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RESEARCH ARTICLE

Bird Study of Bit Error Rate in Underwater Acoustic Channel using OFDM

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Abstract

In our day today life, communication plays a crucial role without communication the world will be in its day of creation. Various communication developments through centuries and eras lead us now to a new technology called as WIRELESS communication. These communication facilities use air as medium for their transmission purposes and underwater acoustic communication is a rapidly growing field of research and engineering. The wave propagation in an underwater sound channel mainly gets affected by channel variations, multipath propagation and Doppler shift which keep lot of hurdles for achieving high data rates and transmission robustness. Furthermore, the usable bandwidth of an underwater sound channel is typically a few kHz at large distances. In order to achieve high data rates it is natural to employ bandwidth efficient modulation. Thus here present a reliable simulation environment for underwater acoustic communication applications (reducing the need of sea trails) that models the sound channel by incorporating multipath propagation, surface and bottom reflection coefficients, attenuation, spreading and scattering losses as well as the transmitter/receiver device employing Quadrature Phase-Shift Keying (QPSK) modulation techniques. To express the quality of the simulation tool various simulation results for exemplary scenes are presented. Usage of OFDM technique to reduce the ISI and check the performance by the addition of cyclic prefix and guard interval for the increase in efficiency of communication.

INTRODUCTION

Multicarrier based communication systems have lately become the norm in many wireless applications. OFDM type techniques are being used in many commercial systems like the IEEE 802.11 family, WiMAX and LTE among others. The prevalence of these systems dictates that they will remain in use for the foreseeable future and a large number of different variations with respect to their waveform parameters will possibly make it to the end user. A common feature of most of these OFDM systems use waveforms which utilize a cyclic prefix for the purpose of reducing multipath channels to a set of independent Gaussian channels. Waveforms having this feature can be easily detected by a simple detector. The detection of a cyclic prefix does not however guarantee the presence of an OFDM waveform. There are also single carrier systems which also utilize a cyclic prefix. It is of interest to have the capability of blindly, quickly and robustly detect the presence of cyclic prefix type of OFDM waveforms. In this paper we will assume that the receiver has no prior information about the transmitted OFDM waveform, though the use of a cyclic prefix will be presumed. This necessitates the receiver to perform the necessary classification completely blindly. Current OFDM classification techniques assume that OFDM waveforms, due to being composed of a large number of semi-orthogonal subcarriers and by the use of the law of large numbers, the resulting OFDM waveforms are Gaussian distributed in time. Goodness of fit algorithms can be used to determine how close the statistics of a waveform are to white Gaussian noise.

In theory, because most of the popular single carrier systems use modulation schemes which generate waveforms having non-Gaussian distributions, OFDM waveforms can be easily classified. However, that is not the case in practice. The authors experience is that real world OFDM waveforms are not as closely distributed to white Gaussian noise as previously claimed. Considerable investigation on specific systems has concluded that Gaussianity is not a reliable measure to classify OFDM waveforms. These findings necessitate us to search for alternative algorithms.

OFDM receivers utilize an FFT to invert the corresponding IFFT operation applied at the transmitter. Since the FFT operation in essence sums up a large number of samples to generate the output vector whose components are the transmitted data symbols, it is clear that if the received waveform is not an OFDM waveform, the FFT output vector will be Gaussian distributed, and otherwise it will be non-Gaussian distributed. We chose to apply a non-Gaussianity test on the FFT output in order to classify the waveform as being OFDM or not.

In order to provide good detection capabilities, the proposed classification system is required to have a very robust synchronization algorithm capable of operating at noise levels preferably below those where the subsequently applied non-Gaussianity test will be able to detect. In this paper, we will present a closed to optimum blind OFDM synchronization technique based on a multi-symbol Maximum-Likelihood algorithm. Subsequently, we will demonstrate the performance of detecting OFDM waveforms utilizing different constellation schemes. Because the underlying channels are frequency selective multipath channels, it will be shown that a much better classification can be obtained if the channel is first estimated and then used to form a better classification statistic.

UNDERWATER CHANNEL

The need for underwater wireless communications exists in applications such as remote control in off-shore oil industry, pollution monitoring in environmental systems, collection of scientific data recorded at ocean-bottom stations, speech transmission between divers, and mapping of the ocean floor for detection of objects, as well as for the discovery of new resources. Wireless underwater communications can be established by transmission of acoustic waves. Underwater communications, which once were exclusively military, are extending into commercial fields. The possibility to maintain signal transmission, but eliminate physical connection of tethers, enables gathering of data from submerged instruments without human intervention, and unobstructed operation of unmanned or autonomous underwater vehicles. Underwater communications in general mainly gets affected due to Channel Variations in Temperature, Salinity of water, pH of water, Depth of water column or pressure and Surface/bottom roughness.

Sound Attenuation in water

The acoustic energy of a sound wave propagating in the ocean is partly: absorbed, i.e. the energy is transformed into heat. Lost due to sound scattering by inhomogeneities. It is not possible to distinguish between absorption and scattering effects in real ocean experiments. Both phenomena contribute to the sound attenuation in sea water. On the basis of extensive laboratory and field experiments the following empirical formulae for attenuation coefficient in sea water have been derived.

- Thorp formula, valid frequency domain

  where, f is frequency [kHz]

$$\beta = \frac{0.11 f^2}{1 + f^2} + \frac{44 f^2}{4100 + f^2} (dB/\text{km})$$

- Francois and Garrison, valid frequency domain

$$\alpha = \frac{APf^2}{f_1^2 + f^2} + \frac{APf^2}{f_2^2 + f^2} + AP_2 \, \text{f}^2 [dB/\text{km}]$$

A general diagram showing the variation of alpha, α with the three regions of Boricacid, B(OH)3, Magnesium sulphate, MgSO4 and Pure water, H2O is depicted in Fig.1

From Fig. 1, it can be observed that for the Boric acid region, Attenuation is proportional to f^2. And for the regions Magnesium sulphate and pure water also Attenuation is proportional to f^2. In the transition domains it is proportional to f. Attenuation increases with increasing salinity and temperature, Fig.2. Attenuation increases with increasing frequency.

Surface and Bottom Scattering

Scattering is a mechanism for loss, interference and fluctuation. A rough sea surface or seafloor causes attenuation of the mean acoustic field propagating in the ocean waveguide. The attenuation increases with increasing frequency. The field scattered away from the specular direction, and, in particular, the backscattered field (called reverberation) acts as interference for active sonar systems. Because the ocean surfacemoves, it will also generate acoustic fluctuations. Bottom roughness can also generate fluctuations when the source or receiver is moving. The importance of boundary roughness depends on the sound-speed profiles which determine the degree of interaction of sound with the rough boundaries. Often the effect of scattering from a rough surface is thought of simply an additional loss to the specularly reflected (coherent) component resulting from the scattering of energy away from the specular direction. If the ocean bottom or surface can be modeled as randomly rough surface, and if the roughness is small with respect to the acoustic wavelength, the reflection loss can be considered to be modified in a simple fashion by the scattering process. A formula often used to describe reflectivity from a rough boundary is

$$p = \mathrm{expik}(\mathrm{x}\sin\theta + \cos\theta)$$

Ambient Noise

An important acoustic characteristic of the ocean is its underwater ambient noise. It contains a great bulk of information concerning the state of the ocean surface, the atmosphere over the ocean, tectonic processes in the earth's crust under the ocean, the behavior of marine animals and so on From, Fig. 2.3, different dominating levels of ambient noise and total noise level can be observed and the individual formulae for all these are as stated below:

- For shipping noise (traffic) 10-300 Hz

  $NL_{Bio}(f, S)$ in [dB]
- Turbulence noise

  $NL_{turb}(f) = 30 - 30 \cdot \log(f)$ f in [kHz]
- Self noise of the vessel

  $NL_{vessel}(f, v_s)$ in [dB]

where f and Vs denote the frequency and vessel speed respectively.

- Biological noise (fishes, scrimps etc.)

  $NL_{Bio}(f, S)$ in [dB]

where f and S denote the frequency and seasonal dependence.

- Sea state noise

  $NL_{ss}(f, v_w)$ in [dB]

The sea state noise can be determined as function of wind speed vw in [kn] and frequency f in [kHz] by

$$NL_{ss}(f, v_w) = 40 + 10.\log\frac{2}{1+j^2}$$

- Thermal noise $NL\ Therm\ f$ in [dB]

The thermal noise is due to molecular agitation (Brownian Motion). It can be expressed as function of frequency f in [kHz] by

$$NL_{Therm} = -15 + 20.\log(f)$$

Thus the total noise level can be determined by:

$$NL(f, v_s S, v_w) = 10.\log(10^{0.1NLtriffic} + 10^{0.1NLsea} + 10^{0.1NLwid} + 10^{0.1NLbio} + 10^{0.1NLss} + 10^{0.1NLthermal}$$

From Fig. 4, it can be observed that with an increase of grazing angle the scattering loss also increases. In the same way with the increase of wind speed, there is an increase in scattering loss [6]. Similarly we can also observe the dependence of Bottom reflection coefficient, 2 R on grazing angle φ_m and bottom type bt . This is illustrated in Fig.5.

Travel Times

The travel time of each ray is the time taken for it to reach the receiver. From the above discussion it is vivid that, all the other paths need more time compared to the direct path. Travel times for all the rays can be easily computed provided we know the length's or distances of all rays and the velocity of each ray. we know the distances of all rays and the velocity of each ray is the speed of sound, c. Thereby, we can write as

$T_{m1} = L_{m1} / c$, $T_{m2} = L_{m2}/ c$, $T_{m3} = L_{m3}/ c$, $T_{m4} = L_{m4}/ c$.

OFDM :

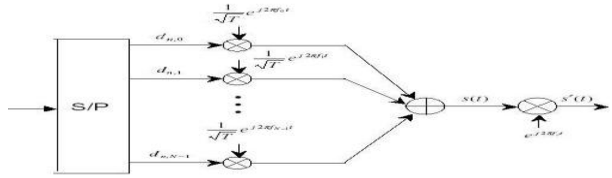
Orthogonal frequency division multiplexing (OFDM) is one of the multi-carrier modulation (MCM) techniques that transmit signals through multiple carriers. These carriers (subcarriers) have different frequencies and they are orthogonal to each other. Orthogonal frequency division multiplexing techniques have been applied in both wired and wireless communications, such as the asymmetric digital subscriber line (ADSL) and the IEEE 802.11 standard.

It is well known that Chang proposed the original OFDM principles in 1966, and successfully achieved a patent in January of 1970. Later on, Saltzberg analyzed the OFDM performance and observed that the crosstalk was the severe problem in this system. Although each subcarrier in the principal OFDM systems overlapped with the neighborhood subcarriers, the orthogonality can still be preserved through the staggered QAM (SQAM) technique. However, the difficulty will emerge when a large number of subcarriers are required. In some early OFDM applications, the number of subcarriers can be chosen up to 34. Such 34 symbols will be appended with redundancy of a guard time interval to eliminate intersymbol interference (ISI). Orthogonal frequency division multiplexing (OFDM) is one of the multi-carrier modulation (MCM) techniques that transmit signals through multiple carriers. These carriers (subcarriers) have different frequencies and they are orthogonal to each other. Orthogonal frequency division multiplexing techniques have been applied in both wired and wireless communications, such as the asymmetric digital subscriber line (ADSL) and the IEEE 802.11 standard.

Basics of OFDM

It is well known that Chang proposed the original OFDM principles in 1966, and successfully achieved a patent in January of 1970. Later on, Saltzberg analyzed the OFDM performance and observed that the crosstalk was the severe problem in this system. Although each subcarrier in the principal OFDM systems overlapped with the neighborhood subcarriers, the orthogonality can still be preserved through the staggered QAM (SQAM) technique. However, the difficulty will emerge when a large number of subcarriers are required. In some early OFDM applications, the number of subcarriers can be chosen up to 34. Such 34 symbols will be appended with redundancy of a guard time interval to eliminate

OFDM Modulation :



Guard Interval and Cyclic Prefix

In Fig 9, the block denoted as “Add Cyclic Prefix” actually should be called the “Add Guard Interval” in general. The cyclic prefix (CP) is the most common guard interval (GI). The GI is introduced initially to eliminate the inter block interference (IBI). Since one block of input data symbols are associated with a single transmitted waveform in an OFDM system, most people refer IBI as ISI. Fig 8 demonstrates how to use the GI to eliminate the ISI.

There are several options for GI. One choice of GI is zero padding. In this scheme, no waveform is transmitted in the GI duration. However, the zero-padded waveform would destroy the orthogonality of subcarriers and results in intercarrier interference (ICI). The cyclic prefix (CP) is a good substitute of the zero-padding GI. In the CP scheme, the GI is a copy of the partial waveform. Based on the fact that the Fourier bases are periodic functions, the orthogonality of subcarriers can be preserved consequently. As depicted in Fig 9, an end-portion of waveform is copied and inserted prior to the beginning of waveform. The time duration of CP, denoted as G T in the Fig 8, is often chosen according to the following:

Result and Discussion

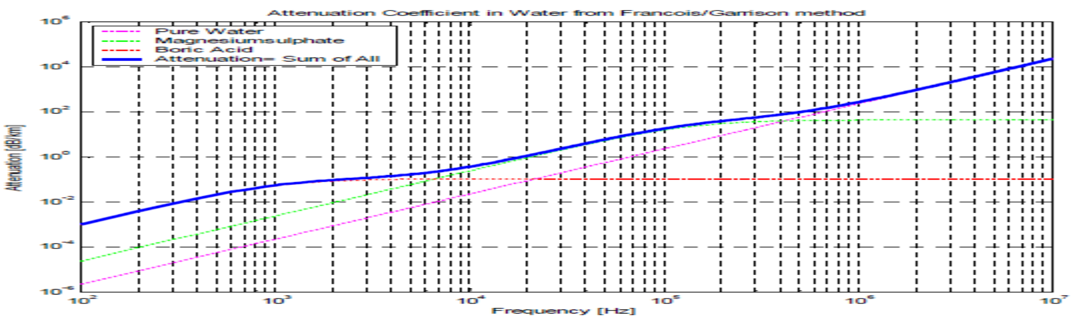


Fig. 1: General diagram indicating the three regions of B(OH)3, MgSO4 and H2O

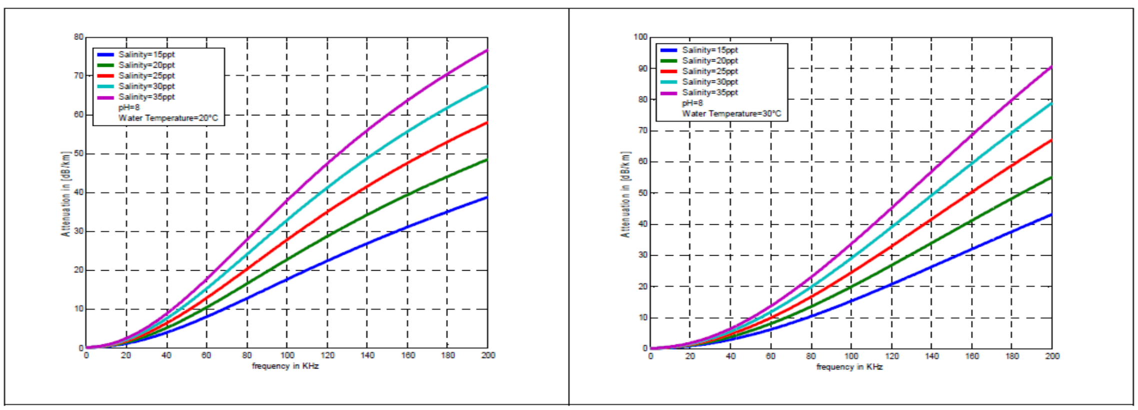


Fig.2: Attenuation plot for various salinities & for temperature a) 20°C b) 30°C

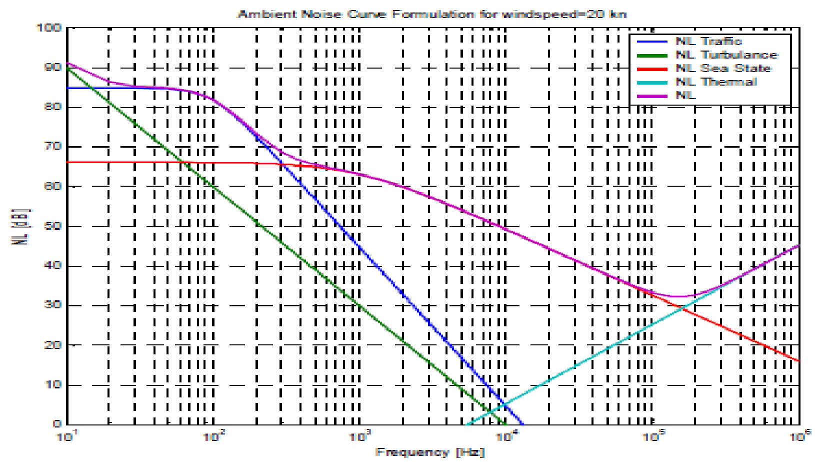


Fig.3: Ambient Noise Level

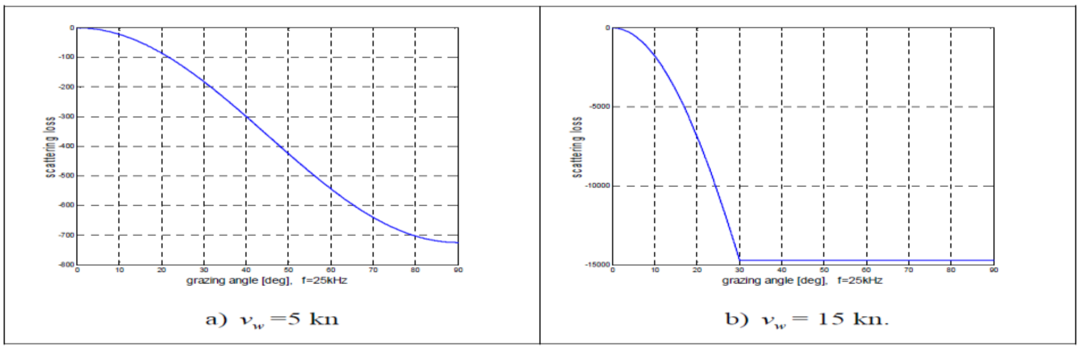


Fig. 4: Diagram illustrating dependence of R_1 on grazing angle, frequency and two wind speeds

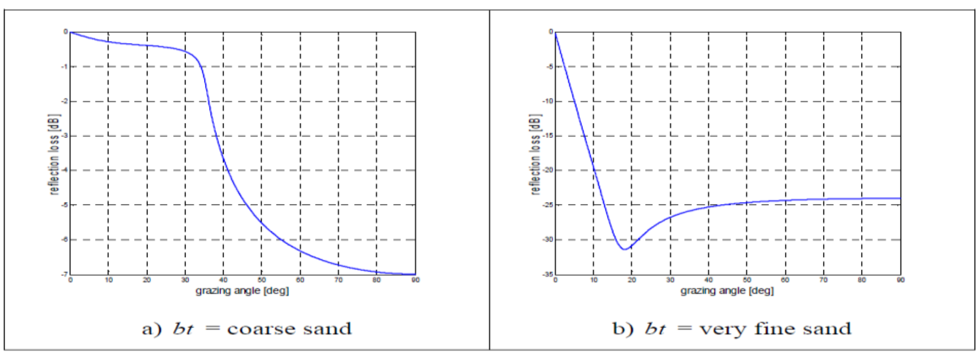


Fig.5: Diagram illustrating dependence of R_2 on grazing angle and two bottom types

Fig 6: Principal OFDM modulation block diagram

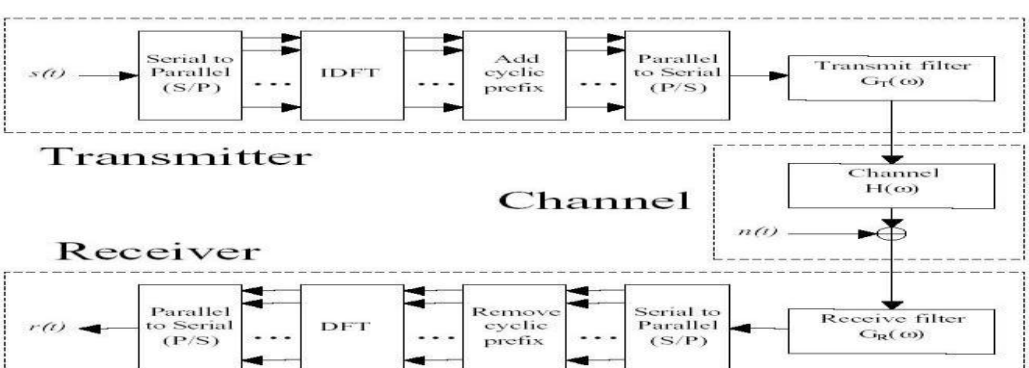


Fig 7 : Modern OFDM system

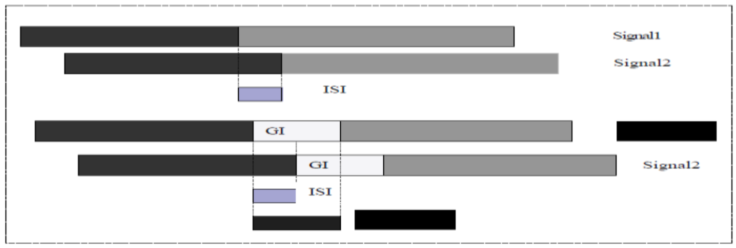


Fig. 8: Guard Interval Elimination of the ISI

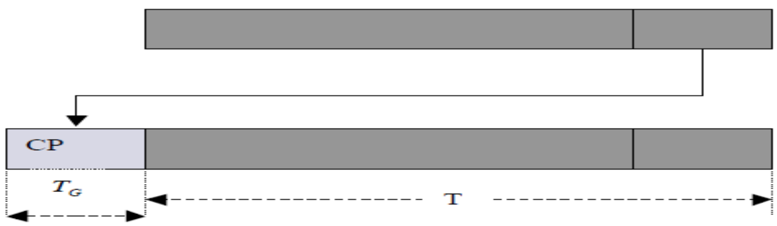


Fig 9 : Generate Cyclic Prefix CP is applied instead of zero-padding GI, both ICI and ISI are eliminated.

Random data

Random data generated in MATLAB using the command 'randsrc'. This command will create a table of random values that have to be transmitted over the channel and hence to the receiver. A randomly generated data is given in Fig.10

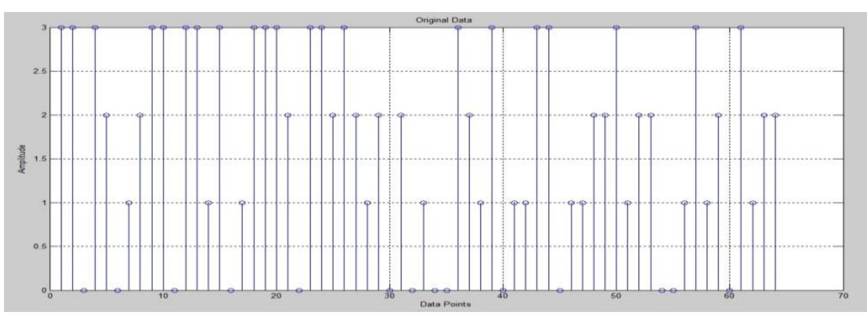


Fig.10: Random data generated in MATLAB

QPSK modulation

Once the source data has been generated for the desired bits then the data bits are mapped into the QPSK mapping using the matlab command 'pskmod' of order 4 and the result is being provided in the Fig 11.

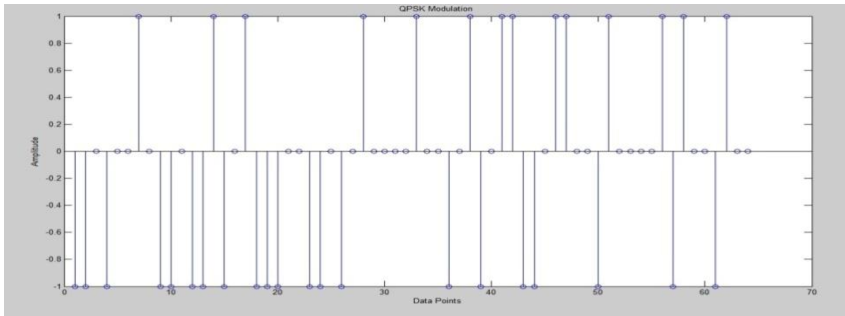


Fig.11: QPSK modulation of the source data

Orthogonal Behaviour

After the baseband modulation the original data to be transmitted is divided into 4 subcarrier for efficient transmission and the subcarriers are parallel to each other. Then the cyclic prefix of desired length is added to them and did the IFFT of the signal using the command 'ifft( )' Fig 12 shows the Orthogonal Behaviour of the Subcarriers.

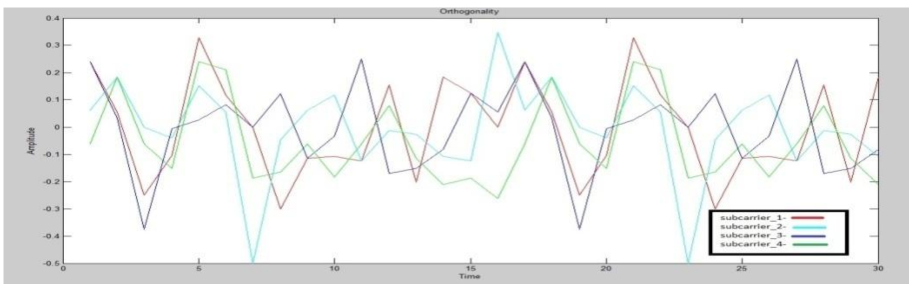


Fig.12: Orthogonal Behaviour of the Subcarriers

OFDM signal

Then the parrellel subcarrier modulated signal hav to be converted to serial for further transmission through the channel. Fig.13 shows the OFDM signal to be transmitted.

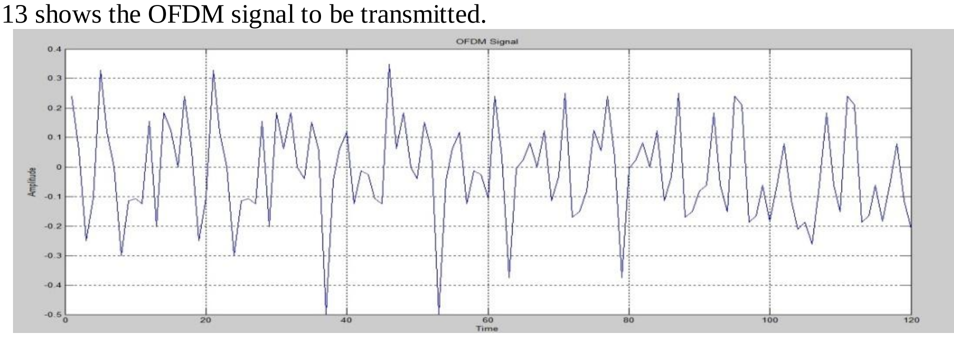


Fig. 13: OFDM signal to be transmitted.

Channel Simulation

The channel for us is Underwater channel which is a critical channel for wireless communication. The channel designing is well explained in chapter 1. Fig 14 shows the over all channel simulation

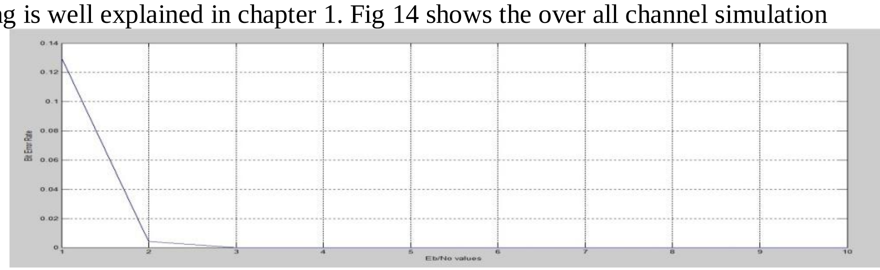


Fig 14 : over all channel simulation

The Fig 15 shows the OFDM Signal after passing through the channel. This channel is changed according to the channel parameters.

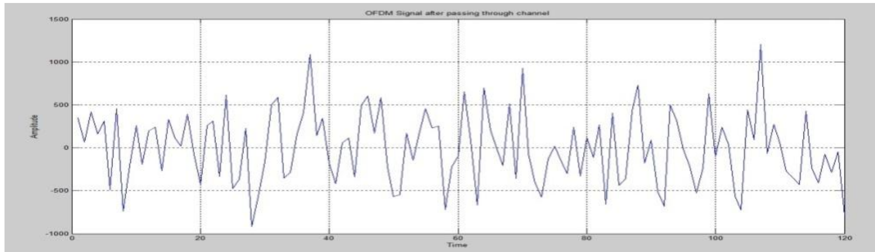


Fig 15 : Signal After Passing through the channel

Retrieval of the original data

Once the signal reches the receiver then demodulation of data and FFT of the signal takes place. This is the reverse of transmitter part and the demodulated signal is hence plotted as in Fig 16.

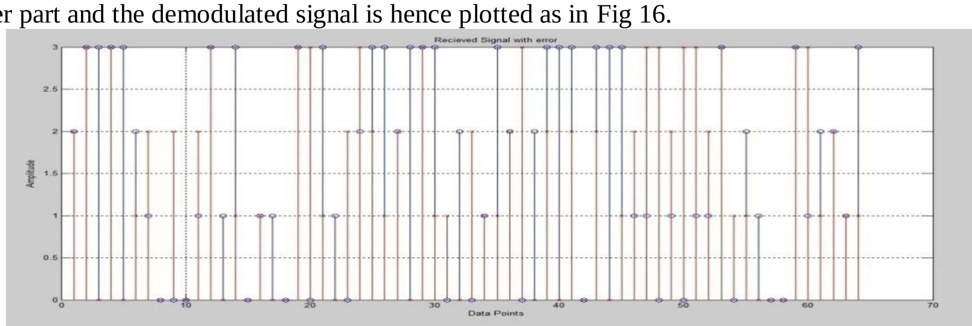


Fig. 16 : Demodulated data

By this way we are able to simulate the underwater channel and OFDM technique for that channel model in matlab software and the BER value is found to be 0.4 – 0.6. Further study needed to reduce the BER value and efficient implementation for future communication.

OFDM technique reduces the BER value to a limited value and for further enhancement of the communication i.e. the reduction of BER value, modern techniques such as usage of adaptive equalizes can be used .this will significantly reduce the BER value and enhance the communication. The main loss of the signals is due to attenuation and noise addition studies to improve the noise margin also helps in further improvement of communication.

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