Design, and Performance Evaluation on Rake Receiver-based Interleave Division Multiple Access (IDMA) System for Underwater Communication

[1]Poonam Yadav, [2] Dr. Kishan Pal Singh, [3] Dr.Prachi Tripathi
[1] Research Scholar Mangalayatan University Aligarh India,[2] Professor Mangalayatan University Aligarh India,[3] Assistant Professor GNIOT Greater Noida India
[1]poonamyadav2481991@gmail.com, [2]drkishan.mu@gmail.com, [3]drprachi.as@gniot.net.in

Abstract

MIMO-OFDM For wireless communications underwater, IDMA is utilized to minimize fading. MIMO enables the simultaneous delivery of data from a number of antennas and its simultaneous reception by a number of antennas. This approach enhanced data rate while maintaining bandwidth and reduced fading. All other underwater multiple access methods are outperformed by IDMA. Low BER was proven using MIMO-OFDM and MIMOIDMA with varying user counts. To minimize burst errors and fade in underwater channels, we integrate MIMO-OFDM with IDMA. Wireless communication underwater deteriorates in a number of ways. MIMO-OFDM with IDMA and hydrophones enhance underwater communication. Acoustic waves, which transmit data at a slower pace than electromagnetic waves, are used for underwater communication. This research lessens fading at low data rates. In this investigation, random interleaving IDMA was applied. A tree-based interleaved might be included in future IDMA updates. User isolation and pattern creation are accomplished via tree-based interleaving. 261

Keywords: - *Underwater Communication, IDMA (Interleavers Division Multiple Access) Scheme, MIMO (Multiple Input Multiple Output), Rake Receiver.*

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1. INTRODUCTION

Construction of MIMO OFDM technology using IDMA method for underwater wireless communication is difficult because of the sluggish speed of acoustic waves, severe fading problems, prolonged multiple routes, bandwidth restrictions, and the refractive properties of the sound channels. The objective of this effort is to develop an underwater ecological sensing and communication system that is able to operate under challenging propagation conditions. We work very hard to avoid fading and maintain bandwidth. The OFDM strategy may reduce bandwidth and get rid of multipath interference in contrast to FDMWalkenhorst, B & Pratt, TG (2008). We look at how well OFDM and FDM perform in terms of BER for underwater communication. Data is sent through several antennas and received via numerous receivers in a MIMO system. Underwater wireless communication has a poor data rate due to a variety of bandwidthsWang, X & Poor, HV (1999); thus, MIMO handles the whole communication bandwidth and increases the data rate. Multiple access techniques are used for underwater communication in order to effectively divide the allocated spectrum or capacity among a large number of communication usersXiong, Xingzhong, Jianhao Hu, and Lan Tian (2007). Other multiple access approaches' outcomes were examined, and we found that the IDMA performed better than the others. The IDMA technique effectively distributes data to consumers by using an interleaving mechanism. Only the IDMA or MIMO-OFDM methodologies have been the focus of recent underwater wireless communication solutions, neither of which is sufficient to lessen the issues with the underwater wireless communication channel. The use of FDMD for underwater communication has historically been inefficient and constrained by its bandwidth restrictions. Previous underwater wireless communication techniques might somewhat address fading issues, but they were unable to reduce bandwidth use or increase data throughput. The MIMO-OFDM with IDMA approach outperforms the earlier technologiesXiong, Xing-Zhong, Jian-Hao Hu, and Xiang Ling (2011).

In the most recent generation of underwater communication systems, OFDM is one of the modulation methods that is most often utilizedYang, Hao, Haiyun Luo, Fan Ye, Songwu Lu, and Lixia Zhang (2004). A data stream traveling at a high bit rate may be divided into several smaller streams in the sub channel using the OFDM technique. The MIMO approach is being used to greatly increase spectrum bandwidth while maintaining the integrity of communication channels in underwater wireless communication networks. This approach is now being investigated to decrease the fading caused by the addition of lots of routes and interference from another user on the frequency where they are both operating Zhang, Xin Ming, Feng Fu Zou, En Bo Wang, and Dan Keun Sung (2010). To produce and receive copies of the given signal at the receiving end, several diversity techniques are used. Recent studies on the IDMA system for underwater wireless communication have shown that IDMA outperforms all other multiple access approaches currently in use. We used a number of algorithms, such as random interleavers and tree-based interleaved algorithms, to assess the efficiency of the IDMA system. In the underwater communication channel, the random Interleavers technique outperforms all other approaches in terms of BER performance.

2. REVIEW OF LITERATURE

E.calvo et al (2012) propose a multi-user detection (MUD) approach based on cyclic coordinate descent for simultaneous data detection and channel estimation. The inspiration for its development was the discovery of a simpler version of the Maximum Likelihood Detector (ML) for severely distorted sea lanes. If data symbols are available, they are used to estimate the channel response and adjust the data symbol estimates. A common optimization criterion for adaptive estimation is the minimum mean squared error. A multi-channel implementation of the receiver allows multiple hydroacoustic channels to achieve the required array processing gain. The number of receiving elements determines the difficulty of the detection method, and this complexity does not depend on the modulation depth of the broadcast signal. Real data collected in the 20kHz range in a 2km shallow channel was used to test the system and showed encouraging results.

Hao He et al (2009)carried out covert communications with low received signal-to-noise ratios (SNR) to prevent eavesdroppers from being detected or intercepted. The processing gain provided through direct-sequence spread-spectrum (DSSS) method is crucial to the success of detection in this area. Additional difficulties arise if clandestine communications occur in underwater acoustic (UWA) situations. Because UWA channels are time-varying, proper channel estimate at low SNR may be impossible. Additionally, UWA settings include long-memory channels that are frequency-selective, which presents difficulties for the spreading waveform's design. We examine covert UWA communications in this study from a non-coherent standpoint. Binary differential phase-shift keying (DPSK) and binary orthogonal modulation are the two modulation methods that are discussed. The DSSS method and a RAKE receiver are the foundations of both plans. In addition to the design of the transceiver and the frequency-selective UWA channel, the employed spreading waveforms contribute to the security of the transmitted data. By using numerical examples, the usefulness of the suggested approaches is shown.

Tsimenidis et al (2015) Both (IDMA) and (CDMA) are looked at as potential synchronous downlink multiple-access systems for realistic underwater communication channels with a lot of multipath dispersion and temporal variation. The proposed dual-frequency-element (DFE) IDMA and DFE-CDMA receivers make use of iterative interference cancellation, adaptive decision feedback equalization at the chip level, carrier phase tracking, and channel coding. The detection algorithms' performance is evaluated and compared using receiver equations. In order to monitor and correct for channel impacts, the turbo processing stage is in charge of constantly exchanging soft information with the DFE and carrier phase tracking units in the form of log-likelihood ratio (LLR) estimations. Soft-chip cancellation can be used to reduce users' multiple-access interference (MAI). We analyze and compare the performance of the proposed receiver structure in short-range, shallow-water acoustic channels using offline signal processing of signals acquired during sea trials in the North Sea. The proposed DFE-based IDMA and CDMA receivers show his BER performance of about 10-5 with an average signal-to-interference-plus-noise ratio (SINR) of 11 dB in synchronous multiuser situations with two or four users. It can be achieved. One achieves an effective rate of 439.5 b/s per user. Moreover, experimental results show that these directly adaptive receivers outperform channel estimation (CE)-based IDMA and CDMA receivers. Significantly reducing bit errors while maintaining a simpler Recipient execution may likewise is equivalent to that of a collector with full information on the interleaver's examples or codes in unambiguous circumstances when such information isn't free.

Xingzhong Xiong et al (2018)deems (IDMA) to be an essential part of current wireless communication systems. We present a strategy for simulating IDMA architectures, examine the function of each model component, and discuss the concept behind IDMA systems in this article. Since the essential IDMA framework model properties are stage free, execution demonstrating for IDMA frameworks might be basically as versatile as required. The reproduction and testing results show that the reenactment stage is equipped for mimicking all elements of the IDMA framework. Additionally, the platform lets users test IDMA systems in a variety of ways and make use of the Simulink library's pre-existing models. This platform makes it simple to increase model functionality and analyze IDMA system performance.

Xing-Peng Mao et al (2014) Here we consider a clever way to achieve fast synchronization in interleaved division multiple input (IDMA) called Spreading-IDMA (S-IDMA). S-IDMA uses a complex code division multiple access (CDMA) technique and adds a second despreader after the interleaver to improve the signal-to-interference-plus-noise ratio (SINR) can be increased. The proportion of sign to impedance + commotion, the piece blunder rate (BER), and the intricacy of S-IDMA are completely estimated and broke down. S-IDMA excels at rapid synchronization at a low computational cost.

Utschick et al (2006) This article compares the performance and complexity of (DS-CDMA) and (IDMA) under the presumption of iterative multiuser detection. Here we consider a clever way to achieve fast synchronization in interleaved division multiple input (IDMA) called

Spreading-IDMA (S-IDMA). S-IDMA uses a complex code division multiple access (CDMA) technique and adds a second despreader after the interleaver to improve the signal-to-interference-plus-noise ratio (SINR) can be increased. The equivalence eliminates the need for expensive matrix-vector multiplications and matrix-inversions in order to guarantee the MMSE solution for IDMA. DS-CDMA, on the other hand, is extremely sensitive to user synchronism, so this rarely occurs. When using the MMSE detector, we still talk about complexity issues, but instead of focusing on specific solutions for reducing complexity, we focus on the main differences between IDMA and DS-CDMA. Virtual experience execution might be assessed in numerous situations utilizing bit blunder rate reenactments and outward data move (Leave) graphs. In terms of practical considerations, this study demonstrates that IDMA is superior to DS-CDMA, particularly in situations with high user demand.

Feng Zhang et al (2014) The same low-rate channelization code for all users can be used for propagation in IDMA. This is a special case of CDMA where user-specific interleavers can be used to separate users. This study analyzes the sub band versus interference performance of an IDMA system. First, let's briefly review the basic assumptions of IDMA. Next, we discuss the creation of a partial-band interference model and its cancellation in an IDMA system. Theoretical study and simulation findings demonstrate that the performance of IDMA systems will be impacted by the iteration, spreading gain, user count, and jamming power. Particularly, the strength of partial band jamming is the factor that will have the most influence on IDMA systems under partial band jamming conditions.

Aliesawi et al (2014)A continuous pilot approach is taken into account when considering two adaptive receivers for widely dispersed underwater acoustic channels (UACs) in an IDMA system. The creators look into their own standard Rake-IDMA recipient, which utilizes versatile semi-blind channel assessment, with a proposed direct versatile impedance dropping (IC) IDMA beneficiary. Every iterative translating collector with a stage locked circle (PLL) is upgraded by the MMSE rule. Both the hypothetical groundworks of every recipient, as well as trial revelations gathered through the investigation of information from genuine submerged correspondence endeavors, are covered. Three users transmitting at 441.3 bps on a 4 kHz bandwidth show that the ICIDMA receiver excels to a Rake-based IDMA receiver and has significantly lower bit errors.

Xingzhong Xiong et al (2013) The most difficult channel on the planet is the underwater acoustic channel, which is both time-varying and frequency-selective. Because of these highlights, channel assessment is expected for cognizant symmetrical recurrence division multiplexing (OFDM) transmissions in marine conditions. Known pilots can be used to evaluate the frequency response of the channel. The BER execution might fluctuate significantly relying upon the sort of pilot design utilized. It has been shown that Block, Brush, and Disperse pilots each succeed in their own particular underwater circumstances. A submerged channel is displayed to go about as a brush channel. The experiment channel's pass and stop bands are located and examined through channel estimation. The probability of channel estimate error in the stop band is greater than in the pass band If the channel coherence bandwidth is small . (ICI), which raises the level of background noise, may result in significant estimation errors. The estimate SNR may drop significantly with a better transform domain filter.

3. DIVERSITY TECHNIQUE FOR UNDERWATER WIRELESS COMMUNICATION

Due to the characteristics of the underwater environment, including its limited bandwidth, high attenuation, and multipath propagation, and Doppler effects, underwater wireless communication presents particular difficulties.

To improve reliability and performance, underwater wireless communication systems, cutting-edge solutions must be used. Diversity is one such method that is often used to counter the negative effects of fading and interference.

Diverse communication channels that are isolated in time or space are used in underwater wireless communication diversity approaches to improve system execution. The main objective is to reduce the effects of fading, which results in fluctuating received signal intensity and signal attenuation. Diversity approaches boost signal quality, dependability, and data rates by taking use of the channel's spatial or temporal fluctuations.

- **There are several diversity techniques used in underwater wireless communication:**

i. Spatial Diversity
ii. Time Diversity
iii. Frequency Diversity
iv. Frequency Diversity
v. Polarization Diversity
vi. Cooperative Diversity

Few of above mentioned are elaborated below

- **Frequency diversity**

A particular kind of diversity mechanism called frequency diversity uses many frequency channels to improve underwater wireless communication. It focuses on mitigating the effects of frequency selective fading caused by underwater channel properties. Frequency diversity offers increased dependability and resistance to signal deterioration by sending the same information across many frequency bands.

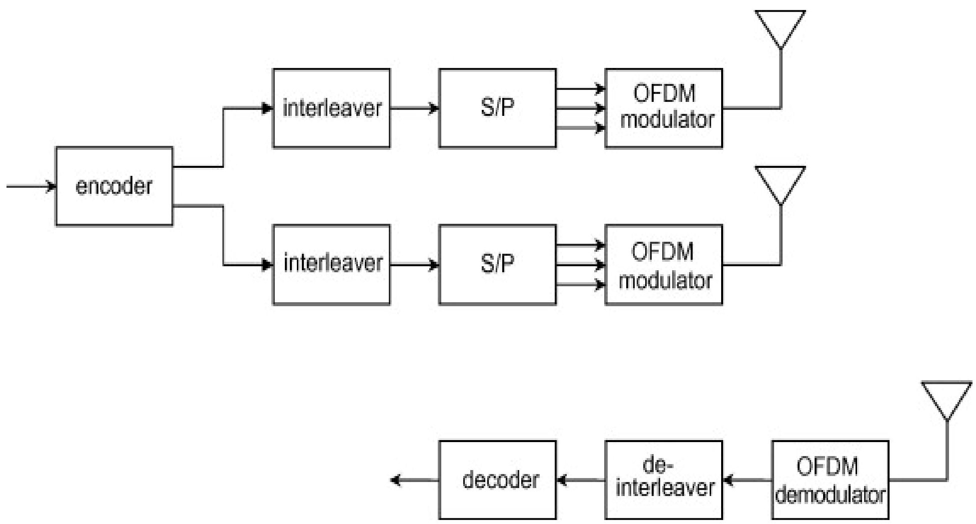

Figure 1: Diagram showing Frequency Diversity in Blocks

- **Time diversity**

Time diversity is a diversity scheme used in underwater radio communications to take advantage of time differences in underwater channels and improve system performance. It entails sending many redundant copies of the same data at various times, enabling the receiver to combine the signals it receives to reduce fading and improve overall signal quality.

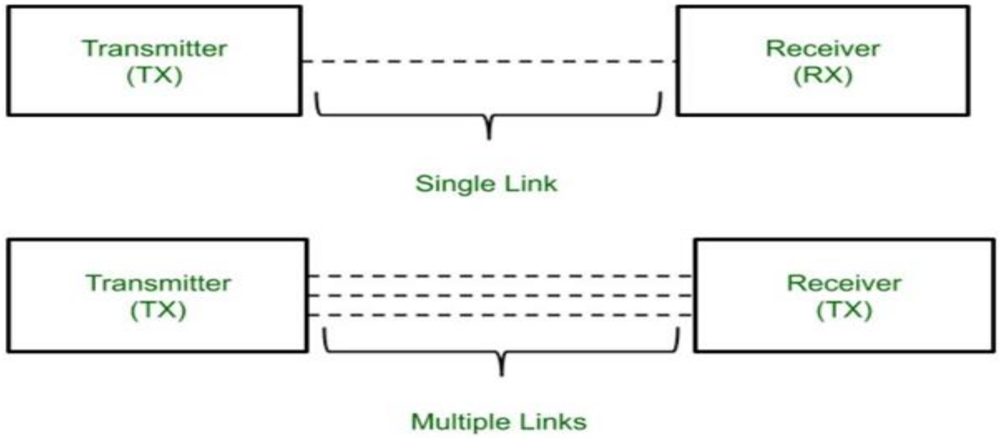

Figure 2: Time Diversity Block Diagram

3.1. Diversity Mechanisms

Diversification strategies are implemented using a variety of ways, which are referred to as diversity mechanisms in underwater wireless communication. These techniques are intended to take advantage of the undersea channel's spatial, temporal, frequency, or polarization diversities. Here are a few examples of often used diversity mechanisms.

i. Selection Diversity
ii. Switched Diversity
iii. Equal Gain Combining (EGC)
iv. Maximum Ratio Combining (MRC)
v. Orthogonal Space-Time Block Coding (OSTBC)
vi. Hybrid Diversity

3.2. Combining Mechanism

In order to increase overall signal quality and counteract the effects of fading, combining mechanisms are vital in underwater wireless communication systems. They combine the received signals from several antennas or diversity branches. These techniques aid in reducing the negative effects of multipath propagation, interference, and noise in the underwater channel.

- **There are many different ways of combining however we're only talking about three of them here:**
  - Selection combining (SC)
  - Maximal ratio combining (MRC)
  - Equal gain combining (EGC)

- **Selection Combining Mechanism**

Underwater wireless communication systems use selection combining as a combining technique to enhance overall signal quality and counteract fading. Based on a set of criteria, the best signal is chosen among those signals that were received from various antennas or diversity branches. The other signals are deleted, and the chosen signal is utilized for further processing.

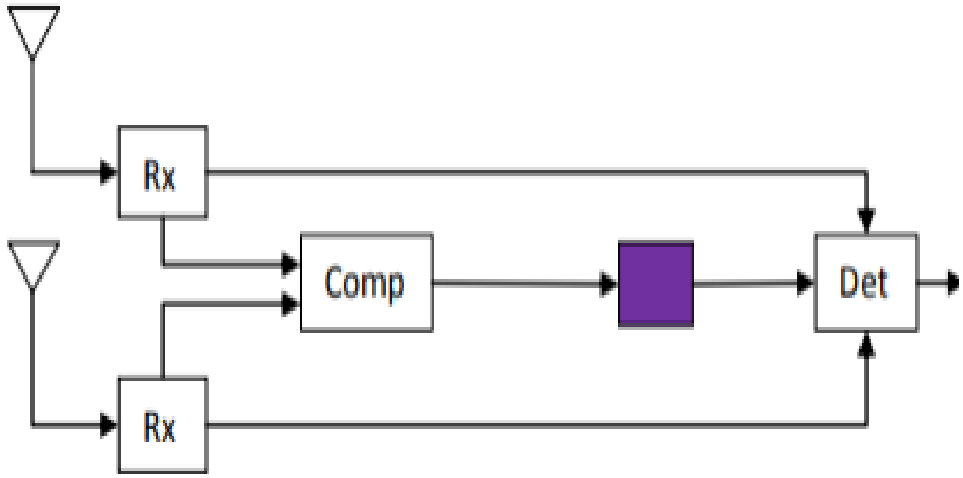

Figure 3: Selection combining (SC)

- **Maximal ratio combining (MRC) Mechanism**

In order to enhance overall signal quality and counteract fading, underwater wireless communication systems often use the combining method known as maximal ratio combining (MRC). Based on the signal intensities of the several antennas or diversity branches that are receiving signals, it entails weighting and merging those signals.

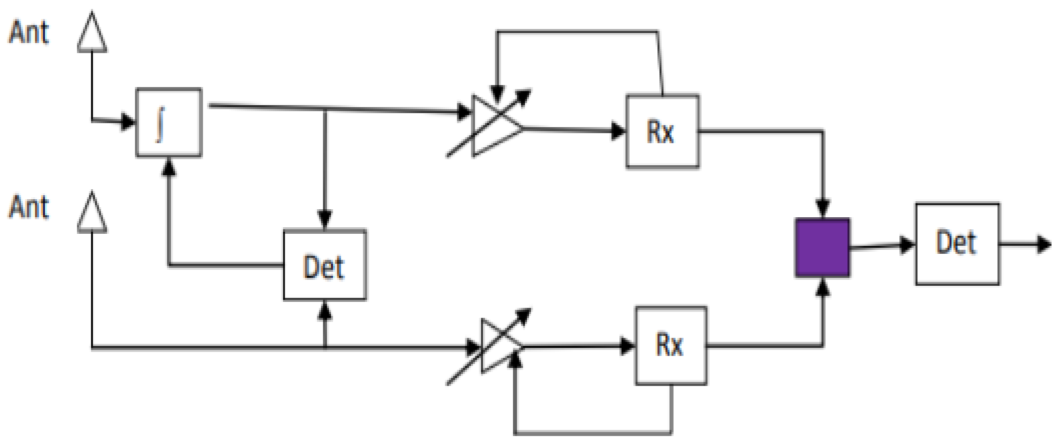

Figure 4: Maximal-ratio combining (MRC)

- **Equal Gain Combining (EGC) Mechanism**

In order to enhance overall signal quality and counteract fading, underwater wireless communication systems employ (EGC), a combining process. An EGC combines received signals from multiple antennas or diversity branches. With equal weights, in contrast to maximal ratio combining (MRC), which weights the signals depending on their signal intensities?

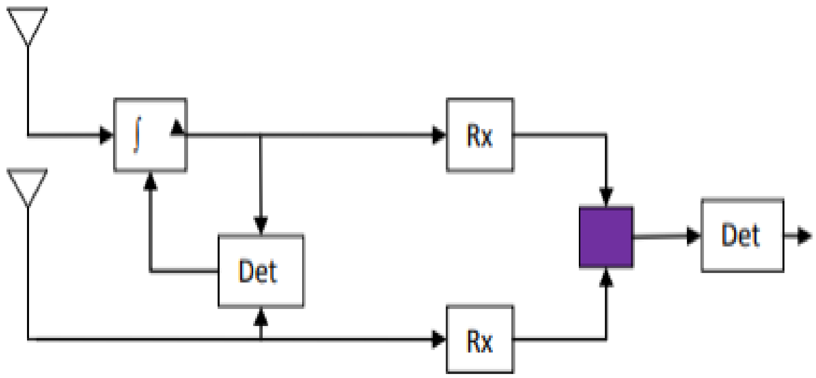

Figure 5: Equal gain combining (EGC)

Each signal branch is equally weighted in accordance with the equal gain combining strategy, which disregards signal loudness. All signals are coherently summed up in this process. EGC's main goal is to raise the SNR on average.

3.3. Simulation Results

One may create a system that benefits from both the IDMA scheme and the underwater channel by combining it with underwater communication. In this example, random interleaver is used. The IDMA scheme with underwater channel and AWGN has been simulated. BPSK is the signaling protocol. The MATLAB platform was used to run every simulation. Here, reducing bit error rate is the major goal. The simulation is run across a distance of 4 km in shallow water that is 40 m deep.One transmitter and a 16-element receiver array sent the signal. When a signal from the hydrophone array is combined, the BER for QPSK without coding at a data rate of 10Kbps is 0.01%. However, error-free transmission was achieved when iterative channel estimation was used.

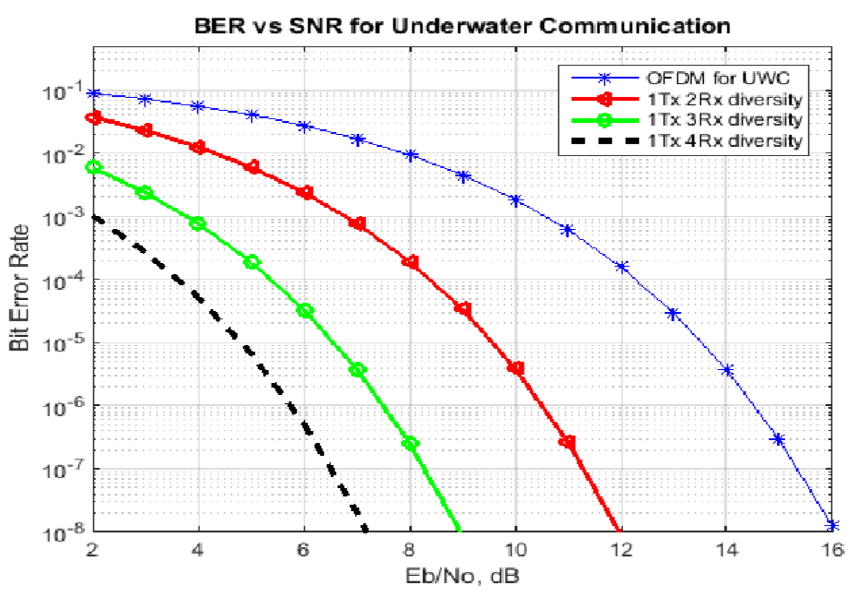

Figure 6: The effectiveness of diversity approaches in terms of bit error rate (BER)

On IDMA systems with random interleavers (RI) for 15 iterations and 512-bit data length, the bit error rate (BER) execution regarding diversity approaches has been tested. Both the diversity approach and no diversity technique were used in the simulation. Following the application of

MRRC diversity methods, BER Performance results illustrate the BER for BPSK modulation in AWGN with receive diversity, demonstrating that MRRC diversity technique with IDMA scheme for underwater communication delivers superior performance results than without diversity. The gain over the single receive antenna scenario in this simulation, which represents the N receive antenna system, is around 10 log10 (N).

4. CHANNEL ESTIMATION BASED RAKE RECIEIVER WITH IDMA SYSTEMS FOR UNDERWATER COMMUNICATION

Due to the unique underwater channel characteristics, including multipath propagation, signal attenuation, and Doppler effects, underwater communication is very difficult. In order to overcome these obstacles, reliable and effective communication technologies that are tailored for underwater conditions must be developed. Underwater communication systems have the potential to perform better when channel estimation methods, the Rake receiver, and Interleave-Division Multiple Access (IDMA) systems are combined. For preventing multipath propagation, the Rake receiver architecture is a popular receiver design. It efficiently reduces the negative effects of intersymbol interference (ISI) by combining the delayed and attenuated multipath components of the received signal using several correlates. The system may enhance the overall signal quality by using the multipath components and the Rake receiver.

4.1. Rake Receiver

Wireless communication systems, especially underwater communication, often use the Rake receiver design. It works especially well to counteract multipath propagation's negative impacts, which are a regular occurrence in underwater channels.

By using several correlators, sometimes known as "fingers," the Rake receiver makes use of the multipath components of the received signal. Each Rake receiver finger compares the signal being received with a duplicate of the sent signal that has been delayed and muted. The various multipath components of the channel are correspondingly represented by these delays and attenuations.

Each model assumes a relentless gain constant; therefore a gain claim agent is not required. Since the gain's total values are positive, the model has no phase change, hence a section adjustor is not present.

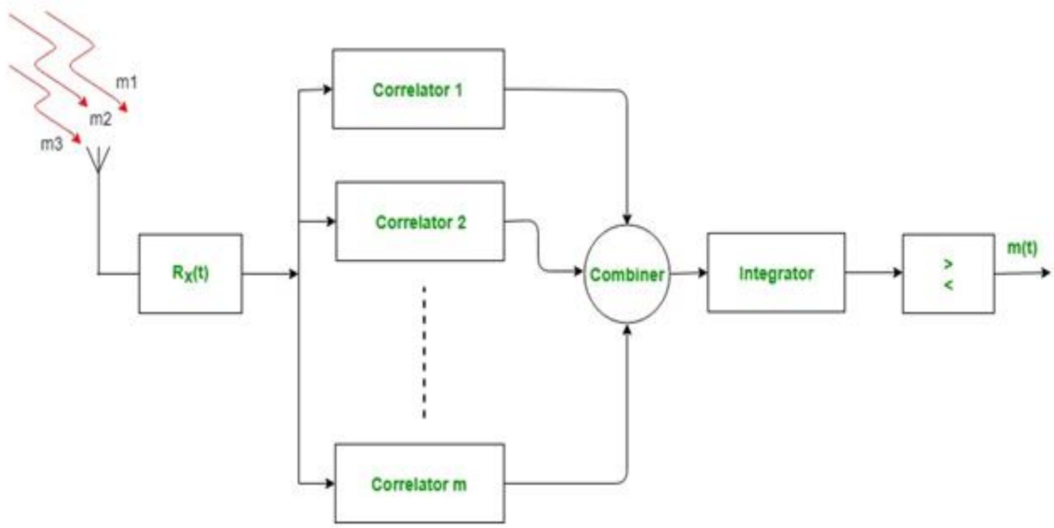

Figure 7: Diagram of the RAKE Receiver in Block

In the RAKE receiver, each correlator has a time shift included into it. The correlator's time shifts should ideally correspond to the multipath components' delays. The 'M' strongest multipath segments are independently identified by a Rake receiver by use of multiple correlators. Every correlator's o/p is weighted to create a considerably more accurate assessment of the transmitted signal than one element can. The weighted outputs of the M correlators are then used to facilitate demodulation and bit selections.

4.2. IDMA Receiver With Soft Rake Structure

For underwater communication systems, a particular receiver design known as the IDMA (Interleave-Division Multiple Access) receiver with a Soft Rake structure combines the advantages of IDMA with the Rake receiver. With this design, the system will be able to handle numerous users more successfully and overcome the difficulties presented by underwater channels, which will increase performance and capacity.

The Soft Rake structure is presented in the context of underwater communication to improve the IDMA receiver's handling of multipath propagation and overcoming intersymbol interference. The IDMA receiver design integrates the Rake receiver idea via the Soft Rake structure.

- **The IDMA receiver with Soft Rake structure operates as follows:**
- **Reception and Synchronization:** The receiver receives the signal it has just received and synchronizes time and carrier frequency.
- **User-specific signature sequences and Interleavers detection:** The receiver uses these techniques to identify the transmitted symbols for each user. Usually, a matching filter or correlation approach is used for this operation.
- **Soft Rake Receiver Processing:** The Soft Rake receiver, like the conventional Rake receiver, features numerous Rake fingers for each user. Each Rake finger associates the signal it receives with an abridged and delayed version of the user's signature pattern. The contributions of the individual multipath components are represented by the correlation outputs.
- **Weighting and Combining:** The Rake fingers' outputs are weighted in accordance with the potency of the associated multipath components. To provide a soft approximation of the transmitted symbols for each user, the weighted outputs are merged.
- **Channel Decoding:** Error correction codes are used to properly retrieve the transmitted data after the soft estimates are utilized for channel decoding.

5. CONCLUSION

Underwater wireless communication poses challenges due to the unique characteristics of the underwater environment. To improve reliability and performance, cutting-edge solutions and diversity techniques are employed. These include spatial diversity, time diversity, frequency diversity, polarization diversity, and cooperative diversity. Diversity mechanisms such as selection diversity, switched diversity, equal gain combining (EGC), maximal ratio combining (MRC), and orthogonal space-time block coding (OSTBC) are used to exploit the spatial, temporal, frequency, and polarization diversities in the underwater channel. Combining mechanisms, such as selection combining (SC), maximal ratio combining (MRC), and equal gain combining (EGC), are vital to enhance signal quality and mitigate fading effects. They involve combining received signals from multiple antennas or diversity branches to reduce the negative impacts of multipath propagation, interference, and noise. Simulation results demonstrate the effectiveness of diversity approaches in terms of reducing bit error rate (BER). Combining the IDMA scheme with underwater communication and applying diversity techniques can significantly improve performance, achieving error-free transmission. The channel estimation-based Rake receiver is a popular receiver design for underwater communication systems. It effectively mitigates the negative effects of multipath propagation by combining delayed and attenuated multipath components of the received signal. By utilizing the multipath components and the Rake receiver, the overall signal quality can be enhanced.

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