PERFORMANCE EVALUATION OF 64-ARY QAM OFDM SYSTEM IN TERMS OF SER CALCULATION AND THROUGHPUT MEASUREMENT FOR AWGN CHANNEL

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Abstract:

In this paper, the performance analysis of 64 QAM-OFDM wireless communication systems affected by AWGN in terms of Symbol Error Rate and Throughput is addressed. 64 QAM (64-ary Quadrature Amplitude Modulation) is the one of the effective digital modulation technique as it is more power efficient for larger values of M. The MATLAB script based model of the 64 QAM-OFDM systems with normal AWGN channel is made for study of error performance and throughput under different channel conditions. This simulated model maximizes the system throughput in the presence of narrowband interference, while guaranteeing a SER below a predefined threshold. Lastly comparative study of SER performance of 64 QAM-OFDM simulated & 64 QAM-OFDM theoretical under AWGN channel is given.

Keywords:

QAM, OFDM, SER, cyclic prefix, Throughput, Digital communication.

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INTRODUCTION:

Modern wireless communication adopts digital modulation techniques instead of analog modulation as digital modulation has several advantages over analog modulation. Digital modulation techniques provide higher data rates, powerful error correction techniques and better security [5]. OFDM technology with QAM modulation is becoming most promising technology to provide high data rate wireless communications, due to its robustness, high spectral efficiency, frequency selective fading, and low computational complexity.

In OFDM systems, the available bandwidth is broken into many narrower subcarriers and the data is divided into parallel streams[1], one for each subcarrier each of which is then modulated using varying levels of QAM modulation e.g. QPSK, 16QAM, 64QAM or higher orders as required by the desired signal quality. The linear combination of the instantaneous signals on each of the subcarriers constitutes the OFDM symbols. Each of the OFDM symbol is preceded by a cyclic prefix (CP) [4] which is effectively used to eliminate intersymbol Interference (ISI).Also to estimate the combined effect of the channel and I/Q imbalances for equalization and data detection, pilot tones can be used in OFDM system [6]. OFDM transceiver can be realized using a number of coherent QAM modems which are equally spaced in the frequency domain and which can be implemented using the IDFT on the transmitter end and the DFT on the receiving end [10].

Literature Survey:

In literature, M.S.EI.Tannany [1] dealt with the problem of modeling of phase noise in OFDM systems and its impact on the BER performance of such systems subject to a number of system variables and to a number of channel conditions for DTTB systems. M.A.Mohamed [2] obtained the detailed simulation of different OFDM systems with different constellation mapping schemes using MATLAB program to study the effect of various design parameters on the system performance. Ebrahim Beeder, et. al [3] presented an adaptive bit allocation algorithm for OFDM CR systems operating in a frequency selective fading environment. Mitalee Aggarwal [4] shows the effects on BER performance of MIMO-OFDM system with Guard period inclusion and without Guard period inclusion and also affect of the different modulation techniques through simulation results. Abhijyoti Ghosh [5] presented a Simulink based model of the MQAM-OFDM system with normal AWGN channel and Rayleigh fading channel for study of error performance under different channel conditions. H. Minn [6] proposed the efficient pilot designing techniques and its advantages for channel estimation of OFDM system. Pussadee Kiratipongvooth [7] presented bit error probability of M-ary QAM OFDM-based system with best-relay selection for different values of the numbers of relays (M), the numbers of subchannels and modulation scheme. Seema Arora [8] carried out the performance analysis of transmission of digital data over indoor power lines using 16-QAM OFDM through simulation results. Abhishek Katariya, et. al [9] has reported the BER performance of OFDM-BPSK, 16 – QAM and 64–QAM system over AWGN fading channel. They presented modeling and simulation of OFDM based on IEEE 802.11a standard.

System Description and Model:

A functional block diagram of OFDM system is shown in Figure 1

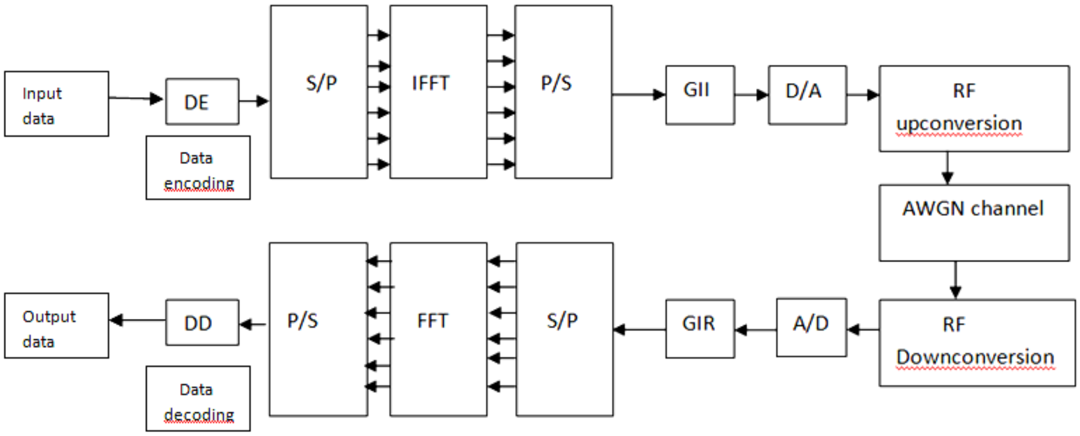

Figure 1 Block Diagram of OFDM system [5]

The incoming data serial data after encoding is applied to S/P converter to form parallel stream and grouped into each L= $\log_2 M$ binary bits into one of the M constellation points. The parallel data is modulated in a baseband fashion by the IFFT and converted back to serial data for transmission. A guard interval (cyclic extension & windowing) is inserted between symbols to avoid ISI. The discrete symbols are converted to analog and low pass filtered for RF up-conversion. The receiver performs the inverse operation of the transmitter. Data is demodulated by using FFT at receiver’s side. Thus OFDM can be realized using IFFT and DFT like DSP operations.

M-QAM constellation

The number of points in the constellation is defined as, $M = 2^b$ where b is the number of bits in each constellation symbol.

Average energy of an M-QAM constellation:

In a general M-QAM constellation where $M = 2^b$ and b the no. of bits in each constellation is even, the alphabets used are

$$\alpha_{MQAM} = \{\pm(2m-1) \pm (2m-1)j\}, \text{ where } m = \{1, 2, \dots, \frac{\sqrt{M}}{2}\}.$$

For computing the average energy of the M-QAM constellation, let us proceed as follows:

(a) Find the sum of energy of the individual alphabets

$$E_\alpha = \sum_{m=1}^{\frac{\sqrt{M}}{2}} |\ (2m-1) + j(2m-1)\ |^2 \qquad = \frac{\sqrt{M}}{3}(M-1) \qquad 1)$$

(b) Each alphabet is used $2\sqrt{M}$ times in the M-QAM constellation.

(c) So, to find the average energy from M constellation symbols, divide the product of (a) and (b) by M. The average energy is,

$$E_{MQAM} = \frac{2\sqrt{M}}{M} E_\alpha = \frac{2}{3}(M-1) \qquad 2)$$

So scaling factor of $1/\sqrt{10}, 1/\sqrt{42}$ is seen along with 16-QAM, 64-QAM constellations respectively for normalizing the average transmit power to unity.

There are three types of constellation points in a general M-QAM constellation:

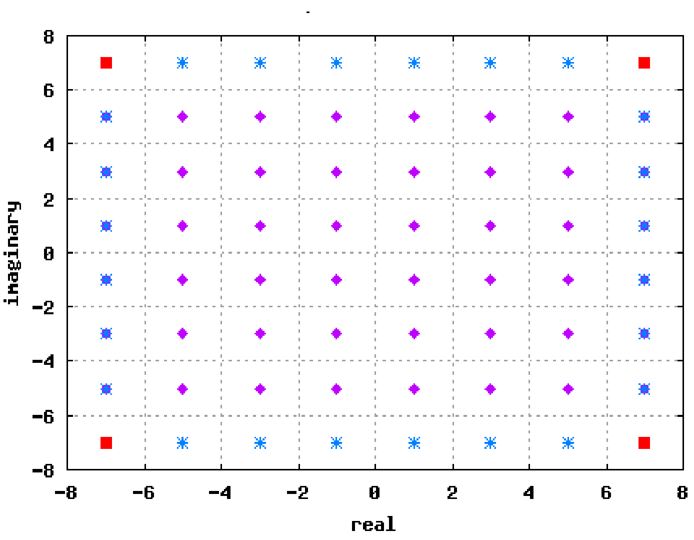

Figure 2 Constellation Plot of 64 QAM

(a) Constellation points in the corner, *I*=+7, *Q*=+7 (red-square)

The number of constellation points in the corner in any M-QAM constellation is always 4, i.e

$$N_{corner} = 4$$

The probability of the symbol decoded being in error is

$$p(e \mid inside) = 1 - \left[1 - erfc\left(k\sqrt{\frac{E_S}{N_0}}\right)\right]$$

$$= 2\,erfc\left(k\sqrt{\frac{E_S}{N_0}}\right) - erfc^2\left(k\sqrt{\frac{E_S}{N_0}}\right) \qquad 3)$$

(b) Constellation points in the inside,$+1, Q = +1$ (magneta-diamond)

The number of constellation points in the inside is,

$$N_{inside} = (\sqrt{M} - 2)(\sqrt{M} - 2)$$

For example with M=64, there are 36 constellation points in the inside.

The probability of the symbol decoded being in error is

$$p(e \mid inside) = 1 - \left[1 - erfc\left(k\sqrt{\frac{E_S}{N_0}}\right)\right]$$

$$= 2\,erfc\left(k\sqrt{\frac{E_S}{N_0}}\right) - erfc^2\left(k\sqrt{\frac{E_S}{N_0}}\right) \qquad 4)$$

(c) Constellation points neither inside nor at the corner, $I = +7, Q = +1$ (blue-star)

The number of constellation points of this category is,

$$N_{neither\ inside\ nor\ corner} = 4(\sqrt{M} - 2)$$

For example with M=64, there are 24 constellation points in the inside.

The probability of the symbol decoded being in error is,

$$p(e \mid neither\ inside\ nor\ corner) = \left[\frac{3}{2} erfc\left(k\sqrt{\frac{E_S}{N_0}}\right) + \frac{1}{2} erfc^2\left(\left(k\sqrt{\frac{E_S}{N_0}}\right)\right]\right. \qquad 5)$$

Additive White Gaussian Noise (AWGN) channel

Let the received symbol is,

$y = k\sqrt{E_s}\,s + n,$ where

$\sqrt{E_s}$ is the energy,

$k = \sqrt{\frac{1}{\frac{2}{3}(M-1)}}$ is the normalizing factor,

Total symbol error probability

Given that we have computed the individual symbol error probability for each of the three types of constellation points, to find the joint symbol error rate we compute the average error i.e.

$$p(e \mid MQAM) = N_{inside}p(e \mid inside) + N_{corner}p(e \mid corner) + \frac{N_{neither\ inside\ nor\ corner}\ p(e|neither\ inside\ nor\ corner)}{M}$$

Plugging in the equation:

$$p(\,e \mid MQAM\,) = 2\left(1-\frac{1}{\sqrt{M}}\right)erfc\left(k\sqrt{\frac{E_s}{N_0}}\right) - \left(1-\frac{2}{\sqrt{M}}+\frac{1}{M}\right)erfc^2\left(k\sqrt{\frac{E_s}{N_0}}\right) \qquad 6)$$

SIMULATION RESULTS

The OFDM system with following specifications is used for simulation setup:

Table 1 OFDM system specifications parameters

Parameters	**Value**
FFT size, nFFT	64
Number of used subcarriers. nDSC	52
FFT Sampling frequency	20MHZ
Subcarrier spacing	312.5kHZ
Used subcarrier index	{-26 to -1, +1 to +26}
Cyclic prefix duration, Tcp	0.8μs
Data symbol duration, Td	3.2μs
Total Symbol duration, Ts	4μs
Modulation Type	64 QAM

The OFDM system with above specifications is developed, analyzed and simulated in MATLAB version 7.6. The simulation results obtained are as shown:

Figure 3 depicts the average throughput as a function of average SNR for different values of SIRs assuming perfect channel estimation. As one can observe, as the average SNR or SIR increases, more bits can be loaded on OFDM subcarriers while achieving the target BER, which translates into an increase in the average throughput. However, the throughput saturates beyond a certain average SNR at a given SIR. This can be explained as, at a certain average SNR value, the OFDM CU subcarriers are loaded with the maximum constellation given a certain SIR value and a further increase in the average SNR will not improve the average throughput.

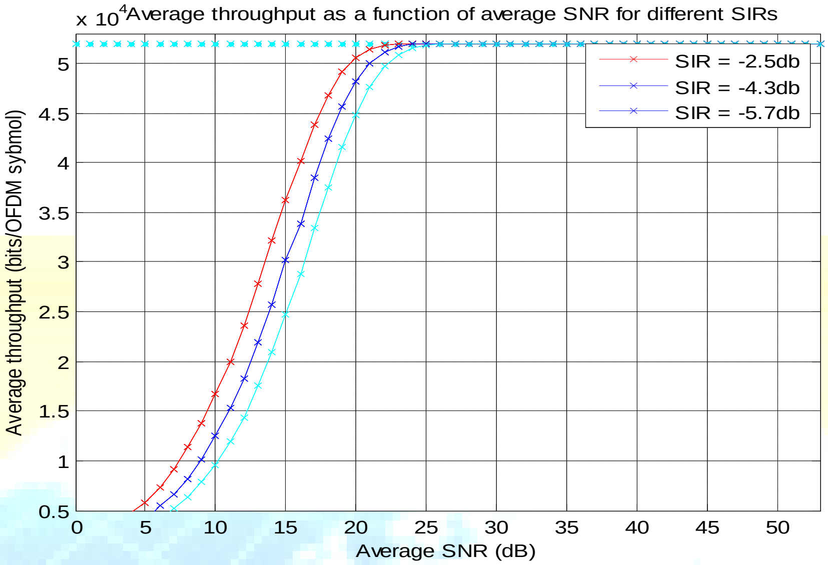

Figure 3 Throughput v/s average SNR for 64-QAM using OFDM.

Figure 4 depicts the Symbol error rate as a function of Average SNR for theoretical and simulated values. As one can observe, as the average SNR increases SER decreases both for theoretical and simulated values. Probability of getting more accurate data increases with increasing strength of the signal data.

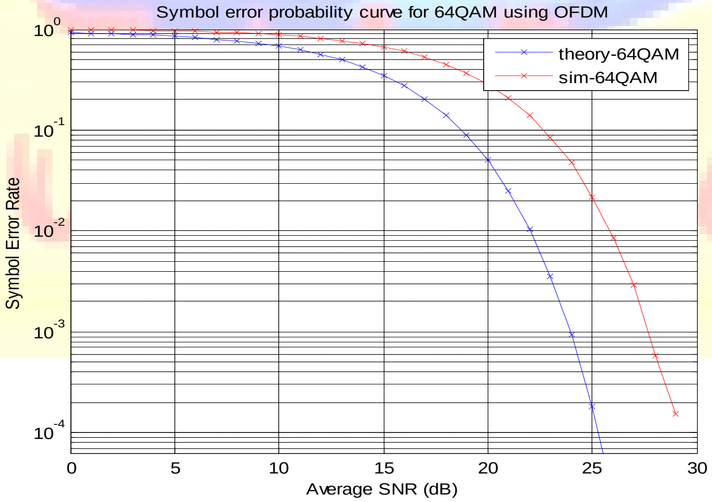

Fig. 4 SER v/s average SNR for 64-QAM using OFDM

From above result graphs, following mathematical observations for Throughput & SER with SNR can be tabulated as:

Table 2 Throughput & SER result table for 64 QAM

INPUT SNR IN dB	THROUGHPUT IN %			SER IN dB
	SIR = -2.5	SIR = -4.3	SIR = -5.7	
1	4.7	3.3	2.5	0.984
25	99.9	99.8	99.1	0.047
53	100	100	100	0.000

Conclusion and Future Work:

Comparative to other low order modulation techniques, M-ary modulation provide better bandwidth utilization. Data rates & bandwidth utilization can be further increased by increasing the value of M. The paper describes the complete performance evaluation of 64-QAM in terms SER and throughput. In future, proposed scheme can be used for PAPR calculation of OFDM system. This work can be extended for offset QAM & differential modulation to further increase spectrum. Also adaptive modulation can be used to improve BER performance.

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