Development of Enhanced 4G Wireless Systems Using Convolutional Encoding with QAM

Shilpa Dhiman[1], Dr. Anubhuti Khare[2]
[1]M-Tech Research Scholar, [2]Research Guide, Deptt. of Electronics & Communication
UIT RGPV, Bhopal

Abstract- BER is the key parameter for indicating the system performance of any data link. In our research work we analyzed that for different values of SNR, the BER increases for high order modulation. On the other hand, the lower order modulation schemes (BPSK and QPSK) experience less BER at receiver thus lower order modulations improve the system performance in terms of BER. The BER increases for high order modulation because of the fact that higher order modulation techniques use more bits per symbol. Hence it is easily affected by the noise. From the simulation results, it is observed that the BPSK allows the BER to be improved in a noisy channel at the cost of maximum data transmission capacity. Use of QPSK allows higher transmission capacity, but at the cost of slight increase in the probability of error.

Keywords- OFDMA, 4G mobile, Additive White Gaussian Noise (AWGN), BER & SNR.

I. INTRODUCTION

In order to fulfill the increasing demands of internet access on mobile phones, wireless telecommunication industry has defined a new air interface for mobile communications called Worldwide Interoperability for Microwave Access (WiMAX) and Third Generation Partnership Project Long Term Evolution (3GPP LTE). To provide voice, data, video and multimedia services on mobile phones at high speeds and low rates are the prominent aims of these technologies. Fourth generation (4G) also called Next Generation Network (NGN) offers one platform for different wireless networks which are connected through one IP core which also decreases latency. 4G integrates the existing heterogeneous wireless technologies such as WiMAX, UMTS, WLAN and GPRS by avoiding the need of new uniform standard. 4G networks will increase the data rates incredibly, by providing 100Mbps to 1Gbps in stationary and mobile environment respectively. In 4G the integration of network and its applications is seamless therefore there is no risk of delay. Figure 3.1 shows the evolution of 4G mobile wireless system. The evolutions of WiMAXv2 (based on IEEE 802.16m) and the evolution of LTE called LTE–Advanced (LTE-A) are the main contenders for 4G wireless systems. Worldwide Interoperability for Microwave Access (WiMAX) technology, also known as the IEEE 802.16 standard, is based on WMAN (Wireless Metropolitan Area Network). It provides data rates up to 75 Mbps over the distance of 50 km.

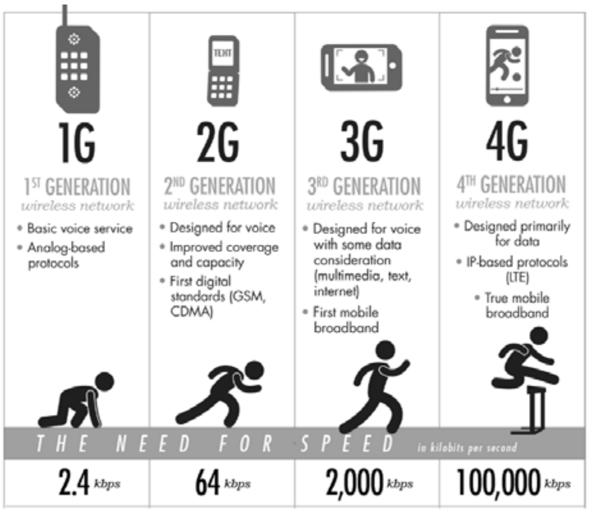

Figure 1.1: Evolution of 4G Mobile Wireless System

WiMAX uses frequency bands of 10-66 GHz. WiMAX uses OFDMA (Orthogonal Frequency Division Multiple Access) as multiplexing technique in uplink and downlink directions. WiMAX covers large geographical areas using licensed or unlicensed spectrum in order to provide wireless Internet services to users with high data rates. It is also provides wireless broadband services within a building from an Internet Service Provider (ISP) and can be used to connect many Wi-Fi networks across different campuses or cities. WiMAX works like any other cellular technology and uses a base station to establish the wireless connection to the subscriber such as Universal Mobile Telecommunication Systems (UMTS). The communication between two or more WiMAX base stations could be Point to Point/ Line of Sight (LOS) whereas between the base station and the subscriber can be Point to Multi Point/ Non Line of Sight (NLOS).

Salient Features of WiMAX

Some of the more salient features of WiMAX that deserve highlighting are as follows:

- OFDM-based physical layer which eliminate multipath effect and allows WiMAX to operate in NLOS conditions.
- Very high peak data rates of 74Mbps when operating using a 20MHz wide spectrum.

- WiMAX has a scalable physical-layer architecture that allows for the data rate to scale easily with available channel bandwidth.
- WiMAX supports a number of flexible adaptive modulation schemes and forward error correction (FEC) coding schemes.
- Support for TDD and FDD as well as a half-duplex FDD, which allows for a low-cost system implementation.
- Orthogonal frequency division multiple access (OFDMA) implementation which facilitates the utilization of frequency diversity and multiuser diversity to significantly improve the system capacity.
- Flexible and dynamic per user resource allocation in both uplink and downlink.
- The WiMAX physical-layer design allows for the use of multiple-antenna techniques, such as beamforming, space-time coding, and spatial multiplexing.
- Quality-of-service support by WiMAX MAC layer which includes a variety of applications such as voice and multimedia services.
- WiMAX supports strong encryption, using Advanced Encryption Standard, and has a robust privacy and key-management protocol.
- The WiMAX Forum has defined a reference network architecture that is based on an all-IP platform. It facilitates easy convergence with other networks, and exploits the rich ecosystem for application development that exists for IP.

Fixed vs. Mobile WiMAX

IEEE 802.16-2004 is known as fixed WiMAX. It uses OFDM to mitigate the effects of multipath and improves the propagation of signals in NLOS. Fixed WiMAX has no mobility and this is also the reason why it does not support handovers. The mobile WiMAX (IEEE 802.16-2005) uses Scalable Orthogonal Frequency Division Multiplexing Access, which divides the carrier up to 2048 subcarriers. This division of the carrier signal makes it possible to improve the signal penetration into the buildings and should enable cheaper products for the end subscriber. A comparison between Fixed and Mobile WiMAX is shown in Table 3.1 [19].

II. SYSTEM MODEL

LTE is an emerging technology for higher data rates in cellular 4G services. LTE is developed as an improvement to Universal Mobile Telecommunication System by 3rd Generation Partnership Project (3GPP) and that project was started in 2004. It brought many benefits to cellular networks in terms of bandwidth, latency, data rates, spectral efficiencies etc. The LTE increases the system capacity and widens the spectrum from existing technology up to 20MHz. It can be deployed in any bandwidth combination because of its flexible usage of spectrum (1.4 MHz to 20 MHz). It uses Frequency Division Duplex (FDD) and Time Division Duplex (TDD) to suit all types of spectrum resources. The mobile TV broadcast is facilitated by LTE over LTE network.

The OFDM is used in LTE as multiplexing scheme; LTE uses SC-FDMA for uplink and OFDMA for downlink transmission. One drawback of OFDM is high peak-to-average power ratio (PAPR). PAPR occurs due to constructive addition of sub-carriers and which results in spectral spreading of the signal leads adjacent channel interference. Hence, LTE uses Single Carrier FDMA (SC-FDMA) with cyclic prefix on the uplink which reduces PAPR as there is only a single carrier as opposed to *N* carriers.

LTE Multiple Access Techniques

The first major design in LTE was to adopt multicarrier approach for multiple access schemes. After proposing this step the candidates for downlink were multiple WCDMA and OFDMA while the candidate for uplink were WCDMA, OFDMA and SC-FDMA. Finally in 2005 it was decided to select OFDMA as a downlink multiple access scheme and SC-FDMA for uplink. Single-carrier means that the information is modulated to only one carrier by adjusting amplitude, phase or both of the carrier signals.

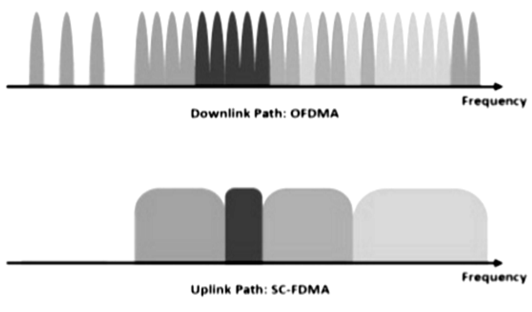

Figure 2.1: Frequency Domain Representation of LTE Access Techniques

OFDMA is robust against multipath fading. In OFDMA transmitter, the available spectrum is divided into number of orthogonal subcarriers. The subcarrier spacing for LTE system is 15KHz with 66.67μs OFDMA symbol duration. The high bit-rate data stream passes through modulator, where adaptive modulation schemes such as (BPSK, QPSK, 16-QAM, 64-QAM) is applied. This multilevel sequence of modulated symbols is converted into parallel frequency components (subcarriers) by serial to parallel converter. The IFFT stage converts these complex data symbols into time domain and generates OFDM symbols. A guard band is used between OFDMA symbols in order to cancel the Intersymbol Interference at receiver. In LTE, this guard band is called Cyclic Prefix (CP) and the duration of the CP should greater than the channel impulse response or delay spread. In LTE, the OFDMA uses two types of CP that are normal CP and extended CP. The normal CP is used for high frequencies (urban areas) and extended CP for lower frequencies (rural areas). At receiver, the CP is removed first and then subcarriers are converted from parallel to serial sequence. The FFT stage further converts the OFDM symbols in to frequency domain followed by equalizer and demodulation.

III. PROPOSED METHODOLOGY

Figure shows the block diagram of the model we used to simulate OFDMA system. We wrote a MATLAB program to simulate the model shown. The focus of the 4G development in the MATLAB software is based on the adaptive modulation techniques. The OFDM simple model which the data stream is first subdivided into a number of sub-streams where each one has to be modulated over a separate carrier signal, called sub carriers.

This subsection describes the transmitter module used for the simulation. In this section the serial input bits are first converted into parallel data streams. Then intereleaving and convolution encoding is performed on it. Interleaving is used to combat burst error during transmission in frequency selective channel. A convolutional encoding is a type of error-correcting code that generates parity symbols to enhance redundancy. The data bits are directly mapped to the complex modulation symbols by using adaptive modulation techniques which are BPSK, QPSK, 16-QAM. The resulting modulated signals are then multiplexed before their transmission by applying the Inverse Fast Fourier Transform (IFFT). The model uses the concept of cyclic prefix that adds additional bits at the transmitter end and then the receiver removes these additional bits in order to minimize the inter symbol interference, improving the bit error rate and reduce the power spectrum. After adding cyclic prefix the parallel data streams are converted back into serial data for transmitting it on the AWGN channel. The AWGN channel adds noise.

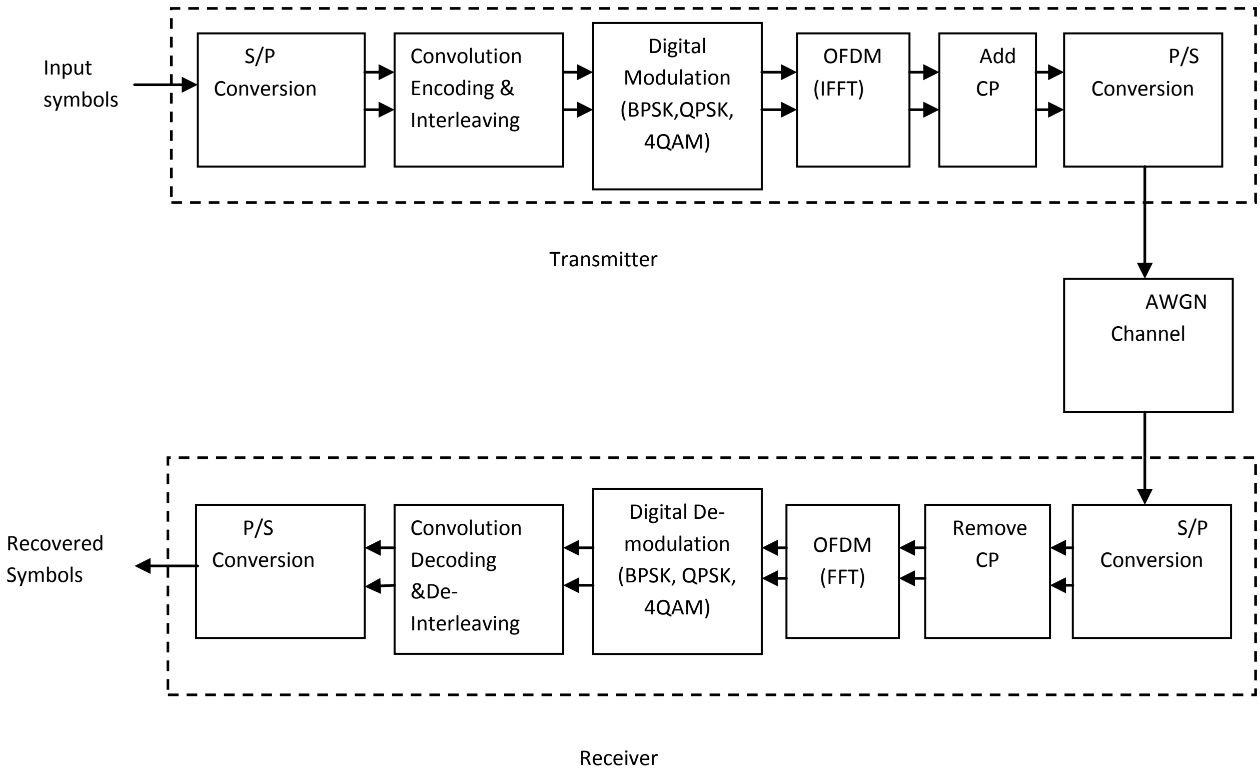

Figure 3.1: Block diagram of the OFDMA system model

Simulation Parameters

We performed our simulation on MATLAB Version 7.12.0.635 (R2011a) with simulation parameters shown in Table 1.

Table 1: Parameters used for simulation

PARAMETERS	ASSUMPTIONS
Channel	AWGN Channel
Cyclic Prefix Ratio	1/16
Data Size (No. of simulated bits)	10^6, 10^5
Digital Modulation Scheme	BPSK, QPSK, 4QAM
FFT and IFFT Size	2, 4
Range of SNR in dB	1 to 15
System Bandwidth (MHz)	5

Following are the steps we followed while writing the program to simulate the model.

- First the simulation environment has been created in which set the value of different parameters as specified in Table 5.1.
- Then the generation of a random binary data has been done and convert it into logical data.
- After this perform convolutional encoding and interleaving on this logical data, respectively.
- Then modulated these streams of data using different modulation schemes. Here we used BPSK, QPSK and 4QAM modulation.
- Then the IFFT has been taken for these mapped streams of data.
- The CP appended by taking some portion from end of each symbol and adding it at the beginning of the symbol.
- Then AWGN channel has been created the noise level is described by SNR per sample and passed serial data stream through this channel.
- CP has been removed from each symbol of corrupted data from channel
- Then perform the reverse function of IFFT that is FFT.
- Demodulate this data by previously mentioned modulation schemes.
- Then de-interleaving and convolution decoding is performed.
- BER has been calculated for received data from each modulation schemes.
- Then display the simulation result.

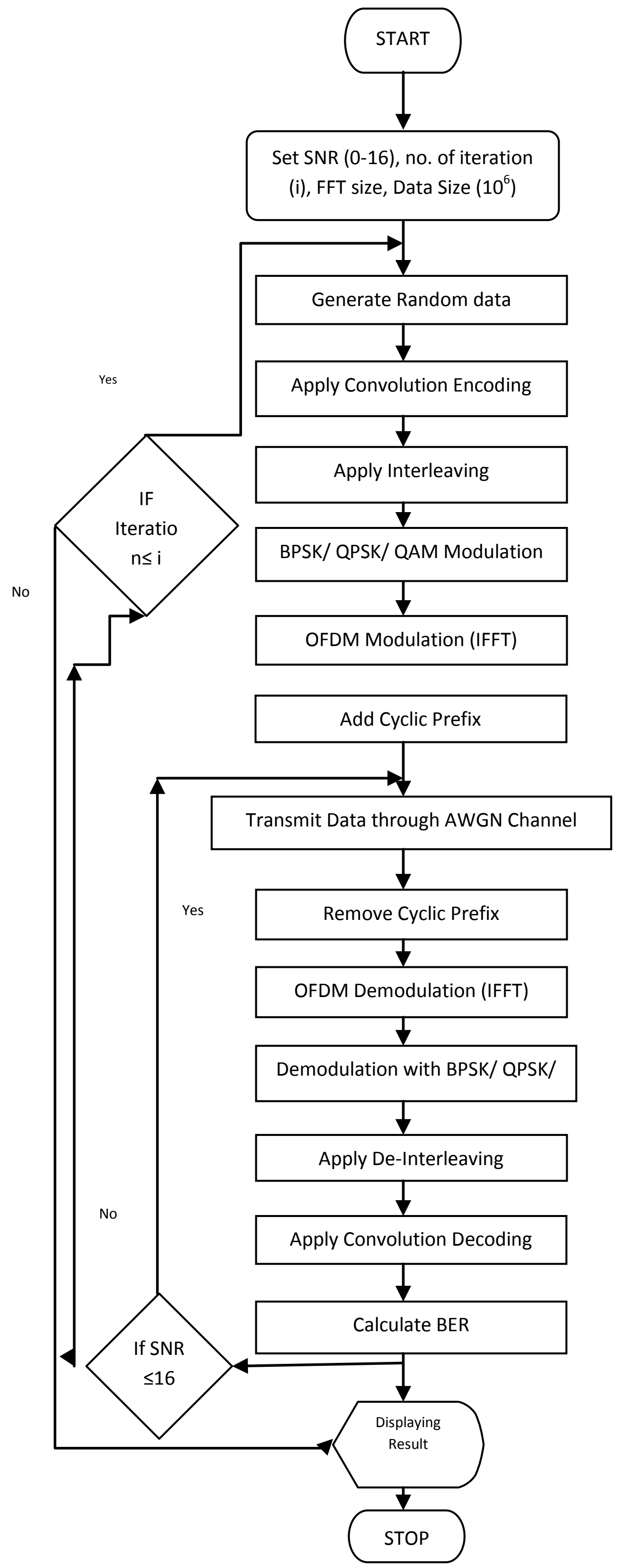

Figure 3.2: Flowchart of Simulation

IV. SIMULATION AND RESULTS

The BER is ratio of number of error bits and total number of bits transmitted. It is given by the following formulae:

BER = Number of Error Bits / Total Number of Transmitted Bits

To plot BER performance first we simulated the developed model and calculate BER for different Signal to Noise Ratio (SNR) values using the above formulae. Then we plotted these values against corresponding SNR values. The procedure was repeated for different modulation techniques.

The SNR is the ratio of bit energy (E_b) to the noise power spectral density (N_0) and it is expressed in dB.

$$SNR = E_b / N_0$$

For any modulation scheme, the BER is expressed in terms of SNR. BER is measured by comparing the transmitted signal with received signal, and compute the error counts over total number of bits transmitted.

Simulation Results for 4 Point FFT OFDM with BPSK

For particular SNR value system is simulated and corresponding probability of error (Bit Error Rate, BER) is calculated.

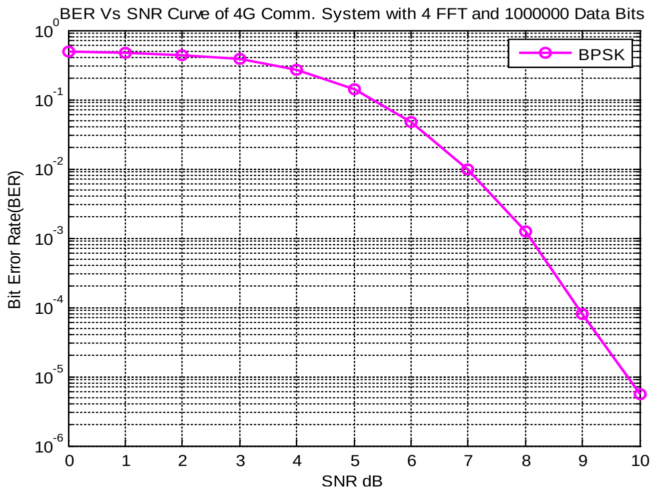

Figure 4.1: BER versus SNR curve for OFDM with BPSK

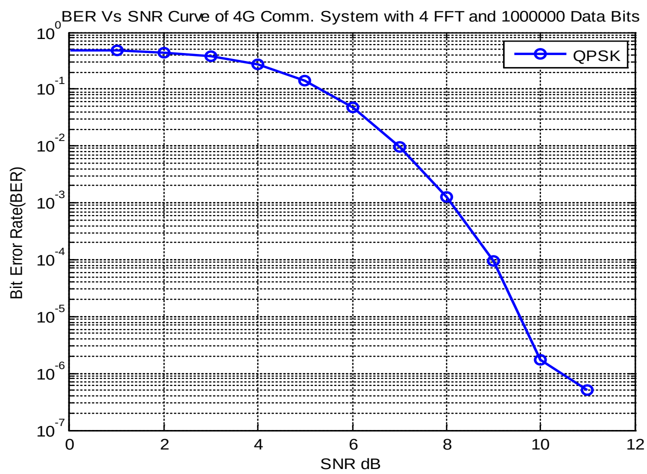

Figure 4.2: BER versus SNR curve for OFDM with QPSK

Figure 4.1 shows the nature of the BER versus SNR curve. As we go on increasing the SNR value, bit error rate reduces.

No. of bits transmitted = 1000000

FFT size = 4

6.3 Simulation Results for 4 Point FFT OFDM with QPSK

6.4 Simulation Results for 4 Point FFT OFDM with 4-QAM

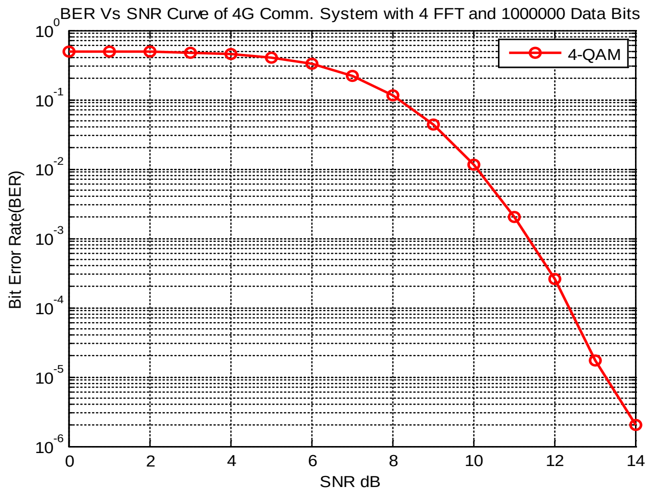

Figure 4.3: BER versus SNR curve for OFDM with 4-QAM

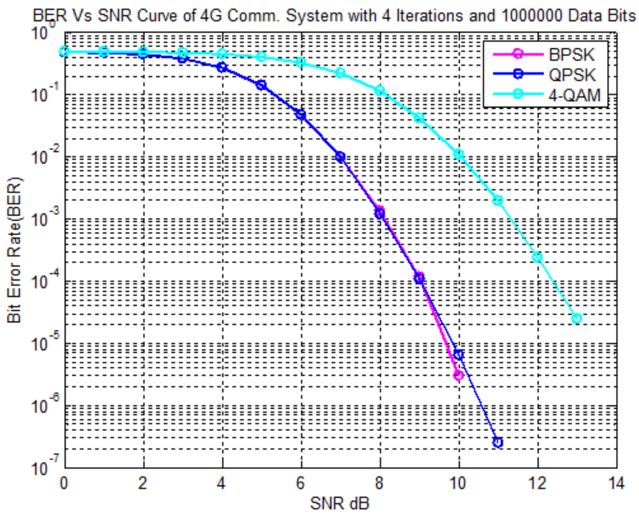

Figure 4.4: Comparison of 4 Point FFT OFDM System with BPSK, QPSK and 4-QAM

6.5 Comparison of OFDM System with BPSK, QPSK and 4-QAM

Tabel 6.1: Comparison of 4 Point FFT OFDM System with BPSK, QPSK and 4-QAM

SNR(dB)	BER(BPSK)	BER (QPSK)	BER(4-QAM)
0	0.4885	0.4891	0.4976
1	0.4747	0.476	0.4942
2	0.4443	0.4452	0.4881
3	0.3812	0.3825	0.4762
4	0.2736	0.2743	0.4528
5	0.1412	0.1424	0.4058
6	0.04746	0.04794	0.3289
7	0.009963	0.09564	0.222
8	$1.235x10^{-3}$	$1.225x10^{-3}$	0.1141
9	$1.025x10^{-4}$	$8.47x10^{-5}$	0.04293
10	$3.25x10^{-6}$	$0.275x10^{-5}$	0.01132

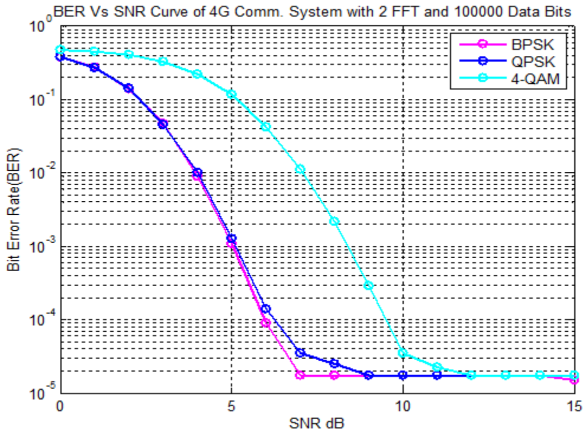

Figure 4.6: Comparison of 2 Point FFT OFDM System with BPSK, QPSK and 4-QAM

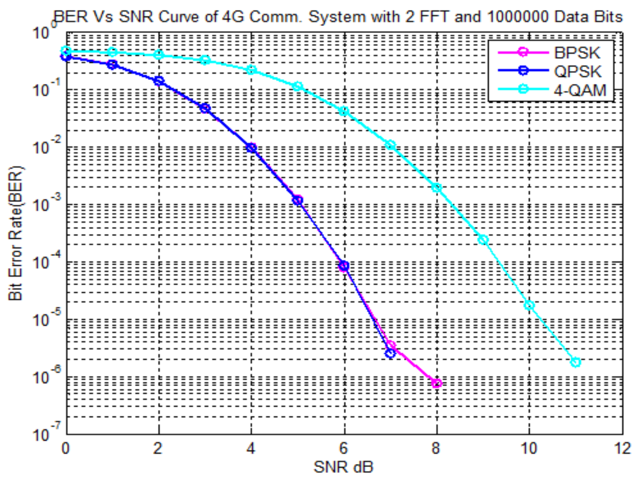

Figure 4.7: Comparison of 2 Point FFT OFDM System with BPSK, QPSK and 4-QAM

V. CONCLUSION AND FUTURE SCOPE

The OFDM makes efficient use of available spectrum by allowing overlapping among the carriers. It basically converts the high data rate stream in to several parallel lower data rate streams and thereby eliminating the frequency selective fading. It has been seen that the OFDM is a powerful modulation technique that is capable of high data rate and is able to eliminate ISI. It is computationally efficient due to the use of FFT techniques to implement modulation and demodulation functions. Using MATLAB software, the performance of OFDM system was tested for the three digital modulation techniques namely BPSK, QPSK and 4QAM. The performance of OFDM system was also tested for the two different size FFT and data bits and there combinations.

REFERENCES

[1] T.S. Rappaport and others, *Wireless communications: principles and practice*, Prentice Hall PTR New Jersey, 1996

[2] Wikipedia: The Free Encyclopaedia https://en.wikipedia.org/wiki/: accessed on May 28, 2016.

[3] A. F. Molisch, Wireless Communications, 2nd ed. Chichester, England:John Wiley and Sons, 2011.

[4] Popescu O. and Popescu D. C. (2014), "*On the performance of 4G mobile wireless systems with multiple antennas*" IEEE, 10th International Conference on, Bucharest, 2014, pp. 1-4.

[5] Kumar P. S., Sumithra M. G. and Kumar E. P. (2013), "*Performance analysis of PAPR reduction in STBC MIMO-OFDM system*" IEEE, Fifth International Conference on Advanced Computing (ICoAC), Chennai, pp. 132-136, 2013.

[6] Jemmali, A.; Conan, J.; Torabi, M. (2013), "*Bit Error Rate Analysis of MIMO Schemes in LTE Systems*" IARIA, The Ninth International Conference on Wireless and Mobile Communications

[7] Astawa G. P., Moegiharto Y., Zainudin A., Salim I. D. A. and Anggraeni N. A. (2013). "*Performance Analysis of MIMO-OFDM Using Convolution Codes with QAM Modulation*" World Academy of Science, Engineering and Technology, International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:7, No:12, 2013

[8] Parveen N. and Venkateswarlu D. S. (2012), "*Implementation of MIMO-OFDM using adaptive multiuser detection in wireless communication*", Communications, Devices and Intelligent Systems (CODIS), International Conference on, Kolkata, 2012, pp. 381-384.

[9] Goel A. and Garg M. K. (2012), "*Comparative Performance Evaluation of Convolutionally Coded and LDPC Coded OFDM System Over AWGN and SUI-5 Fading Channel*", IEEE, 2012 Third International Conference on Computer and Communication Technology.

[10] Mohankumar N. M. and Devaraju J. T. (2012), "*Performance Evaluation of Multi Antenna Techniques in LTE*", IEEE

[11] Srikanth, S., Murugesa Pandian, P. A., and Fernando, X. (2012), worked on "*Orthogonal Frequency Division Multiple Access in WiMAX and LTE: A Comparison*", IEEE Communications Magazine, September 2012

[12] Maslennikov, R.; Trushanin, A.; Shkerin, M.; Shashanov, M.; and Czerepinski, P. (2011), "*Analysis of multiple antenna transmission for HSUPA*", IEEE, 2nd International

Workshop on Recent Advances in Broadband Access Networks.

[13] Adnan T., Masood A. (2011) "*Use of Convolution Coding for Improving SER Performance of OFDM System*", IEEE

[14] T. I. White Paper (2010), "*WiMAX LTE Technology Migration*"

[15] T. I. White Paper (2010), "*LTE in a Nutshell: The Physical Layer*"