Volume 2, Issue 7, July 2012 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Performance Investigation for Different Modulation Techniques in WCDMA with Multipath Fading Channels

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***Abstract*: The technology needed to tackle the challenges to make services like high speed data, video and multimedia traffic as well as voice signals available is popularly known as the Third Generation (3G) Cellular Systems. Downlink transmission (base station to mobile terminal) using high data rate Mary Quadrature Amplitude Modulation (QAM), Quadrature Phase Shift Keying (QPSK) and Binary Phase Shift Keying (BPSK) modulation schemes are considered in a Wideband-Code Division Multiple Access (W-CDMA) system. 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) and multipath Rayleigh fading are considered in the channel. Computer simulation tool, MATLAB, is used throughout the research to evaluate Bit-Error-Rate (BER) for W-CDMA system models.**

Keywords: 3G, QAM, QPSK, BPSK, BER.

I INTRODUCTION

Wideband Code Division multiple Access (WCDMA) is being used by Universal Mobile Telecommunication System (UMTS) as platform of the 3rd generation cellular communication system. High data rate signal transmission can be transmitted over the air by using W-CDMA system, thus enabling video streams and high resolution pictures to end users. 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. 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. Modulation schemes which are capable of delivering more bits per symbol are more immune to errors caused by noise and interference in the channel. 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.

II 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

$$SNR = 10\log\frac{signalpower}{noisepower}dB \qquad (1)$$

c) Energy bit per noise ratio (E_b/N_o)

E_b/N_0 (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

$$z = a + n(6) \qquad (2)$$

where pdf for Gaussian noise can be represented as follows where σ^2 is the variance of n

$$p(z) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{z-a}{\sigma}\right)^2\right] \qquad (3)$$

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 pdf .

III 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.

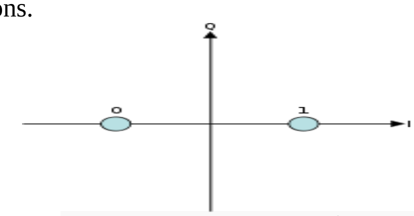

Fig1 Constellation diagram example for BPSK

The general form for BPSK follows the equation:

$$s_n(t)=\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t+\pi(1-n)),n=0,1. \quad (4)$$

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.

$$s_{qpsk}(t)=\left\{\sqrt{E_s}\cos\left[(i-1)\frac{\pi}{2}\right]\phi_1(t)-\sqrt{E_s}\sin\left[(i-1)\phi_2(t)\right]\right\} \quad (5)$$

i=1,2,3,4

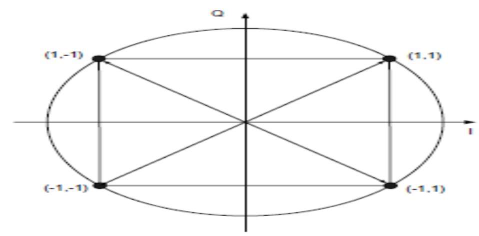

Fig 2: Constellation diagram of a QPSK system

c) Quadrature Amplitude Modulation (QAM)

Quadrature amplitude modulation (QAM) is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, 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

$$s_i(t)=\left\{\sqrt{\frac{2E_{min}}{T_s}}a_i\cos(2\pi f_c t)+\sqrt{\frac{2E_{min}}{T_s}}b_i\sin(2\pi f_c t)\right\} \quad (6)$$

$$0\le t\le T \qquad i=1,2,\ldots.M$$

where E_{min} is the energy of the signal with the lowest amplitude and a_i and b_i are a pair of independent integers chosen according to the location of the particular signal point.

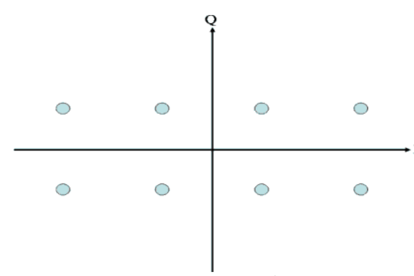

Fig 3 Constellation diagram of 8-QAM system

Theoretically, higher order of M-ary QAM enables data to be transmitted in a much smaller spectrum. 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.

IV RESULTS AND DISCUSSION

Based on data generated by computer simulation of W-CDMA models, relationship for multiple rays using BPSK, QPSK and QAM modulation techniques between BER as a function of the following parameters are obtained.

a) Performance Comparison i.e., BER vs. SNR of WCDMA in AWGN channel.

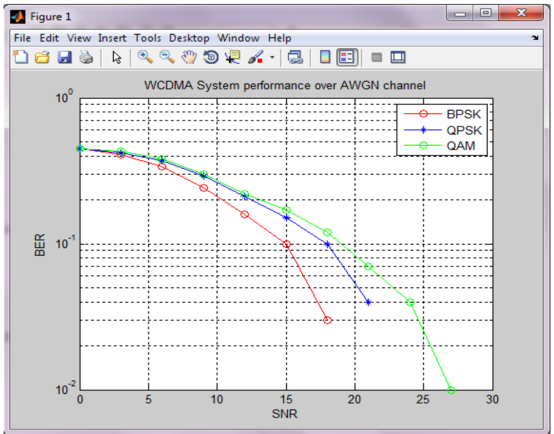

Fig 4 BER vs. SNR

The results show that using QPSK the transmission can tolerate a SNR of >18-25 dB. However, using BPSK allows the BER to be improved in a noisy channel, at the expense of transmission data capacity. Using BPSK the WCDMA transmission can tolerate a SNR of >18-23 dB. In a low noise link, using QPSK can increase the capacity. If the SNR is >25 dB QPSK can be used, doubling the data capacity compared with QPSK. If SNR is >28 dB QAM can be used for data capacity. Fig 4 shows the comparisons of BER Vs SNR graph with different modulation schemes with AWGN channel and 64 carriers.

b) Performance Comparison i.e., BER vs. E_b/N_o of WCDMA in AWGN channel.

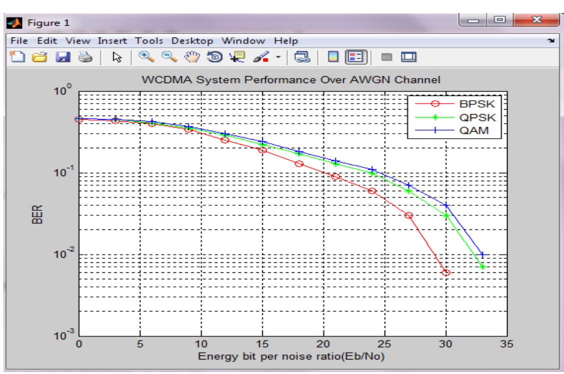

Fig 5 BER vs. E_b/N_o

Fig 5 shows the graph compares the bit-error rates of BPSK, QPSK and QAM. It is seen that higher-order modulations exhibit higher error-rates; in exchange however they deliver a higher raw data-rate. Fig 5 shows the comparisons of BER Vs E_b/N_o graph with different modulation schemes with AWGN channel and 64 carriers.

c) Performance Comparison i.e., BER vs. E_s/N_o of WCDMA in AWGN channel.

E_s/N_o is another 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". Fig 6 shows the comparisons of BER Vs E_s/N_o graph. BER performance of different digital modulation schemes without taking bandwidth into account.

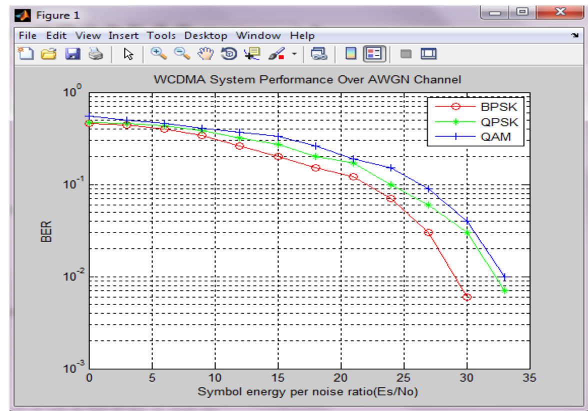

Fig 6 BER vs. E_s/N_o

d) Performance Comparison i.e., BER vs. E_b/N_o of WCDMA in multipath Rayleigh channel.

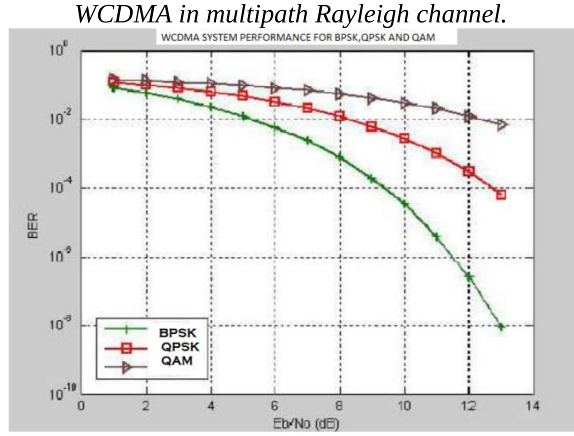

Fig 7 BER vs. E_b/N_o

The fading channel introduces a multiplicative effect whereas the AWGN is additive. The function “QAM fading” has two inputs, ‘n bits’ & ‘E_b/N_o dB’ and one output ‘BER’. The inputs are the number of bits to be passed through the channel, the alphabet size and the Energy per Bit to Noise Power Spectral Density in dB respectively whereas the output is the bit error rate (BER).

V CONCLUSION

Three 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. Furthermore, similar trend is found when the channel is subjected to multipath Rayleigh fading i.e, 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.

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