Reliability Checking for Digital Modulation Schemes in 4G – 5G Communication system

Comparison between QPSK and QAM Modulation Techniques for Beyond LTE

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***Abstract*—In recent days, there have been a race among the communication systems in different schemes and generations. Day by day the data transmission rate is increasing and breaking the record of previous generations. Now, people are thinking of transmitting data beyond imagination. Also, engineers and scientists are also stepping forward for transmitting in a huge range of data. In recent times, 4th Generation and 5th Generation communication system are on transitional state. 4th Generation is almost getting replaced with 5th Generation communication architecture. For LTE and beyond LTE communication system several types of digital modulation schemes are used. Among them QPSK and QAM are quite frequently used. In this research paper, comparative analysis over simulation in a virtual environment (Simulink Based) for these two types of digital modulation schemes in 4G and beyond 4G communication architecture. In both of the cases, BER (Bit Error Rate) with respect to SNR (Signal to Noise Ratio) have been compared for the better and efficient output.**

***IndexTerms*—QAM, QPSK, LTE, BER, SNR etc**

I. INTRODUCTION

In case of 5G communication system modulation process is one of the major issues. If a perfect modulation system is used or a combination of two or more modulation system can be used then the dream of 5G will no longer a dream. QAM has a high data rate but its bit error rate (BER) is also high. On the other hand QPSK has data rate but its bit error rate (BER) is very low compare to QAM. In that cases a combination of this two modulation scheme can be used where QAM can be used in the area close to the tower and QPSK can be used in the border of the cells where low data rate can be accepted and also the data will be better because the BER of QPSK is low. A LTE model has been used to observe the BER rate for different modulation schemes (8 QAM, 16 QAM, 132 QAM) and QPSK. In LTE system the combination of two or more modulation system could be the best solution.

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II. RELATED STUDY

A. Evolution of Digital Communication System (1G-5G)

Depending upon the level of maturity of the underlying technology, we can divide the evolution of wireless telephone technologies into various generations. No demarcation is represented by such classifications into generations. But such generations are commonly agreed by both industry and academia and as a result it has become an unwritten standard.

An analog wireless access system represented The first generation or 1G primarily for voice traffic. This generation was represented by AMPS (Advance Mobile Phone System) in United States and the TACS (Total Access Communication System) in most parts of Europe. It was susceptible to static noise. But the foundation of "cellular" technology was laid by AMPS and it worked as a pioneer of the use of small hexagonal service areas and as a result frequency re-use across the "cells" without interference was supported by it.[1] 1G was first evolved in 1980's and later in early 1990's it was finished. The speed of 1G was limited up to 2.4kbps. [2]

Subsequently the second generation or 2G technologies replaced The 1G technology. This technology replaced analog radio network with digital radio network. The digital technology was much better than analog one as it was less susceptible to noise. Apart from that digital technology is based on discreet bi-level signals rather than continuous analog signals which makes it easier to calibrate and maintain and that's why digital one is cheaper than the analog signal. Two further classifications of 2G is Time Division Multiple Access (TDMA) based and Code Division Multiple Access (CDMA).In Europe TDMA was used and was called Global system for Mobile communications or GSM (originally Groupe Special Mobile) and CDMA was adopted by USA and was called CDMAone or standardized as IS-95a. As CDMA used spectrum in a better way it had the advantage of supporting more users than GSM. Simply in CDMA each user has a distinct code as they are orthogonal to each other so they don't interfere. digital data transfer rates varying between 4.8-14.4 kbps was supported by CDMAone whereas data rates of around 115.2 kbps was supported by CDMAtwo or IS-95b.

An interim Generation of 2.5G then replaced 2G and its extra feature was to implement a packet switched domain in addition to the circuit switched domain. GSM adopted the 2.5G technology which was also known as General Packet Radio Service (GPRS). Data speeds between 56-114 kbps was offered by GPRS. 2.75G was resembled by Enhanced Data Rates for GSM Evolution (EDGE) over GSM and CDMA2000 1xRTT over CDMA. But they could also treated as 3G technologies as they surpass the data rates of 144 kbps which is considered as the benchmark of 3G technologies the data rates of 2.75G is well below actual 3G technologies. Data rates of 236.8 kbps was provided by edge whereas 144 kbps was deployed by CDMA2000.

Then the beginning of the third Generation of Mobile technology, was came which is better known as 3G. According to The International Telecommunication Union (ITU) under the International Mobil Telecommunications Program a system to be qualified as 3G technology has to surpass the minimum data rate of 144kbps. But in reality most technologies falling into this category provide data rates typically between 5-10 Mbps. In order to attain higher data rates and enhanced services, 3G technology uses better spectral efficiency (more bits/ Hertz) over wide area cellular telephone networks. Japan installed the first pre- commercial and commercial 3G technology and South Korea followed them. In Europe the adopted 3G technology is the Universal Mobile Telecommunication System (UMTS). As the air interface it uses W-CDMA (Wideband Code Division Multiple Access). Sometimes UMTS is known as 3GSM because 3G technology has succeeded GSM. CDMA was introduced to 3G through the CDMA2000 family of protocols, especially EV-DO (Evolution-Data Optimized).

By attaining data rates up to 7.2Mbps UMTS based 3G technologies have raised themselves to 3.5G with HSDPA (High Speed Downlink Packet Access). They have a plan to progress into 4G through the 3GPP (3rd Generation Partnership Projects) where they have a strong desire achieve data rates in the order of 100Mbps downlink and 50 Mbps Uplink. Similarly the counterpart situated in North America has desire to get into 4th Generation through the 3GPP2 (3rd Generation Partnership Project 2) by attaining required data rates.

Mainly in Europe 3GPP has given 4th Generation technology development efforts the brand name of Long Term Evolution or LTE whereas in North America similar effort is termed as UMB (Ultra-Mobile Broadband) by 3GPP2. The whole discussion stated above and the evolution of different technologies is illustrated by figure 1 in ref [22]

In different analysis papers the term 5G (5th generation mobile networks or fifth generation wireless systems) has been used. Right now, in any written document the term 5G hasn't been formally used rather different telecommunication firms or standardization bodies like 3GPP and WiMAX forums have been publicly utilizing it. Hopefully around the year of 2020 5G would be implemented.[3]

Keys of 5G are

- In 5G there would be no limitation and it may be termed as REAL wireless world.
- In 5G there might be different additional options for instance there might be Multi-Media Newspapers and T.V programs would have clarity similar to HD T.V
- Internet protocol would be of version vi (IPv6) [3].

The evolution of different network technologies is illustrated by figure 1. [4-8]

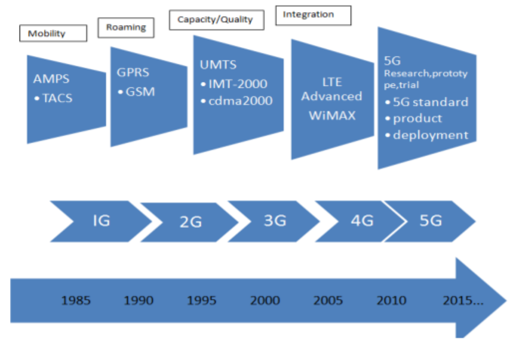

Figure1. Timeline of Mobile Cellular Network Evolution. [9]

B. *Digital Modulation*

1) QPSK

With a view of minimizing the noise or fading effect the modulation process is introduced. In the same frequency bandwidth with a view of increasing data rate research on hierarchical modulation is done [19-20]. For this same reason the competition is getting quite tough

Through the modulation process data signal can be sent over carrier signals. There are two types of modulations i.e analog and digital. In digital modulation the carrier signal is shifted in terms of amplitude, frequency, or phase where the input signal is digital signal. That's why digital signal is called shift keying. Through different M-ary PSK we can obtain different PSKs where M= no. of states or no. of phase shifts and the no. of signals that are combined for modulation are the dependent factor for M. We combine two signals for modulation in QPSK. QPSK has better Bit Error Rate (BER) than that of PSK signals which are higher in order such as 8-PSK, 16-QAM, 32-QAM etc as noise easily affects them. QPSK is also more bandwidth as well as power efficient than higher order PSK. QPSK modulator has various type of applications such as they are used in battery operated devices such as Bluetooth, TDMA cellular communication, Medical Implant Communication Services (MICS) etc. So we need to minimize the power consumption of these devices in order to ensure longevity of battery. So if we can reduce the size of circuit then we can attain longevity. [21]

Two signals can be modulated in same frequency band by the QPSK modulator and it is shown in figure.2 First of all we convert analog signal to digital then one of the signals is modulated with sine and the remaining one is modulated with cosine. As a result we get two signals with four different phase shifts. Now when we will add them we will get QPSK output signal [22]. The QPSK signal is shown below-

$$S_{QPSK} = \sqrt{\frac{2E_s}{T_s}}\cos(2\pi f_c t + (i-1)\frac{\pi}{2})$$

For i=1, 2, 3, 4…………… (1)

Here $\sqrt{\frac{2E_s}{T_s}}$= for the time period T_s and energy E_s the value of constant amplitude of the signal

f_c= frequency of carrier signal.

i= no. of phase for the signal as per the symbols of the data signal from the trigonometric equation given below,

cos(A+B) = cos(A)cos(B) - sin(A)sin(B)……………………..(2)

In figure 2 it is seen that separate sine and cosine waves are generated and in order to these signals two ROM's are required.[23]. Then input binary data signal modulated this signal. Then QPSK signal is achieved by adding these two signals. From eq. (2) the following equation can be written as:

$S_{QPSK} =$
$\sqrt{\frac{2E_s}{T_s}}\cos(2\pi f_c t)\cos\left[(i-1)\frac{\pi}{2}\right] - \sqrt{\frac{2E_s}{T_s}}\sin(2\pi f_c t)\sin\left[(i-1)\frac{\pi}{2}\right]$ ………………………………(3)

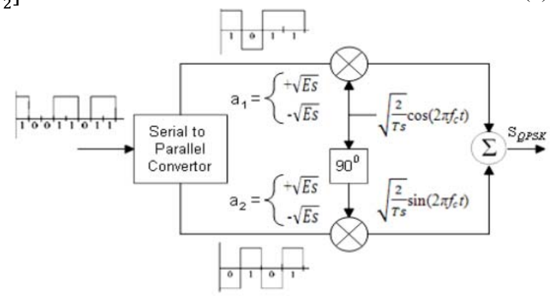

Figure 2. For QPSK modulator Conventional block diagram [21]

In QPSK two signals such as Quadrature phase Q(t) and in phase i(t) can be got. It is shown in equation (3) and it can be written in the form of

$S_{QPSK} = \sqrt{\frac{2}{T_s}}\cos(2\pi f_c t)\,I(t) - \sqrt{\frac{2}{T_s}}\sin(2\pi f_c t)\,Q(t)$…..(4)

Whereas $I(t) = \sqrt{E_s}\cos\left[(i-1)\frac{\pi}{2}\right]$ and

$$Q(t) = \sqrt{E_s}\sin\left[(i-1)\frac{\pi}{2}\right]$$

In figure 3 Output QPSK waveform which has different phase shifts is illustrated. In this figure it is shown that phase angle of original signal is different for each symbol.

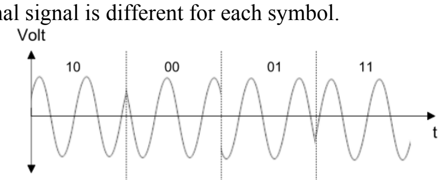

Figure 3:QPSK modulator i.e., S_{QPSk} output waveform [21]

2) QAM

As noise and other interferences sometimes or mostly corrupt information that are transmitted, effective transmission of information is ensured by one of the modulation schemes i.e Quadrature Amplitude Modulation (QAM). In this scheme we can get higher data rates and also we can maintain an acceptable bit error rate for any radio communications system which ensures a balance [24]. In case of in bandwidth efficient digital communication systems, the quadrature amplitude modulation (QAM) has been quite frequently used. Two analog message signals, or two digital bit streams are conveyed by QAM and amplitudes of two carrier waves is changed (modulated) and the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme is used for such purpose. [25]

QAM Bit Error Rate(BER) Calculation:

For MQAM error probability is:

$P_e = 1 - P_c = 2P_{\sqrt{M}} - {P_{\sqrt{M}}}^2 \le 2P_{\sqrt{M}} = \frac{4(\sqrt{M}-1)}{\sqrt{M}} Q(\sqrt{\frac{3}{M-1} \times \frac{E_{av}}{N_0}})$……(4)

$P_{\sqrt{M}}$is really small that's why $P_e \approx 2P_{\sqrt{M}}$. Bit of error is very little for each symbol error if we use Gray coding. In the top bit error bit error rate performance of the system is shown by this. So the following equation can be obtained [26]:

$P_b \approx \frac{P_e}{log_2 M} = \frac{4(\sqrt{M}-1)}{\sqrt{M}*log_2 M} Q(\sqrt{\frac{3}{M-1} \times \frac{E_{av}}{N_0}})$……………(5)

III. Experimental Setup

In the proposed model the model is consist of three major parts. They are LTE transmitter, channel, LTE receiver. In LTE transmitter part the random data has been transmitted by Bernoulli binary generator afterwards CRC code has been generated for error detection and checking and the data has been pass along with CRC. The data along with CRC has been modulated using 16 QAM modulation and OFDM multiplexing multiplex the signal. After that the training sequence has been inserted for communication purpose. As channel Raleigh fading along with AWGN has been used to make the model more realistic. In LTE receiving end the training sequence has been removed first afterwards the OFDM demodulator and remove cyclic prefix has been performed. The equalization has been done by channel estimator and channel compensation. The additional zero and discarded by remove zero block. The modulated signal has been demodulated by 16 QAM demodulator block. After that the error detection and correction has been performed and BER (bit error rate) has been calculated and showed in the model.

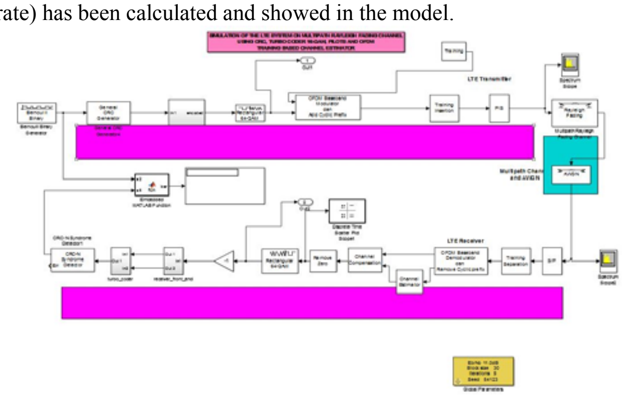

Fig. 4: [Reference must be added for Natalia model][27]

IV. Results & Simulations

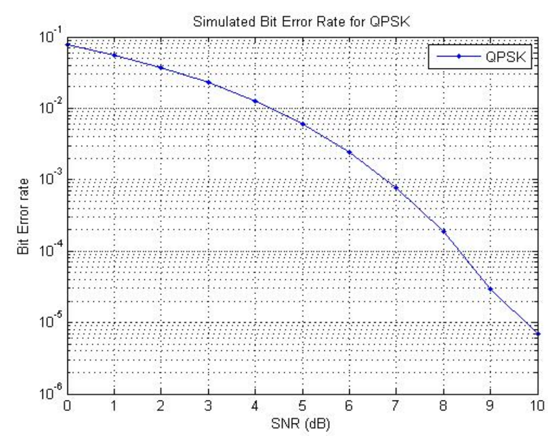

Figure 5: BER performance for QPSK

The modulation scheme of 8QAM which gives the output of BER (Bit Error Rate) shown above with respect to SNR (Signal to Noise Ratio)(in dB). From the graph of 8QAM shown above, it is clear that, for the SNR of 10 dB, the BER was close to 10^{-5}.

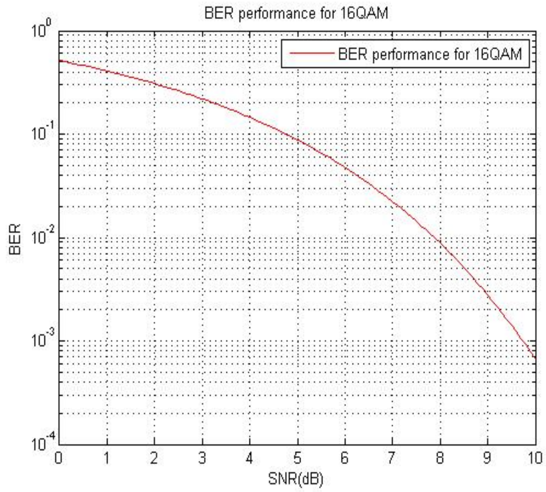

Figure.6: BER performance for 16 QAM

The given model based on what the researcher worked in this paper, is a proposed model for 4G or LTE wireless communication system. In the previous existing model, the modulation scheme was 16QAM which gives the output of BER (Bit Error Rate) shown above with respect to SNR (Signal to Noise Ratio)(in dB). From the graph of 16QAM shown above, it is clear that, for the SNR of 10 dB, the BER was close to 10^{-3}.

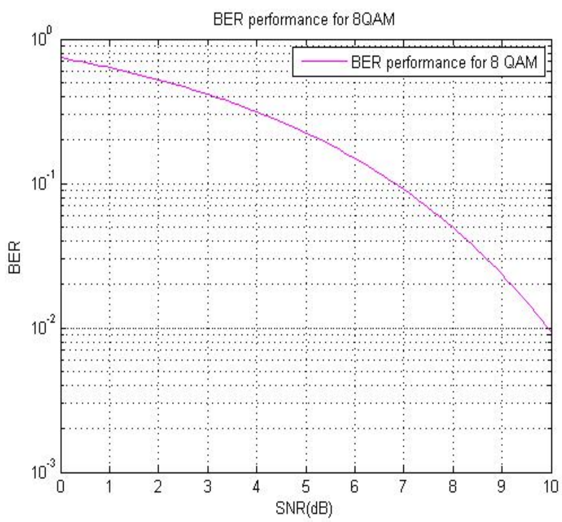

Figure 7: BER performance for 8 QAM

Different types of QAM can be used to get the expected output. it is clearly observed that the SNR of 10 dB, the BER was close to $10^{-0.2}$ for 8 QAM which is not better than the 16 QAM and it can not send as many data as 16 QAM. So in that case 64QAM or higher Quadrature amplitude modulation can be used.

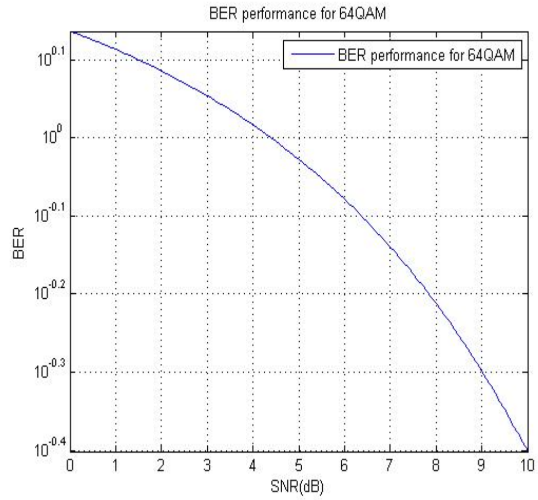

Figure 8: BER performance for 164QAM

From the Figure 7, it is clear that the output of 64 QAM (which are represented as BER and SNR) is better than 16 QAM which was 10^{-4} but still not efficient enough.

The graph shown below is the 4G simulation model result proposed by the researchers. In the graph below, the same parameters have been analyzed and observed except the modulation scheme is QPSK. In the graph below, for the SNR of 10 dB, the BER is found to be $10^{-5.2}$ which is much better than the previous output.

For the existing model, using the 16QAM modulation scheme, the BER of the whole system was 0.1352 which is weigh much larger. But as it has been seen that, using QPSK modulation the BER is lower than using 16QAM modulation scheme, it can be easily conclude that, if QPSK modulation scheme can be applied for the whole system, the BER will be minimized in a noticeable amount.

V. CONCLUSION

In case of 5G higher data rate is required with very low Bit Error Rate. Form the model has been used in this research paper is designed for 16 QAM. As 64 and 132 QAM has higher data rate so for this two modulation system better output is observed from this system. QPSK showed better performance compare to QAM (8, 16, 64, 132). So a combination of QAM and QPSK can be the better solution for implementation of 5G.

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