PERFORMANCE EVALUATION OF FFT BASED OFDM USING MULTIPATH FADING CHANNEL FOR UNDERWATER COMMUNICATION

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Abstract: The OFDM is widely used in many communication systems to improve data rate and reduce the bandwidth. The main purpose is to transmit the OFDM signal with low bit errors in noisy environments. The cyclic prefix works as a buffer area that stores the delayed information of the previous symbols. Different modulation methods, w.r.t bit error rate and SNR ratio are analyzed using MATLAB. In the OFDM system, various modulation techniques are used to analyze the system performance, which are BPSK, QPSK, 8PSK, 16QAM. The goal of our project is to improve system performance with a low bit error rate. Finally, bit error rate of these methods is analyzed by comparing BER and SNR plots.

***Index Terms* - OFDM, BER, SNR, FFT, IFFT, AWGN channel, BPSK, QPSK, 16QAM, 8PSK, Rayleigh fading**

I. INTRODUCTION

With the progression of innovation, the man has moved from the road to the air, as well as communication additionally observing in sub merged. As a result, interest in remote submerged correspondence is expanding due to other human activities such as ocean current monitoring, defense, seismic monitoring and submerged research etc., So far, the FFT-based OFDM is used for terrestrial communication. Achieving high data rate in submerged correspondence is challenging, recent researches in under water communication also suggests use of OFDM for under water communication helps to improve the bit error rate. It plays a very important role in autonomous submerged vehicles, which is leading technology now.

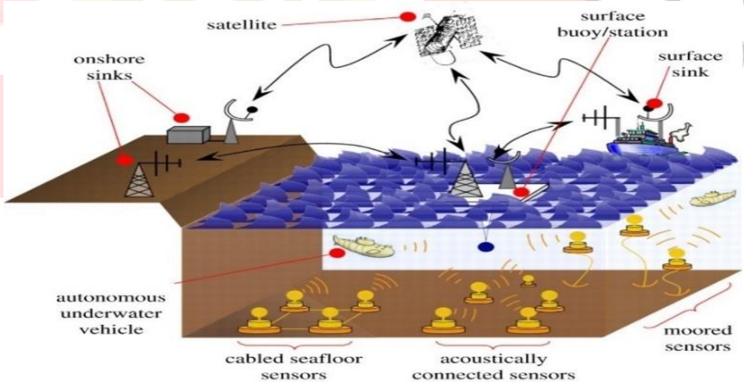

Fig 1.1: Under water Acoustic Sensor Network [7]

In wireless communication, the primary goal is to provide high quality data. Orthogonal frequency division multiplexing (OFDM) has become a more popular technique for transmitting signals through wireless channels. In OFDM, the signals are transmitted in sub-channels of different frequencies in parallel. The frequency of the sub-channel is so selected that these frequencies are orthogonal to each other and therefore do not interfere with each other. This phenomenon allows data to be transmitted over overlapping frequencies, thus significantly reducing the bandwidth requirement. OFDM is beneficial in many ways, such as high efficiency spectra, robustness, low computational complexity, frequency selective fading and easy to implement using IFFT / FFT.

Unlike conventional frequency division multiplexing, orthogonality guarantees subcarrier separation in the receiver to provide better spectral efficiency, so overlapping spectra along subcarriers are allowed in OFDM. An OFDM transmission system provides an imaginable outcome to mitigate a significant number of problems experienced in a single carrier system. It has the advantage of spreading frequency selective fades over a large number of symbols. This arbitrarily randomizes errors caused by fading or impulse interference, so that instead of some neighboring symbols being completely destroyed, many symbols are only slightly distorted. Since the total bandwidth of the signal is divided into a many of narrow sub bands, the frequency response for the individual sub bands is relatively flat, since the sub bands are smaller than the channel coherence bandwidth. Equalization is therefore much simpler than a single carrier system.

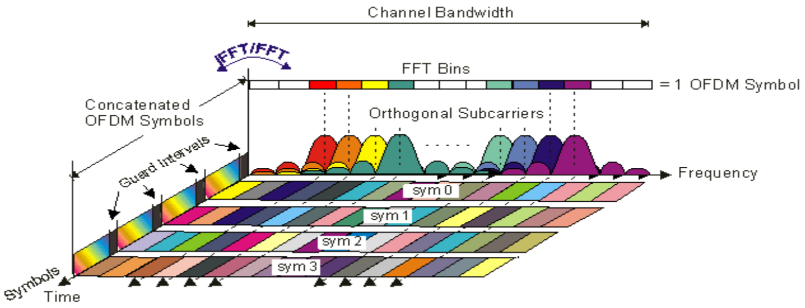

Fig 1.2: Frequency Representative of OFDM Signal [3]

OFDM is a block modulation scheme in which the block 'N' of the information symbol is transmitted in parallel on 'N' subcarriers. The duration of the OFDM symbol is 'N' times the duration of one carrier system. The OFDM modulator may be implemented as an IDFT on the block 'N' of the information symbols followed by the ADC. To mitigate channel-time ISI Impacts each block of IDFT coefficients typically precedes the cyclic prefix (CP) consisting of 'G' samples, to the extent that the length of the CP is at least equivalent to the length of the channel. Under these conditions, the linear convolutional transmission sequence and channel are converted to circular convolutions. As a result, ISI's impact is easily and completely eliminated. In addition, this approach allows the receiver to use fast signal processing, such as a fast FFT for OFDM implementation.

OFDM can be seen as a modulation technique or a multiplexing technique. OFDM makes it possible to increase robustness against selective frequency fading or narrow-band interference. In a single-carrier system, a single fade or interference may cause the entire link to fail. However, in a multicarrier system only a small percentage of the subcarriers will be affected.

On the other hand, there are few restrictions and disadvantages of the different transmission channels in a wireless medium between the receiver and the transmitter where the transmitted signals arrive at the receiver with various power and time delays due to the effects reflection, diffraction and diffusion. In addition, the BER values (Bit Error Rate) of wireless media are relatively high. These shortcomings sometimes introduce destructive effects on wireless data transmission. Therefore, error control is important in these applications. During digital data transmission and storage operations, the performance criterion is generally determined by BER, which is simply: Number of Error Bits / Number of Total Bits. Noise in the transmission medium disturbs the signal and causes data corruption. The relationship between the signal and the noise is described with SNR (signal to noise ratio). Generally, SNR is explained with signal power / noise power and is inversely proportional with BER. It implies, the lower the result of BER is the higher the SNR and the better quality of communication.

II. CYCLIC PREFIX FOR OFDM

One of the most important reasons for choosing OFDM for submerged communication is its effective approach to managing multipath delay propagation. To almost completely eliminate the ISI, a guard time is chosen to be larger than the expected delay propagation so that the symbol interference due to the multipath components is minimized. The guard time without a cyclic prefix signal causes cross-talk between various sub-carriers, causing the problem of Inter Carrier Interference and the subcarriers are no longer orthogonal to each other.

To eliminate ICI, the OFDM symbol is extended cyclically at guard time to ensure that the delayed replicas of the OFDM symbol always have an integer number of cycles within the FFT interval, since the delay is less than the guard time. As a result, signals with delays shorter than guard time significantly reduce ICI.

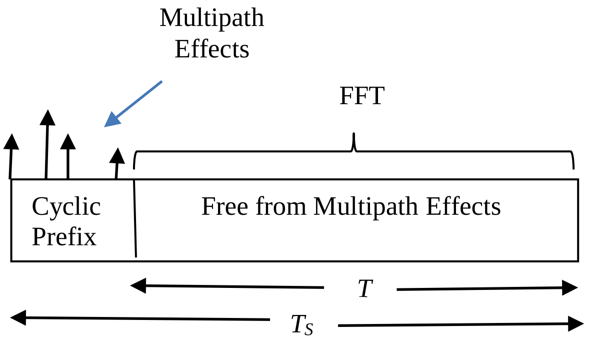

Fig 2.1: Cyclic prefix for Avoiding Multipath Effects

III. CHANNEL ENVIRONMENT

a) Rayleigh Fading Channel

The Rayleigh fading environment is represented by the many multipath components, each having a relatively similar signal amplitude and a uniformly distributed phase, which implies that there is no line of sight between the transmitter and the receiver [2]. The channel in which the signal takes various paths to reach the receiver after reflecting from various objects in the environment. The signal received by the receiver is the sum of the reflected signal and the main signal. The signal in the marine environment is diffracted or reflected due to volume fluctuations, fluctuations in sound velocity, internal waves, river flows, and so forth and forces emitted when the individual signal envelope is included.

The scattered components collected at the receiving end are described by the Rayleigh distributed function and are given by [7],

$$f(x) = \frac{2\pi}{\Omega} e^{\frac{-x^2}{\Omega}} u(x) \qquad (1)$$

Where, Ω is the average received power and u(x) is the unit step function.

b) AWGN Channel

AWGN is the simplest model of all channels. It takes place with well-designed mathematical models of communication system without fading and distortion. The AWGN channel adds white Gaussian noise to the signal as it passes through the channel, where the values of any pair of times are identically distributed and statistically independent of each other.

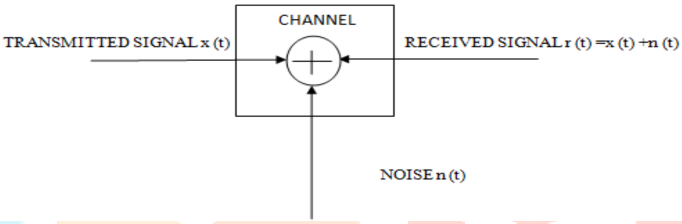

Fig 3.1: The AWGN channel

The fading channel output received a signal is given by,

$$r(t) = x(t) + n(t) \qquad (2)$$

Where, x(t) is transmitted signal and n(t) is white Gaussian noise.

In this AWGN, it is not associated with fading or other system parameters. Noise is added to the OFDM modulated signal only when it passes through the channel.

$$C = \frac{1}{2} log_2\left(1 + \frac{p}{n}\right) \qquad (3)$$

Where, C is the channel capacity.

IV. DIFFERENT MODULATION TECHNIQUES

a) BPSK (Binary Phase Shift Keying)

The PSK uses a finite number of phases; Each is assigned a unique pattern of binary digits. In general, each phase encodes an equal number of bits. Each pattern of the bits generates the symbol that is denoted by the particular phase. The BPSK is the simplest type of Phase Shift Keying (PSK). It consists of two phases that are separated by 180˚ and therefore, can also be named 2-PSK. It does not matter exactly where the points of the constellation are positioned and in the lower figure they are represented on the real axis, at 0˚ and 180˚.

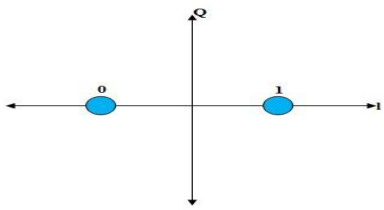

Fig 4.1: Constellation Diagram of BPSK

b) QPSK (Quadrature Phase Shift Keying)

QPSKs have four points on the constellation diagram and are equidistant around a circle. With four phases, QPSK can encode the two bits per symbol, shown in the figure with a gray coding to reduce the bit error rate (BER) - sometimes it is misperceived as twice the BER of the BPSK.

Mathematical studies show that QPSK can either double the data rate compared to a BPSK system while maintaining the same signal bandwidth, or maintain the BPSK data rate but halve the bandwidth needed.

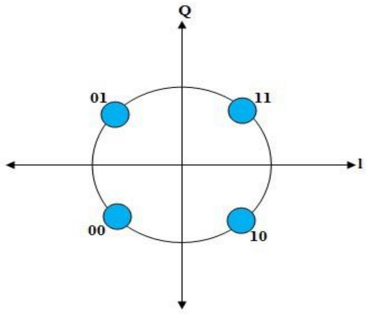

Fig 4.2: Constellation Diagram of QPSK

c) 16QAM (16 Quadrature Amplitude Modulation)

QAM is the encoding of information on a carrier wave by varying the amplitude of both carriers wave and a quadrature carrier that is 90° out of phase with the main carrier according to two input signals. That is, the amplitude and phase of the carrier wave are modified simultaneously according to the information we want to transmit.

In 16QAM, there are four values of I and four of Q. This results in a total of 16 possible states for the signal. It can transition from any state to any other at every moment of the symbol. Since 16 = 2^4, four bits can be sent per symbol. This consists of two bits for I and two bits for Q. The symbol rate is one quarter of the bit rate. Then this modulation format produces a more efficient transmission spectrally. It is more efficient than BPSK, QPSK 0r 8psk.

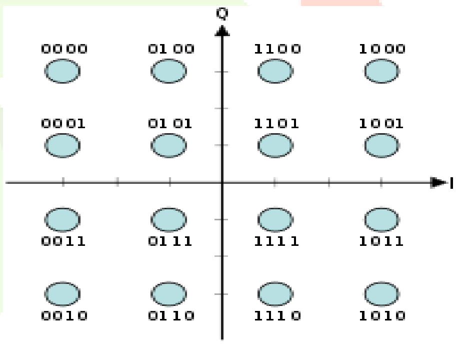

Fig 4.3: Constellation Diagram of 16QAM

d) 8PSK (8 Phase Shift Keying)

This is a type of M-ary PSK where M = 8. In the 8PSK modulation scheme, we can send (k = $\log_2 M = \log_2 8 = 3$) 3 bits of information per symbol.

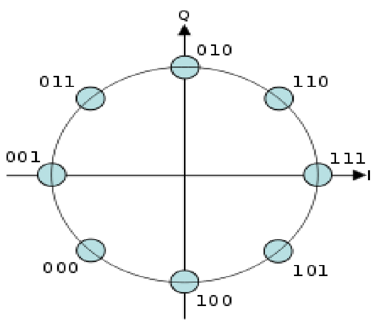

Fig 4.4: Constellation Diagram of 8PSK

V. PROPOSED METHODOLOGY

At the transmitter, the user information bit sequence is first channel coded to reduce the probability of receiver errors due to channel effects. Usually, convolutional coding is preferred. Before transmitting a data bit on a multipath fading channel via an OFDM transmitter, we use the BPSK, QPSK, 8PSK and 16QAM modulation schemes shown in fig 5.1. The transmitting section converts the digital data to be transmitted into a map of the amplitude and phase of the subcarrier using modulation techniques. The spectral representation of the information is then transformed in the time domain using an IFFT which is substantially more efficient from a computational point of view. Adding a cyclic prefix to each symbol resolves both ISI and Inter-Carrier Interference (ICI). The resulting sequence is converted to an analog signal using a DAC.

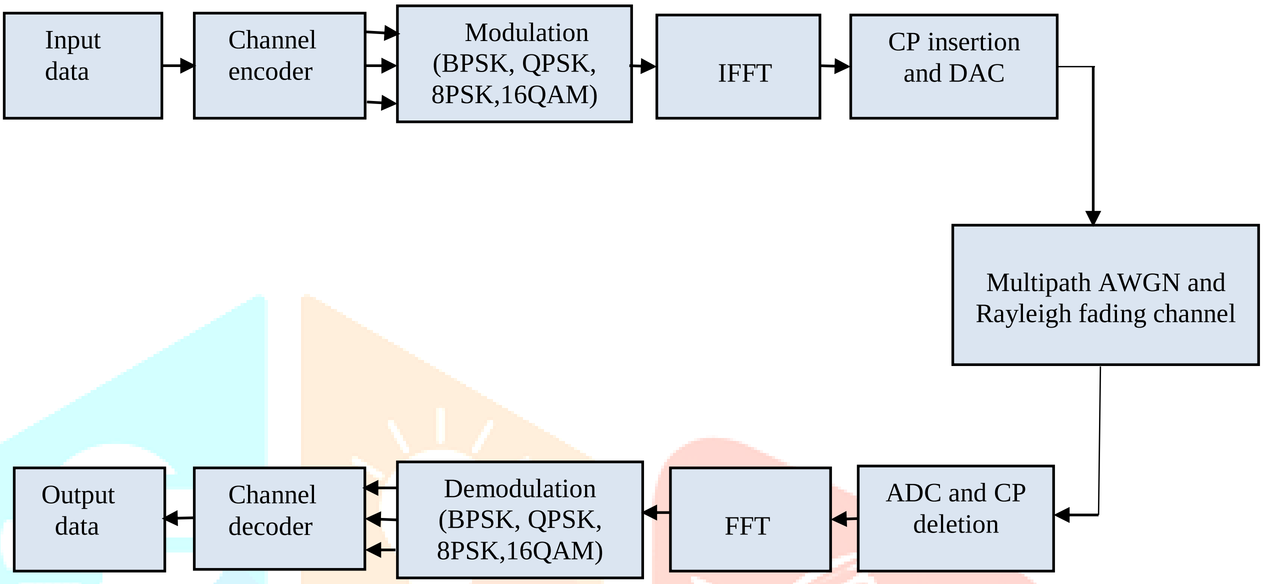

Fig 5.1: OFDM System Model

After the time domain signal passes through the channel, the signal is digitized using an ADC and the prefix is simply deleted. The receiver performs the reverse operation of the transmitter. The advantage of FFT-based OFDM is its low computational complexity and cost of implementation.

VI. SIMULATION PARAMETERS AND RESULTS

a) Simulation Parameters

BER performance calculated on the basis of different parameter,

Table 6.1: Simulation Parameter

Parameters	Specification
Number of Bits	10000
Number of Sub carriers	52
FFT Size	64
Sub carrier index	-26 to -1 1 to 26
Sub carrier spacing	312.5 KHz
SNR	0-35
Modulation Techniques	BPSK, QPSK,8PSK,16QAM
Channels	AWGN, Multipath Rayleigh fading

b) Results and Analysis

The MATLAB simulation was performed to analyze the bit error rate w.r.t SNR for different modulation techniques, such as QPSK, BPSK, 8PSK and 16QAM over the multipath fading channel. The use of the fading channel is to improve the performance of the system, since the high-speed data system becomes more sensitive to errors.

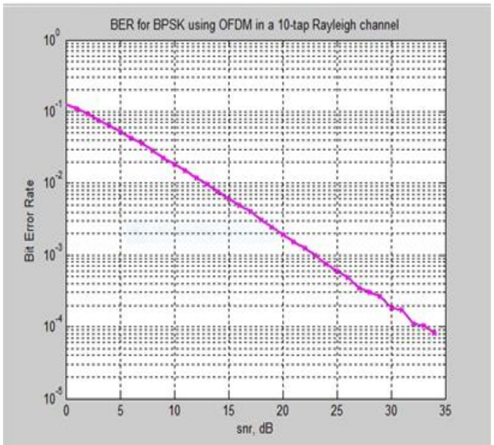

Fig 6.1: BER versus SNR for BPSK

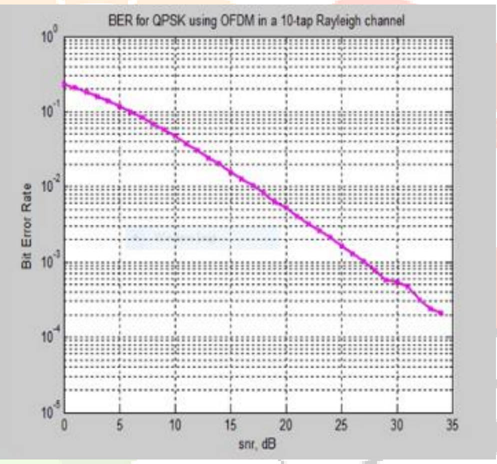

Fig 6.2: BER versus SNR for QPSK

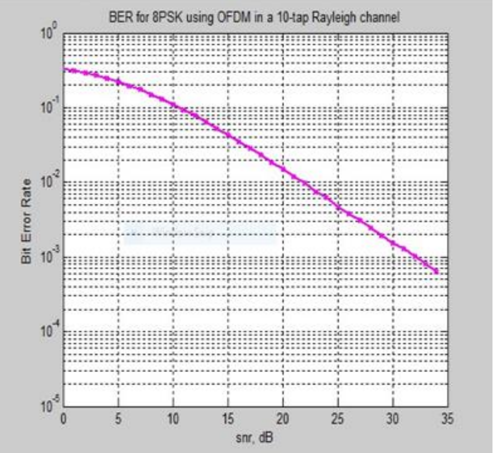

Fig-6.3: BER versus SNR for 8PSK

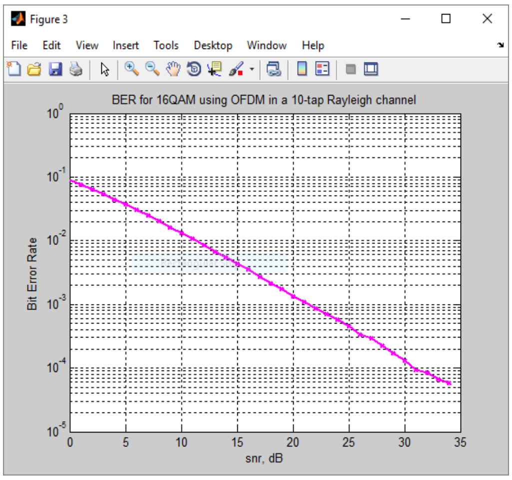

Fig 6.4: BER versus SNR for 16QAM

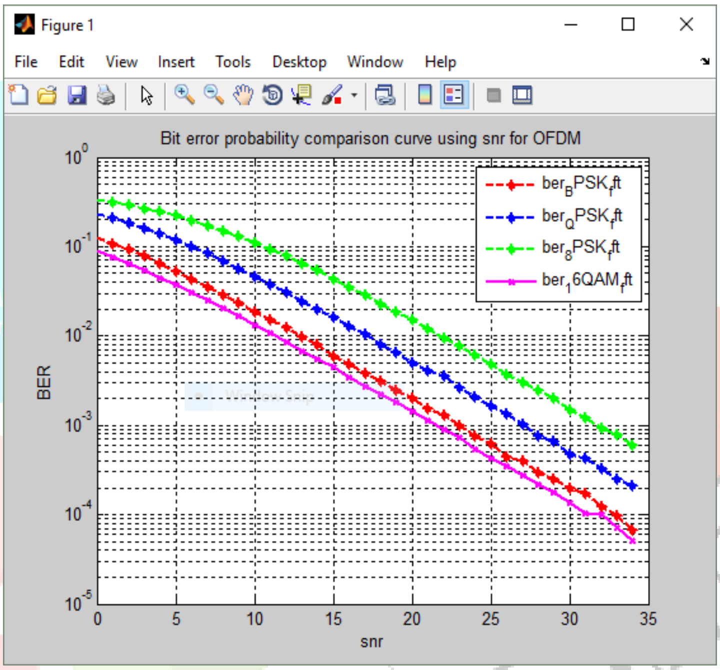

Fig-6.5: Comparison of BER versus SNR of Four Modulation Schemes

Fig 6.5 shows performance analysis of BPSK, QPSK, 8PSK, 16QAM modulation technique over Multipath fading channel. We know that if BER decrease than BER performance will increase.

Table 6.2: Comparison of Four Modulation Schemes over Multipath Fading Channel

SNR (dB)	BER OF 16QAM	BER OF BPSK	BER OF QPSK	BER OF 8PSK
4	0.0650	0.0915	0.1852	0.2925
8	0.0306	0.0441	0.1610	0.1971
12	0.0129	0.0184	0.0461	0.1105
16	0.0054	0.0077	0.0200	0.0533

In the graph, when the SNR value increases, BER decreases in all modulation techniques are shown in Table 6.2, which means that for better performance, the signal-to-noise ratio must be high, that is the noise must be low for better communication. Here, BER performance of 16QAM is better than BPSK. Also, QPSK is better than 8psk.

VII. CONCLUSION AND FUTURE WORK

In this work, the performance of the OFDM system on different modulation techniques has been observed. The analysis is based on the study of the bit error rate (BER) and the signal-to-noise ratio (SNR). To eliminate Inter Symbol Interference (ISI), a cyclic prefix addition method is used here. We finally conclude our work with the help of the graph. From the results obtained, it is concluded that the BER decreases as the SNR increases. The 16QAM has a better overall performance compared to the M-ary PSK techniques. The same analysis has been designed in SIMULINK and in future that can be helpful to test in FPGA.

In the future we can use some other modulation technique like M-QAM. Because after 8PSK (which is the maximum order of PSK) BER it increases abruptly therefore when using QAM BER it is reduced and can handle more bits simultaneously. We can use different order of M-QAM (8, 16, 32 order) to obtain better results than other modulation techniques, we can also use different transforms (DWT, DTCWT, DCT, DHT).

VIII. ACKNOWLEDGEMENT

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