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SEAWATER FOR THE NOVELTY ERA OF COMMUNICATIONS-OPPORTUNITIES AND CHALLENGES

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ABSTRACT

Seawater is an abundant resource that could play an indispensable role in many applications involving electrical conductivity, monitoring security, improved battery power efficiency, and as an antenna transmitter and receiver. Thus in certain circumstances seawater could serve a useful purpose for service providers when other materials are unavailable. The study assesses the comparative strengths and weaknesses of different underwater techniques for creating a large-scale practical utilization while the contribution is to offer a computation method when considering seawater connectivity. The objective of the comprehensive investigation is to examine the signal behaviour for underwater communication to give a remarkable way for developing the new upcoming technology era, particularly in terms of water communication technology. A significant result shows the parameters of the permittivity, salinity, and frequency could notably affect the underwater communication techniques in terms of signal magnitude, phase, and delay rate. The higher frequency leads to more fluctuation in magnitude, while degradation begins after 10 KHz and shows more slope gradient after 100 KHz in the signal phase, added to the notable delay rate that would start after 100 Hz severely.

Keywords*: Seawater Communication; Sonar; Electromagnetic Wave; Optical; Frequency.*

1. INTRODUCTION

Water covers around 71 percent of the earth's surface and provides great life benefits such as transportation, food supply, and natural resources. Different significant applications based on seawater could cause concern globally and would mark the start of a new era for industrial, scientific, and military applications, in addition to navigation and monitoring. Peculiarities of seawater communication would serve various sectors and provide significant solutions for wide society systems via abundant resources [1].

However, to accommodate seawater communication and get full advantages, the water composition should be aware enough to contribute the approach including a new revolution technology such as IoT in the upcoming generation. Incorporate various engineering aspects must be considered when tackling seawater connectivity. Hence, studying the chemical parameters electromagnetically could offer a way to reach seamlessly, accurately, and scientifically [2][3].

Seawater is free and abundant water types that can distinguish by the specific composition characteristics such as salinity which is play an indispensable role in terms of water communication through conducting the signal behaviour.

Different studies exposed the seawater connections to contribute the research, for example, the author in [1] proposed the software-defined underwater network but the hardware complexity considers the main drawback from an architecture perspective. However, the Media Access Control (MAC) is critical to compliance multiple nodes at the same time, while the limited bandwidth in FDMA and long-time guards in TDM are not suitable for underwater acoustic communication due to bandwidth limitations. Another proposal in a seawater communication that worked in solar panels to harvest the power [4], but the study needs to improve in terms of energy harvesting through follow a recent trend such as polymer characteristics to gain more electrical power in addition to respect water types. Extremely coverage for the future connections applications across 6G has been proposed in [5] utilizing the underwater communication Tier via IoT technology, but due to neglecting the water composition and affected parameters, the study gives a sound to enhancement

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requirement. Continuously with the previous studies, the author in [6] presented underwater optical communication to conduct others but the high maintenance cost added to the expensive with extra modulator requirement want to consider significantly. Also, another study suggested evaporation and elevation duct behaviour for the seawater communication [7][8] but the chemical water composition such as salinity clearly affected the results electromagnetically with the care of water type at various areas. Even from chemical aspect, the author at [9] offer an interesting result via analyzed the water properties using weight gain method to improve biocomposite in commercial acceptability.

Generally, the consideration of the underwater studies could be divided into communication relies on the three schemes; Acoustic, Electromagnetic, and Optical communication, and for a holistic investigation, the next section will discuss each one briefly from the seawater perspective to improve the connection and expand the knowledge range added to fill the gap of the researchers that have been attracted to explore their potential on seawater communication. The paper aims to investigate the effective seawater parameter such as salinity to push different aspects of marine communication as considered crucial to the upcoming era of technology development, because up to now not been thoroughly investigated as simplified assumptions need to be validated with high respect to water composition. The following section describes the techniques of seawater communication systems and emphasized advantages and drawbacks while the impact of seawater on communication will mention in section three, section four will discuss the results and the last section demonstrated the conclusion and recommendation of the study.

2. SEAWATER COMMUNICATION TECHNIQUES

Comprehensively the seawater connection is relatively limited due to the fact of low bandwidth and the notable noise added to the inter-symbol interference (ISI) which all clearly affects the transmitting data in seawater [10][11]. However, as aforementioned the seawater communication techniques are mainly divided into three types, the first one is Acoustic under the reputed technique the Sound Navigation And Ranging (Sonar), which is simply defined as a method that uses sound propagation in the underwater environment to communicate as well as to detect objects [12]. It has several different ways to work based on its two types, Active and Passive. The active sonar technology is based on sending sound in direction and then waiting for the echo, and according to the sound time in sending and receiving that would help to determine the object. Whereas the Passive sonar is built on listening after sounds and hence cannot detect the object unless it is used in conjunction with other devices [13]. Ordinarily, the sound pulses are reflected after being recorded and processed for valuable purposes with the assistance of different antenna types that could play a vital role when dealing with the signal in terms of wavelength, which is calculated in a vacuum as $\lambda = c / f$ where c is the speed of light. In contrast, the seawater as affected by the relative permittivity ε_r and relative permeability μ_r [14]. Thus, the speed of light from vacuum to seawater could be expressed by:

$$C_{seawater} = C / \sqrt{\varepsilon_r \mu_r} \qquad (1)$$

$$\lambda = C_{seawater} / f \qquad (2)$$

Then

$$\lambda = C / \sqrt{\varepsilon_r \mu_r}\, f \qquad (3)$$

The seawater composition chemically should be respected to offer a flawless system that would communicate electromagnetically.

Although, the sonar system under the seawater has some drawbacks when needing to deal with the real-time processes and notable broadband due to the high latency and low data rate without any link security, despite it could consider a long-range connection. Whereas to design antennas for seawater, significantly to understand the effect of the conductivity σ, on the antenna material with attention to the seawater types [15][16]. Figure 1 shows the simple sonar system under seawater

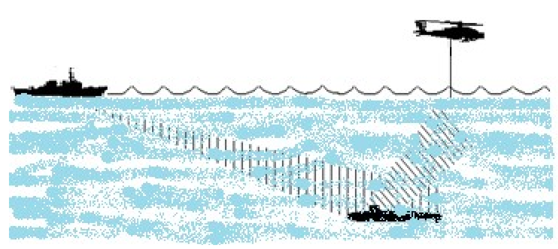

Figure 1. Sonar System Under Seawater

The second method to communicate under the seawater is through electromagnetic waves via radio frequency RF spectrum [15]. By way of various frequencies band, the transmitter could radiate the single in seawater medium, but despite that one of the main challenges the fact that is increasing the frequency would lead to an increase

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the attenuation according to the scattering and absorption phenomenon. The seawater propagation is totally different from the air but also the water composition plays a crucial role in terms of conductivity aspect.
Also, the water electric properties which are represented in permittivity in correlation with conductivity would give strong sound to investigate the seawater communication chemically to achieve the connection seamlessly. The figure 2 shows the signal radiates from different devices while the next equation describes the powerful relation between the permittivity and conductivity chemically which is offer unprecedented benefits in water communication electromagnetically.

$$\varepsilon = \varepsilon_r - j60\lambda\sigma \qquad (4)$$

Equation 4 considers the key to solution the salt seawater conductivity as well as connection cross the water medium.

While to identify a more valuable contribution, the relation between salinity ϕ via the conductivity σ to give a remarkable sound and accommodate a wide range of different seawater environments when considering an electromagnetic wave communication [17][18].

$$\sigma = 0.001 * e^{4.99+0.05\,\phi} \qquad (5)$$

Then equation 4 will be

$$\varepsilon = \varepsilon_r - j0.060\lambda e^{4.99+0.05\,\phi} \qquad (6)$$

The comprehensive equation 6 would consider an enormous role that could be fundamental in seawater communication in terms of signal behaviour.

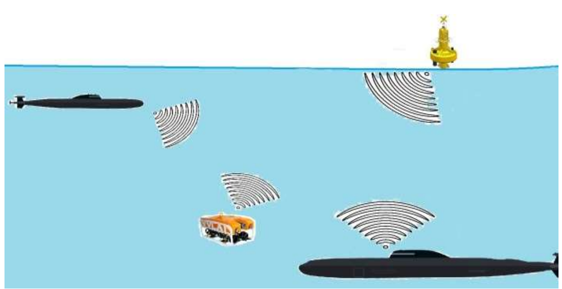

Figure 2. EM Signal Radiation Under Seawater

The third method of seawater communication is Optical which is considered a real way to overcome the acoustic and electromagnetic via providing high bandwidth, particularly when considering the fiber optics as an efficient and fastest medium for data transfer in addition to the communication backbone [19]. The main disadvantages of fiber optics are costly and easy to damage physically in addition to the difficulty of maintenance. On the other hand, the researchers push the laser technology in the seawater communication to avail unique characteristics like monochromatic behaviour, high intensity and low dispersion quality. The proposed in [20] explored the attenuation in marine life and found the least signal attenuation in normal cases, whereas, the resulting contrast in the oceans, particularly near the coast, where more chemical parameters occurred such as salinity, in addition to the tidal places that had the most attenuation in term of signal manner. Another holistic investigation from [21] employed unimaginable capabilities of the laser to achieve seawater cycle through a proposed optical beam station that can serve the communication in the marine environment. Whereas the less attenuation occurred in [22] when using the 450-550 nm range in blue and green lights referring to the photosynthesis process in warm seasons for the seawater.
Despite the extremely advantages of the optical communication compared with acoustic and electromagnetic, but still many challenges that could be faced such as the undesirable effect due to absorption and scattering when photons interact with various water molecules and particles types that are obviously based on the water parameters such as salinity and significantly cause multi path fading. Another downside of optical seawater communication is beam divergence via misalignment and seawater turbulence due to surface movement. The next figure shows the under seawater optical communication

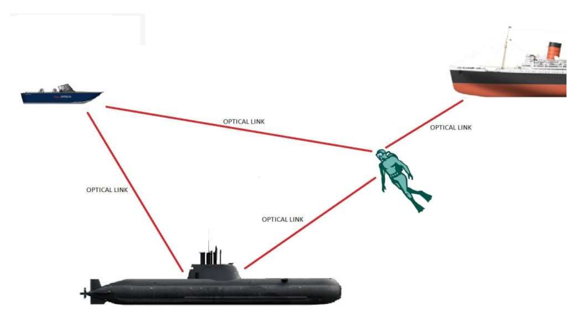

Figure 3. Optical seawater communication

3. IMPACT OF SEAWATER ON COMMUNICATION

Different water types can be classified into oceanic and coastal depending on the downwelling radiation of sunlight added to the water characteristics [23]. Pure or salt seawater, clear ocean, coastal ocean, and turbid are the most

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famous water types. However, Salinity considers the most significant pillar that affects the water types and contributes to the formation of suspended particulate matter. Hence investigating the salinity would be an inevitable precedent when thinking about various water types electromagnetically. All the aforementioned will open a wide door to wireless water communication monitoring as a trend in upcoming decades.

The essential component of any communication system is an antenna [24][25], and through the technological revolution in the cloud, IoT, and AI the smart seawater antenna (SSA) will play a key position via adjusted seawater properties to directly manipulate the incident signals by way of seawater properties. The ability to tune the amplitude and/or the phase of incident signals could be the intelligent aspect of the SSA under works simultaneously in two modes; reflection and transmission via programmable specification. Whereas for a comprehensive understanding, modelling that incorporate the seawater effective parameters with communication techniques which have discussed earlier would be high recommended to achieve the study objectives.

In the context, the path loss is known as decreasing in the power of the signal spread and is defined as [26][27]:

$$PL\ [dB] = 10Log_{10}\left(\frac{p_T}{p_R}\right) \quad (7)$$

Where $p_T$and $p_R$are power transmitted and received respectively. However, the received power from Friis low equation as a function of distance defined as [27]:

$$\rho_r(d) = \frac{\rho_t G_t G_r \lambda^2}{(4\pi\ \ )^2} \quad (8)$$

Where d distance between the two parities is, λ is the wavelength, G_t and G_r are the antennas gain.

The path loss for the seawater composed of many different parts: external path loss when the communication including outside seawater station PLo, penetration path loss which describes the seawater has been penetrated PLp and indoor loss that based on the depth inside the seawater PLi, which could be modeled as:

$$PL\ (dB) = PL\ o + PL\ p + PL\ i \quad (9)$$

While for a convenience will calculate the loss as

$$TL\ = \frac{Lw}{Td} \quad (10)$$

Where TL is the transmission loss, Lw represents the loss due to water type, and Td is the transmission distance.

From the aforementioned and to high appreciate the seawater medium, the received power can calculate as:

$$\rho_r(d) = (\varepsilon Q + 1)\ \frac{\rho_t G_t G_r \lambda^2}{(4\pi d)^2} + TL \quad (11)$$

And for serviceability $G_t = G_r = 1$

$$\rho_r(d) = (\varepsilon Q + 1)\ \rho_t\ \left(\frac{\lambda}{4\Pi d}\right)^2 + TL \quad (12)$$

Where $\varepsilon = \varepsilon_r - j0.060\lambda e^{4.99+0.05\,\phi}$, and Q represents an element was supposed to be set on the seawater to assist the communication.

4. RESULT AND DISCUSSION

From the equations obtained under the effective parameters such as permittivity and salinity, the Matlab simulation demonstrates the signal attitude to provide a holistic knowledge for the seawater communication.

The signal behaviour would determine the system performance in the seawater through study the magnitude and phase under the various conditions. From the Magnitude perspective at the figure 4, the higher frequency via a distance leads to higher signal fluctuation with respect to the power dB. In another words, the more power dB the more degradation occurs, while the less power will offer a relatively steady. Whereas the figure 5 shows the signal phase response which is clearly affected by polarization as well as the frequency transmission, but generally the degradation begun after 10Khz and show more slope gradient after 100Khz. While the combination for a comprehensive view in figure 6 gives obvious vision to predict the signal performance manner

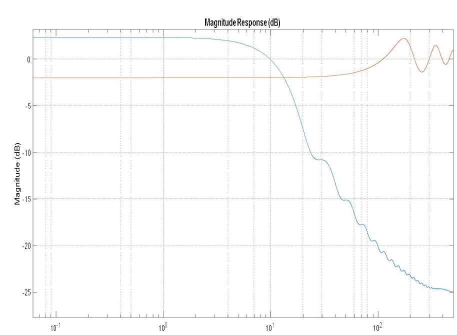

Figure 4. Signal Magnitude Response

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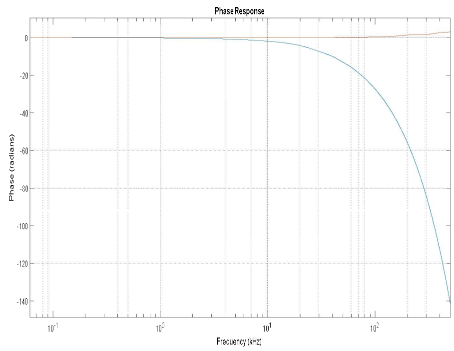

Figure 5. Signal Phase Response

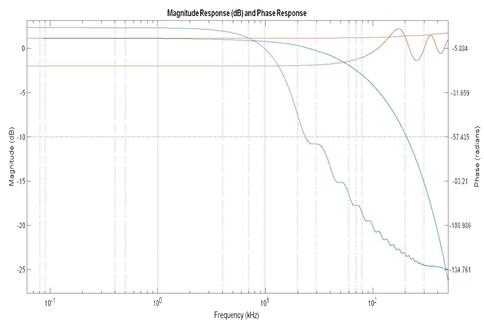

Figure 6. Signal Magnitude And Phase Response

Despite the fact that data could transmit underwater seamlessly somehow through the aforementioned techniques, but inevitably under the different circumstances that should be aware when thinking about the seawater communication. Figure 7 explains the delay rate and how the data interact with the frequency in particular conditions and give a spotlight when going forward through high frequencies.

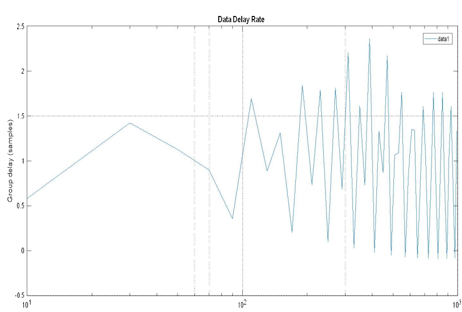

Figure 7. Signal Delay Rate Interaction In Frequency

5. CONCLUSION

Last decades, seawater communication witnessed immense growth and could promise to play a crucial role in the upcoming revolution technology era. Seawater communication considers an indispensable life demand that would offer various modern aspects. The paper discussed the challenges of different seawater communication techniques considering a wide effective parameters range to come up with the technical requirements. The result focuses on signal behaviour in terms of magnitude, phase, and delay rate with respect to the water type composition such as permittivity and salinity, and giving away to show the higher frequency leads to more signal fluctuation in sea communication The study also offers a new model that appreciates the seawater medium and the unparalleled role that could play in the nearest technology era. Future work will be on the Seawater Intelligent Reflecting Surface (SIRS) based on water formation that could able to enhance the performance of sea communication data transmission system.

REFERENCES:

[1] A. Celik, N. Saeed, B. Shihada, T. Y. Al-Naffouri, and M. S. Alouini, “A Software-Defined Opto-Acoustic Network Architecture for Internet of Underwater Things,” IEEE Communications Magazine, vol. 58, no. 4, pp. 88–94,2020,doi: 10.1109/MCOM.001.1900593.

[2] T. Liu et al., “In-situ Detection Method for Microplastics in Water by Polarized Light Scattering,” Frontiers in Marine Science, vol. 8, Oct.2021,doi:10.3389/FMARS.2021.739683/FULL.

[3] Akhtarian zand, M. "Challenges and Opportunities of Using Models for Optimal use of Water Resources Systems", Journal of Engineering in Industrial Research, 2(1), 22-27. 2021, doi: 10.22034/jeires.2021.269442.1022.

[4] D. C. Nguyen et al., “6G Internet of Things: A Comprehensive Survey,” IEEE Internet of Things Journal, vol. 9, no. 1, pp. 359–383, 2022, doi: 10.1109/JIOT.2021.3103320.

[5] W. Fei and G. Yunjing, “Channel simulation analysis of seawater laser communication,” 2021 IEEE International Conference on Artificial Intelligence and Computer Applications, ICAICA 2021, pp. 1108–1109, Jun.2021,doi:10.1109/ICAICA52286.2021.9498183.

[6] X. Sun et al., “Field Demonstrations of Wide-Beam Optical Communications through Water-Air Interface,” IEEE Access, vol. 8, pp. 160480–160489,2020, doi:10.1109/ACCESS.2020.3020878.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[7] Imadeldin Elsayed Elmutasim and Izzeldin I. Mohd., “Radio Propagation in Evaporation Duct Using SHF Range,” IJASTInternational Journal of Advanced Science and Technology, vol. 29(12s), pp. 1080–1088, 2020.

[8] I. E. Elmutasim and I. I. Mohd, “Modeling over the Sea Surface within Elevated Duct,” in 2020 7th International Conference on Frontiers of Industrial Engineering (ICFIE), 2020, doi: 10.1109/ICFIE50845.2020.9266731.

[9] Gangadharan, S., & Anbazhagan, V. (2021). Effect of hybridization on mechanical, thermal and water absorption properties of biocomposite. Eurasian Chemical Communications, 3(11), 779-785. doi: 10.22034/ecc.2021.301331.1226

[10] V. K. Ivanov, Y. V. Levadny, and V. N. Shalyapin, “Millimeter wave propagation in coastal area,” Telecommunications and Radio Engineering (English translation of Elektrosvyaz and Radiotekhnika), 2013, doi: 10.1615/TelecomRadEng.v72.i8.30.

[11] Imadeldin Elsayed Elmutasim and Izzeldin I. Mohd., “ Comparison of the Self-Piloting Constructive and Destructive Interference in 7 and 23 GHz Band Over the Seawater Surface,” 2021, doi: 10.1109/SIST50301.2021.9465895.

[12] M. Graflund, “Communication Using an Underwater Sonar,” 2017.

[13] I. Bennaceur, X. Cristol, R. Docquois, and F. R. De Pampelone, “Target Localization in Depth and Range from Passive Sonar,” OCEANS 2018 MTS/IEEE Charleston, OCEAN 2018, Jan. 2019, doi: 10.1109/OCEANS.2018.8604853.

[14] H. El-Sallabi, A. Albadr, and A. Aldosari, “UAV propagation channel characteristics in SHF band,” https://doi.org/10.1117/12.2518854, vol. 11021, pp. 108–115, May 2019, doi: 10.1117/12.2518854.

[15] S. Al-Zhrani et al., “Underwater Optical Communications: A Brief Overview and Recent Developments,” Engineered Science, vol. 16, no. 20170540671, pp. 146–186, 2021, doi: 10.30919/es8d574.

[16] B. Cochenour, L. Mullen, A. Laux, and T. Curran, “Effects of multiple scattering on the implementation of an underwater wireless optical communications link,” OCEANS 2006, 2006, doi: 10.1109/OCEANS.2006.306863.

[17] C. Yang and J. G. Peng, “A study on the effect of water conductivity in the underwater active electrolocation,” 2013 IEEE International Conference on Applied Superconductivity and Electromagnetic Devices, ASEMD 2013, pp. 34–37, 2013, doi: 10.1109/ASEMD.2013.6780702.

[18] S. Constable, “Conductivity, Ocean Floor Measurements,” Encyclopedia of Geomagnetism and Paleomagnetism, pp. 71–73, Jul. 2007, doi: 10.1007/978-1-4020-4423-6_30.

[19] H. Kaushal and G. Kaddoum, “Optical Communication in Space: Challenges and Mitigation Techniques,” IEEE Communications Surveys and Tutorials, vol. 19, no. 1, pp. 57–96, 2017, doi: 10.1109/COMST.2016.2603518.

[20] Y. Huo, X. Dong, and S. Beatty, “Cellular Communications in Ocean Waves for Maritime Internet of Things,” IEEE Internet of Things Journal, vol. 7, no. 10, pp. 9965–9979, Apr. 2020, doi: 10.48550/arxiv.2004.07417.

[21] K. H. B. Imadeldin ELMUTASİM , Izzeldin I. MOHD, “Contemplation of the Photonics Beam to Complement the Water Cycle in Gulf Region,” vol. 2, no. 2, pp. 15–21, 2021, doi: 10.5281/zenodo.5037867.

[22] P. Singh, “A Review of Underwater Communication Systems,” no. June, 2022, doi: 10.1729/Journal.30274.

[23] L. Xing, Y. Huang, Q. Xu, and S. S. Alja’Afreh, “Overview of water antenna designs for wireless communications,” Proceedings of the 2015 IEEE 4th Asia-Pacific Conference on Antennas and Propagation, APCAP 2015, vol. 11, pp. 233–234, 2016, doi: 10.1109/APCAP.2015.7374350.

[24] C. A. Balanis, “Antenna Theory: A Review,” Proceedings of the IEEE, vol. 80, no. 1, pp. 7–23, 1992, doi: 10.1109/5.119564.

[25] J. Bach Andersen, “History of Communications/Radio Wave Propagation from Marconi to MIMO,” IEEE Communications Magazine, vol. 55, no. 2, pp. 6–10, Feb. 2017, doi: 10.1109/MCOM.2017.7841460.

[26] I. E. Elmutasim and I. I. Mohd, “Examination rain and fog attenuation for path loss prediction in millimeter wave range,” in Lecture Notes in Electrical Engineering, 2021, vol. 666, pp. 935–946, doi: 10.1007/978-981-15-5281-6_67.

[27] J. Huang et al., “Reconfigurable intelligent surfaces: Channel characterization and modeling,” vol. XX, no. Xx, pp. 1–21, 2022.