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A Hybrid Optical-Acoustic Modem Based on Mimo-Ofdm for Reliable Data Transmission in Green Underwater Wireless Communication

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Abstract

Green Underwater Wireless Communication (GUWC) are greatly finding its applications in seashore explorations, Internet of Underwater Things (IoUTs), Water Quality monitoring, Offshore data collection, Tactical surveillance, Assisted navigation, natural disaster alerts and preventions etc. Therefore, the undersea activities are changed according to the development tactics and may offer new technology. this new technology directly in support of ongoing science and engineering programs during the subsequent years, there'll be exploring applications of. Many potential applications in a long range of environments from the deep sea to coastal waters was done by using the high-speed underwater optical-acoustic(hybrid) communication. Therefore, there is a need for both visual (optical) and acoustical communication together in a one modem called optical-acoustic modem towards the varying depths and variety of nature of ocean causes. a hybrid MIMO-OFDM based opto-acoustic modem for Green Underwater Wireless Communication (GUWC) was proposed in this paper, that increases the network performance, and affirms eminent rate/speed by choosing the allowable communication either optical or acoustical link.

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Introduction

Communication in underwater is badly confined in comparison to air because body of water is actually unintelligible to electromagnetic radiation exclude within the seeable circle. Still within the seeable circle, light diffuses just some hundreds of meters within the cleanest bodies of water. Accordingly, acoustic techniques were developed for underwater communication systems and represents a comparatively grow and rich in technology. Therefore, acoustic communication system offers a limited data rates and substantial latency due to the speed of sound in water. The system that enhances and integrates with existing acoustic systems leading to an underwater communications capability offering high data rates and low latency was achieved by an optical communication. Therefore, the changes in the development schemes may extend new chances in the various fields of subsea activities. a subsea node devoted to a remote-controlled battery-controlled vehicle and that may be wirelessly functioned through a mixture of acoustical and visual (optical) communications, are going to be a crucial strength for some technological geographic expedition and commercial applications of Green Underwater Wireless Communication (GUWC). This infrastructure will enhance the development in subsea research activities and provides an efficient communication among sub-marine vehicles, seabed and surface vessels.

In txhe current scenario, the terrestrial wireless communication has several benefits, in the similar manner the underwater wireless communication has that same competence. It is interesting to note that water covers around 70% of Earth's surface[2] and this region is largely unexplored. Therefore, in the past few eras, the Underwater Wireless Communication (UWC) has become more importance in the fields of civilian, military and defense applications for security and reliability. Due to the dynamic nature of the aquatic medium and its inherent properties, attaining a dependable UWC faces numerous important and distinctive difficulties.[3] In the underwater medium, the principal challenging issue is global radio frequency (RF) technology is unfeasible because of the hard fading of radio emission in water, on degraded properties in conductive sea water.[4] In addition to its severe energy constraints is another major challenge issue in UWC. Therefore, to overcome these challenges many researchers have developed the different techniques such as underwater acoustical and visual communication, underwater magnetic induction communication (UMIC) and subaquatic hybrid opto-acoustic communication (UHOAC) etc.

But, each of these methods has advantages and disadvantages of its own. For example, UAC offers long distance connectivity but has concerns with multipath, poor speed, low bandwidth, and high energy consumption. Similarly, eminent speed, greater bandwidth, low power consumption at shorter distance with less dependability are offered by UMIC and UOC. Therefore, the GUWC area has quick progress in the research study activities, civil, commercial and specially to provide security in military and marine applications and also resulting in the demand on IoUT etc. To address the needs posed by the IoUT, a single communication technology was insufficient because it encompasses numerous applications with various network on demands. Seismology, military tactical operations, oceanography, and offshore activities for oil and gas explorations are just a few of these uses. [5]. Recently, a lot of these applications needed to use ROVs and AUVs, as seen in Fig. 1.[1]

The things that are arranged in underwater used to gather the information for a predetermined amount of time. Less measurements, eminent data rate, better quality photos are just a few examples of the data types that can be used.[6]. Data rates are therefore likely to rise in the near future due to the rapidly expanding interest in IoUT.[7] Nevertheless, due to the slow sound propagation in water (1500 m/s), the inability of UAC meets the greater rate requirements.[8]. Consequently, adopting UOC using laser diodes (LD) and LEDs,[9] is the obvious solution to meet these traffic demands. Based on the above discussion, The UOC comes with some costs, namely the need for precise Tx. /Rx. configuration in the choppy and active undersea circumstances, and short-range communication. Since optical beams cannot pass through opaque, dull water, UOC has high bit error rates (BER) in unfavorable weather situations such stormy oceans with very turbid water.[10] UAC is a more dependable option for the UWC in this case. To sum up, UWCN may face fluctuating busy loads depending on the variety of applications it supports on a given day, and it may also experience dynamic water conditions due to shifting weather.

The necessary SNR cut-off for UOC's is impacted via the turbidity of the water. The paper describes thoroughly the event of the opto-acoustic modems. A novel hybrid MIMO-OFDM based opto-acoustic modem provides larger data rates for undersea applications and reduces network power consumption is proposed in this paper for a green underwater wireless communication model. This model supports high-data rate/speed underwater applications while reducing network power consumption by choosing the proper communication links. High data rates are provided through underwater optics, which also uses less electricity. The underwater optics communication range is limited. On the other hand, long distance communications are possible with acoustic communication, despite its high-power consumption and low data rate.

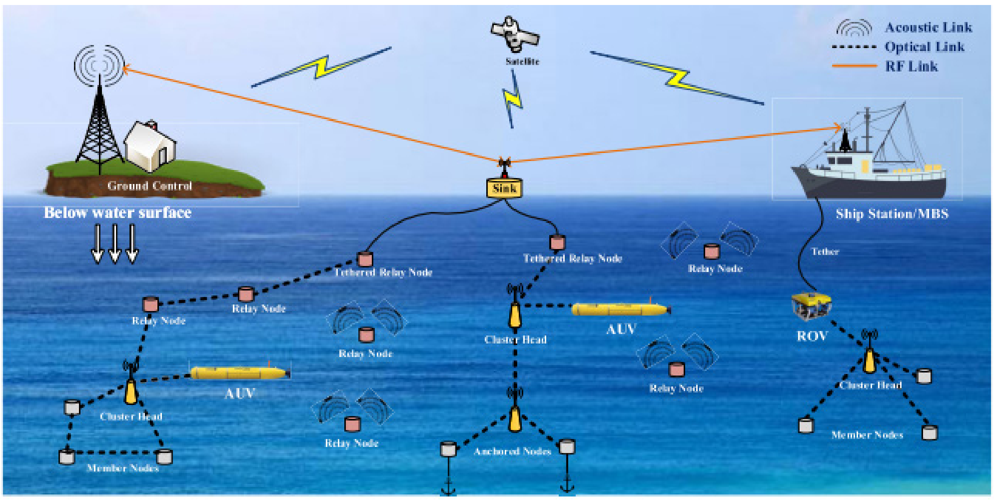

Fig. 1: Underwater Wireless Communication (UWC) Structure[1].

Related Works

A number of studies on hybrid opto-acoustic techniques for underwater wireless communications have been published in the scientific literature due to the reciprocal nature of sound and visual UWC techniques. In the current situation, combined opto-acoustical solutions for UWC have piqued the interest of researchers. Nodes and modems have been studied and developed in some research projects and experimental AUV prototypes.

The authors of paper[11] looked into the characteristics of underwater optical and acoustic communications and proposed the idea of a hybrid system in which a node has both optical and acoustic modems. The use of optical transceivers to transmit data at a high rate in a hybrid communication system has been discussed. In terms of energy usage and throughput, a hybrid acoustic-optical communication mode may perform better than standalone acoustic modes, as shown by Han et al.[12] in their simulation study. This is one of the first studies to look at how a hybrid UWC system can affect power consumption. More recently, a system of hybrid optical-acoustic communication with multi-hop transmission modes has been proposed by Wang et al.[13] When the SNR was over a desirable threshold, their method uses the optical-acoustic way, and when it was below that threshold, it switched to the traditional acoustic mode. This work's performance only gives a general idea of the transmittal lengths and data speeds that any of these systems is capable of. One of the first hybrid works on underwater wireless sensor networks (UWCNs) was published by Vasilescu et al.[14 UAC is employed for low-speed undersea recording indications while UOC is utilized for communication in UWSNs. The authors of this paper have shown that, it is feasible to transmit low-resolution underwater figures.

A hybrid opto-acoustic network architecture for the Internet of Underwater Things (IoUTs) has been proposed by Abdulkadir Celik et al. [15]. The authors of this paper develop Software-defined Underwater Networking (SDUN), which they present as a means of combining the advantages of optical and acoustic systems for the purpose of enabling IoUT nodes to adapt to the demanding and constantly changing underwater environment. The notion of network function virtualization (NFV) is then presented to provide cross-layer protocol suites that are tailored to an application using an NFV management system. According to the varying service requirements of various subsea applications, SDUN and NFV can utilize the network resources that are currently accessible. A hybrid paradigm for uses of underwater communication, such as weather forecasts, military hardware, and lost debris, was proposed in article [16]. The hybrid approach has the flexibility to change the information rate and execution.

Proposed Hybrid Mimo-Ofdm Based Opto-Acoustic Modem Design Using Matlab Simulink

In this article, a unique hybrid MIMO-OFDM based opto-acoustic modem was proposed and designed using MATLAB Simulink. The Fig. illustrates the design model of a unique hybrid MIMO-OFDM based Opto-Acoustic modem for GUWC system. It accepts input from optical (light) and ultrasonic (sound) signals. Both optical and acoustic transmission have their own channels. The optical channel receives light signals, while the acoustic channel receives ultrasound signals. The MIMO-OFDM section received both inputs because it is the adaptive modulation method best suited for this proposed modem. Thus, this modulation was accomplished by Fast Fourier Transform (FFT). In order to lessen the Inter Symbol Interference (ISI), the optical and acoustic signals were

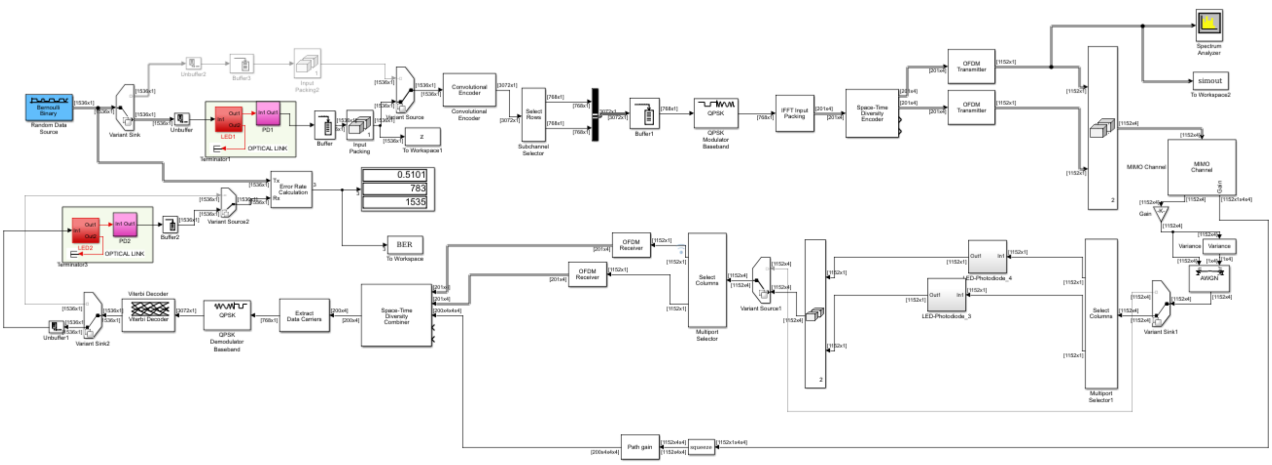

Fig. 2: proposed hybrid MIMO-OFDM based opto-acoustic modem design using MATLAB Simulink.

merged into a single data stream and separated into a number of narrowband channels at different frequencies and increasing the spectral efficiency by using MIMO.

First, Quadrature Phase Shift Keying (QPSK) modulation is applied to the input signals in a MIMO-OFDM transmitter before being used to create and analyses the received OFDM signals. Before to demultiplexing and demodulating, after that, the modulated signal is sent through a white additive Gaussian noise. The amount of bit errors is then determined. The signals are demultiplexed and demodulated at the receiver component, and depending on the need, they are divided into visual (optical) and acoustic (ultrasound) signals, then which are obtained by the appropriate output devices' channels. The sources for the creation of the acoustic and optical signals in the test bed are ultrasound and LED. Both the optical and acoustic signals have been successfully conveyed using the proposed hybrid MIMO-OFDM based opto-acoustic modem, and was able to effectively receive both optical and acoustic signals at the respective output devices after transmitting both signals through a single modem.

MIMO-OFDM Tx. and Rx. Section

The Fig. 3 shows the block diagram of a proposed MIMO-OFDM transmitter and it generates the MIMO-OFDM signal at the Tx. section. Similarly, Fig. 4 shows the schematic diagram of a proposed MIMO-OFDM Tx. section. Fig. 5 shows the block diagram of a proposed MIMO-OFDM receiver and it collects the MIMO-OFDM signal at the Rx. section. Fig. 6 shows the schematic diagram of a proposed MIMO-OFDM Rx. Section. At the MIMO-OFDM Tx. Section, a MIMO-OFDM system simultaneously transmits the data that has been independently OFDM modulated from several antennas with MIMO encoding on each of the sub channels. Similarly, at the MIMO-OFDM Rx. Section, the data from all the broadcasting antennas on all the sub channels is extracted at the receiver using OFDM demodulation and MIMO decoding on each of the sub channels. The transmitter and receiver sections of a MIMO-OFDM employ IFFT and FFT, respectively.

The MIMO-OFDM combo is advantageous because OFDM makes it possible to accommodate more antennas and wider bandwidths by greatly simplifying equalization in MIMO systems. Indoor wireless systems can achieve data rates of several hundreds of Mbits/s and spectral efficiencies of several tens of bits/Hz/s by implementing with MIMO-OFDM. In reality, MIMO and OFDM are parallel transmission technologies in the frequency and spatial domains, respectively and accounts for the improvements in data throughput and spectral efficiency. When an OFDM signal is created and sent across many antennas for increasing transmission rate or diversity, this technique is known as MIMO-OFDM. The FFT/IFFT algorithm and MIMO encoding, like Space Time Block coding (STBC), are the foundations for an effective MIMO-OFDM system implementation. Each channel is given as subgroup of subcarriers in the OFDM system. Therefore, each channel would receive a modest portion of the carriers with thousands of subcarriers. In order to achieve throughputs of 1 Gbit/sec and higher, OFDM is combined with the MIMO technique, which increases range, spectral efficiency and link reliability.

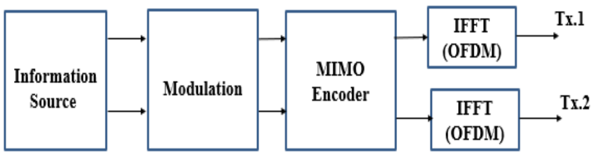

Fig. 3: MIMO-OFDM Tx. Section

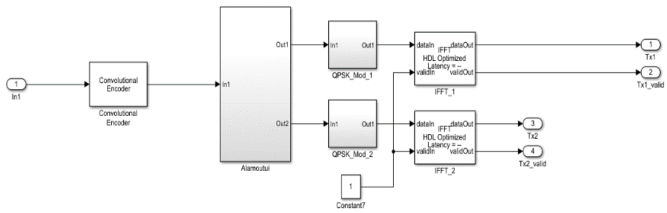

Fig. 4. Schematic Diagram of a Proposed MIMO-OFDM Tx. Section

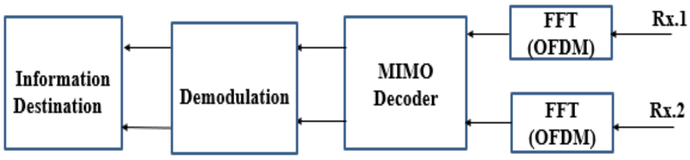

Fig. 5. MIMO-OFDM Rx. Section

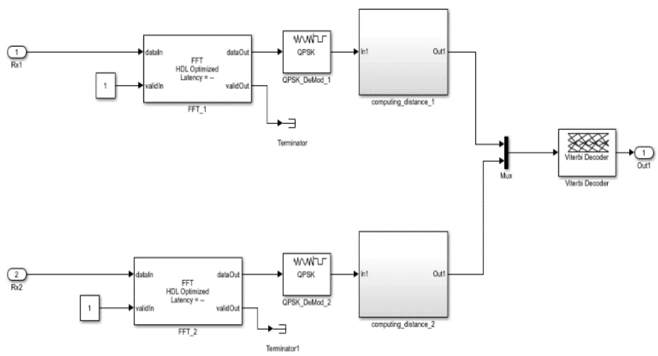

Fig. 6: Schematic Diagram of a Proposed MIMO-OFDM Rx. Section

Simulation and Synthesis Results

Matlab simulation results

A Novel hybrid MIMO-OFDM based Opto-Acoustic Modem for Green Underwater Wireless Communication (GUWC) was designed and simulated using MATLAB-Simulink. By sending the acoustic and optical signals through a toggle switch, a MIMO-OFDM-based GUWC system was tested. The error rate (BER) plot for both auditory (EM) and optical (light) signals is shown in Figures 7 and 8, respectively. Using the MATLAB simulation environment, an error rate (BER) plot for both acoustic and optical signals was graphically shown.

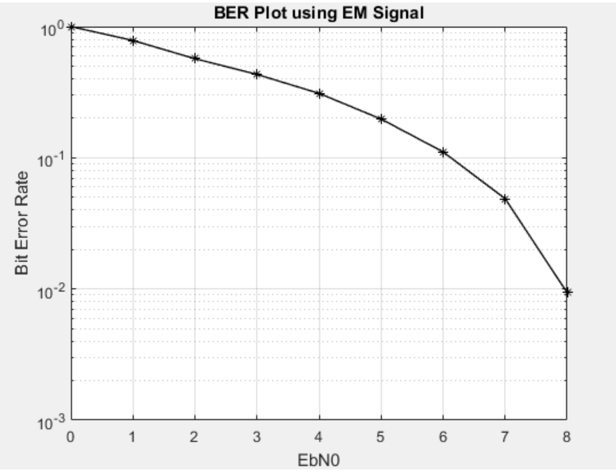

Fig. 7: An error rate (BER) plot for Acoustic (EM) signal

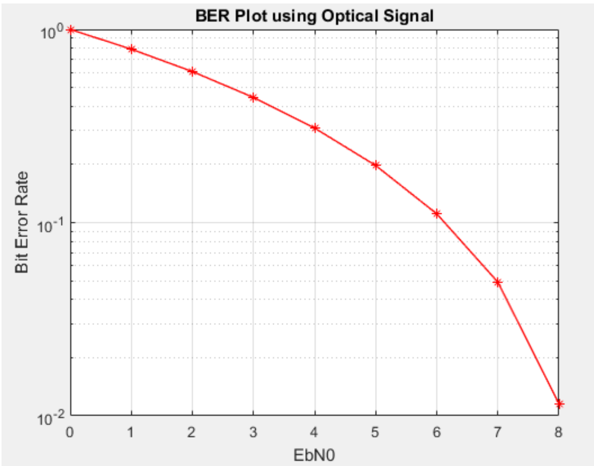

Fig. 8. An error rate (BER) plot for Optical (light) signal

Xilinx synthesis results

After MATLAB simulation, each block was converted into the VHDL code and synthesized using Xilinx ISE 14.1. The synthesis results for both the MIMO-OFDM Tx. and Rx. sections were shown in below figures. Fig. 9 and Fig. 10 shows the RTL schematic and Technology Schematic of a MIMO-OFDM Tx. Section. Similarly, Fig. 11 and Fig. 12 shows the RTL schematic and Technology Schematic of a MIMO-OFDM Tx. Section respectively.

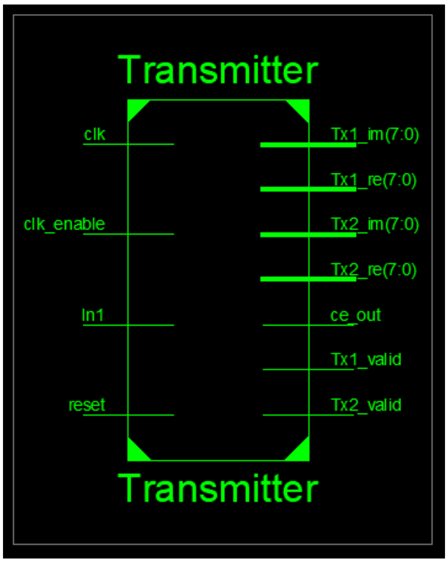

Fig. 9. RTL schematic for MIMO-OFDM Tx. section

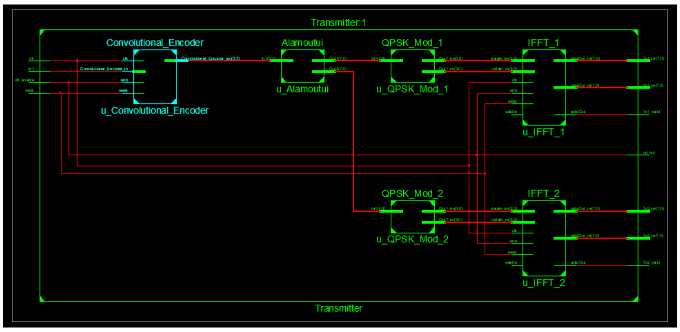

Fig. 10. Technology schematic for MIMO-OFDM Tx. section

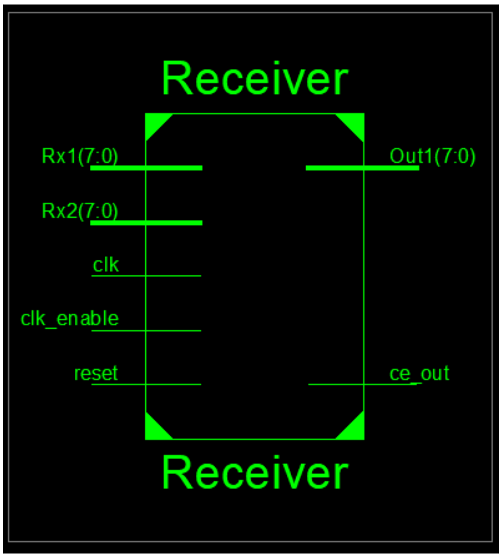

Fig. 11. RTL schematic for MIMO-OFDM Rx. section

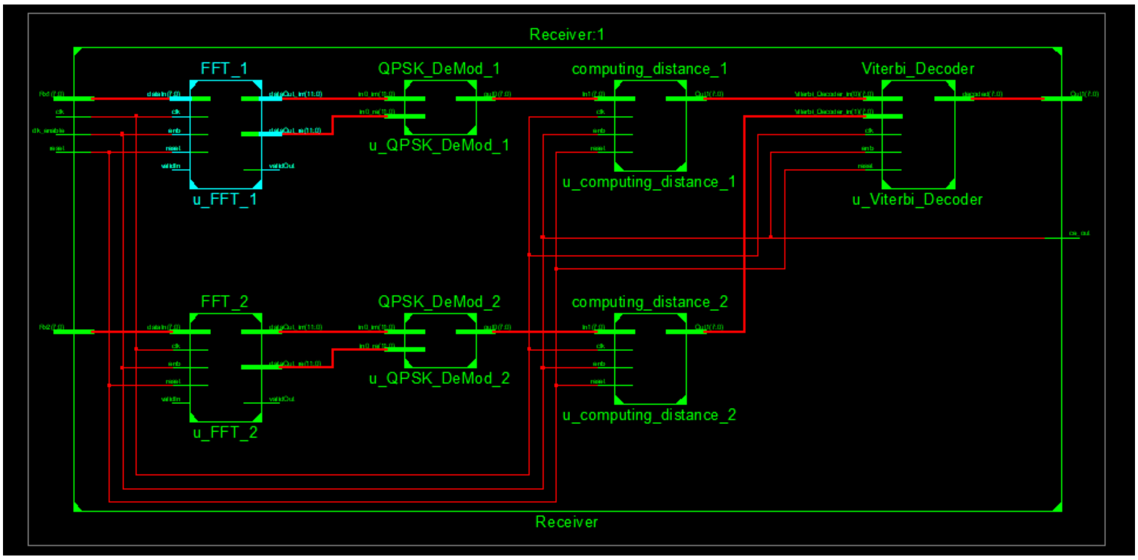

Fig. 12: Technology schematic for MIMO-OFDM Rx. section

Conclusion

This paper describes the design of a unique hybrid MIMO-OFDM based opto-acoustic modem for GUWC using MATLAB-Simulink and synthesized using Xilinx 14.1 was discussed. the error rate (BER) calculation of optical and acoustic signals was shown in simulation results. the transmitter and receiver sections were synthesized using Xilinx 14.1. Therefore, the transmitter and receiver sections of a MIMO-OFDM based opto-acoustic modem was designed and which improves the performance of a GUWC system. The vision towards the underwater Opto-Acoustic networks (UOAN), which overcomes the underwater environment hostility by utilizing the advantages of Underwater Acoustic Networks (UAN) and Underwater Optical Networks (UON). It is also useful in global alignment for multi-vehicle configuration networks. Opto-acoustic modems are also highly recommended in GUWC and is very useful to share information efficiently among connected sensors, underwater vehicles, computing devices, surface stations, robotic equipment, and other devices. It is helpful for monitoring underwater assets, microorganisms, human activities, sudden disasters, and other things in the real world. Further, Resource sharing, system integration, underwater mobile ad hoc networks (UMANet), and protocol optimization are other technical strengths of the GUWC that are essential for efficient underwater communication. With increasing demand in marine communication, oceanography etc., the usage of opto-acoustic modem goes on increasing in the direction of future technologies like 5G and coming 6G in hand for the success of Green Underwater Wireless communication (GUWC).

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