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Performance Analysis of OFDM-IDMA System using Random and Tree-based Interleaver for Underwater Acoustic Communication

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Abstract: The ocean display episode of changing acoustic signal transmission due to its non-stationary nature. To set up wireless communication system of communication purpose is challenging in underwater application because transmitter sector section and receiver section are not fixed. Sound causes large delay in acoustic signal because of multipath phenomena and speed of sound is 1500 m/s. inter-symbol interference (ISI) occur due to large time delay and ISI decrease the performance of many system or receivers. However orthogonal frequency division multiplexing (OFDM) is a multi-tone modulation scheme which is used to reduce the long-time delay spreads of acoustic channels. OFDM-IDMA system is designed to mitigate the error burst in multi-access underwater application. An efficient random base interleaver is present which is simple and could produce orthogonal interleavers for generating user specific chip level interleaver for different user. Performance of OFDM-IDMA system was observed through analysis of BER with respect to SNR.

Keywords: IDMA, FDMA, BER, ISI, MAI and underwater communication.

I. INTRODUCTION

Acoustic wave is also known as RF wave which require high transmission power and size of antenna is larger. Communication in underwater mostly depends on acoustic wave. Optical wave have difficulty to communicate in mobile communication because optical wave do not travel much distance and need line-of-sight in between the transmitter and receiver. In modern time, underwater acoustic communication has many applications in the field of unmanned submarines, underwater robots and sensor modes.

One of the difficult acoustic medium is the shallow-water channel for data transmission. To develop a good communication system for underwater application is really difficult task. Multipath interference and bandwidth of operation play major difficulties in underwater acoustic communication [1]. Orthogonal frequency division multiplexing (OFDM) is a technique use to transmit a bit stream by dividing into parallel bit-streams each with low bit rate and this parallel bit stream is further modulated over several modulation sub carriers and then transmitted over additive white Gaussian noise channel [2]. OFDM is use to avoids the overlapping of each subcarriers channels thus it mitigate the inter-carrier interference. Today, OFDM widely used terrestrial digital radio and television broadcasting application. To construct OFDM system transmitter and receiver in discrete time IFFT and FFT are used respectively. OFDM is used to reduce ISI which is possible when OFDM symbol period should be greater than maximum delay speared [3, 4].

Interleave division multiple access (IDMA) is used for differentiate each user with particular or unique random interleaver code. Multi-access interference (MAI) and Inter-symbol interference (ISI) present in CDMA which affect the performance of CDMA [5, 6].Interleave division multiple access(IDMA) most widely used in recent year which can be treated as a special case of code division multiple access (CDMA)[7] Which has much consideration for multiple access communication. It is distinct from CDMA, where Orthogonal or Quasi-Orthogonal signature sequences are used in code domain for user separation. IDMA used for different interlever to obtain the exact function. Since, user specific interleavers can be generated in simple way for a larger number. The limited number of user specific signal sequence can be bypass which is limitation of CDMA and this exhibit the advantage of IDMA over CDMA. Orthogonal frequency division multiplexing (OFDM)-interleave division multiple access IDMA is a multicarrier system which is used in new and developing broadband wireless communication systems. OFDM-IDMA has many profits like the analysis of inter-symbol interference (ISI) and sufficient reduction of multi-access interference.

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In this paper we discuss the basic principle of OFDM-IDMA system for underwater acoustic communication and analysis of bit error rate (BER). CDMA require knowledge of correlation factors for all CDMA spreading codes. If number of user increase then it is problem in CDMA. IDMA does not provide this type of signature sequence and IDMA also include low cost iterative MUD for system with larger number of users.
Section II describes the implementation of OFDM-IDMA system. In section III describe the different type of interleaver. Section IV indicate the comparison of bet error rate of AWGN channel and underwater acoustic channel and section V gives the final conclusion.

II. IMPLEMENTAION OF OFDM-IDMA SYSTEM

OFDM-IDMA system was developed for underwater acoustic communication. A block diagram is designed for underwater communication system which consist transmitter section, receiver section and channel.

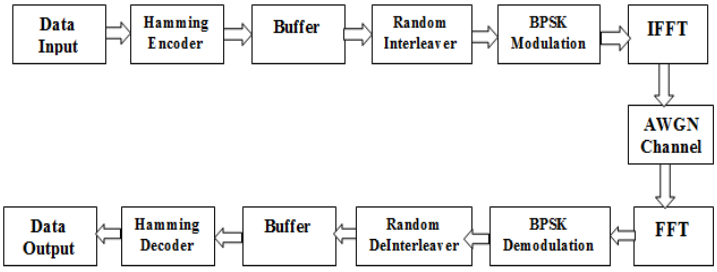

Figure (1). Block diagram of OFDM-IDMA system.

In transmitter section hamming encode, buffer, random interleaver, BPSK modulation and IFFT present. Hamming encoder is used to encode the input data after this interleaving process is used with the help of random interleaver. In this paper we used BPSK modulation technique to perform IFFT operation then transmit the complex signal over additive white Gaussian noise channel. There are two type of noise one is man-made noise and other is ambient noise. In ocean both type of noise are present. The near sea surface and around sea shore man made noise dominates, whereas ambient noise is dominant at deep sea level. We consider AWGN channel for underwater application because source of ambient noise having continuous spectrum and Gaussian statics [8].
At the receiver side, to convert time domain signal into frequency domain signal we use fats Fourier transform (FFT) operation. Demodulation is done by using BPSK demodulation technique which convert complex signal into integer value. Random de-interleaver is used to convert integer to bit and after this we get originally bit steam by using hamming decoder [9].

IFFT AND FFT OF OFDM

Complex valued symbol vector is

$$X^m = [X_0^m \dots\dots\dots\dots X_{N-1}^m]^T \quad (1)$$

(m = complex symbols)

$$x^m(n) = [x_0^m \dots\dots\dots\dots x_{N-1}^m]^T \quad (2)$$

(transformed into a discrete time signal)

$$x^m(n) = X^m = \frac{1}{\sqrt{N}} \sum_{k=0}^{n-1} X_k^m \exp\left(\frac{j2\pi k_n}{N}\right) (3)$$

where N is length of FFT

$$x^m(k) = \sum_{n=0}^{N-1} X_n^m \exp\left(\frac{-j2\pi k_n}{N}\right) \quad (4)$$

III. TYPE OF INTERLEAVERS

Due to their user-specific application, the interleaver used in IDMA system is bound to be orthogonal in nature. Orthogonally of interleavers provides the means of user separation and avoid the risk of collision of interleavers in the system. Initially, user specific random interleavers were employed in IDMA system.
The primary role of an interleaver is to construct a long block code from small memory convolution codes, as long code can approach the Shannon-capacity limit. Interleaving is the process of re-arranging the ordering of a data sequence in a one to one deterministic format. Interleaving is a practical technique to enhance the error correcting capability of coding.

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(a) RANDOM INTERLEAVER

Random interleavers scramble the data randomly and independently for different user with different pattern. Pattern of scrambling the data of users are generated randomly. The user specific randominterleaver re-arranges the component of the input vector using a random permutation. The transmitter and receiver need to store or communicate many bits in order to agree upon an interleaver then lot of memory space is required. If random interleavers are used for the purpose of user separation then the effective amount of bandwidth will be consumed for transmission of all these interleavers and most important factor computational complexity will also increase. Spreading is the important factor of random interleaver.

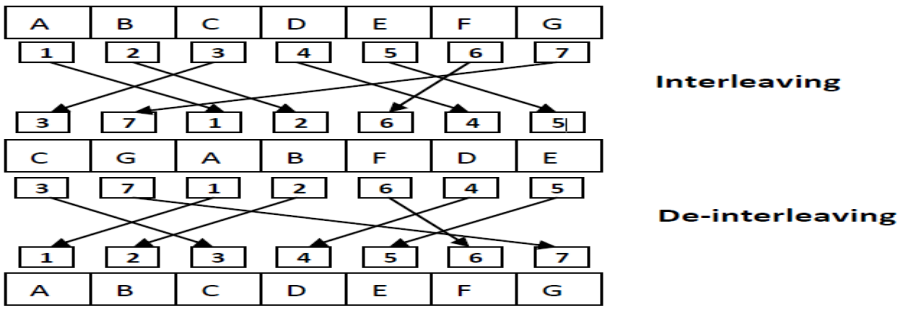

Figure (2). Random interleaving of data.

(b) MASTER RANDOM INTERLEAVER

In master random interleaver, each interleaver is generated independently and randomly. In this even though there is no burden on the user device but it affects the bandwidth. The random position setter (RPS) block, generate the interleaving position for master random interleaver. The master random sequences, generated by RPS block. The algorithm for master random interleaver generation consists one master interleaver i.e. π which is allotted to first user as user-specific interleaver.

(c) TREE BASED INTERLEAVER

Primary purpose of tree based interleaver is to reduce the problem of computational complexity and memory requirement which occurs in MRI and RI respectively. In case of TBI generation mechanism, to randomly generatedπ_2 and π_2 master interleavers.

To generate TBI, two randomly generated master interleavers π_2 and π_2 are taken which having zero-cross correlation the location of the interleaving masks follow the tree formate as shown in figure

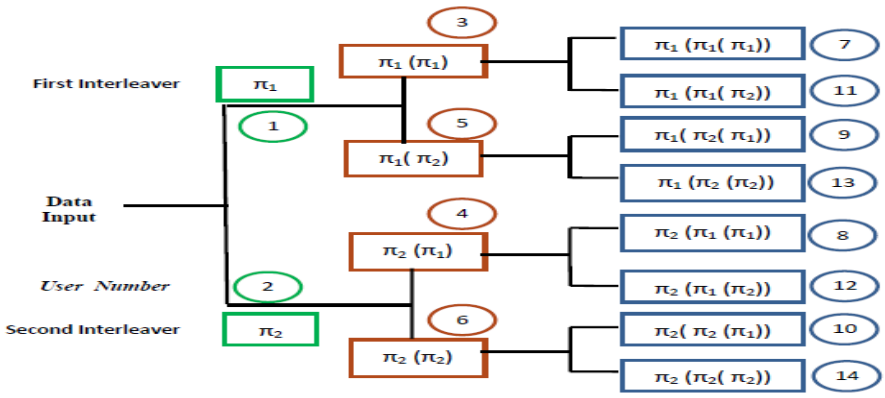

Figure (3) Interleaving masks allocation for the tree based interleaving scheme.

For obtaining the interleaving sequence of the 14th user, the TBI mechanism needs only two cycle of clock but in case of master random interleaver it require many more cycles.

$\pi_{14} = \pi_2(\pi_2(\pi_2))$ (5)

(d) PRIME INTERLEAVER

Prime number is required to generate prime interleaver and it requires minimum consumption of bandwidth during transmission. It gives BER performance same as that of random interleaver. For understanding the mechanism of prime interleaver, let us consider a case of interleaving n bits with seed P. first we take a Galois field GF (n) then the bits are

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interleaved with a distance of seed over GF (n). The prime interleaving scheme reduced the computational complexity that occurs in master random interleaving scheme.

IV. COMMUNICATION CHANNEL

To transmit the information from one point to another point a channel is required. In this paper we discussed AWGN and UWA channel.

(a) AWGN CHANNEL

Channel play important role for any type of communication system. Noise is one of the factors which affect the performance of communication channel. There are so many factors which cause the AWGN like fluctuation of atom in conductor, emission from earth, shot noise and other sunny object and from ethereal sources such as sun. There are different types of communication channel. One of the simplest models of channel is AWGN channel and it is convenient for wired communication. It is LTI (linear time invariant). White Gaussian noise compute to the signal when signal goes through it. Characteristic of this channel is amplitude frequency response and phase response is flat and linear for all frequency [10] respectively. It does not exist fading but only distortions occur when modulated signal passes through it.Received signal can be written as,

$$r(t) = x(t) + n(t) \quad (6)$$

Where, n (t) indicate the noise which has variance as the noise power and Gaussian distribution with zero mean. x (t) indicate the transmitted signal.

(b) UNDERWATER ACOUSTIC CHANNEL

Under water acoustic channel can be characterized by a linear filter which have impulse response h (t,.τ) or Fourier transform H(f,τ) where frequency and time domain are taken into consideration[11].

The solution of the propagation equation can be considered as the mean value of h (t) which is not time varying. The noise b (t) is uncorrelated with the signal. Despite of the particle reverberation effect [12]. Absorption, divergence losses and the additive ambient noise b (t) are affecting the SNR. The numerous experiments in an underwater communication the frequently fading can be neglected. Frequency spreading occurs due to temporal fluctuation, reverberation and surface reflection which are less than 0.5 Hz so it is negligible as compared to the transmission signal language.

However the Doppler shift presents because of transmitter and receiver are not fixed. For a communication channel the discrete multipath model is given as

$$h(t) = \sum_{i=1}^{n} a_i \exp j\emptyset_i \delta(t - \tau_i) \quad (7)$$

Where n= number of path
a_i= magnitude for the i^{th} path
ϕ_i= low frequency phase and τ_i= delay

BER ANALYSIS

It is the ratio ofnumber of bits with error to the total number of bits that have been transmitted over a given time period that is

$$\text{BER} = \frac{\text{number of bits with error}}{\text{total number of bits sent}} \quad (8)$$

Simulations of OFDM-IDMA scheme with AWGN channel and underwater acoustic channel are shown in figure4 and 5. In this Simulation OFDM-IDMA system is used with random interleaver and tree based interleaver. performance is shown by using data length, number of user, block length and number of iteration. Block length, data length and iteration are taken as 100, 512 and 5 respectively.

Figure (4) indicates the BER performance for random interleaver of OFDM-IDMA system for 64 users with BPSK modulation. In this simulation UWA channel give the better result as compare to AWGN channel.

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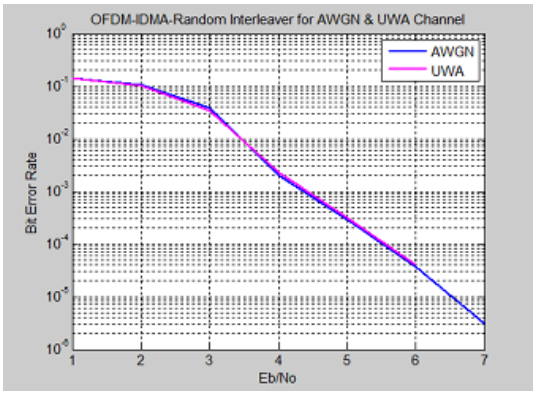

Figure (4). BER performance of random interleaver with OFDM-IDMA for 64 user with AWGN and UWA channel.

Figure (5) indicate the BER performance for Tree based interleaver of OFDM-IDMA system for 64 users with BPSK modulation. In this simulation UWA channel give the better result as compare to AWGN channel.

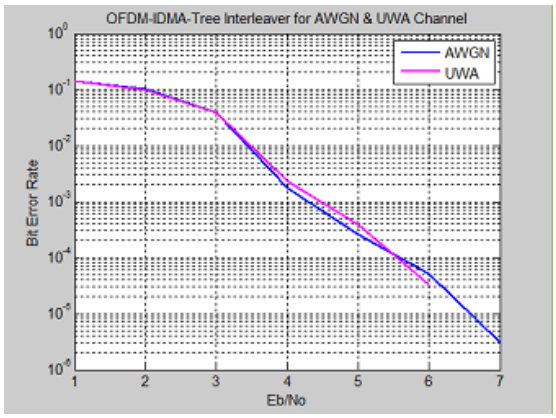

Figure (5). BER performance of tree based interleaver with OFDM-IDMA for 64 user with AWGN and UWA channel.

V. CONCLUSION

In this paper compassion between AWGN channel and UWA channel of random inteleaver and tree based interleaver have been done on the bases of parameter like BER (bit error rate). It is note that the BER depends on many factors like high peak to average power ratio (PAPR), diversity, and Doppler shift, number of user, fluctuation, reflection and complexity. In this paper we consider OFDM-IDMA system with random interleaver and tree based interleaver with AWGN and UWA channel and concludes that under water acoustic (UWA) channel gives better BER as compared to AWGN cha

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