Design and Implementation of Underwater Sea Network Medium with Transmission Power using EM Waves

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Abstract: The field of underwater wireless electromagnetic communication (UWEC) network is acquiring much consideration because of a rise in several activities at the bottom of the sea such as military practices, underwater unmanned vehicles (UUV), and military practices etc. There is need of increased bandwidth and an error free data link network for performing such activities. The highly conductive medium of the seawater affects both requirements of the field. The performance evaluation of underwater wireless communication UWC, are demonstrated by focusing on Electromagnetic wave (EM) analysis, to offer a reliable solution for underwater activities. At last, an experimental system is developed, with underwater network based on simulation of the EM-based wireless link. There is reason of using EM waves because its bandwidth and speed is higher than optical and acoustic approaches. During a sequence of trials in the tank, the lowest bit error rate (ber) is detected only using high power transmission. In this paper, the characteristics of EM (Electromagnetic wave) communication in sea water medium are investigated through simulation with theoretical results to meet practical specifications. Moreover, some more important factors such as electrical conductivity, underwater environment noise, turbid conditions affect Electromagnetic wave communication in sea water medium. The advantages of using Electromagnetic waves is less impact on marine life in underwater and provide us high data rate and high speed. The simulation and theoretical analysis provide results which prove the feasibility of Electromagnetic wave wireless communication under the useful frequency range and transmission power in turbid and high loss environments of sea medium.

Keywords: Electrical conductivity, Attenuation, Permittivity, Bit error rate, Path Loss.

1. Introduction

Because of the increasing demand for application of underwater activities, creating a wireless communication network in water medium of sea has become a challenging research domain in current years. As a proof, many research papers [1, 2] presented underwater activities, including geological educations and offshore observation, and accompanying underwater solutions. But, because of high attenuation in the high conductive medium of sea, which result high bit error rate and low signal to noise ratio and , current models for wireless communication in the air medium cannot be developed in underwater [3]. The EM wave, Acoustic and optical waves, are the most normal methods for construction of an underwater wireless sensor network. However, all of the method has some pro and cons. As, a secure techniques, an acoustic waves have been utilized for a long times [4]. However, lately, they have been demonstrated to fail when used in shallow water. It is affected by reflections from the sea and bottom surface. Furthermore, a slow data transfer speed is produced by acoustic waves. So there is need of using EM waves which has less impact on marine life in underwater and offer us high data rate capacity, high speed of communication and the low delay in propagation . The low delay in propagation and high speed will diminish the duration of propagation , which will also diminish the consumption in power , and accordingly it will upturn the span life span of EM waves with the wireless nodes network in underwater [5].In underground wireless EM network, sensor nodes are submerged in soil. EM wave spreads in soil medium between wireless network nodes, and transmission features are obvious decided by characteristics of soil. Due to light density of soil medium as compared to the air, which generates great attenuation and absorption and high path losses to the EM wave [6-7]? However, as a consequences, at the result of this paper, there are many claims where need of large capacity of date rate , high data speed, low delay in propagation ,low consumption of consumption of Electromagnetic waves which brings many profits [8-9]. In [10], Researches conducted a research study of the propagation of EM waves in fresh water for frequencies between 23 kHz and 1 GHz. In [11-15], research paper achieved a research study on Radio frequency communication in the 2.4 GHz frequency band. In this paper, performance of underwater communication in sea water medium tests at upto 20KHz frequency band with application of transmission power with its effect on communication range, bit error rate (ber), Data rate capacity was investigated with effect of transmission power which directly increase data rate capacity and reduce bit error rate which make EM wave more feasible in sea water medium.

2. RELATED WORKS

2.1 Design and Implementation of Underwater Sea Network Medium

In this section, the with impacts of different parameters like Bit error rate, Channel data rate capacity , Path loss with power transmission in underwater wirelesss communication was investigated with examination of feasibility of EM waves. Experimental setup was designed here as shown in Figure (1) by communication between UWSN (under water sensor node) communicates through single path propagation with transmission power Tp and receiver side received power Rp with Transmission gain Tg and Receiver gain Rg .As, it can be observed in Figure 1[15].UWSN as transmitting mode transmits the signal to receiver node via underwater sea medium with communication range (Rr) negligible turbidity of sea water. As, this experiment was investigated in sea water at numerous depths in underwater, the signal strength received at receiver side was decreased with increase of path losses while attenuation begins to increase. The received signal strength in form of path losses was varied with path communication ranges at different depths. As, sea water is imperfect and conducting medium. As, waves travel through sea water medium, propagation constant ($\aleph_c$) term [10]-[12] is generated which depends upon the phase ($\Im$) of signal and attenuation ($\wp$) of signal in water medium. As above consideration, following expression in equation (1) can be written for high conductive medium [13]-[15].

$$\aleph_c = \left(\wp + \hat{j}\Im\right) = \left(\left(\varpi^2_{freq}\cdot\mu_p\cdot\varepsilon_p\right) \Big/ \left\{ \left(\hat{j}\frac{\Omega_c}{\varpi_{freq}\cdot\varepsilon_p}\right) - 1 \right\}^{-1} \right)^{1/2} \tag{1}$$

As consideration in [12]-[14] and equation (1) and (2), subsequent expression in form of equation (3) can be rewritten at frequency below THz.

$$\left\{\Omega_c \big/ \left\{\varpi_{freq}\cdot\varepsilon_p\right\}\right\} >> 1 \tag{2}$$

$$\wp \approx \Im = \left(\left[\varpi_{freq}\cdot\mu_p\cdot\Omega_c\right]/2\right)^{1/2} \tag{3}$$

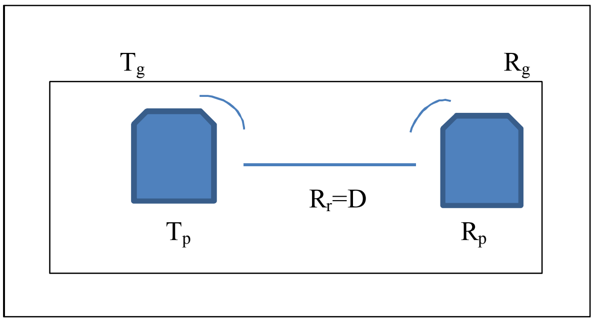

Figure 1.Channel modeling architecture

Where, as consideration in [3]-[6]

$\varpi_{freq} = 2\pi\cdot\upsilon_{freq}$ is angular frequency, (ξ_{freq}) is frequency of signal , $\mu_p = \mu_0\cdot\mu_r = 4\pi\cdot10^{-7}(Henry/meter)$, μ_p is permeability of water medium $\mu_p = \mu_0 = 4\pi\cdot10^{-7}$ is permeability of free space same as of water medium [4]-[6]. $\varepsilon_p = \varepsilon_0\cdot\varepsilon_r = 778.8\cdot10^{-12}(Farad/meter)$, $\varepsilon_0 = 8.85\cdot10^{-12}(Farad/meter)$ $\varepsilon_r = 81(Farad/meter) for\ sea\ water$, ε_p is permittivity of medium , Ω_c is 4 (mho/meter) conductivity of medium, $\mu_r = 1$ is relativity permeability [3]-[6]

As shown in figure (1), Total Path losses developed between transmitter and receiver node because signal transmitted by power Tp is affected by noise power N_p.and recived signal by Rp received power will be attenuated by path losses.

As calculated path Loss (L_p) in equation (5) using Friis equation (4) [10]-[12], the received power consist of power transmitted (T_p), Power of received signal (Rp), (T_g) gain of Transmitter and (R_g) gain of receiver . As it is well known, that Path loss in air is different from path loss occuring in sea water [5-6]. So, Path loss in air as per Friss equation can be modified and extended in equation (5).

$$R_p = 10\log_{10}\left\{\left\{T_p.T_g.R_g\right\}/L_p\right\} \tag{4}$$

As calculated path losses ($L_{\Im m}$) due to phase change in signal as in equation (5) and ,path loss ($L_{\wp m}$) as in equation (6) due to attenuation of signal

$\vec{\zeta}(x) = \zeta_0 \cdot e^{-(\wp \cdot R_r)} \cdot \cos(\Im \cdot R_r - \varpi_{freq} \cdot t)$.Total path loss ($L_p$) as in equation (7) is consist of two parts due to change phase constant of water medium w.r.t air and path loss ($L_{\alpha m}$) as wave amplitude (ζ_0) attenuate by factor $e^{-\wp . R_r}$ [13] .

$$\sqrt{L_{\Im m}} = (2 . \Im . R_r) \tag{5}$$

$$\sqrt{L_{\wp m}} \cong 1 / e^{-(\wp \cdot R_r)} \tag{6}$$

Total path loss in equation (7) as shown below [11-13],

$$L_{pdb} = 10 \log_{10}\left(L_{\Im m} + L_{\wp m}\right) \tag{7}$$

Where

(ζ_0) is amplitude of waves, (R_r) is communication range, ($\Im$) is phase constant of signal and ($\wp$) is attenuation constant of signal in sea water medium

2.2. Channel Capacity or data rate and Bit error rate (ber) of EM waves in sea water

As per, Shannon's theorem [14], a given communication system has a maximum rate of information known as the channel data rate capacity ($\subset_{drc}$) as shown in equation (8), can be calculated after placing signal to noise ratio $\Re_{s/n}$ as shown in equation (9)

$$\subset_{drc} = \omega_{bw} \cdot \log_2(1 + \Re_{s/n}) \tag{8}$$

Bandwidth ω_{bw} for sea water can be defined as that frequency range over which signal can be transmitted easily [10-14].In this paper ω_{bw} considered 100 kHz.

As it is known form , [10-11, 13-14], Signal to noise ratio ($\Re_{s/n}$) can be written by division of receive power signal R_p and transmitted power T_p affected by noise power N_p.

$$\Re_{s/n} = R_p / \mathrm{n}_p \tag{9}$$

As, Received power (R_p) considering transmitter gain (T_g=1), receiver gain (R_g=1) will be written in form of equation (10) with help of equation (4)

$$R_p = T_p / \mathrm{L}_p \tag{10}$$

As, from combination of equation (9) and equation (10), following equation (11) in form of signal to noise ratio $\Re_{s/n}$ can be wriitten as follows.

$$\Re_{s/n} = 10 \log_{10}\left({T_p}/{n_p} \cdot L_p \right) \tag{11}$$

Where

L_p is path losss, T_p is transmitted power in (db. m), n_p is noise power in (db. m)

The bit error rate (ber) is the ratio of numbers of bits which are in error, divided by the total number of bits transmitted [11, 14].Bit Error rate (ber) in equation (12) can be calculated after placing the value of $\Re_{s/n}$ from equation (11).

$$\beta^{er} = 1/2 \bullet erfc(\{\Re_{s/n}\}^{1/2}) \tag{12}$$

3. RESULTS AND DISCUSSION

3.1. The variations of Data Rate Capacity and Bit Error Rate of EM wave in sea water

As, observation through simulation on was observed in figure.2 and Table.1.The **Bit Error Rate (**ber) increases with increase of communication range. As observed in figure.2 and Table .1, **Bit Error Rate** increase with increase of communication range . At fixed D=0.1 meter and at D=0.2 meter communication range , low The **Bit Error Rate (ber)**,was observed .But, as seen in Table.1 and from figure.2 for sea water, It was detected that EM wave is more efficient at lower distance with low bit error rate as compared to higher communication range. Because at communication range D=0.5 meter, The **Bit Error Rate (ber)**, is 0.498 high for sea water at fixed frequency with power transmission 5db.m. The **Bit Error Rate (ber)**, was observed high in sea water at large communication range.One of most important solution to this problem, by increasing transmission power to 25db.m, The **Bit Error Rate (ber)** is 0.289 at same communication range 0.5 as shown in figure.2 and Table 1.

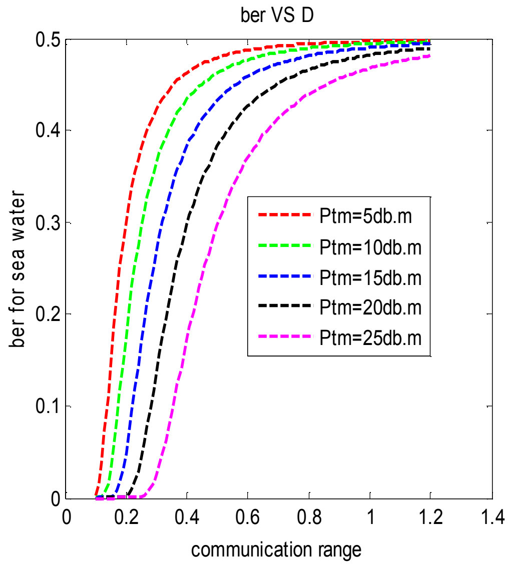

Figure .2 Bit Error Rate ratio variation with communication range at different transmission power

As , in figure (2) , final decision from entire study about Bit error rate and efficiency of EM waves in sea water that Bit error rate and efficiency of EM waves are high at high power transmission for high communication range.

As, observed in figure.3 and Table .2, **Data Rate Capacity** decreases with increase of communication range . At fixed D=0.1 meter and at D=0.2 meter communication range , high **Data Rate Capacity** was observed .

But, as seen in Table.2 and from figure.3 for sea water, It was detected that EM wave has more ability to high dtata rate transfer at lower distance with low bit error rate as compared to higher communication range. Because, at communication range D=0.1 meter, The The **Data Rate Capacity** is 0.4*10^5 very low for sea water at fixed frequency with power transmission 5db.m. But at same communication range D=0.1 meter, The **Data Rate Capacity** is 1.7*10^5 very high for sea water at fixed frequency with power transmission 25db.m .

One of most important solution to this problem, by increasing transmission power to 25db.m , The **Data Rate Capacity** can be increased with use of higher power transmission as shown in figure.3 and Table 2 to make EM waves more efficient for long distance range and there is possibility of high data transfer.

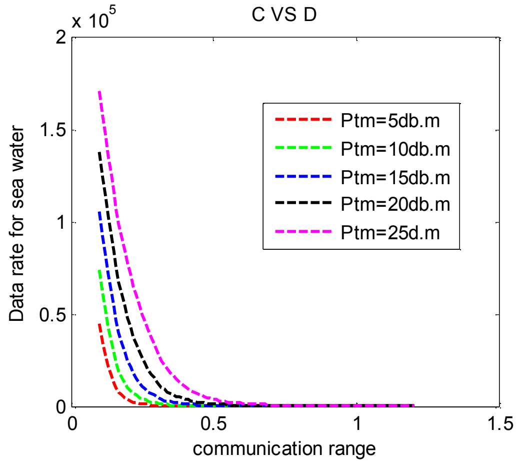

Figure .3. Data Rate Capacity variation with communication range at different transmission power

Where

D is communication range.

As , in figure (3) final decision from entire study about **Data Rate Capacity** and efficiency of EM waves in sea water that **Data Rate Capacity** and efficiency of EM waves are high at high power transmission for high communication range.

3.2. The Variation of Path Loss (db) of EM waves in sea water at different communication range

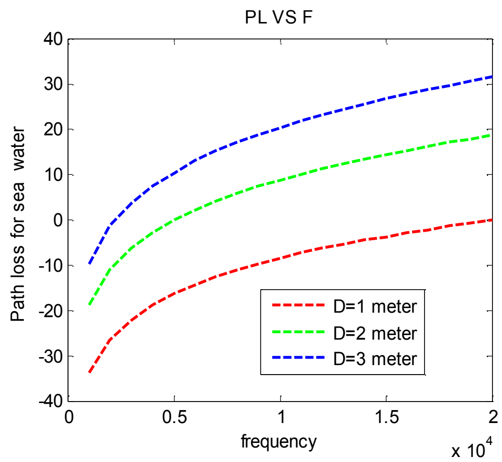

Figure . 4 Path Loss variation with frequency at different communication range

As, shown in figure 4 and Table.3, the comparative analysis of Path losses for sea water was observed at different communication range and frequency. After complete investigation, It was detected that Path losses are higher for sea water at same communication range with increase of frequency band. For example, at communication range D=1 meter, the path losses is -20db at frequency 5 kHz. Similarly, at communication range D=2 meter, the path losses is 1db at frequency 5 kHz but and at communication range D=3 meter, the path losses is 10db at frequency 5 kHz. No doubt, the Path losses are higher for sea water with increase of frequency and communication range. But, Channel capacity is high at high signal frequency and high signal bandwidth, If there is need of high data rate and low bit error rate, by increasing transmission power , path losses can be compromised with increase of frequency and transmission power .

Table 1.BER variations for sea water medium at transmission power Ptm=5dbm, 15db.m, 25db.m

A Ptm 5 db.m	At range D=0.5	At range D=1	At range D=1.5
BER for sea water	0.45	0.46	0.50
A Ptm 15 db.m			
BER for sea water	0.40	0.42	0.47
A Ptm 25 db.m			
BER for sea water	0.30	0.38	0.40

Table 2.Channel capacity (bits/sec) for sea water medium at transmission power Ptm=5dbm, 15db.m, 25db.m

A Ptm 5 db.m	At range D=0.2	At range D=0.5	At range D=1
Data Rate for sea water	0.4×10^5	0.001×10^5	0.0001×10^5
A Ptm 15 db.m			
Data Rate for sea water	0.7×10^5	0.2×10^5	0.1×10^5
A Ptm 25 db.m			
Data Rate for sea water	1.7×10^5	0.3×10^5	0.2×10^5

Table 3.Path Loss (in db) variations for sea water medium at frequency 5 KHz, 10KHz, 20KHz

A frequency 5KHz	At range D=1	At range D=2	At range D=3
Path loss for sea water	-19	-2	1
At frequency 10K Hz			
Path loss for sea water	-11	6	17
At frequency 20 K Hz			
Path loss for sea water	1	18	31

CONCLUSION

The one most challengeable question for high data rate capacity of Information and low bit error rate is emerged out which can be achieved through some mathematical and practical investigation in this paper. In this paper, the feasibility of (EM) waves is developed through some strong efforts made to achieve high data rate data rate and small Bit error rate (ber) with variation of transmission power. However, immersing the transmitter to a depth created reliable results in terms of low (ber) and high data rate, basic and main parameters for evaluating performance of EM wireless communication links. Furthermore, attempts such as inserted high power transmission are considered to spread the examination to a more extended reliable link. At last, an experimental system is developed, with underwater network based on simulation of the EM-based wireless link. There is reason of using EM waves because its bandwidth and speed is higher than optical and acoustic approaches. The simulation and theoretical analysis provide results which prove the feasibility of Electromagnetic wave wireless communication under the useful frequency range and transmission power in turbid and high loss environments of sea medium.

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REFERENCES

[1] Goh, J. H., Shaw, A., & Al-Shamma'a, A. I. (2009). Underwater wireless communication system. Journal of Physics, Conference Series.

[2] A. I. Al-Shamma'a, A. Shaw and S. Saman, "Propagation of Electromagnetic Waves at MHz Frequencies through Seawater," IEEE Transactions on Antennas and Propa- tion, Vol. 52, No. 11, November 2004, pp. 2843-2849.

[3]. Jiang, S., & Georgakopoulos, S. (2011). Electromagnetic wave propagation into fresh water. Journal of Electromagnetic Analysis and Applications,3(7),261–266.

[4] Cella, U. M., Johnstone, R., & Shuley, N. (2009). Electromagnetic wave wireless communication in shallow water coastal environment: Theoretical analysis and experimental results. In Proceedings of the Fourth ACM International Workshop on Under Water Networks.

[5] M. Rhodes, " Electromagnetic Propagation in Seawater and its Value in Military Systems," SEAS DTC Technical Conference, Edinburg, UK, 2007.

[6] X. Che et al., "A Static Multi-Hop Underwater Wireless Sensor Network Using RF Electromagnetic Communications," Proc. 2nd IEEE Int'l. Wksp. Specialized Ad Hoc Net. Sys., June 2009, pp. 460–63.

[7] GhaithHattab,MohamedEl-Tarhuni,MoutazAl-Ali,TarekJoudeh,andNasserQaddoumi , "An Underwater Wireless Sensor Network with Realistic Radio Frequency Path Loss Mode", Hindawi Publishing Corporation International Journal of Distributed Sensor Networks Volume2013,pp.1-9.

[8] U. M. Cella, R. Johnstone, and N. Shuley, "Electromagnetic Wave Wireless Communication in Shallow Water Coastal Environment: Theoretical Analysis and Experimental Results," Proc. 4th ACM Int'l. Wksp. UnderWater Net., Nov. 2009.

[9] Xianhui Che, Ian Wells, Gordon Dickers, Paul Kear, and Xiaochun Gong, Swansea Metropolitan University, "Re-Evaluation of RF Electromagnetic Communication in Underwater Sensor Networks", I EEE Communication Magazine (2011.

[10] D. Griffiths, Introduction to Electrodynamics, Pearson Education, 2003.

[11] Arsem Zoksimovki et al., "underwater elecgromagnetic waves using conduction-Channel characteristics",adhoc netwok (2015)

[12] M. Sadiku, Elements of Electromagnetics, Oxford University Press, NewYork, NY, USA,2007.

[13]. Gursewak, S., & Mahendra, K. (2019). The characteristics of EM waves wireless communication sensor network in shallow water medium with variation of salinity. International Journal of Management, Technology And Engineering, IX(I), 1989–1999.

[14] C. E. Shannon, A Mathematical Theory of Communication, Reprinted with corrections from The Bell System Technical Journal, Vol. 27, pp. 379–423, 623–656, July, October, 1948.

[15]. Gursewak, S., & Mahendra, K. (2019). Performance analysis of electromagnetic (EM) wave in sea water medium. Wireless Networks, The Journal of Mobile Communication, Computation and Information,june,2019.