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To study BER in LTE system using various digital modulation techniques

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Abstract
An analysis and comparison of all modulation strategies that may be used to LTE systems operating in the OFDM AWGN channel is presented in this study. BPSK, QPSK, 16QAM, and other modulation schemes since selection of an adequate and suitable modulation technique in wireless communication systems is of paramount importance, the paper presents the modulation technique with the lowest bit error rate and investigates whether it is capable of providing the required data rate in LTE systems. The paper presents the modulation technique with the lowest bit error rate and investigates whether it is capable of providing the required data rate in LTE systems.

Keywords: BER, SNR, LTE, LTE-A, BPSK, QPSK, QAM

1. Introduction

We are now living in an age of rapid technological advancement in the field of mobile data. Increasingly, customers are requesting apps and services that are not just restricted to speech but go far beyond it as a result of the widespread usage of tablets, mobile phones, desktops, and laptops. Rapid growth and development in services and applications such as social networking, video streaming, online surfing and music consumption have pushed mobile data technology towards next-generation wireless communication standards, which are now being developed [1].

These sorts of rich multimedia applications are being delivered via LTE and LTE-A, which have been designed with the goals of increasing system capacity, increasing data rates, decreasing latency, and lowering operating costs. For the sake of this discussion, LTE and LTE-A are the representations of the fourth generation standards, which may be considered a development of the third generation [2].

The current wireless standards, LTE and LTE-A, are mostly comprised of OFDM and SC-FDMA, which are the primary components. The original version of OFDM was created in 1960. In LTE and LTE-A systems, OFDM is the dominating technology because of its characteristics, which include resilience to multipath fading channels, high spectral efficiency, and simplicity of implementation [3].

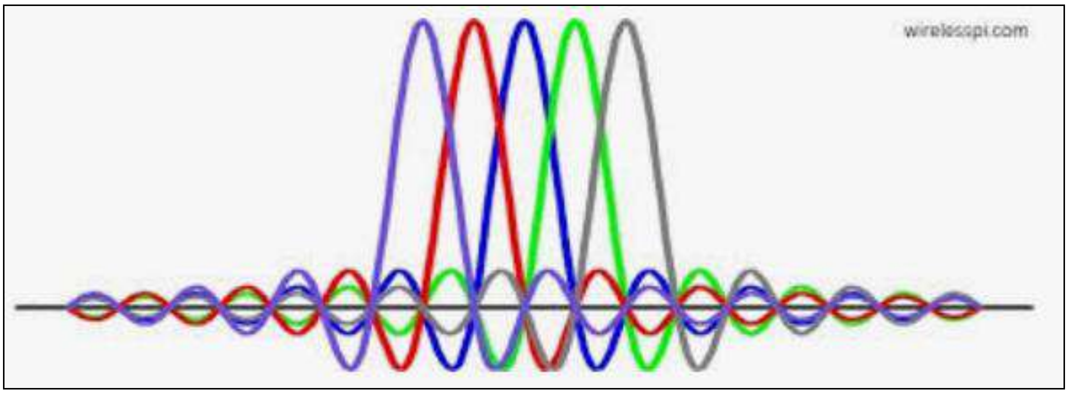
OFDM may be implemented using both digital and analogue modulation methods, depending on the application. However, digital modulation methods provide increased information-carrying capacity, enhanced data security, interoperability with digital data services, higher communication quality, rapid system availability, as well as RF spectrum sharing to accommodate an ever-increasing number of users [4].

Services are provided. As a result, digital modulation methods are becoming more popular, particularly in high data rate systems such as LTE and LTE-A. BPSK, QPSK, 16 QAM, and 64 QAM are some of the digital modulation methods that are employed in LTE and LTE-A networks. The selection of the optimum modulation method to be employed is based on many factors, including signal to noise ratio (SNR), bit error rate (BER), cost efficiency, and the capacity to deliver increased data rates. This study compares several modulation schemes in an OFDM AWGN channel on the basis of two parameters: signal to noise ratio (SNR) and bit error rate (BER).

2. OFDM

For high data rate wireless communication systems, orthogonal frequency division multiplexing (OFDM) is an extremely efficient, promising, and reliable method of transmitting several signals simultaneously.

It is used in OFDM to use a multicarrier modulation strategy, in which the data from each transmission is divided down into several new signals that are modulated to different frequency channels, after which the data is received and combined on several channels at the receiver. OFDM uses orthogonal channels that are orthogonal to one another, and these channels are referred to as subcarriers. Orthogonality is defined as the presence of two opposites.



$$\int \cos(2\pi n f t)\cos(2\pi m f t)dt = 0$$

$$(m \neq n)$$

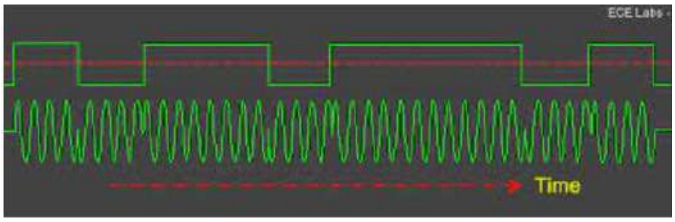
Fig 1: Orthogonal frequency division multiplexing

3. Modulation Techniques

Different modulation techniques that can be used in the LTE systems are given below

3.1 BPSK

Digital modulation techniques such as phase shift keying transfer data by altering the phase of the carrier wave, which is a kind of digital modulation. BPSK is the most basic variant of the PSK modulation (also known as 2PSK), in which two phases are separated by 180 degrees. The generic version of the equation is provided by and is as follows: [5].



$$s_n(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t + \pi(1-n)), n = 0, 1.$$

Its constellation diagram is given by

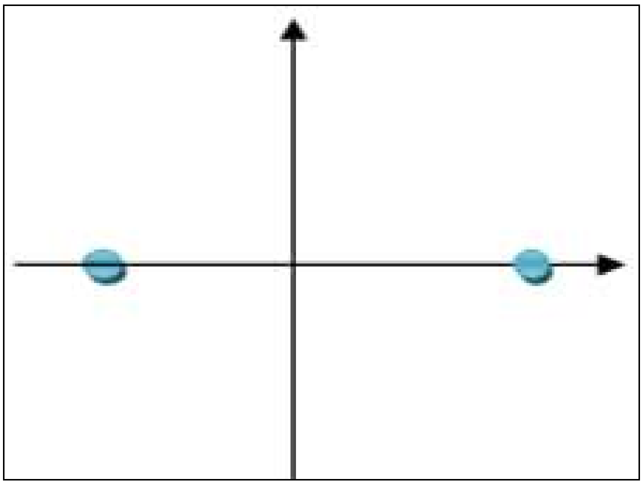
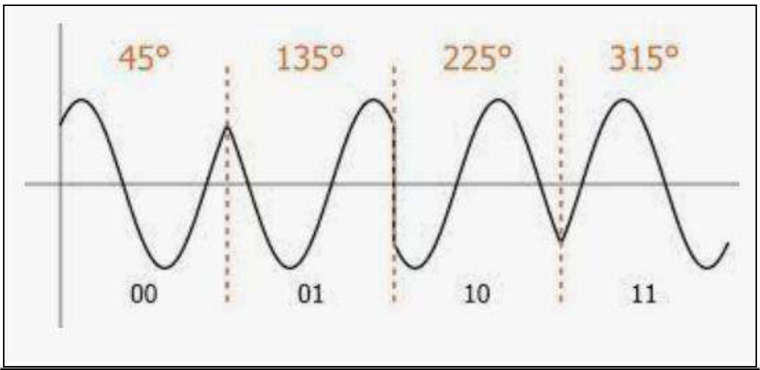


Fig 2: Constellation size example of BPSK

3.2 QPSK

Higher-order PSK is another digital modulation approach that transmits two bits per symbol concurrently by using a four-level phase state and picking one of the four carrier phase shifts of 0, 2, 3, and 3/2. Each phase shift corresponds to a bit of 00, 01, 10 and 11, respectively. As a result of utilising the same bandwidth twice, double information is sent. It is denoted by the mathematical formula.



$$s_n(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right), \quad n = 1, 2, 3, 4.$$

Its constellation diagram is given by

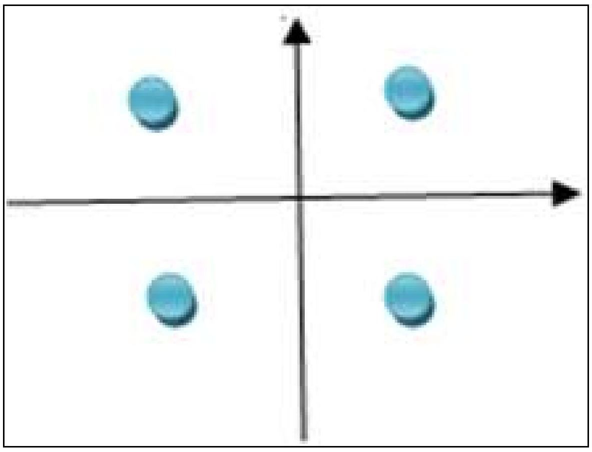
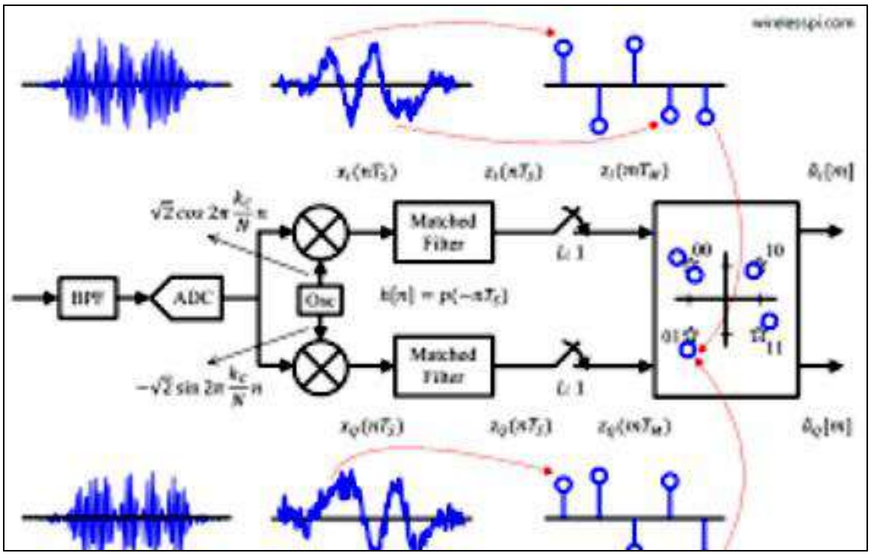


Fig 3: Constellation diagram for QPSK

3.3 QAM

With the exception of the fact that amplitude may also change with phase, QAM is similar to PSK in that it allows two separate signals to be delivered on the same carrier frequency. QAM may be divided into a variety of schemes, including 8QAM, 16QAM, 64QAM, and others. Higher order QAM provides more points inside the constellation and, as a result, is capable of transmitting more bits per symbol, allowing data to be transferred across a considerably lower bandwidth [6].



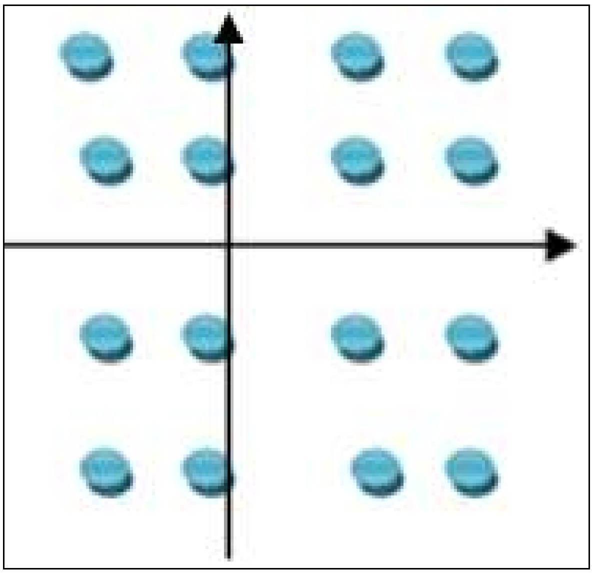
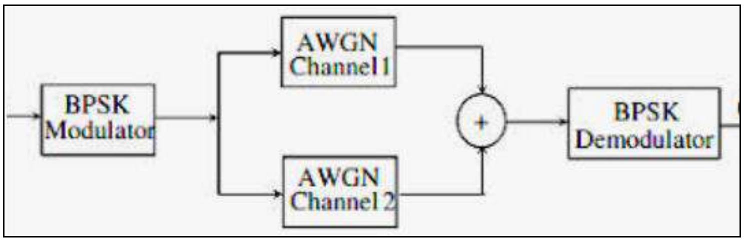


Fig 4: Constellation size of 16 QAM

4. AWGN Channel

A radio channel is essentially an electromagnetic medium that transmits and receives information between the transmitter and the receiver. The Gaussian channel model, often known as the additive white Gaussian noise (AWGN) channel, is the most extensively used channel model in communication systems. The AWGN channel is very simple, and it is often used as a starting point for the development of the fundamental system for performance assessment. In the field of OFDM research, the AWGN channel model is commonly employed. White noise with a constant spectral density and an amplitude distribution of Gaussian distribution is the sole noise introduced into this model via linear addition. The model does not take into account factors like as fading, frequency selectivity, interference, and so on. It is being utilised for producing simple and controlled mathematical models to examine the fundamental behaviour of a system in the absence of the characteristics described above, despite the fact that it is not very suited for most terrestrial linkages [7].



5. System Set-Up

For the purpose of comparing various modulation schemes in the OFDM channel, the AWGN channel is employed. SNR (signal-to-noise ratio) and BER (bit error rate) are two parameters that are utilised in the LTE system simulation, which is performed in MATLAB. The signal-to-noise ratio (SNR) in OFDM is defined as the ratio of signal margin to noise level. If the signal-to-noise ratio is greater than 1:1, it indicates that there is more signal than noise present. It is defined as the power ratio between a signal (which contains relevant information) and background noise (which contains undesired information)

For example:

SNR = P (signal)/P (noise)

Where, P is an average power. Also bit error rate is the ratio of number of errors and number of bits sent. Can be explained
By using formula:

BER = number of bits sent in error/total number of bits sent.

There are some specifications used in simulation environment

Table 1: Work specifications in simulation work

Parameters	Values
Number Of (M)subcarriers	2048
Guard interval samples(M/4)	512
Guard interval length	2.5us
Modulation level (q) for: BPSK QPSK 16QAM 64QAM	 2 4 16 64

6. Results and Discussion

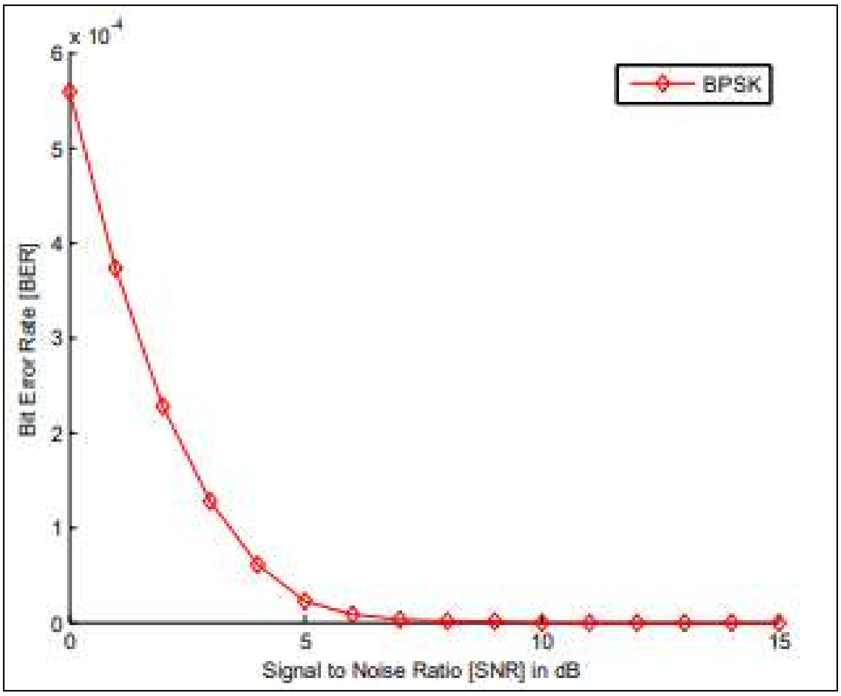


Fig 5: BPSK

From the graphic, it is evident that, in BPSK, the BER curve approaches 0 as the SNR approaches 6. As a result, when the error rate is taken into account, the performance of the BPSK modulation method is pretty excellent. However, if we utilise BPSK, we will not be able to deliver data at greater rates due to the fact that BPSK constellations are more difficult to find. Consequently, BPSK is inappropriate for use in situations where very high data rates are needed due to this limitation [8].

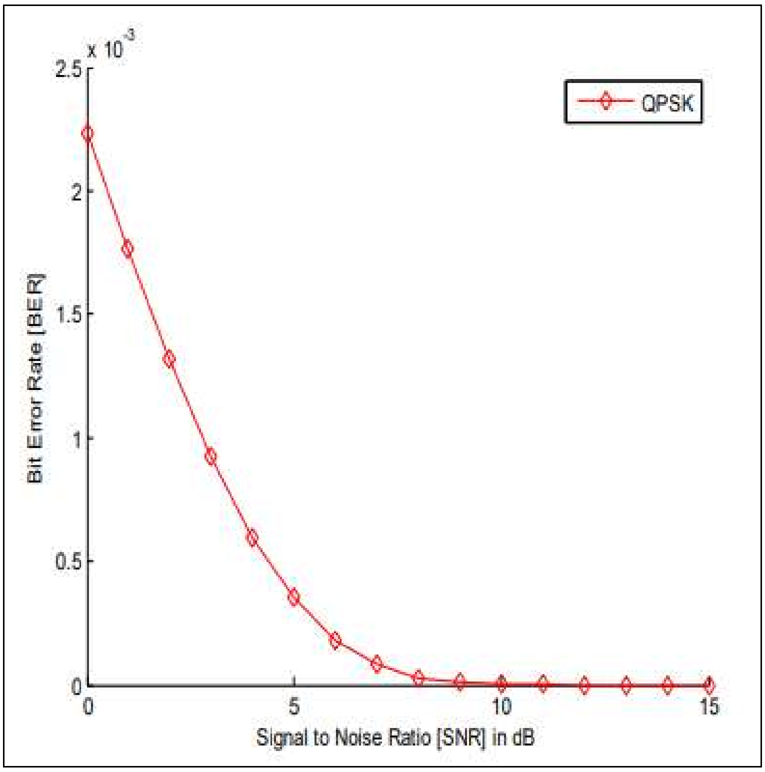


Fig 6: QPSK

In QPSK, as shown in Figure [6], the BER curve approaches zero as the SNR approaches eight. On the graph, it can be seen that QPSK has a higher error rate than BPSK does. As a result, in situations where noise and mistakes are the most important parameters to consider, QPSK is favoured over BPSK transmission [9].

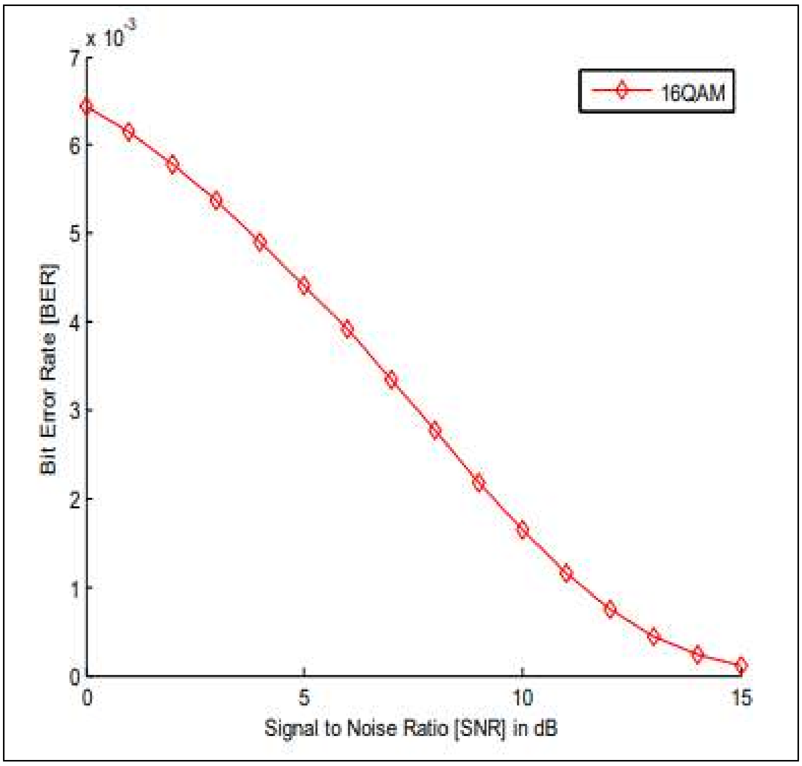


Fig 7: 16QAM

From figure [7] it can be seen that in 16QAM, BER curve approaches to zero when SNR approaches to 15. It shows that 16 QAM will not be used where low error rate is prioritised.

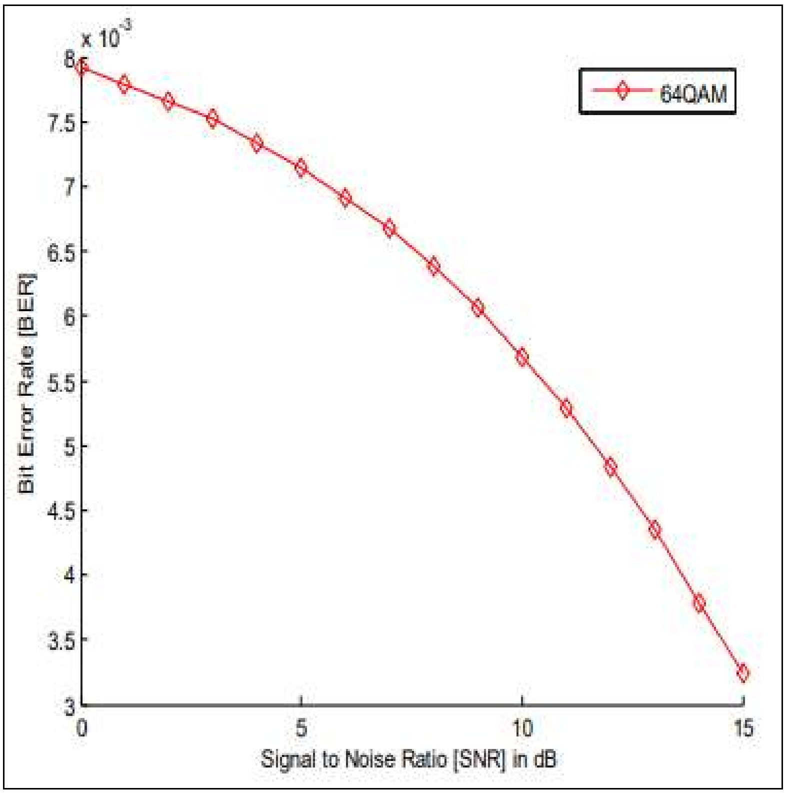


Fig 8: 64QAM

Even though the SNR is 15 in 64 QAM, the BER does not approach zero. As a result, the use of the 64QAM modulation approach will be deemed inadvisable. However, owing of the denser constellation, 64 QAM is also capable of transmitting data at very high data speeds [10].

From figure it is very clear that:

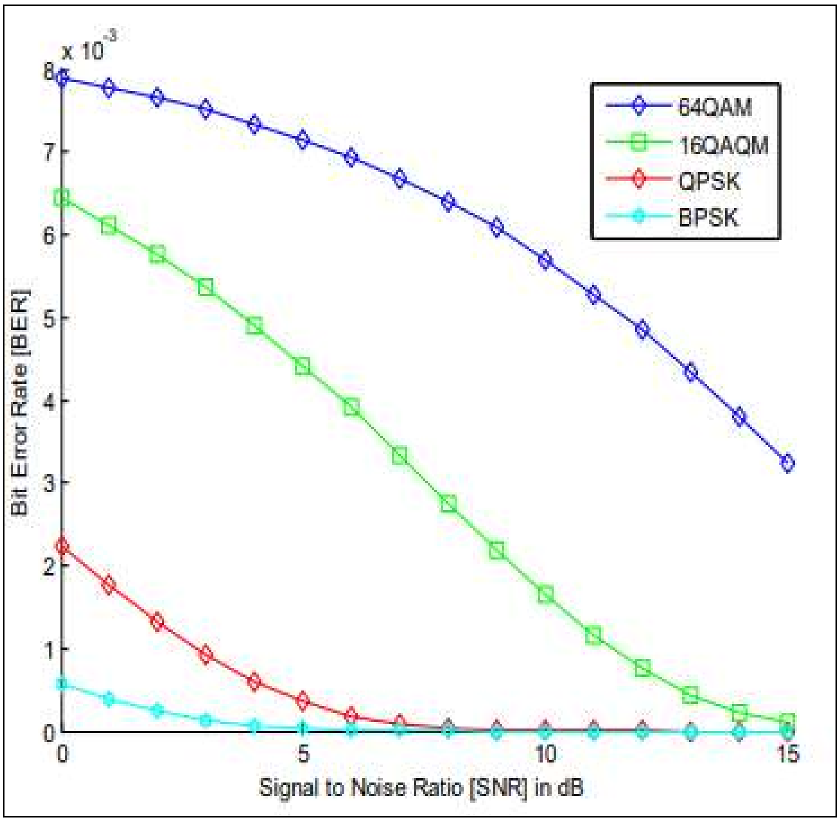


Fig 9: comparison of modulation techniques from figure [9]. It is very clear that

$BER_{BPSK} < BER_{QPSK} < BER_{16QAM} < BER_{64QAM}$

According to appearances, BPSK has the lowest error rate, and when the order of modulation is increased, the bit error rate increases in tandem with the signal to noise ratio, as seen in Figure 1. The highest error rate is achieved with 64 QAM. As a result, BPSK is the most resilient technology to apply in terms of noise resistance, although greater data rates are necessary in systems such as LTE and LTE-A, as can be seen in the table [11].

Table 2: Theoratical Peak Data Rates

Technology	THEORATICAL PEAK DATA RATES(At low mobility)
GSM	9.6kbps
IS-95	14.4kbps
GPRS	171.2kbps
EDGE	473kbps
CDMA-2000	307kbps
WCDMA	1.92kbps
HSDPA(Rel-5)	14Mbps
HSPA+(Rel-6)	84Mbps
LTE(REL 8)	300Mbps
LTE-ADVANCED	1Gbps

64QAM is capable of delivering faster data rates than 16QAM because to its denser constellation, however it is very susceptible to interference and mistakes. So methods such as bit level scrambling and turbo coding should be created so that 64 QAM may be employed with a comparably lower error rate, such as bit level scrambling and turbo coding.

7. Conclusion
The authors of the research came to the conclusion that the higher the order of the digital modulation method, the greater the bit error rate would be. However, in order to obtain greater data rates in the LTE system, higher order modulation must be used. This is only achievable with higher order modulation [12].
So bit error rate reduction methods like as turbo coding, equalisation, and other similar techniques should be used in LTE systems to enable higher order modulation. As a result, larger data rates may be attained while the bit error rate is reduced [13].

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