# CHALLENGES AND OPPORTUNITIES IN INTELLIGENT SYSTEM DEVELOPMENT USING FUZZY INFERENCE SYSTEM FOR UNDERWATER COMMUNICATION

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*Abstract*— **Communication technology is currently growing rapidly, especially underwater communication that has existed since the first world war. Each network has different channel characteristics. In this paper, the researcher discusses the challenges and opportunities in the development of communication using an intelligent fuzzy inference system. Problems that often occur are transmission speed, high bit error rate, propagation delay and bandwidth limitations, propagation delay because in general the characteristics of underwater channels cannot be determined precisely. This paper tries to describe the research design for underwater communication research with fuzzy intelligent systems. The development of the modem aims to test algorithms and simulations on underwater communications that have been carried out according to the characteristics of underwater canals. Fuzzy Inference Systems are used to make control decisions to improve performance or to fix problems that conventional theory fails to achieve in network uncertainty due to mobility, unstable links, limited resources, energy constraints, and node security.**

**Keywords—**Acoustics , underwater communication simulation, test bed modem, Fuzzy inference system

## I. INTRODUCTION

Communication technology is developing and experiencing rapid progress, especially underwater communication that has existed since the First World War. Acoustic communication is the only viable underwater medium as it operates at a low frequency which allows long distance transmission and reception [1] .

Unlike terrestrial wireless sensor networks, UWSN (Underwater Wireless Sensor Networks) faces various challenges such as bandwidth limitations, high propagation delays, high bit error rates, and Doppler effects [2] [3] [4] [5] .

These factors cause errors in communication performance and maximum propagation distance, the phenomenon of multipath propagation arises due to reflection of waves on the sea surface and seabed [6] .

This paper presents an overview of research on the development of underwater communication systems with fuzzy intelligent systems inference system and challenges to opportunities faced by researchers and present research designs that we will do in the future.

## II. DEVELOPMENT OF RESEARCH ON C COMMUNICATION UNDER A IR

*The Time-Reversal (TR)* technique has the ability to compress multiple paths both temporally and spatially (temporal-spatial focusing) [7] . In [8] [9] analyzed the effect of multipath and transducer movement on the quality of underwater acoustic communication signals by applying the *passive time reversal mirror* (PTRM) method. [10] The TR acoustic communication method using *filtered multitone* (FMT) is intended to reduce the residual ISI and the complexity of the adaptive equalizer for post-processing. *High Frequency (HF)* radio communication system has the advantage of utilizing the ionosphere layer to reflect the signal, so that the *High Frequency* (HF) communication system can reach long distances [11] . To maximize the efficiency of the HF channel, it can be increased by using the *Time-Reversal Division Multiple Access* (TRDMA) method [12] .

In this study [13] used adaptive equalization with *Least Mean Square* (LMS) algorithm, with modulation (BPSK) to determine the characteristics of underwater canals. In [14] designed an adaptive control system using a neural network and a PID (Propositional Integral Derivative) control system. This paper [15] constructs an AMC system with a limited number of transmission modes in the context of underwater orthogonal frequency division multiplexing (OFDM). [16] Explored the design aspects of adaptive modulation based on *orthogonal frequency-division multiplexing* (OFDM) for underwater acoustic communication (UWA). The need for fast data transmission with limited bandwidth makes *Orthogonal Frequency Division Multiplexing* (OFDM) a solution for high transmission communication with modulation using *Binary Phase-Shift Keying* (BPSK) [17] .

Miscellaneous forward propagation effects are presented, which are relevant to channel models for the design of modulation schemes, network protocols, and simulation environments [18] . In [19] presented a new underwater acoustic channel model based on beam acoustics including time variability and multipath effects for underwater acoustic communication which addresses both issues. In research [20] has designed a GUI to test the behavior of acoustic signals with the transmission frequency band (9 K to 90 KHz). In [21] analyzed the evolution of underwater acoustic prediction models to be more detailed and accurate.

*Received Signal Strength* (RSS) is implemented for secret key generation in a simple UACS system, by selecting a certain RSS value for the purpose of a communication link [22] . The selection of relays in research [23] with the criteria considered, namely maximizing SNR ( *Signal to Noise Ratio* ) and low BER is intended to overcome problems in the underwater communication system. [24] Proposed the *Cooperative MAC for Underwater* (CoopMAC-U) protocol. Limited bandwidth and propagation delay on underwater channels are greater than HF channels, causing a high *Bit Error Rate* (BER) [25] .

Underwater acoustics states that underwater communication is challenged by characteristics of acoustic propagation through the underwater environment such as speed of sound, surface scattering, noise, and absorption [26] . In [27] introduced the intelligent algorithm-based UASN routing protocol and investigated the development trend of the UASN protocol. In [28] stated that an intelligent system for underwater acoustic applications is a detection technique that distinguishes between acoustic pressure wave fields so that wave manipulation can be carried out. [29] designed a flexible platform to achieve high performance with more complex modulation schemes so as to support the development of short-range underwater communication systems using various wireless underwater communication technologies. In [30] the transmission of the acoustic signal is carried out with different frequencies, namely 500Hz and 1500Hz simultaneously. In research [31] separated the acoustic signal using the Natural Gradient ICA based on the *Generalized Gaussian* Model which was obtained from the distribution characteristics of the non-Gaussian acoustic signal source, namely *ship radiated noise and sea ambient noise.*

Transmitter In papers [32] [33] has designed an acoustic wave transmitter device for water communication consisting of a power amplifier and a transducer for transmitting messages and information signals underwater. [34] Proposed an underwater acoustic platform using software to improve information transmission more efficiently. In [35] carried out the design and realization of a prototype transmitter consisting of an amplifier and a transducer.

Presents information on the development of underwater communication systems which are influenced by three factors, namely sound attenuation, multipath propagation, and low speed of sound propagation [36] . on [37] [38] developed underwater acoustic communication such as multipath phenomenon and limited bandwidth capacity, so that the characteristics of the ARM9 processor to increase the various limits and describe the underwater communication process demonstrating and designing a test-bad underwater acoustic sensor network with a similar actual environment, also developed testbad for underwater dual access communication but uses an internal modem. Encourage the cooperative development of underwater communications and networks by providing scientists with the world's hardware capabilities [39] .

In [40] describes the application of fuzzy logic in the field of artificial intelligence, in order to be able to think systematically which underlies fuzzy reasoning or logic. In [41] the introduction of modulation of UWA communication has attracted significant attention, but UWA channels are less friendly with regard to time, frequency and space variations which are complex and very challenging. [42] Has proposed a new scheme for forming *clusters* using *fuzzy clustering* and *particle swarm optimization* where the scheme is simulated in Matlab. [43] and [44] developed a new method for shallow water so as to obtain sound propagation characteristics using the finite time domain method (FDTD), which takes into account the sound propagation in shallow waters with lost seafloor. The structure of the fuzzy logic system optimized by genetic algorithms for underwater acoustic signal recognition in *real time* .

Table 1.
U NDERWATER C OMMUNICATION R ESEARCH P ROGRESS

| Topic | Sub Topic and author | | |
|---|---|---|---|
| Underwater Acoustic Channel Propagation & Modeling | Propagation Effect (2013) Paul A van Walree | Acoustic propagation channel modeling (2014) Muhammad Waqas Khan, Yimin Zhou, Guoqing Xi | Modeling using ray tracing method (2017) Sana Gul, S Sajjad Haider Zidi, Rehan Khan |
| Modulation &Transmission | FSK TRANSMITTER DESIGN (2021) Ardiansyah, Alfin Rizky | Modular short-range underwater communication development (2016) Gunther Ardelt, Jan Markmann, Martin Mackenberg | transmission new routing protocol (2015) Jian Shen, Haowen Tan, Jin Wang, Sungyoung Lee |
| Modem Test Bed | underwater acoustic communication model (2013)Tri Budi Santoso, Wirawan, Gamantyo Hendrantoro | Testbed receiver configuration (2014) George Sklivanitis, Emrecan Demirors, Stella N. Batalama | testbed collaborative development (2012) Joao Alves, John Potter,Giovanni Zappa, Piero, Robert Been |
| Fuzzy | fuzzy logic implementation (2012) Helfi Nasution | Fuzzy modulation recognition (2018) Junkai Liu, Weihua Jiang, Feng Tong, Dongseng chen | Fuzzy-Based Clustering Scheme (2019) Vani Krishnaswamy, Sunilkumar |

## III. D EVELOPMENT OF CUSTIC MODEL A BELOW A IR

### A. Characteristics of Underwater Canals

The underwater acoustic canal has three parts, namely the shallow sea ( *Shallow Water* ), the medium sea ( *Medium water* ), and the deep sea ( *Deep Water* ). Each of the channels has different characteristics both in terms of signal reflection conditions with the bottom and the water surface ( *boundary* ), limited *bandwidth* , salinity, currents, surface waves, Doppler effect, and others [45] .

This research will be conducted at Kalanganyar Beach in Sidoarjo Regency, East Java. In shallow water canals ( *Shallow water* ), *multipath* occurs because the signal bounces back when it hits the water surface and boundaries to deep water. The properties of water which consist of salinity and temperature will affect the number of multipaths that occur. In shallow water the *salinity* level and temperature level are higher than in deep water, this is because shallow water is exposed to more sunlight and more water movement. The test is carried out by calculating the *Signal to Noise Ratio* (SNR) to compare the signal level with the noise *level* .

$$\boldsymbol{SNR} = \frac{\boldsymbol{SignalPower(SP)}}{\boldsymbol{Nose\ Power\ (NP)}}$$

### B. Fuzzy Inference System Development at UWA

The development of the modem aims to test algorithms and simulations that will be carried out. The acoustic development of the *test bed modem* can be seen in Figure 2. In the sending section, it begins with sending messages and generating binary data, the binary data is encoded using the BCH code. The coded data will be modulated using BPSK modulation modeling. In the OFDM block, the modulated data sender will be converted from serial to parallel and utilize a *fuzzy control system* when carrying messages. The signal sent through the channel must be in serial form, so conversion from parallel to serial is required. At the receiving end, the FFT process is carried out to convert into complex symbols . Then the complex symbol is processed by demodulation so that the data will return to its original form when received by the recipient.

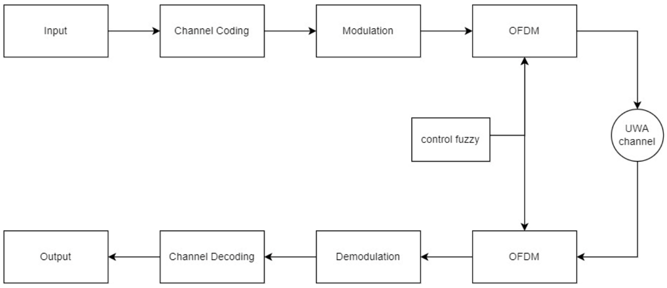


**Figure 2.** Design of underwater communication *test bed*

### C. Modem Test Bed

## IV. Conclusions And Future Challenges

This paper presents an overview of research on the development of underwater acoustic communication systems and the challenges faced by researchers. In another section, we also present a record of the research we have carried out and the design of our future research .

Based on the summary of research developments in Chapter 2, many researchers have investigated signal quality in underwater acoustic communications such as transmission speed, high bit error rate, bandwidth limitations, propagation delays because in general the characteristics of underwater channels cannot be determined precisely.

Based on the problems that occurred in chapter 2, it can be seen that researchers use various methods or techniques such as designing and realizing a prototype, implementing a single strength receiver (RSS) to generate a scret key in a simple UACS system, maximizing SNR and BER, paying attention to different frequencies individually. Simultaneously, OFDM with modulation uses binary BPSK for high transmission, filtered multitone (FMT) to reduce residual ISI and complexity of adaptive equalizer for post-process to apply intelligent algorithms such as fuzzy in order to be able to think systematically underlying reasoning or fuzzy logic, which is used to detect the difference between the acoustic pressure wave field in shallow water to the lost seabed.

In this paper, the author also tries to describe the research design for underwater communication research with fuzzy intelligent systems. The development of the modem aims to test algorithms and simulations that have been carried out according to the characteristics of underwater canals.

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