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CDMA2000 FOR UNDER WATER ACOUSTIC COMMUNICATION SYSTEM

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ABSTRACT

During the last few decades, the growing interest in the conditions and resources of the oceans has driven many researchers to investigate the reliability of the Under-Water Acoustic (UWA) channels as a communication medium. This channel is one of the most complex and hostile environments to be encountered for the transmission of data. Many applications such as offshore exploration, seismic monitoring, oceanographic data collection, disaster prevention, equipment monitoring etc. can be carried out by means of underwater sensor networks. For making these applications capable, we have to include underwater communications among these underwater devices. In this paper a successful attempt was made to design MIMO- CDMA2000 system for underwater Acoustic (UWA) Communication using MATLAB/SIMULINK Tools. It consists of various sections which perform different functions. The performance of the designed system has been checked in terms of Bit Error Rate (BER).

Key Words-Acoustic Communication, CDMA2000, MIMO, Diversity and Bit Error Rate.

I. INTRODUCTION

Underwater acoustic networking field is rapidly growing because of the role it plays in commercial and military applications. A large number of sensors and vehicles are connected together to form a network called as Underwater Acoustic Sensor Networks. These networks work together for performing the monitoring task within a given volume of matter .For achieving these objective sensors and vehicles make autonomous network by self-organizing themselves in a way so as to adapt to changing characteristics of ocean environment. Underwater acoustic propagation channel is affected by high delay and delay variance, Doppler spread[1], Path Loss, noise[2] and multipath propagation. As a result protocol design for underwater acoustic sensor networks face multiple challenges across various layers of networking protocol stack.

In radio channel the propagation speed is five times greater than the propagation speed of the UW-A channel. Due to this delay in propagation speed the throughput of the system gets reduced considerably. For efficient protocol design this high delay variance proves to be harmful. Doppler frequency spread causes degradation in performance of digital communication. This conversion of acoustic energy into heat results in attenuation of signal. The attenuation is also caused by refraction ,scattering and reverberation (on rough ocean surface and bottom) and also due to dispersion (due to displacement of the reflection point caused by wind on the surface).Water depth plays an important role in determining the attenuation. The other factor which affects the propagation channel is noise. Noise can be man- made or ambient i.e., the noise is caused due to biological and seismic phenomena. In [2], noise caused due to boat and snapping shrimps in shallow water have been found to be the primary source of noise due to experiments performed on the ocean bottom. Multi-path generates Inter Symbol Interference (ISI) which degrades acoustic communication signals. The multi-path geometry is dependent on the link configuration. Vertical channels have extremely little time dispersion, while as horizontal channels are characterized by long multi-path spreads. The spreading extent is mainly a strong function of the depth and the distance between the transmitter and the receiver.

In this paper, multiple input-multiple output MIMO- CDMA2000 system for underwater Acoustic (UWA) Communication was designed using MATLAB/SIMULINK Tools. The authors being from the communication fields were moved by this application due to the recent devastation caused by the water movements that could not be predicted well in advance in India and abroad. In last few decades there has been a great progress in the wireless communications using radio frequency. However, the underwater communications didn't grow so fast and nowadays there is a great demand in the market to improve this technology. The work presented is an attempt towards the improvement of underwater communication utilizing the existing technology. In this work the combined advantages of Code Division Multiple Access (CDMA),Multiple Input Multiple Output (MIMO) has been exploited for underwater communication. The explanation of both the techniques has been covered in this paper. The complete architect of the underwater communication system has been demonstrated and performance is checked in terms of its Bit Error Rate (BER).

II. Theoretical background

A. Underwater modulation techniques

Various types of modulation techniques are used for underwater acoustic communication. The use of a modulation technique depends on the application for which it is used and the environment it is operated. Thedetail of various modulation techniques used is:

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1) *Frequency Shift Keying (FSK) modulation:*

This modulation is based on energy detection and hence phase tracking is not required in this modulation. Multi-path effects are suppressed for FSK modulation methods tailored for underwater. This is done by inserting time guards. These time guards are inserted between the successive pulses so that the reverberations vanish before subsequent pulses are received.

2) *Non-coherent modulation*

Since non-coherent demodulators are having the inherent disadvantage of high bit error rate and low bandwidth efficiency. To mitigate the ISI channel equalization techniques are widely used. DFE types of channel equalizer are relatively used in slow varying channel response and therefore are having the high through put[3].

3) *Differential Phase Shift Keying (DPSK)*

In terms of bandwidth efficient this modulation scheme lies halfway between incoherent and fully coherent systems. Each information symbol in DPSK is encoded relative to the previous symbol instead of some randomly chosen fixed threshold and is thus referred to as partially coherent modulation. In this way the carrier phase tracking becomes easy, but all this comes at the cost of increased error rates then PSK at the same data rate [4].

4) *Orthogonal Frequency Division Multiplexing*

OFDM spread spectrum technique is particularly efficient when noise is spread over a large portion of the available bandwidth. OFDM is a multi-carrier modulation wherein the data is transmitted over multiple sub-carriers simultaneously. The carriers used are orthogonal to each other which allows for overlapping amongst the sub-carriers as long as orthogonality is maintained. In OFDM system if there is a deep fade only a small percentage of these sub-carriers is effected which can also be corrected using some error correction technique . Thus OFDM systems perform robustly in severe multi-path environments, and achieve a high spectral efficiency [5].

B. Underwater Multiple Access techniques

Underwater multiple access techniques poses additional challenges because of the peculiarities of the underwater channel, in particular limited bandwidth , and high and variable delay.

1) Frequency Division Multiple Access (FDMA)

Narrow bandwidth of UW-A channel and errors in the limited band system caused by fading and multipath effects make FDMA technique unsuitable for the UW-ASNs.

2) Time Division Multiple Access (TDMA)

In UW-A channel long time guards are required which reduces the bandwidth efficiency of TDMA. Therefore long time guards must be designed. This will account for the large propagation delay and for the delay variance of the underwater channel. This will minimize the packet collision between the adjacent time slots.

3) Carrier Sense Multiple Access (CSMA)

CSMA is another multiple access technique which avoids collisions with the on-going transmission at the transmitter side. To prevent collisions at the receiver side , however, it is necessary to add guard time between transmissions dimensioned according to the maximum propagation delay in the network. This makes the protocol intensely inefficient for UW-ASNs .The use of contention- based technique that rely on handshaking mechanisms such as RTS/CTS in shared medium access is impractical in underwater.

C. CDMA2000

CDMA systems based on CDMA2000 standards are capable of using distinct carrier configurations, employing carriers with bandwidths of 1.25 MHz (backward compatibility to CDMA IS-95 systems) and 3.75 MHz (to achieve data transmission rates compatible to 3G requirements)[6].

The need of increasing system capacity (voice and data traffic channels) has motivated theimplementation of additional logical channel types. To allow smooth system backwards compatibility, some of the original logical channels were kept. The use of cdma2000 channels, however, depends on new characteristics, such as Radio Configuration (RC) and Spreading Rate (SR). There are ten RCs for the forward link and six RCs for the reverse link [7].

D. Multiple Input Multiple Output (MIMO)

MIMO technique refers to the utilization of more than one antenna at both ends of (wireless) communication. MIMO exploits multipath propagation to increase the channel capacity which otherwise is perceived as a severe problem in wireless communication. MIMO is one of the possible solutions to spectrum scarcity. The MIMO can also be thought of as multi-dimensional wireless communication system. Better spectral efficiency, enhanced data rates, greater range, an increased number of users, high reliability or any combination of the above mentioned factors can be achieved by the MIMO technology. By increasing the spectral efficiency, MIMO in combination with OFDM and CDMA has opened the door to a variety of new applications and allowed more economical implementation for existing applications. MIMO is under significant consideration for development of 4G wireless systems[8].MIMO systems may be implemented in different ways. They can be used to obtain either a diversity gain to combat signal fading, or to obtain a capacity gain. Generally, MIMO techniques can be classified into the following three classes:

- First class: it is used enhance the power efficiency by maximizing spatial diversity such as delay diversity, space-time codes.
- Second class: the aim of this class is to increase the capacity through layered approach such as V-BLAST system.
- Third class: it exploits the channel knowledge at the transmitter to decompose the channel coefficient matrix in order to achieve capacity.

The main goal of the study is to test the efficiency of the MIMO techniques applied to underwater channels and also its combination with CDMA.

III. results and discussion

In this work a SIMULINK model has been developed for the realization of MIMO-CDMA2000 for under water acoustic communication system. The whole communication system has been divided into various blocks e.g data generator, encoder, transmitter, OSTBC encoder and channel and on the receiver side there is decoder and the receiver block.

The complete Simulink model is given in Fig. 1. The Bernoulli binary generator block is used to generate the data for transmission. The next block is encoder. It performs various operations on the input data sequence; it adds redundancy to combat fading. Power control Sub-channel block generates the power control bits.

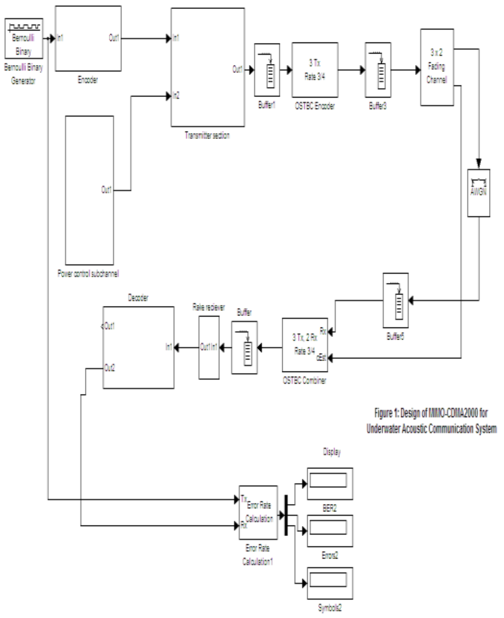

Figure 1: Design of MIMO-CDMA2000 for Underwater Acoustic Communication System

This sub-channel conveys instructions for the sensor node to increase or decrease transmission power on the reverse channel. PCSCh transmits bit'0' to indicate that the underwater sensor node needs to increase its transmission power, and transmits bit'1' to indicate that the underwater sensor node needs to reduce the power. This process consists of closed loop power control scheme [9].

The transmitter section consists of two main blocks i.e, long code scrambling and spreading block. The scrambling process offers encryption and security to the data sequence. This is because by screening the input data by different values, different codes can be generated. This can be used to identify a specific underwater sensor node as each underwater sensor node will have its own code with a specified mask. The Spreading block spreads the data by quasi orthogonal function using Walsh code and PN sequence.The framed output is then given to Orthogonal Space Time Block (OSTBC) encoder.This block encodes an input symbol sequence using orthogonal space time block code. It maps the input symbols block-wise and concatenates the output code-word matrices in the time domain. Channel used in this simulation has been considered as slow underwater Rayleigh fading channel.At the receiving end the encoded data is received by OSTBC combiner which combines the input signal (from all the receiver antennas) and channel estimate signal to extract the soft information of the symbols encoded by an OSTBC Encoder. The receiver then detects the start and end of each frame in the received signal by an envelope detector. Each detected frame of the time signal is then demodulated into the useful data.

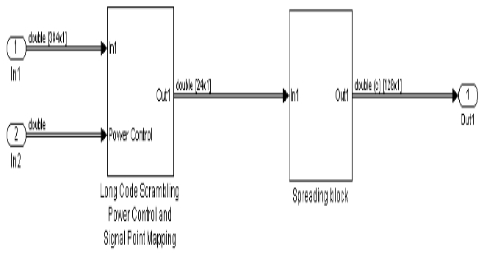

Figure 2: Transmitter design

The CDMA receiver performs the time correlation operation to detect only the specific desired code-word. All other code-words appear as noise due to de-correlation. For detection of the message signal, the receiver needs to know the code word used by the transmitter. Each user operates independently with no knowledge of the other users. The output of the correlator is sent to a narrowband filter. The filter allows all of the desired signal's energy to pass through, but reduces the interfering signal's energy by the ratio of the bandwidth before the correlator to the bandwidth after the correlator. This reduction greatly improves the signal-to-interference ratio of the desired signal. This ratio is also known as the processing gain. The signal-to-noise ratio is determined by the ratio of the desired signal power to the sum of all of the other signal powers. It is enhanced by the processing gain or the ratio of spread bandwidth to baseband data rate.This block demodulates the data obtained at the receiver end. The block operates on data using four fingers of a rake receiver and generates the demodulated symbols for each finger. The demodulation process utilizes the channel estimate or pilot signal for each finger to demodulate the symbols for each finger. Rake receiver is a radio receiver designed to counter the effects of multipath fading. It does this by using several "sub-receivers" individual multipath components.

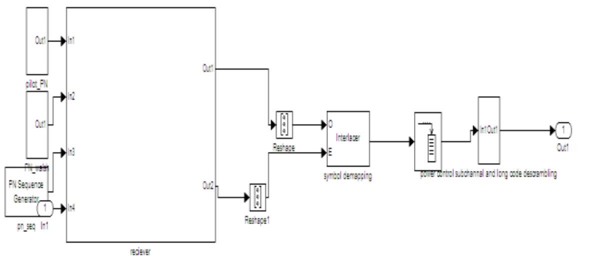

Figure 3: Receiver design

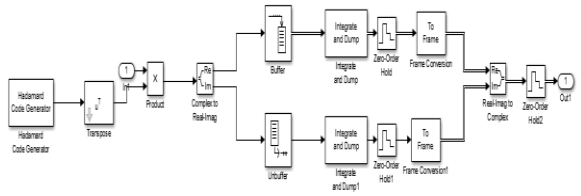

Figure 4: Rake finger

Each component is decoded independently, but at a later stage combined in order to make the most use of the different transmission. The next block is decoder. This block uses the Viterbi algorithm to optimally decode a frame of convolutionally encoded information. Figure 5 shows the bit error rate after the receiver stage. The bit error rate has been calculated by comparing the signal that has actually been transmitted and the signal received after the decoding block. Error rate calculate block shows three outputs. The first output shows the bit error rate having a value of 0.5088. Second output shows the total number of error samples i.e.80. Third output is the total number of samples i.e. 171. Thus, the conclusion is that among 171 samples, 80samples have error having a total bit error rate of 0.5088. The error in the sample is due to the power control bit addition on the transmitter side and extraction of the power control bit on the receiver side in addition to various other transmission losses.

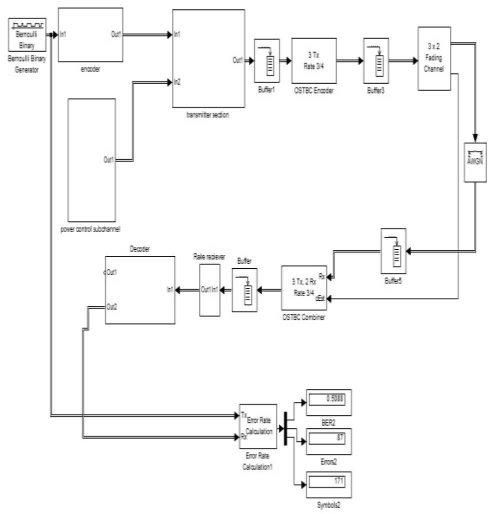

Figure 5:Working model of MIMO-CDMA2000 for Underwater Acoustic Communication System.

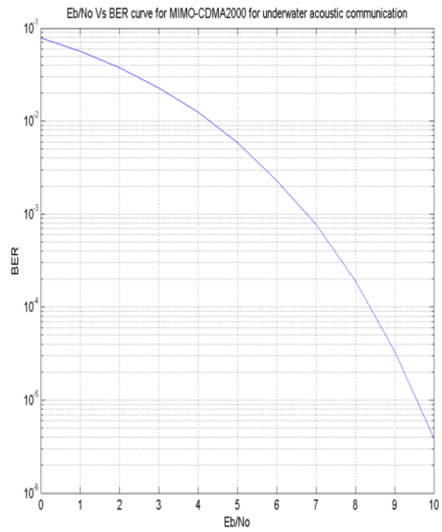

Figure 6: BER VsEb/No for MIMO-CDMA2000 for Underwater Acoustic Communication System.

IV. Conclusion

Underwater Communications plays an important role in various fields of Science and Technology besides defence. Lot of work have been carried out in this direction for efficient transmission and reception of sensitive information. A MIMO based under water communications is a new field for Acoustic communications. An attempt has been made inthis paper to combine the features of CDMA 2000 and MIMO. A successful attempt has been made to designed MIMO- CDMA2000 system for underwater Acoustic (UWA) Communication using MATLAB/SIMULINK Tools. It consists of various sections which perform different functions. The performance of the designed system has been checked in terms of Bit Error Rate (BER). From the results it was found that the proposed scheme outperforms the existing state of art acoustic communication systems.

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