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UWA Channel for Data Communication of UWASN using OFDM

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ABSTRACT

In this paper, the Underwater Acoustic Channel modeling and its estimation for successful data communication between the underwater nodes is presented, since the underwater wireless communication is a rapidly growing area of research and engineering. For designing the underwater sensor network, underwater channel is required for efficient communication. The acoustic channel used for propagating the underwater data from transmitter to receiver, in place of RF signal because RF signal attenuates under the water and Optical signal can be used for long distance communication. Therefore; the acoustic signals are used for data transmission. This channel is having formidable challenges like slow transmission of data, prescribed bandwidth, varying transmission delay and many more, which gives multipath fading and Doppler Effect. In this paper, we present the estimation and modeling of efficient underwater acoustic channel for data communication. The channel is modeled based on designed algorithm for noise interference, transmission losses, multipath fading effect, Doppler Effect, transmission delay and bandwidth limitation. Acoustic signal scattered and propagates very slow under the water, due to which data may get scattered and lost. These issues are solved using OFDM approach. As the signal gets scattered in to the water, therefore orthogonal frequency division multiplexing technique is implemented, which divide the carriers into equivalent sub-carriers. Here 16 to 64 sub-carriers at the frequency of 3.6 MHz and each sub-carrier are made to process 256 bits per sub-channel; therefore, maximum 4096 bps to 16384 bps can be actually transmitted with the help of each sub-carrier. Based on this concept, the system is simulated for 25 numbers of nodes. Here, we design the acoustic channel is particularly modeled based on Gaussian distribution, where the delay varies with time rapidly. The Orthogonal Frequency Division Multiplexing technique, which is used to overcome the problem of scattering by using the method called maximum entropy modeling method. In this method, the delay between transmitting signal and received signal has been calculated referred as Doppler Spread. It also calculates the bit transmitted rate and bit error rate by diving the channel in to sub-channels using OFDM. Because acoustic signal when travel under the water it get scattered in almost all direction due to which fading problem increases also it increases the issues of Doppler spread, Doppler shift, Doppler delay, etc. In this work, the system design and its simulation results are shown, the underwater acoustic communication channel is model using Maximum Entropy modeling technique for Acoustic channel simulation with its root mean square. Doppler spread is calculated as 0.5 to 2 Hz. The Acoustic communication channel satisfy smart antenna approach by using IEEE standard 802.15.4 which gives the data transmission rate up to 250 Kbps at 2.4 GHz carrier frequency for at least 2m vertical communication link and approximately 2m horizontal link by keeping the depth of water up to 1m, since shallow water acoustic communication is consider. For this, the bandwidth was kept up to 2.4 GHz. The system can generate the maximum signal-to-noise ratio (SNR) is up to 1.477 dB and its Signal-Error-Rate (SER) is calculated as -14.9513 dB. The system is tested for all atmospheric condition under different environment. The proposed system is designed and tested for shallow water using two tested nodes. The low cost sensor nodes are designed which can continuously read the data like temperature, pressure and salinity below the water and it can then be transmitted to the receiver which is also kept under the water. The receiver receives the data and displays it on Laptop continuously. This process demonstrates the vertical and horizontal communication.

Keywords : Underwater Sensor Network, Wireless Communication, Orthogonal Frequency Division Multiplexing, Acoustic Channel, Channel Estimation.

I. INTRODUCTION

Wireless Data Transmission in Underwater Sensor Network is the Challenging job for the researcher. Lot of research is being carried out in this upcoming field. Estimation of proper data transmission channel is required, since the data get lost under the water due to attenuation and data get scattered under the water due to its multi path fading effect. To reduce these problems, the transmission channel is model in this paper using OFDM system used for Underwater Acoustic Sensor Network (UWASN). In this model, the data get transmitted using multiple orthogonal subcarrier, through which various bit stream get transmitted using lower data rate. The orthogonality can be achieved by placing the sub-carriers at the multiple of 1/T, where T is the OFDM Time period. Due to this the data rate of each of the sub-carriers gets reduced than the total data transmission rate, which also reduce the bandwidth of the corresponding sub-carriers. By reducing the sub-carrier bandwidth, the multi path fading effect is also reduces and relatively flat fading effect can be considered. In this paper, the channel estimation can be achieved based on the OFDM technique, where the channels are separated into number of sub-carriers based on their data carriers, guard carriers and pilot carriers for OFDM system. In this system, the data sub-carriers are 100, guard sub-carriers are 10 and pilot sub-carriers are 12. With the help of these parameters, the orthogonal sub-carriers are estimated and mapped for designed transmitter and receiver. The designed OFDM system is totally based on the ECMA International Standards; Data bit are convolution encoded for generating coded bits for OFDM system. This OFDM System is modeled using MATLAB for generating coded bits for UWASN transmission. In this proposed system, the underwater Acoustic Communication channel is model using maximum entropy modeling technique with its root mean square. Doppler spread is 0.5 - 2 Hz only. Here, the acoustic channel satisfy the smart antenna approach by using IEEE standard 802.15.4, which gives the data transmission rate up to 250 Kbps at 2.4 GHz carrier frequency for at least 2m vertical link and approximately 100 m horizontal link, by keeping the depth of water up to 1.5m. The system is tested in a 25m x 13m (i.e. 325 m2) swimming pool with 1m to 1.5m depth. Therefore, the acoustic channel is also estimated based on shallow water conditions. Since shallow water acoustic communication is consider. For this the bandwidth was kept up to 2.4GHz. This can generate the maximum signal-to-noise ratio (SNR) is up to 1.477 dB and its Bit Error-Rate (BER) is calculated as -14.9513 dB. As the signal gets scattered in to the water, therefore orthogonal frequency division multiplexing technique is implemented, which divide the carriers into equivalent sub-carriers. Here 16 to 64 sub-carriers at the frequency of 3.6 MHz are used and each sub-carrier are made to process 256 bits per sub-channel, therefore, maximum 4096 bps to 16384 bps can be actually transmitted with the help of sub-carriers. Based on this concept, the system is simulated for 20 numbers of nodes then, for simulating this network the maximum energy required is 0.4094 Joules. Based on above tested and simulated results, here we designed the smart underwater acoustic communication system with fast communication and less power consumption.

II. OFDM MODEL FOR UWASN

The OFDM System generate the input bit pattern using Scramble function in MATLAB, which generate the one particular initial value out of various random values using generator polynomial which gives initial values with the help of LFSR which identifies one value among the four initial values using LFSR. Number of bits to generate for scrambling function must be equal to the number of bits in the input. This can be achieve using bitwise XORing between input bits and generated pseudo-random bits to get the scrambled output bits. This scrambled function now generates the coded bits for the OFDM system. The symbol intervals bits is done by grouping the coded bits into blocks of 6 X 'bits Per Symbol' and then permuting it, which interleaves the coded bits into 6 OFDM symbols. The system generate the interleaves bits using cyclic convolution shift of the coded bits, number of bits gets shifted and the bits per symbols. This process will create the permuted matrix for interleaving symbols. This cyclic shifting should be done for OFDM block by block for all the coded bits or input bits. The figure 2.1, shows the coded bits generation pattern for regular interval from pseudo random bits. This coded bits or input bits then transmitted through the designed trans-receiver and from there to the base station using proper channel. The channel was already estimated and was explained in [1].

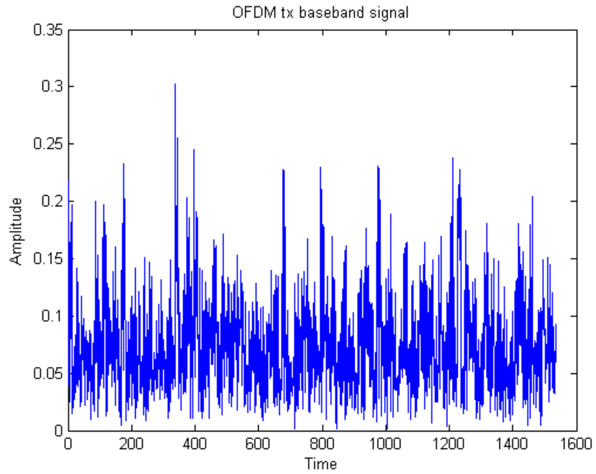

Figure. 2.1. Coded bits generation

III. UNDERWATER ACOUSTIC CHANNEL ESTIMATION

Taking into account the physical models of acoustic propagation loss and ambient noise, the optimal frequency allocation for communication signals can be calculated. Considering optimal signal energy allocation, such frequency band is defined so that the channel capacity is maximized [5]. The results that are assessed suggest that, despite the fact that frequency spectrum [6][8] for underwater acoustic communications, the possibilities in terms of usable frequency bands are not numerous, due to acoustic path propagation and noise characteristics.

A. SNR and SER

The narrow-band signal to noise ratio (SNR) observed at a receiver over a distance L m when the transmitted signal is a tone of frequency f and power P is given by:

$$SNR(l,f) = \frac{\frac{p(F)}{A(L,F)}}{Nf\Delta f}$$

where f is a narrow band around the frequency f, and S(f) is the power spectral density of the transmitted communication signal. Directivity indices and losses other than the path loss are not counted. The AN product, A(l,f)N(f), determines the frequency-dependent part of the SNR. The inverse of the AN product is illustrated in Figure 2.2.

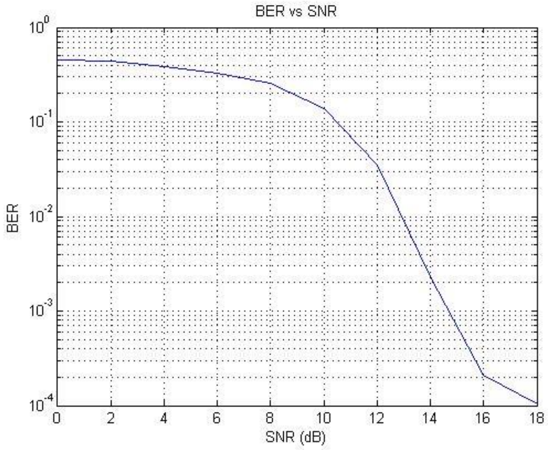

Figure 2.2 Simulation results of SNR with BER

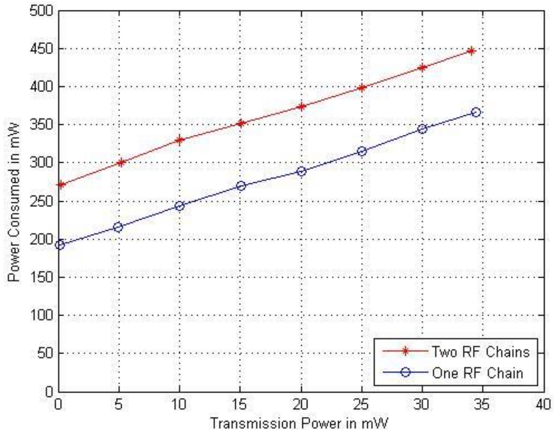

Figure 2.3 Simulation results of Transmission Power with Power Consumption

B. CHANNEL ESTIMATION

Xbee systems are based on the IEEE 802.15.4 standard. The physical interface is based on OFDMA, which is a multiuser multicarrier modulation technique, in which the different sub-carriers of each symbol may be shared between several users. The bandwidth can be scaled from 1.1 MHz (corresponding to 64 sub-carriers) to 3.6 GHz (corresponding to 64 subcarriers), leading to significant flexibility in system design. The bandwidth of each sub-carrier is 25.6 MHz in all configurations leading to a constant OFDM symbol duration of 3.2 μs, not including the cyclic prefix. Several coding and modulation schemes are contained in the standard.

There are seven mandatory schemes including modulations from QPSK to 64 QAM and convolution coding with rates 1/2, 2/3 and 3/4. The spectral efficiency can then be varied from one information bit per symbol to 4.5 information bits per symbol and hence enabling systems to adapt to varying received SNRs.

Multiple antenna techniques further enhance the performance of the technology. There are mainly two MIMO techniques included in the standard. In order to estimate the underwater acoustic channel using OFDM approach. The channel is sub-divided into 64 sub-carriers through which the data can be transmitted with 25.6MHz bandwidth of each sub-carrier. Each sub-carrier is having is used to transmit 256 bits at a time. The OFDM symbol duration is 3.2μs and it generate the Doppler spread up to 0.5-2Hz with delay spread is 1ms. The proper guard intervals are inserted to avoid the Interference in between the sub-carriers as shown in figure 6.5. The underwater system performance can be tested based on the three different algorithms, like Rayleigh fading channel, MSE of the channel estimator and BER performance.

IV. DENSITY OF WATER

Every sea water is having two major parameters: Temperature and Salinity (the concentration of dissolved salts), because the decomposition of seawater is brought due to volcanic eruption, erosion of rocks, various acids and alkaline decomposition, available minerals in the seawater, etc. The density of seawater ranges from 1020 to 1030 kg/m3 while the density of freshwater is about 1000 kg/m3 [3]. The density of seawater is depending parameter on salinity and temperature, as the temperature increases density of water decrease whereas density increases with increased values of salinity. Generally, oceanic water having 1025 kg/m3 density. Density of seawater can be calculated by using many methods out of that here coppen's formula is used for calculating the density of sea water. This parameters are tested using Matlab code for shallow water where the temperature of the water was kept constant at 320 and salinity is calculated in the laboratory using chemical solution. Since the density was calculated for the shallow water in the water tank therefore; the depth of water was not more than 6' approximately 1.8288 meters. Therefore; the calculated value of density of shallow water is shown in the figure 3.1. This shows that the shallow water is denser, due to its cross-sectional area.

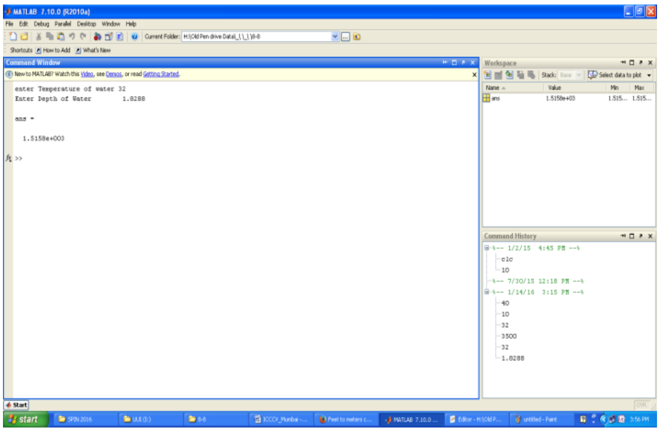

Figure. 3.1 Calculation of Shallow water Density using

V. IMPLEMENTATION OF THE UWASN ON THE REAL TIME ATMOSPHERE

The hardware implementation of Underwater Acoustic Sensor Network is a complication process. The proposed system is implementing and partially tested based on the real time environment. The shallow water scenario is initially considering for the testing purpose and further the system can be tested into the real oceanic environment. The equipment required for measuring the parameters like temperature, pressure and salinity of the oceanic water at the real time environment is bit difficult and also cost effective issue, therefore, it has been kept it for the further studies. The designed system used different sensors like temperature sensor, pressure sensor and sensor for salinity of water, which has been designed using microcontroller. The designed system is tested in shallow water for temperature and salinity can be calculated based on the calibration of chemical formula using laboratory experiment, where the hardness of the water was calculated using titration and alkalinity method, here three different water sample was consider, standardization of HCL was performed on that water sample and then the titration were carried out for alkalinity. Based the given result the salinity of the water samples were calibrated in the laboratory in the presence of some expert faculty of chemistry. The pressure is calibrated using load cell. Here the load cell is used as the pressure sensor for reducing the cost of the system. This load cell can bare the pressure of water up to 40Kg in terms of load. Initially, the calibration of the pressure was done in a water tub further it can be tested in the water tank where the volume of water can vary, which increases it pressure, the load cell can consider the pressure in both the direction that is upward direction and backward direction. Since the volume of water is less in water tub; therefore the backward pressure was more, which gives negative resultant pressure. To overcome this problem, the load cell is covered with iron plate placed 3mm below the load cell, which reduced the effect of negative pressure value. This arrangement is made for temporary. Once the system will be tested in the large volume area at that time the actual pressure (upward pressure and backward pressure) both can be consider. All these parameters can read by the various nodes place under the water and transmit this value to either another node as well as the base station continuously. The system is designed is such a way, that the continuous data transmission should be carried out for transmitter to the base-station's receiver. Here in this proposed system two trans-receivers are designed which continuously read the values under the water and transmitted to the base-station. The system is also measure the temperature. The various damages occurred while testing the system under the water which were tried to overcome time-to-time using different techniques and methods like water leakage inside the circuit due to which the complete circuit gets damage, which then gets seal using permanent sealing solution. The circuit provides some weight by designing a heavy metallic box otherwise the circuit box was floating on the water. Here two such boxes were designed for two trans-receivers.

VI. SIMULATION RESULTS

In this paper, an algorithm is presented for estimating the standard deviation of some AWGN when observations derive from signals less present than absent in this background. According to experimental results, this algorithm is very promising. An application of two sensor nodes have been designed and tested on free air environment and under acoustic /aquatic environment for transmitting the data from transmitter to receiver. Using this MC-ESE algorithm, the efficient energy consumption is calculated and its simulating results are shown using MATLAB coding results as per the table given in Table 1.

Table 1:

Existing Algorithm		*Proposed Algorithm*	
Distance Travels by Nodes (m)	Energy Consumption (J)	Distance Travels by Nodes (m)	Energy Consumption (J)
20	0.15	10-20	0.2962
40	0.35	21-30	0.3471
78	0.39	31-45	0.275
100	0.72	**46-100**	**0.3459**

The energy efficiency can also be calculated using Greedy algorithm; these algorithms rely on the connectivity matrix. In short, a logical matrix where true represents a connection and the connections are determined by the distance between nodes and the range of the active modem. When a node receives a radio message it will use the connectivity matrix to determine it's furthest connected neighbor, the performance of the model implementing this algorithm is summarized in Table 2.

Therefore it is very much clear from the table shown above that, as the number of nodes increases, the power consumption to that much number of nodes reduces up to certain extended depends upon the distance between the transmitting and receiving nodes. Here simulated results using Greedy algorithm shown, where the nodes distance is kept within the range of 10m to 100m and its power consumption is ranging from 0.2962J to 0.3459J. as shown in the table 2. These results are achieved using the algorithm 2 of Greedy Furthest Acoustic.

TABLE 2:

Parameters	**Number of Nodes**			
	25	***50***	***75***	***100***
Avg. Distance (m)	90.0642	89.235	68.9515	57.6881
Avg. Energy (J)	0.4050	0.2007	0.2232	0.2052
Avg. Depth (m)	25	25	25	25
Avg. Time (ms)	0.22	0.31	0.28	0.38

VII. CONCLUSION

Research on underwater communications and the use of Underwater Sensor Networks is becoming a very hot topic because of the appearance of new marine/oceanographic applications. As a consequence, other available underwater acoustic technology can support mostly point-to-point, low-data-rate, delay-tolerant applications. Some of the shown experimental results for point-to-point acoustic modems use signaling schemes that can achieve data rates lower than 20 kbit/s with a link distance of 1 km over horizontal links. Whereas in the proposed system, where Communications is based on RF signal transmission offers great benefits such as, increase of the data rate of the link to transmit more information.

The underwater acoustic communication channel is model using Maximum Entropy modeling technique for Acoustic channel simulation with its root mean square. Doppler spread is 0.5 to 2 Hz. The Acoustic communication channel satisfy smart antenna approach by using IEEE standard 802.15.4 which gives the data transmission rate up to 250

Kbps at 2.4 GHZ carrier frequency for at least 2m vertical communication link and approximately 2m horizontal link by keeping the depth of water up to 1m, Since shallow water acoustic communication is consider. For this, the bandwidth was kept up to 2.4 GHz. The system can generate the maximum signal-to-noise ratio (SNR) is up to 1.477 dB and its Signal-Error-Rate (SER) is calculated as -14.9513 dB.

As the signal gets scattered in to the water, therefore orthogonal frequency division multiplexing technique is implemented, which divide the carriers into equivalent sub-carriers. Here 16 to 64 sub-carriers at the frequency of 3.6 MHz and each sub-carrier are made to process 256 bits per sub-channel; therefore, maximum 4096 bps to 16384 bps can be actually transmitted with the help of each sub-carrier. Based on this concept, the system is simulated for 25 numbers of nodes. For simulating this network the maximum energy required is 0.4094 Joules.

Thus, the smart underwater acoustic communication system is designed with fast communication and less power consumption.

This proposed system is developed with low cost consider for shallow water environment. Here the scattering function was developed for underwater data transmission. The results shown the minimum data scattered when it transmitted through the underwater channel. The channel is developed using entropy method, which gives the maximum data transmitted using this channel. The multipath fading and Doppler Effect was studied using OFDM technique and their respective results are shown. The hardware is developed using some sensor nodes for temperature, pressure and salinity. The salinity is calculated using titration due alkalinity method in the chemistry laboratory. The pressure is calculated using load cell which measure the pressure upto 40kg. the given results shows the maximum data can be transmitted through the Acoustic channel in less time using various sub-carriers, which can be shown in fig.1. The data absorption is shown in fig.3, which calculates the attenuation losses and spreading losses during underwater data transmission. The absorption coefficient is proportional to its frequency. The system is designed using home-made sensors for various parameters and tested in the shallow water environment. The system further be tested in water tank, swimming tank and also in the lake, and their corresponding Matlab result will be shown for further study.

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