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Simulation Study and Performance Comparison of OFDM System with QPSK and BPSK

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Abstract: **FDMA, TDMA and CDMA are the well-known multiplexing techniques used in wireless communication systems. While working with the wireless systems using these techniques various problems are encountered especially when a typical transmitted signal arrives at the receiver using various paths of different lengths. Since multiple versions of the signal interfere with each other, it becomes difficult to extract the original information. The use of orthogonal frequency division multiplexing (OFDM) technique provides better solution for the above mentioned problem. OFDM technique distributes the data over a large number of carriers that are spaced apart at precise frequencies. This spacing provides the "orthogonality", which prevents the demodulator from seeing frequencies other than their own. The benefits of OFDM are high spectral efficiency, resiliency of RF interference, and lower multi-path distortion. OFDM is a powerful modulation technique that is capable of high data rate and is able to eliminate ISI. Using MATLAB, simulation of OFDM was done with different modulation techniques using different transform techniques. The digital modulation schemes such as BPSK and QPSK were selected to assess the performance of the designed OFDM system.**

Keywords: **Bit Error Rate (BER), BPSK, Orthogonal Frequency Division Multiplexing (OFDM), QPSK.**

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM):

In order to solve the bandwidth efficiency problem, orthogonal frequency division multiplexing was proposed, where the different carriers are orthogonal to each other. With OFDM, it is possible to have overlapping subchannels in the frequency domain, thus increasing the transmission rate. This carrier spacing provides optimal spectral efficiency. Today, OFDM has grown to be the most popular communication system in high-speed communications. OFDM is becoming the chosen modulation technique for wireless communications. OFDM can provide large data rates with sufficient robustness to radio channel impairments.

II. PAPER PREPARATION GUIDELINES

Modulation - a mapping of the information on changes in the carrier phase, frequency or amplitude or combination.

Multiplexing - method of sharing a bandwidth with other independent data channels.

OFDM is a combination of modulation and multiplexing. Multiplexing generally refers to independent signals, those produced by different sources. In OFDM the question of multiplexing is applied to independent signals but these independent signals are a sub-set of the one main signal. In OFDM the signal itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier.

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OFDM is a special case of Frequency Division Multiplex (FDM). In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-carriers are transmitted in parallel. These carriers divide the available transmission bandwidth. The separation of the sub-carriers is such that there is a very compact spectral utilization.

As an analogy, a FDM channel is like water flow out of a faucet, a whole bunch of water coming all in one stream; In contrast the OFDM signal is like a shower from which same amount of water will come as a lot of small streams. In a faucet all water comes in one big stream and cannot be sub-divided. OFDM shower is made up of a lot of little streams.

Fig.1 (a) A Regular-FDM single carrier (b) Orthogonal-FDM

The advantage one over the other is that if I put my thumb over the faucet hole, I can stop the water flow but I cannot do the same for the shower. So although both do the same thing, they respond differently to interference. Both methods carry the exact same amount of data. But in case of any interfere to some of these small streams, only some part of data in the OFDM method will suffer.

These small streams when seen as signals are called the sub-carriers in an OFDM system and they must be orthogonal for this idea to work. The independent sub-channels can be multiplexed by frequency division multiplexing (FDM), called multi-carrier transmission or it can be based on a code division multiplex (CDM), in this case it is called multi-code transmission.

Working of OFDM Model Used for Simulation:

Fig.2 shows the basic block diagram of OFDM transmitter and receiver used for simulation. OFDM is generated by choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned data to be transmitted. The required amplitude and phase of the carrier is then calculated based on the modulation scheme (typically BPSK, QPSK, or QAM). For example, if we have to transmit incoming 8 bit digital data, we have to choose 8 different carrier signals, which are orthogonal to each other. Each carrier is assigned to a different bit and its amplitude and phase are chosen according to modulation scheme used. The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform. After the required spectrum is worked out, an Inverse Fourier Transform is used to find the corresponding time domain waveform. The guard period is then added to the start of each symbol.

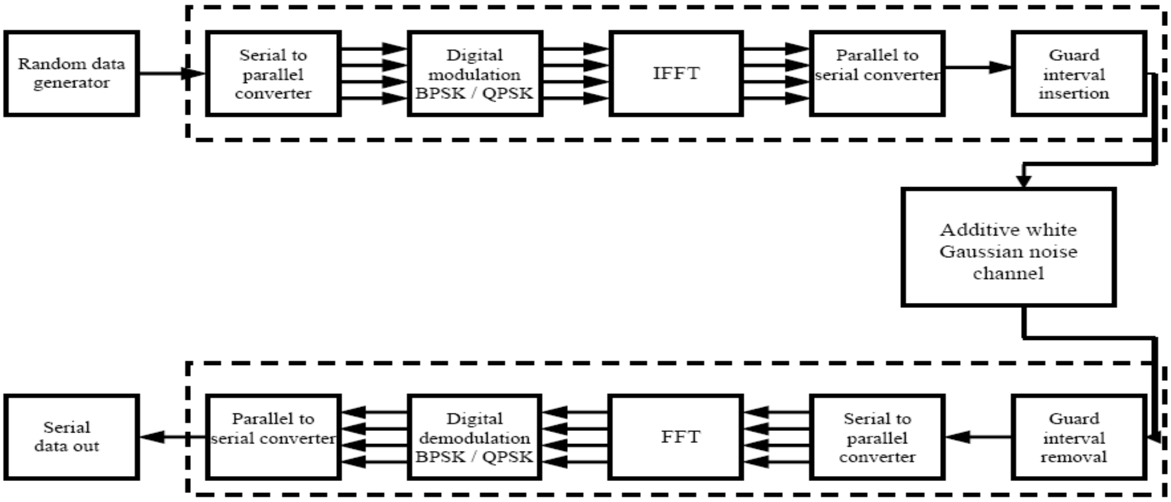

Fig. 2 OFDM model used for simulation

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OFDM SYSTEM SIMULATION WITH BPSK:

The random binary generator block, generates random binary numbers that are applied to BPSK modulator. This modulates using the binary phase shift keying method. The output is a baseband representation of the modulated signal. The input must be a discrete-time binary-valued signal. If the input bit is 0 or 1, then the modulated symbol is exp(θ) *or* -exp(θ) respectively, where θ is the Phase offset parameter. This frequency domain data is then applied to IFFT block as shown in the Fig.2.

The IFFT block computes the Inverse Fast Fourier Transform (IFFT) of length-M input, where M must be a power of two. While working with other input sizes, the Zero Pad blocks can be used to pad or to truncate the length so that it will be of size M. The output is always frame-based, and each output frame contains the M-point Inverse Discrete Fourier Transform (IDFT) of the corresponding input. Thus IFFT converts the frequency domain data in to time domain signal and at the same time maintains the orthogonality among the carriers. The AWGN channel block adds white Gaussian noise to a real or complex input signal. When the input signal is real, this block adds real Gaussian noise and produces a real output signal. When the input signal is complex, this block adds complex Gaussian noise and produces a complex output signal.

At the receiver basically the reverse operation to the transmitter will be done. After the removal of guard band the FFT block computes the Fast Fourier Transform (FFT) of length-M input, where M must be a power of two. To work with other input sizes, use the zero pad block to pad or truncate the length-M dimension to a power-of-two length. The data is converted back into frequency domain so that it can be processed by the BPSK Demodulator block. This block demodulates a signal that was modulated using the binary phase shift keying method. The input is a baseband representation of the modulated signal. The input must be a discrete-time complex signal. The block maps the point *exp(*θ*)* and - exp(θ*)* to 0 and 1, respectively, where θ is the Phase offset parameters.

The bit error rate is calculated by comparing the input data from a transmitter with input data from a receiver. It calculates the bit error rate by dividing the total number of unequal pairs of data elements by the total number of input data elements from source.

Simulation Results for OFDM with BPSK:

No. of bits transmitted = 12000

No. carriers used = 6

Bits per each carrier = 2000

TABLE 1: BER results for OFDM model using BPSK modulation

SNR(dB)	**BER(using BPSK)**
0	0.0756
1	0.0554
2	0.0378
3	0.0220
4	0.0117
5	0.0057
6	0.0024
7	8.2×10^{-4}
8	2.4×10^{-4}
9	0

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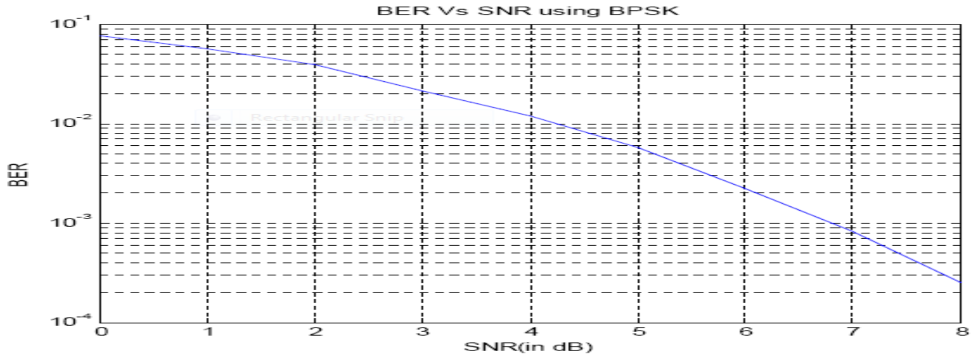

Fig. 3: BER versus SNR curve for OFDM with BPSK

These are categorized as tabular results, and graphical results. Signal to Noise ratio (SNR) also called as E_b/N_o where E_b is bit energy and No is noise energy. SNR values in dB are adjusted every time by adding noise in the AWGN channel. For particular SNR value system is simulated and corresponding probability of error (Bit Error Rate, BER) is calculated. These results are noted in Table 6.1. Figure 6.3 shows the nature of the BER versus SNR curve. As we go on increasing the SNR value, bit error rate reduces.

OFDM SYSTEM SIMULATION WITH QPSK:

Simulation of OFDM with QPSK modulation technique is similar to the simulation of OFDM with BPSK modulation. The difference is that the BPSK modulator/demodulators are replaced by the QPSK modulator/demodulators. The QPSK modulator modulates using the quaternary phase shift keying method. The output is a baseband representation of the modulated signal. The QPSK demodulator demodulates a signal that was modulated using the quaternary phase shift keying method.

Simulation Results for OFDM with QPSK:

The entire simulation process to be carried out is similar to that of OFDM with BPSK scheme. For particular SNR value system is simulated and corresponding probability of error (Bit Error Rate, BER) is calculated. These results are noted in Table2. Fig. 4 shows the nature of the BER versus SNR curve. As we go on increasing the SNR value, bit error rate reduces.

No. of bits transmitted = 12000

No. carriers used = 6

Bits per each carrier = 2000

TABLE 2: BER results for OFDM model using QPSK modulation

SNR(dB)	BER(using QPSK)
0	0.2067
1	0.1807
2	0.1485
3	0.1128
4	0.0800
5	0.0558
6	0.0315
7	0.0175
8	0.0092
9	0.0036
10	0.0013
11	5.84x 10^{-4}

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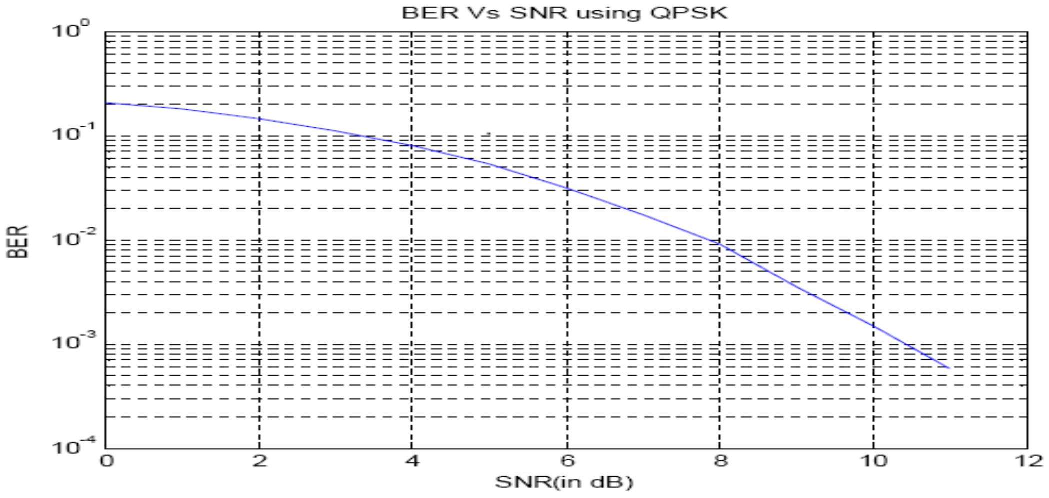

Fig. 4: BER versus SNR curve for OFDM with BPSK

COMPARISON OF OFDM SYSTEMS WITH BPSK AND QPSK:

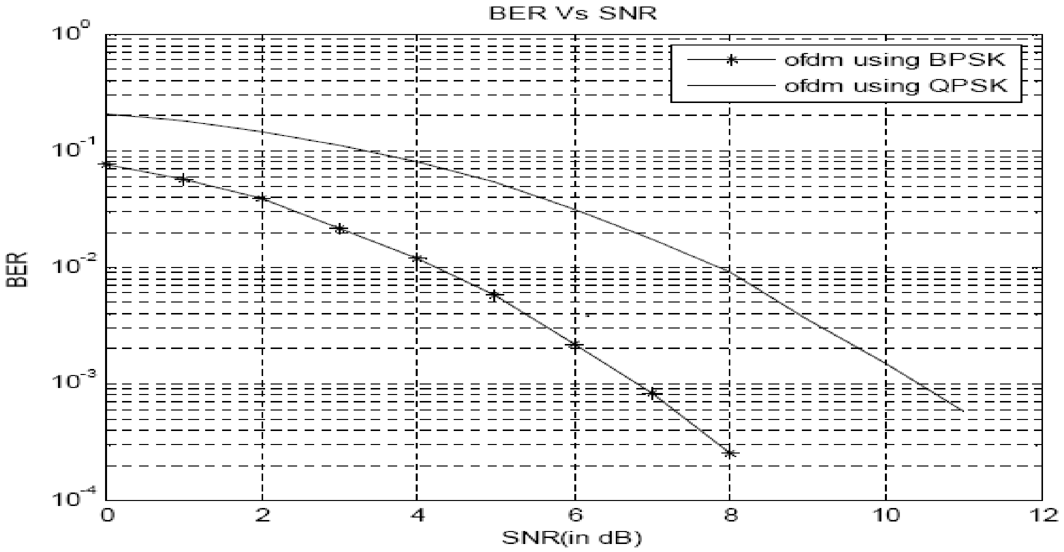

Fig. 5: Comparison of BER versus SNR of Two Modulation Schemes

Using MATLAB software, the performance of OFDM system was tested for two digital modulation techniques namely BPSK and QPSK. Fig.5 shows comparison of the BER versus SNR curves obtained in the OFDM systems with BPSK and QPSK modulation schemes. It is clearly observed that the curve in latter system is always above the curve in the earlier system

III. CONCLUSION

The OFDM makes efficient use of available spectrum by allowing overlapping among the carriers. It basically converts the high data rate stream in to several parallel lower data rate streams and thereby eliminating the frequency selective fading. It has been seen that the OFDM is a powerful modulation technique that is capable of high data rate and is able to eliminate ISI. It is computationally efficient due to the use of FFT techniques to implement modulation and demodulation functions.

From the simulation results, it is observed that the BPSK allows the BER to be improved in a noisy channel at the cost of maximum data transmission capacity. Use of QPSK allows higher transmission capacity, but at the cost of slight increase in the probability of error. This is because of the fact that QPSK uses two bits per symbol. Hence QPSK is easily affected by the noise. Therefore OFDM with QPSK requires larger transmit power. From the results, use of OFDM with QPSK is beneficial for short distance transmission link, whereas for long distance transmission link OFDM with BPSK will be preferable.

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