BER Analysis of OFDM System Using BPSK Modulation Over Different Channel

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Abstract

The most widely used modulation technique for wireless communications is Orthogonal Frequency Division Multiplexing (OFDM). To provide high data rates OFDM uses parallel data transmission system is used. Digital modulation techniques contribute in our mobile wireless communications by increasing the capacity, speed as well as the quality of the wireless network. In this paper, I concentrate on the BPSK digital modulation technique for OFDM system over AWGN and Rayleigh fading channels. BPSK modulation technique is simulated under different channel conditions. Subsequently, a comparison study is carried out to obtain the BER performance of BPSK- modulation scheme under AWGN and Rayleigh channel conditions, respectively and to identify which combination gives better performance. From comparison study we can observe that the OFDM- BPSK modulation has no any specific advantage over a conventional BPSK modulation scheme in AWGN channel but OFDM-BPSK modulation in AWGN channel has great advantage over OFDM-BPSK modulation in Rayleigh fading channel.

Keywords

OFDM, BPSK, BER, SNR

I. Introduction

In wireless communication technology the main objective is to provide high quality of data. Orthogonal Frequency Division Multiplexing (OFDM) has become a more popular technique for transmission of signals over wirelesschannels. In OFDM, signals are transmitted in sub-channel of different frequency in parallel fashion. The frequency of sub-channel are so selected that these frequencies are orthogonal to each other and therefore do not interfere with each other. This phenomenon makes it possible to transmit the data in overlapping frequency and hence reduces the bandwidth requirement considerably. OFDM is beneficial in many aspects such as high spectral efficiency, robustness, low computational complexity, frequency selective fading, and easy to implementation using IFFT/FFT [1].

In contrast to conventional Frequency Division Multiplexing, the spectral overlapping among sub-carriers are allowed in OFDM since orthogonality will ensure the subcarrier separation at the receiver, providing better spectral efficiency. OFDM transmission system offers possibilities for alleviating many of the problems encountered with single carrier systems. It has the advantage of spreading out a frequency selective fade over many symbols. This effectively randomizes errors caused by fading or impulse interference so that instead of several adjacent symbols being completely destroyed, many symbols are only slightly distorted. Because of dividing an entire signal bandwidth into many narrow sub-bands, the frequency response over individual sub-bands is relatively flat due to sub-band are smaller than coherence bandwidth of the channel. Thus, equalization is potentially simpler than in a single carrier system [2]. OFDM is a block modulation scheme where a block of N information symbols is transmitted in parallel on N subcarriers. The time duration of an OFDM symbol is N times larger than that of a single-carrier system. An OFDM modulator can be implemented as an IDFT on a block of N information symbols followed by an ADC. To mitigate the effects of ISI caused by channel time spread, each block of IDFT coefficients is typically preceded by a Cyclic Prefix (CP) or a guard interval consisting of G samples, such that the length of the CP is at least equal to the channel length. Under this condition, a linear convolution of the transmitted sequence and the channel is converted to a circular convolution. As a result, the effects of the ISI are easily and completelyeliminated. Moreover, the approach enables the receiver to use fast signal processing transforms such as a fast FFT for OFDM implementation [3].

OFDM has many advantages compared with other transmission techniques. One of such advantages is high spectral efficiency (measured in bits/sec/Hz). The orthogonal in OFDM implies a precise mathematical relationship between the frequencies of the sub channels that use in the OFDM system. Each one of the frequencies is an integer multiple of a fundamental frequency. This ensures that a sub channel does not interfere with other sub channels even though the sub channels overlap. This results in high spectral efficiency.

OFDM can be seen as either a modulation technique or a multiplexing technique. One of the main reasons to use OFDM is to increase the robustness against frequency selective fading or narrowband interference. In a single carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only a small percentage of the subcarriers will be affected.

II. General OFDM System

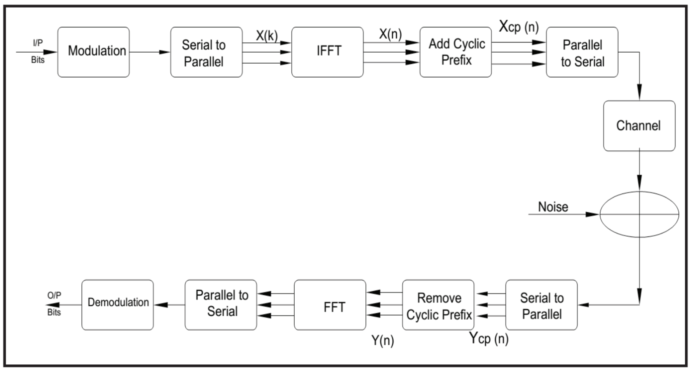

Fig. 1: Block Diagram of OFDM System

Fig. 1 represents the basic block diagram of OFDM system. It consist of transmitter and receiver sections, named OFDM transceiver system. The data bits inserted from the source are firstly mapped with BPSK modulation technique and after that converted from serial to parallel through convertor. Now N subcarriers are there and each sub-carrier consists of data symbol X (k) (k=0, 1,… .,N-1), where k shows the sub-carrier index. These N subcarriers are provided to Inverse Fast Fourier Transform (IFFT) block. After transformation, the time domain OFDM signal at the output of the IFFT [6-7] can be written as:

$$x(n)=\sum_{k=0}^{N-1}X(k)\exp(\frac{j2\pi kn}{N}) \quad (1)$$

where, n is the time domain sample index of an OFDM signal. After that, Cyclic Prefix (CP) is added to mitigate the ISI effect. We get signal $x_{cp}(n)$, which is sent to parallel to serial convertor again and then, this signal is sent to frequency selective multi-path fading channels and a noisy channel with independent and identically distributed (i.i.d.) AWGN noise. The received signal can be given by

$$y_g(n)=x_g(n)*h(n)+w(n), \quad (2)$$
$$0 \le n \le N-1$$

W(n) i.i.d. additive white Gaussian noise sample and h (n)is the discrete time Channel Impulse Response (CIR).

At the receiver, firstly serial to parallel conversion occurs and cyclic prefix removed. After removing the CP, the received samples are sent to a Fast Fourier Transform (FFT) block to de-multiplex the multi-carrier signals. Then the output of the FFT in frequency domain signal on the k^{th} receiving subcarrier can be expressed as:

$$y(k)=\frac{1}{N}\sum_{n=0}^{N-1}y(n)\exp(\frac{-j2\pi kn}{N})$$
$$=X(k)H(k)+W(k)\ 0 \le k \le N-1 \quad (3)$$

where, W(k) is noise in time domain and H(k) is the channel frequency response.

III. Channel Models For OFDM System

When there are large numbers of paths, applying Central Limit Theorem, each path can be modelled as circularly symmetric complex Gaussian random variable with time as the variable. This model is called Rayleigh fading channel model. A circularly symmetric complex Gaussian random variable is of the form, circularly symmetric complex Gaussian random variable is of the form, $Z=X+jY$, where real and imaginary parts are zero mean independent and identically distributed (iid) Gaussian random variables. For a circularly symmetric complex random variable Z, $E[Z]=E[e^{j\theta}Z]=e^{j\theta}E[Z]$. The statistics of a circularly symmetric complex Gaussian random variable is completely specified by the variance, $\sigma^2=E[Z^2]$. The magnitude $|Z|$ which has a probability density,

$$p(z)=\frac{z}{\sigma^2}e^{\frac{-z^2}{2\sigma^2}}, \quad z\ge 0$$

It is called a Rayleigh random variable. This model, called Rayleigh fading channel model, is reasonable for an environment where there are large numbers of reflectors. The channel is modelled as n-tap channels with each the real and imaginary part of each tap being an independent Gaussian random variable. The impulse response is,

$$h(t)=\frac{1}{\sqrt{n}}\left[h_1(t-t_1)++h_2(t-t_2)+\cdots+h_n(t-t_n)\right],$$

where $h_1(t-t_1)$ is the channel coefficient of the 1st tap, $h_2(t-t_1)$ is the channel coefficient of the 2nd tap and so on. The real and imaginary part of each tap is an independent Gaussian random variable with mean 0 and variance 1/2. The term $\frac{1}{\sqrt{n}}$ is for normalizing the average channel power over multiple channel realizations to 1.

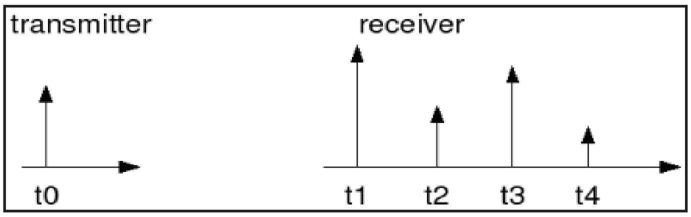

Fig. 2: Impulse Response of a Multipath Channel

IV. Performance of OFDM System

This section presents the relationship between the relation between Es/N0 orEb/N0 for OFDM system. In order to do a Monte Carlo simulation of an OFDM system, required amount of channel noise has to be generated that is representative of required Eb/N0. In MATLAB it is easier to generate a Gaussian noise with zero mean and unit variance. The generated zero-mean-unit-variance noise has to be scaled accordingly to represent the required Eb/N0 or Es/N0. Normally for a simple BPSK system, bit energy and symbol energy are same. So Eb/N0 and Es/N0 are same for a BPSK system. But for an OFDM-BPSK system, they are not the same. Because, each OFDM symbol contains additional overhead both time domain and frequency domain. In the time domain, the cyclic prefix is an additional overhead added to each OFDM symbol that is being transmitted. In the frequency domain, not all the subcarriers are utilized for transmitted the actual data bits, rather a few subcarriers are unused and are reserved as guard bands. The relation between symbol energy and the bit energy is as follows [3]:

The relation between symbol energy and the bit energy is as follows:

$$\frac{E_s}{N_0}=\frac{E_b}{N0}\left(\frac{nDSC}{nFFT}\right)\left(\frac{Td}{Td+Tcp}\right).$$

Expressing in decibels,

$$\frac{E_s}{N_0}dB=\frac{E_b}{N0}dB+10log_{10}\left(\frac{nDSC}{nFFT}\right)+10log_{10}\left(\frac{Td}{Td+Tcp}\right)$$

where, Td is the data symbol duration, Tcp is the cyclic prefix duration and n.DSC is the number of used subscriber in the OFDM system. Sinceorthogonality is important property for an OFDM system, so synchronization in frequency and time must be extremely good. Once orthogonality is lost we experience Inter-Carrier Interference (ICI). This will introduce interference from one subcarrier to another. There is another reason for Inter-Carrier Interference (ICI) in OFDM system. If we add the guard time with no transmission then it creates problems for IFFT and FFT, which results in Inter-Carrier Interference (ICI). A delayed version of one subcarrier can interfere with another subcarrier in the next symbol period. This can be avoided by extending the symbol into the guard period that precedes it. And this is known as a cyclic prefix. It ensures that delayed symbols will have integer number of cycles within the FFT integration interval. This removes ICI so long as the delay spread is less than the guard period. We should note that FFT integration period excludes the guard period. In an OFDM transmission, we know that the transmission of cyclic prefix does not carry 'extra' information in Additive White Gaussian Noise channel. The signal energy is spread over time Td+Tcp whereas the bit energy is spread over the time Td i.e.

$$E_s\cdot(Td+Tcp)=E_b\cdot Td.$$

Simplifying,

$$E_s=\frac{Td}{Td+Tcp}E_b$$

A. BPSK Modulation

BPSK is the simplest form of Phase Shift Keying (PSK). It uses two phases which are separated by 180° and so can also be 2-psk it . 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

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

B. Bit Error Rate (BER)

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors. 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. The bit error rate or bit error ratio (BER) is defined as the rate at which errors occur in a transmission system during a studied time interval. BER is a unit less quantity.

$$P_b = \frac{1}{2}\left(1 - \sqrt{\frac{\left(E_b/N_0\right)}{\left(E_b/N_0\right)+1}}\right)$$

C. Signal To Noise Ratio

There are a number of ways in which the noise performance, and hence the sensitivity of a radio receiver can be measured. The most obvious method is to compare the signal and noise leval for known signal levali.e signal to noise ratio.

$$SNR = \frac{P_{signal}}{P_{noise}}$$

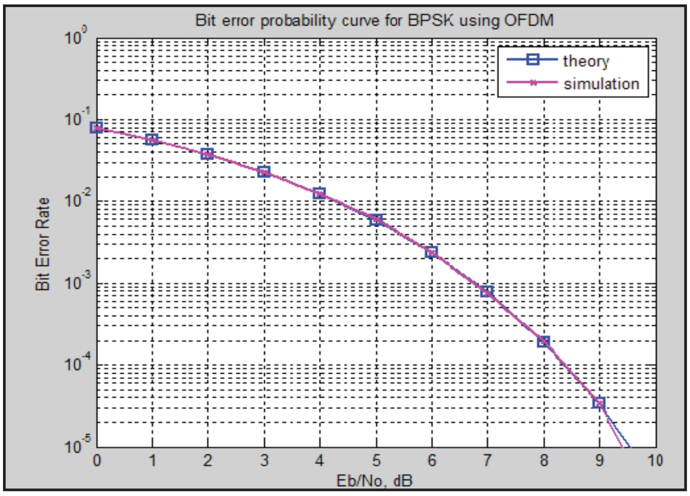

Fig. 3: BER VsEb/N0 for OFDM With BPSK Modulation Over AWGN Channel

In this section I represent the BER performance of BPSK digital modulation with OFDM technique over AWGN and Rayleigh fading channels, respectively. The performance of BER of BPSK modulation has been investigated by means of The OFDM technique MATLAB simulations are based on 802.11a specifications that shown in Table 1. The BER performance of an OFDM system with BPSK modulation over AWGN channel and N = 64 is shown in Figure 3. From the simulation result we can observe that the theoretical and simulated results of BPSK modulation over AWGN channel are the same. Hence this result is correct.

Fig. 4 shows the BER performance of conventional BPSK modulation over AWGN channel. It can be seen that the BER performance of conventional BPSK modulation is almost same with the BPSK using OFDM over an AWGN channel. From comparison study we can observe that the OFDM- BPSK modulation has no specific advantage over a conventional BPSK scheme in AWGN channel.a computer simulation using MATLAB. Both the AWGN and Rayleigh fading based OFDM systems are implemented using MATLAB programming and the graphical results found show the bit error rate probabilities of both the systems. The results presented show the BER performance as a function of the energy per bit to noise ratio.

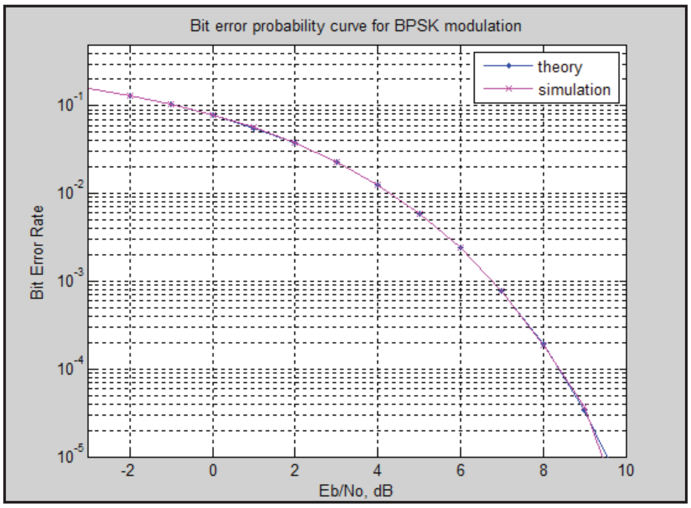

Fig. 4: BER VsEb/N0 for Normal BPSK Modulation over AWGN Channel

Fig. 5 shows the BER performance of an OFDM system having N=64 and BPSK modulation scheme over frequency flatRayleigh multipath fading channel. As can be seen, the numbers of taps do not introduce much deviation to the realperformance given by simulation results. Comparing the theoretical BER for Rayleigh equation, it is identical with the simulation result

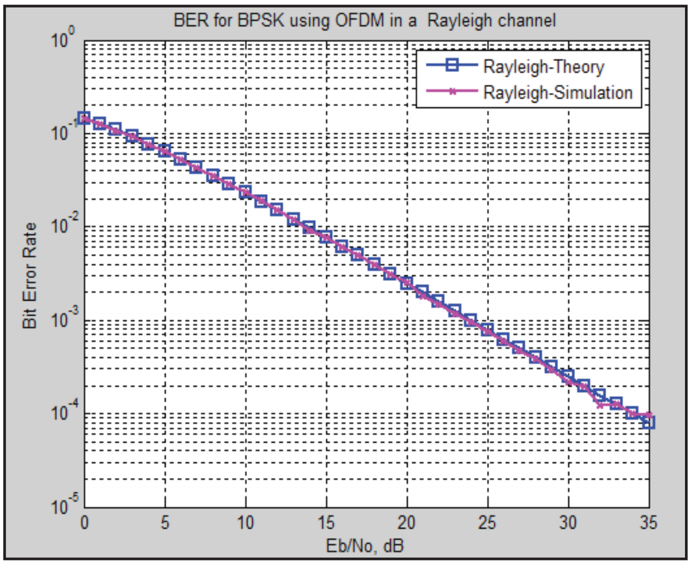

Fig. 5: BER VsEb/N0 for OFDM with BPSK Modulation Over Rayleigh Channel

As seen in Figs. 3, 4 and 5, it is found that as the energy per bit to noise ratio increases in any system, a decrement in bit error rate is encountered. Also, AWGN based system performs better in terms of bit error rate probability as compared to Rayleigh fading system.

V. Conclusion

It can be conclude that From the performed simulations in the AWGN channel, it is found that OFDM- BPSK modulation has no advantage over a conventional BPSK modulation scheme. But it is found that both OFDM-BPSK and conventional BPSK having small bit error rate probability than that of the Rayleigh fading based BPSK system. The purpose of this paper is to implement and find the efficient modulation combination that performs better in the wireless channels that are mostly multipath. The paper compares the performance of the OFDM system using binary phase shift keying whereas the future work may include the implementation of other modulation schemes and different channel scenarios for performance evaluation of any OFDM based system

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