Design of Low Power Hybrid Communication Model

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Abstract

Communication in underwater is a growing research topic that plays a big role in forecasting accurate weather conditions. In which Acoustic communication is the upcoming technology well qualified for its long-distance underwater communication with certain restrictions like low data rate and high latency. To overcome this constrain wireless optical communication are preferred for high data transmission and less delay. The attempts are made to analyze the performance of the turbid and coastal water conditions.To improve the underwater communication model,a hybrid model is proposed for the applications like weather forecasts, military equipment, and missing debris.

Keywords: Underwater Communication, Acoustic communication, Optical communication,Underwater Wireless Sensor Network

DECLARATIONS

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1. Introduction

Global warming has been an issue for many years due to the increased intervention of global climate [1]. When global warming continues to increase, the polar ice caps steadily dissolve and give rise to seawater levels rising. Due to this monitoring of Oceanic environmental practices, the analysis of maritime information, ocean test, and contamination of water became necessary. In present, the importance of research in the global atmosphere gained significant importance in the discovery of the oceanic target tracking and inquiry of the unguided treatment plant. "Underwater wireless communication" (UWC) is a process of analysis for the study of the planet's oceans, referring to the data transmission mechanism in the undiscovered medium [2]. "UWC" is a creative underwater communication technique, chosen in the modern age to investigate and observe underwater data [3]. Nowadays wireless communication becomes a part of the everyday life of humans and is an important area of study to be investigated in recent years. UWC techniques are predicted using "acoustic, optical, and electromagnetic" signals . The primary factor behind the growth of underwater communication is acoustic technologies and their networking. The divers interact with ships to travel across the ocean using the acoustic system. Due to the attenuation in frequency, acoustic methods possess low data rates.The noises caused by acoustic signals affects the underwater communication. [4] [5]. In such conditions, optical communication is preferable since it results in high data transfer with low noise. These optical signals are used in wireless data protection and reliability improvisation. More importantly, for longer communication distances, a hybrid connection is created. The primary issue raised when constructing acoustic communication was the acoustic latency [6][7]. Multi path fading solves the power loss issue and the fault that occur during transmission. Optical misalignment takes place to design an optical connection. In addition to design effects, the key problem is often known to be vulnerability to the variation in the marine environment and reflection of light waves due to the ocean. In this paper, a hybrid method is proposed consisting of both acoustic and optical connections. The model is called a hybrid since it solves the shortcomings of the traditional system by combining acoustic and optical systems. A higher data rate and lower latency optical link [8] is used as a compensation for the drawback in acoustical transmission. Acoustic method in the downlink communication causes less bandwidth in wide angles [9]. As a result of the high directional property, uplink communication is preferred in optical links. To help signals travel faster than traditional connections, ranging from 5 Mbps to 10 Mbps, a hybrid model is required.

2. Underwater Acoustic Link

The transmission of acoustic signals is an efficient tool for underwater mapping [10][11], and communication system [12][13]. Following the modeling of the underwater acoustic communication channel [14][15], a broad study was conducted to establish, build and identify underwater parameters that depend on the acoustic connectivity [16] [17] [18]. "Underwater Acoustic Sensor Networks" (UASNs), consisting of detectors and vehicles deployed in the marine network to accomplish necessary tasks. In an aquatic environment, several variables influence communication networks with wide differences in time and space caused by salt content, viscosity, temperature distribution, and many others [19][20]. Typically, UWASN is planned to cover a few kilometers (maximum) in length, usually within the 500-10000 Hz frequency range. Also, one of the most serious limitations of network capacity is the long delay in the transmission of acoustic signals rather than the need for a more suitable transmission medium to deal with communication latency [21] [22].However, the most widely used method for communication underwater is still acoustic signals (often including boys).

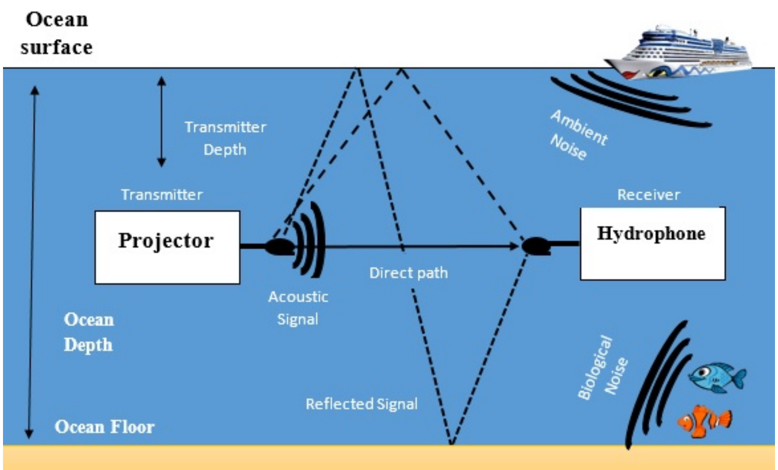

Figure 1: Underwater Acoustic Scenario

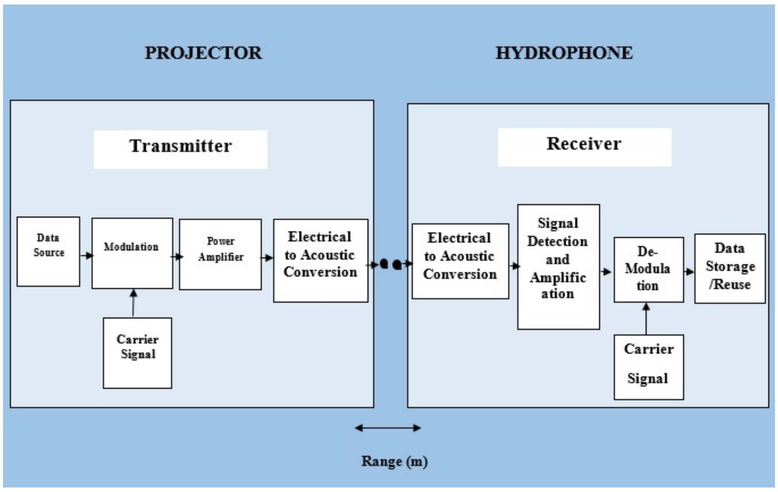

Figure 2: Block diagram of Hydrophone and Projector

The information transmitted over the acoustic link in the form of sound is always used for downlink transmission. A projector and a hydrophone are used to create an acoustic connection. A typical underwater data transmission system using a single pair of transmitter-receiver systems is shown in figure 1. For capturing navigation and sensor data, a projector-shaped transmitter is used and separates into bits of data source packets. The block diagram in Figure 2 is explained with a basic data transmission system with the projector as transmitter and hydro-phone as the receiver. The sensed and navigated data collected are stored, formatted, and converted into a frequency-modulated carrier. The encoded signal is amplified to a sufficient degree such that the receiver absorbs the signal. There is an acceptable degree of amplification since there is an interchange between error-free transmission and energy conservation of batteries. The electro-acoustic conversion block refers to the acoustic energy generated from the projection screen to the electrical energy transmitted to the projector. The conversion should be at an appropriate level that can be obtained by the receiver. The susceptibility of the hydro-phone at the receiver end converts the sound pressure, measured in dB / V, into electrical power that reaches the hydro-phone. To locate a detectable signal, signal identification requires amplification and feedback shaping. A threshold level is observed during mean signal to SNR conversion. The microphone which is used to record the sounds underwater is the acoustic to electrical conversion in hydrophone. Electricity is generated in sound form during pressure variations. Microphones generate electricity when exposed to pressure variations occurring in the form of sound. Piezoelectric materials are responsible for this conversion. In simple terms, to transform audio signals to electrical pulses, a piezoelectric material is used. Microphones, when applied to pressure deviations arising in the form of sound, generate energy. Piezoelectric materials are responsible for this conversion. In simple terms, to transform acoustic input to electric signals, a piezoelectric material is used. In line with the input signal, these electrical signals are then amplified and formed to create an amplified signal, as shown in figure 3. In carrier frequency, shaping is done during demodulation to differentiate the message and carrier signal. This can then be utilized for data exploration. The wireless charging system uses an inductive coil and the power passes between the charging station and the appropriate unit. The power supply which can be carried easily is mounted with a coil is used in the inductive charging method for the optical transmission. It's trouble-free and does not require detailed wiring. One advantage of the system is that it need not be in the same place for charging because electrical systems have to charge instantly. The biggest drawback is that it has a much lower charging rate than a normal coherence. The wireless charging is successful in the underwater application as the systems are coated with polymer resistance which provides continuous performance without disturbance.

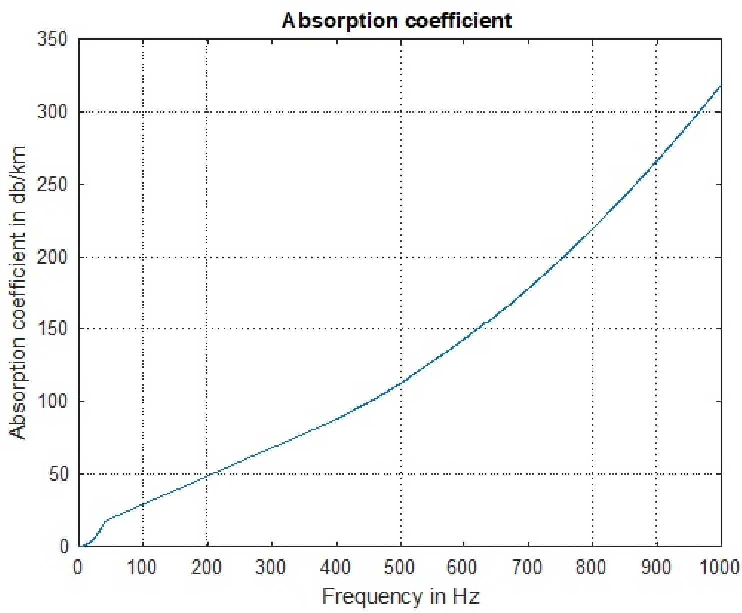

Figure 3: Plots that define the relationship between the PSD noise and absorption coefficient

$$\alpha = \frac{c_1 d_1 f_1 f^2}{f^2 + (F_1)^2} + \frac{c_2 d_2 f_2 f^2}{f^2 + (f_2)^2} + c_3 d_3 f^2$$

Where C1, C2 and C3 are elements of seawater in boric acid, pure water, magnesium sulphate, d1, d2 and d3 are the concentration levels of seawater of boric acid, pure water and magnesium sulphate, f1 and f2 are the magnesium sulphate and boric acid frequencies. Throp's formula is calculated for 100 HZ high frequency as

$$\alpha = \frac{0.1f^2}{1+f^2} + \frac{40f^2}{4100+f^2} + 2.75 * 10^-2f^2 + 0.003$$

For lower frequencies the absorption coefficient is calculated as

$$\alpha = 0.002 + 0.11\frac{f^2}{1+f^2} = 0.011f^2$$

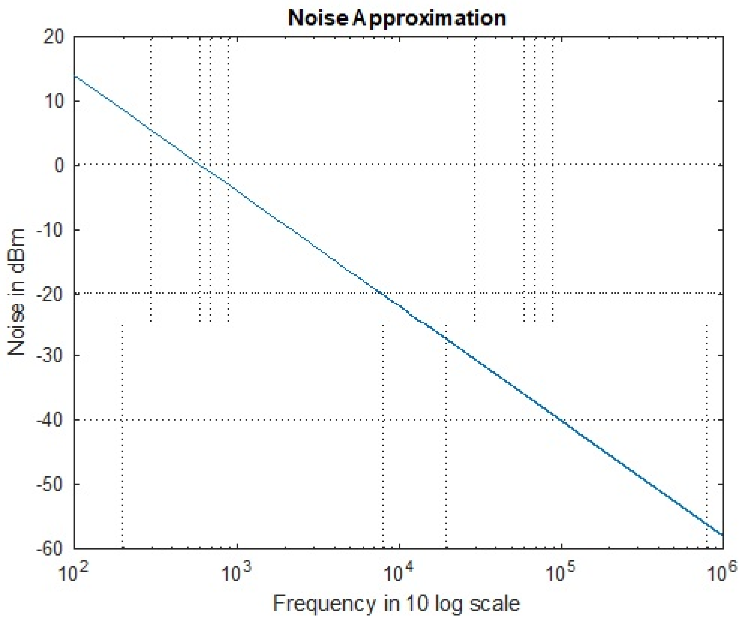

Figure 4: Noise approximation plotted between noise power and frequency in UWAC

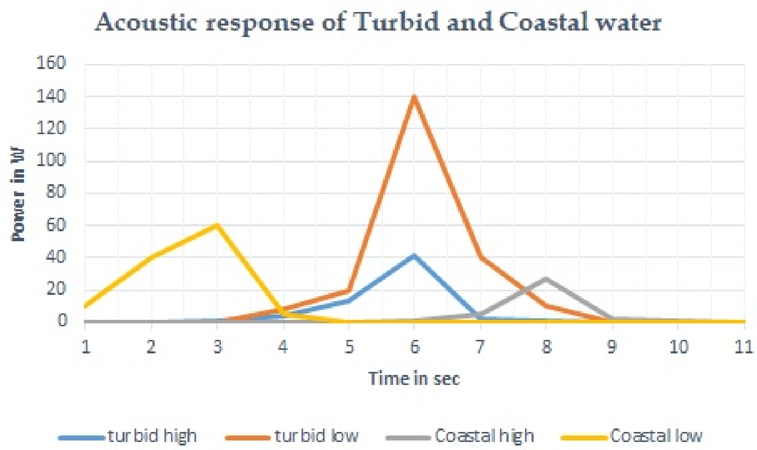

Figure 5: Acoustic response curve for turbid and coastal water conditions

With an array of the ultracapacitor, the battery or the internal supply can be made. Each ultracapacitor has a supply capacity of only 2-3V, so we need an array of ultracapacitors in series connection as in Figure 4 to get it up to the necessary supply. Compared to traditional batteries, ultracapacitors have several benefits.

They have almost infinite cycles for charging. Compared to a normal battery, they have very low maintenance. The ultracapacitor is cost comparatively lower than the battery cost. The ultracapacitor has more power density and the battery have an energy density, this is the difference between using them. The disadvantage in using ultracapacitor is that the attenuation of acoustic signals are present in between the transceivers of ultracapacitors. In these types of signals, the transmission has losses like absorption, spreading, and scattering loss. Absorption loss is the transfer of energy from signal propagation to heat due to fluid resistance. The absorption coefficient is determined based on certain oceanic parameters such as acidity, strain, temperature, salinity[23]in Figure 5. Frequency absorption varies from 100 HZ to 1 MHZ.

A study is done in turbid water and water near coasts to know how power changes concerning time. When the transmitter and receiver are at comparatively larger and short distances, the figure shows the graph plotted for power and time. A distance of 50m and 20m was taken exactly to deploy the transceivers in both turbid water and coastal water conditions. The results are plotted for the power and time consumed during the transmission of sound signals in water. The results infer that in turbid water conditions: to travel long-distance power consumption is very high then sound travels for short distances while in coastal water conditions: the power consumed is less for a large distance. Because temperature and salinity are independent of depth, sound travels in coastal water faster than in turbid water.

3. Underwater Optical Link

Optical waves can transmit in wide bandwidth concerning salinity [24]and it can also transmit some tens of thousands of meters in water. Optical signals can transfer some tens of thousands of meters in water with zero delays during communication. To reach higher-order data transfer, an optical link of about 10-100 Mb/s up to 1 Gb/s is created which is the best alternate for acoustic signals. A fading strength of about 0.15 0.5dB/m can be achieved in clear water in the blue-green unit, so that the operating range of optical underwater modems in the purest water is around 100 m. Also, the bit-per-joule energy needed for the transmission of the optical signal is considerably lower than that required for acoustics, which also allows for minimum power consumption for large data transfers. The issue of low-speed data transfer and the quality of data is solved using an optical path. Absorption initially hangs on the wavelength of the optical signal causing suspended substrate or particles to disperse light in all directions. Due to multipath impacts, the file transfer speed is hindered by scattering. Aside from the quality of water, it relies on several spatial factors, including the separation of the source beam, the distance of propagation, the angle of vision of the receiver, and the imbalance of the source beam. The information collected from the underwater device is sent to a modulator (along with the carrier signal). To raise the signal power, it is further amplified. It then transfers this amplified signal to a receiver. The receiver, which detects the optical signal, has a photodetector. This signal is transmitted into the optical amplifier and [25] amplified. By producing electrical output to give the processed information, the amplified data is demodulated. From this method, the efficiency of optical communication for underwater is analyzed concerning relative SNR as in [26]

$$SNR = [\frac{pt}{tan^2\theta}.\frac{e^-HL}{4L^2}.\frac{R^2cos\phi}{EP}]^2$$

Where the factors in the brackets represent the transmitter, channel used for communication and the receiver with pt as power transmitter, is the half-angle measured in the transmitted beam width, H c/3 is the attenuation coefficient in the clean water which ranges from 0.2m-1 to 0.8m-1 for coastal turbid water [27]. C - beams attenuation coefficient , L- optical length of link and R-diameter of received aperture , the angle between the line of sight and received optical axis is denoted as between the transceivers, EP is the equivalent power of noise given as

$$EP = \sqrt{P_{bgsn}^2 + P_{sigsn}^2 + P_{darksn}^2 + P_{ampn}^2}$$

where P_{bgsn} is the short noise signal background, P_{sigsn} shot noise of the signal depending on the optical received power. Multiple dark current P_{darksn} depending on I_{dark}. current gain of photo diode G_{det}, P_{ampn} current noise density of preamplifier, these all depends on the photodiode response S, bandwidth with effective noise $BW = \pi BW/2$ and the noise factor F of photodiode. The relation of bit rate and bandwidth related to SNR is given as

$$Bitrate = Bandwidth.log_2(1 + SNR)$$

and by considering the On-off shift keying in the typical optical communication systems the BER is given as

$$BER = \frac{1}{2}.erfc\sqrt{\frac{E_b}{2N_o}}$$

where erfc is the complementary error function and $\frac{E_b}{N_o}$ is the energy to noise density ratio with respect to SNR. The expression of bit error rate and Bandwidth is given as

$$\frac{E_b}{N_O} = SNR.\frac{BW}{BR}$$

Numerous experiments were made in recent years to tackled existing underwater optical capabilities [28]. By examining the above factors of optical and acoustic underwater communication parameters certain hybrid models are designed to analyse the parameters of underwater and its efficiency

4. Underwater hybrid Link Design

The man issue face by communication engineers is the absence of successful underwater wireless communication with high-speed data transfer with low latency [29][30]. Therefore, the design of underwater hybrid communication is required. The hybrid method has the capacity to switch from acoustic to optical scheme and vice versa [31]. During insecure conditions, the security of data should be ensured for communicating. "The hybrid communication is developed by first evaluating the fault probability of optical and acoustic medium using the Monte Carlo simulation process". The channels is analyzed in coastal weather, pure and turbid water conditions. For the channels given, the stochastic solution was acquired and efficiency of the systems under the above conditions are measured. The convergence compares the average transmission speed based on optics to provide a reliable and highly efficient low loss connection. An IGBT will perform the switching portion of the system.

The Insulated Gate Bipolar Transistor is a combination of a traditional "Bipolar Junction Transistor (BJT) and a Field Effect Transistor (MOSFET)", also called an IGBT for short, which makes it great as a switching system for semiconductors. To introduce another form of transistor switching system that is up to the challenge of managing broad collector-emitter currents on behalf of all but zero gates current drive. The key benefits of such types of common transistors are that high input impedance and higher FET-based device switching speeds and low bipolar junction device saturation voltage, are combined. IGBT has a major advantage as the ability to turn in hundredths of a nano-second, which ensures that the delay in modem switching is minimal and almost insignificant (only in ps range for a single node). Just around 10 us will be the total delay, although 10^6 nodes were observed. An ultracapacitor would fuel the entire apparatus. The ultracapacitor seems to be more commercially robust compared to an equally Lithium-ion battery array. The only drawback of the ultra-capacitor is the cost of procurement and the unfavorable discharge time curve. Unlike the lithium-ion cell that has a charge time of 10-60 minutes, the ultracapacitor charging speed is also significantly higher (only about 10s). There is no data loss as IGBT provides successful communication. In the following areas of the ocean, sound and light signals are tested. Based on the depth of the ocean's surface, the ocean is divided into 5 distinct layers. The topmost epipelagic zone is found in visible light which is 200meters apart from the water surface. The Mesopelagic Zone is the second zone that ranges from 200m to 1000m. The third is the bathypelagic zone from 1000m to 4000m which has more pressure. The Abyssopelagic Zone is the fourth zone that ranges from 4000m to 6000m. No light can be observed, and the water temperature is near the freezing point (273K). The lower hadalpelagic zone extends from 6000 meters in the deep ocean. Here few aquatic organisms can survive because of immense pressure and non-zero temperature. To obtain low loss and high-efficiency acoustic and optical comparisons must be made based on temperature, strain, depth, and salinity. In case of optical and acoustic links, velocity is the notable factor. The three variables are taken into account are temperature, salinity, and pressure.

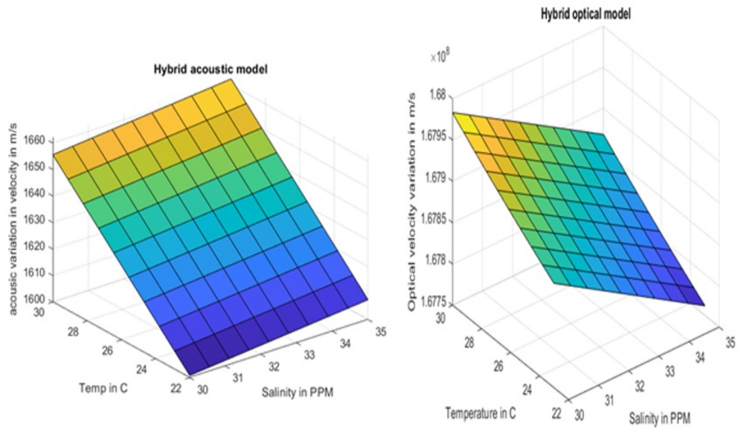

Figure 6: Temperature and salinity variation in Hybrid Acoustic and Optical Model

Velocity variation (m/s)	Temperature(C)	Salinity(ppm)
1604	-	30
1604	-	32
1613	24	-
1625	26	-

Table 1: Temperature and salinity variations in acoustics

In figure 6 graphical representation the variations of temperature and salinity is shown in terms of velocity. It is shown that as the temperature increases, velocity variations increase. With an improvement in salinity, velocity rises. With rising salinity, a decrease in velocity variation is noted in optical systems. As the temperature increases, there is a minimal increase in velocity.The two tabulated values above indicate velocity differences concerning temperature, salinity, depth, and pressure for acoustic systems. It can be concluded from the figure and tabular column that in the event of salty water, acoustic systems are stronger.

variation in velocity (m/s)	Depth (m)	Pressure (Pa)
1529	0	-
1538	550	-
1529	-	2200
1529	-	4200

Table 2: Depth and pressure variations in acoustics

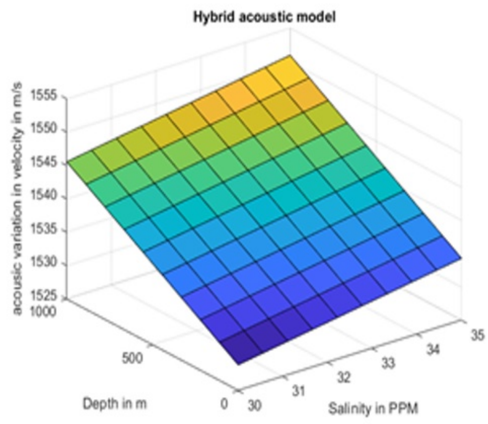

Figure 7: Depth and salinity variation in Hybrid Acoustic model

Optical structures, where there is less salinity, are stronger.For acoustic systems, the rise in depth is evident as the there is also a rise in velocity variations as shown in Figures 7 and 8. The variation in velocity is nearly 2 to 3 times higher than speed of light in optical systems, as depth increases. It undergoes reflection when hitting each layer as light penetrates through the infinitely oceanic layers. Full internal reflection is also called this reflection. Therefore, fluctuations in velocity are higher in optical systems due to this phenomenon.

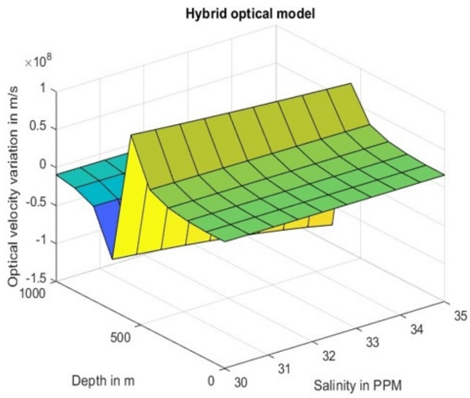

Figure 8: Depth and salinity variation in hybrid Optical Model

variation in velocity (m/s)	Temperature(C)	Salinity(ppm)
$1.6785*10^8$	-	30
$1.678*10^8$	-	32
$1.679*10^8$	24	-
$1.6795*10^8$	26	-

Table 3: Temperature and salinity variation in Optical model

The tabular representations and velocity variance values for optical systems regarding temperature, salinity, depth, and pressure are shown in Tables 3 and 4. It can be concluded from the second graph and tabular column that acoustic systems are stronger in colder. In the Arctic and Antarctic areas, acoustic systems may be employed. In hotter areas, such as the equator, optical systems perform better.

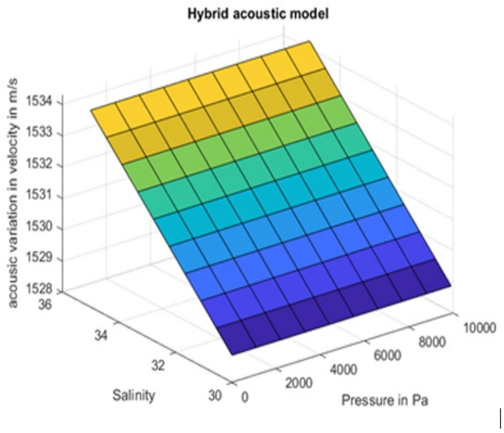

Figure 9: Salinity and pressure variation in Hybrid Acoustic model

The third analogy is pressure-based. In Figures 9 and 10, velocity does not differ with pressure in acoustic systems and is constant with a rise in pressure. There is a drop in velocity in optical systems as pressure grows. Acoustic systems are stronger when the pressure is high, from the third graph and tabular column (abyssopelagic and hadalpelagic zones in the ocean). In low - pressure settings, optical systems are stronger.

variation in velocity (m/s)	Depth (m)	Pressure (Pa)
$1.68*10^8$	0	-
$9*10^8$	550	-
$1.567095*10^8$	-	2200
$1.567090*10^8$	-	4200

Table 4: Depth and pressure variation in Optical model

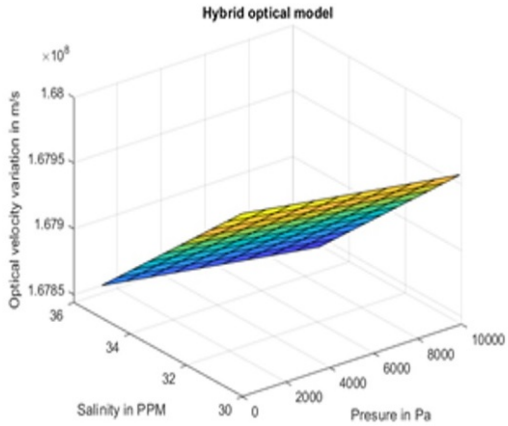

Figure 10: Salinity and pressure variation in Hybrid Optical Model

5. Conclusion

Based on the simulation conducted and the analytical work performed on the underwater parameters of optical and acoustics signal transmission, the technologies of underwater networking, the properties of optical and acoustic communication is discussed. From the simulation of turbid and coastal water conditions, acoustic signals travel longer distances with low power consumption and it is independent of its temperature, pressure, and salinity.In transmitting more number of bits per joules the hybrid optical model the acoustic model is very useful in supporting high frequencies.The optical transmission has the capability to transfer 30,000 bits per joules of energy. As it is a complete underwater experiment, turbidity can be a very major aspect that is overlooked. So to overcome this turbidity, we use acoustic transmission as optical may fail us. Acoustic signals have the capacity to transfer 100-200 bits per joules of energy.But at no time it had 0 bits transfer, this means that this hybrid model is very reliable and will improve the system's data rate and performance. In the future, this analysis may open up to a new communication model and research opportunities in overcoming the drawbacks of underwater communication.

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Figures

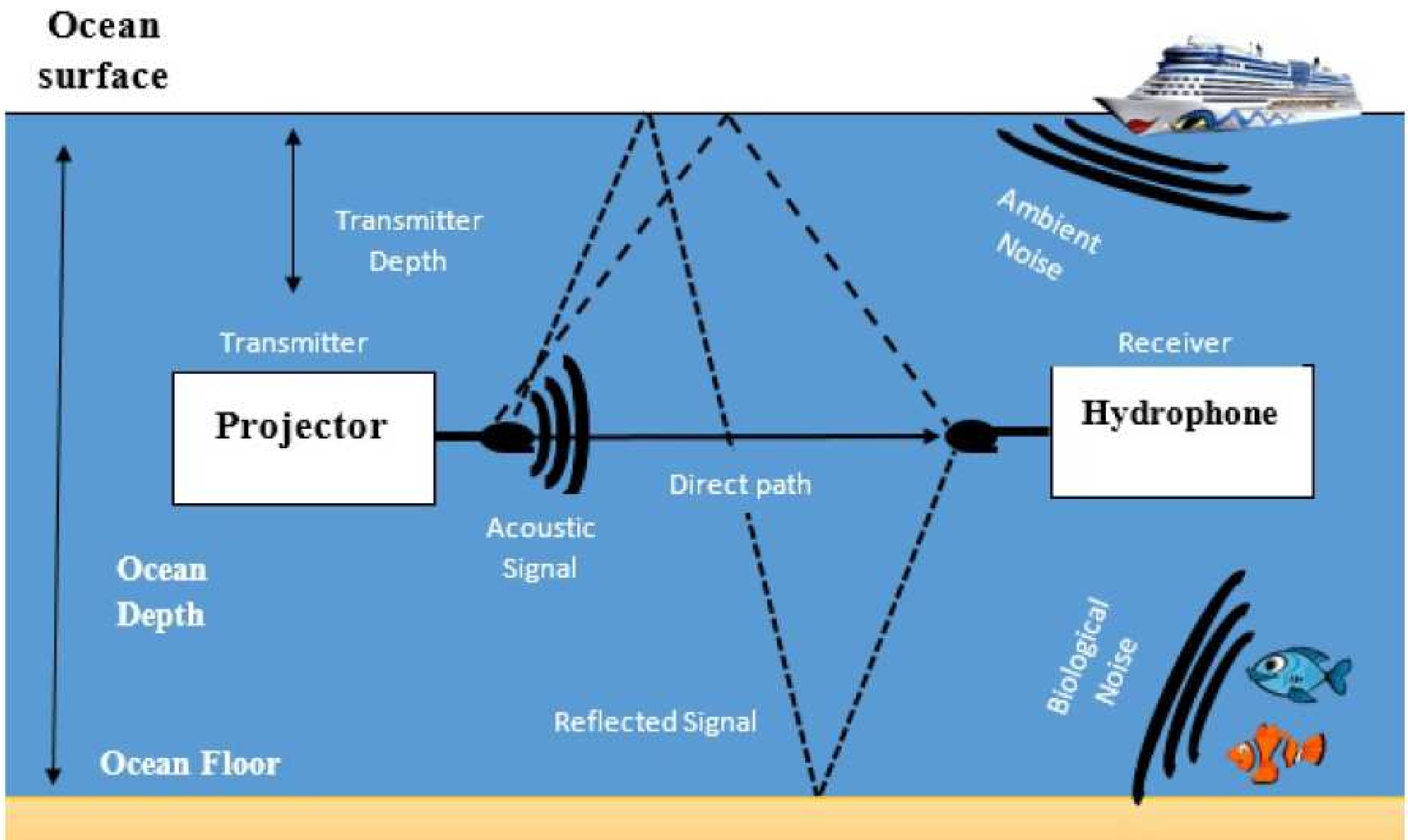

Figure 1

Underwater Acoustic Scenario

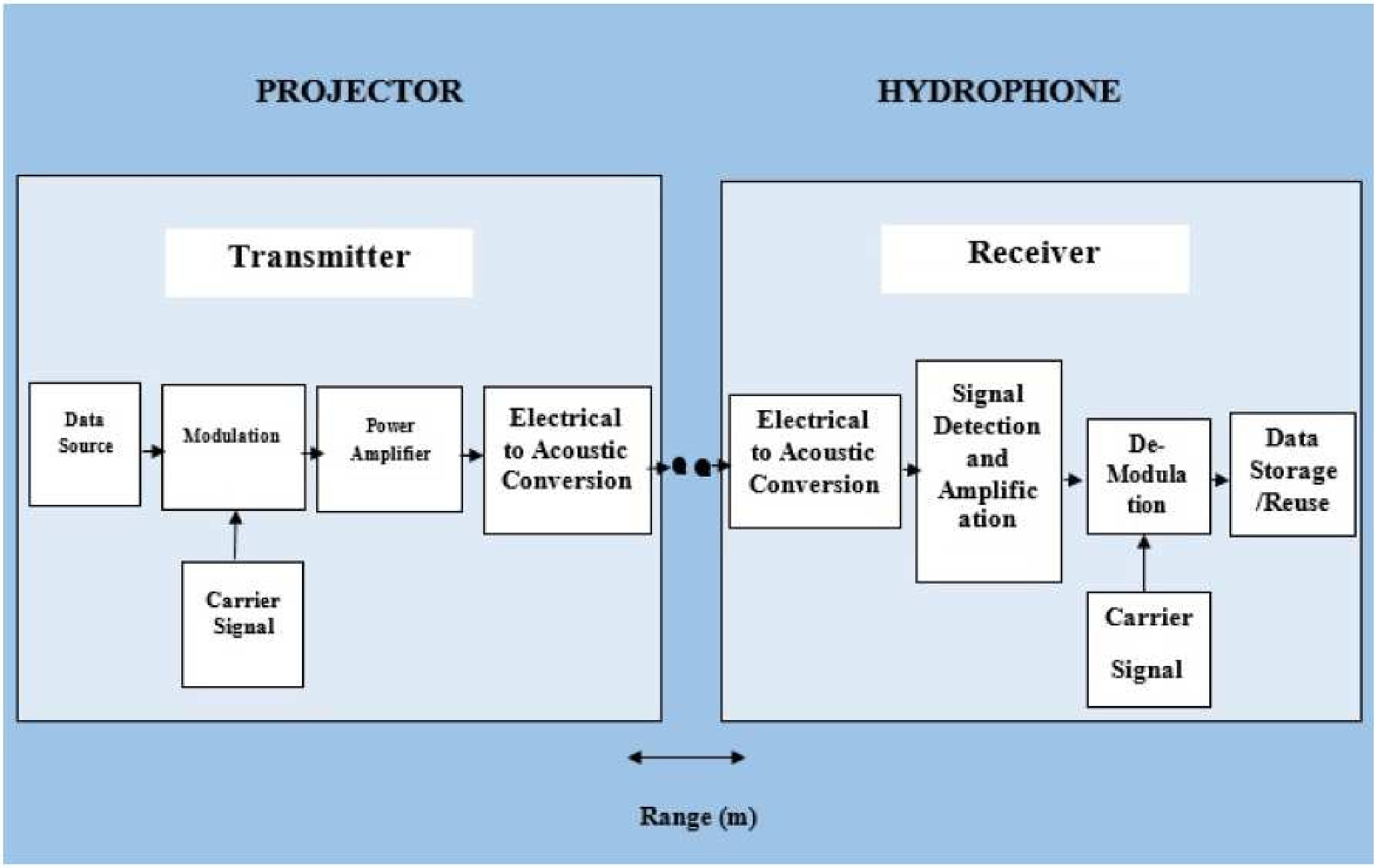

Figure 2

Block diagram of Hydrophone and Projector

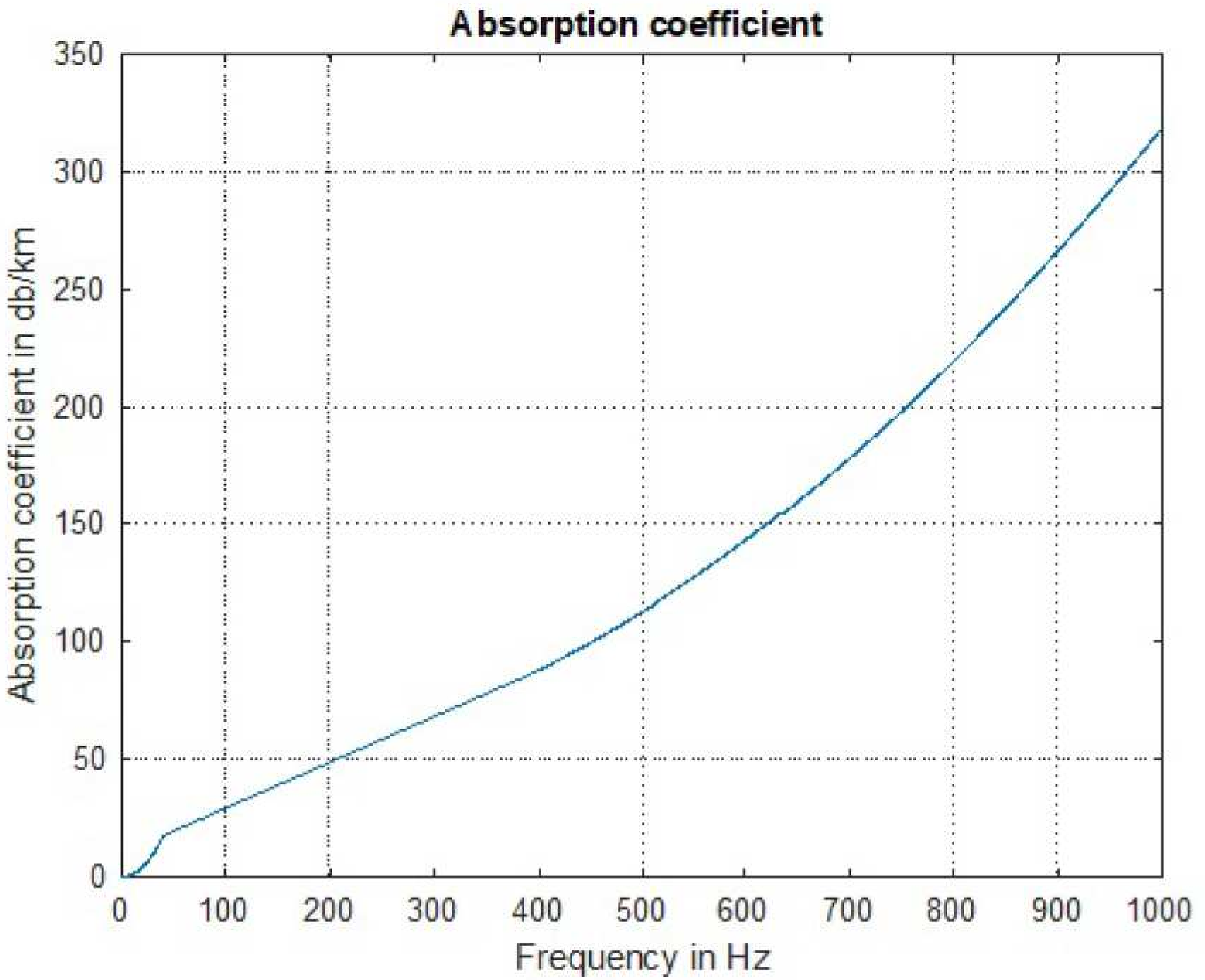

Figure 3

Plots that dene the relationship between the PSD noise and absorption coefficient

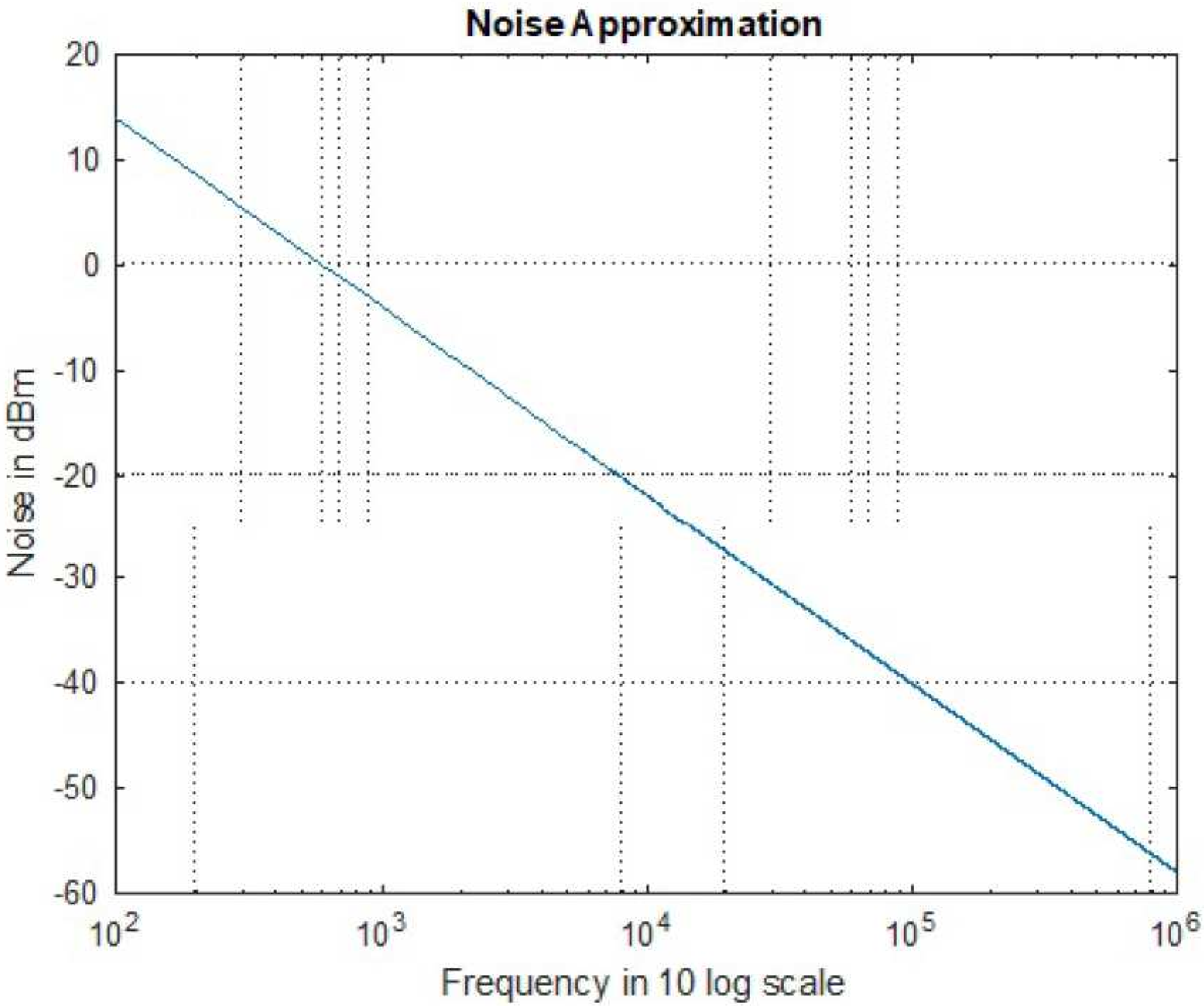

Figure 4

Noise approximation plotted between noise power and frequency in UWAC

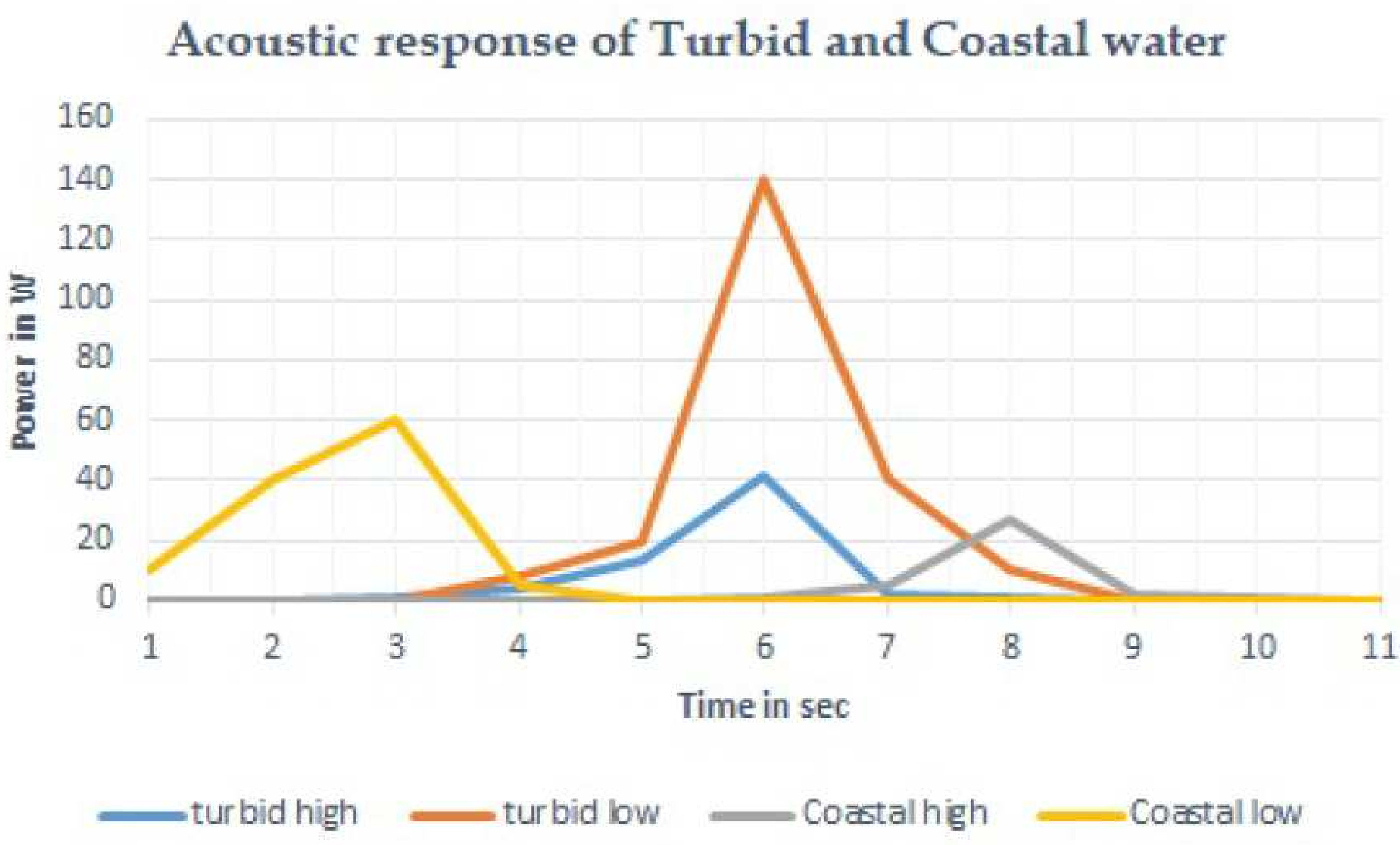

Figure 5

Acoustic response curve for turbid and coastal water conditions

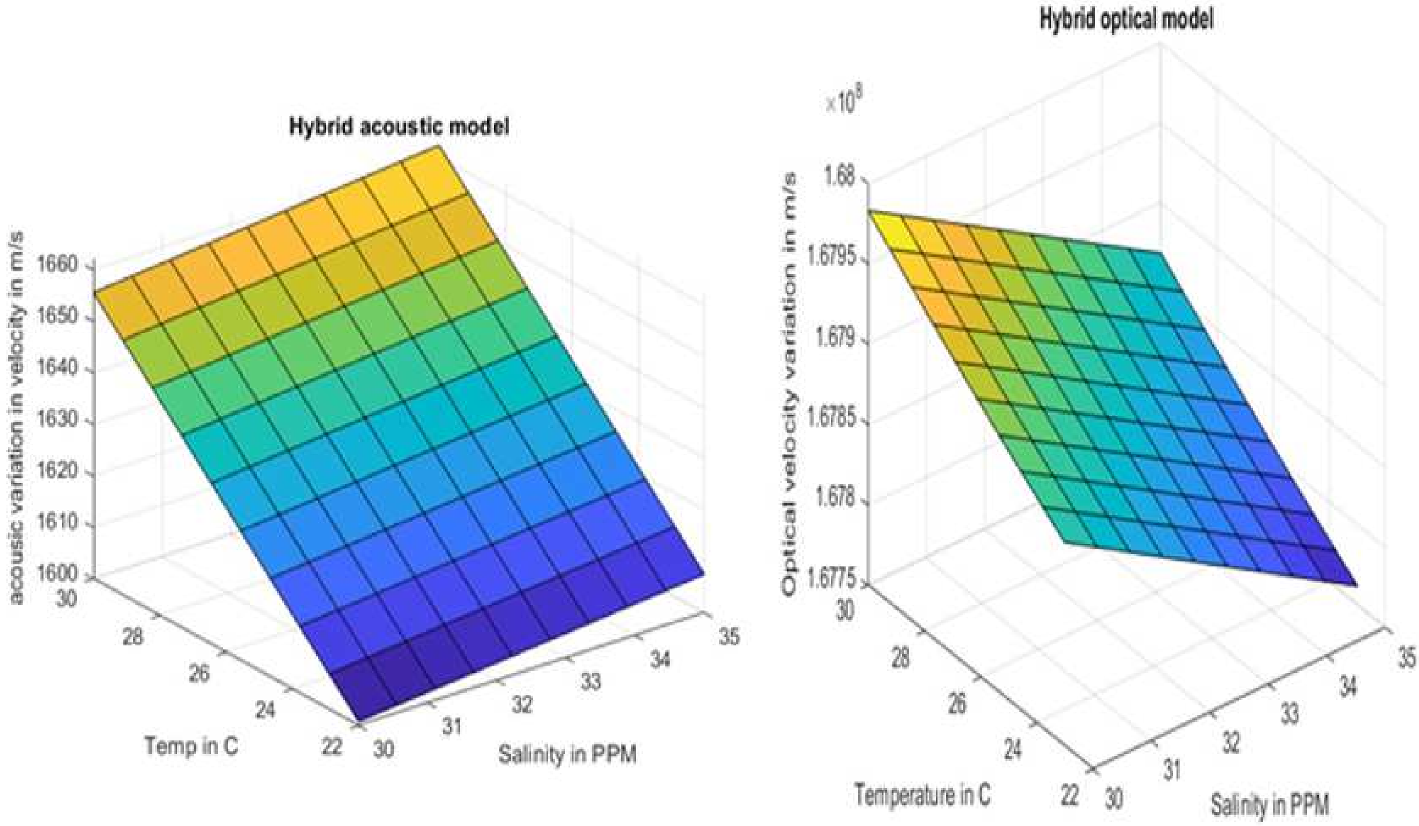

Figure 6

Temperature and salinity variation in Hybrid Acoustic and Optical Model

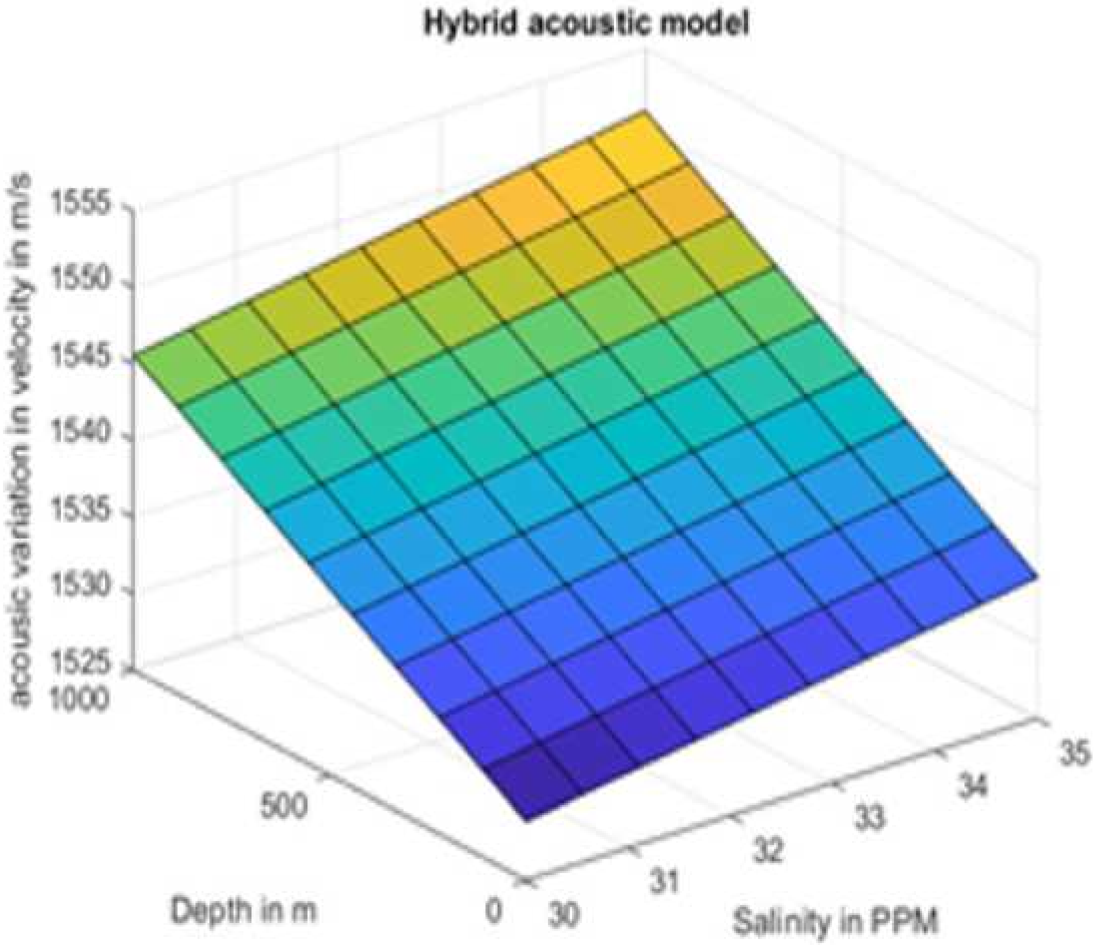

Figure 7

Depth and salinity variation in Hybrid Acoustic model

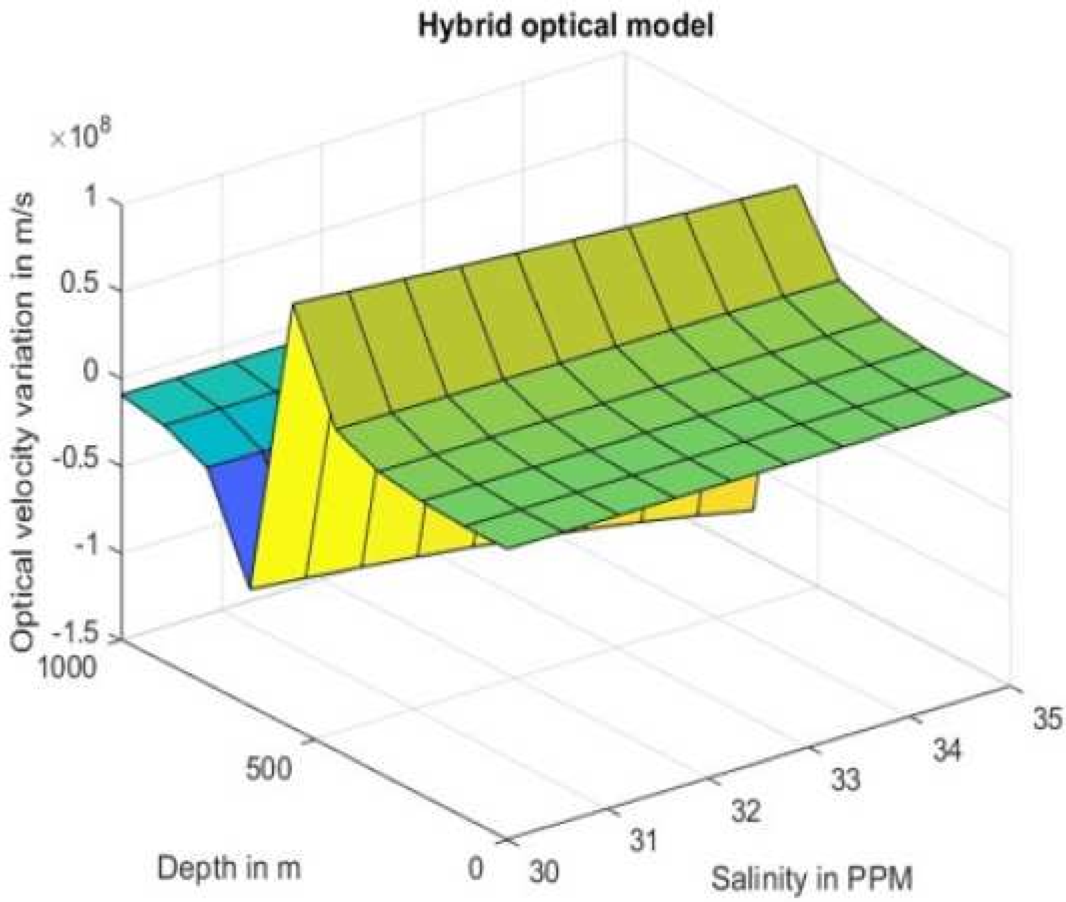

Figure 8

Depth and salinity variation in hybrid Optical Model

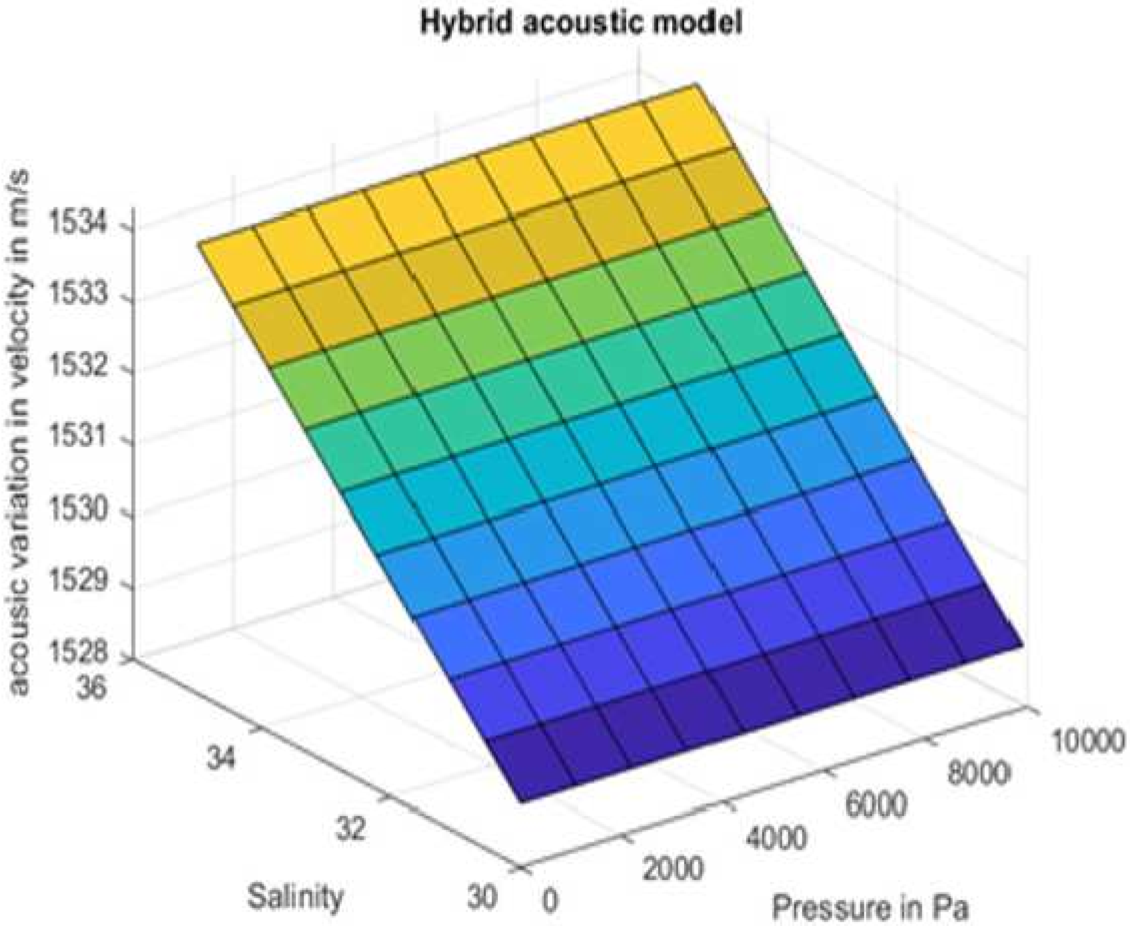

Figure 9

Salinity and pressure variation in Hybrid Acoustic model

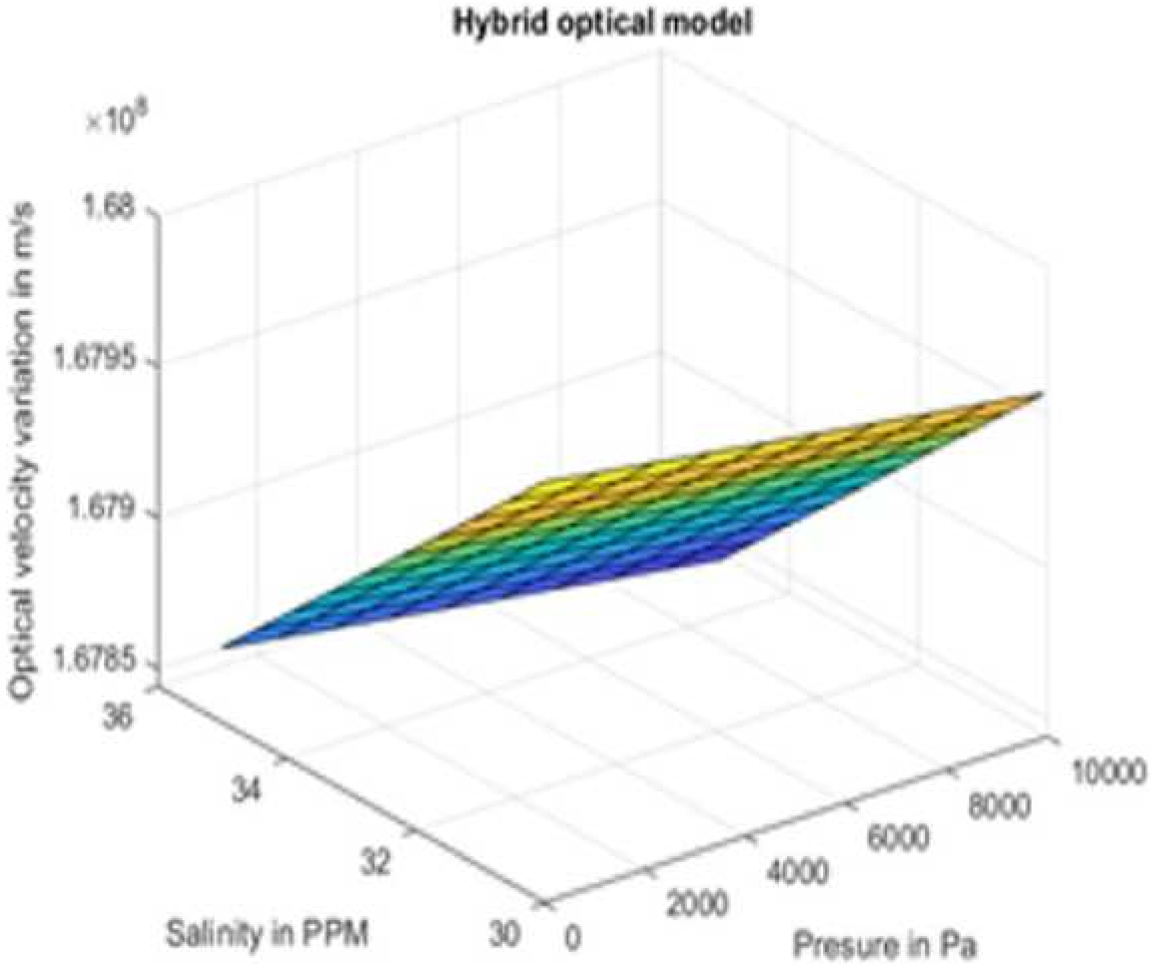

Figure 10

Salinity and pressure variation in Hybrid Optical Model