Global Journal of Enterprise Information System

Paper Performance Analysis of OFDM-IDMA and SC-FDMA-IDMA Scheme in Underwater Communication

Ajay Patel[1*], Ruchi Gupta[2] and M. Shukla[1]

[1]Department of Electronics Engineering ,Harcourt Butler Technological Institute, Kanpur, India; ajayhbtri@gmail.com, manojkrshukla@yahoo.in

[2]Department of Electronics Engineering , Amity University Uttar Pradesh, Lucknow, India; 19.ruchi.gupta@gmail.com

Abstract

The IDMA scheme based receiver complexity over multi-path channels is related to the channel length. OFDM-IDMA scheme was proposed as an alternative to plain IDMA over multi-path channels. OFDM-IDMA scheme inherits most of the merits of OFDM and IDMA scheme. The key advantage of OFDM-IDMA scheme is that MUD can be realized efficiently with complexity per user, independent of the channel length and the number of users, which is significantly lower than that of other alternatives. Single Carrier Frequency Division Multiple Access (SC-FDMA-IDMA) scheme structure is achieved by adding Discrete Fourier Transform (DFT) and inverse DFT (IDFT) blocks at the transmitter and receiver respectively, so SC-FDMA scheme is sometimes referred to as DFT-spread or DFT-precoded OFDMA scheme. The transmitter of SC-FDMA scheme uses different subcarriers to transmit information data as in OFDMA scheme. However SC-FDMA schemes transmit the subcarriers sequentially rather than in parallel. Due to addition of above blocks low PAPR is obtained which is important to increase cell coverage and to prolong the battery lifetime of mobile terminals. There are no major differences between the BER performance of SC-FDMA-IDMA and OFDM-IDMA schemes, but SC-FDMA-IDMA scheme has low PAPR than OFDM-IDMA scheme.

Keywords: OFDM, IDMA, ISI, MAI, LTE, MUD, DFT, SC-FDMA

(**Date of Acceptance:** 08-01-2015; **Plagiarism Check Date:** 10-01-2015; **Peer Reviewed by Three editors blindly:** 10-02-2015; **Reviewer's Comment send to author:** 24-02-2015; **Comment Incorporated and Revert by Author:** 5-03-2015; **Send for CRC:** 18-03-2015)

1. Introduction

First generation communication systems of wireless communication, presented in the early 1980s, were considered by analog speech transmission[14] however Second generation technology, deployed in the 1990s, were amalgamated the speech and data signal in digital format. In addition to it, second generation systems also introduced progressive security and networking technologies which made it possible for a subscriber to initiate and receive phone calls throughout the world. Even before the original second generation systems arrived on the market, the cellular community twisted its attention to third generation (3G) technology with the focus on developed bit rates, better spectrum efficiency, and information services in addition to voice telephony. The International Telecommunication Union (ITU) in 1985 introduced studies of Future Public Land Telecommunication Systems. After fifteen years, under the heading International Mobile Telecommunications (IMT-2000), the ITU allotted a set of approvals, approving five technologies as the basis of 3G mobile communications systems. In 2008, cellular operative companies were deploying two of these schemes, referred to as Wideband Code Division Multiple Access (WCDMA) and Code Division Multiple Access 2000 (CDMA2000) schemes. In the meantime, the industry is looking beyond 3G and considering SC-FDMA scheme as a prominent candidate for the "Long Term Evolution" (LTE) of radio transmissions from cellular phones to base stations[1]. OFDM-IDMA scheme is a hybrid multiple access scheme which was projected for multi-path channels combining OFDMA and IDMA schemes. In OFDM-IDMA scheme, Multi User Detection (MUD) can be realized efficiently because complexity per user is independent of the channel length as well as the number of users. Complexity per user in case of OFDM-IDMA scheme is also significantly lower than that of earlier multiple access techniques. As we know that instruments of underwater network are battery operated so it is essential that power consumption must be less which is possible by low PAPR

*Author for correspondence

(Peak to average power ratio). In this paper it is given that a hybrid multiple access scheme is used for LTE uplink, because this hybrid SC-FDMA-IDMA scheme has lower PAPR than other schemes.

2. Underwater Channel

Underwater acoustic communication is a technique of sending and receiving message below water. Although some animals (dolphins and bats) have used sound for communication and object detection for millions of years, use by humans in the water is initially recorded by Leonardo da Vinci in 1490 a tube inserted into water was said to be used to detect vessels by placing an ear in to tube. There are several ways of employing such communication but the most common is using hydrophone. Underwater communication is difficult due to factors like multi-path propagation, time variation of the channel, small available bandwidth and strong signal attenuation, especially over long ranges. In under water communication there are low data rates compared to terrestrial communication, since under water communication uses acoustic waves instead of electromagnetic waves.

2.1 Characteristics of Signals Carrier

There are three types of carrier wave for under water environment that are most commonly used in wireless communication[6].

2.1.1 Electromagnetic Wave

Using electromagnetic wave, the communication can be established at higher frequency and bandwidth. The limitation is due to high absorption/attenuation that has significant effect on the transmitted signal. Radio Frequency wave travels long distance over conductive salty water but at very low frequency (30 to 300Hz) because of these big antennas also required for this type of communication, thus affects the design complexity and cost.

2.1.2 Optical Wave

Optical wave also offers high data rate transmission. Nevertheless, the signal is rapidly absorbed in water and suffers from scattering effect. This will affect the data transmission accuracy.

2.1.3 Acoustic Wave

Acoustic wave is the most preferred signal used as carrier by many applications, owing to its low absorption characteristic for underwater communication. Even though the data transmission is slower compared to other carrier signal, the low absorption characteristic enables the carrier to travel at longer range as less absorption faced by the carrier.

2.2 Environment/Propagation Medium

The challenge occurs in underwater communication are quite different from the terrestrial communication. Water itself has become the main source for the signal interference. The type of water (freshwater/sea water), depth pressure, dissolved impurities, water composition and temperature affect the sound propagation. Common terrestrial phenomena like scattering, reflection, refraction also occurs in underwater communication.

2.3 Characteristics of Underwater Acoustic Channel

Seawater is very complex and variable, and its absorption of sound energy as well as the energy loss of expansion during the propagation causes the signal fading. The refraction on the top and bottom of sea interface and refraction of the different sound velocity gradient result in severe multi-path propagation. Seawater's random heterogeneity and various noise sources cause acoustic signal distortion.

2.3.1 Propagation Loss

During the process of transmitting sound signal from acoustic source to the reception, the signal energy is one of the important factors that intense signal-to-noise ratio of receiver losses. The absorption loss of sound energy is the main part of the attenuation loss, and the absorptions are usually seawater medium absorption and interface medium absorption[7]. When the sound wave frequencies are above 1 KHz, seawater acoustic absorption is the chief factor causing acoustic wave attenuation and is proportional to the square of the wave frequency. After integrating a large number of measure results, the empirical formula of the seawater absorption coefficient of sound waves, which is proposed by Thorp, etc., is expressed as[8].

$$\alpha\left(f\right)=\frac{0.11f^2}{1+f^2}+\frac{44f^2}{4410+f^2}+2.75*10^{-4}f^2+0.003 \qquad (1)$$

where (f) is given in dB/km, f is the centre frequency of the transmitted signal, in units of kHz. In order to assure that the receiver which is x km away can receive the input power level of $P0$, the transmitter power should be $P0A(x)$. Here, $A(x)$ is the attenuation factor and its formula is as follows[9]

$$A\left(x\right)=X^k a^x \qquad (2)$$

where, k is the power expansion factor, and represents sound waves expansion in the form of cylindrical wave when its value is 1; k takes 1.5 when it represents that sound waves expand in the form of actual expansion. a, which is obtained from the absorption coefficient (f) and based on frequency, is a coefficient. And its formula is as follows:

$$a = 10^{\frac{a(f)}{10}} \tag{3}$$

2.3.2 *Multi-path Effect*

In water, broadcast speed of sound wave is slow (acoustic propagation speed 1500m/s). Heterogeneity of seawater, reaction of the sea bottom and surface of the underwater sound propagation channels, as well as the existence of various reactors and scatterers in seawater result in the phenomenon of multi-path of underwater acoustic channel. Intersymbol interference caused by expansion multi-path is the fundamental obstacle of data transfer (especially high-speed data transfer). However, signal decline and inter-symbol interference caused by multi-path effect can be described by Rayleigh fading channel[10, 11].

3. Hybrid Mulitple Access Scheme

3.1 OFDMA Scheme

Orthogonal Frequency Division Multiple Access (OFDMA) is a form of transmission that uses a large number of adjacent spaced carriers that are modulated with low rate data. Normally these signals would be expected to interfere with each other, but by making the signals orthogonal to each another there is no mutual interference. This is achieved by having the carrier spacing equal to the reciprocal of the symbol period. This means that when the signals are demodulated they will have a whole number of cycles in the symbol period and their involvement will sum to zero - in other words there is no interference contribution.

The data to be transmitted is split across all the carriers and this means that by using error correction techniques, if some of the carriers are lost due to multi-path effects, then the data can be reconstructed. Moreover having data carried at a low rate across all the carriers means that the effects of reflections and inter-symbol interference can be overcome. It also means that single frequency networks, where all transmitters can transmit on the same channel can be employed[5].

OFDMA scheme is similar to FDMA scheme in which multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users. However, OFDMA scheme uses the spectrum much more efficiently by spacing the channels much closer together. OFDMA scheme transmission technology is based on simultaneous transmission on n frequency bands (between 2 and 30 MHz) with N carriers per band. The signal is shared between the carriers. The working frequencies are chosen according to regulations, others are "spread out" with the use of software.

3.2 OFDM –IDMA Scheme

The IDMA scheme based receiver complexity over multi-path channels is related to the channel length. OFDM-IDMA scheme was proposed as an alternative to plain IDMA over multi-path channels. OFDM-IDMA scheme inherits most of the merits of OFDM and IDMA scheme. The key advantage of OFDM-IDMA scheme is that MUD can be realized efficiently with complexity per user independent of the channel length and the number of users, which is significantly lower than that of other alternatives.

The transmitter/receiver structure of an OFDM-IDMA scheme based system contains K users. The coded signals are first interleaved by user-specific interleavers $\{\pi_k\}$. Then the resultant signals, again denoted by $\{x_k(n)\}$, are modulated onto subcarriers by using IDFT in Figure 1. Each subcarrier can be occupied by several users, so users are solely distinguished by their interleavers. The received signal after DFT can be represented by-

$$R(n) = \sum_{k=1}^{K} H_k(n) X_k(n) + Z(n) \tag{4}$$

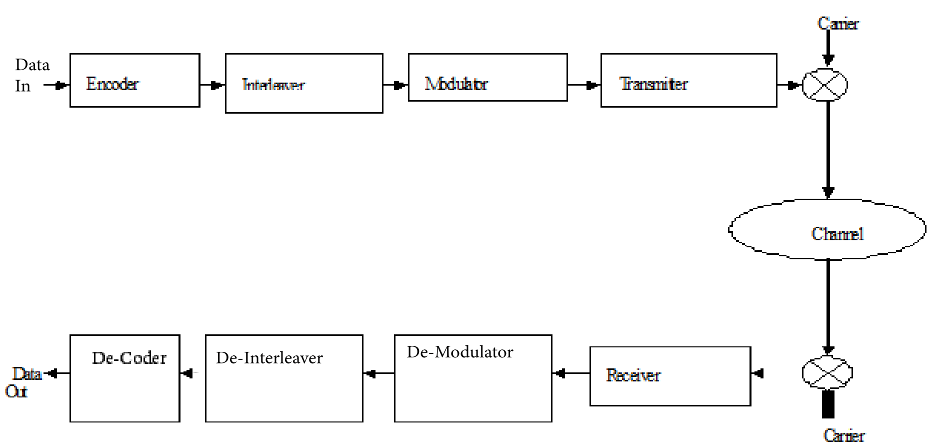

Figure 1. OFDM scheme based block diagram.

= Hk (n) xk(n) + Ξk(n) (5)

Where Hk (n) is referred to as the channel gain of the nth subcarrier for user k,

Z (n) denotes AWGN at subcarrier n, and

$$\Xi_k(n) = \sum_{m \neq k} H_m(n) X_m(n) + Z(n) \quad (6)$$

Equation (6) represents the interference plus noise component in R(n) with respect to user k at subcarrier n. From the central limit theorem, X_k(n) can again be approximated by a Gaussian random variable. The similarity between receiver equations of OFDMA and OFDM-IDMA schemes exists so principles outlined for IDMA scheme earlier can be directly applied to OFDM-IDMA scheme.

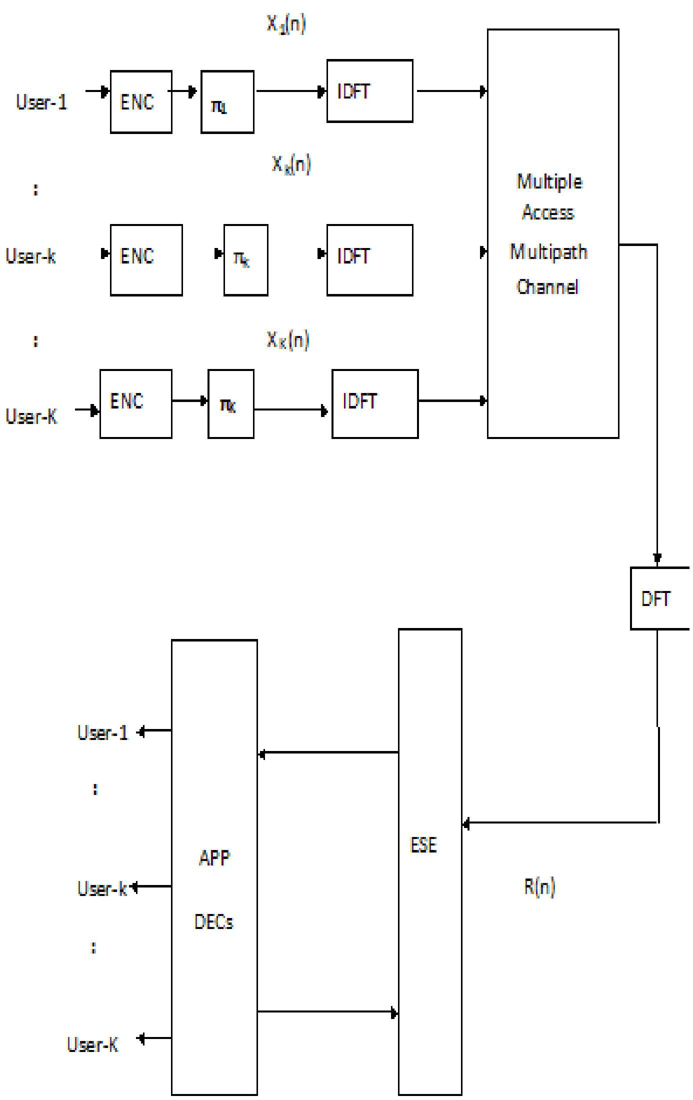

Figure 2. Block Diagram of OFDM-IDMA scheme based system.

The above also implies a fast technique to predict the performance of OFDM-IDMA scheme based on Knowledge of the average channel gains. The availability of a fast performance prediction technique is crucial for search-based system optimization. Spectral and power efficiency of IDMA scheme can be greatly enhanced by using an unequal power allocation strategy. The same principle also applies to OFDM-IDMA scheme for power allocation strategy. The optimized OFDM-IDMA scheme possesses several attractive properties, including

- Very high spectral efficiency.
- Flexibility in multi-user as well as single-user mode transmission.
- Multi-user gain in fading channels.

3.3 SC-FDMA-IDMA Scheme

SC-FDMA (Single Carrier Frequency Division Multiple Access) scheme utilizes single carrier modulation and orthogonal frequency division multiplexing. Additional names of SC-FDMA are DFT-spread or DFT-pre-coded OFDMA because DFT and Subcarrier Mapping blocks are new in OFDMA scheme to obtain SC-FDMA scheme.

The uplink transmitter and receiver structures of SC-FDMA-IDMA scheme and OFDM-IDMA scheme systems with K simultaneous users are shown in Figure 5 Author build SC-FDMA-IDMA scheme system model based on OFDM-IDMA scheme. In this SC-FDMA-IDMA scheme system, the input data of user k is encoded based on a low-rate code C, generating sequence $C_k=[C_k(1),......., C_k(j),....., C_k(J)]^T$ Where J is the block length. Then c is permutated by an interleaver π_k, yielding $X_k=[x_k(1),......., x_k(j),....., x_k(J)]^T$ For simplicity, the symbol mapping process is not shown in the Figure 3. With regard to a complex sequence complex sequence X_k by using quadrature phase shift keying (QPSK), each dimension of X_k is denoted by X_k^{Re} or X_k^{Im}. After the IDMA signal processing, X_k is passed to SC-FDMA modulation. X_k Represents the M samples of the DFT of X_k. The size of DFT is equal to the frame length, namely $M=J$

$$X_{k,v} = \sum_{m=0}^{M-1} x_{k,m} e^{-j2\pi mv/M}, v = 0,.......M-1 \quad (7)$$

Thus in Figure 2, X_k is implemented by subcarrier mapping, achieving $Y_k(l)(l=0,1.......N\text{-}1, N=Q.M)$, where Q is spreading factor. Conventional subcarrier mapping methods are distributed mode and localized mode. In the localized subcarrier mapping mode[1], the modulation symbols are assigned to M adjacent subcarriers[13]. In the distributed mode, the symbols are equally spaced across the entire channel bandwidth. In both modes, the IDFT in the transmitter assigns zero amplitude to the N-M unoccupied subcarriers[1]. The localized subcarrier mapping mode of

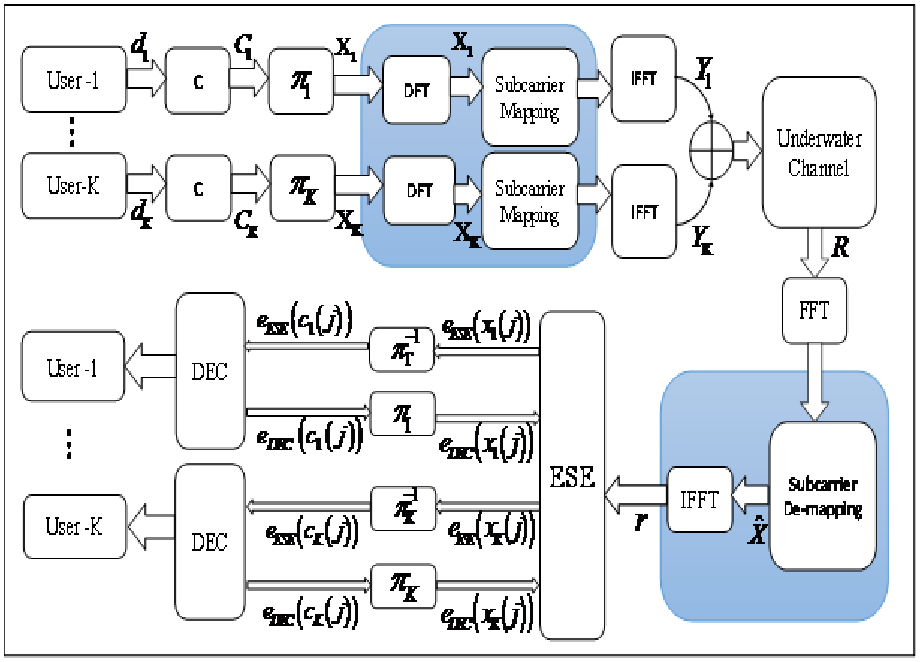

Figure 3. Uplink transmitter and receiver structures of SC-FDMA-IDMA scheme and OFDM-IDMA scheme (Except the blue frame models) over under water channel.

SC-FDMA scheme is called as Localized FDMA (LFDMA) mode and distributed subcarrier mapping mode is called as Distributed FDMA (DFDMA) mode. The case of $N = Q.M$ for the distributed mode with equidistance between occupied subcarriers is referred to as Interleaved FDMA (IFDMA) mode[1].

After subcarrier mapping the frequency samples $Y_{k,j}$ for LFDMA mode can be described as follows-

$$\begin{aligned} Y_{k,l} &= \{X_{k,l}, 0 \le l \le M-1\} \\ &= \{0, M \le l \le N-1\} \end{aligned} \tag{8}$$

The description of $Y_{k,j}$ can be given as

$$\begin{aligned} Y_{k,l} &= \{X_{k,l}, l = Q'.m(0 \le l \le M-1)\} \\ &= \{0, otherwise\} \end{aligned} \tag{9}$$

where $0 \le l \le N$-1, $N = Q.M$ and $1 \le Q' < Q$

Similarly the IFDMA mode can be described and $Y_{k,j}$ given as

$$\begin{aligned} Y_{k,l} &= \{X_{k,l}, l = Q.m(0 \le l \le M-1)\} \\ &= \{0, otherwise\} \end{aligned} \tag{10}$$

Y_k Represents the transmitted time domain channel symbol that are obtained from the inverse DFT (IDFT) of Y_k

$$Y_{k,n} = \frac{1}{N}\sum_{l=0}^{N-1} Y_{k,l} e^{j2\pi nl/N}, n = 0, \ldots\ldots\ldots, N-1 \tag{11}$$

IFFT has been taken instead of IDFT. Let the discrete length of the guard interval is L_g. The sampled sequence with cyclic extended guard interval results in

$$Y_{k,n} = \frac{1}{N}\sum_{l=0}^{N-1} Y_{k,l} e^{j2\pi nl/N}, n = -L_g, \ldots\ldots\ldots, N-1 \tag{12}$$

Consider a K user multiple access system over quasi-static flat-fading channels. On assuming that the channel gains h_k are not dependent, identical distributed and perfectly known at transmitter and receiver. The received signal in a multiple access channel can be written as

$$R = \sum_{k=1}^{K} h_k Y_k + n \tag{13}$$

Here n is an Additive White Gaussian Noise (AWGN) with variance σ^2 and Y_k is user transmitting signal[14]. On assuming that Y_k are not dependent, Gaussian distributed with the AWGN (additive white Gaussian noise) channel, i.e. $h_k = 1, \forall k$

First of all received data is implemented by FFT. Then it implements subcarrier de-mapping and IDFT[13]. For the sake of attaining the best possible performance, the structure of iterative multiple user detection of IDMA is shown in Figure 3. This structure consists of a Soft-In-Soft-Out (SISO).

Elementary Signal Estimator (ESE) and a bank of K individual SISO Decoding (DEC), where the soft information exchanged between the receiver components is constituted by the extrinsic Log-Likelihood Ratios (LLRs). In the process of iteration, the ESE generates the extrinsic output information $e_{ESE} = (x_k(j))$ and de-interleaves it in order to create the stream $e_{ESE} = (c_k(j))$, which is forward as a priori information to the SISO DEC. In the feedback loop, the SISO DEC computes the extrinsic information stream of $e_{ESE}=(c_k(j))$, which is interleaved to generate the stream of $e_{ESE}=(x_k(j))$ as a priori information for ESE[2]. The ESE employs Soft Interference Cancellation (SIC) on a subcarrier-by-subcarrier basis. The DECs carry out APP decoding using the output of the ESE as input[1].

4. Simulation Results

The simulations have been performed for SC-FDMA-IDMA scheme under acoustic environment on MATLAB platform. Certain assumptions have been taken into consideration including single cell environment with one transmitter and one receiver architecture means it is assumed that there is no adjacent-channel and co-channel interference. OFDM-IDMA scheme is being done over AWGN and underwater channel. Results of this simulation is sometimes differs from SC-FDMA-IDMA scheme.

Different values of parameters are used here for simulation of OFDM-IDMA scheme over AWGN and underwater channel. The values of block length and data length are taken as 5 and 512 respectively. Iterations are fixed as 5 and spreading factor is 2. The values of different number of user are taken as 8 and 16. The spreading length is 16. Cut-off frequency is 25000 Hz, depth of water channel is 40m, salinity is 30%, temperature is 14 degrees Celsius, PH level of water is 6 and speed of wind is taken as 10 meters per second. There are some observations occur after this simulation. BER depends on different number of users. BER values increases on increasing values of number of users from 8 to 16. Value of Bit Error Rate increases in some cases and decreases in some cases on increasing due to value of no. of user from 8 to 16.

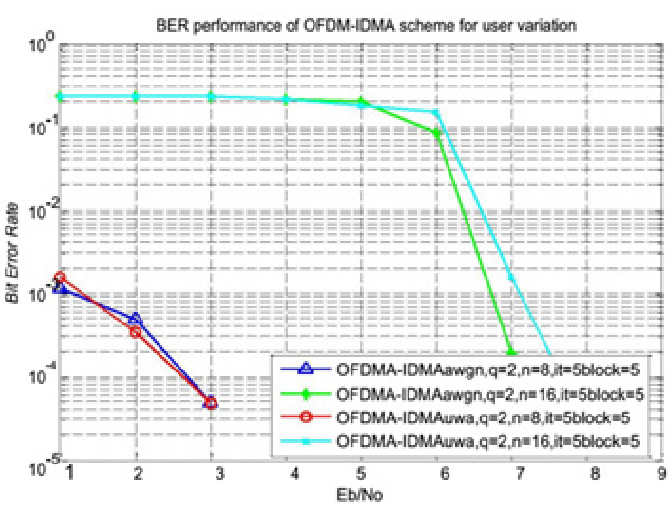

Figure 4. BER performance of OFDM-IDMA scheme for variation in number of users.

The next simulation is done for SC-FDMA-IDMA scheme with LFDMA mode for the variation of block length over underwater channel. Different values of parameters used for underwater communication is given as data length is 512, different no. of users is 16, spreading factor is 2, value of number of iterations used is 10, cut-off frequency is 25000 Hz, depth of water channel is 40 meters, salinity is 30 %, temperature is 14 degree Celsius, PH level of water is 6, speed of wind and is taken as 10 meters per second. The block length is taken as 5, 50, 100 and 200.

There are following observations for this simulation. Bit Error Rate depends on different values of block length while taking all other parameters constant for underwater channel. Values of Bit Error Rate remain same on increasing value of block length from 5 to 50 at Eb/No equal to 1 to 5. Values of Bit Error Rate increases further on increasing value of block length from 50 to 200 at Eb/No equals to 5 to 8. From the figure it is found that value of block length 200 is optimized value for further simulations because after that no major changes occurs in BER performances.

5. Conclusion

In this paper we have seen the history of underwater communication, characteristic of underwater communication, propagation loss and losses due to noise with mathematical

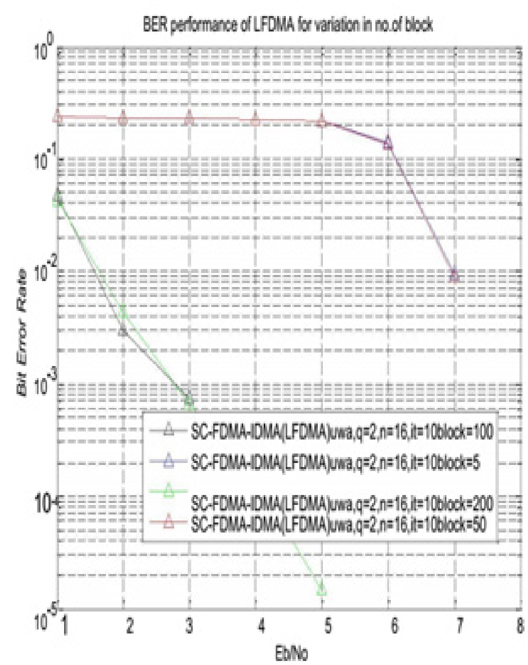

Figure 5. BER performance of SC-FDMA-IDMA scheme with LFDMA mode in underwater channel for variation in number of block.

model. The description of the multipath effect in underwater communication is also given[4]. In this paper, various hybrid multiple access schemes have been described. Hybrid multiple access schemes described in this paper includes OFDM-IDMA scheme & SC-FDMA-IDMA scheme. Hybrid multiple access schemes contain more than one schemes[3]. OFDM-IDMA combines OFDM scheme and IDMA scheme. SC-FDMA-IDMA scheme is the combination of SC-FDMA multiple access scheme and IDMA multiple access scheme[15]. The values of BER are calculated for all simulations and then observations are given for each simulation. According to results it is found that there are no major differences between the BER performance of SC-FDMA-IDMA and OFDM-IDMA schemes. But it is known that SC-FDMA-IDMA scheme has low PAPR than OFDM-IDMA scheme. So SC-FDMA-IDMA scheme is best suited for LTE uplink in underwater communication.

6. References

1. Xingzhong X, Zhongqiang L. SC-FDMA-IDMA: A Hybrid MultipleAccess Scheme for LTE Uplink ©2011 IEEE.
2. Li P, Lihai L, Keying W, Leung WK. Interleave-Division Multiple-Access. IEEE Transactions on Wireless Communications; 2006 April; 5(4).
3. Hyung GM. Introduction to Single Carrier FDMA. Proc. of 15th European Signal Processing Conference (EUSIPCO 2007); 2007 Sep 3-7; Poznan, Poland.
4. Baldo N, Casari P, Zorzi M. Cognitive spectrum access for underwater acoustic communications. Proc. of IEEE Oceans Conference; 2008 Sep 15-18; Quebec City, Canada. Project No. 2007-R/RT-2/ RCM-21
5. Ethem MS, Milica S, John GP, Life F. IEEE Underwater Acoustic Networks. IEEE journal of oceanic engineering. 2000 Jan; 25(1).
6. Proakis JG, Sozer EM, Rice JA, Stojanovic M. Shallow water acoustic networks. IEEE Communications Magazine. 2001 Nov. p. 114–9.
7. Chengsheng P, Liangchen J, Ruiyan C, Yuanming D. Modeling and simulation of channel for underwater communication network. International Journal of Innovative Computing, Information and Control ICIC International. 2012 Mar; 8(3(B)): 2149–56.
8. Jensen FB, Kuperman WA, Porter MB. Computational Ocean Acoustics. AIP Press: New York; 1994.
9. Akyildiz IF, Pompili D, Melodia T. Underwater acoustic sensor networks: Research challenges. Ad Hoc Networks. 2005; 3:257–79.
10. Kilfoyle DB, Baggeroer AB. The state of the art in underwater acoustic telemetry. IEEE Journal of Oceanic Engineering. 2000 Jan; 25(1):4–27.
11. Akyildiz IF, Pompili D, Melodia T. Challenges for Efficient Communication Underwater Acoustic Sensor Networks. IEEE Communications Surveys & Tutorials. 2004 Jul; 6:114–9.
12. Available from: http://www.radioelectronics.com/info/cellulartelecomms/cellular_concepts/multipl e_access_schemes.php
13. Rappaport TS. Wireless Communications. NJ: Prentice Hall, Englewood Cliffs; 1996.
14. Pahlavan K, Levesque AH. Wireless Information Networks. Wiley: New York; 1995.
15. Falconer DD, Adachi F, Gudmundson B. Time division multiple access methods for wireless personal communications. IEEE Commun Mag. 1995 Jan; 33–36.
16. Shukla MK. Performance Evaluation of IDMA Scheme in Wireless communication [PhD thesis] 2010 Nov.

Citation:

Ajay Patel, Ruchi Gupta, and M. Shukla
"Paper Performance Analysis of OFDM-IDMA and SC-FDMA-IDMA Scheme in Underwater Communication",
Global Journal of Enterprise Information System. Volume-7, Issue-2, April-June, 2015. (www.gjeis.org)

Conflict of Interest:

Author of a Paper had no conflict neither financially nor academically.