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PERFORMANCE ANALYSIS OF OFDM SYSTEM WITH QAM MODULATION OVER AWGN CHANNEL

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Abstract— **The next generation wireless communications systems demand higher data rates transmission in order to meet the high quality services. Orthogonal Frequency Division Multiplexing (OFDM) offers high data rate, high Spectral Efficiency (SE), and immunity against narrow band interference. Spectral efficiency is one of the major issues in wireless communication system. The spectral efficiency of a channel is a measure of the number of bits per second per Hz. The spectral efficiency is presented in many ways in the literature. In wireless communication system SE depends on Bit Error Rate (BER), coding rate and modulation technique. This study investigates the SE and Bit Error Rate (BER) performance OFDM system over AWGN channel with different QAM modulation techniques. Simulation results show that minimum SE obtained with the 16QAM modulation technique with coding rate ½ at lower Signal to Noise Ratio (SNR). The comparative show that minimum BER can be achieved with the 16QAM modulation technique.**

Index Terms - OFDM, SE, BER, AWGN, QAM.

I. INTRODUCTION

The next generation wireless communications systems demand higher data rates transmission in order to meet the high quality services. Since there have been an increased demand for higher data rate transmission, the systems are using the Orthogonal Frequency Division Multiplexing (OFDM) transmission techniques. The main advantage of multicarrier transmission is its robustness in frequency selective fading channel. Therefore, OFDM is one of the efficient choices in wireless systems. OFDM has been adopted in many wireless standards such as *worldwide interoperability for microwave access* (WiMAX) and Long Term Evolution (LTE) [1-3]. Wireless communications techniques have been growing very rapidly in the last few decades. Therefore more reliable wireless communication systems are required having higher spectral efficiency [4]. Also there is need to provide high data rate in a mobile environment for new services like multimedia, internet, digital video broadcasting, wireless LANs (IEEE 802.11a, IEEE 802.11g). But the transmission of higher data rates makes a highly hostile radio channel. To combat the problem, the OFDM seems to be a solution. OFDM can be seen as either a modulation technique or a multiplexing technique. OFDM can save almost fifty percent of bandwidth by dividing the available spectrum into many overlapping carriers. These multicarriers should be orthogonal. OFDM is a special case of multicarrier transmission, where a single data stream is transmitted over a number of low data rate subcarriers [1,5]. This low symbol rate will decrease the effects of ISI. OFDM increase the robustness against frequency selective fading. In single carrier system a single fade or interferer can cause the entire link to fail, but in multicarrier only a small percentage of the subcarriers will be affected OFDM also provides high immunity against multipath dispersion [1,2,4].

This paper investigates spectral efficiency and bit error rate of OFDM system over AWGN channel for different QAM modulation techniques. Simulation results show that better spectral efficiency obtained with the lower order QAM modulation technique. The comparative study of BER over different modulation techniques show that minimum BER can be achieved by 16QAM modulation technique with lower coding rate.

The rest of the paper is organized as follows: Description of the transmitter and receiver model for OFDM system is given in Section 2. Performance results are shown in section 3 and paper is concluded in section 4.

II. SYSTEM MODEL

System model is based on OFDM. In OFDM a high-rate data stream is divided into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. The relative amount of dispersion in time caused by multipath delay spread is decreased because the symbol duration increases for lower rate parallel subcarriers. Therefore it is used to enhance the data rate transmission between transmitter and receiver. OFDM transmitter and receiver are described in next section.

A. OFDM Transmitter

OFDM transmitter is shown in Fig-1. Randomly generated data are encoded by forward error correcting code, in which Reed

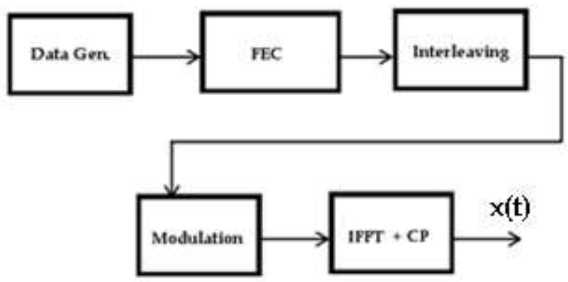

Fig.1 OFDM transmitter

Solomon and convolutional coding are used. This coded data are interleaved and modulated. Different QAM techniques are used for modulation. The modulated output is transmitted simultaneously on N parallel subcarriers of bandwidth Δf. These parallel subcarriers are orthogonal to each other and can be generated by using Inverse Fast Fourier transform (IFFT). Now cyclic prefix is added as a guard interval to minimize the effect of Inter Carrier Interference (ICI). Finally parallel to serial converter (P/S) converts parallel data into serial data stream and transmit over channel. Let us denote N frequency domain subcarrier as $S = [S_0, S_1, S_2, \ldots\ldots, S_{N-1}]$. In time domain operation $s = [s_0, s_1, \ldots\ldots\ldots, s_{N-1}]$. Thus the sampled transmitted sequence is given by

$$s[n] = \frac{1}{N}\sum_{k=0}^{N-1} S[k]e^{\frac{j2\pi kn}{N}} \quad , \quad 0 \le n \le N \qquad (1)$$

B. OFDM Receiver

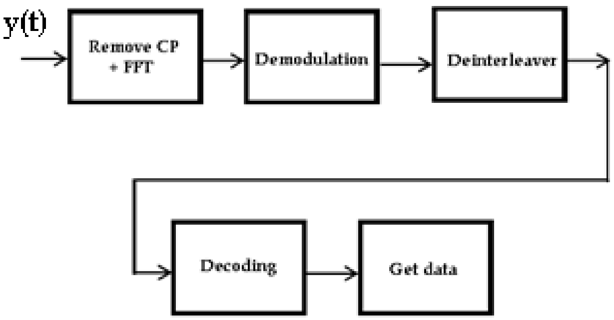

Fig.2 OFDM Receiver Model

Receiver model of OFDM is shown in Fig-2. From serial to parallel converter (S/P) received signal converts serial data into parallel. Cyclic prefix is removed from parallel converted data and then inverse IFFT is performed. These data are demodulated. The output of demodulator passes through the channel decoder to obtain the users data. The received signal is given by

$$r[n] = \sum_{k=0}^{N-1} R[k]e^{\frac{j2\pi kn}{N}} \quad , \quad 0 \le n \le N \qquad (2)$$

Where *r[n]* is the sampled received signal and *R[k]* is the received complex modulation symbol of the *kth* subcarrier. The received symbol after multicarrier demodulation is

$$R[k] = H[k]S[k] + \eta \qquad (3)$$

Where *H[k]* is the transfer function of the channel and η is additive noise of the channel.

The spectral efficiency is presented in several ways in the literature. The spectral efficiency of a channel is a measure of the number of bits per second per Hz. We derived the spectral efficiency using the relation [5]:

$$\eta_s = (1 - BER)^l kr \qquad (4)$$

Where, *BER* is the bit error rate, *l* is the number of bits in the block, *k is* the number of bits per symbol and *r* the overall coding rate.

III. SIMULATION RESULTS

Physical layer of mobile WiMAX is simulated using OFDM. Each block of OFDM transmitter and receiver is individually coded in MATLAB. The OFDM simulation parameters are given in Table 1. The system used for simulation employs RS and convolution channel coding. In channel coding rate is taken as ½, and ¾. For Modulation 16QAM and 64QAM are used with different coding rate. Simulation is done under AWGN environment

Table 1 OFDM parameters of fixed WiMAX

S.No	Parameters	Values
1	FFT size	256
2	Number of used data subcarrier	192
3	Number of pilot subcarrier	8
4	Number of null/guardband subcarrier	56
5	Cyclic prefix	1/4
6	Coding rate	½, ¾

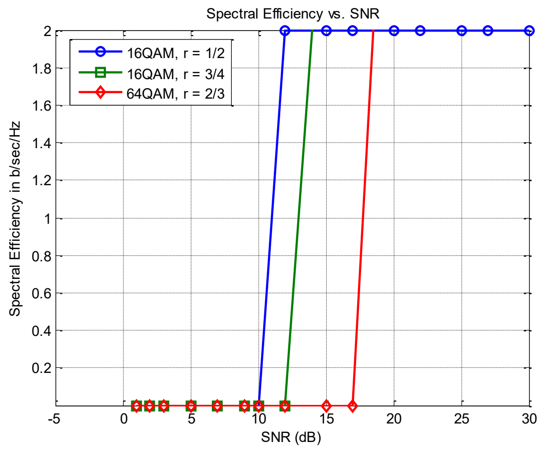

Fig.3 SE versus SNR at different modulation technique with channel coding and overall rate r = ½, ¾ and 2/3

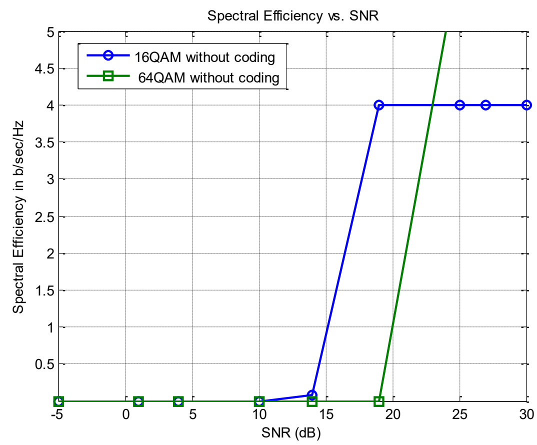

Fig.4 SE versus SNR for 16QAM and 64QAM modulation techniques, without channel coding.

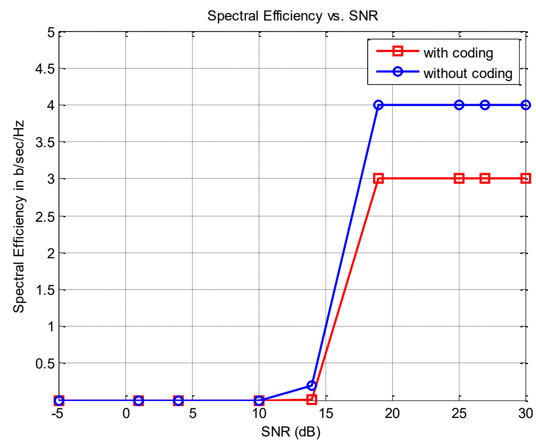

Fig.5 SE versus SNR for 16QAM modulation and overall rate r = ¾

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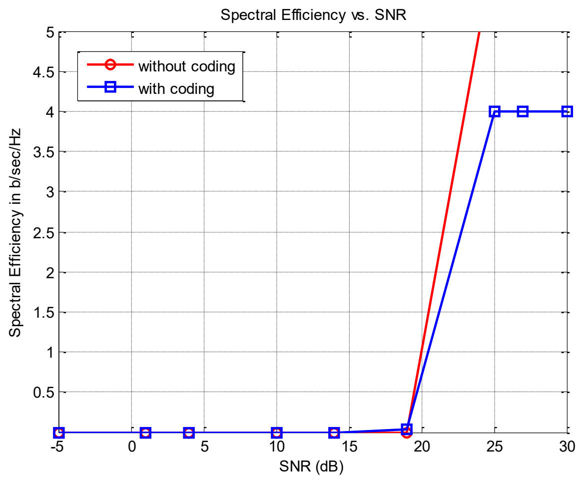

Fig.6 SE versus SNR for 64QAM modulation technique and overall rate r =2/3

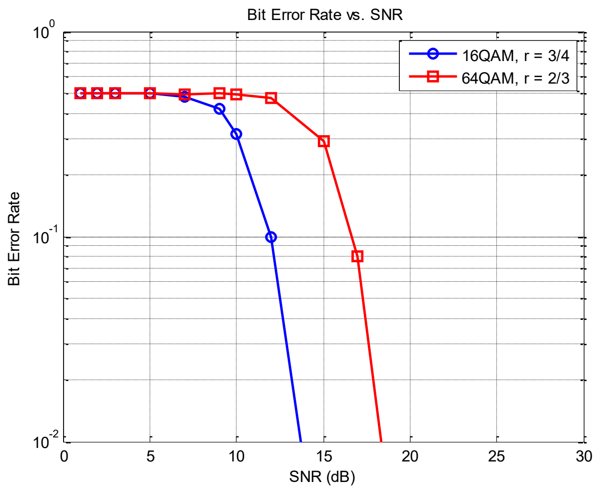

Fig.7 BER versus SNR at different QAM modulation technique, with channel coding and overall rate r = 3/4, 2/3

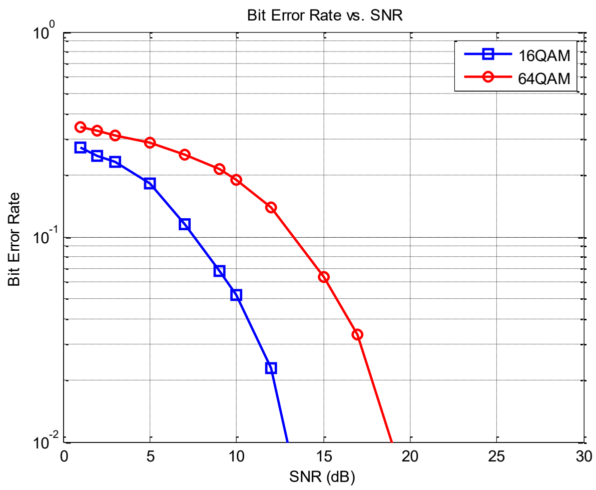

Fig.8 BER versus SNR at different QAM modulation techniques and without channel coding.

Fig-3 shows spectral efficiency of OFDM system for different order QAM modulation techniques. From figure it is observed that better spectral efficiency obtained with the lower order modulation techniques at low SNR that is 16QAM with overall coding rate is 1/2. It is clearly visible from the Fig-3 lower coding rate has better spectral efficiency than the higher coding rate at lower SNR.

From Fig-4 it is clealy visible that without channel coding better spectral efficiency obtained for 16QAM in comparison with 64QAM.

Spectral efficiency of OFDM system for without channel coding and with channel coding is compared in Fig-5 and 6 for different modulation techniques. From results it is clear that without channel coding spectral efficiency is better than the with channel coding at lower SNR.

In Fig-7 and 8 a comparison of BER performance is made among the different modulation techniques. Lower order modulation has improved BER than the higher order BER. Also BER is decreasing with SNR.

IV. CONCLUSION

In this paper we described the OFDM system over AWGN channel with QAM modulation techniques. From simulation results it is observed that better spectral efficiency obtained with the 16QAM with coding rate ½ at lower SNR. The comparative study of BER over different modulation techniques show that minimum BER can be achieved with the lower modulation technique. Coding rate also affects the BER performance. Less coding rate gives less bit error rate than high coding rate.

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