary number increases for the same Eb/No value. However for Eb/No greater than 15db, it was observed that the BER increases as the M-ary number increases for the same Eb/No value.

Keywords- *OFDM, FFT, IFFT, AWGN, BER, QAM*

I. INTRODUCTION

The sporadic spread of wireless communications and Internet access has produced a strong need for advanced wireless techniques [1]. The goal of the future wireless communication is to provide communication with high data rates. OFDM has been adopted by in Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), Digital Subscriber Line (DSL), and Wireless Local Area Network (WLAN) standards such as IEEE 802.11a/b/g/n.it has also been adopted for wireless broadband access standards such as the IEEE 802.16e, and as the core technique for the fourth-generation (4G) wireless mobile communication. [3]

When data is transmitted at high rates over wireless radio channels, the symbols may overlap each other which can lead to ISI.OFDM can combat the effect of ISI. The development of OFDM system is divided into three parts. They are Frequency Division Multiple Access (FDMA), multicarrier communication and orthogonal FDM [2]. In FDMA the available bandwidth is divided into multiple channels and then allocated to the users.in multicarrier communication the signal is divided into a number of signals over a frequency range, whereas OFDM spaces the channels as much closer by placing the carriers orthogonal to each other, thus using the spectrum efficiency as seen in the figure below.

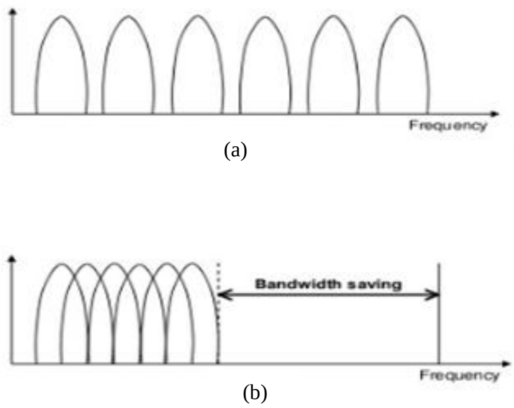

Figure 1. (a) Multicarrier technique FDM (b) OFDM

II. RELATED WORKS

In their paper [2], simulation was performed for OFDM using BPSK and QPSK modulation in AWGN and Rayleigh fading channel. To analyze the multiple signal arriving at the receiver due to the reflections of the transmitted *signal for large objects, diffraction and electromagnetic waves around the object .this causes the received signal to be distorted. The BER performance is similar for both, but QPSK is expensive in terms of bandwidth when compared to BPSK.

In their research [1], focuses on techniques that improve the performance of OFDM based wireless communication and its commercial and military applications. John et al studied the efficiency of OFDM and assesses its suitability as a modulation technique in mobile communication [5]. [3], in their paper described typical constraint faced during OFDM transmission such as large peak to mean envelop power ratio, which can result in significant distortion when transmitted through a nonlinear device, also the effect of clipping and filtering on the performance of OFDM.

A. OFDM system model

The term orthogonal means that the center frequencies of the sub-channel are separated by the reciprocal of the OFDM block time T. suppose the symbol length is T, sinusoidal signal differing in frequency by 1/T, will be orthogonal over the period T.[2]

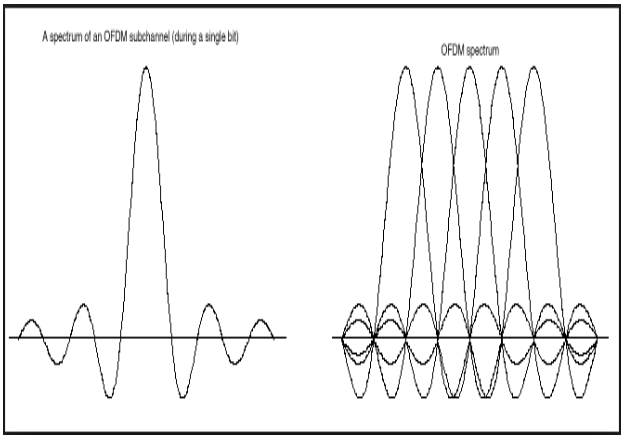

Figure 2. A spectra of an OFDM subcarriers (during a single-bit) and OFDM Spectrum

The bandwidth upon which the channel response can be assumed to be flat is known as coherence bandwidth of the channel. If the data is transmitted at high rate, the bandwidth of the channel becomes wide and may exceed the coherence bandwidth of the channel. This distorts the signal and causes inter symbol interference (ISI). [2]

A guard interval in introduced to eliminate ISI. To approaches are followed to in OFDM to insert guard interval. The first is known as the zero padding, where zeros are inserted between OFDM symbols, the second one is known as cyclic prefix. Cyclic prefix is being used in this research because FFT algorithms require the signal to be periodic to produce accurate results and cyclic prefix makes the signal periodic [2].

Guard interval specifies the guard interval time (also referred to as the cyclic prefix in this paper). It is specified as a fraction of the OFDM FFT Length. It is used to ensure that district transmission do not interfere with one another. Guard interval is a ratio of the cyclic prefix "CP" time to the inverse FF time.

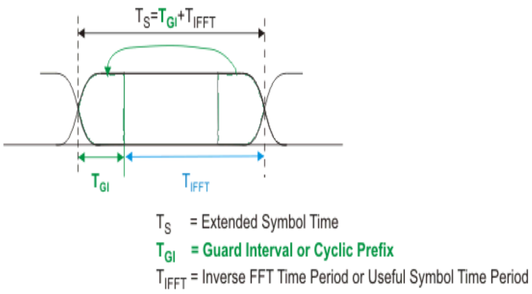

Figure 3. Typical OFDM Frame with Cyclic extension

B. OFDM Modulation and Demodulation

In FFT-Based implementation of OFDM, each output OFDM sample is a summation of all the N input complex data to the IFFT. In transmitters using OFDM as multicarrier modulation technology, the OFDM symbol is constructed in frequency domain by mapping the input bits on the I and Q components of the QAM symbol and then ordering them in a sequence with specific length according to the number of subcarriers in the OFDM symbols. To transmit them, the signals must be represented in the time domain. This is accomplished by the Inverse Fast Fourier transform IFFT. At the receiver, the Fast Fourier transform FFT converts the signal back from the time domain to frequency domain. FFT analyses the signal in the frequency domain which would be used at the receivers to know the information contained in the sub-bands.

The scaled samples:

$$x_k = \sqrt{T/N_{x(KT/N)}} \quad (1)$$

Where k=0 to N-1, of an OFDM symbol can be generated by taking the IFFT of the complex modulation symbols as shown in the following equation:

$$x_{k=} \frac{1}{N} \sum_{n=0}^{N-1} x_n \ e^{j\frac{2\pi kn}{N}}, k = 0, \dots, N-1 \quad (2)$$

Where x_n is the modulate data symbols, 'N' is the number of FFT samples, n = 0, …, N-1 are the position of the subcarriers (input IFFT samples) and k=0,…,N-1 are the output FFT samples.

At the receiver, a forward FFT is used to demodulate the OFDM signal, thus;

$$x_{n=} \sum_{k=0}^{N-1} x_k \ e^{-j\frac{2\pi kn}{N}}, n = 0, \dots, N-1 \quad (3)$$

FFT – based implementation of OFDM, each output OFDM sample is a summation of all N input complex data to the IFFT.

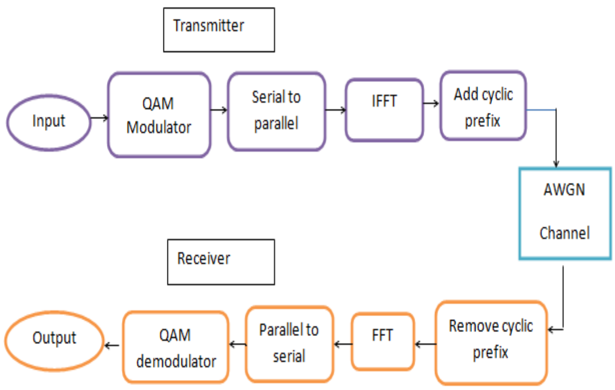

Figure 4. Basic OFDM model

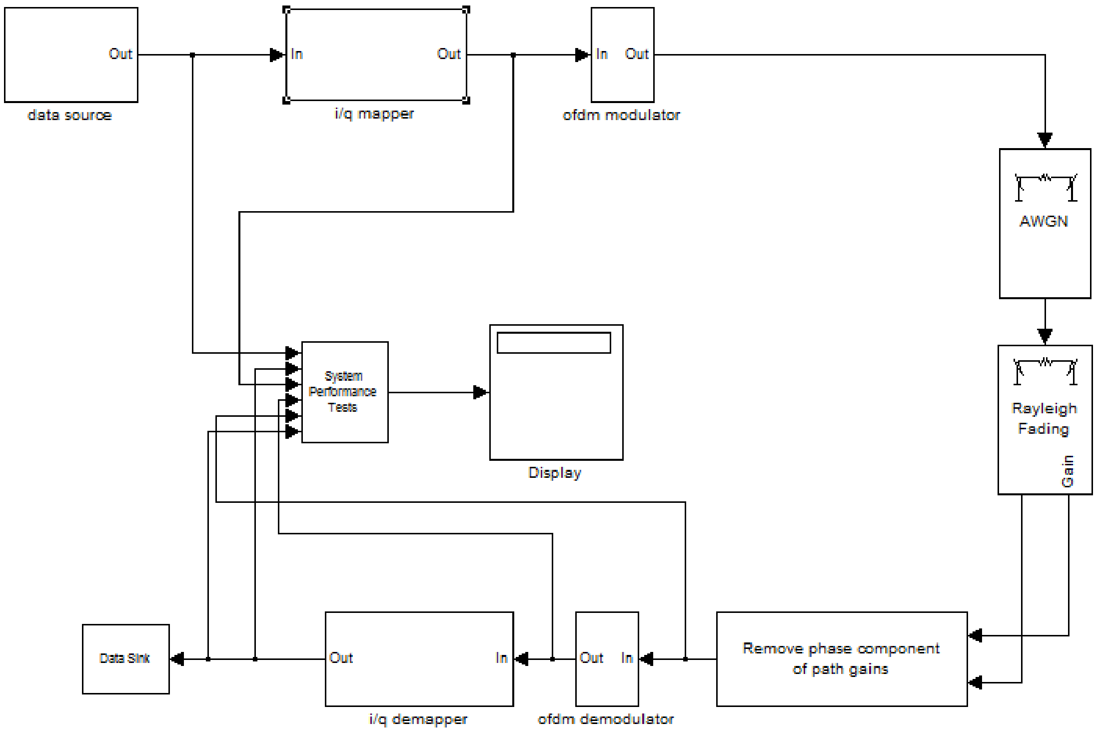

Figure 5. Simulink Model of OFDM System using QAM with AWGN and Rayleigh fading channel

III. DESIGN METHODOLOGY

The OFDM system was modeled using Matlab/Simulink. Its purpose is to measure the performance of OFDM under various channels such as AWGN and Rayleigh fading connected in series.

- A bit stream is generated by data generator. It is processed using M-ary QAM modulator to map the input data into symbols.
- These symbols are now sent through The IFFT block which performs IFFT operation on the sent symbols to generate N parallel data streams.
- The modified output is now attached with cyclic prefix. The cyclic prefix (CP) is added before transmission, to reduce ISI effect. It is then passed through AWGN and Rayleigh fading channel connected in series with proper input power set.
- At the receiving end, the reverse operation is done to reclaim the original data.
- The BER is then calculated and results taken.

IV. RESULT AND DISCUSSION

The BER of different M-ary QAM for various SNR are tabled below. The number of bits per symbol is modified for every M-QAM.

A. Discussion

From table 1 above, it is observed that for lower values of Eb/No between 5 -15 db, ie increase in signal power with respect to noise energy, the BER decreases as the M-ary number increases for the same Eb/No value. However for Eb/No greater than 15db, it is observed that the BER increases as the M-ary number increases for the same Eb/No value.

It is also observed that the BER decreases for an OFDM M-ary communication system. This is as a result of an increase in the nunber of bits transmitted as the M-ary number increases. It is observed that at certain values of Eb/No 40 – 70(db), the BER becomes constant.

V. CONCLUSION

The BER performance analysis of OFDM M-ary QAM in multipath Rayleigh channel with AWGN has been achieved. It is observed the BER decreases as the value ofEb/No increases for M-ary QAM. For efficient BER performance in an OFDM system using M-QAM, 4-QAM presents the lowest BER performance and as such is more efficient than other M-QAM.

TABLE I. BER FOR DIFFERENT M-QAM AT VARIOUS SNR

Eb/No	BER				
	4-QAM	8-QAM	16-QAM	32-QAM	64-QAM
5	0.4405	0.4141	0.39	0.3508	0.3153
10	0.3778	0.3011	0.2418	0.2107	0.2064
15	0.2592	0.1533	0.1201	0.1326	0.1658
20	0.08774	0.06533	0.07987	0.1173	0.1599
30	0.0009798	0.05972	0.07204	0.1147	0.1593
40	0.000954	0.04835	0.07133	0.1145	0.1594
50	0.0009282	0.04822	0.07127	0.1146	0.1594
60	0.0009282	0.04823	0.07124	0.1146	0.1594
70	0.0009282	0.04823	0.07124	0.1146	0.1594

TABLE II. TABLE 1 MODIFIED

M-ary Number	Bit Error Rate (BER)			
	Eb/No: 5db	Eb/No: 10db	Eb/No: 15db	Eb/No: 20db
4	**4.4050E-01**	**3.7780E-01**	**0.2592**	**0.08774**
8	**4.1410E-01**	**3.0110E-01**	**1.5330E-01**	**0.06533**
16	**3.9000E-01**	**2.4180E-01**	**1.2010E-01**	**0.07987**
32	**3.5080E-01**	**2.1070E-01**	**1.3260E-01**	**0.1173**
64	**3.1530E-01**	**2.0640E-01**	**1.6580E-01**	**1.5990E-01**

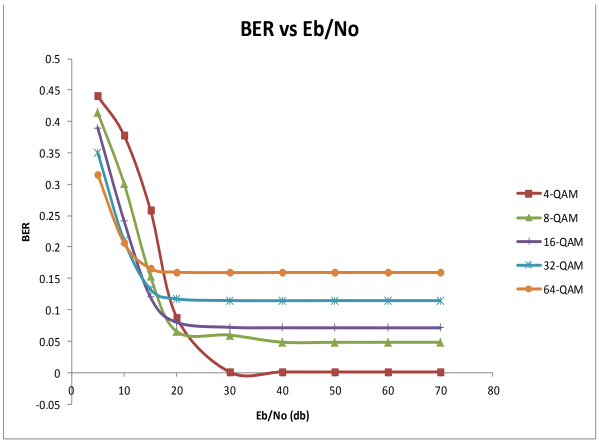

Figure 6. BER vs. Eb/No for different M-ary number for M-QAM

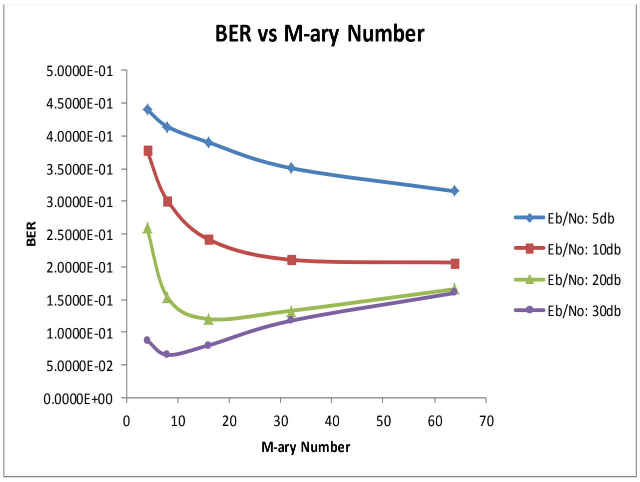

Figure 7. Graph of BER vs. M-ary number for M-QAM

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