Design and Challenges of Underwater Optical Wireless Communication - An Analysis

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Abstract— Recently, the application of naval surveillance systems has been developed by developed the significance of underwater optical wireless communication. Through studies, the communication technology is expected to present a prominent role in its impact on the sea, ocean environment, marine biology in the lake, discovery of natural resources, prediction of natural disasters and climate changes. In this paper, will present a vision and many challenges in the field of Underwater Optical Wireless Communications by moving through the features inherent to these communication technologies, putting into perspective their technical aspects, current research challenges, and to-be-explored potential.

Key words: AUV, ROV, Underwater Optical Communication, Wireless Communication

I. INTRODUCTION

Due to the many treasures in the underwater world, which covers 70% of the world's surface, underwater wireless was discovered. However, wire and Wireless communication have varied challenges when comparing them. In fact, sound waves travel faster in water than in air with little attenuation. Therefore, due to the short distance and uncovered portions of land, wire and wireless communication is not suitable for these varied types of transmission locations. This is why using underwater optical wireless communication, although it has many challenges, is still a more suitable and efficient channel for wireless communication. Optical and Acoustical signal transmission in underwater is of necessary interest for many human applications [1]. Operated vehicles (ROV) and autonomous underwater vehicles (AUVs) are applications, which aid to see and discover the underwater deepness, which is beyond human skills. These vehicles have been in service for collecting data, retrieving objects or to performing many underwater tasks. Offshore gas and oil drilling are going further to deep underwater and offshore as energy companies search to find a production with low-risk sources area. The operation of these vehicles is challenging but is a necessity in order to improve wireless communication [2].

II. LITERATURE REVIEW

Underwater wireless communication has a hierarchy concerning the development for various physical transmissions. The first transmission, underwater acoustic wireless communication, was developed in the United States using frequency division multiplexing (OFDM) to achieve high data rates. However, this technique has a factor for time varying multipath propagation that leads the postpone spread consequence of inter-symbol interference (ISI) [3]. The second transmission, underwater radio wireless communication, uses Radio Frequency (RF) waves to improve the data rate. This design involves a direct radio frequency communication connect between two channels sender and receiver that is submerged under water or one channel in water and the other in the air. This technique gives maximum distances compared to an acoustic wave but suffers from the absorption coefficient due to a conductivity of seawater and high attenuation [4,5].

The third and best transmission for underwater communication is to bolster a high data rate, a longer distance and low attenuation using an optical signal. This communication exists by emitting light in a narrow beam. The major advantage compared to RF communications is the possibility of keeping the same conditions underwater without considerable losses. The disadvantage of optical is scattering and interference with ambiance light that can alter communications [6].

III. TYPES OF MODERN UNDERWATER COMMUNICATIONS TECHNOLOGY

In this section, the three types of new Underwater Communications Technology have been discussed. The first one is, the Underwater Acoustic Communication. The acoustic wave due to the long propagation distance can increase well in seawater and which can also travel long distances, on great swaths of underwater communication. In order to overcome the present constraints, the research of the issue of underwater acoustic communication is yet under way. Therefore, disadvantages of audio dialects cause the attenuation losses of the acoustic wave communication to increase with the rising of its frequency [7]. The second type of Modern Underwater Communications Technology is The Underwater Electromagnetic Communication. Voice communication exploits electromagnetic (EM) fields; actually the problem occurs when using radio waves underwater. This is due to attenuation because of the nature of the sea water. In particular, in the case of high-frequency radio waves, the attenuation becomes very large. The underwater electromagnetic wave communication also has some advantages. The electromagnetic wave is not affected by reflection and refraction in low water.

Though, when compared with the underwater optical communication the suspended particles and marine plankton have a small effect on the electromagnetic wave [8]. And the third type of Modern Underwater Communications Technology is Underwater Optical Communication Wireless System. With the development of the world and the increasing number of data users, it is difficult for voice communications to transform a huge volume of data at huge data rates, so the optical communication has a huge capability to transfer the huge volume of data at huge data rates [8].Underwater optical wireless communication systems that used the light emitting

diodes (LEDs) to improve bit error rate and the underwater optical link. The diode's impact the reduction and spread in actual ocean water were used by utilizing a simple analytical method based on Pspice Simulator. Underwater Optical Communication system uses a short range the photodiode as a receiver and the visual light (LED) as a transmitter [9].

IV. SYSTEM DESIGN

In this part, the design constraints for the underwater optical wireless communication have been defined. Also, it has given a multi choice for each component of the system, beginning in the transmitter, modulation technique and the optical receiver. The general system design overview is shown in Figure 1. The description of the system design is that the data is inserted in the computer that modulates the signal and sends it to the transmitter. The transmitter sends the light signal that is captured by the receiver, demodulating the signal and then showing the message in end terminal. [10].

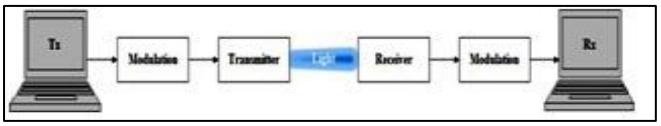

Fig. 1: General System Design Overview

The studies show that underwater optical wireless communication is a viable solution to be implemented in many areas such as a remotely operated vehicle (ROV) and automates underwater vehicle (AUV). For instance, AUV is an autonomous vehicle so it must satisfy some standard necessities. Hence, the energy and the physical size should be efficient as possible for the device that will attach to AUV. For this reason, the initial simple requirements are maximum Range, high data rate, low power, small size, low weight and low complexity. There are two possibilities of choices the optical transmitter, one of them is LED, which is a diffuse light source, or a laser, which is concentrated beam. Actually, choosing the diffuse LED system is better than the laser due to the prime difference between them, which is that a diffuse light, if an optic is inserted in the transmitter, the light beam can be adjusted to become more diffuse, or tighter, but the misalignment with the laser is a very complex and difficult obstacle. Furthermore, there is another idea that will be the best, which is having three lights with different wavelengths. Therefore, it will have more comparable data. Optical modulation is the second basic component of the underwater optical wireless communication system. Actually, the perfect modulation can benefit the data rate and range of all the system. Also, it can have some importance in energy efficiency. Some of the modulation modes that most used today include optical a pulse position modulation (PPM), a frequency shift keying (FSK), an on-off keying modulation (OOK), and a differential phase shift keying (DPSK) [11]. Based on the result of recent studies, the PPM has a greater advantage than the others, especially in the practical applications. The third important component of the underwater optical wireless communication system is the receiver. This is fundamentally a photoreceptor that plays an important role since it is the part that captures the signal to be demodulated. Here, there are a lot of possibilities choices, which are a photo resistor, a phototransistor, a photomultiplier, a photodiode, and an avalanche photodiode [12]. By reviewing many studies, the detectors that most used in this application are the photodiode (PD) and the avalanche photodiode (APD). In fact, PD is more promising than the APD, due to its simplicity and tolerance to the noisy ambiance light, but the APD is more sensitive.

V. DIFFERENT CHALLENGES OF UNDERWATER OPTICAL WIRELESS COMMUNICATION

Optical beam propagation is one of the challenges for underwater optical wireless communication. By the cause of fundamental characteristics of different water bodies, for example, it varies from the deep ocean to shallow water. Understanding the environment of complex properties of substances of underwater, the properties of the different substances water bodies are concentrated of dissolved substances varying on geographical location like littoral waters near land and the blue Ocean. Generally, the amount of absorption in pure seawater the same as pure water. This is caused by the absorption of salts in pure salt water and lack of suspended particulate matter.

On the other hand, the higher concentration of dissolved particles is considered a reason. For example, dissolvability of mineral components, colored organic matter and salts are found in clear ocean water and coastal ocean water. The highest concentration of suspended particles and dissolved found in Turbid harbor, due to scattering and absorption which are two prime phenomena resulting in the change in direction of optical signal of underwater or in intensity loss. It can limit the propagation of the optical beam[2].Underwater turbulence is a challenge too. Because of fluctuations in the temperature, salinity, and density of the underwater structure, this has lead to the huge fluctuations in the intensity of the signal at the receiver. Interference and dispersion must also be taken into account for UOWD problems. Multipath interference led to waveform time dispersion due to the multiple reactions or scattering objects from other underwater bodies or obstacles. This was before an optical signal could reach the detector, considering the occurrence of intersymbol interference (ISI) causing the data rate to decrease. Nonetheless, to suppress interference at the receiver, advanced signal processing techniques were the solution by equalization and adaptive optics in a channel. In fact, the optical beam was very narrow and caused temporary loss of the signal at the receiver. To solve this issue, appropriate error correction techniques were used to process lost transmission data. There are two types of error correction techniques in underwater forward error correction (FEC) and repeat request (ARQ). The combination of these two correction techniques which is called hybrid ARQ and is used to advance the reliability and optical link quality of the UOWC system and to maintain a robust system by breaking physical obstruction [3].

VI. CONCLUSION

This paper gives the overall view of the recent developments and the top technologies of underwater optical wireless communication, system design, visions and its challenges. In brief, the underwater optical wireless communication plays an important role in communication systems today due to increased number of the recent researching and uses of

underwater vehicles. Furthermore, one of the most important attributes of the optical wireless network is to be shall able of delivering high data rate services for the underwater environment at long distances. Traditionally, it has been used the coaxial cables or the optical fibers, which makes the range and maneuverability very limited of the underwater operations. Hence, using the underwater optical wireless communication can be more useful since it has a lot of advantages such that augment classical acoustic communication due to its more data rates, less power consumption, minimal packaging and smallest latency. To summarize, the underwater optical wireless communication technology will be more promising in the near future due to its benefits which it provided.

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