SER Performance of M-ary QAM OFDM System under AWGN Channel

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ABSTRACT

OFDM is a multicarrier technique in which modulated data streams are divided into number of parallel substreams which occupies a very less bandwidth. However, full justice was done in proper utilization of bandwidth in OFDM where subcarriers overlap orthogonally. In this paper, the performance analysis of M-ary QAM-OFDM wireless communication systems affected by AWGN in terms of Symbol Error Rate is presented. The MATLAB script based model of the M-ary QAM-OFDM systems with normal AWGN channel is made for study of error performance. Lastly a comparative study of error performance of 64,128 and 256 QAM-OFDM system is made showing the effects of increase in value of M on SER.

Keywords

SER, Digital Communication, cyclic Prefix, ISI, QAM

1. INTRODUCTION

The need for future communication systems to support mobile users with complete real time access to broadband services calls for robustness against fast frequency-selective multipath fading [9]. An effective solution to this impairment is to adopt the orthogonal frequency division multiplexing (OFDM) as the multiplexing strategy. 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 can be implemented using the IDFT on the transmitter end and the DFT on the receiving end [10].

2. SYSTEM DESCRIPTION & MODEL

The functional Block Diagram of OFDM system is shown in figure 1.

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.

Figure 1 Block Diagram of OFDM system [5]

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.

3. 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

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

- (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,

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

So scaling factor of $1/\sqrt{10}$ and $1/\sqrt{42}$ is used along with 16 QAM and 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

$$p(e | inside) = 1 - \left[1 - \operatorname{erfc} \left(k \sqrt{\frac{E_s}{N_0}} \right) \right] = 2 \operatorname{erfc} \left(k \sqrt{\frac{E_s}{N_0}} \right) - \operatorname{erfc}^2 \left(k \sqrt{\frac{E_s}{N_0}} \right) \quad (3)$$

- (b) Constellation points in the inside, $I=+I, Q=+I$ (magenta-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:

$$p(e | inside) = 1 - \left[1 - \operatorname{erfc} \left(k \sqrt{\frac{E_s}{N_0}} \right) \right] = 2 \operatorname{erfc} \left(k \sqrt{\frac{E_s}{N_0}} \right) - \operatorname{erfc}^2 \left(k \sqrt{\frac{E_s}{N_0}} \right) \quad (4)$$

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

$$p(e | neither inside nor corner) = \left[\frac{3}{2} \operatorname{erfc} \left(k \sqrt{\frac{E_s}{N_0}} \right) + \frac{1}{2} \operatorname{erfc}^2 \left(k \sqrt{\frac{E_s}{N_0}} \right) \right] \quad (5)$$

Additive White Gaussian Noise (AWGN) channel:

Let the received symbol is,

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

$\sqrt{E_s}$ is the energy,

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

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.

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

Plugging in the equation:

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

4. SIMULATION RESULTS

The OFDM system with specifications as given in table 1 is used for simulation setup.

Table 1. OFDM specification Parameters

Parameters	Value
FFT size, nFFT	64
Number of used subcarriers, nDS	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:

Fig.3.1, 3.2, 3.3 depicts the Symbol error rate as a function of Average SNR for theoretical and simulated values. SER for 64, 128 and 256 QAM has been plotted. 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.

Figure 3.1 SER v/s average SNR for 64-QAM using OFDM

Figure 3.2 SER v/s average SNR for 128-QAM using OFDM

Figure 3.3 SER v/s average SNR for 256-QAM using OFDM

Figure 4 shows the plot of simulated SER with average SNR for different values of M. From the plot it is seen that as value of M increases, SER also increases. SER for 256 is maximum but it has high data rate. So there is trade-off between data rate and SER.

Figure 4. SER for different values of M

From above result graphs following observations are made for SER calculation

Table 2. SER result table for different values of M

INPUT SNR IN dB	SER		
	64 QAM	128QAM	256QAM
1	0.984	0.992	0.996
25	0.047	0.211	0.374
53	0.000	0.000	0.000

5. 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.

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

6. REFERENCES

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