Performance Analysis of Different M-ARY Modulation Techniques in Cellular Mobile Communication

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ABSTRACT
Cellular communication systems are the most widely used wireless communication systems. It is our primary need today to achieve the higher data rates in limited spectrum bandwidth to improve the performance of signals. We know digital communication system outperforms analog ones in terms of noise performance and flexibility. Hence, there has been great deal of search for a digital communication system that is bandwidth efficient and has low bit error rate at a relatively low signal to noise ratio. Various digital modulation schemes are incorporated but they are not feasible or cannot fulfill actual requirement varying in different kind of environment. In this paper we provide a general theoretical approach to analyze various M-ary modulation schemes using MATLAB taking BER as measure of performance when the system is subjected to AWGN and multipath Rayleigh fading channel. Based on these performances a desirable modulation scheme is suggested that provides low BER at low received SNR, performs well in multipath & fading conditions occupies a minimum of bandwidth and is easy & cost effective to implement in present cellular communication .

General Terms
M-ARY Modulation, Quadrature Amplitude Modulation

Index Terms
Phase Shift Keying (PSK), Bit Error Rate (BER), Signal-to-Noise Ratio (SNR), AWGN (Additive White Gaussian Noise).

1. INTRODUCTION
The evolution objective of wireless cellular technology from 1G to 3G is capable of delivering high data rate signal so that it can transmit high bit rate multimedia content in cellular mobile communication [5]-[9]. There are several digital modulation schemes that have been proposed but there is a tradeoff between data rate and mismatch of the three basic parameters as phase, frequency and time between the transmitter and receiver [1].These digital modulation schemes include basic schemes such as MPSK (M-ary Phase Shift Keying), MPAM (M-ary Pulse Amplitude Modulation), MQAM (M-ary Quadrature Amplitude Modulation), MFSK (M-ary Frequency Shift Keying), and GMSK (Gaussian Minimum Shift Keying). In 2G networks, GMSK modulation scheme is widely used in GSM (Global System for Mobile Communication). This modulation can only transmit data rate of 1 bit per symbol thus this kind of modulation scheme is not suitable for the next generation communication system. So, there is a need to study the performance of new modulation technique that could deliver higher data rate effectively in a multipath fading channel. M-ary modulation schemes are one of most efficient digital data transmission systems as it achieves better bandwidth efficiency than other modulation techniques and give higher data rate [11].

The objective of this paper is to review the key characteristics and performance of digital modulation schemes. Simulations are used to compare the performance and tradeoffs of M- ary techniques, including analysis of BER in the presence of Additive White Gaussian Noise (AWGN) and multipath fading environment.

2. M- ARY MODULATION TECHNIQUES
Digital baseband data may be sent by varying both the envelope and phase (or frequency) of an RF carrier as the envelope and phase offer two degrees of freedom and modulation techniques map baseband data into four or more possible RF Carrier signals. Such modulation techniques are called M-ary modulation, since they can represent more signals than if just the amplitude or phase were varied alone [13].

In an M-ary signaling scheme, we may send one of M possible signals s1(t),s2(t)…sm(t), during each signaling interval of duration Ts. For almost all applications, the number of possible signals M=2n, where n is an integer. The symbol duration Ts=nTb, where Tb is the bit duration. In pass-band data transmission these signals are generated by changing the amplitude, phase, frequency of a sinusoidal carrier in M discrete steps thus we have M-ary ASK, M-ary PSK and M-ary FSK digital modulation schemes [13][14][15]. Different bandwidth efficiency at the expense of power efficiency can be achieved using M-ary modulation schemes.

2.1 M-ary PSK
In M-ary PSK, the carrier phase takes on one of M possible values, namely θi=2(i-1) , where i=1, 2…M. the modulated waveform can be expressed as:

Si(t) = ( ) Cos(2 πfct + θi) i= 1, 2…M (1)

0≤ t ≤T

Where ES= (Log2M)Eb is the energy per symbol and TS= (Log2M)Tb is the symbol period [13]. The above equation can be rewritten in quadrature form as:

Si(t)={ cos[(i-1)]Φ1(t)- sin[(i-1)]Φ2(t)} i=1, 2……M (2)

By choosing orthogonal basis signals $\Phi1(t)=\sqrt{(2/Ts)}\cos(2\pi fct)$ and $\Phi2(t)=\sqrt{(2/Ts)}\sin(2\pi fct)$ defined over the

interval $0 \leq t \leq Ts$, the M-ary PSK signal set can be expressed as:

SMPSK(t)={ cos[(i-1)]Φ1(t)- sin[(i-1)]Φ2(t)}

i=1, 2……M (3)

Since there are only two basis signals, the constellation of M-ary PSK is two dimensional. It is clear from fig.1 MPSK is a constant envelope signal when no pulse shaping is used [17].

Average symbol error probability of an M-ary PSK system is given by

$Pe \leq 2\ Q\ (\ \sin\ (\ ))$ (4)

2.2 M-Ary QAM

By allowing the amplitude to vary with the phase, a new modulation scheme called Quadrature Amplitude Modulation (QAM) is obtained. It is such a class of non-constant envelope schemes that can achieve higher bandwidth efficiency than MPSK with the same average signal power [13].

The general form of an M-ary QAM signal can be defined as:

Si(t)={ ai cos(2 fct) + bi sin(2 fct)

$0 \leq t \leq T$ i=1,2……M (5)

Where Emin is the energy of the signal with the lowest amplitude and ai and bi are a pair of independent integers chosen according to the locations of the particular signal point. M-ary QAM does not have constant energy per symbol, nor does it have constant distribution between possible symbol states. It is for the

reasons that particular values of S i(t) will be detected

with higher probability than others [13].

If rectangular pulse shapes are assumed, the signal S i(t) may be expanded in terms a pair of basis function defined as

$\Phi1\ (t) = \cos\ (2\pi\ fc\ t)$ $0 \leq t \leq Ts$ (6)

$\Phi2\ (t) = \sin\ (2\pi\ fc\ t)$ $0 \leq t \leq Ts$ (7)

The average probability of error in an AWGN channel for M-ary QAM, using coherent detection:

$Pe \approx 4(1 - (1 /))\ Q\ (\ )$ (8)

In terms of average signal energy Eavg :

$Pe \approx 4(1 - (1 /))\ Q\ (\ )$ (9)

3. SYSTEM PERFOMANCE MEASURES

3.1 Bit Error Rate or Probability of Bit Error

BER is a performance measurement that specifies the number of bit corrupted or destroyed as they are transmitted from its source to its destination. Several factors that affect BER include bandwidth, SNR, transmission speed and transmission medium.The definition of bit error rate can be translated into a simple formula:

BER = No. of Errors /Total No. of bits sent (10)

BER can also be defined in terms of the probability of error or POE. Each different type of modulation has its own value for the error function. This is because each type of modulation performs differently in the presence of noise [17].

3.2 SNR, signal-to-noise density ratio, (Eb is the energy per bit and No is the noise density)

Signal to noise ratio (SNR) is a measure of the amount of good signal divided by the amount of noise being received. In general a high Signal-to-Noise Ratio is good because it means we are getting more signal and less noise. SNR is usually measure using a logarithmic scale, meaning the SNR value is the logarithm of the actual ratio. Generally, high noise (low SNR) can lead to high BER. High BER is bad, and usually leads to observable problems with the signal. It is important to note that POE is proportional to Eb/No and is a form of signal to noise ratio [15].

SNR = 10log10 ( ) dB (11)

3.3 Constellation Diagram

Constellation diagram provides a graphical representation of the complex envelope of each possible Symbol state. The x- axis of the constellation diagram represents the in-phase component of the complex envelope and the y-axis represents the quadrature component of the complex envelope. The distance between the signals on the constellation diagram relates to how different the modulation waveform are, and how well a receiver can differentiate between all possible symbols when random noise is present.

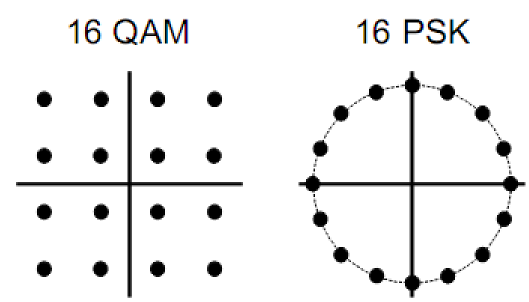

Fig.1 : Constellation Of 16QAM & 16PSK

The Probability of bit error is proportional to the distance between the closest points in the constellation, this implies that a modulation scheme with a constellation that is densely packed is less energy efficient than a modulation scheme that has sparse constellation [13][15][16].

3.4 AWGN (Additive white Gaussian noise)

In communication systems, the most common type of noise added over the channel is the Additive White Gaussian Noise (AWGN). It is additive because the received signal is equal to the transmitted signal plus the noise. It is white because it has a constant power spectral density. It is Gaussian because its probability density function can be accurately modelled to behave like a Gaussian distribution. It is noise because it distorts the received signal. Because the bandwidth of the signal is very less as compare to the bandwidth of the AWGN channel. The higher the variance of the noise, the more is the deviation of the received symbols with respect to the constellation set and, thus, the higher is the probability to demodulate a wrong symbol and make errors [15].

3.5 Rayleigh fading

Small-scale fading is also known as Rayleigh fading since the fluctuation of the signal envelope is rayleigh distributed when there is no predominant line of sight between the transmitter and receiver and its probability

density function (pdf) is given by

fRayleigh(r) = (0≤ r ≤) (12)

Where σ is the root mean squared value of the received signal before detection and σ2 is the average power of the received fading signal [16].

4. SIMULATION RESULTS & DISCUSSIONS

4.1 Performance of MPSK and MQAM for an AWGN Channel

The Comparison curve of two Modulation techniques for various M in an AWGN Channel is given below for N= 1000 samples

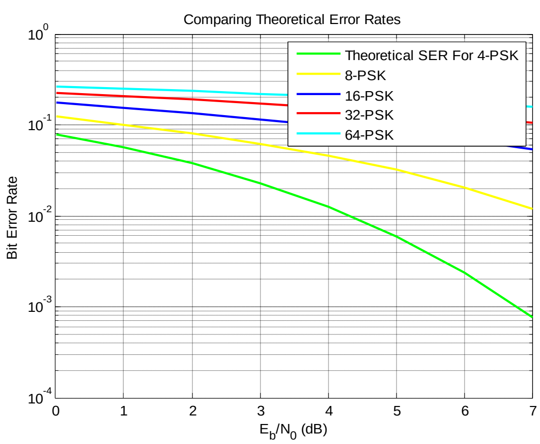

Fig. 2: BER Vs Eb/No for MPSK , M= 4 ,8, 16, 32, 64

From above graph it can be concluded that BER for all systems decrease monotonically with increase in Eb/No. Normally the Bit Error Rate is measured by the distance between two nearest possible signal points in the signal space diagram (constellation diagram) as the distance between two points decreases the possibility of error increases. Hence distance should be as large as Possible. So, probability of BER increases as M increases. We also observe that there is no significant change in BER when M value is above 16, so instead of increasing the complexity of system by higher order technique (i.e. 32 or 64) it is recommended to use modulationwith M<16.

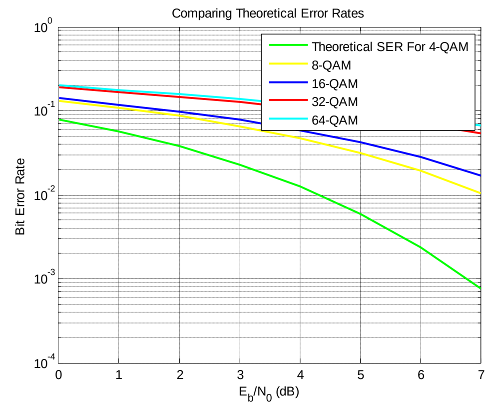

Fig. 3: BER Vs Eb/No for MQAM , M= 4, 8, 16, 32 ,64

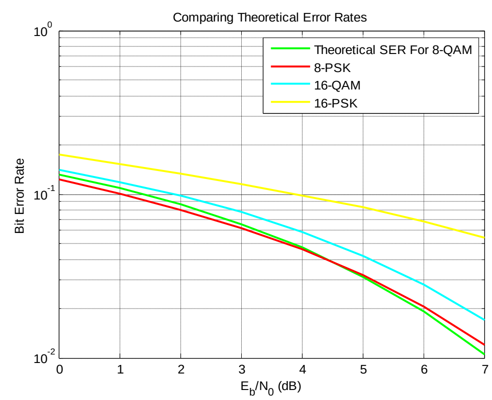

Fig. 4 : Comparison of 8-PSK, 8- QAM ,16-PSK &16QAM for a AWGN Channel.

From fig.4 we conclude that in an AWGN Channel M-ary QAM outperforms the corresponding M-ary PSK in error performance for M>4. However, the superior performance of M-ary QAM can be realised only if the channel is free from non-linearity.

4.2 Performance of MPSK and MQAM for a Rayleigh Channel

The Comparison curve of two Modulation techniques for various M in a Rayleigh Channel is given below for N= 1000 samples and Doppler Shift = 100Hz:

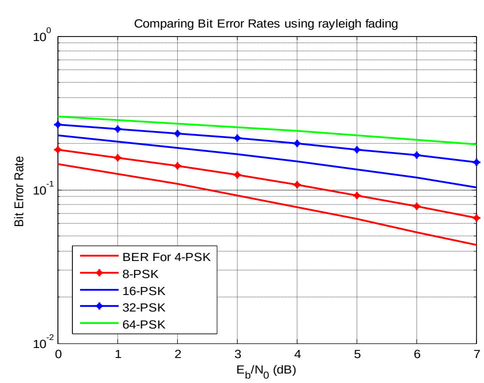

Fig. 5: BER Vs Eb/No for MPSK , M= 4, 8, 16, 32 ,64

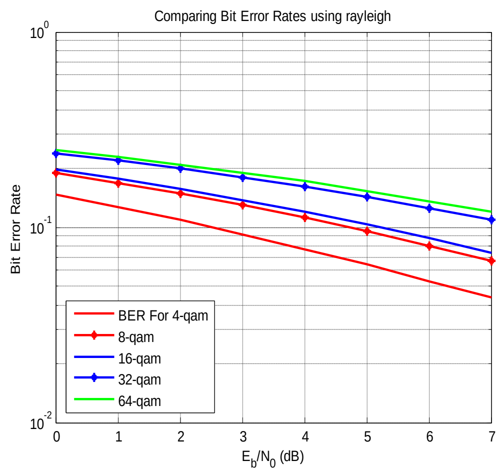

Fig. 6: BER Vs Eb/No for MQAM , M= 4, 8, 16, 32 ,64

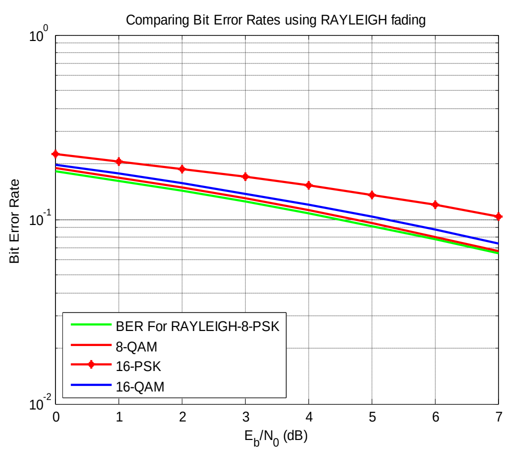

Fig. 7 : Comparison of 8-PSK, 8- QAM ,16-PSK &16QAM For Rayleigh Fading Channel

4.3 Performance comparison of MPSK and MQAM for a Rayleigh Channel & AWGN Channel

The Comparison curve of two Modulation techniques for various M in an AWGN and Fading Channel is given below for N= 1000 samples with Doppler shift in fading channel as 100 Hz

In a AWGN channel, for large values of Eb/No, the error probability decreases exponentially with respect to Eb/No ,while in a rayleigh fading channel the probability of error decreases linearly with respect to Eb/No. The smaller the value of BER required, the worse is the performance degradation. Thus the power required to maintain a particular BER, for small values, is much higher in fading channels. From figure.8 we observe that 8-PSK requires 1dB SNR to maintain 10-1 bit error rate in AWGN fading channel while it requires 4dB SNR to maintain the same error rate in Rayleigh fading. Similar results for the error probabilities of MQAM are shown in fig. 9. From this figure it is clear that to maintain low power it requires some technique to remove the effect of fading and rayleigh fading is one of the worst case fading scenarios.

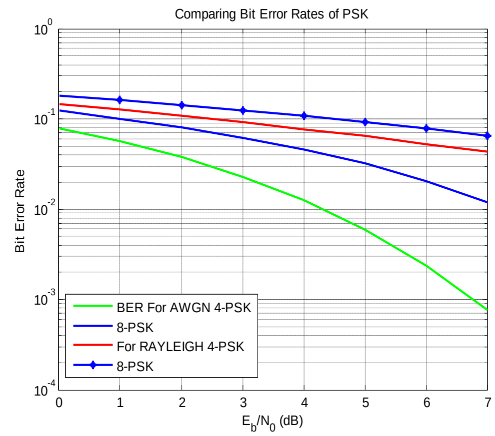

Fig. 8 : Comparison of 4 ,8-PSK, For Rayleigh Fading Channel & AWGN Channel.

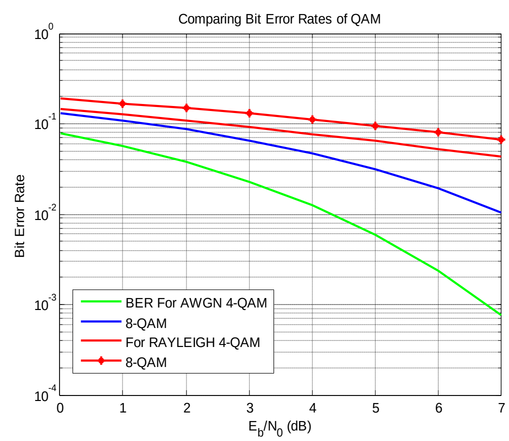

Fig.9 Comparison of 4 ,8-QAM,For Rayleigh Fading Channel & AWGN Channel

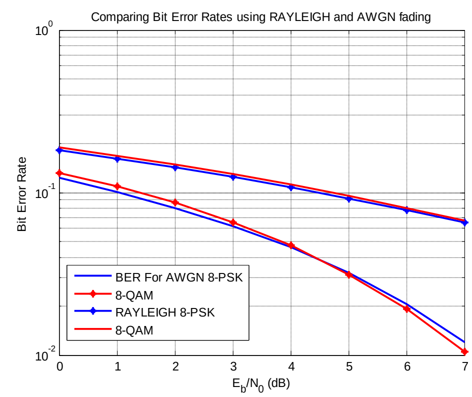

Fig. 10 : Comparison of ,8-PSK, 8-QAM For Rayleigh Fading Channel & AWGN Channel

From figure. 10 it is clear that in an AWGN channel M-ary PSK gives better performance for M≤8 while M-ary QAM outperforms for M>8. The smilar fashion can be seen for rayleigh channel, for M≤8 M-ary PSK gives better performance for M≤8 while M-ary QAM outperforms for M>8. Thus for both the channel M-ary PSK is better than M-ary QAM for M≤8.

5. CONCLUSIONS

In this paper, the comparison between MPSK and M-QAM for fading channel are shown. By analyzing the graphical representation of Eb/No vs BER of these two modulation techniques we found higher-order modulations (i.e. large) are more spectrally efficient but less power efficient (i.e. BER higher). The bit error probability for lower value of M is lower in case of AWGN environment and increases in fading scenario. The performance of QAM and PSK for M=8 is approximately similar but as the M value increases to 16 there is a slightly increase in BER (i.e., 10-1 to 2*10-1). In case of Rayleigh fading if we choose low order modulation technique then QPSK is better option than the 4-QAM but as we increase the order (M≥8) QAM gives a better performance than PSK.

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