International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

The Feasibility of Electromagnetic Wave Underwater Wireless Communication in Shallow Pure Water Medium at Frequency Band 0.5GHz-4.5GHz

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DOI: https://doi.org/10.55248/gengpi.5.0224.0617

ABSTRACT:

In this paper, the characteristics of EM (Electromagnetic wave) communication in pure water medium were investigated through simulation with theoretical results to meet practical specifications. Moreover, some more important factors such as electrical conductivity, underwater environment noise, turbid conditions, path loss, Bit error rate (BER), Signal to noise ratio (SNR) largely affect Electromagnetic wave communication in pure water medium. The advantages of using Electromagnetic waves has less impact on marine life in underwater and provide us high data rate, high speed, low bit error rate, better signal to noise ratio at high frequency. In this paper, the propagation based on electromagnetic wave wireless communication up-to the frequency 4.5 GHz in these turbid and high loss environments in pure water medium was analyzed in order to explore its applicability. The simulation and theoretical analysis provide results which prove the feasibility of Electromagnetic wave wireless communication up-to the frequency 4.5 GHz in these turbid and high loss underwater environments.

Keywords: Path loss, Bit error rate, Signal to noise ratio, Wireless sensor network, Transmitted power

1. Introduction

In present era, the development in technology and functional requirement of underwater wireless propagation network is increasing the excitation and interest towards the employment of underwater wireless EM waves in underwater wireless sensor networks (UWSNs) for the different purposes such as search of sea natural resources, pre-warning of earthquake, pre-warning of tsunami, etc in underwater [1]. The Electromagnetic waves in ocean have less impact on marine life and provide the low communication delay, better data rate, better signal to noise ratio and high speed. The low propagation delay reduce the propagation duration period, which will also reduce the consumption of power and consequently ,the life span of the wireless sensors nodes is increased in underwater [2].In wireless underground sensor network, sensor nodes were buried in soil. In underwater wireless sensor network, the Electromagnetic wave (EM) was passed through soil medium and soil characteristics decided the propagation performance analysis of EM waves. Soil density is less as compared to the air, which cause high attenuation and absorption of the electromagnetic wave in soil medium [3-4]. The challenges and concept of underwater wireless sensor network and related to the underground wireless channel medium have been analyzed in [5-9].The thinking underwater propagation in the 1 GHz to 2GHz band was understood impractical and not helpful because underwater medium channel has a great attenuation at these frequencies. However, at the end of this paper of research in [10-12], it was investigated that there are many uses of EM waves where requirements of high speed, high date rate, low power consumption of EM waves which provide us many benefits [10-12]. The characteristics of atmospheric communication were computed by the dielectric properties of water and effects of remote sensing produced by rain drops and by hanging droplets in clouds or fogs [13-14]. Other effects considered in propagation models relate to molecular absorption by line (HP, OJ and continuum (H_20, NJ spectra [15].Path loss, Signal to noise ratio, Bit error rate, transmitted power are main important parameters to analyze the channel model as study in [16]. Because, Path loss, Signal to noise ratio, Bit error rate cause the difference between the transmitted signal power and the received signal power. The Channel modeling at large-scale can be done using term Path loss in terrestrial wireless communication systems as air channel medium [17]. In [18],author conducted a study of the EM wave propagation in fresh water for frequencies between 23 kHz and 1 GHz. In [19], the authors of the paper performed a study on RF communication in the 2.4 GHz ISM frequency band. In this paper, we have found the performance of underwater communication in pure or fresh water medium tests up to 4.5GHz frequency band.

2. Underwater channel modeling propagation Analysis

As, It is well known that EM wireless communication in air medium is different from EM wireless communication in the water medium because of some important parameter variations as electrical conductivity and permittivity of water. Electromagnetic wave Propagation consists of energy cycle between magnetic fields and electric field.The high electrical conductivity of water and high frequency of signal cause to high attenuation and propagation loss. In figure (1), a underwater wireless communication sensor network (UWSNs) is designed here. The wireless sensors communicate through pure water medium at particular path distance (d).In this paper, EM waves propagation will be characterized through pure water medium with variations of path loss, Bit error rate (BER), Signal to noise ratio (SNR), speed of EM waves and frequency of EM waves. In this paper, pure water is considered with its electrical-conductivity σ =0.01[1] Siemen/meter at normal temperature.

The propagation constant (γ) derive the effect of the complex permittivity on the attenuation constant factor (α) and phase constant factor (β) which can be expressed in equation (1) as follows [20- 22].

$$\gamma = \alpha + j\beta \qquad (1)$$

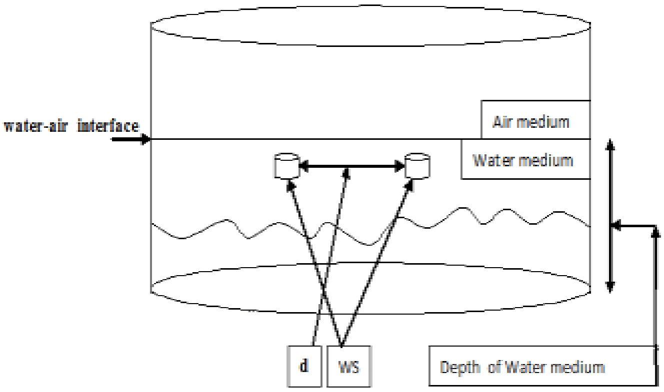

Figure 1.Underwater communication wireless sensor network

Where

d is distance between sensors, WS is wireless sensors

The attenuation factor is decrease in signal strength with travelling at particular path distance can be expressed as given below in equation (2) [20-22].

$$\alpha = \left(2\pi^2 f^2 \mu \left(\left\{(\varepsilon_{real})^2 + (\varepsilon_{imag})^2\right\}^{1/2} - \varepsilon_{real}\right)\right)^{1/2} \qquad (2)$$

The phase constant factor can be expressed as given below in equation (3) [20- 22].

$$\beta = \left(2\pi^2 f^2 \mu \left(\left\{(\varepsilon_{real})^2 + (\varepsilon_{imag})^2\right\}^{1/2} + \varepsilon_{real}\right)\right)^{1/2} \qquad (3)$$

The permittivity can be represented as the dielectric constant, which is the ability of any medium to allow an electric field to be transmitted through medium. The complex permittivity can be expressed difference between real permittivity and imaginary permittivity as in equation (4) [23-26]. The permeability can be expressed as the ability of any medium to allow magnetic energy to be stored in medium. A water is a nonmagnetic medium, its permeability is same as vacuum [27]. The complex permittivity can be written as below [23-26].

$$\varepsilon_{complex} = \varepsilon_{real} - j\varepsilon_{imag} \qquad (4)$$

The real permittivity in pure water channel consist of the static dielectric permittivity (ε_{so}) at low frequency, static dielectric permittivity ($\varepsilon_{s\infty}$) at high frequency, frequency of signal and relaxation time, as can be written in form of expression in equation (5) [23-26].

$$\varepsilon_{real} = \left(\begin{array}{l} \varepsilon_{s_\infty}\left(1 - \dfrac{1}{\left(1+\left(2\pi f \tau_{rt}\right)^2\right)}\right) \\ + \left(\dfrac{\varepsilon_{s_0}}{1+\left(2\pi f \tau_{rt}\right)^2}\right) \end{array} \right) \qquad (5)$$

On the other side, The imaginary permittivity in pure water channel consist of electrical conductivity of pure water medium and frequency of signal, free space permittivity, static dielectric permittivity (ε_{so}) at low frequency , static dielectric permittivity ($\varepsilon_{s\infty}$) at high frequency and relaxation time and frequency of signal as written below in form of expression in equation (6)[23-29].

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$$\varepsilon_{imag} = \left(\frac{(\sigma)}{(2\pi f \varepsilon_0)} + \frac{(\varepsilon_{s_0} - \varepsilon_{s_\infty})}{\frac{1}{(2\pi f \tau_{rt})} + (2\pi f \tau_{rt})} \right) \quad (6)$$

Where; $\varepsilon_{s_0} = \begin{pmatrix} 87.134 \text{ -}1.949 \times 10^{-1} T - \\ 1.276 \times 10^{-2} T^2 + 2.491 \times 10^{-4} T^3 \end{pmatrix}$ [28]

(ε_{real})[23-29] and (ε_{imag})[23- 26] are the real and imaginary dielectric constants of pure water, respectively,(ε_{s_0})[28] =78.1787 at temperature 25 ºC is the static dielectric constant at low frequency , (ε_{s_∞}) = 4.9[23-29] is the dielectric constant at high frequency limit, $(\varepsilon_0) = 8.85 \times 10^{-12}$ F/m is the permittivity of free space,(σ) =0.01S/m is the pure water conductivity at temperature 25 ºC [23-26], (τ_{rt})[28] = $8.0892\,ps$ is the relaxation time in *pico* at temperature 25 ºC. (ε_{s_∞}) is independent of salinity, and hence, (f) is frequency range [0.5GHz-4.5GHz] considered in this paper

For reliable wireless communication system, the analysis of channel characteristics should be proper. The Proper analysis of Channel characteristics provides us accurate information about Bit Error rate, path loss, Signal to noise ratio in multipath structure. But, as, it is well known that electrical properties of air and ocean or sea water are different. As a result, the channel modeling of air can be done in different ways from water channel modeling. To make relationship of air and water channel modeling, a new model was proposed for underwater channel .Path loss, Signal to noise ratio, Bit error rate, Transmitted power are main important parameters to analyze the channel model. Because, Path loss, Signal to noise ratio, Bit error rate cause the difference between the transmitted signal power and the received signal power. The Channel modeling at large-scale can be done using term path loss. In terrestrial wireless communication systems as air channel medium, the analysis is done at large path distances. However, in the proposed underwater wireless communication sensor network architecture, the distance between the wireless sensors nodes is very small. The path loss in water is to be considered in this work as expressed in dB as [16-17,20-22]. The Channel modeling can be done using with performance analysis of important parameters given below.

1.path loss (*PL*)

2.Signal to noise ratio (SNR)

3.Bit error rate (BER)

Path loss (PL) [17, 22] depends upon factors given below.

1. Pure water conductivity (σ)
2. Attenuation constant (α)
3. Phase constant (β)
4. Complex permittivity ($\varepsilon_{complex}$)
5. Path distance (d)

Path loss [17,22] is :

$$PL = (2.\beta.R_r)^2 + \frac{1}{e^{-2(\alpha \cdot R_r)}} \quad (7)$$

The Signal to noise ratio (SNR) compare the desired signal to undesired noise .It is ratio of the desired signal to undesired noise , expressed in decibels [16,20,22,29].

The bit error rate (BER) is the ratio of numbers of bits error divided by the total number of bits transferred during a studied interval [16, 20, 22, 29].

The BER of a communication system depends upon three factors given below [29]

i) SNR, ii)The modulation technique used by the system

Considering the underwater channel model, the SNR is given by [8, 16, 29-30]:

$$\left(SNR\right)db = 10\log 10\left({}^{P_t}\!\Big/_{P_n} \cdot PL\right) \quad (8)$$

Where

(P_t) is transmitted power in dbm, (P_n) is noise power in (db.m), (PL) *is* path loss. Here assumed that (P_t) is between [110db.m-200 dB.m] [30] for our evaluations and (P_n) is −40 dB.m [30]

The Binary Phase Shift keying (BPSK) modulation [16,20,22] is a two phase modulation scheme where the 0's and 1's in a binary message are represented by two different phase in carrier signal $\theta = 0^0$ for binary 1, $\theta = 180^0$ for binary 0. BPSK modulation for long range is best [7, 8], Bit Error rate (BER) is

$$BER = 0.5erfc(\sqrt{SNR}) \quad [29] \quad (9)$$

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3. Results and performance analysis

3.1 Path loss variation with variations of path distance and frequency level

As shown in figure (2), path loss in decibel increases with increase in different level of frequencies but increment in path loss decreases at different level of frequencies at same path distance. At fixed path distance d=0.5 m distance, the path loss increases by factor 62.8529 db, 71.7088db, 76.0588db, 78.9230db and 81.0440db at frequency 0.5 GHz, 1.5GHz, 2.5GHz, 3.5 GHz and 4.5GHz.At 0.5 m path distance, increment in path loss is decreasing by factor 8.8559db, 4.35db, 2.8642db, 2.121db with increase in frequency of 1GHz from 0.5GHz to 1.5GHz, 1.5GHz to 2.5GHz,2.5GHz to 3.5GHz, 3.5GHz to 4.5GHz.As ,we can see that increase in frequency ,the increment in path loss decreases at same path distance. As it can be investigated in this paper that at same distance between sensor nodes, if we increase the frequency of 1GHz, the increment in path loss decreases.

At fixed frequency 0.5GHz, the path loss increases 62.8529db, 65.8629db, 67.6237db, 68.8730db, 69.8420db, 70.6338db, 71.3033db, 71.8832 db, 72.3947db, and 72.8523db with increase in path distances d=0.5m, 1m, 1.5m, 2m, 2.5m, 3m, 3.5m, 4m, 4.5m, and 5m. As, it is investigated that the increment in path loss decreasing by factor 3.01db, 1.7608db, 1.2493db, 0.969, 0.7918db, 0.6695, 0.5799db, 0.5115db and 0.4576db.At fixed frequency 1.5 GHz, the path loss increases 71.7088 db, 74.7190db, 76.4799 db, 77.7293 db, 78.6984db, 79.4902db, 80.1597db, 80.7396db, 81.2511db, 81.7087db with increase in path distances d=0.5m, 1m, 1.5m, 2m, 2.5m, 3m, 3.5m, 4m, 4.5m, and 5m. As it is investigated that the increment in path loss decreasing by factor 3.0102 db, 1.7609db, 1.2494db, 0.9691, 0.7918db, 0.6695, 0.5799db, 0.5115db and 0.4576db.The increment in path loss remain almost same with increase in frequency of 1GHz in this paper at fixed distance.

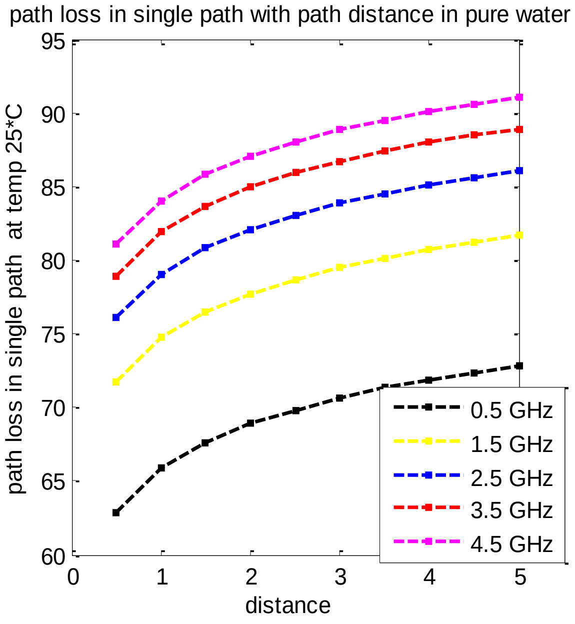

Figure 2. Path loss VS path distance with variation of frequency in pure water

A ,it can be observed from above discussion that increases in frequency, the path loss increases with increase in path distance.But increment in path loss decreases with increase in path distance at fised level of frequencies. If, we increases the frequency of signal from 0.5GHz to 1.5 GHz in this paper, the increment of path loss remain almost same but decreases with increase of distance. Similarity happens with other frequencies level.

3.2 Variations of Signal to noise ratio with variation of path loss, path distance, frequency in pure water at fixed transmitted power

As, It can be investigated from figure (2) about path loss with variation of path distance and frequency, same can be seen in figure (3) about path loss, Mainly, we will discuss in this section about signal to noise(SNR) ratio variations with path distance (d), path loss ,frequency of signal. About reliable communication, the SNR should be always high. So, if we communicate the signal at high frequency in pure water medium, the SNR is always high. No doubt, SNR decreases at high frequency with increases of path distance, the decrement in SNR becomes very small at high frequency as it can be observed from figure (3).

At the fixed frequency 1.5GHz, the SNR is decreasing 78.2912db, 75.2810db, 73.5201db, 72.2707db, 71.3016db, 70.5098db, 69.8403db, 69.2604db, 68.7489db,68.2913db at increase of path loss 71.7088db, 74.7190db, 76.4799db, 77.7293db,78.6984 db,79.4902db, 80.1597db, 80.7396db,81.2511db, 81.7087db and at increase in path distance d=0.5m ,1m , 1.5m ,2m, 2.5m,3m ,3.5m,4m,4.5m,5m.

As it was investigated that the decrement in SNR is decreasing 3.012db, 1.7609db, 1.2494db, 0.969, 0.7918db, 0.6695, 0.5799db, 0.5115db and 0.4576db with increase of path loss 3.0102 db, 1.7609db, 1.2494db, 0.9691, 0.7918db, 0.6695, 0.5799db, 0.5115db and 0.4576db at fixed frequency 1.5GHz.

At fixed frequency 2.5 GHz, the SNR is decreasing 73.9412db, 70.9309db, 69.1700db, 67.9206db, 66.9515db, 66.1597db, 65.4903db, 64.9103db, 64.3988db, 63.9412db, with increase of path loss 76.0588db, 79.0691db,80.8300 db,82.0794 db,83.0485db,83.8403db,84.5097db, 85.0897db, 85.6012db, 86.0588db.

As it is investigated that the decrement in SNR is decreasing 3.013db, 1.7609db, 1.2494db, 0.969, 0.7918db, 0.6695, 0.5799db, 0.5115db and 0.4576db with increment of path loss 3.0102 db, 1.7609db, 1.2494db, 0.9691, 0.7918db, 0.6695, 0.5799db, 0.5115db and 0.4576db at fixed frequency 2.5GHz.Similarity happen with other frequency.

But on the other side, at fixed path distance d=0.5 m distance, the path loss is 62.8529 db, 71.7088db,76.0588db, 78.9230db and 81.0440db at frequency 0.5 GHz, 1.5GHz, 2.5GHz, 3.5 GHz and 4.5GHz.At 0.5 m path distance, increment in path loss is decreasing 8.8559db, 4.35db, 2.8642db, 2.121db with increase in frequency of 1GHz from 0.5GHz to 1.5GHz, 1.5GHz to 2.5GHz,2.5GHz to 3.5GHz, 3.5GHz to 4.5GHz.As ,we can see that increase in frequency ,the increment in path loss decreases at same path distance. As it can be investigated in this paper that at same distance between sensor nodes, if we increase the frequency of 1GHz, the increment in path loss decreases. The SNR is decreasing 87.1471db, 78.2912db, 73.9412db, 71.0770db, 68.9560db with increase in frequency of 1GHz from 0.5GHz to 1.5GHz, 1.5GHz to 2.5GHz, 2.5GHz to 3.5GHz,3.5GHz to 4.5GHz and at increase in path loss 62.8529db, 71.7088db, 76.0588db, 78.9230db, 81.0440db.The decrement in SNR is also decreasing 8.8559db, 4.35db, 2.8642db, 2.121db. we can see that with increase in frequency ,the decrement in SNR decreases more at same path distance.As, it can be investigated in this paper that at same distance between sensor node, if we increases the frequency of 1GHz, the decrement in SNR decreases more.

But on the other side, at fixed path distance d=5 m distance, the path loss is 72.8523db, 81.7087db, 86.0588db,88.9230db and 91.0440db at frequency 0.5 GHz, 1.5GHz, 2.5GHz, 3.5 GHz and 4.5GHz.At 0.5 m path distance, increment in path loss is decreasing 8.8564db, 4.3501db, 2.8642db, 2.121db with increase in frequency of 1GHz from 0.5GHz to 1.5GHz, 1.5GHz to 2.5GHz,2.5GHz to 3.5GHz, 3.5GHz to 4.5GHz.As ,we can see that increase in frequency ,the increment in path loss decreases at same path distance.

As it can be investigated in this paper that at same distance between sensor node, if we increases the frequency of 1GHz, the increment in path loss decreases. The SNR is decreasing 77.1477db, 68.2913db, 63.9412db, 61.0770db, 58.9560db with increase in frequency of 1GHz from 0.5GHz to 1.5GHz, 1.5GHz to 2.5GHz, 2.5GHz to 3.5GHz, 3.5GHz to 4.5GHz and at increase in path loss 72.8523db, 81.7087db, 86.0588db, 88.9230db and 91.0440db at frequency 0.5 GHz, 1.5GHz, 2.5GHz, 3.5 GHz and 4.5GHz.The decrement in SNR is decreasing 8.8559db, 4.35db, 2.8642db, 2.121db.

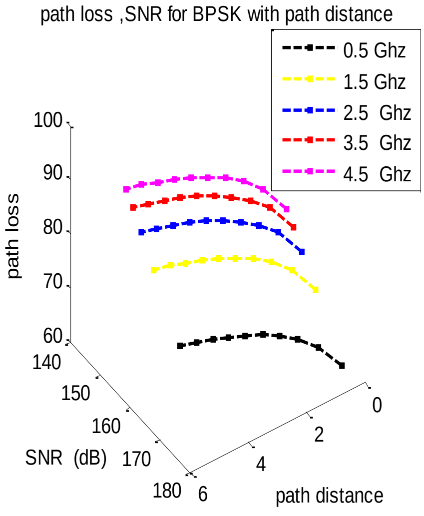

Figure 3. Path loss, Signal to noise ratio, with variation of path distance , frequency in pure water

we can see that with increase in frequency ,the decrement in SNR decreases at same path distance. As it can be investigated in this paper that at same distance between sensor node, if we increases the frequency of 1GHz, the decrement in SNR decreases as shorn in figure (3).

3.3 Bit error rate (BER) variations for BPSK modulation with variation of SNR, path distance, frequency in pure water with increase of transmitted power

As shown in figure (4), BER increases with increase in different level of frequencies at same path distance. At fixed path distance d=1 m distance and fixed transmitted power P_t=110dbm, the BER is increasing 0.000000000009 x10^{-27} , 0.00000007 x10^{-27}, 0.000005x10^{-27}, 0.0001 x10^{-27} and 0.0008x10^{-27} at frequency 0.5 GHz, 1.5GHz, 2.5GHz, 3.5 GHz and 4.5GHz.At 5 m path distance, increment in BER is increasing 0.00000069991 x10^{-27}, 0.00000493000 x10^{-27}, 0.00009500000x10^{-27}, 0.00070000000 x10^{-27} with increase in frequency of 1GHz, from 0.5GHz to 1.5GHz, 1.5GHz to 2.5GHz, 2.5GHz to 3.5GHz,3.5GHz to 4.5GHz. As,we can see that increase in frequency, the increment in BER increases at same path distance.

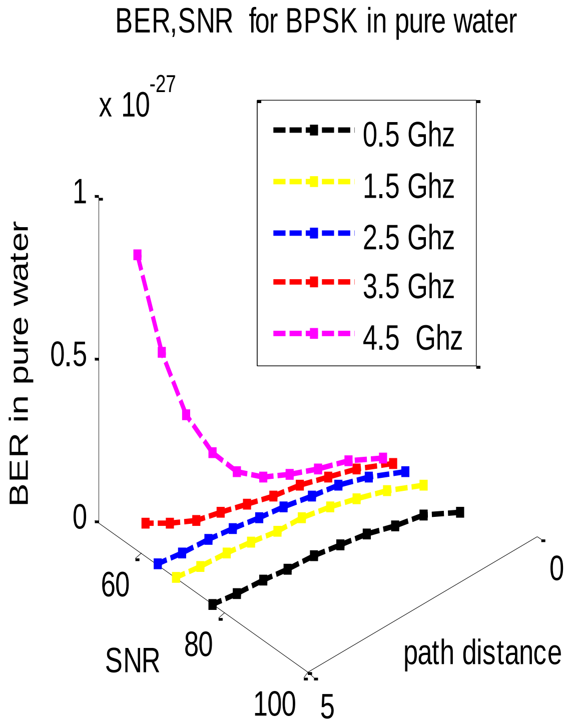

Figure 4. Bit error rate, Signal to noise ratio with variation of path distance and frequency in pure water at P_t **=110dbm**

In figure (4), at fixed path distance d=5 m distance and fixed transmitted power P_t=110dbm, the BER is increasing 0.000000009980x10^{-27} , 0.00007440x10^{-27}, 0.005954 x10^{-27}, 0.1068x10^{-27} and 0.9062x10^{-27} at frequency 0.5 GHz, 1.5GHz, 2.5GHz, 3.5 GHz and 4.5GHz.At 5 m path distance, increment in BER is increasing 0.00007439002 x10^{-27}, 0.0058796 x10^{-27}, 0.100846x10^{-27}, 0.7994 x10^{-27} with increase in frequency of 1GHz, from 0.5GHz to 1.5GHz, 1.5GHz to 2.5GHz, 2.5GHz to 3.5GHz,3.5GHz to 4.5GHz.As, we can see that increase in frequency, the increment in BER increases at same path distance. As it can be investigated in this paper that at same distance between sensor node, if we increases the frequency of 1GHz, the increment in BER increases. As shown in figure (5), BER increases with increase in different level of frequencies at same path distance.

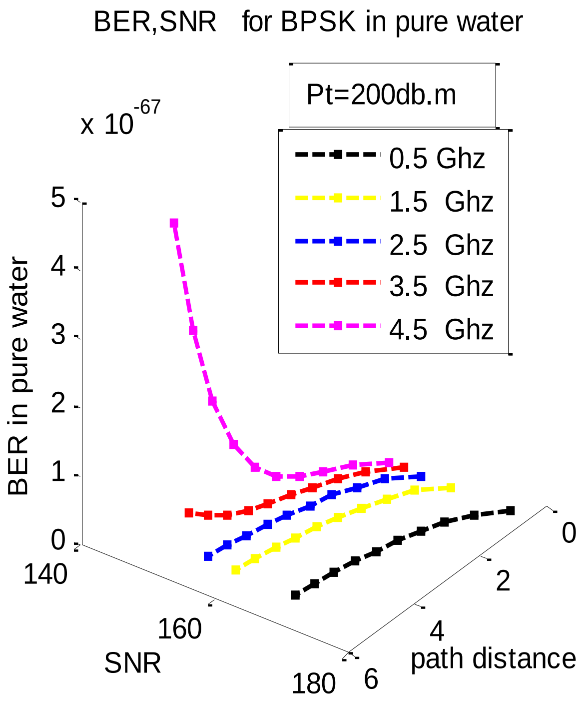

Figure 5. Bit error rate, Signal to noise ratio with variation of path distance and frequency in pure water at P_t **=200dbm`**

At fixed path distance d=1 m and fixed transmitted power P_t=200dbm, the BER is increasing 0.00000000005x10^{-67}, 0.0000004 x10^{-67} 0.00003x10^{-67} ,0.0005x10^{-67}, 0.004x10^{-67}, at frequency 0.5 GHz, 1.5GHz, 2.5GHz, 3.5 GHz and 4.5GHz.At 5 m path distance, increment in BER is increasing 0.00000039995 x10^{-67}, 0.0000296 x10^{-67}, 0.00047x10^{-67}, 0.0035 x10^{-67} with increase in frequency of 1GHz, from 0.5GHz to 1.5GHz, 1.5GHz to 2.5GHz, 2.5GHz to 3.5GHz,3.5GHz to 4.5GHz.As ,we can see that increase in frequency ,the increment in BER increases at same path distance.

In figure (5) ,at fixed path distance d=5 m distance, the BER is increasing 0.00000005575 x10^{-67} , 0.0004020 x10^{-67}, 0.03159 x10^{-67}, 0.5591x10^{-67}, 4.695 x10^{-67} at frequency 0.5 GHz, 1.5GHz, 2.5GHz, 3.5 GHz and 4.5GHz.At 5 m path distance, increment in BER is increasing 0.00040194425 x10^{-67} ,0.031188 x10^{-67} ,0.52751 x10^{-67} ,4.1359 x10^{-67} with increase in frequency of 1GHz, from 0.5GHz to 1.5GHz, 1.5GHz to 2.5GHz, 2.5GHz to 3.5GHz,3.5GHz to 4.5GHz.As, we can see that increase in frequency ,the increment in BER increases at same path distance. As it can be investigated in this paper that at same distance between sensor nodes, if we increase the frequency of 1GHz, the increment in BER increases. As a result, after examination, we have to compromise between SNR and BER.

As a result from BER comparison of figure (4) and figure (5), it was investigated that No doubt, BER increases with increase of frequency, but BER decreases with increase of transmitted power P_t =110dbm to P_t =200dbm as proposed in this paper .If , we want less BER ,then high power transmission factor should be considered. Comparison between BER after increasing transmitted power can be investigated from Table (2) ,Table (3) .Table (2) and Table (3) in which transmitted power P_t is increased to P_t =200dbm (see also figure (5)) from P_t =110dbm(see also figure (4)).

Table 1. Parameters variations with variations of frequency

Frequency	**0.5GHZ**	**1.5GHZ**	**At 2.5GHZ**	**At 3.5GZ**	**At 4.5GHZ**
$V_{rf} = \sqrt{\frac{f \times 10^7}{\sigma}}$ **m/s** [1]	0.7×10^9	1.2247×10^9	1.5811×10^9	1.8708×10^9	2.1213×10^9
τ relaxation time in pico	$8.0892Ps$	$8.0892Ps$	$8.0892Ps$	$8.0892Ps$	$8.0892Ps$
ε_{static} fixed	78.1787	78.1787	78.1787	78.1787	78.1787
ε_{real} real permittivity	78.1312	77.7533	77.0092	75.9209	74.5196

ε_{imag} imaginary permittivity	2.2299	5.7018	9.2806	12.7500	16.0464
σ (S/m) fixed pure water	0.01	0.01	0.01	0.01	0.01
$\alpha_{constant}$ (db)	56.4723	65.3288	69.6789	72.5431	74.6641
$\beta_{constant}$ (db)	74.9288	79.6920	81.8945	83.3322	84.3928

Table 2. Parameters variations at fixed frequency 0.5GHz with variation of transmitted power (P_t)

Path distance	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**
SNR At P_t=110dbm	87.1471	84.1371	82.3763	81.1270	80.1580	79.3662	78.6967	78.1168	77.6053	77.1477
BER At P_t=110dbm	0	0.0009×10^{-35}	0.0052×10^{-35}	0.0182×10^{-35}	0.0483×10^{-35}	0.1071×10^{-35}	0.2100×10^{-35}	0.3763×10^{-35}	0.6297×10^{-35}	0.9980×10^{-35}
SNR At P_t=200dbm	177.1471	174.1371	172.3763	171.1270	170.1580	169.3662	168.6967	168.1168	167.6053	167.1477
BER At P_t =200dbm	0×10^{-74}	0.0005×10^{-74}	0.0029×10^{-74}	0.0103×10^{-74}	0.0272×10^{-74}	0.0602×10^{-74}	0.1179×10^{-74}	0.2109×10^{-74}	0.3523×10^{-74}	0.5575×10^{-74}

Table 3. Parameters variations at fixed frequency 1.5 GHz with variation of transmitted power (P_t)

Path distance	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**
SNR At P_t =110dbm	78.2912	75.2810	73.5201	72.2707	71.3016	70.5098	69.8403	69.2604	68.7489	68.2913
BER At P_t =110dbm	0	0.0007×10^{-31}	0.0038×10^{-31}	0.0135×10^{-31}	0.0359×10^{-31}	0.0797×10^{-31}	0.1563×10^{-31}	0.2803×10^{-31}	0.4692×10^{-31}	0.7440×10^{-31}
SNR At P_t =200dbm	168.2912	165.2810	163.5201	162.2707	161.3016	160.5098	159.8403	159.2604	158.7489	158.2913

BER At P_t=200dbm	0 $\times10^{-70}$	0.0004 $\times10^{-70}$	0.0021 $\times10^{-70}$	0.0074 $\times10^{-70}$	0.0196 $\times10^{-70}$	0.0434 $\times10^{-70}$	0.0850 $\times10^{-70}$	0.1521 $\times10^{-70}$	0.2540 $\times10^{-70}$	0.4020 $\times10^{-70}$

In Table (1) ,Some important variations of parameter is considered with variation of frequency such as Vrf [1] is velocity of EM wave in water medium which increases with increase of frequency of EM wave signal at fixed electrical conductivity σ (S/m) as in pure water medium σ =0.01(S/m) fixed

CONCLUSION

As,it is well known that the application of Underwater EM wireless communication has few scope. But, with advancement of technology and functional requirements of EM waves with high speed and high date rate at high frequency ,low propagation delay and better signal to noise ratio at high frequency, the entire scenario have changed since electromagnetism in underwater was evaluated. The use of underwater EM Wave's communication has revealed that EM waves propagation assembled with digital technology has many advantages that make it suitable for many underwater applications. The analysis of EM waves in this research paper has shown that the propagation based on electromagnetic wave wireless communication under the frequency upto 4.5 GHz in these turbid and high loss environments in pure water medium has feasibility to explore its applicability. The simulation and theoretical analysis provide results which prove the feasibility of Electromagnetic wave wireless communication at the frequency 4.5 GHz in these turbid and high loss underwater environments to meet practical specifications.

ACKNOWLEDGEMENTS

I would like to thank to Dr. Mahendra Kumar for constant support and encouragement to carry out this innovative work. The completion of this study would have been not possible if not dependent on the steadfast support and encouragement of my parents. They hence paid equal contribution to the study for which I always feel profound gratitude in my heart.

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