Implementation of M-QAM techniques in 4G Communication

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Abstract:
This paper presents implementation of OFDM with M-QAM techniques on BER performance with an AWGN channel model. We evaluated the performance of OFDM in the downlink using M array QAM.These modulation schemes are the 16-QAM and 64-QAM and 256-QAM, in order to improve achievable data rated. Simulations are performed and demonstrate the effectiveness based on recovered data bits, the obtained bit error rates are analysed, compared and discussed at different SNR values.

***Keywords**: 16-QAM; 64-QAM;256 QAM; BER and SNR.*

I. Introduction

Evolution of cellular wireless communication systems from 1G to 4G is all about transmitting higher rates of data at faster speed such that one is able to access high quality multimedia on the network. LTE (Long Term Evaluation) is the current 4G Cellular Technology. LTE uses OFDM with QAM modulation in 10 or 20 MHz channels along with MIMO to provide downlink data rates of up to 150 Mb/s. More recent versions such as LTE-Advanced and LTE-Advanced Pro use carrier aggregation (CA) to widen the bandwidth by combining up to 32 channels to achieve 100 MHz or more of bandwidth to get even higher speeds. With the right combination of CA, 256 QAM and 4 × 4 MIMO, LTE can achieve data rates up to 1 Gb/s.

Wireless Communication Systems depends on modulation techniques, i.e., how to modulate signals in different phases, amplitudes and frequencies such that one can transmit higher data rates with good efficiency. These techniques include OFDM, QPSK, QAM, MPSK, MPAM, MFSK and GMSK. In our simulation we will be looking at QAM or M–QAM which is an acronym of M Quadrature. Amplitude Modulation and here M depict how many bits are transmitted per time interval or symbol for each unique amplitude/phase combination. The term "symbol" means some unique combination of phase and amplitude. The value of M which can be 4, 16, 64, 256, etc. indicates the number of combinations a set of bits can have while a unique combination of bits represents a unique phase angle and a unique amplitude in the transmitted signal. The distance between the coordinate and the center indicates the amplitude while the M-QAM is also called BW Conservation scheme as in the same limited BW we are able to transmit higher rates of data thereby in the same BW the speed of data transmission increases significantly. However, the drawback with M-QAM is that as the rate of bits increase the signal becomes less resilient according to Error Vector Magnitude (EVM) boundaries and in this case QPSK and BPSK are more efficient. EVM boundaries measures the distance (error) of displacement of coordinate in the constellation diagram which is the distortion of the wavelength or amplitude of the signal from an ideal position. The boundaries of error in BPSK are the widest that is within those boundaries any distortion in respect to ideal position will still indicate the bit 1 or 0 as if it was supposed to indicate at the ideal position. The boundaries shorten as we increase the number of bits per signal. This simply means that at higher bit transmission rate the signal does not have much freedom to distort in wavelength or amplitude from its ideal position.

II. Methodology

a) Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transport technology for high data rate communication system. The OFDM concept is based on spreading the high speed data to be transmitted over a large number of low rate carriers. The carriers are orthogonal to each other and frequency spacing between them are created by using the Fast Fourier transform (FFT).It originates from Frequency Division Multiplexing (FDM), in which more than one low rate signal is carried over separate carrier frequencies. In FDM, separation of signal at the receiver is achieved by placing the channels sufficiently far apart so that the signal spectra does not overlap. Of course, the resulting spectral efficiency is very low as compared with OFDM, where a comparison is depicted in Fig. Also, analogy of OFDM against single carrier and FDM in terms of spectral efficiency. FDM is first utilized to carry high-rate signals by converting the serial high rate signal into parallel low bit streams. Such a parallel transmission scheme when compared with high-rate single carrier scheme is costly to build. On the other hand, high-rate single carrier scheme is more susceptible to inter symbol interference (ISI). This is due to the short duration of the signal and higher distortion by its wider frequency band as compared with the long duration signal and narrow bandwidth subchannels in the parallel system. The major contribution to the FDM complexity problem was the application of the FFT to the modulation and demodulation processes. Fortunately, this occurred at the same time digital signal processing techniques were being introduced into the design of modems. Figure 1 shows the OFDM block diagram of transmitter and receiver.

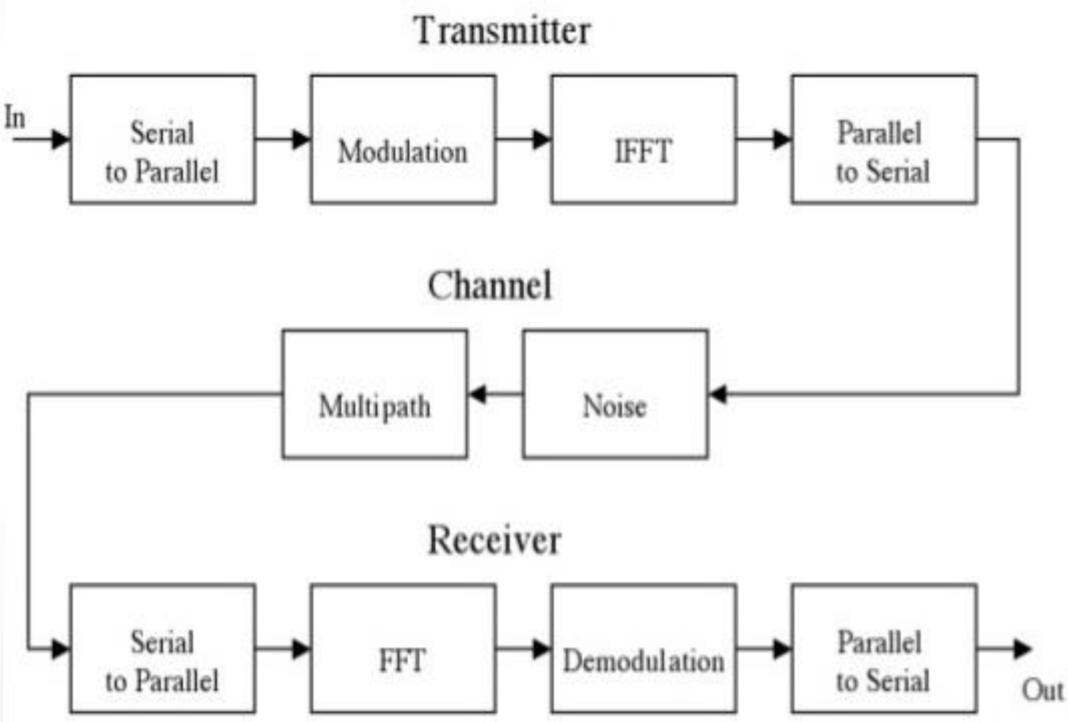

Figure 1: OFDM Diagram of transmitter and receiver

Figure 2 shows subcarriers system of OFDM signals after FFT. If N subcarriers are used, and each subcarrier is modulated using M alternative symbols, the OFDM symbol alphabet consists of M^N combined symbols. The low-pass equivalent OFDM signal is expressed as:

$$\nu(t) = \sum_{k=0}^{N-1} X_k e^{j2\pi kt/T}, \quad 0 \le t < T, \qquad (1)$$

Where, N is the number of subcarriers, and T is the OFDM symbol time. The subcarrier spacing of makes them orthogonal over each symbol period; this property is expressed as:

$$\frac{1}{T}\int_0^T \left(e^{j2\pi k_1 t/T}\right)^* \left(e^{j2\pi k_2 t/T}\right) dt = \frac{1}{T}\int_0^T e^{j2\pi(k_2-k_1)t/T} dt = \delta_{k_1 k_2} \qquad (2)$$

To avoid inter-symbol interference in multipath fading channels, a guard interval of length T is inserted prior to the OFDM block. During this interval, a cyclic prefix is transmitted such that the signal in the interval -Tg < t < 0 equals the signal in the interval (T-Tg) < t < T. The OFDM signal with cyclic prefix is thus:

$$\nu(t) = \sum_{k=0}^{N-1} X_k e^{j2\pi kt/T}, \quad -T_g \le t < T \qquad (3)$$

The low-pass signal above can be either real or complex-valued. Real-valued low-pass equivalent signals are typically transmitted at baseband wireline applications such as DSL use this approach. For wireless applications, the low-pass signal is typically complex-valued; in which case, the transmitted signal is up-converted to a carrier frequency fc. In general, the transmitted signal can be represented as:

$$s(t) = \Re\left\{\nu(t)e^{j2\pi f_c t}\right\}$$
$$= \sum_{k=0}^{N-1} |X_k| \cos(2\pi[f_c + k/T]t + \arg[X_k]) \quad (4)$$

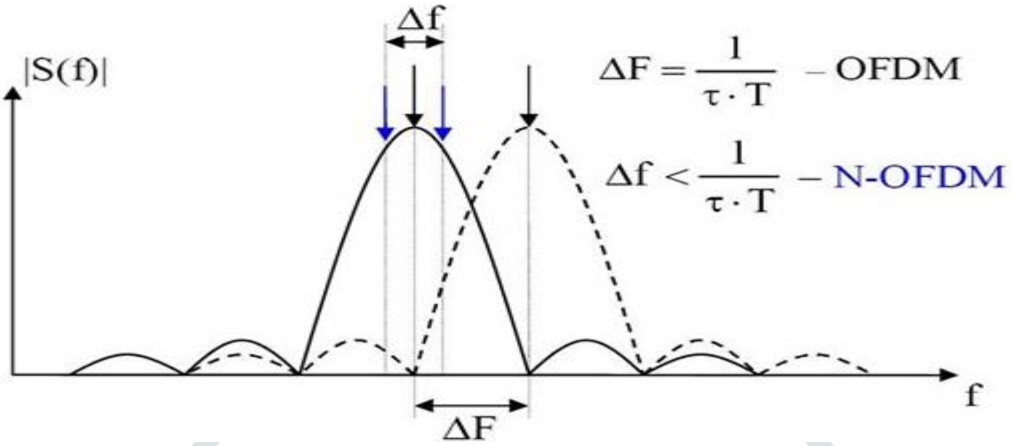

Figure 2: Subcarriers system of OFDM signals after FFT

b) M - Quadrature Amplitude Modulation (QAM)

Quadrature Amplitude Modulation or also known as M–QAM is a modulation technique involving both phase shift and amplitude shift in order to conserve bandwidth and transmitting more information within the same. The term M here is an indication of the number of bits transmitted per time interval or per symbol; here "symbol" is a unique combination of phase and amplitude but as bits per symbol increase it also means that the amount of information being transmitted through that unique combination has also increased. The reason M-QAM scheme is used in 4G LTE is that it conserves both BW and power to achieve high data transfer rates within low noise immunity though the economic costs of M-QAM circuitry is costlier than PSK. Under M-QAM scheme we are able to send more bits per wave cycle however as we increase the no. of bits to be send per cycle the signal becomes less resilient to information losses as EVM (Error Vector Magnitude) boundaries gets smaller with the successive increment of bits per symbol. EVM boundaries decide the magnitude constraints (phase and amplitude) within which the distorted signal from the ideal position will not result in loss of information. The positions are those unique combinations of phase and amplitude of bits representing symbols. For example for BPSK or 2-QAM scheme the EVM boundary constraints are between 1° to 179° for one combination while its between 181° to 359° for another combination; in BPSK amplitude is nit undertaken for the representation of ideal position of the respective combinations hence it's not included in EVM boundary constraints but from 16-QAM onwards amplitude is also included as a constraints. The term "Quadrature" in M-QAM simply means 4 or 4 possible phase shifts, i.e, in M-QAM one can have a phase shift for the second input within 4 given phases namely 0°, 90°, 180°, 270°. M-QAM multiplexes signals generated through both amplitude and phase modulations to generate the output signal. The serial digital signal first goes through S/P converter such that the serial bit stream x(t) is converted into 2 parallel message bit stream $x_1(t)$ and $x_2(t)$. The digital S/P converter use D-flip flops to for the conversions and thereafter the parallel bit stream is split into two streams using shift registers. After splitting the stream goes through D/A converters in order to convert the digital signal into analog signals.

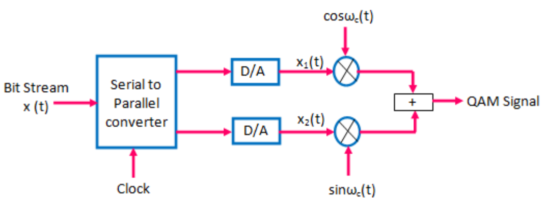

Figure 3 : Generation of QAM signal

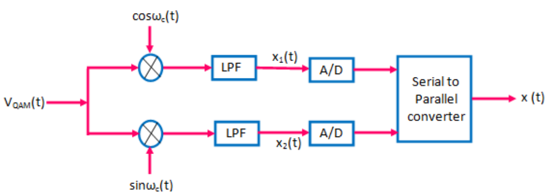

Figure 4 : QAM Receiver

As shown in figure 3 the two converted message streams $x_1(t)$ and $x_2(t)$ goes through product modulators or amplitude modulators or mixers. A local oscillator generates a carrier signal c(t) = $A\cos\omega_C(t)$ which is given to both product modulators. For message signal $x_1(t)$ the carrier signal mixes directly without any changes to its phase but for the amplitude modulation of message signal $x_2(t)$ there is an induced phase change of 90° in the carrier signal thereby $A\cos\omega_C(t)$ changes into $A\sin\omega_C(t)$ before mixing into message signal. The carrier signal c(t) is modulated in phase before mixing into message signal $x_2(t)$ and thereafter the mixed signal gets modulated in amplitude. The altered message signals due modulations with carrier signal which are also known as DSBSC (Double Sideband Suppress Carrier); are then multiplexed together to form a one signal at the output known as QAM signal $V_{QAM}(t)$.

III. Results and Discussion

Figure 5 shows the BER vs SNR plot for M-QAM modulation techniques using 16,64 and 256 QAM.So,from the figure it can be seen that 16 QAM has a BER of 0.8 at SNR 20 dB, 64 QAM has a BER of 0.9 at SNR 26 dB and 256 QAM has a BER of 1.0 at SNR 33 dB. It can be seen that with increasing M complexity increases and hence BER increases.

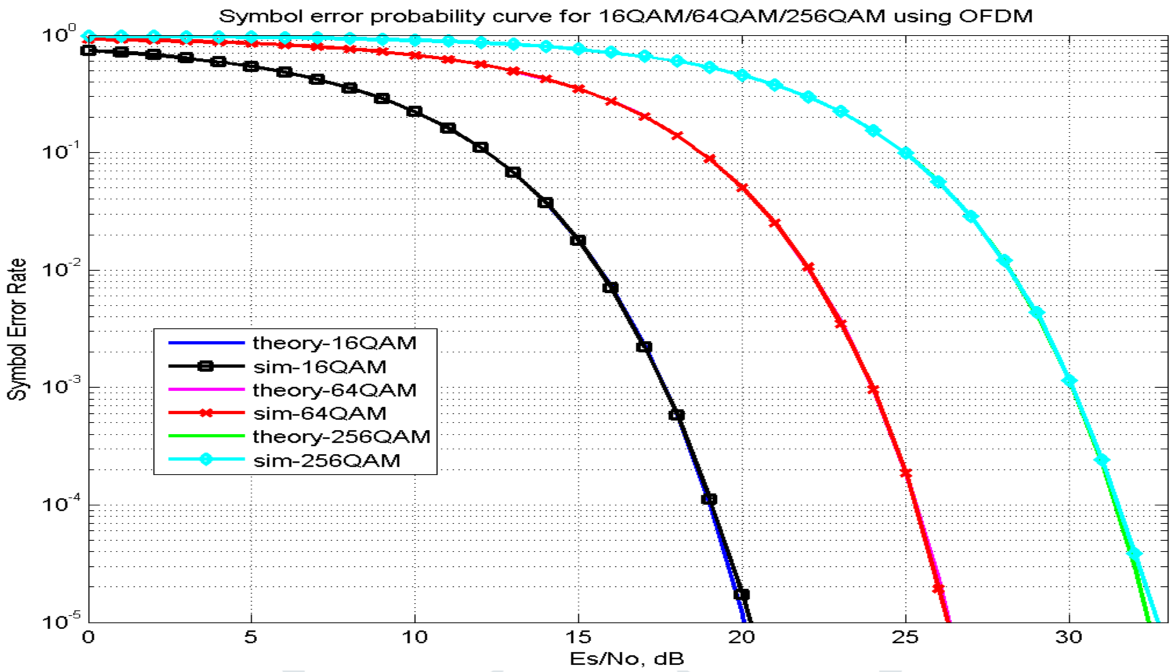

Figure 5: BER vs SNR curve for 16,64 AND 256 QAM using OFDM

IV. Conclusion

In this paper, Monte Carlo simulation were used in the downlink to demonstrate the performance of the OFDM in downlink M-ary QAM modulation was used at basic modulation techniques to evaluate the performance of the OFDM. Simulations were performed at M=16,64 and 256.BER and SNR tools were used to evaluate the graphical performance. It was observed that with increase in M,BER and complexity increases.Moreover,with the implementation of this technique, it can be used for next generation wireless communication.

References

[1] Wu and W. Y. Zou, "Orthogonal frequency division multiplexing: A multi-carrier modulation scheme," IEEE Trans. Consumer Electronics, vol. 41, no. 3, pp. 392–399, Aug. 1995.
[2] Shinsuke Hara, Ramjee,"Principle and history of MCM/OFDM," in Multicarrier techniques for 4G mobile communication, Artech House.
[3] Sandeep Kaur and Er. Pradeep Sharma,"BER and PAPR Analysis by Estimating the Channel in OFDM System,"International Journal of Advanced Research in Computer Science and Software Engineering, Volume 4, Issue 10, October 2014.
[4] Ove Edfors, Magnus Sandell and JAn-Jaap van de Beek ," An Introduction to Orthogonal Frequency-Division Multiplexing," September 1996.
[5] John G. Proakis, "Digital Communications," McGraw-Hill, l995.
[6] Orlandos Grigoriadis, H. Srikanth Kamath, "BER Calculation Using Mat lab Simulation for OFDM Transmission", Proc. Of the International multi conference of engineering and computer Scientists, 19-21 March 2008, Hong Kong.
[7] Ramjee Prasad, OFDM for Wireless Communications Systems", Artech House 2004.
[8] A. R. S. Bahai, B. R. Saltzberg, and M. Ergen,"Multi-Carrier Digital Communications –Theory and Applications of OFDM," 2nd ed., Springer.
[9] T. Hwang, C. Yang, G. Wu, S. Li, and G. Ye Li, "OFDM and its wireless applications: a survey," IEEE Trans. on Veh. Tech, vol. 58, no. 4, May 2009, pp. 1673-1694.
[10] Sanjeev Kumar, Swati Sharma, "Error Probability of Different Modulation Schemes for OFDM based WLAN standard IEEE 802.11a" *International Journal of Engineering (IJE),* Volume: 4, Issue: 4.
[11] Van Wyk, Jacques H., and Louis P. Linde. "Bit error probability for a M-ary QAM OFDM-based system." *AFRICON 2007*. IEEE, 2007.