Data Communication using OFDM System for Underwater Acoustic Sensor Network

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ABSTRACT
In this paper, the low cost home-made underwater sensors are designed for underwater Acoustics Sensor Network. This system is used to read the values of pressure, temperature and salinity using these sensors under the water and then the values are transmitted from underwater sensor to base station receiver. The sensors are continuously reading these values. Here, the communication channel estimation model is designed using Rayleigh Fading method, where the Gaussian processes for complex values were used. The channel is called Rayleigh Fading since its phase is uniformly distributed in the range of $(0,2\pi)$ for the zero value of the coefficients of amplitude and phase for time-varying delay line complex channel. Different algorithms and formulas are used for successful transmission of these values from one sensor to another. Acoustic channel is used for data transmission, which is estimated using Scattering function estimation and maximum data transmission can be possible using OFDM technique. Since the scattering nature of underwater communication raised the problem of multipath fading, Doppler delay, Doppler shift and Doppler spread. These all issues were tried to solve based on the maximum entropy modeling method. In this method the Doppler spread were identified in between the transmitted signal and the received signal. In this paper all the proposed method is tested with Matlab codes and their result are shown in terms of different plots. The hardware is designed and tested in shallow water environment and further be tested for other environment. The Matlab results are shown here for scattering function and absorption loss.

General Terms
Underwater Sensor Network, Wireless Communication, Orthogonal Frequency Division Multiplexing, Acoustic Channel, Channel Estimation.

Keywords
Underwater Sensor Network, Acoustic Transmission, OFDM, Multipath Fading, Doppler Spread Effect.

1. 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.

2. 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

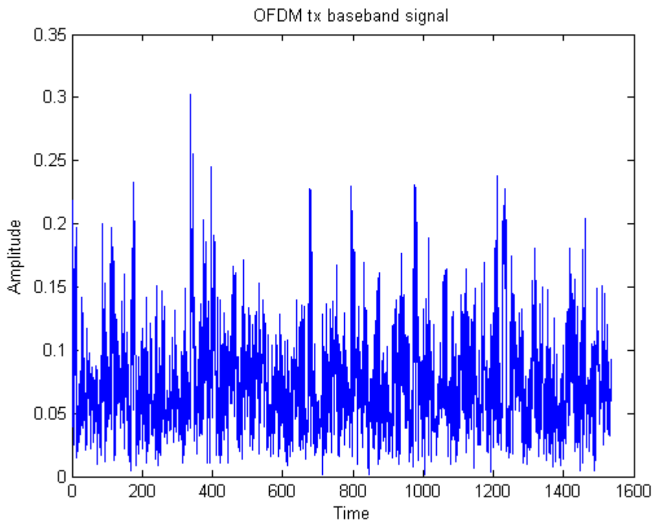


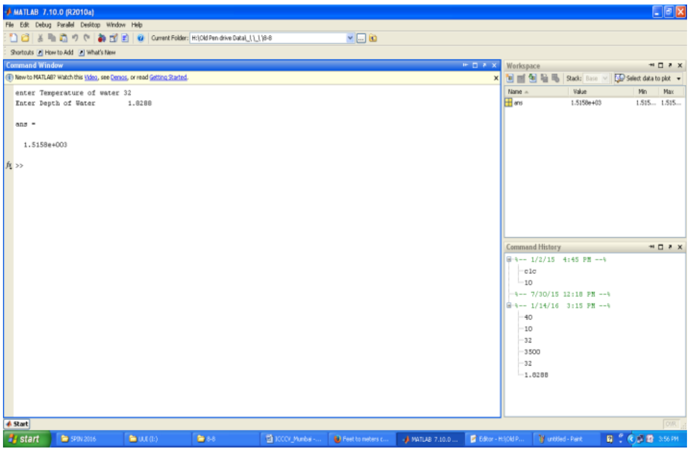
Fig. 1. Coded bits generation

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 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].

3. 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/m^3 while the density of freshwater is about 1000 kg/m^3 [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/m^3 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 32^0 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. The density calculation is depending on the coppen's conversion formula: Therefore; the calculated value of density of shallow water is shown in the figure 2. This shows that the shallow water is denser, due to its cross-sectional area.

Fig. 2. Calculation of Shallow water Density using



Coppen's Formula

$$c1 = 1449 + 4.6t + 0.055t^2 + 0.003t^3 + (1.39 - 0.012t)(s - 35) + 0.017d$$

Where t is temperature in degree Celsius, s is the Salinity where as d is the Depth of water in meters. The propagation delay can then be calculated as

$$\tau = \frac{l}{c1}$$

Where τ is time in seconds and *l* is distance in meters.

3.1 Transmission Losses:

In Underwater communication system, acoustic channel creates path loss depends upon the signal frequency. It can vary from 100Hz- 3 KHz. Path Loss in the sea water can be measured in terms of Attenuation Loss and Spreading Loss. Attenuation Loss includes Absorption Loss and losses due to leakage, Scattering and diffraction. The absorption loss for low frequency can be calculated as:

$$\alpha = \frac{0.011 f^2}{10 + f^2} + \frac{44 f^2}{410000 + f^2} + 2.75x10^{-4} f^2 + 0.003 \; x10^{-3}$$

Where f is the frequency in KHz and α is the absorption coefficient. The absorption coefficient increases with increase in distance; whereas the spreading loss can be calculated using spherical spreading (consider for deep water) and cylindrical spreading (consider for shallow water environment). The spreading losses increase with distance between the transmitter and receiver. The spherical spreading can be calculated as:

$$SS = 20\log_{10^r}$$

Where r is distance in meter between transmitter and receiver. The spreading loss increases with distance. Finally, the transmission loss can be calculated as:

$$TL = SS + \alpha(f)r \times 10^{-3}$$

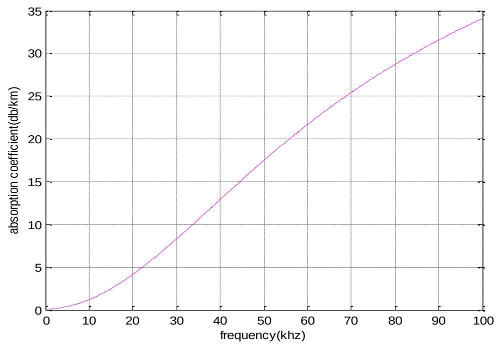


Fig. 3. Calculation of Absorption Loss with respect to Frequency (KHz)

4. 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 come 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.

5. 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 Consumptio n (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.

6. CONCLUSION

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.

Table-2

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

7. ACKNOWLEDGMENTS

I would like to thanks all the authors whose papers are reviewed and refer for the work and to all the anonymous reviewers for their very useful and constructive comments. Also would like to thanks my supervisor for their constructive criticism and progressive help towards this work.

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