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A Bird Eye View on MIMO OFDM for Under Water Acoustic Communication

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***Abstract*—The underwater acoustic channel (UAC) is known to supply poor communications channel. The channel medium is extremely assimilative and therefore the transmission bandwidth is proscribed. Additionally, the channel is extremely frequency selective; the degree of selectiveness depends on a detailed geometry of the channel. Further, the response changes over time as conditions moving the response (such as water temperature, ocean surface wind, salinity, etc are time-varying. A system design to trot out the frequency and time selective channel in UAC, therefore, becomes terribly difficult. In this review paper review of different technique used in the SWAC in shallow water communication region. The performance parameters of different methods are, first one is the bit error rate (BER) and second one is the frame error rate (FER).**

***Keywords*— SWAC, UWAC, FER, BER. MIMO, OFDM, LDPC, etc.**

I. INTRODUCTION

During the last years, underwater communication has become a dynamic field of analysis as there's still a huge gap between the communication technology for terrestrial and underwater application [1-4]. Researchers and scientists have overtimes placed a considerable work discovering the underwater world. The provision in underwater technology helps robot to know higher concerning subordinate in underwater abode that has completely dissimilar setting in terms of its landscape, creatures, composition and physics. The rising demand for analysis of underwater application has drawn the interest of many sectors and industries round the world; government, primarily based or non-public sector. Among the sectors that benefited a lot from the development of this technology are military, oil and gas industries, fisheries, underwater instrumentation corporations, analysis agency etc. Works like seismic observance, underwater golem operation, underwater police investigation and detection, ocean exploration, ocean mapping and information assortment are becoming easier because of this improvement [1-4]. Communication is the most significant method in underwater technology. The strategy permits the information transfer between transmitter and receiver or additional teams. This information is used for navigation, plan of action ways, monitoring, identification etc.

Communication may be recognized either by wired or wireless association. Each strategies have their own benefits and downsides, reckoning on the appliance. The current trend has opted wireless communication because the most well-liked manner, particularly once it involves contend with the depth, that word association isn't sensible or not possible.

1.1 MIMO-OFDM

The major challenges in future wireless communications system design are increased spectral potency and improved link responsibility. The wireless channel constitutes a hostile propagation medium that suffers from weakening (caused by harmful addition of multipath components) and interference from different users. Diversity provides the receiver with many (ideally independent) replicas of the transmitted signal and is thus a strong means to combat weakening and interference and there by improve link responsibility. Common sorts of diversity are time diversity (due to physical spread) and frequency diversity (due to delay spread). In recent years the utilization of abstraction (or antenna) diversity has become very popular, that is because of the fact that it can provide replicas with no loss in its spectral potency. Receiver diversity, that is, the utilization of multiple antennas on the receive facet of a wireless link, may be a well-studied subject [1].

Driven by mobile wireless applications, wherever it's difficult to deploy multiple antennas within the handset, the utilization of multiple antennas on the transmit facet combined with signal process and cryptography has become acknowledged under the name of space-time continuum cryptography [2–4] and is presently a full of life space of analysis. The utilization of multiple antennas at each ends of a wireless link (multiple-input multiple-output (MIMO) technology) has recently been incontestable to possess the potential of achieving extraordinary knowledge rates [5–9]. The corresponding technology is understood as abstraction multiplexing [5,9] and provides increase in spectral efficiency. Most of the previous implimentation of MIMO wireless has been restricted to narrowband systems. Besides abstraction diversity broadband MIMO channels, however, provide higher capability and frequency diversity due to delay unfold. Orthogonal frequency division multiplexing (OFDM) [11, 12] considerably reduces receiver quality in wireless broadband systems. The utilization of MIMO technology together with OFDM, i.e., MIMO-OFDM [8, 9, 13], thus appears to be an attractive resolution for future broadband wireless systems.

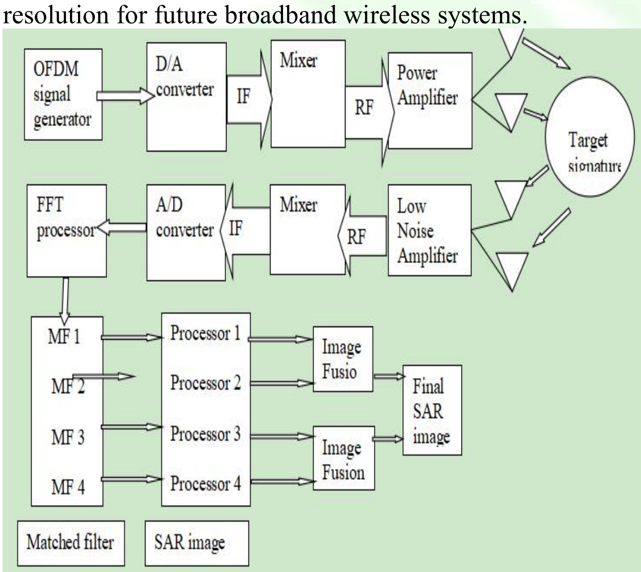


Fig. 1: Block Diagram Of MIMO-OFDM

1.2 Working Principle of MIMO

Traditional radio system either do nothing to combat multipath interference, relying on the primary signal to muscle out the interfering copies or employ mitigation techniques. One technique uses a no. of antennas to capture the strongest signal at each moment in time. All techniques assume that the multipath signal is harmful and strive it to limit the damage.

- On the contrary MIMO takes advantage of multipath propagation (direct and reflected signals).
- MIMO uses multiple antennas to transmit multiple parallel signals.
- In an urban environment, signals will bounce off trees, high rise buildings and reach the receiver through different path.
- Receiver end uses an algorithm / DSP to sort out the multiple signals to produce one signal having originally transmitted data.
- Multiple data streams are transmitted in a single channel at the same time and at the receiver multiple radios collect the multipath signal.
- MIMO OFDM uses IFFT in the transmitter and FFT in the receiver.
- MIMO increase range, throughput and reliability.

1.3 Multipath Propagation

In wireless communications, fading refers to a time-varying, frequency dependent, loss of received signal strength. Fading can be multipath induced or due to shadowing from objects obstructing the signal path. Multipath propagation occurs when numerous versions of a transmitted signal reach the receiver along different propagation paths. The received duplicates of the original signal can encounter different time-delays, attenuation, phase shifts and frequency shifts. These signals superimpose to form a resultant signal of greater or lower amplitude, a phenomenon called interference. As a consequence of the coalescing signals, the received signal is often highly distorted.

In the underwater environment, surface and bottom reflections contribute to severe multipath distortion. To predict the effects of multipath propagation we construct a simplified model of a typical worst case underwater channel. Let us consider a semi-infinite water body with is velocity. Straight-line ray traces can be used to identify propagations paths between the transmitter and receiver. These paths are called Eigen paths. By calculating the distance of each eigen path and dividing it by the sound velocity, we can determine the time spreading of reflections arriving at the receiver. If we take into account that no bounding surface is completely smooth and lossless, an incident wave will suffer partial scattering and absorption by the receiving medium.

1.4 Doppler Effect

The Doppler Effect describes the shift in observed frequency of acoustic waves when a transmitter and receiver are in motion relative to each other and/or the medium. The observed frequency will be higher as the transmitter and receiver approach each other and lower as they depart. Depending on the movement of the transmitter and receiver the Doppler Effect can vary in its occurrence. A stationary transmitter will emit acoustic waves with uniform wavelength in all directions, while a moving transmitter will create a wave field with wavelengths dependent on direction. We recognize two cases of the Doppler Effect: one-way propagation where the received signal is from a remote transmitter and two-way propagation where the received signal is echoed from an object. The frequency shift from two-way propagation is often used in sonar applications to determine the velocity of an object. One-way propagation is primarily applicable to communication channels, although two-way propagation can occur when the signal is reflected from a moving object.

II. Literature Survey

The Altabbaa, M. T. (2020, December), This research work presented a new sparse channel estimation algorithm for underwater MIMO OFDM-based communications systems with Alamouti's SFBC transmit diversity. Utilizing the OMP algorithm for initialization, the proposed double focusing algorithm utilizes two continuous functions for the estimation of the complex underwater channel parameters. The simulation results show that, optimization utilizing the presented continuous functions allows the algorithm to estimate better channel coefficient values and guarantees the estimation of an unreachable coefficients. Simulation results depicted in this paper show that the behavior of the presented approach outperforms the OMP and GAMP algorithms in the MSE and SER **[01].**

Lee, H. S., et. al (2019, July), In this research work presented, AMC technique is an attractive method for acoustic communication that improves system efficiency by changing transmission parameters according to channel conditions in rapidly changing underwater acoustic channel. In AMC technique, it is very important to select the transmission mode according to the channel environment. In this research work, four modes are constructed through convolutional code (1/2, 1/3) and modulation method (BPSK, QPSK). Also, researcher presents the three threshold detection algorithm to determine the transmission mode. Researcher analyzed the relationship between four modes and three threshold algorithms through underwater experiment. Researcher analyzed the optimal thresholds for each mode according to the RSNR, PES and PN BER. As a result, we estimated approximate thresholds in terms of RSNR, PES and PN BER for four modes. Based on these result, it is considered that more accurate threshold value can be determined by comprehensively considering the threshold values of RSNR, PES and PN BER **[02].**

Pranitha, B., et. al. (2018, July), This research work presented, Underwater Acoustic Communications (UWAC) using Multiple Input and Multiple Output (MIMO) system is an emerging technology to enhance the data transmission throughput and allow multiple transmitters to simultaneously communicate in underwater environment. The research work presents the concept and analysis of a 2× 2 MIMO UWAC system, that uses a 4- QAM spatial modulation scheme thus minimizing the decoding complexity and overcoming the Inter Channel Interference (ICI). Bit Error Rate (BER) investigation is carried out over different link distances under acoustic Line of Sight (LOS). The utilization of Zero Forcing (ZF) and Least Mean Square(LMS) equalizers, which estimates the transmitted data proves a success of removing inter symbol interference (ISI) **[03].**

Fauziya, F., et. al. (2017, June), In this research work presented, an AoA based analysis of a compact vector sensor receiver which outperforms the scalar receiver at not extra computational cost. The receiver exploits the intrinsic diversity provided by the vector sensor receiver to operate at an improved SNR. The simulation results clearly demonstrates the superior performance of this compact receiver. This research work also analyses the channel estimation BER vs SNR plot of various receivers. techniques and shows the CS based channel estimation offers performance advantage over traditional LS estimation**[04].**

Shingo Yoshizawa, et. al., 2016, This research work presented Underwater acoustic communication is used for remote control and data transmission in autonomous underwater vehicle (AUV) and underwater sensor networks. It is difficult to keep communication reliability under multipath environment, where a delay wave interferes in a desired wave due to reflections from water bottoms, surfaces, and obstacles. Orthogonal frequency-division multiplexing (OFDM) is attractive for making use of frequency domain equalization (FDE). OFDM inserts a guard interval (GI) into data blocks. A long GI induces a large delay in communication response. They have studied a new scheme of OFDM rake reception to keep stable communication performance even for a short GI.This paper reports experimental results of OFDM rake reception in harbor area comparing with other conventional methods. The combination of OFDM and DSRake has shown the best performance in FER and has increased available data rates two to five times when compared to the other methods **[33].**

Pooyan Amini, et. al 2015, In this research work presented and developed the use of filter-bank multicarrier (FBMC) technique for communications in the underwater acoustic channels.A novel cost function for optimization of the filter-bank prototype filter, to achieve a better performance in doubly dispersive channels, is presented. A design algorithm that optimizes the proposed cost function is then developed. The developed FBMC technique is compared with the orthogonal frequency-division multiplexing (OFDM).Their study shows that in doubly dispersive channels, in terms of signal-to-interference-plus-noise ratio (SINR), FBMC is better than OFDM by several decibels as it compensates both time and frequency spreading that occur in UWA communication where as OFDM compensates only time spreading. Among the various FBMC systems in the literature, They found FMT to be an excellent choice for UWA communications **[32].**

III. MULTIPLE INPUT MULTIPLE OUTPUT (MIMO)

In 1998 Bell Laboratories successfully demonstrated the MIMO system under laboratory conditions. In the following years Gigabit wireless Inc. and Stanford University developed a transmission scheme and jointly held the first prototype demonstration of MIMO. MIMO is an antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination (receiver).The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. MIMO is one of several forms of smart antenna technology, the others being MISO (multiple input, single output) and SIMO (single input, multiple output). For example a 2*2 MIMO will have 2 antennas to transmit signals (from base station) and 2 antennas to receive signals (mobile terminal).This is also called downlink MIMO.

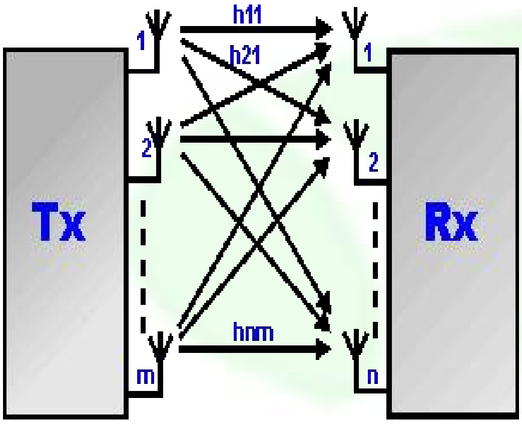


Fig. 2: MIMO System

It is found that the signal can take many paths between a transmitter and a receiver. Additionally by moving the antennas even a small distance the paths used will change. The variety of paths available occurs as a result of the number of objects that appear to the side or even in the direct path between the transmitter and receiver. Previously these multiple paths only served to introduce interference. By using MIMO, these additional paths can be used to advantage. They can be used to provide additional robustness to the radio link by improving the signal to noise ratio, or by increasing the link data capacity. The two main formats for MIMO are given below:

Spatial multiplexing: This form of MIMO is used to provide additional data capacity by utilizing the different paths to carry additional traffic, i.e. increasing the data throughput capability.

Spatial diversity: Spatial diversity used in this narrower sense often refers to transmit and receive diversity. These two methodologies are used to provide improvements in the signal to noise ratio and they are characterized by improving the reliability of the system with respect to the various forms of fading.

As a result of use of multiple antennas, MIMO wireless technology is able to considerably increase the capacity of a given channel while still obeying Shannon's law. By increasing the number of receive and transmit antennas it is possible to linearly increase the throughput of the channel with every pair of antennas added to the system. This makes MIMO wireless technology one of the most important wireless techniques to be employed in recent years. As spectral bandwidth is becoming an ever more valuable commodity for radio communications systems, techniques are needed to use the available bandwidth more efficiently. MIMO wireless technology is one of these techniques.

Two significant advantages of MIMO over SISO/ MISO are as given below:-

1. In MIMO, there is a significant increase in the system's capacity and spectral efficiency. The capacity of a wireless link increases linearly with the minimum of the number of transmitter or receiver antennas. The data rate can be increased by spatial multiplexing without consuming more frequency resources and without increasing the total transmit power.

2. In MIMO, there is a dramatic reduction of the effects of fading due to the increased diversity. This is particularly beneficial when the different channels fade independently.

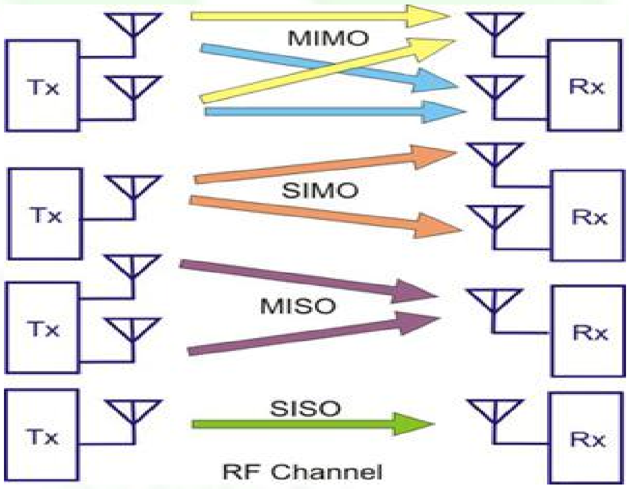


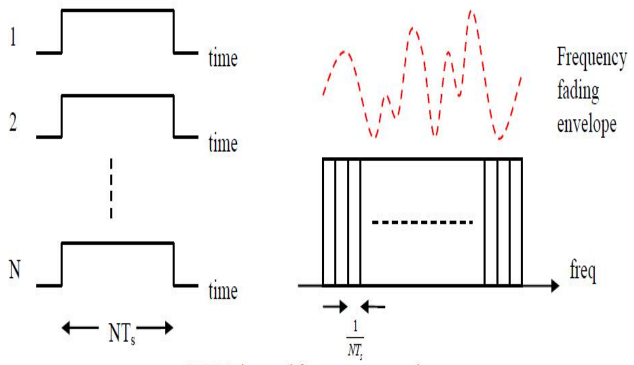
Fig. 3: Diagram Showing MIMO, SISO, MISO AND SIMO

A. Uplink MIMO

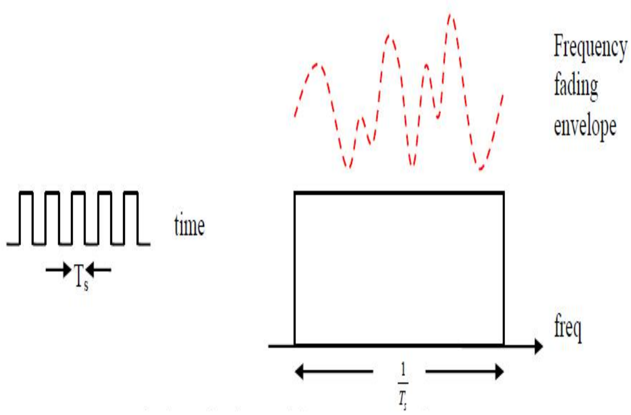
Uplink MIMO schemes for LTE will differ from downlink MIMO schemes to take into account terminal complexity issues. For the uplink, MU-MIMO can be used. Multiple user terminals may transmit simultaneously on the same resource block. This is also referred to as spatial domain multiple access (SDMA). The scheme requires only one transmit antenna at user equipment (UE) side which is a big advantage. The UEs sharing the same resource block have to apply mutually orthogonal pilot patterns. To exploit the benefit of two or more transmit antennas but still keep the UE cost low, antenna subset selection can be used. In the beginning, this technique will be used, e.g. a UE will have two transmit antennas but only one transmit chain and amplifier. A switch will then choose the antenna that provides the best channel to transmit from user equipment to base terminal.

IV. LIMITATIONS IN OFDM

A fuel cell system comprises of four different subsystems such as air flow supply system to the cathode, hydrogen flow supply system to the anode, cooling system, and humidification system. The air flow supply subsystem is used to provide requisite air flow into the stack cathode. Hydrogen flow supply subsystem is used to provide sufficient hydrogen flow into the stack anode. Air temperature will elevate during compressing, so an air cooler is needed to cool the air before it enters the stack. A humidifier is used to add moisture into the air flow to hydrate the proton exchange membrane for higher proton conductivity. Fast changing load profile will cause sudden drop in fuel cell voltage in short span of time. This phenomenon is called fuel starvation process which limits the life cycle of fuel cell. In fuel starvation process, the fuel cell operates at sub-stoichiometric condition. On the cathode side of the stack, the electrochemical reaction occurs between oxygen and protons to form water, together with heatPrevious sections have detailed the advantages of OFDM, however the advantages are offset by some problems that are unique to OFDM, namely time and frequency synchronization problems and non linearities.



OFDM time and frequency properties



Single carrier time and frequency properties

Figure 4: Time And Frequency Properties Of Single Carrier And OFDM Techniques

V. PROBLEMS IN UNDER WATER COMMUNICATION

A. Acoustic Channel:

The underwater acoustic (UWA) channel is quite different from the terrestrial radio channel in many aspects and has more challenges. The UWA channel is affected by noise, multipath, Transmission loss, Doppler spreading and variable delay. This makes underwater acoustic communi--cation challenging and in next sections the limitations that affects the communication will be discussed.

B. Noise

The noise sources in an UWA channels can be divided into ambient noise and man-made noise. The ambient noise is caused by biological creatures, seismic phenomenon and movement of water such as waves. The ambient noise often follows some curves called Knudsen curves. These Knudsen curves show that the ambient noise is being reduced as the frequency increases. According to the curves the ambient noise will be reduced with about 17 dB per decade of frequency, [14]. For high frequencies the thermal noise can be very dominating, especially over 100-200 kHz, where the thermal noise increases with 20 dB per decade. Another source of ambient noise is water bubbles that can a_ect underwater communication. According to [5] in the 10-20 kHz band the dominant noise source may be resonant air bubbles in the area near the surface. The resonant frequency f0 is given by the following equation:

$$fo = \frac{1}{2\pi R}\sqrt{\frac{2\gamma P0}{\rho}} \qquad (1)$$

Here is the ratio of specific heats, P0 is the ambient pressure and γ is the water density. The other source of noise is the so called man-made noise that may be caused by noise from ships, oilrigs and similar. This is especially an important noise source when UWA sensor networks (UWA-SN) is being used for 4D-seismic close to oilrigs.

C. Loss

UWAC-Transmission loss is caused by attenuation and geometric spreading for signals that are transmitted directly to the receiver. Reflected signals will also have transmission loss due to the transmission coefficient, [14]. The geometrical spreading is caused by the movement of the wave-front, and for further distance the wave front is spread over a larger area. There are in general two types of geometrical spreading in underwater acoustic communication: Cylindrical and spherical. Cylindrical spreading is typical for shallow water UWA communication and has only horizontal spreading. Spherical spreading is typical for deep water UWA communication and can be seen as an omnidirectional point source, [2]. Geometrical spreading will cause the acoustic intensity to decrease with increased distance. Cylindrical wave propagation results in the following geometrical spreading of the intensity I(r).

D. Multi Path and time-delay:

Multipath is a huge problem that might affect the communication severely, and will give inter Symbol interference (ISI). How much the multipath will occur depends on many physical factors, but the depth depended sound velocity is most important. In this is illustrated for 5 an depth depended sound velocity that will give a bending of the sound rays in the horizontal direction, as described in [14]. The choice of spacing size between the sensors needs to take this effect into account. Another problem is that the depth depended sound velocity changes through the season and thereby change the multipath through the season making it harder tode sign the UWA-SN system. This may lead to constructive or destructive interference. The received signal may be amplified or it may be reduced depending on the phase of different multipath. Multipath occurs because of reflection of waves from the surface and the bottom. The receiver will receive multiple signals, both direct, and reflected signals from the surface and the bottom. But there may also be several direct waves that may arrive at different times depending on how much the waves have been bend. Large time delay is caused by the fact that the sound speed under water is in the area of 1500 m/s, which is much lower than the speed of radio waves that is approximately 3 _ 108 m/s. In terrestrial radio communication multipath and reflection will not be a problem since the delay is so little, but in UWA communication these delays may arrive very late and cause problem for the communication. This is further complicated by the fact that the delays may vary a lot. Multipath may reduce the data transmission data severely, depending on how the receiver deals with different multipath.

VI. CONCLUSION

In this survey paper, we studied the basic system model of underwater acoustic channel communication in which the transmitter, channel capacity and estimation, receiver, main characteristics of acoustic channel losses in underwater acoustic communication as transmission loss, absorption, attenuation noise (ambient & Gaussian). Low frequency is less than 500 Hz and high frequency is more than 500 Hz. The importance of each effect for system design depends on both its impact on communication performance and frequency of occurrence. We should take more values reported propagation effects and channel characterizations should be adopted as being typical for underwater acoustic communication channels.

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