Performance Evaluation of Various Digital Modulation Schemes for an Efficient Wireless Mobile Communication System

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Abstract - *The Bit Error Rate and Signal to Noise Ratio are the major key component for choosing any modulation schemes. The digital modulation techniques are used to develop a new level of expectation to wireless communication devices. The performance of modulation techniques are measured by estimating its probability of error produced by noise and channel interference. The main objective of our work is to measure Bit Error Rate with different modulation schemes and come to with the best configuration to achieve better utilization of bandwidth in OFDM systems. This work has been designed in MATLAB simulation environment with various digital modulation techniques such as BPSK, QPSK, DQPSK and π/4-DQPSK.*

Key Words: Modulation Schemes, Bit Error Rate, Noise and Channel Interference, Phase Shift Keying, OFDM System, etc.

1. INTRODUCTION

The wireless communication has the emerging and fastest growing area in our modern life which creates enormous impact in our daily life. Present fourth and fifth generation telecommunication system provides higher capacity, more flexible data rate and a tightly integrated service. The main objective of communication system is transmitting unit information. The basic features for transmitting and receiving information in wireless and wired system is modulation and demodulation. Thus the fundamental component in wired and wireless equipment is modulator. The digital modulation scheme as an essential module for transmitting and receiving information instead of analog modulation. Comparing to analog modulation, the digital modulation have better noise immunity and robustness to channel impairment. The reuse of frequency spectrum in different geographical areas fascinates the development of large scale cellular and wireless mobile networks.

The transmission of audio or video signal has to pay more cost of bandwidth and need to have lossless information at receiving end[5]. Therefore it is more useful to analysing the performance of digital modulation schemes in wireless communication system. Due to their increased spectral efficiency, the digital modulation schemes are widely used. Depending upon the phase recovery circuit, the Digital modulation is classified into two types which are coherent and non-coherent[4]. The phase recovery circuit ensures that the oscillator supplying the locally generated carrier wave in receiver is synchronized to the oscillator, which supplies carrier wave and uses the originally modulate the incoming data stream in the transmitter. There are three basic signaling schemes and they are identified as amplitude shift keying, frequency shift keying and phase shift keying. In this paper we have discussed about phase shift keying or phase modulation. Determining the bit error rate is one of the factor to finding the performance of communication system[6-8].

The phase modulation offers many phase shift keying techniques such as BPSK(2bits), QPSK(4bits) and Differential QPSK. Determining the bit error rate is one of the factors to finding the performance of communication system. The objective of this paper is to analyse and compares the performance of BPSK, QPSK, DQPSK and *π/4-DQPSK* modulation schemes[1-4].

2. BIT ERROR PROBABILITY OF MODULATION SCHEMES

2.1 Binary Phase Shift Keying(BPSK)

The BPSK was developed during the early days of deep space program. PSK is now widely used in both military and commercial communication systems. The BPSK is more efficient of all digital modulation schemes[7]. So BPSK is used for high bit rates with lower power efficiency. In binary phase shift keying, phase of the sinusoidal carrier is changed according to the data bit to be transmitted. Also, a bipolar non-return to zero(NRZ) signal is used to represent the digital data coming from the digital source[4,10]. The coherent binary phase shift keying has one dimensional signal space with two message points, the input binary data in polar form with symbol '0' and '1' which is represented with a constant amplitude level of $-\sqrt{E_b}$ and $\sqrt{E_b}$. In coherent BPSK modulation, the pair of signals $s_1(t)$ and $s_2(t)$ is used to represent binary symbols 1 and 0 respectively is defined by

$$s_1(t) = \sqrt{\frac{2\,E_b}{T_b}}\cos(2\pi f_c t)$$

$$s_2(t) = -\sqrt{\frac{2\,E_b}{T_b}}\cos(2\pi f_c t)$$

Where $0 \le t \le T_b$, and E_b is the transmitted signal energy per bit. To ensure that each transmitted bit contains an integral number of cycles of the carrier wave, the carrier frequency fc is chosen equal to n_c/T_b for some fixed integer n_c. A pair of sinusoidal waves differs only in a relative phase shift of 180 degrees. From this pair of equations it is clear that, in BPSK there is only one basis function which is unit energy,

$$\phi(t) = \sqrt{\frac{2}{T_b}}\cos(2\pi f_c t) \quad , 0 \le t \le T_b$$

Then we express the transmitted signals are $s_1(t) = \sqrt{E_b}\,\phi(t)$ and $s_2(t) = -\sqrt{E_b}\,\phi(t)$. To demodulate the original binary message sequence of 0 and 1, the incoming BPSK signal is passed into a correlator and decision device. The output of the correlator is compared with the threshold and the output is obtained. Constant transmitted bit energy, noise level and other distortion gives the lowest bit error rate in BPSK system since it has largest distance between two signal points. The bit error rate for coherent binary PSK is,

$$P_e = \frac{1}{2}\,\mathrm{erfc}\sqrt{\frac{E_b}{N_0}}$$

As we increase the transmitted signal energy per bit E_b, for a specified spectral density N_0, the message points corresponding to symbol 1 and 0 move further apart and the average probability of error P_e is correspondingly reduced in accordance with above equation.

2.2 Quadrature Phase Shift Keying (QPSK)

The QPSK modulation scheme is like the binary PSK, which is characterized by the fact that the information carried by the transmitted wave is contained in phase. The QPSK system has two successive bits in a bit stream which is combined together to form a message and each message is represented by a distinct value of phase shift of the carrier. Symbol contains two bits, so the symbol duration is equal to twice of transmitted bits duration[4]. In particular, in quadrature phase-shift keying, the phase of the carrier takes on one of four equally spaced values, such as *π/4, 3π/4, 5π/4 and 7π/4.* The carrier wave is represented as,

$$s_i(t) = \sqrt{\frac{2E}{T}}\cos[2\pi f_c t + (2i-1)\frac{\pi}{4}]$$

where i =1, 2, 3, 4 and E is the transmitted signal energy per symbol, t is the symbol duration, and the carrier frequency fc equals to n_c /T for some fixed integer n_c . Each possible value of the phase corresponds to a unique pair of bits and is called as dibit. For example, choose the preceding set of phase values to symbolize the Gray encoded sets of dibit: 10, 01, 11 and 00. Using a well-known trigonometric identity,

$$s_i(t) = \sqrt{\frac{2E}{T}}\left[\cos(2i-1)\frac{\pi}{4}\right]\cos(2\pi f_c t) - \sqrt{\frac{2E}{T}}\left[\sin(2i-1)\frac{\pi}{4}\right]\sin(2\pi f_c t)$$

For QPSK modulation scheme There are two normal orthonormal basic functions, $\phi_1(t)$, $\phi_2(t)$ contained in the expression of $s_i(t)$. In a QPSK system, the transmission rate is two bits per symbol. This means that twice the signal energy per bit is equal to the transmitted signal energy per symbol. So the average probability of error is represented in terms of ratio E_b/N_0 and bit error probability is,

$$P_e = \frac{1}{2}\,\mathrm{erfc}\sqrt{\frac{E_b}{N_0}}$$

Due to multilevel modulation used in QPSK, it is possible to increase the bit rate to double the bit rate of BPSK without increasing the bandwidth and noise immunity.

2.3 Differential QPSK (DQPSK)

The differential QPSK is developed from QPSK system but in the Differential QPSK the initial phase of modulated signal is effected by the initial phase of the previous modulated signal. In QPSK, we assume that the previous modulated signal has zero initial phase, but in the Differential QPSK the initial phase of previous modulated signal is added with initial phase of transmitted signal[1]. As like in QPSK the pair of bits will modulate the carrier signal and determines the initial phase of modulated output signal.

In the QPSK the transmission pair bits are 00, 01, 11, 10 and the phase shifts of corresponding pair bits are *π/4, 3π/4, 5π/4 and 7π/4* radiant's respectively. Whereas in Differential QPSK we first determines the rule of phase shift from input pair bit and the phase shift is added with initial phase of previous signal. So the output signal is the phase output of transmitter or the initial phase of present time modulated signal. For example, let us assume the sequential inputs for Differential QPSK system is 00, 01, 11, 10, 10, and 10. The first step is to determine the phase shift for pair of input sequences 00, 01, 11, 10 and the phase shifts are 0, *π/2, 3π/2, -π/2* radiant's respectively.

Now we need to determine the sequences phase shift by assuming the initial condition. Consider the phase of the previous modulated signal is *π*/4 radiant, then the phase shift above sequence is 0, *π/2, π, -π/2, -π/2, -π/2* radiant's. The output of Differential QPSK transmitter is

$$s_i(t) = \sqrt{\frac{E_s}{T_s}}\cos(2\pi f_c t + \phi_i) + \sqrt{\frac{E_s}{T_s}}\sin(2\pi f_c t + \phi_q)$$

Here the parameter ϕ_i represents the initial phase of output signal from transmitter. The bit error probability of Differential QPSK is

$$P_e = \frac{1}{2}\,\mathrm{erfc}\sqrt{\frac{2E_b}{N_0}}\,sin\left(\frac{\pi}{2\sqrt{2}}\right)$$

Alternatively, the bit error rate for DQPSK on AWGN channel is given by

$$P_e = e^{\frac{-2E_b}{N_0}}\left\{\sum_{i=0}^{\infty}(\sqrt{2}-1)^i I_i\left(\sqrt{2}\frac{E_b}{N_0}\right) - 0.5\, I_0\left(\sqrt{2}\frac{E_b}{N_0}\right)\right\}$$

In the QPSK modulation the receiver part must understand the frequency as well as the phase of transmitted signal. It is very difficult in real process and carrier recovery process to get ideal output. Whereas in Differential QPSK, the receivers don't need to recover the phase of received signal and the system design is very simple compare to QPSK.

2.4 π/4 Differentially Encoded QPSK(π/4 DQPSK)

The π/4 shifted differentially encoded quadrature phase shift keying (π/4-DQPSK) is simpler in demodulator design, high efficient and more useful in wireless communication system. The π/4–DQPSK modulation technique represents a compromise solution between the QPSK and Differential QPSK. For BPSK modulation scheme the carrier signal is shifted between 0° and 180°, corresponding to the bit values of 0 and 1. In the M-ary PSK modulation, the M data bits from each symbol and the orthogonal modulator according to the symbols controls the carrier phase. For QPSK modulation the phase would be shifted between 0°, 90°, 180° and 270° for the symbols 00, 01, 11 and 10 respectively. At present, in the π/4–DQPSK modulation system the symbols and the carrier phase difference 0, forming differential encoding scheme i.e the phase difference are 45°,135°,-135° and -45° and the corresponding symbols are 00, 01, 11 and 10 respectively[1].

The transmitted carrier phase of π/4–DQPSK signals are generated by differential encoding the 2-bit symbol into 3-bit symbol. Each carrier phase of the signals is produced according to the transition of the points on the QPSK signal space. The carrier phase of i^{th} symbol interval is expressed by,

$$\theta_I = \theta_{i-1} + \Delta\theta_i$$

Where $\Delta\theta_i$ is the transition angle or phase shift and θ_{i-1} is previous shift of one QPSK signal point to the next, which only takes the values ± π/4, ±3π/4. The ith in-phase(I_k) and quadrature phases(Q_k) at the output of the signal mapping circuit are determined by the following pair of expressions.

$$I_k = I_{k-1}\cos\Delta\theta_i - Q_{k-1}\sin\Delta\theta_i$$

$$Q_k = I_{k-1}\sin\Delta\theta_i - Q_{k-1}\cos\Delta\theta_i$$

In the case of QPSK, four phase ambiguity are likely to occur, causing considerable bit error rate. To remove the phase ambiguity, a differential encoder may be employed in the modulator and a differential decoder in the demodulator. In the differentially encoding modulation, information is transmitted by the amount of the difference in phase rather than absolute phases. The encoded information in the phase transition overcomes the phase ambiguity problem. Further in π/4–DQPSK, the maximum phase shift is restricted to ±135° in contrast to QPSK which allows 180°. Hence the band limits of π/4–DQPSK signal preserves the constant envelope property better than limited QPSK. In this method, four values of phase changes, ±π/4, ±3π/4 are used to modulate the carrier. Since four different phase changes are used, each phase change can be symbolized of two bits.

On the other hand the π/4–DQPSK signals have significant advantages over QPSK signal. The differentially shifted signals are less prone to envelope fluctuation. This enables the signals to have a higher spectral efficiency in the presence of non-linearity. Then the transmitted signal is less sensitive to noise. This signaling format also increase the ability of the receiver to recover the transmitted data in non-coherent fashion, in other words, there is no need to keep track of the phase lag introduced by the carrier frequency. Therefore the design of the receiver is greatly simplified. The differential encoding also provide a sense of security to the signal data.

3. SIMULATION RESULTS

Digital modulation schemes in wireless communication systems are analysed and the function of bit error rate is calculated. This simulation has been bone in Matlab simulation environment. The figure shows the bit error rate comparison of BPSK, QPSK, DQPSK and π/4–DQPSK modulation schemes. The figure clearly shows that the π/4–DQPSK has better bet error rate compare to other modulation schemes. When comparing with BPSK, the QPSK, DQPSK and π/4–DQPSK provides twice the spectral efficiency with exactly the same energy efficiency.

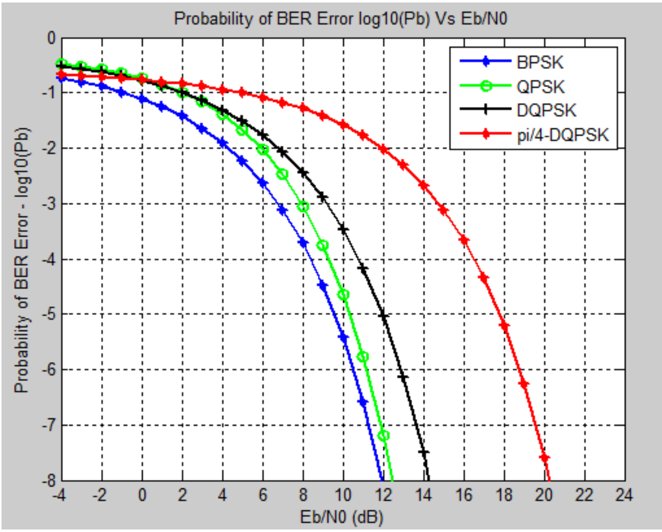

Fig -1: BER against SNR for OFDM System

3. CONCLUSIONS

The faster communication system is an increasing demand in the modern communication world, for fulfills that need developers provided various modulation techniques such as ASK, FSK and PSK etc. In this paper, we has been designed and compared different digital modulation schemes such as BPSK, QPSK, DQPSK and π/4-DQPSK in Matlab simulation environment. The work is to measure Bit Error Rate of various modulation schemes and come with the best configuration to achieve better consumption of bandwidth in OFDM systems. As per our design and comparison of modulation schemes it can be concluded that π/4-DQPSK can transmit more data and it has low error rate.

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