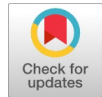


# Coding Techniques using IDMA OFDM MIMO for Underwater Wireless Acoustic Communication



Salma S. Shahapur, Rajashri Khanai, D.A. Torse

**Abstract:** Future Underwater communication demands high speed data transmission. Present Underwater communication can only provide a limited data rate, where the available bandwidth is limited. To increase the data rate, we simulate the MIMO-OFDM with IDMA technique. In MIMO method many transmitter and many receiver antennas are present. MIMO method offer a very high capacity which raises linearly with the numeral of antennas. Data rate increases with MIMO method, bandwidth is saved and fading is reduced with OFDM. In OFDM technique the complete sign orthogonally overlays in a frequency field that secures the bandwidth. IDMA system is constructed on interleaving procedure. In this paper different coding techniques Convolutional, RS code, LDPC code, Turbo code with IDMA OFDM MIMO technique are compared. IDMA OFDM MIMO with Turbo code, BER performance is improved up to  $10^{-6}$ .

**Keywords:** Convolutional Code, IDMA, Interleaver,, OFDM, Turbo coding,

## I. INTRODUCTION

A rapid growth in Underwater Sensor Networks (UWSN) have experienced, owing to their high significance in applications such as commercial and military [1]. Such as oceanographic data gathering, pollution monitoring, offshore investigation, adversity prevention and tactical observation. Though presently available underwater wireless acoustic technology provisions delay tolerant and low data rate requests. State of the art typical investigational point to point acoustic modems use signaling scheme that can achieve data rates lower than 20kilobits/sec with a link distance of 1kilometer [2], [3], [4].

For underwater multimedia observation, underwater investigations, video assisted navigation and environmental monitoring applications would be enabled with Multimedia underwater wireless communication. These application demands for considerable higher data rates than presently

existing acoustic knowledge, and also additional adaptable protocol strategy to accommodate diverse traffic problems in terms of reliability, delay and bandwidth. On acoustic links for such traffic weights we offer to leverage the probable of

Multiple Input Multiple Output (MIMO) communication method, to decrease intercarrier interference. There is a rising works on physical layer as well as in coding characteristics of underwater wireless MIMO OFDM communication [5], [6].

This paper offers key solutions for important Underwater communication difficulties. Future Underwater communication requires high speed data transmission. Though present Underwater communication can only provide a limited data rate, where the available bandwidth is limited. Better performance can be obtained with IDMA OFDM MIMO. In [7] the authors have used hamming encoder for IDMA OFDM MIMO and have got BER up to  $10^{-4}$ . In the underwater acoustic wireless communication for transmitting and receiving data number of nodes are placed at different depths. Nodes are connected through acoustic link to send the data to external station. The underwater acoustic wireless channel is influenced by attenuation, noise and multipath propagation [6], that results in propagation delays, communication errors and reduced channel bandwidth. To overcome these stated problems in underwater acoustic wireless communication channel coding procedures are used. Channel coding technique improves the system performance in terms of BER (Bit Error Rate) and energy consumption. Compare to WSN (Wireless Sensor Network) in underwater acoustic communication, Energy effectiveness is more important as the losses forced by the wireless underwater acoustic environment can be very thought-provoking. In this paper coding techniques Convolutional, RS, LDPC, Turbo code are simulated and compared.

## II. RELATED WORK

For saving of energy in terrestrial wireless sensor networks the channel coding methods are preferred [10]. In [11], wireless sensor networks the authors have determine the trade-off between transmission and consumption of energy. The work recognizes and chooses the suitable coding technique to be used in wireless sensor node, so that the network life period is maximized. In [8] the author has demonstrated for Additive White Gaussian Noise (AWGN) and Rayleigh fading channels in wireless sensor network the best coding rate choice a between wireless nodes. The detailed study in [9], investigates the ARQ method achieved when the code rate of the error-correcting coding technique is improved.

Manuscript received on December 10, 2020.

Revised Manuscript received on December 20, 2020.

Manuscript published on January 30, 2020.

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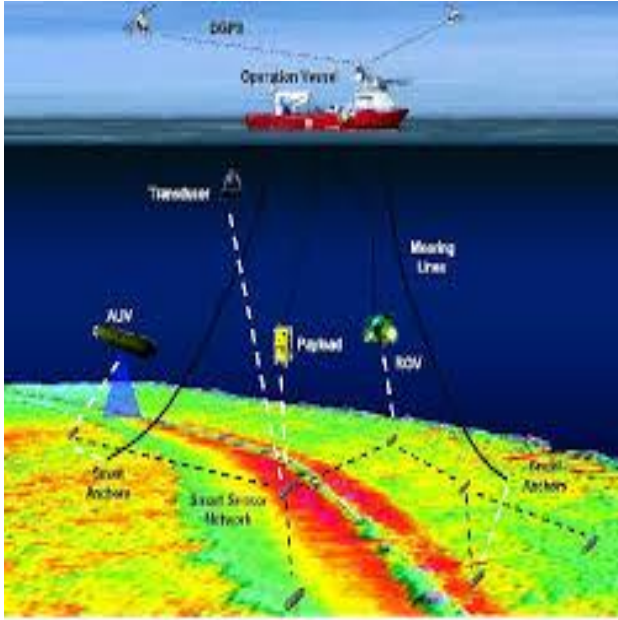
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In underwater wireless acoustic networks, due to the nodes potential energy savings the optimization of channel coding strategies has also been investigated. In [12], authors have examined convolutional coding technique and Frequency Shift Keying modulation technique in underwater wireless communication. To improve Signal to noise ratio(SNR) and code rate the authors have enhanced the frame error rate processing frequency.

The outcome illustrates that the appropriate selection of code rate has a more influence on the



**Fig. 1. Underwater acoustic communication**

complete energy consumption and lifetime of the nodes in underwater communication. In [13], the authors have measured the energy needed to send the data on a multi-hop underwater acoustic channel taking into account optimum retransmissions, code rate, and number of hop, SNR. An optimization method is adopted to get the optimal code rate, Signal to Noise Ratio for energy effective acoustic underwater communications using ARQ technique [14]. In [15] the author experimentally inspected the benefits of fountain code technique in Underwater Acoustic Communication. The coded packets are send by the sender with a fixed redundancy through a simplex channel and no feedback is used. The approach uses Orthogonal Frequency Division Multiplexing and results are investigated for the relation between Frame Error Rate and the amount of essential transmissions. In [16], in order to reduce the energy consumption, the random linear fountain codes associated with an adaptive power control strategy is used. Authors shown a consistent communicating approach for underwater wireless communication using acoustic link that uses ARQ schemes with fountain codes. At the receiver in order to satisfy a pre-defined reliability in [5] the authors have improved the number of coded packets, taking ARQ method with stop and wait technique.

In [17] the authors have done the initial study of energy consumption in underwater acoustic communication retaining fountain codes. Authors key idea is to transmit large volume of coded bits to achieve target Frame Error Rate without the necessity of retransmissions at the receiving end.

In [17] the authors used a fixed amount of coded data bits, the code rate optimization results in less number of data bits, for long distance it becomes the problem as the code rate results be small. In [18], the authors have designed a system wherein the number of required coded packets is determined to accomplish a specified reliability. From the receiver through feedback channel the transmitter alters its power and the number of coded packets using the channel state information. In [19] the authors have proposed fountain codes for underwater wireless acoustic communication. For underwater communication the authors have used feedback channel and also used Automatic Repeat Request (ARQ) scheme. In [20] the authors have explained the delinquent happening during fountain decoding course and the problem of discontinuing sets is presented for Underwater Wireless Communication. The authors have mainly considered improving the process of fountain algorithm for encoding and decoding. In [21] the authors have proposed a hybrid, FOCAR protocol. FOCAR protocol combines resending in case of failure hop by hop with fountain coding technique. This method requires selective repeat ARQ and a feedback channel for communication. At every in-between node the authors optimized the extent of the data block. From every hop the authors used packet error rate information based on a dominant optimization. As the learning process does not reflect the use of exact Forward Error Correction codes and their communication with fountain codes.

In [22] the authors have presented an algorithm for Underwater Acoustic Communication; a sender node arbitrarily transmits the data to the receiver nodes. The nodes in underwater are placed within an assumed terrestrial part. A mathematical model is derived to define the performance of a fountain code with ARQ algorithm. The Forward Error Correction codes uses are not considered and applied propagation protocol was not presented. In underwater acoustic channel for communication a fountain code based on ARQ scheme is presented [23]. The advantages of fountain code with ARQ, stop and wait method is considered to improve the communication in underwater acoustic communication. The choice and uses of Forward Error Correction code limits are not considered.

The authors have presented manipulating the approximating procedure of data of channel state a fountain grounded dependable unicast communication system [24]. In [24] authors used Raptor code the certain type of fountain-code. To adjust the parity relation the authors used stochastic optimization to progress the throughputs. The authors have examined a coding approach layer wise, this technique uses correcting errors with individual packet and across the packet removal modification is used [25]. The authors considered a scenario of wireless connection and measured the tradeoff between correcting the errors and erasing the errors. Authors have considered coding parameters, optimized focusing on maximizing the network energy resources, the network rate, which may be more desirable in sensor networks. In this section the survey related to IDMA-OFDM-MIMO is made as shown in Table I.

Table- I: Comparison of performance parameters

Reference	Method	Coding Technique	Modulation	Interleaver	BER
[8]	IDMA OFDM MIMO	LDPC	BPSK	Random	$10^{-4}$
[2]	IDMA OFDM MIMO	Hamming Encoder	QAM	Random	$10^{-4}$

### III. SYSTEM MODEL

We basically explain the 3-dimensional architecture for underwater communication then provisionally define the typical of underwater acoustic transmission [26]. And we present underwater wireless MIMO OFDM transmitter receiver model, discourse the influence of frequency reliant on noise and attenuation in OFDM MIMO infrastructures.

#### A. Network Architecture

Nodes are positioned at dissimilar depths in 3D underwater wireless networks to detect a specified task then forward to a moving buoy [27]. In underwater communication the deepness of every sensor node can be controlled by fine-tuning the measurement of the cable that joins the sensor node to the anchor node. Through multi hop ways underwater acoustic sensor nodes are talented to communicate data to the external station. As in [28], for underwater wireless acoustic sensor networks existing deployment methods potentials that the network topology be continuously linked. Hence, we admit that at least one route from each sensor node to the external station continually happens, that developed sensor mass increases the number of likely tracks. Additionally, few external stations are positioned on the surface of the deep-sea. Each. external station is furnished with acoustic transmitter receiver so that it can handle numerous communications with the underwater bottom sensor node and external stations [29].

#### B. Underwater Propagation Model

For underwater acoustic wireless communication, the attenuation  $a(x, \omega)$  is influenced by the frequency  $\omega$  over distance  $x$ , which can be approximated as [10]

$$a(x, \omega) = x^m, r(\omega)^x \quad (1)$$

Where  $m$  is the Linear dispersion, and is absorption constant which is denoted by the Thorp's formula :

$$10 \log r(\omega) = f(x) = \begin{cases} 0.11 \frac{\omega^2}{1 + \omega^2} + 44 \frac{\omega^2}{4100 + \omega^2} + 2.75 * 10^{-4} \omega^2 + 0.003 & \omega \geq 0.4 \\ 0.002 + \frac{0.11 \omega^2}{1 + \omega^2} + 0.011 \omega^2, & \omega < 0.4 \end{cases} \quad (2)$$

Where  $r(\omega)$  is in decibel/kilometer and  $\omega$  is in kilohertz

$$10 \log \partial_t(\omega) = 17 - 30 \log \omega \quad (3)$$

$$10 \log \partial_h(\omega) = 40 + 20(h - 0.5) + 26 \log \omega - 60 \log(\omega + 0.03) \quad (4)$$

$$10 \log \partial_v(\omega) = 50 + 7.5 v^{\frac{1}{2}} + 20 \log \omega - 40 \log(\omega + 0.4) \quad (5)$$

$$10 \log \partial_{th}(\omega) = -15 + 20 \log \omega \quad (6)$$

Where  $\partial_t(\omega)$ ,  $\partial_s(\omega)$ ,  $\partial_v(\omega)$ ,  $\partial_{th}(\omega)$  are the thermal, shipping, waves and thermal noise.  $h$  represents a shipping activity factor between 0 and 1, and  $v$  is the wind speed. Thus, the overall p.s.d of the ambient noise in underwater is  $\partial_t(\omega) + \partial_s(\omega) + \partial_v(\omega) + \partial_{th}(\omega)$  (7)

#### C. Acoustic MIMO OFDM trans receiver model

We replicate an underwater network where in each and every node has transmitted fundamentals and receive fundamentals. When the information is send from one node to another node, complete bit stream is divided into substitute streams and each substitute stream is send by one of the transmitter instantaneously to the receive element. With the assumption that channel is static with OFDM subcarrier, at the receiver side the received signal can be exhibited as [11].

$$X(w_k) = \sqrt{P(w_k)} * a(x, w) + n(f_k) \quad (8)$$

Where  $w_k$  is the central frequency of  $k - th$  subcarrier.

$X(k) = [X_1(w_k), X_2(w_k) \dots \dots \dots X_{U_R}(w_k)]$  is the received signal vector whose component  $X_n(w_k)$ ;  $1 < n \leq U_R$  is the received signal at receiver element  $n$ ,  $y = [y_1, y_2, y_3 \dots \dots \dots y_{U_T}]$  is the transmitted signal from transmit element  $m$ .

$n(w_k) = [n_1(w_k), [n_2(w_k)] \dots \dots \dots [n_{1U_R}(w_k)]$  is the noise vector whose components modelled as Gaussian random variables,

$a(x, w) = \{\varphi_{m,n}(x), w_k; 1 \leq m \leq U_T, 1 \leq n \leq U_R\}$  is the channel matrix whose component  $\varphi_{m,n}(x), w_k$  denotes the channel fading coefficient between transmit element  $n$ ,  $1 \leq n \leq U_R$ . We consider the channel environment is now on the receiver sideways, but unidentified at the transmitter sideways. The communicated data route  $x$  is imagined to follow a power restraint  $\sum_{m=1}^{U_T} |x_m|^2 = 1$ .

### IV. INTERLEAVER DIVISION MULTIPLE ACCESS ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING MULTIPLE INPUT MULTIPLE OUTPUT

Illustration of Interleaver Division Multiple Access Orthogonal Frequency Division Multiplexing Multiple Input Multiple Output is shown in Figure 2. In this paper we presented an efficient IDMA OFDM MIMO technique for underwater communication to progress the demonstration of BER. MIMO scheme contains many transmitter and many receiver antennas. MIMO technique offers theoretically very high capacity that approximately linearly raises with quantity of antennas. IDMA OFDM MIMO method rises the data rate, defends the bandwidth and decreases fading. As the whole sign orthogonally overlays in an occurrence arena this system saves the bandwidth. There are Number of multiple access techniques for underwater wireless acoustic communication and Interleaver Division Multiple Access method gives better performance than other present multiple access methods.

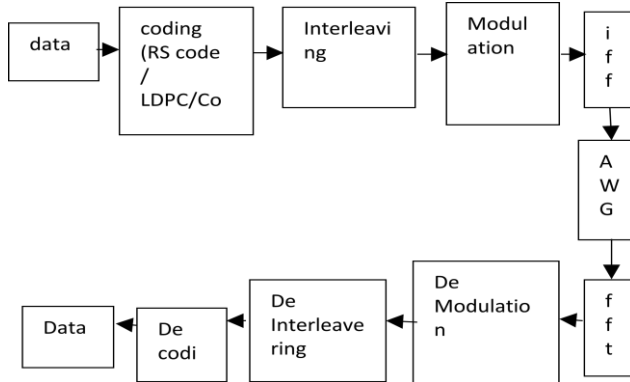


Fig. 2. Block Diagram of Interleaver Division Multiple Access

## V. RESULTS

The IDMA OFDM MIMO scheme for underwater acoustic communication is simulated. Initially data is encoded with the help of convolutional encoder then random interleaver interleaves the encoded data. For modulation BPSK is used and IFFT is achieved and transmitted over AWGN channel. The BER and power consumption is plotted as shown in Figure 3 and Figure 4. To improve the BER performance data is encoded with RS (Reed Solomon) code/ Turbo code and random interleaver is used for interleaving. BPSK is used as modulation technique.

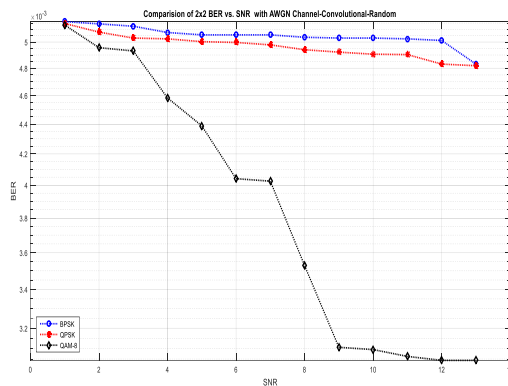


Fig. 3. Bit Error Rate of Convolutional Code

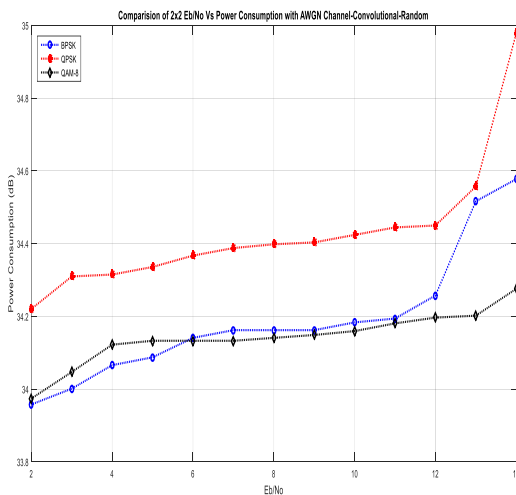


Fig. 4. Power consumption for Convolutional Code

Table II. comparison of performance parameters with Convolutional Code

Modulation Technique	Coding Technique	interleavers	BER	Power consumption (dB)
BPSK	Convolutional	Random	$10^{-3}$	35
QPSK	Convolutional	Random	$10^{-3}$	34
QAM	Convolutional	Random	$10^{-3}$	<b>20</b>

In Figure 3 we analyze the Bit Error Rate (BER) as a function of  $E_b/N_0$ . This result considers convolutional coding technique and random interleaver. Data is initially encoded with Convolutional encoder, with random interleaver encoded data is interleaved. And results are compared for different modulation techniques BPSK, QPSK, QAM. In Figure 4, the power consumption for different modulation techniques such as BPSK, QPSK, QAM are compared and tabulated in Table II.

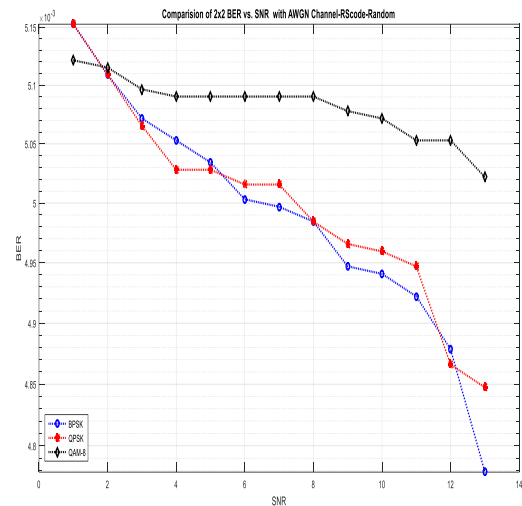


Fig. 5. Bit Error Rate of RS Code

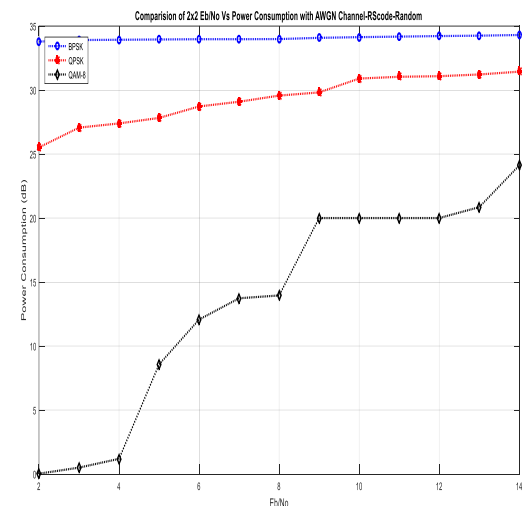
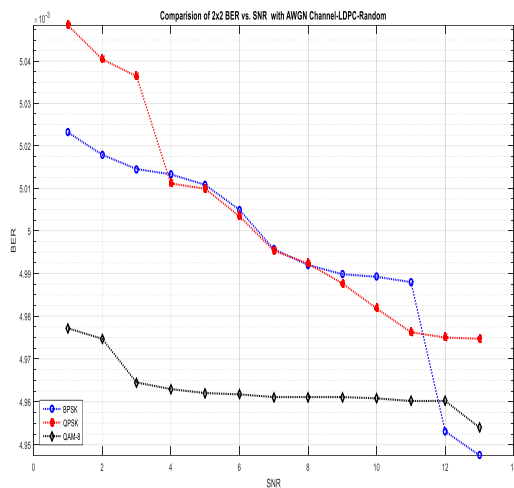


Fig.6. Power consumption of RS Code

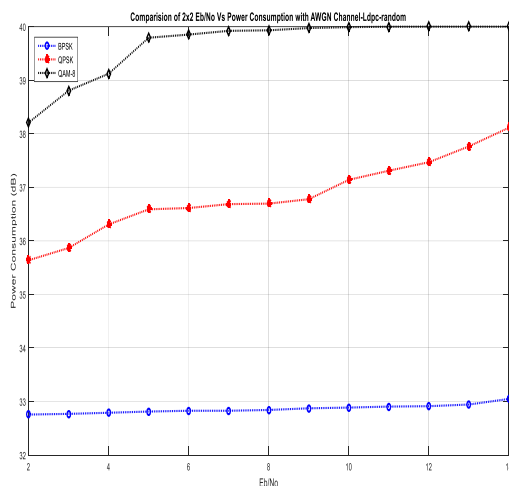
**Table III. comparison of performance parameters with RS code**

Modulation Technique	Coding Technique	interleavers	BER	Power consumption (dB)
BPSK	Reed Solomon	Random	$10^{-3}$	35
QPSK	Reed Solomon	Random	$10^{-3}$	34
QAM	Reed Solomon	Random	$10^{-3}$	<b>20</b>

In MIMO method many transmitter and many receiver antennas are present. MIMO method offer a conceivably very high volume which raises linearly with the numeral of antennas. Data rate increases with MIMO method, and bandwidth is saved and fading is reduced with OFDM. In OFDM technique the complete sign orthogonally overlays in a frequency field that defends the bandwidth. In Figure 5 Bit Error Rate and in Figure 6 power consumption for Interleaver Division Multiple Access technique is shown. Results are compared and tabulated in Table III.



**Fig. 7. BER of LDPC code**



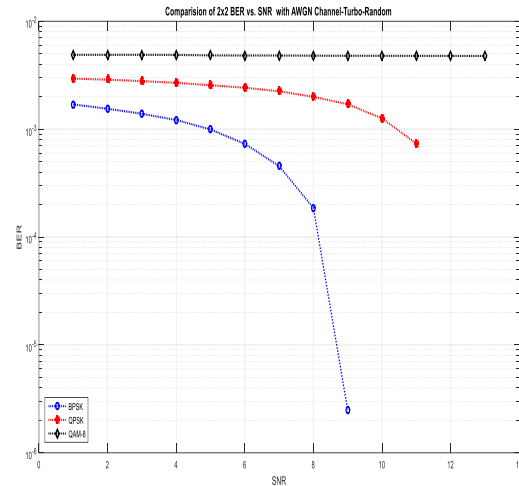
**Fig. 8. Power consumption of LDPC Code**

**Table IV. Comparison of performance parameters with LDPC code**

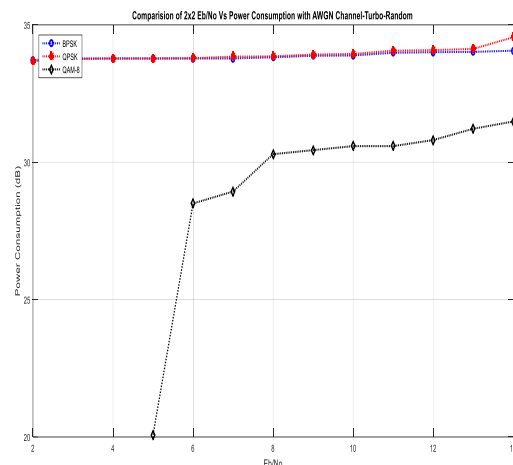
Modulation Technique	Coding Technique	interleavers	BER	Power consumption (dB)
BPSK	LDPC	Random	$10^{-3}$	35

QPSK	LDPC	Random	$10^{-3}$	34
QAM	LDPC	Random	$10^{-3}$	<b>20</b>

In Figure 7 and in Figure 8 we present a comparison of BER and power consumption respectively by taking coding technique as LDPC, interleaved with Random interleaver. Modulation as BPSK, QPSK, QAM. Comparison results are shown in Table IV.



**Fig. 9. BER of Turbo Code**



**Fig. 10. Power Consumption of Turbo Code**

**Table V. Comparison of performance parameters with Turbo code**

Modulation Technique	Coding Technique	interleavers	BER	Power consumption (dB)
BPSK	Turbo	Random	$10^{-3}$	35
QPSK	Turbo	Random	$10^{-3}$	34
QAM	Turbo	Random	$10^{-3}$	<b>20</b>

IDMA system is constructed on interleaving procedure. Compared to the available multiple access methods in underwater communication, IDMA is preferable. In Figure 9 and in Figure 10 we present a comparison of BER and power consumption respectively by taking coding technique as

Turbo code, interleaved with Random interleaver. Modulation as BPSK, QPSK, QAM. Comparison results are shown in Table V.

## VI. CONCLUSION

In underwater acoustic communication the acoustic medium is used to send information from one node to another. The acoustic communication has challenges in terms of BER, power, Bandwidth and fading. In this paper IDMA OFDM MIMO method is used to improve BER. When compared to previous work the proposed scheme gives better performance in terms of BER. The combination RS code, Convolutional code /Random interleaver/ BPSK modulation gives BER up to  $10^{-3}$  and  $10^{-4}$  respectively and power consumption 25dB. Whereas the combination Turbo code/ Random interleaver/ BPSK modulation Gives BER up to  $10^{-6}$  and power consumption is 35dB. The outcomes give the balance among BER and power consumption.

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