Design of Attenuation loss and Multipath propagation Model for Underwater Acoustic Communication in Tank

Sweta S Panchal, Ved Vyas Dwivedi, Jayesh P Pabari

Abstract: The wireless sensor network uses some sort of sensors to detect in general physical quantity of interest. The wireless sensor network has potential to explore difficult-to access area on the earth and the concept is extended to underwater applications in future. Past several years studies has been focused on development of reliable and robust communication systems for underwater wireless sensor network for various underwater applications. The scenario of communication is different in underwater compared to that on land as environment is completely different. Also radio waves cannot propagate for longer distance, so instead of that acoustic waves are used. The efforts are made to devise a model for acoustic frequency ranges in the environment for underwater tanks using basic equations governing various physical phenomena occurring during acoustic wave propagation. The model uses scenario of underwater tank filled with raw water diluted with sodium chloride with communicating devices placed at various distances. Attenuation model can be proposed for such communication scenario with respect to distance between transmitter and receiver for acoustic frequency ranges. The acoustic wave travelling through propagating medium suffers from multiple reflections resulting into multipath propagation. The multipath propagation model is proposed for calculation of length of multipath signals propagating in bounded shallow water. Propagation delays of each multipath signals are proposed. Empirical relationship is developed between number of multipath components and distance between transmitter and receiver. Arrival time lag jitter of various multipath signals are developed with respect to distance between transmitter and receiver and height of transmitter and receiver with respect to water bottom is also proposed.

Keywords : Attenuation loss, Multipath Propagation, Underwater acoustic signal, Wireless Sensor Network.

I. INTRODUCTION

The study of analysis of acoustic signals helps to develop application for bounded underwater tank. Earlier study has proposed models for understanding phenomenon exhibiting for underwater acoustic sensor network. Recently, underwater environment has emerged as a new domain of wireless sensor networks. Underwater Wireless Sensor Networks (UWSN) deployed in a underwater tanks, a pond, or a river or a ocean. An Acoustic underwater communications are governed by factors: Signal attenuation, limited bandwidth, time-varying multipath propagation, and low speed of sound in water. In order to detect impurities settled at the bottom of underwater tank, a wireless sensor network is deployed in underwater acoustic environment which is capable of working in aquatic medium. To accomplish faithful underwater communication in underwater tank, finds a solution to multiple problems related to cleanliness and hygiene. Acoustic sensor network may include acoustic sensors, made feasible to work in the acoustic frequency range [1].

This paper introduces a model describing shallow underwater tank channel by using its physical and environmental parameters. The underwater acoustic communication is comparatively difficult as it faces multiple problems. The problems are due to channel characteristics like attenuation, fading, time-varying characteristics and channel inhomogeneities. Due to change in chemical composition of water in tank, the physical parameter like absorption of acoustic signal increases. The attenuation model for underwater tank is developed for raw water filled tank which is diluted with sodium chloride for wireless acoustic sensor network. Also, the absorption loses are dependent on distance between communication devices in acoustic frequency range. Acoustic signals are used for underwater communication because radio frequency signal gets faded at long distance and optical signal suffers scattering loss. In the underwater tank multipath signals are attenuated by spreading, sediments and chemical composition of water. Signal strength gets reduced due to more concentration of sodium chloride in raw water. As the acoustic signal is transmitted from transmitter, it travels through multipath before reaching receiver. The multipath signals travelling in the direction of receiver arrives via various paths with time delay. The discrimination of direct and multipath signals however is impossible. Also under certain conditions, the multipath adds up constructively to increase strength of received signal.

This study aims to determine time varying property for underwater tank and development of channel model for acoustic communication system. The number of multipath signals arriving at receiver varies with change in distance between transmitter and receiver. The proposed model helps to find number of multipath for given distance between communicating devices. Last section suggests the arrival time lag jitter for all possible multipath signals as suggested.

Arrival time lag jitter for multipath components is derived with respect to change in distance between transmitter and receiver and height of transmitter and receiver.

II. UNDERWATER ACOUSTIC CHANNEL CHARACTERISTICS

The main focus is on parameters of underwater acoustic channel characteristics that affects the acoustic signal propagation through acoustic medium.

A. Acoustic Signal Velocity

The fundamental parameters help to determine the behavior of signal propagation in the acoustic medium. The wide range of formulas has been developed over period of time that helps in calculation of sound velocity. Acoustic velocity depends on components like temperature, hydrostatic pressure and depth. The sound velocity has noticeable impact on acoustic signal propagation. The expression for acoustic velocity using giving formula for raw water with no salinity content is shown in (1) [2].

$$c = 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3 + 0.016d \quad (1)$$

Where T is temperature in ℃ and d is depth of medium in meters.

B. Acoustic Signal Attenuation

An underwater acoustic signal experiences attenuation due to absorption and other losses. The absorption co-efficient for underwater acoustic frequencies in kHz for channel which consist of raw water saturated with sodium chloride can be calculated using formula defined in $\alpha_{overall}(\frac{dB}{m})$ as function of frequency of f (kHz) Eq.(2) [3].

$$\alpha_{overall} = 0.9534\alpha_{water} + 0.0466\alpha_{NaCl} \quad (2)$$
$$\propto_{water} = A * P * f^2 \quad (3)$$
$$P = 1 - 3.83 * 10^{-5}z + 4.9 * 10^{-10}z^2 \quad (4)$$
$$A = 4.937 * 10^{-4} - 2.59 * 10^{-5}T + 9.11 * 10^{-7}T^2 - 1.5 * 10^{-8}T^3 \quad T < 20℃ \quad (5)$$
$$A = 3.964 * 10^{-4} - 1.146 * 10^{-5}T + 1.45 * 10^{-7}T^2 - 6.5 * 10^{-10}T^3 \quad T > 20℃ \quad (6)$$
$$\alpha_{Nacl} = (0.0225 * f^2/2\rho v^3)\big[(4\eta/3 + \eta^v) + \tau 1Cp - 1Cv \quad (7)$$

where attenuation due raw water is given by α_{water} in dB/m [4] which is affected by hydrostatic pressure P in bar [4], z is depth of water medium in meter, T is temperature in ˚C and A is atmospheric pressure which is constant till 20℃ . α_{NaCl} is the attenuation due to sodium in dB/m, f is frequency in kHz, ρ is density g/m^3, v velocity in m/s, η^v is volume viscosity, τ is thermal conductivity, C_p and C_v are specific heat constants at constant pressure and constant temperature [5][6].

The mentioned model is applicable to the channel consisting of 95.34% of raw water saturated with 4.66% of sodium chloride [7]. The concentration of sodium chloride corresponding to 4.66% is approximately 3 moles/liter. The model for attenuation due to raw water is valid for temperature 20℃ , hydrostatic pressure of 1 bar and depth of tank 100m [8]. The attenuation co-efficient is dependent on distance between transmitter and receiver. As the transmission range increases, the attenuation of acoustic signal as function of acoustic frequency ranges also increases.

$$\propto_{absorp} = (0.9534\alpha_{water} + 0.0466\alpha_{NaCl}) * L \quad dB \quad (8)$$

Eq. (8) shows the direct relationship between attenuation measured $\propto_{absorp}$ in dB and transmission range L in meters.

The proposed model of Eq. (8) gives the attenuation loss for underwater acoustic communication channel as tank which is bounded area of communication as function of length L is distance between transmitter and receiver. at various acoustic frequencies . The channel consists of raw water saturated with sodium chloride.

## III. UNDERWATER ACOUSTIC COMMUNICATION

The significant limitation for underwater wireless acoustic sensor network compared to terrestrial radio wave communication is due to speed of sound in underwater medium. It becomes difficult for acoustic wave to send same amount of information in underwater acoustic communication compared to terrestrial communication. Also the amount of loss is very high for long distance communications with limited energy availability.

The underwater acoustic communication is challenging as underwater acoustic channel is affected by noise, transmission loss, time varying property and multipath propagation. The reflections of acoustic signal from various parts of channel medium as well as infrastructure geometry in due course of propagation of signal from transmitter and receiver is one of the reasons for multipath propagation. The reflections caused in communication channel mainly dependent on distance between transmitter and receiver. In underwater tank, the reflections due to channel geometry and tank geometry occurs through water surface, water bottom and side walls of the receiver [9]. The number of reflections is reason for occurrence of multipath. The acoustic signals take multiple paths to reach receiver from transmitter.

IV. MULTIPATH PROPAGATION

In due course of transmission of acoustic signal from transmitter to receiver in underwater tank, it faces number of reflections. The acoustic signals get reflected from water surface, water bottom and side walls of underwater tank, after transmitted and from due course of its emergence from arrival. The distance between transmitter and receiver plays important role in number of reflections and hence multiple paths it has to travel. Therefore as distance changes, the reflections taking place also changes.

The number of reflections makes acoustic signal to travel through multiple paths. This reflection that leads to multiple paths give rise to multipath propagation [10]. This paper, consider channel geometry and bounded medium as tank as infrastructure geometry as shown in Fig. 1.
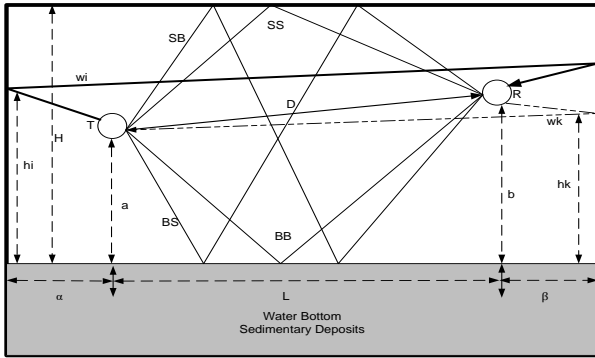
Fig. 1.Multipaths due to reflections from channel geometry and tank geometry

The acoustic signals travelling to receiver has delayed in accordance to channel geometry due to number of reflections. Acoustic channel is a shallow bounded region as uniform depth of h, height of transmitter and receiver is a and b respectively. S and R are transmitter and receiver respectively. The acoustic channel medium has constant velocity as shown in Eq. (1) and n is order of reflection. The distance between transmitter and receiver is L. The distance of transmitter and receiver from two side walls is α and β respectively. The height of point of reflection from side walls behind transmitter and receiver is h_k and h_i respectively.

A. Path lengths

The path length of direct signal from transmitter to receiver is D is as shown in Eq.(9) [10]. According to various reflections from various boundaries of channel medium, the multipath occurs as following types. The path length of multipath due water surface and water bottom is SS and SB as shown in Eq. (10) and Eq. (11) respectively [10]. The path length of surface to bottom and bottom to surface reflections is given by SB and BS as in Eq. (12) and Eq. (13) respectively [10]. The path length for signal reflected from side walls behind receiver and transmitter is given by W_k Eq. (14-15) and W_i Eq. (16-17) respectively. The path lengths of direct signal and reflected signals are calculated using following equations.

$$D = \sqrt{L^2 + (b-a)^2} \qquad (9)$$

$$SS = \sqrt{L^2 + (2nh - a - b)^2} \qquad (10)$$

$$SB = \sqrt{L^2 + (2nh - a + b)^2} \qquad (11)$$

$$BS = \sqrt{L^2 + (2nh + a - b)^2} \qquad (12)$$

$$BB = \sqrt{L^2 + (2(n-1)h + a + b)^2} \qquad (13)$$

$$W_k = \sqrt{(1+\beta)^2 + (a - h_k)^2} + \sqrt{(b - h_k)^2 + \beta^2} \quad (14)$$
$$\text{for,} \qquad h_k < a < b$$

$$W_k = \sqrt{(1+\beta)^2 + (a + h_k)^2} + \sqrt{(b - h_k)^2 + \beta^2} \quad (15)$$
$$\text{for,} \qquad a < h_k < b$$

$$W_i = \sqrt{\alpha^2 + (a - nh_i)^2} + \sqrt{(\alpha + l)^2 + (b - nh_i)^2} \quad (16)$$
$$\text{for,} \qquad h_i < a$$

$$W_i = \sqrt{\alpha^2 + (a + nh_i)^2} + \sqrt{(\alpha + l)^2 + (b - nh_i)^2} \quad (17)$$
$$\text{for,} \qquad h_i > a$$

B. Propagation Delays

The differences in arrival time between direct and reflected path signals gives propagation delay of the reflected signals. The propagation delay of the reflected signals is given by Eq. (18) [10] for surface to bottom, bottom to surface, bottom and surface reflections. For side wall reflections, the propagation delay is as given in Eq. (19),

$$\tau_{SS} = \frac{SS - D}{C}; \tau_{SB} = \frac{SB - D}{C}; \tau_{BB} = \frac{BB - D}{C}; \tau_{BS} = \frac{BS - D}{C} \quad (18)$$

$$\tau_{W_k} = \frac{W_k - D}{C}; \tau_{W_i} = \frac{W_i - D}{C} \qquad (19)$$

Propagation delays are calculated for reflected ray with respect to direct ray, as it is important parameter for underwater acoustic channel. Number of multipaths resulting due to reflections varies in accordance with the distance between transmitter and receiver depends on propagation delay Eq. (18-19) of various paths followed by underwater acoustic signal.

C. Number of Multipath Components

The number of multipath components depends on reflection of transmitted signal from various parts of communication medium in an underwater tank as medium of transmission. The underwater tank uses sensors acting as communicating devices for communication. The distance between sensors employed for transmission as well as reception also plays vital role for finding number of multipath components. The bandwidth of communicating device plays vital role for number of multipaths [11]. The specifications of the sensors like bandwidth, operating frequency, sensitivity, dynamic range etc. are important for underwater acoustic communication in tanks. The number of multipath can be evaluated according to maximum propagation delay of the reflected signal and bandwidth of the sensor in use. The propagation delay of multipath components are calculated using Eq. (18) - Eq. (19) and the maximum propagation delay from the calculation is utilized as τ_{max}. Thus the number of multipaths can be calculated using Eq. (20) [12].

$$\delta = [2\tau_{max}B] + 1 \qquad (20)$$

where τ_{max} is maximum propagation delay of the various reflected signal from various reflection undergone in due course of its propagation from Eq. (18) and Eq. (19) for specific distance between communicating devices, B is the bandwidth of operating frequency ranges of communication [13].

V. MULTIPATH COMPONENTS AS A FUNCTION OF DISTANCE

The underwater acoustic signal suffers from reflections from various parts of tank like water surface, tank bottom and side walls of tank. These reflections are dependent on distance between communicating device. The numbers of reflections directly affect number of multipaths. As distance between transmitter and receiver changes, the number of reflections and ultimately number of multipaths are changed. For a particular communicating set of devices, the number of multipath for the acoustic wave propagating through underwater tanks depends on distance between transmitter and receiver. The expression representing relation between distance between communicating devices and number of multipaths is given by Eq. (20).

$$\delta = 4.17e^{0.224}d \tag{21}$$

Number of multipaths δ can be calculated using Eq. (21) till distance of $20\,m$ between transmitter and receiver for bounded shallow medium of communication like tank.

Eq. (21) shows exponential increasing relationship between number of multipaths and distance between communicating devices. As the distance between acoustic sensors increases, the number of multipaths taken by acoustic signal to reach receiver also increases. Suggested relationship in Eq. (21) helps to find number of multipaths for underwater tank with respect to distance between transmitter and receiver.

VI. ARRIVAL TIME LAG JITTER

The variation in arrival time lag can be observed due to mobility of source and receiver. The stability of the arrival time lag can be analyzed with respect to change in communication range, change in position of source/receiver. To inspect the change on arrival time lag jitter, it is differentiated with respect to communication range, depth of source and depth of receiver.

$$\frac{\partial \tau_{SS}}{\partial L} = \frac{1}{c}\left\{\left[1 + \left(\frac{2H-(a+b)}{L}\right)^2\right]^{-\frac{1}{2}} - \left[1 + \left(\frac{b-a}{L}\right)^2\right]^{-\frac{1}{2}}\right\} \tag{22}$$

$$\frac{\partial \tau_{SS}}{\partial a} = \frac{1}{c}\left\{-\left[\left(\frac{L}{(a+b)}\right)^2 + \left(\frac{2H}{(a+b)} - 1\right)^2\right]^{-\frac{1}{2}} + \left[1 + \frac{b-a}{L}2-12\right]\right\} \tag{23}$$

$$\frac{\partial \tau_{SS}}{\partial b} = \frac{1}{c}\left\{-\left[\left(\frac{L}{(a+b)}\right)^2 + \left(\frac{2H}{(a+b)} - 1\right)^2\right]^{-\frac{1}{2}} - \left[1 + \frac{b-a}{L}2-12\right]\right\} \tag{24}$$

Eq. (22) shows the rate of change of surface reflected acoustic wave with respect to distance between transmitter and receiver which suggest the stability dependency on distance between transmitter and receiver. Eq. (23) and Eq. (24) shows the stability of arrival time lag of surface reflected multipath component, is dependent on height of transmitter and receiver. It is observed that the rate of change of propagation delay due to surface reflected component with respect to height of transmitter and receiver is equal when transmitter and receiver are kept at same height.

$$\frac{\partial \tau_{SB}}{\partial L} = \frac{1}{c}\left\{\left[1 + \left(\frac{2H-(a-b)}{L}\right)^2\right]^{-\frac{1}{2}} - \left[1 + \left(\frac{b-a}{L}\right)^2\right]^{-\frac{1}{2}}\right\} \tag{25}$$

$$\frac{\partial \tau_{SB}}{\partial a} = \frac{1}{c}\left\{-\left[\left(\frac{L}{(a-b)}\right)^2 + \left(\frac{2H}{(a-b)} - 1\right)^2\right]^{-\frac{1}{2}} + \left[1 + \frac{b-a}{L}2-12\right]\right\} \tag{26}$$

$$\frac{\partial \tau_{SB}}{\partial b} = \frac{1}{c}\left\{-\left[\left(\frac{L}{(a-b)}\right)^2 + \left(\frac{2H}{(a-b)} - 1\right)^2\right]^{-\frac{1}{2}} - \left[1 + \frac{b-a}{L}2-12\right]\right\} \tag{27}$$

The stability of propagation time delay is tested by differentiating propagation delay of surface bottom reflected multipath component with respect to transmitter height a,

receiver height b and distance between them L as shown in Eq. (25) - Eq. (26). It shows that the change of propagation delay for very long distance of communication is independent of distance of communication as well as height of communicating devices. If transmitter and receiver are placed at equal heights, $a = b$, the arrival time lag jitter tends to infinite.

$$\frac{\partial \tau_{BB}}{\partial L} = \frac{1}{c}\left\{\left[1 + \left(\frac{(a+b)}{L}\right)^2\right]^{-\frac{1}{2}} - 1/2\left[1 + \left(\frac{b-a}{L}\right)^2\right]^{-\frac{1}{2}}\right\} \tag{28}$$

$$\frac{\partial \tau_{BB}}{\partial a} = \frac{1}{c}\left\{-\left[\left(\frac{L}{(a+b)}\right)^2\right]^{-\frac{1}{2}} - 1/2\left[1 + \left(\frac{b-a}{L}\right)^2\right]^{-\frac{1}{2}}\right\} \tag{29}$$

$$\frac{\partial \tau_{BB}}{\partial b} = \frac{1}{c}\left\{\left[\left(\frac{L}{(a+b)}\right)^2\right]^{-\frac{1}{2}} - 1/2\left[1 + \left(\frac{b-a}{L}\right)^2\right]^{-\frac{1}{2}}\right\} \tag{30}$$

Similarly, the propagation time jitter for bottom reflected component shows that the change of propagation delay is dependent on change on height of transmitter, receiver and distance between transmitter and receiver as shown in Eq. (29) - Eq.(30),

$$\frac{\partial \tau_{BS}}{\partial L} = \frac{1}{c}\left\{\left[1 + \left(\frac{2H+(a-b)}{L}\right)^2\right]^{-\frac{1}{2}} - \left[1 + \left(\frac{b-a}{L}\right)^2\right]^{-\frac{1}{2}}\right\} \tag{31}$$

$$\frac{\partial \tau_{BS}}{\partial a} = \frac{1}{c}\left\{\left[\left(\frac{L}{(a-b)}\right)^2 + \left(\frac{2H}{(a-b)} + 1\right)^2\right]^{-\frac{1}{2}} + \left[1 + \left(\frac{b-a}{L}\right)^2\right]^{-\frac{1}{2}}\right\} \tag{32}$$

$$\frac{\partial \tau_{BS}}{\partial b} = \frac{1}{c}\left\{-\left[\left(\frac{L}{(a-b)}\right)^2 + \left(\frac{2H}{(a-b)} + 1\right)^2\right]^{-\frac{1}{2}} - \left[1 + \frac{b-a}{L}2-12\right]\right\} \tag{33}$$

Eq. (31) - Eq. (33) suggest the stability of arrival time lag jitter of change of propagation delay of Bottom to surface reflected wave with respect to distance of communication, height of transmitter and receiver respectively. The differentiation shows the multipath component propagation delay is highly dependent factors like transmission range, height of source/receiver as it increases with increases in these factors and affects the stability of arrival time lag delay. As the distance of transmission increases to large extend, the jitter in arrival time lag due to BS components can be neglected.

$$\frac{\partial \tau w_i}{\partial L} = \frac{1}{c}\left[\frac{(\alpha+L)}{\sqrt{(\alpha+L)^2+(b-h_i)^2}} - \frac{L}{\sqrt{L^2+((b-a)^2}}\right] \tag{34}$$

The change of propagation delay of multipath component reflected by the wall behind transmitter with respect to distance between transmitter and receiver is shown in Eq. (34).The arrival time lag jitter of wall reflected wave when strikes walls behind transmitter at any height equal to height of receiver i.e. $b=h_i$ it becomes independent to range of communication.

$$\frac{\partial \tau w_k}{\partial L} = \frac{1}{c}\left[\frac{(L+\beta)}{\sqrt{(L+\beta)^2+(a-h_k)^2}} - \frac{L}{\sqrt{L^2+((b-a)^2}}\right] \; if \; h_k < a < b \tag{35}$$

$$\frac{\partial \tau w_k}{\partial L} = \frac{1}{c}\left[\frac{(L+\beta)}{\sqrt{(L+\beta)^2+(a+h_k)^2}} - \frac{L}{\sqrt{L^2+((b-a)^2}}\right] \; if \; a < h_k < b \tag{36}$$

The arrival time jitter for propagation delay of wave reflected from the wall behind receiver with respect to distance between transmitter and receiver is shown in Eq. (35) - Eq. (36). The stability of arrival time jitter wall reflected wave is strictly dependent on distance between transmitter and receiver.

VII. RESULTS AND DISCUSSION

The proposed model for attenuation as shown in Eq. (8) is simulated using MATLAB. The attenuation loss is simulated at various acoustic frequencies ranging from $10\ kHz$ to $200\ kH$. Evaluated attenuation losses for acoustic frequencies are also simulated for various distances between transmitter and receiver. The distance between transmitter and receiver is changes till $20\ meters$ and corresponding attenuation losses are simulated.

Table- I: Variation in attenuation as function of distance between transmitter and receiver for acoustic frequency range

Length (Meter)	Attenuation (dB)			
	Frequency (1 kHz)	Frequency (5 kHz)	Frequency (100 kHz)	Frequency (200 kHz)
1	0.0013	0.034	0.1372	0.5487
5	0.0068	0.1715	0.6859	2.743
7	0.0096	0.24	0.9602	3.841
10	0.0137	0.3429	1.372	5.487
12	0.0164	0.4115	1.646	6.584
15	0.020	0.5114	2.058	8.23
18	0.0246	0.617	2.469	9.876
20	0.027	0.68	2.743	10.97

Table I shows the increase in absorption loss for various acoustic frequency ranges as the distance between transmitter and receiver termed as length also increases. This suggests the maximum usable distance between transmitter and receiver which can be used at particular acoustic frequency range.
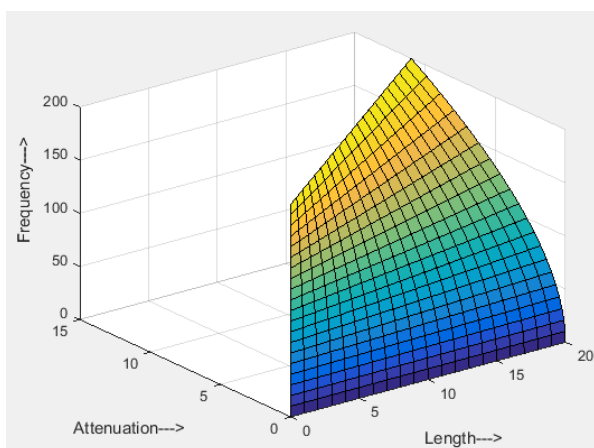
Fig. 2.Attenuation as function of distance between transmitter and receiver at various acoustic frequency ranges

Fig.2 shows the simulated results for attenuation model suggested in Eq. (8) for frequency ranges till 200 kHz and distance between transmitter and receiver is maximum 20 meters. The absorption loss is due to energy loss taking place due to viscous friction and various types of ionic relaxation occurring as acoustic signal is propagating and range of communication between acoustic sensor as shown in Eq. (8). The Acoustic sensors used for underwater acoustic communication are employed in range of 20 kHz to 1MHz. For acoustic frequency till range of 200 kHz are simulated in scenario of underwater tank with dimension of 20 m in length. Diluted raw water with sodium chloride in amount of 3 moles/liter is used as propagation medium.

Table- II:- Number of multipaths of Underwater Acoustic signal communication as function of distance between transmitter and receiver

Distance between transmitter and receiver (m)	Number of multipaths
0	0
5	4
6	5
10	8
12	9
14	12
15	14
18	22
20	26

Table II shows the number of multipaths as function of distance between transmitter and receiver of Underwater acoustic signal communication in bounded channel like tank.

The graph of distance between transmitter and receiver and number of multipaths is as shown in Fig. (3).
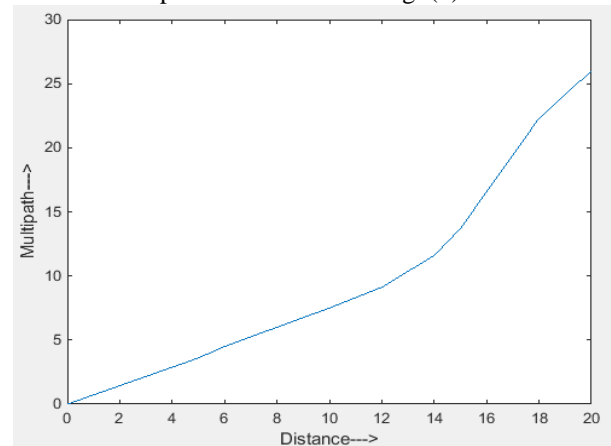
Fig. 3.Relation between number of multipaths and distance between acoustic sensors

The exponential relationship shown in Fig. 3. is the result of simulation of model for number of multipaths as suggested in Eq. (21). The model of Eq. (21) suggest the number of multipaths as function of distance between transmitter and receiver. For particular distance between transmitter and reciever, the number of multipaths can be obtained for the acoustic communication in bounded water area like tank.

VIII. CONCLUSION

In this paper, we have suggested the attenuation model for the underwater tank with raw water saturated with sodium chloride as function of communication distance between transmitter and receiver. In contrast to the existing model of attenuation, the model is proposed for communication medium consisting of raw water saturated with sodium chloride of 3 moles/Liter concentration.

As the underwater tank is bounded shallow medium for communication, the acoustic signal travelling from transmitter gets reflected from various parts of channel geometry as well as walls of water tank. The path lengths of various reflected signals are also suggested and used to find propagation delay. Multipaths are caused due to changing distance between transmitter and receiver. Relation between number of multipaths and distance between source and destination underwater acoustic devices is suggested using various maximum propagation delays of multipaths. The relationships of arrival lag time jitter with respect to distance between transmitter and receiver suggest the change of propagation delay of particular multipath component as distance is altered between transmitter and receiver. Also arrival time lag jitter for multipath components generated due to channel geometry is suggested with change in height of transmitter and receiver.

REFERENCES

1. Ian F. Akyildiz, Dario Pompili, and Tommaso Melodia, "Underwater acoustic sensor networks: Research challenges," Ad Hoc Networks, Vol. 3, No. 3, pp. 257–279, February,2005.
2. Lurton X., "Underwater Acoustic wave propagation", An Introduction of Underwater Acoustics Principles and Applications", XXXVI, pp. 13-74, 2010.
3. Sweta S. Panchal and Jayesh P. Pabari, "Development of Attenuation model for saturated water and Sedimentary deposits for Underwater Acoustic Signal Communication," International Journal of Engineering and Analytical Technology (IJEAT), Vol. 8, No. 6, pp. 6–10, August, 2019.
4. R. E. Francois, G. R. Garrison, "Sound absorption based on ocean measurements : Part I : Pure water and magnesium sulfate contributions " , The journal of Acoustical Society of America, Vol. 10, pp. 896–907, April, 1982.
5. Maria L. V. Ramires, Carlos A, Nieto. de Castro, Joao M. N. A. Fareleira, and William A. Wakeham, "Thermal Conductivity of Aqueous Sodium Chloride Solutions," The Journal of Chemical Engineering Data, Vol. 39,vNo. 1, pp. 186–190, 1994.
6. J. Kestin and I. R. Shankland, "Viscosity of aqueous NaCl solutions in the temperature range 25-200 °C and in the pressure range 0.1-30 MPa," International Journal of thermodynamics, Vol. 5, No. 3, pp. 241–263, 1984.
7. A. M. Nikanorov, L. V Brazhnikova "Water Chemical composition of rivers, lakes and wetlands", Encyclopedia of life support systems, vol. II, 2009.
8. R. E. Francois, G. R. Garrison, "Sound absorption based on ocean measurements . Part II : Boric acid contribution and equation for total absorption of sound" The Journal of Acosutical Society of America, Vol. 72, pp. 1879–1890, 1982.
9. Ian F. Akyildiz, Doria Pompili, and Tommaso Melodia, "Challenges for efficient communication in underwater acoustic sensor networks," ACM SIGBED Review, Vol. 1, Issue 2, pp. 3–8, July 2004
10. A. Zielinski, S. Member, Y. Yoon, and L. Wu, "Performance Analysis of Digital Acoustic Communication in a Shallow Water Channel," IEEE Journal of Oceanic Engineering, Vol. 20, Issue. 4, pp. 293-299, October 1995.
11. D. M. Lopes, "Multipath Acoustic Navigation PDI Final Report," February, 2014.
12. Y. Y. Al-aboosi and A. Z. Sha'ameri, "Experimental Multipath Delay Profile of Underwater Acoustic Communication Channel in Shallow Water," Indonesian Journal of Electrical Engineering and Computer Science, Vol. 2, No. 2, pp. 351–358, May 2016.
13. https://www.benthowave.com/products/BII-8080TR%20ACGAC.html.

AUTHORS PROFILE

Miss. Sweta S Panchal has received the B.E. (Electronics & Communication Engineering.) degree from Gujarat University and M.E. Electrical (Automatic Control & Robotics) from The M S University of Baroda, Vadodara in 2007 and 2010 respectively. At present she is pursuing Ph.D. from C U Shah University, Wadhwan. She is presently working as an Asst. Professor, Electrical Engineering Department, Faculty of Technology & Engineering, The M S University of Baroda, Vadodara since 2015. Her research interest includes MANET, Wireless Communication, and Under water Acoustic wireless Sensor Network, etc.

Dr. Vedvyas Jayprakashnarayan Dwivedi, Vice-Chancellor, C U Shah University, Wadhwan City, Gujarat, India. He has received his B.Tech. M.Tech. and Ph.D. all degree in E & C Engineering. He has also received D.Litt. from University of South America. He has 24 years of experience at various levels in industry and academics. Under his guidance 9 Ph.D. awarded, 4 M.Phil. awarded, and 34 M.Tech. awarded. He has completed 12 research consultancy projects. He has published 8 patents and 1 patent is under review. He has authored 14 books (7 International and 7 National).
He has worked in various capacities as HoD, Academic council, Board of studies, Governing body, Board of Management, Research council, Board of Examiners, Recruitment and Selection Committees, Post Doctoral Program Reviewer at NASA advisory since 2017.
His google scholar citation is 2136, h-index is 17 and i10 index is 25. He has published 60 Scopus papers and Scopus index is 7.

Dr. Jayesh P Pabari has received the M.E. degree from R. D. University, Jabalpur in 1998 and Ph.D. degree from Indian Institute of Technology (IIT), Bombay in 2011. He had been a lecturer in Electronics Engineering Department of Nirma Institute of Technology, Ahmedabad for about 3 years. He has been working involved in the research activities at Physical Research Laboratory, Ahmedabad for more than 18 years. His Major research interests are in the interplanetary dust science, Planetary lightning science, Sensor development, Wireless Communication, and Signal processing. At present he is involved in the research activities for applications in the areas of Planetary Sciences. He is a reviewer for many of reputed international journals. He is a fellow of Institution of Electronics and Telecommunication Engineers (IETE) and a fellow of The Institution of Engineers (India). He has published number of research papers in Thomson Reuter's indexed journals.