Performance of Digital Modulation Techniques on Basis of Bit Error Rate and Signal to Noise Ratio

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***1. Abstract** The transmission from base station to mobile or downlink transmission using M-ary Quadrature Amplitude modulation (QAM) and Quadrature phase shift keying (QPSK) modulation scheme are consider in W-CDMA system. We can analysis the performance of these modulation techniques when the system is subjected to AWGN and multipath Rayleigh fading are consider in the channel. We will use MatLab 7.4 for simulation and evaluation of BER and SNR for W-CDMA system models. We will go for analysis of Quadrature phase shift key and 16-ary Quadrature Amplitude modulations which are being used in wideband code division multiple access system, so that the system can go for more suitable modulation technique to suit the channel quality, thus we can deliver the optimum and efficient data rate to mobile terminal. The performances of these modulation techniques are evaluated when the system is subjected to a number of users as well as noise and interference in the channel. Additive White Noise Gaussian (AWGN), multipath Rayleigh fading and Rician fading are considered in the channel. By implementing the different modulation techniques, the criterion is comparison of the variation of BER for different SNR. It is observed that the BER is minimum for AWGN. And to identify which modulation scheme gives best BER performance.*

***Keywords:** AWGN, DSSS, Multipath Rayleigh fading, CDMA, BER, SNR, QPSK, 16-QAM*

2. INTRODUCTION

The growing demands for voice and multimedia services on mobile wireless communication spur the advancement of the wireless communication field in the recent decade. One of the major underlying technologies is the digital modulation technique which allows digitized data to be carried or transmitted via the analog radio frequency (RF) channels.Wideband Code Division multiple Access (WCDMA) is being used by Universal Mobile Telecommunication System (UMTS) as platform of the 3rd generation cellular communication system. Digital modulation techniques contribute to the evolution of our mobile wireless communications by increasing the capacity, speed as well as the quality of the wireless network. This paper concentrates on PSK modulation techniques in which a finite number of phases are used to represent digital data. This paper concentrates on PSK modulation techniques in which a finite number of phases are used to represent digital data. Digital modulation schemes have greater capacity to convey large amounts of information than analog modulation schemes. Thus, we need suitable modulation technique and error correction mechanism to be used in W-CDMA system. Since 2 G in which Gaussian Minimum Shift Keying (GMSK) modulation scheme is widely used in GSM (Global System for Mobile) Communication could not deliver the high data bit rate as it transmits data rate of 1 bit per symbol. Thus this modulation scheme is not suitable for next generation system. The modulation formats here consider are Binary phase shift keying (BPSK) [1] due to its simplicity Quadrature phase shift keying (QPSK)[2] and Gaussian minimum shift keying(GMSK)[3] due to its importance for current mobile and cordless communication systems such as GSM[4]. Moreover, errors can be easily produced as the number of users is increased and the mobile terminal is subjected to mobility. In cellular system, different users have different channel qualities in terms of signal to noise ratio (SNR) due to differences in distance to the base station, fading and interference. WCDMA systems can employ the high order modulation (8PSK or M-QAM) to increase the transmission data rate with the link quality control. The comparative bit error rate performance of different PSK based modulation techniques under multi path fading is studied to get best results by removing obstacles and reflectors in wireless propagation channel.

3. NOISE AND INTERFERENCE

a) Bit Error Rate (BER)

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage.

b) Signal-to-Noise Ratio (SNR)

SNR is defined as the ratio between signal power to noise power and it is normally expressed in decibel (dB). The mathematical expression of SNR is

SNR =10log (signal power/noise power) db (1)

c) Energy bit per noise ratio (Eb/No)

Eb/N0 (the energy per bit to noise power spectral density ratio) is an important parameter in digital communication or data transmission. It is a normalized signal-to-noise ratio (SNR) measure, also known as the "SNR per bit".

d) Additive White Gaussian Noise (AWGN)

The term additive means the noise is superimposed or added to the signal that tends to obscure or mask the signal where it will limit the receiver ability to make correct symbol decisions and limit the rate of information transmission. Mathematically, thermal noise is described by a zero-mean Gaussian random process where the random signal is a sum of Gaussian noise random variable and a dc signal that is

$$Z = a + n(\sigma) \quad (2)$$

$$P(z) = 1/\sigma\sqrt{2\pi}\ \exp[-1/2(z-a/\sigma)2] \quad (3)$$

When noise power has such a uniform spectral density, it is referred as white noise. The adjective "white" is used in the same sense as it is with white light, which contains equal amounts of all frequencies within the visible band of electromagnetic (EM) radiation.

e) Rayleigh Fading

Generally, there are two fading effects in mobile communications: large-scale and small-scale fading. Large-scale fading represents the average signal power attenuation or path loss due to motion over large areas. On the other hand, small-scale fading refers to the dramatic changes in signal amplitude and phase that can be experienced as a result of small changes (as small as a half-wavelength) in the spatial separation between a receiver and transmitter. Small-scale fading is also called Rayleigh fading because the envelope of received signal can be represented by a Rayleigh probability density function (pdf).

4. MODULATION SCHEMES

a) Binary Phase Shift Keying (BPSK)

BPSK is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, and in this figure they are shown on the real axis, at 0° and 180°. This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol (as seen in the fig3.1) and so is unsuitable for high data-rate applications.

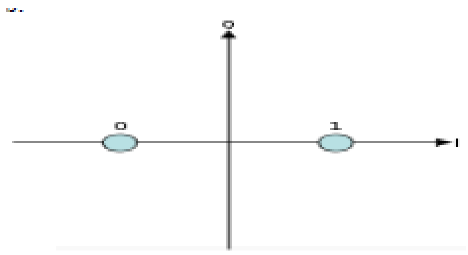


Fig1 Constellation diagram example for BPSK

The general form for BPSK follows the equation:

$$Sn(t)=\sqrt{2Eb/Tb}Cos(2\pi fct+\pi(1-n))$$

$$n=0,1,2,3 \quad (4)$$

b) Quadrature Phase Shift Keying (QPSK)

QPSK is one example of M-ary PSK modulation technique (M = 4) where it transmits 2 bits per symbol. The phase carrier takes on one of four equally spaced values, such as 0, π/2, π and 3π/2, where each value of phase corresponds to a unique pair of message bits as it is shown in figure 2. The implementation of QPSK is more general than that of BPSK and also indicates the implementation of higher-order PSK. Writing the symbols in the constellation diagram in terms of the sine and cosine waves used to transmit them.

$$S_{qpsk}(t) = \{\sqrt{E}\ Cos[(i-1)\pi/2]\emptyset_1(t) - \sqrt{E}\ Sin[(i-1)\emptyset_2(t)\} \quad (5)$$

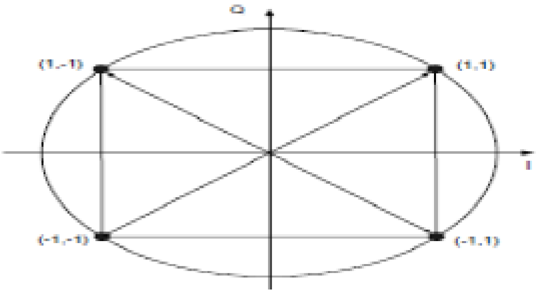


Fig 2: Constellation diagram of a QPSK system

c) Quadrature Amplitude Modulation (QAM)

Quadrature amplitude modulation (QAM) is both an analog and a digital modulation scheme. It conveys two analog message signals, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components The modulated waves are summed, and the resulting waveform is a combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK), or (in the analog case) of phase modulation (PM) and amplitude modulation.Fig 3 shows the constellation diagram of 8-ary QAM. The general form of an M-ary signal can be defined as:

$$S_n(t)= \sqrt{2E_{min}/T_s}\, a_i\, Cos(2\pi f_c t)+ \sqrt{2E_{min}/T_s}\, b_i\, sin(2\pi f_c t)$$

$$0\leq t\leq T \quad \text{and} \quad i=1,2,3\ldots M \quad (6)$$

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 location of the particular signal point..

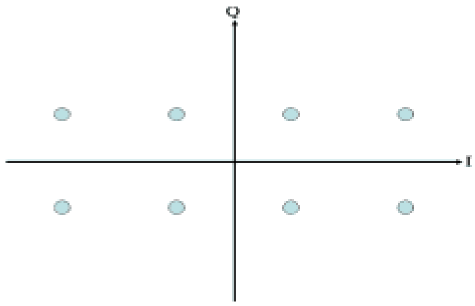


Fig 3 Constellation diagram of 8-QAM system

However, the symbols are easily subjected to errors due to noise and interference because the symbols are located very closed together in the constellation diagram. Thus such signal has to transmit extra power so that the symbol can be spread out more and this reduces power efficiency as compared to simpler modulation scheme.

3. System model

(a)Ideal channel-Additive White Gaussian Noise (AWGN) Channel

In constructing a mathematical model for the signal at the input of the receiver

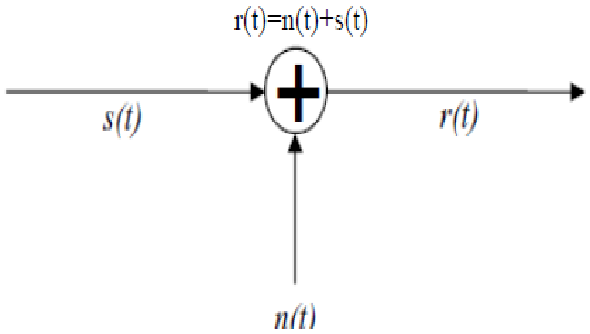


Fig 4 Received signal corrupted by AWGN

the channel is assumed to corrupt the signal by the addition of white Gaussian noise as shown in Figure 1 below, therefore the transmitted signal, white Gaussian noise and received signal are expressed by the following equation with s(t),n(t) and r(t) representing those signals respectively[8]: Where n(t) is a sample function of the AWGN process with probability density function (pdf)and power spectral density as follows:

$$\Omega_{nm} f = \tfrac{1}{2} N_0 \ [W/Hz] \qquad (7)$$

Where N0 is a constant and called the noise power density. Each user's data sequence is first modulated using QPSK modulation. The transmitted signal of user k can be expressed as,

$$x_k(t) = \sqrt{E_K}\sum_{i=-\infty}^{\infty} s_K(i)\, a_{k,i}(t-IT) \qquad (8)$$

Where E_k is the average symbol energy and T is symbol duration.

The spreading waveform for the k_{th} user,

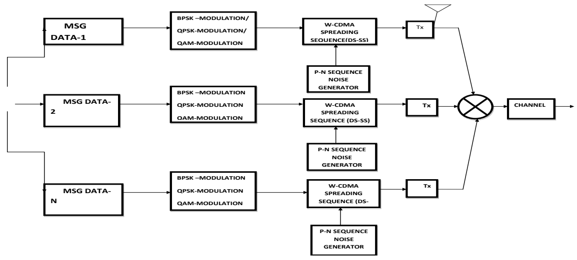
$$a_{k,i}(t) = \frac{1}{\sqrt{N}} \sum_{j=0}^{N-1} c_{k,i}(j)\, p(t-jT_C) \qquad (9)$$

The received signal can be obtained as,

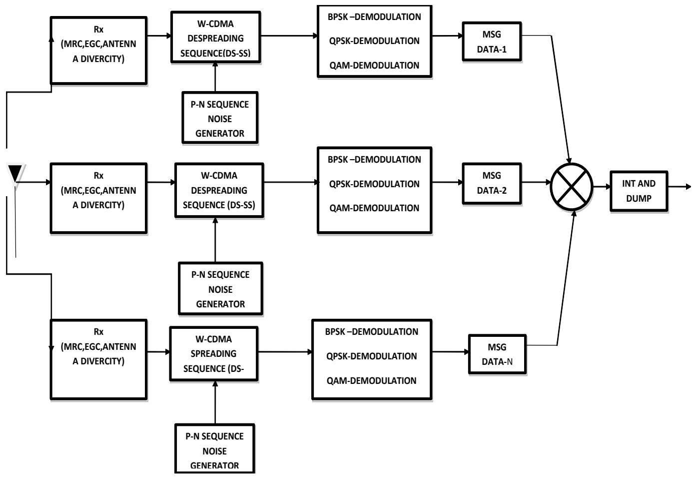
$$r(t) = \sum_{l=0}^{L-1} g_l x_0(t-T_l) + \sum_{k=1}^{K-1}\sum_{l=0}^{L-1} g_l x_k(t-Tl) + n(t) \qquad (10)$$

(b.)Proposed W-CDMA System Model

Transmitter model



Receiver model



4. Result and discussion

AWGN Channel, Rayleigh channel,Rician channel

BPSK and QPSK obtained similar result. Comparing their theoretical BER for AWGN equation, they are identical. Hence this result is correct. Even so, it can be observed that BPSK requires less signal power to obtain a 0 BER. GMSK BER performance is significantly higher than BPSK. This might be due to the Gaussian filtering.

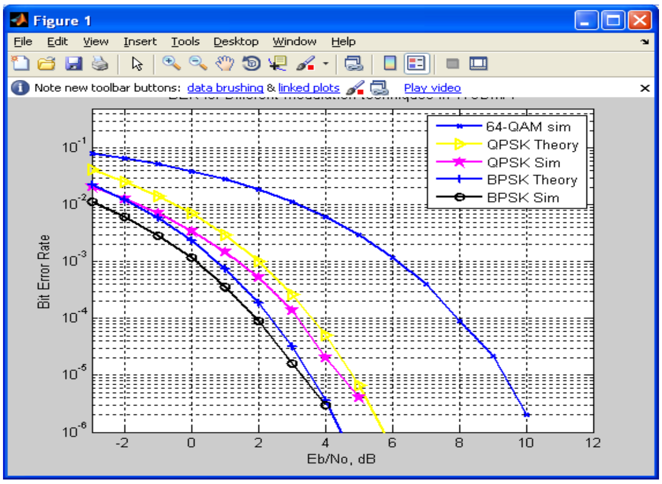


Fig 8 SNR Vs BER for BPSK/QPSK, 32QAM, 64 QAM

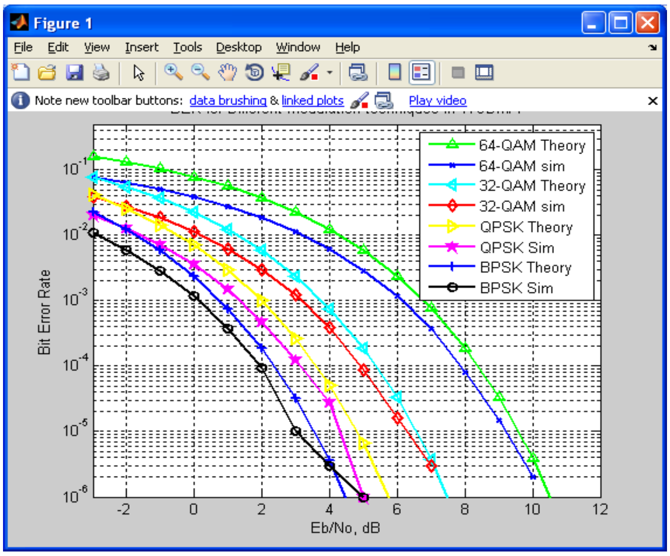


Fig 9 SNR Vs BER 256 QAM, GMSK

Once more, BPSK and QPSK obtained similar result with BPSK requiring less signal power to obtain a 0 BER than QPSK. Comparing their theoretical BER for 1-path fading equation, they are identical [11]. Hence this result is correct. GMSK BER performance is again significantly higher than BPSK. This might be due to the Gaussian filtering.

BPSK and QPSK obtained similar result with BPSK requiring less signal power to obtain a 0 BER than QPSK. GMSK BER performance is slightly higher than BPSK/QPSK and at higher *E* b/N0 (>15dB), the BER is slower than both BPSK and QPSK. This might the reason why GMSK is chosen to be the standard in GSM or it might due to the inaccuracy of the simulation program. and suboptimal detectors.

Performance Comparison i.e., BER vs. SNR of WCDMA Modulation techniques

5. CONCLUSION

Implementing the different modulation techniques, the criterion is comparison of the variation of BER for different SNR. It is observed that the BER is minimum for AWGN and maximum for Rayleigh and Rician. For Rician it is found that the BER is less than AWGN and Rayleigh except in case of 16- DPSK. And it is observed that 16-QAM is performing better than 64-QAM.BER obtained for GMSK is higher compared to BER obtained for BPSK and QPSK but at higher *E* b/N0 , the BER for GMSK is lower than both BPSK and QPSK.All modulation techniques i.e., BPSK, QPSK and QAM has been analyzed to reduce the error performance of the signal and to compare which technique is better through Rayleigh Fading Channel in the presence of AWGN. The performance of WCDMA system in AWGN channel shows that QAM modulation technique has a better performance compared to that of BPSK and QPSK.It also shows that QAM technique is better as compared to BPSK and QPSK. Also, BPSK and QPSK suffers signal degradation and error probed when the simulations are done in these channels. As the number of users is increased, the QPSK & BPSK modulation technique performs poorly in W-CDMA system.Thus, it is suggested that high data rate modulation technique such as BPSK and QPSK needs an error correction coding such as convolutional coding or turbo coding so that the interference from the adjacent carrier phase in the constellation of BPSK and QPSK can be eliminated if not minimized. It is seen that higher-order modulations exhibit higher error-rates; in exchange however they deliver a higher raw data-rate for higher values of Eb / N0, the BER is decreasing in all the fading channels for different modulation schemes.

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