ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization   Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th -18th July -2014

GUI Implementation of UAC Using DPSK, PN, Hadamard, Walsh, Barker and OVSF Code

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ABSTRACT: Underwater Acoustic Channel (UAC) is a time varying fading channel, which is constant over some transmissions after which UAC changes to a new independent status. It is critical to capture the distribution of the channel gain for designing a UAC communication system. A key research area in UAC is the development of advanced modulation and detection schemes for improved performance and range-rate product. In this paper, we propose a GUI to illustrate the BER for eight different coding techniques. Phase Shift Keying (PSK) signalling is employed to make efficient use of the available channel bandwidth. The mathematical modelling of the multi-path effects is based on the image method. Also, the attenuations due to wave scatterings at the surface and their bottom reflections are accounted for. In addition, we consider the loss due to the frequency absorption of different materials and the presence of ambient noises such as the sea state noise, ship-ping noise, thermal noise and turbulences.

KEYWORDS: Propagation loss, Ambient Noise, Graphical User Interface, Underwater Acoustic Channel, Pseudo Random code, Multipath loss, Phase Shift Keying.

I. INTRODUCTION

Modelling a UAC is very complex because there are spill over effects from surface waves, irregular funds, effects of wave-guiding channels in the marine and inter-symbol interference (lSI) [6]. Acoustic propagation is characterized by three major factors: attenuation that increases with signal frequency, time-varying multipath propagation, and low speed of sound (1500 m/s). The background noise, although often characterized as Gaussian, is not white, but has a decaying power spectral density. The channel capacity [14] depends on the distance, and may be extremely limited. Because acoustic propagation is best supported at low frequencies, although the total available bandwidth may be low, an acoustic communication system is inherently wideband in the sense that the bandwidth is not negligible with respect to its center frequency. The channel can have a sparse impulse response, where each physical path acts as a time-varying low-pass filter, and motion introduces additional Doppler spreading and shifting. Surface waves, internal turbulence, fluctuations in the sound speed, and other small-scale phenomena contribute to random signal variations. At this time, there are no standardized models for the acoustic channel fading, and experimental measurements are often made to assess the statistical properties of the channel [9] in particular deployment sites.

The most important characteristic of the seawater is its inhomogeneous nature, which can be classified into regular and random varieties. Regular variations of sound speed in different layers of water lead to the formation of sound channels and this phenomenon facilitates long distance sound propagation. Random in-homogeneities cause the scattering of sound waves and result in sound field fluctuations. The wave equation of sea water gives the theoretical basis of the mathematical models of underwater acoustic propagation. Based on the solutions to the wave equation, we can obtain five models for underwater channel: ray-theoretical model, normal mode model, multipath expansion model [1], fast-field model and parabolic equation model. In our paper, we use the multipath expansion model to model the channel. Direct

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sequence spread spectrum (DSSS) [3, 11] uses a code sequence to spread the symbols at the transmitter and a despreader at the receiver to recover the transmitted symbols.

The de-spreader via a correlator or a matched filter [7] provides a processing gain (matched filter gain) which enhances the symbol energy over noise thus allowing communications at low input signal-to-noise ratio (SNR). In Section II overview of UAC is explained and GUI implementation is carried out in Section III and followed by conclusion.

II. OVERVIEW OF UAC

The UAC is characteristics by four parameters Ambient Noise, Absorption Loss, Bottom and surface loss and multipath loss. These parameters are explained in short as below.

A. Ambient Noise:

Major sources of background noise in deep water are Tides, Seismic, Turbulence, Ship Traffic, Sea state, sea surface agitation and Electronic Thermal Noise. Tides, Seismic and Turbulence are significant at very low frequencies (<100 Hz). Ship Traffic and Sea state are most significant at frequencies ranges from 100 Hz to 1000 Hz. Sea surface agitation is dominant when frequencies lies between 1 to 100 KHz. For frequencies above 100 KHz, Thermal noise plays a vital role in Noise level calculation. Wenz Curves are plots of the average ambient noise spectra for different levels of shipping traffic, and sea state conditions (or wind speeds). It is used to predict the ambient noise levels for a given condition and frequency band. Noise Level (NL) generally decreases with frequency increasing, and also at great depths since most noise sources are at the surface.

B. Attenuation loss:

On the basis of extensive laboratory and field experiments [15], the attenuation due to the absorption effects of Boric acid (B(OH)3), Magnesium sulphate (MgSO4), and pure water (H2o) is considered for modelling UAC. The total loss is the sum of individual losses due to each component. The five independent variables for attenuation loss [2] (in decibels per kilometre) are frequency (in kilohertz), (measured on the NBS scale), salinity (g/kg), temperature (in degrees Celsius), and depth (in kilometres). It is also referred as Transmission loss (TL).

C. Surface and Bottom Loss:

A description of the reflection of underwater sound [8] incident upon a real ocean surface boundary is a necessary component of an acoustic transmission model. For predictions of signals received at medium-to-long ranges (10 km to 30 km or more), especially for oceans with an isothermal surface duct or for shallow oceans, the acoustic interaction at small angles of incidence (about 10° and less) is particularly relevant. Descriptions of surface loss for such situations are needed for matters relating to detection of either submerged or surface vessels, and in relation to the impact of underwater acoustic signals. The available surface loss models include the Kirchhoff, Beckmann-Spizzichino and the small-slope model from the Applied Physics Laboratory of the University of Washington, Seattle.

The underwater acoustic channel poses many obstacles to sound propagation. Especially, when sound propagates over a long range [10] (>80Km),it will always encounter an extremely complicated environment with multi sound-speed profiles and water depth varying with range. In such a case, the channel characteristics vary a lot from the flat bottom one. The characteristics of flat bottom propagation are single and multi sound speed distributions. For sloping bottom propagation are Upslope and Downslope propagation.

D. Mathematical Modeling of Multipath Effect:

To calculate the loss due to wave scattering at the surface, we use the probability density function of the Gaussian Normal

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distribution for the surface displacement variable. For the calculation of wave bottom reflection coefficient, we use the Jackson pattern to select the bottom water type which is simulated based on the Strait of Hormuz conditions and the Hamilton-Bachman models. In the image method, according to Fig 2.1, the surface and bottom are considered as two mirrors. In the cylindrical coordinates, for a channel with depth D, the surface is at Z = 0 and the bottom is at Z = D. Assume that a transmitter is at (0, Zs) and a receiver is at (0, Z). Therefore, the first image of the transmitter, due to the mirror effect of the surface, is located at (0, –Zs).

Then, the transmitter and this image, in relation to the bottom, are located at (0, 2D – Zs) and (0, 2D + Zs), making the second and third images, respectively. In general, the number of images or the sources of virtual transmitters equal infinity, and in each of the image repetitions, four new images are generated, each of which is related to one of the Eigen rays.

According to this theory [4, 5], the sound pressure field can be expressed largely through equation (1). In the above equation, A is the amplitude of the sound wave; R_1 and R_2 are the reflection coefficients of the surface and bottom respectively; $\varphi_{m1} \ldots \varphi_{m4}$ are the reflection angles of the four Eigen rays; K is the wave number; and L_{m1}, L_{m2}, L_{m3}, L_{m4} are the lengths of the displacement vectors of the Eigen rays Reflected Surface Reflected Bottom Reflected (RSRBR), Reflected Bottom Reflected (RBR), Reflected Surface Reflected (RSR), Direct Path (DP) in the $(m + 1)^{th}$ stage of the production cycle of virtual resources, respectively. Considering the location of the generated image in the m^{th} stage, the displacement vector lengths of propagation paths are in accordance with equation (2).

$$P(r,z,\omega) = A(\omega)\sum_{m=0}^{\infty}\left\{\begin{aligned} & R_1^{m}(\varphi_{m1},\omega)\,R_2^{m}(\varphi_{02},\omega)\,\frac{e^{-jkL_{m1}}}{L_{m1}} \\ & +R_1^{m+1}(\varphi_{m2},\omega)\,R_2^{m}(\varphi_{m2},\omega)\,\frac{e^{-jkL_{m2}}}{L_{m2}} \\ & +R_1^{m}(\varphi_{m3},\omega)\,R_2^{m+1}(\varphi_{m3},\omega)\,\frac{e^{-jkL_{m3}}}{L_{m3}} \\ & +R_1^{m+1}(\varphi_{m4},\omega)\,R_2^{m+1}(\varphi_{m4},\omega)\,\frac{e^{-jkL_{m4}}}{L_{m4}} \end{aligned}\right\} \quad ...(1)$$

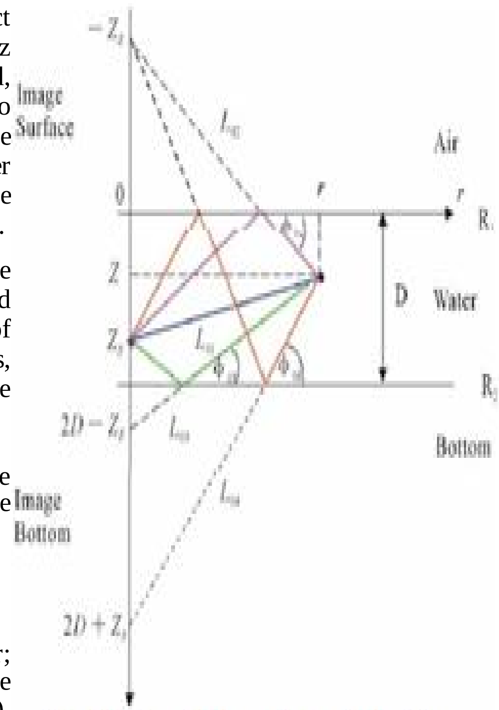

Fig 2.1 Schematic of a transmitter and its first three images in the image theory

$$\left.\begin{aligned} L_{m1} &= \sqrt{r^2 + (2Dm - Z_s + Z)^2} \\ L_{m2} &= \sqrt{r^2 + (2Dm + Z_s + Z)^2} \\ L_{m3} &= \sqrt{r^2 + (2D(m+1) - Z_s - Z)^2} \\ L_{m4} &= \sqrt{r^2 + (2D(m+1) + Z_s - Z)^2} \end{aligned}\right\} ...(2)$$

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E. Choosing the best carrier frequency

The TL × NL product, determines the frequency dependent part of the SNR. For each transmission distance d and the factor 1/(TL x NL), there exists an optimal frequency (f_0) for which the maximal narrow-band SNR is obtained. This survey [12, 13] permit to determine optimal parameters for better underwater communication. The optimal frequency will be calculated for the various range individually. In our GUI model, the optimal frequency plot is modelled and it is given in equation 3. Both the modelled and actual curve is shown in Fig 2.2

$$opt\_freq = 40e^{-0.2d} + 2....(3)$$

Where d is the distance between the transmitter and receiver. o_0 We can see from the graph that the modelled graph is identical to the actual one.

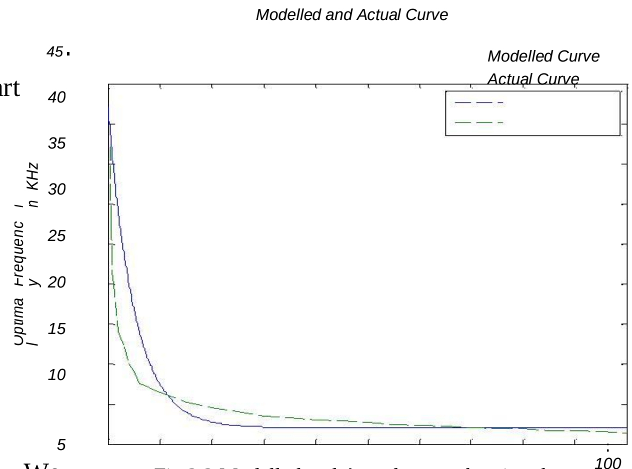

Fig 2.2 Modelled and Actual curve showing the optimal frequency for different range

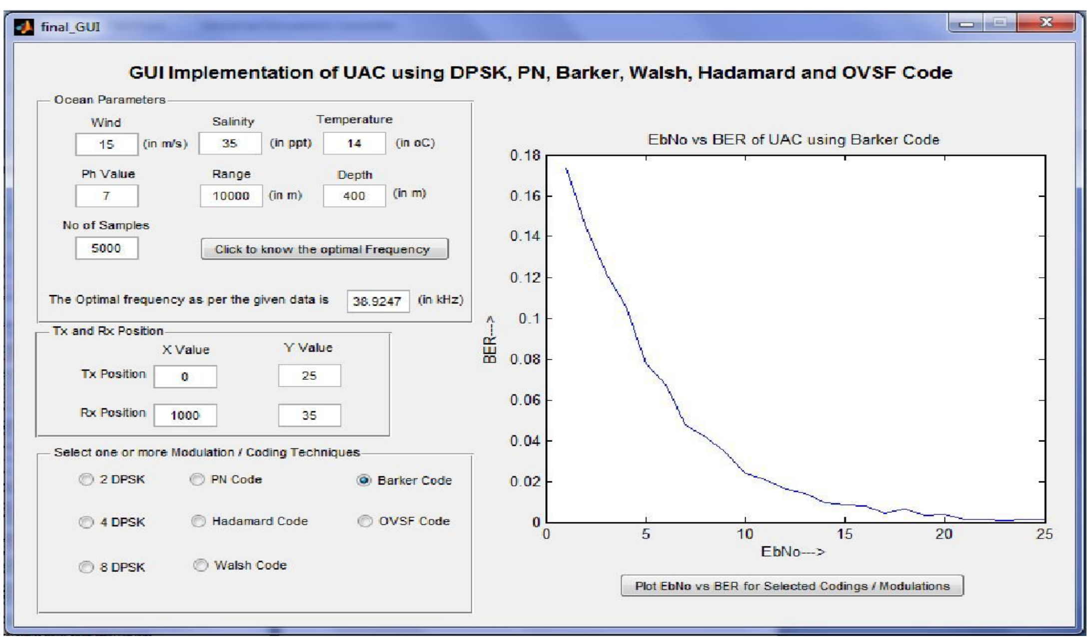

Fig 3.5 Complete GUI of UAC

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III. GUI IMPLEMENTATION

The GUI is designed into four section, in the first section as shown in figure1, the ocean parameters like wind speed, salinity, temperature, Ph value, Range (Distance between the transmitter and receiver), depth of the ocean are taken as input and according to the data, the optimal frequency will be calculated and shown in the Fig 3.1. In the second section, the transmitter and receiver position will be taken as the input and noise and attenuation will be calculated according to that data which is shown in Fig 3.2. The Fig 3.3 shows the third section in GUI design, in which we can select the type of modulation / coding techniques for which BER calculation will be displayed in Fig 3.4. The complete GUI is shown in Fig 3.5 which display the BER for UAC using barker code where EbNo is ranging from 1 to 25.

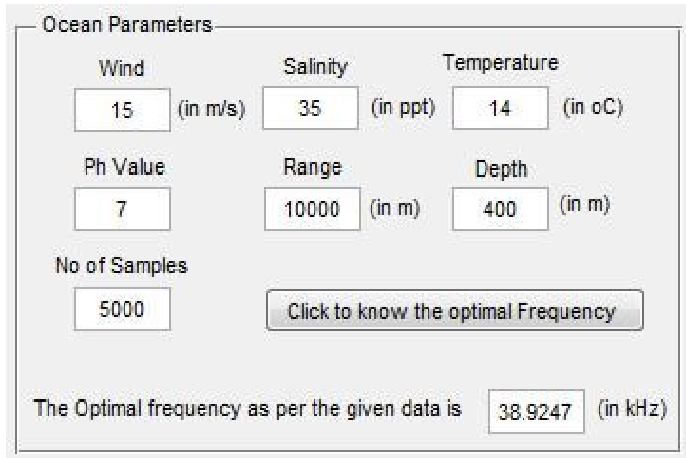

Fig 3.1 Ocean parameters to obtain the optimal frequency

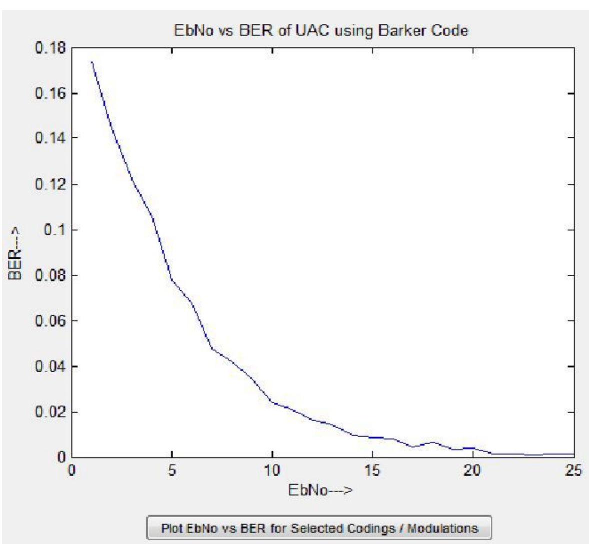

Fig 3.4 Panel for displaying the BER Vs EbN

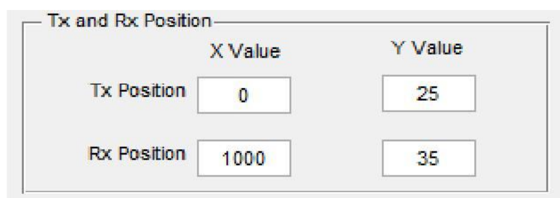

Fig 3.2 Panel to feeding the Transmitter and Receiver ***Position***

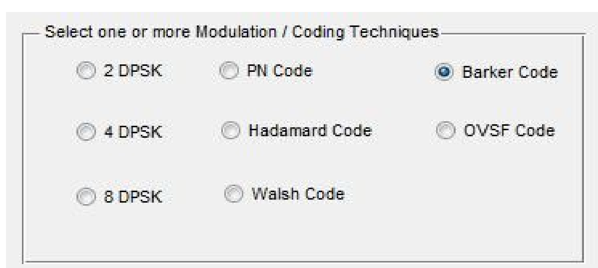

Fig 3.3 Panel for selecting the type of modulation / coding

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IV. CONCLUSION

In our GUI model, we have considered all the necessary parameter and to model the channel, image mirror theory is used. Optimal frequency is calculated from the user data and the BER is calculated for the different modulation / coding techniques is shown in the Table 1. It is observed form the table that coding techniques gives better result than the DPSK. Using coding techniques we obtain the BER ranges from 0.2116 to 0.0002 (EbNo ranges from 1 to 25) which is 100 times better than 8 DPSK. To obtain the better performance Orthogonal Frequency Division Multiplexing (OFDM) and adaptive equalizer can be used. Equalizer will be effective in eliminating the ISI.

Table 1 : BER value for different type of modulation / coding Techniques

Modulation / Coding Techniques	BER (EbNo ranges from 1 to 25)	
	BER Maximum	BER Minimum
2 DPSK	0.3598	0.0939
4 DPSK	0.2258	0.0474
8 DPSK	0.1726	0.0366
PN Code	0.1766	0.0024
Hadamard Code	0.1808	0.0004
Walsh Codee	0.1962	0.0002
Barker Code	0.2116	0.0004
OVSF Code	0.1770	0.0008

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