Performance Analysis of Error Control Codes for Underwater Wireless Acoustic Communication

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Abstract

In underwater acoustic communication, the information transmitted from 1 sensor node to another is corrupted due to errors persuaded by the noisy channel and other issues. To reduce the bit error rate, it is essential to propose suitable error regulator structure. In this paper, we simulate the performance analysis of Orthogonal Frequency Division Multiplexing Interleaver Division Multiple Access Multiple Input Multiple Output scheme with different channel codes to improve bit error rate performance. Bit error rate and consumed power are measured by communicating arbitrarily generated information through AWGN network. From the simulation results and assessment of the 2 divergent channel coding, 2 interleavers and 3 modulation techniques. We conclude that turbo codes with random interleaver and binary phase shift keying are best suitable to improve reliability performance for underwater wireless acoustic communication. To reduce the burst error in underwater acostic communication we propose an hybrid approach IDMA OFDM MIMO. BER performance is improved upto 10^{-6}.

Keywords: Convolutional coding, Matrix interleaving, OFDM MIMO, Turbo coding

Introduction

The information send through the acoustic channel is exposed to manipulation due to noise, to decrease the bit error rate, error control systems are required. In underwater acoustic communication because of severe energy limitation, we cannot rise transmitted power of the signal. Hence to reduce bit error rate another method is we can use the error control codes. Encoder circuit, decoder circuit of error controller codes demolish ample quantity of energy. This encourages us to learn error finding and error improvement codes. The 2 main treats in communication system are Additive White Gaussian Noise (AWGN) and interference. Years of analysis, we will handle Additive White Gaussian Noise mistreatment committal to inscription techniques (forward error improvement codes) like low-density redundant check codes [1] and turbo codes [2]. Interference continues to be a problematic, the advance is being created progressively [3-5]. In communication system Interference could are available completely in different forms, example;

1) Interference because of multiple-access,
2) In multipath channels lay to reference because of inter image interference,
3) In multiple transmit antenna systems interference because of cross antenna interference.

We will think about interference as additive noise; this principle is taken for capricious code division multiple access wave form schemes in single-user detection [6]. In scientific theory, for communication apply of random cryptography forms the most conception. Remarkably, in communication interference is an inevitable price, as imaginary by technologist in an optimum communication theme. Random cryptography technique, from a few years is viewed as a creative speculative means that for the resilient of capability of channel. The event and therefore the renovation of pseudo-random codes, example turbo codes and Low-Density Parity Check (LDPC) codes [7-10], proves the real-world result of reliability values.

Forward Error Correction (FEC) or channel coding [11,12] is an exemplary method to expand the presentation and unwavering quality of a correspondence channel. At the point when re-transmission is

moderately expensive and the framework is post pone delicate, FEC is utilized in the correspondence framework. When FEC is applied in a correspondence framework, controlled repetition is acquainted with the communicated bundle at the transmitter utilizing Error Control Codes (ECC) that permits identification and amendment of a specific measure of mistake at the beneficiary side. Channel encoding activity is the way toward including repetition at the transmitter where the activity changes over data pieces to codewords. The blunder can be distinguished and fixed at the recipient during the channel translating activity. Consequently, it wipes out the requirement for re-transmission. This is the key comfort of FEC which supports defer delicate correspondence frameworks. The points of interest gave by FEC come a few extra expenses [13-17]. The utilization of FEC in Under Water Sensor Network (UWSN) is supported based on a few variables. The utilization of FEC in coded correspondence framework can accomplish a specific dependability at essentially lower Signal to Noise Ratio (SNR) than an un coded framework. The data in SNR among un coded and coded frameworks is called coding gain and the estimation of coding gain relies upon 3 factors: The sort of ECC, code rate and unraveling calculation (i.e., the intricacy of translating calculation). The lower signal force transmission prerequisite at the transmitter (because of coding gain) which comes at the expense of additional vitality utilization because of channel encoding, channel interpreting and the transmission of excess pieces presented by FEC [18-20]. In this way, we have to think about the additional force utilization acquainted due with encoding, deciphering and transmission of additional pieces and the force sparing because of utilization of FEC. The utilization of FEC is possibly legitimized if additional force utilization because of encoding, deciphering and additional transmission, is lower than the force sparing because of coding gain, due to vitality obliged nature of UWSN hub. To make a reasonable correlation among un coded and coded framework with assortment of balance arranges, the SNR is estimated as the proportion of vitality per bit to the upsetting demand. When sending text data from one node to another node in underwater important performance parameter is bit error rate and power, In this paper the characteristic of BER and power for different modulation techniques, different coding and different interleavers are verified. For simulation purpose MATLAB 2015 is used. Desired BER for text is 10^{-5}. We propose an hybrid approach to reduce the burst error in underwater communication. The simple channel code convolution is not able to improve BER at decoding output. For this reason, turbo code is introduced to enhance the performance. OFDM saves the Bandwidth. MIMO technique increases the data rate. IDMA reduces channel noise such as burst error and fading. We propose an efficient and hybrid technique that combines MIMO OFDM with IDMA scheme to mitigating the fading issue in underwater wireless communications.

System configuration

Binary phase shift keying (BPSK)

In communication basic modulation technique is BPSK. $\sqrt{A_b}$ and $-\sqrt{A_b}$ symbols are used to represent binary data 1 and 0. Mathematically it is written as;

$$K_1(t) = \sqrt{\frac{2A_b}{\tau_b}} \cos(\Omega_c t + \Phi) \ (\Phi = 0) \tag{1}$$

$$K_2(t) = \sqrt{\frac{2A_b}{\tau_b}} \cos(\Omega_c t + \Phi + \pi) = -K_1(t) \tag{2}$$

duration of bit is τ_b, energy of bit is denotes as A_b, angular incidence is denoted as Ω_c and Φ represents the phase angle. R is the received data, it is written mathematically as;

$$R(t) = K(t) + N \tag{3}$$

where N is the noise. Bit error rate probability is given as;

$$S_e\left(\frac{\bar{e}}{K_2(t)}\right) = S_e\left(\frac{\bar{e}}{0}\right) \tag{4}$$

$$= \frac{1}{\sqrt{\pi N}} \, e^{\left[-\frac{1}{N}(e - K_{21})^2\right]} \tag{5}$$

$$= \frac{1}{\sqrt{\pi N}} \, e^{\left\{\left[\frac{-[e - (-\sqrt{A_b})]}{N}\right]\right\}^2} \tag{6}$$

$$= \frac{1}{\sqrt{\pi N}} \, e^{\left[-\frac{1}{N}(e+A_b)^2\right]} \tag{7}$$

when 0 is transmitted receiver accepts as 1 is represented as;

$$\int_0^\infty S_e\left(\frac{\bar{e}}{0}\right) dr = E_n(0) \tag{8}$$

$$E_n(0) = \int_0^\infty e^{\left[-\frac{1}{N}(e+A_b)^2\right]} dr \tag{9}$$

$$\frac{1}{\sqrt{N}}(r + A_b) = N \tag{10}$$

Above equation can be written as;

$$S_n(0) = \frac{1}{\sqrt{\pi}} \int_{\frac{\sqrt{A_b}}{N}}^\infty e^{\left[-\frac{1}{N}(z)^2\right]} dz \tag{11}$$

Multiplying Eq. (11) by 2;

$$S_n(0) = \frac{1}{2}\frac{2}{\sqrt{\pi}} \int_{\frac{\sqrt{A_b}}{N}}^\infty e^{\left[-(z)^2\right]} dz \tag{12}$$

$$S_n(0) = \frac{1}{2} \, erfc\left(\sqrt{\frac{A_b}{N}}\right) \tag{13}$$

$$S_n(0) = P\left(\sqrt{\frac{2A_b}{N}}\right) \tag{14}$$

similarly;

$$S_n(1) = \frac{1}{2} \, erfc\left(\sqrt{\frac{A_b}{N}}\right) \tag{15a}$$

The complete BER for BPSK is represented as;

$$\text{BER} = \frac{1}{2} S_n(0) + \frac{1}{2} S_n \tag{15b}$$

In case of BPSK demodulation carrier frequency of sender and detector coherent signal should be equal. It is less complex compared to other modulation technique.

Quadrature phase shift keying (QPSK)
In QPSK 2 bits are used to represent symbol. QPSK is represented mathematically as [10];

$$K_1(t) = \sqrt{\frac{2A_b}{\tau_s}} \, \cos\left(2\pi\Omega_c t + (2j-1)\,\frac{\pi}{4}\right) \tag{16}$$

It can be represented as;

$$K_1(t) = \sqrt{\frac{2A_b}{\tau_s}} \, \cos\left((2j-1)\,\frac{\pi}{4}\right) \, \text{cosine}\Omega_c t - \sqrt{\frac{2A_b}{\tau_s}} \, \text{sine}\left((2j-1)\,\frac{\pi}{4}\right) \, \text{sine}\Omega_c t \tag{17}$$

here j = 1,2,3,4. τ_s are duration of symbol. The final output is;

$$e_1(t) = K_1(t) + N \tag{18}$$

N is the noise.

In $K_4(t)$ the correct data is sent as;

$$E_{K_{4(t)}} = \int_0^\infty \frac{1}{\sqrt{\pi N}} e^{\left[\left[-\frac{1}{N}\left(e_1-\sqrt{\frac{A_b}{2}}\right)^2\right]\right]} dr_1 \int_0^\infty \frac{1}{\sqrt{\pi N}} e^{\left[\left[-\frac{1}{N}\left(e_1-\sqrt{\frac{A_b}{2}}\right)^2\right]\right]} dr_2 \tag{19}$$

e_1 and e_2 are independent, $\frac{e_i-\sqrt{\frac{A_b}{2}}}{\sqrt{N}}$ is substituted as r. Here i = 1, 2.

$$E_{K_{4(t)}} = \left[\frac{1}{\sqrt{\pi}} \int_{-\sqrt{\frac{E_b}{N}}}^\infty e^{[-(z)^2]}\right]^2 dz \tag{20}$$

That is;

$$\frac{1}{\sqrt{\pi}} \int_{-a}^\infty e^{[-x^2]} \, dx = 1 - \frac{1}{2} \, erfc \, (c) \tag{21}$$

Can be written as;

$$E_{K_{4(t)}} = \left[1 - \frac{1}{2} \, erfc \, \left(\sqrt{\frac{A_b}{2N}}\right)\right]^2 \tag{22}$$

Error is denoted by;

$$\xi_{eK4(t)} = 1 - \xi_{K4(t)} \tag{23}$$

$$\xi_e = \frac{1}{2} \, erfc \, \left(\sqrt{\frac{A_b}{N}}\right) \tag{24}$$

In QPSK communication system 1 symbol is represented by 2 binary data. That consumes the more power. In underwater communication QPSK technique is very complicated.

Quadrature amplitude modulation (QAM)
In QAM phase and magnitude variation is used to characterize bits, both amplitude and phase QAM is represented as;

$$K_i(t) = \sum_{l=-\infty}^\infty \sqrt{\frac{A\tau_Q}{\tau}} \, h_\tau(t - l\tau) \, cosine\left(2J_l + 1 - \sqrt{L}\right) \tag{25}$$

$$K_Q(t) = \sum_{l=-\infty}^\infty \sqrt{\frac{A\tau_Q}{\tau}} \, h_\tau(t - l\tau) \, sine\left(2J_l + 1 - \sqrt{L}\right) \tag{26}$$

$A\tau_Q$ is energy of symbol, where $L = 4$.

BER is considered as;

$$E_{O,MQAM} = \frac{1}{log_2\sqrt{M}} \left(1 + 2 + 4 \dots\dots + 2^{log_2 \sqrt{M-1}}\right)E_p \tag{27}$$

in general;

$$E_{O,MQAM} = \frac{4}{log_2 L} \left(1 - \frac{1}{\sqrt{L}}\right) \sum_{i=1}^{\sqrt{\frac{L}{2}}} P\left((2j - 1)\sqrt{\frac{3A_b log_2 L}{(L-1)N}}\right) \tag{28}$$

underwater communication is limited by battery power as solar energy cannot be used to charge the battery. As QAM receiver circuit is extra complex when compared to other modulation techniques.

Materials and methods

In this paper, we assess the consumed power of convolutional code, turbo code. The code which consumes less power is recognized, assessment is based on the hypothesis that error control performance that is assessed by bit error rate examination. In this paper user-specific interleavers (random and matrix interleaving) are used to completely differentiate different users. For planet suitableness these interleavers is selected haphazardly and it's not needed that they're orthogonal. In communication system interference is unpredictable between the users, for multiple access channels at first Interleaver Division Multiple Access (IDMA) was planned, same construct is being applied for alternative requests, like transmission schemes, coded tone, antenna systems. IDMA theme offers the flexibility and power. At the supply finish, mistreatment forward error correction encoder information is initially encoded for sender b_i with rate as t and therefore the encoded data is interleaved by an interleaver into a chip order. Before sending the information, modulation is employed as in **Figure 1**. The users are unit separated by specific interleavers, and it is not needed to use predictable spreading method employed in CDMA. Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing Interleaver Division Multiple Access (MIMO OFDM IDMA) is represented (**Figure 1**). In this process we assume that in a single communication cell k users are arbitrarily spread. The following assumption is made: Tt transmitting antennas are used at the transmitter and Tr receiving antennas are used at the receiver.

Let b_i denotes the input bit stream representing to the ith user. Using turbo code/ convolution coding, we first encode the bit stream. Them using random / matrix interleaving encoded data is inreleaved. Binary phase shift keying (BPSK) modulation method is used on encoded and interleaving bit stream. Here m_i represents the bit stream to be transmitted to the ith user after performing channel coding.
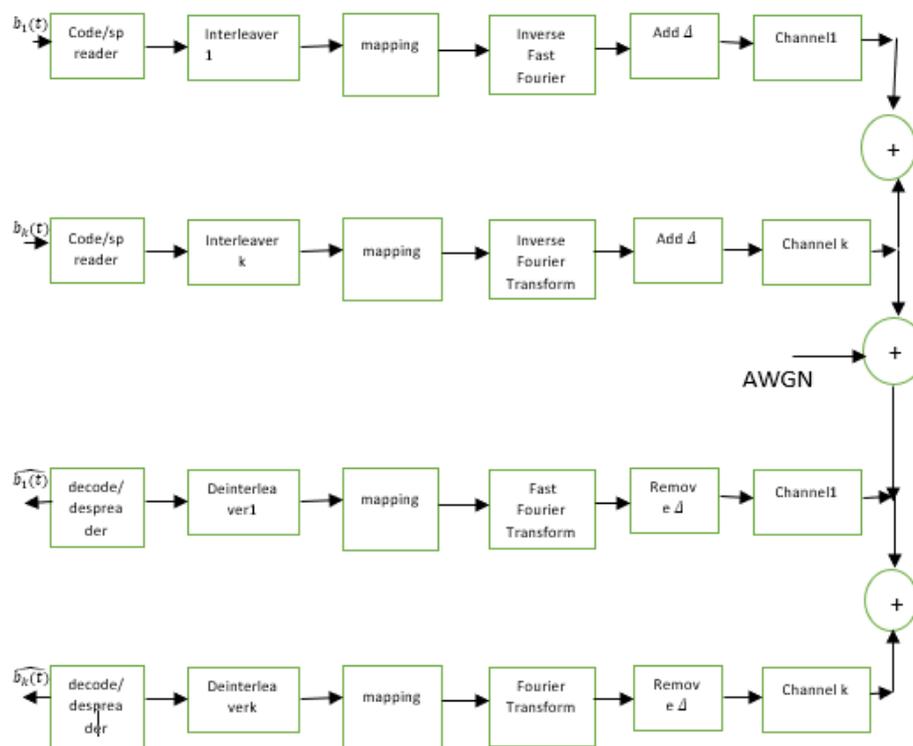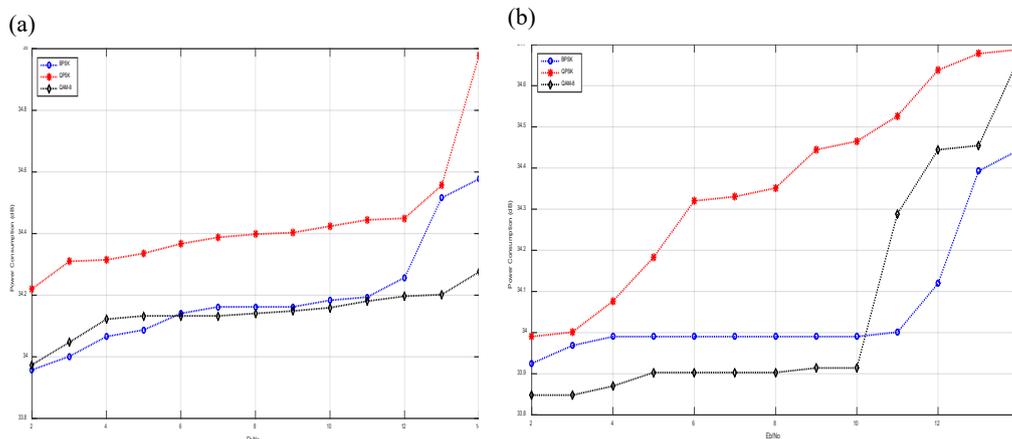

Figure 1 MIMO OFDM IDMA.

Results and discussion

Convolutional coding technique with random interleaving and 3 modulation techniques
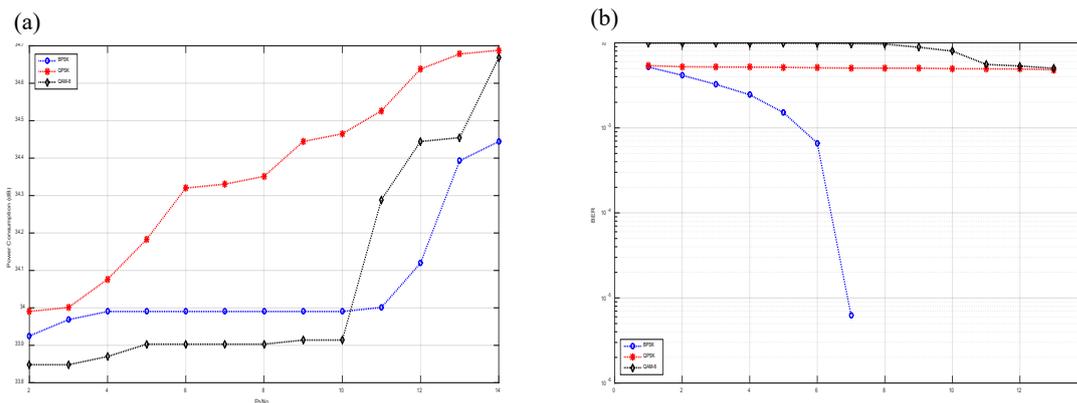
Figure 2(a) compares the consumed power and in **Figure 2(b)** compares the bit error rate of MIMO OFDM IDMA for UWAN. In **Figure 2** for coding we take convolution code, for interleaving we take random interleaver and 3 modulation techniques BPSK, QPSK, QAM. Simulation results shows that consumed power for BPSK is 31 dB and for QPSK and QAM is around 35 dB for E_b/N_o 12 to 14 dB and bit error rate is around 10^{-3} for SNR 13 to 15 dB.

Figure 2 (a) Power consumption, and (b) BER for convolution coding and random interleaving method.

Convolutional coding technique with matrix interleaving and 3 modulation techniques

Figure 3(a) compares consumed power and in **Figure 3(b)** compares the bit error rate of MIMO OFDM IDMA for UWAN. In **Figure 3** for coding we take Convolution code, for interleaving we take Matrix interleaver and 3 modulation techniques: BPSK, QPSK, QAM. Simulation results shows that consumed power for BPSK is 31dB and for QPSK and QAM is around 35 dB for E_b/N_o 12 to 14 dB and bit error rate is around 10^{-3} for SNR 13 to 15dB.

Figure 3 (a) Power consumption and (b) Bit error rate for convolution coding and matrix interleaving method.

Turbo coding technique with random interleaving and 3 modulation techniques

Turbo code is a new class of Convolutional code. Turbo code gives higher performance when compared to convolution code. **Figure 4(a)** compares consumed power and in **Figure 4(b)** compares the bit error rate of MIMO OFDM IDMA for UWAN. In **Figure 4** for coding we take turbo code, for

interleaving we take random interleaver and 3 modulation techniques BPSK, QPSK, QAM. Simulation results shows that consumed power is around 34 dB for E_b/N_o 12 to 14 dB and bit error rate for BPSK is 10^{-6} and for QPSK and QAM is around 10^{-3} for SNR 13 to 15 dB.
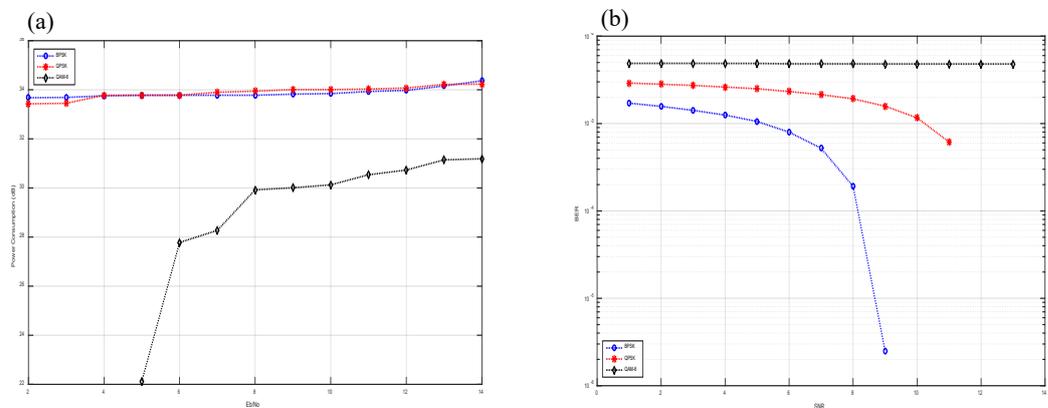

Figure 4 (a) Power consumption and (b) Bit error rate for turbo coding and random interleaving method.

Turbo coding with matrix interleaving

Figure 5(a) compares consumed power and in **Figure 5(b)** compares the bit error rate of MIMO OFDM IDMA for UWAN. In **Figure 5** for coding we take turbo code, for interleaving we take matrix interleaver and 3 modulation techniques BPSK, QPSK, QAM. Simulation results shows that consumed power for BPSK and QPSK is 34 dB and consumed power for QAM is 29 dB for E_b/N_o 12 to 14 dB and bit error rate for BPSK, QPSK and QAM is 10^{-3} for SNR 13 to 15 dB.
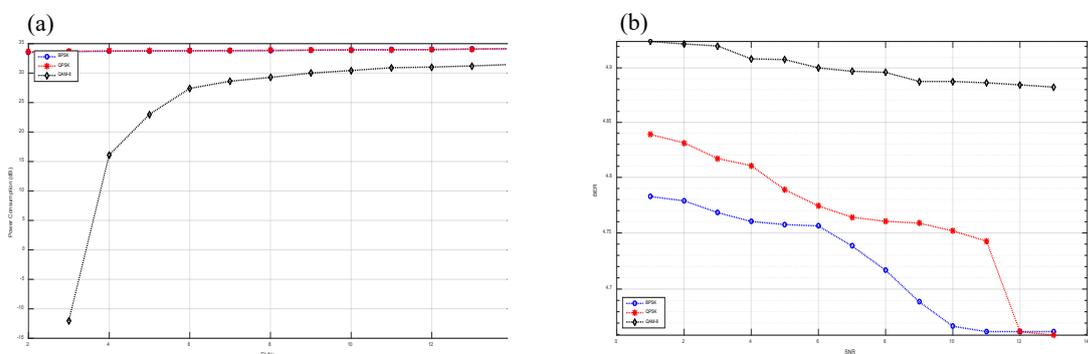

Figure 5 (a) Power consumption and (b) Bit error rate for turbo coding and matrix interleaving method

Performance parameters comparison

For error correction turbo codes are very powerful tool when combined with interleaver gives better results. Performance parameters are compared for Orthogonal Frequency Division Multiplexing Interleaver Division Multiple Access Multiple Input Multiple Output by captivating 2 coding methods convolutional code and turbo code, with 2 interleaving method random interleaver, matrix interleaver and 3 modulation methods BPSK, QAM and QPSK. Results are tabulated in **Table 1**. We observe from simulation results that turbo code with binary phase shift keying and random interleaving improves the bit error rate performance.

Table 1 Evaluation of performance constraints.

Modulation method	Coding method	Interleaving technique	Bit error rate	Consumption of power
BPSK	Convolutional code	Random interleaving	10^{-3}	31 dB
QPSK	Convolutional code	Random interleaving	10^{-3}	35 dB
QAM	Convolutional code	Random interleaving	10^{-3}	35 dB
BPSK	Convolutional code	Matrix interleaving	10^{-3}	31 dB
QPSK	Convolutional code	Matrix interleaving	10^{-3}	35 dB
QAM	Convolutional code	Matrix interleaving	10^{-3}	35 dB
BPSK	Turbo code	Random interleaving	10^{-6}	36 dB
QPSK	Turbo code	Random interleaving	10^{-3}	35 dB
QAM	Turbo code	Random interleaving	10^{-3}	33 dB
BPSK	Turbo code	Matrix interleaving	10^{-3}	36 dB
QPSK	Turbo code	Matrix interleaving	10^{-3}	36 dB
QAM	Turbo code	Matrix interleaving	10^{-3}	32 dB

Conclusions

Due to limited energy and reliability, underwater acoustic wireless communication is postured to numerous issues and challenges. Sending information in underwater wireless communication using acoustic link is challenging. In this paper we present reliable channel coding with MIMO OFDM IDMA which provides reliability. This technique provides reliable communication from source to destination. In underwater node energy is very important parameter. From Simulation result we conclude that convolution coding with random and matrix Interleaving gives power up to 30 dB and BER 10^{-3}. The performance is improved when we combine turbo code with random interleaving and BPSK gives BER up to 10^{-6} and power 36 dB. Simulation result offers the transaction between BER and consumed power. As a future work the physical layer is combined with network layer as a cross layer approach to improve the performance.

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