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An Analysis of Channel Estimation Techniques for Rake Receiver in Underwater Communication Systems

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ABSTRACT

Cellular transmission on land is extremely different from communication underwater because an ocean has separate water columns in each of its parts. A transmitter-receiver pair designed to operate at deep sea level will not function in those regions because the characteristics of the water column that exist between the transmitter and receiver will be drastically different from those present in shallow coastal sites. It is more challenging to establish a communication connection since there are so many different types of water bodies. Acoustics is now the most promising technique being utilized to create UWC connection. This tactic is hampered by the multipath phenomenon, which creates a large delay spread. As a consequence, Inter-symbol Interference (ISI) will become worse and reduce system performance. The spread of the delay will be reduced by using OFDM technology. A better method to lessen error bursts in multi-access underwater applications is provided by OFDM combined with IDMA. This study presents an IDMA-OFDM Simulink model. On the BER graph, which showed a BER v/s SNR plot, its performance was evaluated.

Keywords: Communication, Surface Water, Rake Receiver, IDMA System, Underwater Communication

1. INTRODUCTION

Due to the significant attenuation, multipath propagation, and background noise prevalent in the underwater environment, underwater communication is a difficult undertaking. Researchers have recently devised a number of methods to increase the effectiveness and dependability of underwater communication systems Baosheng L, Jie H, Shengli Z, Ball K, Stojanovic M, Freitag L, Willett P. (2009). Rake receiver-based Interference Division Multiple Access (IDMA) systems are one such method Coates RFW (1989).

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By employing several antennas and comparing the received signals to retrieve the pertinent information, rake receivers are used to address the multipath propagation issue Dixit S, Tripathi P, Shukla M (2015). Using distinct codes to distinguish users, IDMA is a multiple access technology that enables several users to communicate simultaneously on the same frequency channel Hu Z, Zhu G, Xia Y. (2004). Effective underwater communication is made possible by the combination of Rake receivers and IDMA because it lessens the effects of multipath propagation and enables numerous users to transmit data at once Kalaivani D, Karthikeyen S. (2015). Numerous possible uses for this technology exist, including underwater data transfer, monitoring, and exploration Kasiselvanathan M, Kumar NS (2015).

Recent underwater wireless communication solutions have only focused on IDMA or MIMO-OFDM techniques, neither of which is sufficient to minimize the problems with the underwater wireless communication channel Li K, Wang X (2007). FDMD has always been inefficient and hampered by its bandwidth limitations when used for underwater communication. Early underwater wireless communication methods could address fading concerns to some extent, but they couldn't cut down on bandwidth use or boost data transmission Manikandan C, Neelamegam P, Divya (2015). A superior technology than what was previously available is MIMO-OFDM with IDMA. One of the modulation technologies most frequently used in the most recent generation of underwater communication systems is OFDM. Using the OFDM technique, a data stream traveling at a high bit rate can be split into numerous smaller streams in the sub channel Meng X, Wu S, Kuang L, Ni Z, Lu J. (2014). In underwater wireless communication networks, the MIMO strategy is being used to significantly enhance spectrum bandwidth while retaining the integrity of communication channels Paulraj AJ, Gore DA, Nabar RU (2004). In order to lessen the fading brought on by the addition of numerous routes and interference from another user on the frequency where they are both operating, this strategy is now being researched Sayeed AM, Brady JH. (2015). Different diversity techniques are applied to generate and receive copies of the provided signal at the receiving end. Recent research on the underwater wireless IDMA system has shown that IDMA performs better than any other multiple access techniques currently in use. To evaluate the efficiency of the IDMA system, we test various approaches, including random interleave algorithms and tree-based interleaved algorithms. The random interleaver method beats all other methods in the underwater communication channel in terms of BER performance.

Finally, by increasing the accuracy and effectiveness of data transfer, Rake receiver-based IDMA systems have the potential to transform underwater communication. These technologies may be developed further and become essential tools for a variety of underwater applications.

1.1.PROBLEM STATEMENT

Addressing the difficulties brought on by the underwater environment is the statement of the problem for Rake receiver-based IDMA systems in underwater communication. It is challenging to establish dependable and effective communication in the underwater environment because to

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the high attenuation, multipath propagation, and ambient noise. The dependability, bandwidth utilization, and data transfer speeds of the current underwater communication systems are constrained. Therefore, the issue is to create a communication system that is effective and efficient, can overcome the difficulties of the underwater environment, and can deliver dependable and high-speed data transfer. This system should be able to handle numerous users concurrently, mitigate the impacts of background noise, and counteract the effects of multipath propagation. To be useful for underwater applications, the system must also be economical and energy-efficient. Researchers must create novel methods that use Rake receivers and IDMA to solve this issue and enhance the functionality of underwater communication systems. These methods must be able to address the particular difficulties posed by the underwater environment and be flexible enough to be used in a variety of underwater applications. Further study is required to investigate the potential of this technology and enhance its functionality.

2. OVERVIEW OF INTERLEAVE DIVISION MULTIPLE ACCESS SCHEME FOR UNDERWATER COMMUNICATION

2.1.INTRODUCTION OF INTERLEAVERS

An interleave is a method used in information theory and communication engineering to change the sequence of bits or symbols in a data stream. An interleave is primarily used to spread out and add redundancy to any transmission faults. In communication systems that transmit data over noisy channels, such wireless or satellite channels, interleaves are frequently used. The impact of burst mistakes can be lessened, and the likelihood of error correction can be increased, by interleaving the data. Block interleaves, convolutional interleaves, and turbo interleaves are a few examples of interleaves. The symbols within each block are permuted using block interleaves, which divide the input data into blocks. Convolutional interleaves permute the symbols in a sliding window form using a shift register Schmid TM, Cox DC (1997). Turbo interleaves, which are utilized in turbo coding, use several interleaves concurrently to improve error correction performance. Among the various uses of interleaving in contemporary communication systems are digital television, satellite communications, and mobile networks.

Random Interleaves

Uneven interleavers are among the most well-known and important interleavers used in cutting-edge multiple entrance systems, such as IDMA and coordinated IDMA (IIDMA) systems. The use of arbitrary interleavers is practically analogous to the use of irregular stages to rearrange the components of an informative index.

2.2.IDMA (INTERLEAVE DIVISION MULTIPLE ACCESS)

Introduction of Interleave Division Multiple Access (IDMA)

A multiple access scheme known as "Interleave Division Multiple Access (IDMA)" uses interleavers as a solitary technique of splitting the signal from distinct users. A user specified spreading grouping is not used in the IDMA system, which is unusual for a CDMA system. With regard to availability improvements, the (IDMA) technique was developed as the much relevant ideas Shukla M, Srivastava VK, Tiwari S. (2009). The IDMA machine is accounted for to have a greater bit error rate (BER) than traditional CDMA. System has unparalleled blurring and interference power. At a brilliant BER stage, it also creates a simple CBC-MUD (chip-by-chip) design. For multi-way channels using IDMA, the MUD calculation's user complexity is considerably lower. In all systems administration scenarios, the CBC-MUD component provides more accurate results for larger populations of users.

The CDMA system's most well-known method for addressing burst problems is interleaving. In any case, user-explicit interleavers are made using symmetric interleaving algorithms in the IDMA plot for a variety of purposes.

As a change regulation, "interleaving" is said to scratch information at several locations. Information was initially interleaved on a transmitter in the field of correspondences designing, and with the help of user-explicit interleavers, the received information is appropriately interleaved. An effective IDMA-reasonable symmetrical interleaver should produce outcomes like execution ease with little hassle and minor errors. Since the IDMA system for user division uses least collisions among user-explicit interleavers, these measures are regarded as significant ones Yang H. (2005).

2.3.IDMA SCHEME AND SCIENTIFIC MODELING FOR SINGLE PATH AND MULTIPATH CONDITIONS

The IDMA (Interleave Division Multiple Access) communication scheme uses interleaving techniques to increase the capacity and reliability of remote communication way. In an IDMA system, several users share a common frequency band and window of time. In a creative example, the data from each user is mixed together to prevent user tampering. A spreading code that is a new code assigned to each user is still deciding how to interleave Meng X, Wu S, Kuang L, Ni Z, Lu J. (2014).

Data is sent across a single channel in a single-path IDMA system. The receiver must use the proper spreading code to decode the data from each user that has been interleaved. The transmitted data is identified by the receiver using a soft-decision decoder. The system's performance can be predicted using mathematical analysis and simulation software. Data is transmitted across numerous pathways in a multipath IDMA system, each with a unique delay and attenuation. The receiver must mix the signals from each path and separate the interleaved data from each user using a process called rake reception. To simulate the system's performance in multipath scenarios, channel models like the Rayleigh fading channel model and the Rician fading channel model may be utilized Meng X, Wu S, Kuang L, Ni Z, Lu J. (2014).

3. RESEARCH METHODOLOGY

3.1.OFDM Technique

OFDM is the most used technique for signal transmission over wireless channels. Orthogonal Frequency Division Multiplex was developed with the intention of delivering signals concurrently without inter-symbol interference. When designing a parallel system, crosstalk between close channels is more crucial than channel performance. Due to the high implementation complexity, its use has long been limited. Frequency-selective fading channels are transformed by OFDM into a group of parallel fading subchannels, which simplifies the structure of the receiver. A composite data rate with a lengthy symbol time may be provided via an OFDM system. As a result, inter-symbol interference in a multipath channel with a brief symbol period is made more visible. OFDM is frequently utilized in wireless underwater communication channels. We use OFDM techniques to sustain the channels orthogonally since the undersea spectrum is scattered and the channel divergence is significant. OFDM can divide the wireless spectrum into a number of smaller channels (subcarriers). In Europe, rectangular pulses are frequently employed for digital audio transmission.

3.2.OFDM Modulation Algorithm

The block diagram for OFDM modulation. Prior to changing the message signal Ci[k] from serial to comparable bit, parallel stream data is IFFTed to ensure that all parallel streams are orthogonal. Assuming that m and n are integers and that sin (mt) and sin (not) are orthogonal, the FFT multiplies each parallel stream with a different frequency sinusoidal carrier signal. As shown in the Equation, the channel's signal may be mathematically described. (1). N = 1 and N c (t) = mn (t) sin (2 nt).

The FFT formula is the same when n is an integer and m(t) is the message signal. At the receiver, a parallel stream of serial data is received by an FFT block. Ultimately, the information is changed back into a serial stream, where it is decoded to get the original message signal. Because they are both invertible, FFT and IFFT are interchangeable at the transmitter and receiver. The first noteworthy advance was the introduction of FFT for baseband modulation and demodulation. The number of air thematic operations is reduced from N2 to NlogN using FFT (N is FFT Size). VLSI technology has made it feasible to create high-speed FFT devices. One problem with employing only OFDM to transmit data across underwater channels is doppler distortion. It results in the acoustic sound's frequency bandwidth being non-uniform.

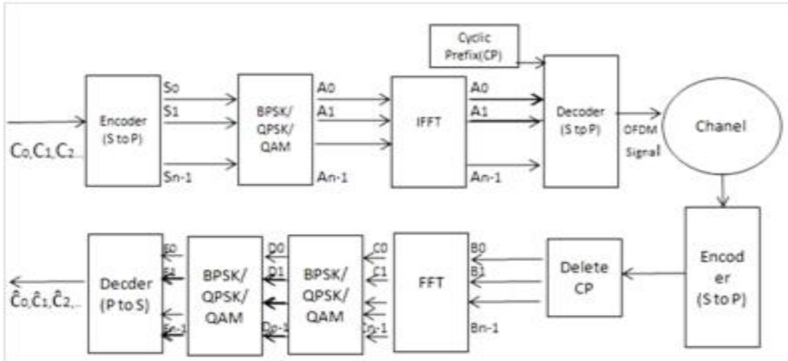

Figure 1: Block diagram of OFDM.

3.3.MIMO-OFDM Technique

Through diversity, the Single-Input-Multiple-Output (SIMO) technology produces but is unable to increase the channel's capacity despite a greater signal. Using MIMO-OFDM, orthogonal frequency division multiplexing simulates wireless technology10. It has been the most widely used technology in terms of how well it performs in various channel conditions and at low data rates. When two signals are transmitted simultaneously using the Multiple-Input-Single Output (MISO) technique, the channel capacity is not increased at aLL. Antenna configurations with many inputs and outputs offer increased capacity, spectrum efficiency, and high data rates all at once. High data rates were delivered using the OFDM technology in parallel, low-rate sub-streams. Figure 2 displays a MIMO block diagram.

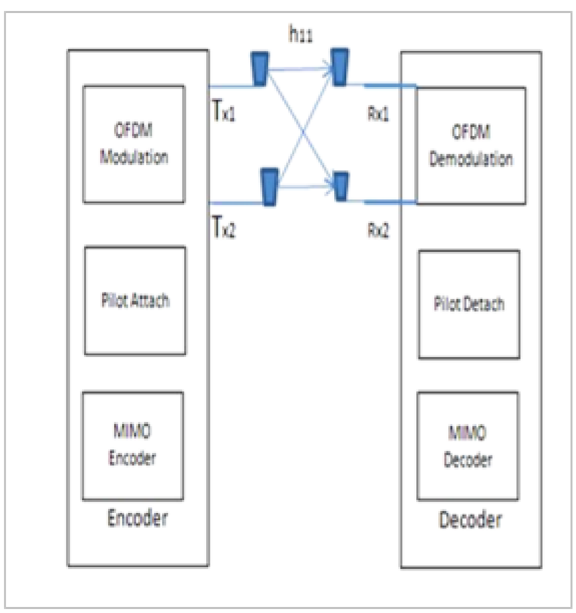

Figure 2 displays a MIMO block diagram.

3.4.IDMA Scheme

Multiple transmitters and receivers may communicate over the same multiple-point transmission medium using the access technique in wireless communication. The Multiple Access Protocol and Control (MAC), commonly referred to as the multiple access control idea, is also employed in the channel access scheme. Concerns like link reply, address the point, multiple channel allocation, and collision avoidance are all covered by this protocol. The terms "multiple access techniques" refer to the Interleaver Division Multiple Access (IDMA), FDMA (Frequency Division Multiple Access), TDMA (Time Division Multiple Access), CDMA (Code Division Multiple Access), SDMA (Space Division Multiple Access), and CDMA (Code Division Multiple Access). There is a lot of noise and a very poor data rate on underwater wireless communication channels. A lot of people are trying to utilize the channels at once, and the data rate is poor. For frequent trips to channels with high data rates and little fading problems, we advise using the IDMA approach. A technique of interleaving is the IDMA scheme. 13. The interleaving algorithm restructures the input data stream so that subsequent bits are divided among different groups of blocks and move in accordance with a known pattern. The interleaved data stream was put back in order at the receiving end using a deinterleave. The greatest results for error correction are achieved when related noise is not dynamically independent at the receiver. For underwater wireless communication, a variety of interleave algorithms have been utilized, including Prime interleaves, Tree-based interleaves, Master Random interleaves, and Random interweavers.

Equation 1 below illustrates how the one-to-one index mapping function represents an interleaver:

$$\prod(B\ B): j = \prod[i] \qquad (1)$$

Where terms "where term i' and j" are indices of an element of the original sequence a" and an interleaved sequence "P," respectively. The order set for the mapping function known as the interleaving vector is Equation (2).

$$\prod = [\prod[0], \prod[1] \dots \prod[N-1] \qquad (2)$$

Equation (3) shows the kth part of the series P that has been switched around. Term i' and j' are the numbers of the kth element in the original sequence A and the kth element in the permuted sequence P, respectively. The order set for the mapping function known as the interleaving vector is Equation (2).

$$Pk = C \prod[k] \qquad (3)$$

As a result, subscripts that are either created by the PSE or the DECs are used to further identify the LLRs. The received channel output DESs are built using deinterleaved output PSE blocks in the PSE portion.

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4. RESULTS & DISCUSSION

The AUV Fest in Panama City, Florida, in June 2007 served as the setting for gathering the experimental data for this test. The water was 20 meters deep. Two antennas were put in the air about 9 meters below a surface float. A boat was around 9 meters below the receiving array. Four of the 16 hydrophones on the vertical array's 2 meters of aperture were utilised by us. Here, we present the performance findings for 500- and 1500-meter transmission distances. Table I is a list of the important system parameters.

Table: 1. System Parameters for Auv07

Sampling rate	$f_s = 96\ kH_z$
Center frequency	$f_c = 32kH_z$
Signal bandwidth	$B = 12kH_z$
OFDM block duration	$T = 85.33ms$
Guard interval	$T_g = 25ms$
Subcarrier spacing	$\Delta f = 11.72H_z$
Number of subcarriers	$K = 1024$
Number of data carriers	$K_d = 672$
Number of pilot carriers	$K_p = \frac{K}{4} = 672$
Number of null subcarriers	$K_n = 96$
Spectral efficiency (two transmitters, QPSK modulation, rate ½ coding)	$a = 1.015\ bits/s/H_z$
Data rate	$R = 12.18\ kb/s$

a) Channel profiles via preamble correlation

The preamble for synchronization is a signal that is linearly frequency-modulated (LFM). Figure 2 for the 500 m instance and Figure 3 for the 1500 m example both display the correlation results. As expected, the 500-m channel has a bigger delay spread than the 1500-m channel.

b) CFO and channel estimation

The CFO estimates for one data packet on one receiver are shown in Figure 4. The reason the CFO is between [-2] and [2] Hz is because the sender and receiver are moving with the waves. Figure 5 shows the predicted channel for a single OFDM block. It matches the channel features in Figures 2 and 3 very well. It is clear that there is more energy in the duct for the 500 m case. We can guess 128 channel taps in discrete time, with Kp/2 = 128 subcarriers for each channel estimate. This gives us a delay spread of 10.7 ms. So, all entries after 10.7 ms will be thought of as extra noise. Figure shows that the noise floor at 500 m is about 8 dB higher than that at 1500

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m because there are a lot of arrivals after 10.7 ms on the channel at 500 m. Even though the signal energy at 500 m is higher than at 1500 m, the pre-demodulation (SNRs) become the same in both cases. To figure out the pre demodulation SNR, take the average signal energy on the pilot subcarriers and divide it by the average energy on the null subcarriers.

5. CONCLUSION

Considering the ideal value for several parameters such the number of iterations, the length of the data, the size of the block, and the spread length. Better performance on underwater wireless communication channels is provided by OFDM-MIMO with IDMA. This simulation outperforms OFDM-MIMO as a standalone method. This paper introduced a MIMO-OFDM system with spatial multiplexing. For Doppler and channel estimates, the receiver uses subcarriers, and MIMO detection and decoding is accomplished using an iterative framework. We talked about the performance results based on data processing from three different tests, which showed that using parallel data sharing with high order groups made the most of the spectrum. Based on the results of these tests, MIMO-OFDM looks like a good choice for high-speed underwater voice transmissions. Capacity limits in underwater channels, complex receiver designs, and trial results in increasingly difficult channel conditions with large Doppler spread all call for more study on MIMO underwater audio communications, both single-carrier and multi-carrier methods.

References

1. Baosheng L, Jie H, Shengli Z, Ball K, Stojanovic M, Freit- ag L, Willett P. MIMO-OFDM for high-rate underwater acoustic communications. IEEE Journal of Oceanic Engi- neering. 2009; 34(4):634–44.
2. Coates RFW. Underwater Acoustic Systems. Wiley; 1989.
3. Dixit S, Tripathi P, Shukla M. SC-FDMA-IDMA scheme for underwater acoustic communications. IEEE Communica- tion, Control and Intelligent Systems (CCIS); 2015 Nov 7-8.
4. Hu Z, Zhu G, Xia Y. Multiuser subcarrier and bit allocation for MIMO-OFDM systems with perfect and partial chan- nel information. IEEE Wireless Communications and Net-working Conference; 2004 Jul 21-25.
5. Kalaivani D, Karthikeyen S. VLSI implementation of ar- ea-efficient and low power OFDM transmitter and receiv- er. Indian Journal of Science and Technology. 2015 Aug; 8(18):1–6.
6. Kalaivani D, Karthikeyen S. VLSI Implementation of ar- ea-efficient and low power OFDM transmitter and receiv- er. Indian Journal of Science and Technology. 2015 Aug; 8(18):1–6.
7. Kasiselvanathan M, Kumar NS. BER performance analy- sis and comparison for large scale MIMO Receiver. Indian Journal of Science and Technology. 2015 Dec; 8(35):1–5.

8. Li K, Wang X, Ping L. Analysis and optimization of inter- leave-division multiple-access communication systems. IEEE Transactions on Wireless Communications. 2007; 6(5).
9. Manikandan C, Neelamegam P, Divya E. OFDM techniques for MIMO-OFDM system: A review. Indian Journal of Science and Technology. 2015 Sep; 8(22).
10. Meng X, Wu S, Kuang L, Ni Z, Lu J. Expectation propa- gation based iterative multi-user detection for MIMO-ID- MA Systems. IEEE 79th Vehicular Technology Conference; 2014.
11. Paulraj AJ, Gore DA, Nabar RU, Bolcskei H.An over view of MIMO communications- A key to gigabit wireless. Pro- ceedings of the IEEE. 2004; 92(2).
12. Sayeed AM, Brady JH. High frequency Differential MIMO: Basic theory and transceiver architectures. IEEE Interna- tional Conference on Communications; 2015Jun. p. 8–12.
13. Schmid TM, Cox DC. Robust frequency and timing syn- chronization for OFDM. IEEE Trans Commun. 1997; 45(12):1613–21.
14. Shukla M, Srivastava VK, Tiwari S. Analysis and design of optimum interleaver for iterative receivers in IDMA scheme. Wiley Journal of Wireless Communications and Mobile Computing. 2009; 9(10):1312–7.
15. Yang H. A road to future broadband wireless access: MI- MO-OFDM-based air interface. IEEE Communications Magazine. 2005; 43(1):53–60.