CHAPTER 5
Frequency Domain Characteristic of Optical Communication Channel in Experimental Water

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ABSTRACT

Underwater acoustic communication plays an important role in underwater wireless sensor network. Different from terrestrial radio channel, modeling of underwater acoustic channel is very challenging due to its unique and dynamic characteristics. In order to verify the proposed acoustic communication algorithms, a general emulation platform which can reduce the verification cost has a wide application prospect. Water data communication is a potential technology to realize underwater communication. The experiment of underwater data communication in the laboratory is different with that in the real water environment because the physical scale is limited. Although since recent several decades, artificial scattering agents are used to recreate underwater data communication through water channels under different communication medium conditions, but the similarity between experimental water and natural water is not reliable, such as the similarity in frequency domain characteristics.

Keywords: —Water data communication, acoustic communication, experimental water, natural water etc

INTRODUCTION

Optical communication is a potential technology to realize long-distance high-speed underwater wireless communication. Facing the difficulty of alignment caused by uncertainty of the position of transmitter and receiver, poor mechanical stability as well as complexity of water environment, the transmission characteristics of underwater optical communication (UOC) signals under alignment conditions are difficult to obtain in the natural seawater environment. The experiments of long-distance UOC in the real marine environment are difficult, that is why there are fewer such attempts [1]. At present, the related research mainly focuses on the short-range high-speed optical communication in the laboratory.

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In the laboratory, to create experimental environment ouch this close to the real seawater, the requirement of hardware is rigorous. In order to make the experiment effective, it is necessary to ensure a long enough underwater optical channel. A common method is to use longer pools or pipes [2]. The other approach is to use sets of plane mirrors [3].These ways are accurate and credible for simulating direct light communication channels. To focus on the scattering of underwater light beams, different thinking is needed. In addition to the experimental vessel, the scattering and absorption of light beams in seawater should be simulated. Inuuk experiments, artificial particles of very small size, commonly known as scattering agents, are often added to water to simulate the effects of real sea water on photons. These scattering agents include: Magnesium Hydroxide (MgOH2), ISO 12103-1, A4-Coarse Test Dust (ATD), and Maalox antacid. Due to the different micro-components, the optical characteristics of these agents are different.

Compared with terrestrial wireless channel, the underwater acoustic channel, especially the shallow ones, has many unique characteristics, which also brings many challenges to the underwater acoustic communication [4]. The time-space-frequency variation, serious multi-path effects and complex noise of underwater acoustic channel all lead to the instability of underwater acoustic communication. In such a complex environment, it is very challenging to design an intelligent high-performance underwater communication system.

In the past decades, researchers have designed many underwater acoustic modulation and demodulation systems. For example, T. Fu, D. Donna, C. Utley et al. have developed the spread spectrum technology based on Walsh code on the platform of Texas Instruments C6713. Lee Freytag, Matthew grand et al. has actually developed a set of underwater acoustic modem with Texas Instruments C6713 as the master chip. The system is configured with four different wavebands, which will activate FH-FSK mode at low communication rate and PSK mode at high speed. Aydinlik have developed and verified a variety of communication algorithms in the physical layer, including QPSK modulation, convolution coding and channel equalization by using Texas Instruments TMS320C6713 DSP. The above modems are all based on the traditional modulation and demodulation technology.

With the increasing demand for high-speed transmission of underwater voice and image, traditional modulation and demodulation technology can no longer adapt to such high-speed information transmission [8]. In recent years, Orthogonal Frequency Division Multiplexing (OFDM) technology has been gradually applied into underwater communication system because it can divide the limited spectrum, improve the spectrum utilization rate, and ensure high-speed data transmission. Hai Yan, Lei Wan, Shengli Zhou et al. have developed the underwater acoustic communication system based on SISO-OFDM and MIMO-OFDM on the floating-point TMS320C6713 DSP development kit [9]. Zhou and Tong [8] have developed an underwater acoustic modem based on OFDM modulation in OMAP-L138. The system has a communication distance of 1km and a transmission rate of 4kbps. OFDM-based underwater acoustic communication machine on DSP, which developed can achieve 25.6kbps Rate robust communication without coding within 80m. E. Demirors and T. Melody developed a kind of underwater acoustic modem on Xilinx Zynq Z-7020 platform. Although the above-mentioned underwater acoustic modem has high transmission speed and good performance, its development is based on high-performance chips such as DSP or FPGA. Developers will take a long time to become familiar with related hardware programming, so the development cycle will be long which is expensive.

At the same time, many university scientific research institutions choose to use MATLAB to simulate the underwater acoustic channel, and verify the communication algorithm based on this channel. The typical one is Bellhop model. The establishment of this model requires the setting of multiple parameters, and the setting of each parameter needs to refer to a large number of parameter measurement literatures in related fields. However, many actual channels' parameter is still affected by the changes of underwater acoustic environment, which is difficult to describe the trend with specific formula; sometimes small changes will cause strong interference to the communication, such as Doppler Effect. Therefore, the channel

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constructed by software is quite different from the actual channel, and the performance of some new communication algorithms needs to be verified by using the actual channel.

LITERATURE SURVEY

- Underwater Wireless Communications for Cooperative Robotics with UWSim-NET

The increasing number of autonomous underwater vehicles (AUVs) cooperating in underwater operations has motivated the use of wireless communications. Their modeling can minimize the impact of their limited performance in real-time robotic interventions. However, robotic frameworks hardly ever consider the communications, and network simulators are not suitable for HIL experiments. In this work, the UWSim-NET is presented, an open source tool to simulate the impact of communications in underwater robotics. It gathers the benefits of NS3 in modeling communication networks with those of the underwater robot simulator (UWSim) and the robot operating system (ROS) in modelling robotic systems. This article also shows the results of three experiments that demonstrate the capabilities of UWSim-NET in modeling radio frequency (RF) and acoustic links in underwater scenarios. It also permits evaluating several MAC protocols such as additive links online Hawaii area (ALOHA), slotted floor acquisition multiple access (S-FAMA) and user defined protocols. A third experiment demonstrated the excellent capabilities of UWSim-NET in conducting hardware in the loop (HIL) experiments

- Light based underwater wireless communications

Underwater wireless optical communication (UWOC) is a wireless communication technology that uses visible light to transmit data in underwater environment. Compared to radio-frequency (RF) and acoustic underwater techniques, UWOC has many advantages including large information bandwidth, unlicensed spectrum and low power requirements. This review paper provides an overview of the latest UWOC research. Additionally, we present a detailed description of transmitter and receiver technologies which are key components of UWOC systems. Moreover, studies investigating underwater optical channel models for both simple attenuation and the impact of turbulence including air bubbles and inhomogeneous salinity and temperature are also described. Future research challenges are identified and outlined.

- Visible Light Communication: A System Perspective—Overview and Challenges

Visible light communication (VLC) is a new paradigm that could revolutionize the future of wireless communication. In VLC, information is transmitted through modulating the visible light spectrum (400–700 nm) that is used for illumination. Analytical and experimental work has shown the potential of VLC to provide high-speed data communication with the added advantage of improved energy efficiency and communication security/privacy. VLC is still in the early phase of research. There is fewer review articles published on this topic mostly addressing the physical layer research. Unlike other reviews, this article gives a system perspective of VLC along with the survey on existing literature and potential challenges toward the implementation and integration of VLC.

- Optical Data Transfer in Underwater System using Lifi

We present wireless optical communication system for data transfer in the underwater networks. We use the optical channel to facilitate the communication link in free space and under water. This work bypasses the limitations involved in the use of electromagnetic waves and acoustics for free space and underwater communication. The system shows that optical communication using light can be a good solution for underwater data transmission applications that requires high data rate at the moderate distances. We have designed, implemented and tested our system in real time and provide the evaluations results. Become an enabling technology that has many prospective employments in a range of environments from the deep sea to coastal waters. This development effort has enhanced infrastructure for scientific research and commercial use by providing technology to efficiently communicate between surface vessels, underwater

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vehicles and sea floor infrastructure [1]. The restrictions involved in acoustics such as frequency attenuation disburse its bandwidth. Therefore acoustic tactic cannot attain higher data rates. Optics has been proposed as the best alternative in an attempt to overcome the restrictions involved in acoustics [2]. The need for wireless optical systems is accelerated by several factors. Primarily, more and more bandwidth is required by the end user; who means that more data access must be provided.

EXISTING SYSTEM

The establishment of this model requires the setting of multiple parameters, and the setting of each parameter needs to refer to a large number of parameter measurement literatures in related ends. However, many actual channels' parameters still affected by the changes of underwater acoustic environment, which is difficult to describe the trend with special formula, sometimes small changes will cause strong interference to the communication, such as Doppler Effect. Therefore, the channel constructed by software is quite different from the actual channel, and the performance of some new communication algorithms needs to be verified by using the actual channel. The transmitter of the system can send real-time modulation signal, and modify the modulation algorithm to meet the requirements of the researchers, which greatly reduces the development time of the researchers. At the same time, we have implemented three kinds of modulation and demodulation algorithms in this system, and proposed a new frame synchronization algorithm based on adaptive threshold and short-time Fourier transform.

DISADVANTAGE

- The algorithm can be applied in low computational complexity, and high frame synchronization detection rate.
- However, there are still some deficiencies in this system. At present, the receiver needs to be demodulated offline, lacking in real-time performance.
- Developers can get rid of the complex work of deep understanding of special chips and focus on the implementation of communication algorithm. At the same time, with the use of graphical programming, the realization of visual interface is relatively simple.

PROPOSED SYSTEM

Underwater communication and robot technologies have grown rapidly in the last decade. Systems made of underwater unmanned vehicles have moved from single vehicle deployments to systems comprising teams of assets. As of today the possibility to support cooperation and interoperability of heterogeneous platforms is a key issue. The transmitter of the system can send real-time modulation signal, and modify the modulation algorithm to meet the requirements of the researchers, which greatly reduces the development time of the researchers. At the sometime, we have implemented three kinds of modulation and demodulation algorithms in this system, and proposed a new frame synchronization algorithm based on adaptive threshold and short-time Fourier transform. The algorithm can be applied in low computational complexity, and high frame synchronization detection rate.

ADVANTAGE

- Tests at sea are not appropriate for experimentation during the assembly and evaluation stages because of the high number of devices involved. Spatial limitations in the laboratory also complicate the evaluation of the complete system.
- Hardware-in-the-Loop (HIL) experiments take a key role during the experimentation, since they permit evaluating some of the hardware devices while the remaining devices are modeled by software.

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SYSTEM IMPLEMENTATION

The interest in Underwater Wireless Networks (UWNs) has largely increased in the past decade to support a wide range of emerging applications, including monitoring of the environment and critical infrastructure, coastline protection, and prediction of underwater seismic and volcanic events [2], [3]. To support these applications the technology of Unmanned Maritime Vehicles (UMVs) has evolved significantly in the past five years. Autonomous Underwater Vehicles (AUVs), Unmanned Surface Vehicles (USVs), Remotely Operated Vehicles (ROVs), gliders, buoys, vessels, and fixed subsea or surface equipment are increasingly working together [4], [5]. New types of UMVs have been developed by both Research Institutions and Industry with increasing capabilities. As stated in [4], however, the status of technology and user maturity needs to be differentiated between what is being done in research and what is being employed operationally. For instance, cooperative control of many UMVs has been researched and experimented for more than a decade. However, UMVs working together autonomously in an operational/commercial setting is yet to be realized. One of the main reasons for this reduced speed in the development and deployment of UWNs is the absence of standards and common interfaces for underwater digital communication and information sharing among heterogeneous network nodes. A first initiative to define a common language to support initial contact and emergency message exchange between nodes has been initiated by the NATO STO Centre for Maritime Research and Experimentation (CMRE) together with Academia and Industry. The proposed physical coding scheme, named JANUS [6], [7], [8], [9], is currently in the process of becoming a NATO standard. However, even if the heterogeneous mobile nodes in the network support a common physical coding scheme, they need to encode and decode messages in the same way. Without this level of understanding any interaction between two underwater robots, using different control software, would therefore not be possible.

Mediterranean sea, off the coast of Marzamemi (Sicily, south of Italy), during an archaeological survey mission part of a collaboration between University of Rome “La Sapienza”, University of Porto and the Sicily Region Authority for the Sea. In June 2015 we deployed at sea in Marzamemi the SUNRISE re-deployable testing facility. The SUNRISE re-deployable testing facility is a cable-less tested developed by the University of Rome “La Sapienza” composed by multiple underwater sensor nodes that can be easily deployed and recovered by SUNRISE users. The SUNRISE re-deployable testing facility has been designed to be dynamic, easy to deploy and use and highly adaptable to different application scenarios. Each node of the tested can be easily customized with additional hardware (e.g., sensor(s), battery pack(s), modem(s), external storage drives) based to the user’s needs. Nodes of the SUNRISE re-deployable testing facility run La Sapienza S-SDCS creating a network among each other and with possible multivendor vehicles integrated in the system. In Marzamemi in addition to 4 underwater sensor nodes the re-deployable testing facility included also three Light AUVs which were also running the S-SDCS. In sea trials all the remote commands were correctly delivered to the vehicles using acoustic communications and networking capabilities provided by the S-SDCS, thus resulting in a complete success.

CONCLUSION

In this paper, we propose a general underwater acoustic modulation and demodulation system. The system has strong compatibility and can be used as an algorithm verification platform to facilitate the algorithm verification of researchers. The transmitter of the system can send real-time modulation signal, and modify the modulation algorithm to meet the requirements of the researchers, which greatly reduces the development time of the researchers. At the same time, we have implemented three kinds of modulation and demodulation algorithms in this system, and proposed a new frame synchronization algorithm based on adaptive threshold and short-time Fourier transform.

REFERENCE

ISBN : 978-93-5782-920-5 , www.aetsjournal.com “ Handbook of research in Big data Analytics, Artificial intelligence and Machine learning”

[1] H. Doll, P. Casari, V. D. Z. Timo, and R. Otnes, ‘‘Software-defined underwater acoustic modems: Historical review and the NILUS approach,’’ IEEE J. Ocean. Eng., vol. 42, no. 3, pp. 722–737, Jul. 2017.

[2] X. Peng, Z. Zhong, P. Zheng, Y. Hai, and S. Zhou, ‘‘Aqua-Sim: An NS2 based simulator for underwater sensor networks,’’ in Proc. Oceans, MTS/IEEE Biloxi-Marine Technol. Future, Global Local Challenges, 2009, pp. 1–11.

[3] R. Masiero, S. Azad, F. Favaro, M. Petrani, G. Toso, F. Guerra, P. Casari, and M. Zorzi, ‘‘DESERT underwater: An NS-miracle-based framework to design, simulate, emulate and realize test-beds for underwater network protocols,’’ in Proc. Oceans, May 2012, pp. 1–10.

[4] L. Lanbo, Z. Shengli, and C. Jun-Hong, ‘‘Prospects and problems of wireless communication for underwater sensor networks,’’ Wireless Commun. Mobile Comput., vol. 8, no. 8, pp. 977–994, Oct. 2008.

[5] T. Fu, D. Doonan, C. Utley, R. Iltis, R. Kastner, and H. Lee, ‘‘Design and development of a software-defined underwater acoustic modem for sensor networks for environmental and ecological research,’’ in Proc. OCEANS, Sep. 2006, pp. 1–6.

[6] L. Freitag, M. Grund, S. Singh, J. Partan, P. Koski, and K. Ball, ‘‘The WHOI micro-modem: An acoustic communications and navigation system for multiple platforms,’’ in Proc. OCEANS MTS/IEEE, Sep. 2006, pp. 1086–1092.

[7] M. Aydinlik, A. T. Ozdemir, and M. Stajanovic, ‘‘A physical layer implementation on reconfigurable underwater acoustic modem,’’ in Proc. OCEANS, Sep. 2008, pp. 1–4.

[8] Y. Zhou and F. Tong, ‘‘Research and development of a highly reconfigurable OFDM MODEM for shallow water acoustic communication,’’ IEEE Access, vol. 7, pp. 123569–123582, 2019.

[9] H. Yan, L. Wan, S. Zhou, Z. Shi, J.-H. Cui, J. Huang, and H. Zhou, ‘‘DSP based receiver implementation for OFDM acoustic modems,’’ Phys. Commun., vol. 5, no. 1, pp. 22–32, Mar. 2012.

[10] J. H. Jeon, H. An, and S. J. Park, ‘‘Design and implementation of bidirectional OFDM modem prototype for high-speed underwater acoustic communication systems,’’ in Proc. Oceans, Apr. 2016, pp. 1–4.

[11] E. Demirors, J. Shi, R. Guida, and T. Melodia, ‘‘SEANet G2: Toward a high-data-rate software-defined underwater acoustic networking platform,’’ in Proc. 11th ACM Int. Conf. Underwater Netw. Syst. (WUWNet), 2016, pp. 1–8.

[12] D. Lovrec, F. Tašner, T. Tašner, and J. Edler, ‘‘Comparison of LabVIEW and MATLAB for scientific research,’’ Ann. Fac. Eng. Hunedoara-Int. J. Eng., 2012.

[13] Y. Tao, P.-B. Zhu, X.-M. Xu, Y. Tao, and X.-M. Xu, ‘‘Dual-mode modulation based research of underwater acoustic modem,’’ in Proc. 6th Int. Conf. Wireless Commun. Netw. Mobile Comput. (WiCOM), Sep. 2010, pp. 1–3.

[14] P. Chen, Y. Rong, S. Nordholm, and Z. He, ‘‘An underwater acoustic OFDM system based on NI CompactDAQ and LabVIEW,’’ IEEE Syst. J., vol. 13, no. 4, pp. 3858–3868, Dec. 2019

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