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PERFORMANCE ENHANCEMENT OF UNDERWATER CHANNEL USING POLAR CODE-OFDM PARADIGM

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ABSTRACT

Large industrial and marine applications are adopted the technology of under-water acoustic channel in their communication systems. The technology is undergone several obstacles that made it one of stringent communication as compared with other communication media. The underwater channel is attributed by its narrow bandwidth and suffocated multipath propagation that produce sever Inter-Sample-Interface (ISI). Orthogonal Frequency Division Multiplexing (OFDM) is proposed in this paper to carry the encrypted data (Polar coded) through-out the under-water channel. In presence of above limitations, the proposed system is drawn good performance to overcome under-water channels obstacles. Block error rates examined with respect to signal to noise ratio in order to find the best constraint length value for Polar code-OFDM system with different code rates. Results found that cyclic redundancy check bit (CRC-bit) is one of key points to reserve a good performance with high constraint length.

Keywords: Under-water channel (UWC), Polar code (PC), Orthogonal Frequency Division Multiplexing (OFDM), cyclic redundancy check bit (CRC-bit).

I. INTRODUCTION

Under-water communications are populated as permissible means to serve such applications operated in water environment; for that reason, a lot of researches were conducted in this regard. Under water environments are found as strong degradation medium where any communication is suffered from severe multipath fading [1]. Performance of communication through acoustic channel is limited by set of phenomenon alike inter-symbol-interface (ISI) , inter-carrier-interface(ICI), Doppler shift and Noise. These facts made the degradation of radio signal in acoustic channel a strong drawback. However, the intensity of noise and other limitations in underwater (acoustic) environments is termed by the time variant nature of this channel which it difficult to overcome these obstacles in traditional ways [2]. The OFDM was used to replace the broadband modulation for ensuring transmission of higher data rate over Compressed Sensing (CS) approach [3]. The impairments alike impulsive noise and other PLC problems are found more resistible with OFDM approach more than other signal carrier systems [4][5]. After invention of Polar code [6] and impression gained by such coding for optimizing the capacity in Memory-less Binary Discreet Channel, Polar code is utilized to ensure the capacity with large enough codeword. The enhanced capacity is met in PC by employing the channel polarity concept. Polarization is a combination method where several versions of same binary memory-less discreet channel can be merged into one channel and this channel is spreadable into frozen group and information group. The frozen group can be attributed as approached to zero capacity that no information can be transmit over the such; whereas, the information channel is termed with unity approach capacity which make it suitable to transmit the information. The Bhattacharyya indicator Z(W) is used to examine the Polar code channel reliability by indicating the position of frozen and information bits respectively as:

$$Z(w) \triangleq \sum_{y\in Y} \sqrt{p(y|0)p(y|1)} \qquad (1)$$

Where the received signal “y” conditional probability is given by P(y). The performance polar code over successive cancelation list (SCL) can be optimized with using of CRC aided polar [7] code as demonstrated in [4a] [5a]. The integration of codded modulation alike polar coding with orthogonal frequency multiplexing is being used as a method to enhance the immunity against deep fading environments as in [5]

In this paper, we aimed to design a rudest under-water communication system overcoming the limitations of the time variant obstacles; however, Polar code based orthogonal frequency multiplexing is used for ensuring the channel immunity for underwater limitations. The same is planned by maximize the data rate by transmitting of fewer samples. Results may highlight the performance Polar code in terms of Bit Error Rate (BER) comparable with turbo code performance while transmitting the data over OFDM-PLC method.

Proposed Model

The idea of OFDM- Polar code integration is inherited from the properties of simple receiver where efficient bandwidth can be achieved with channel restrictions immunity. In this study, Polar code- OFDM approach is used with stuff alike random inter-leaver, pulse sharper and synchronizer to combat the strongly faded underwater channel. For deploying the Polar codes-OFDM paradigm on acoustic channel, specifications of the last may need to be considered while design of such communication system. The acoustic signal transmission under sea environments is suffering from large attenuation especially with high frequency signals which leads to poor link quality as a result to multipath. Since the multipath fading is increasing with higher frequency, the frequency range of (12 KHz-19 KHz) is found suitable for under-water communications. However, the model of Polar code-OFDM (PC-Orthogonal Frequency Division Multiplexing) based under-water communications is implemented in Matlab environments and Table 1 reveals the parameters setup.

Table 1: The model parameters for setting up the same in Matlab environment.

Subject	Attribute	Subject	Attribute
Number of sub carriers	6	Data rate	10.08 Kbps
Frequency of sampling	44.1 KHz	IFFT length	256
Carrier's separation	24.6 Hz	CP duration	10 ms
Frequency of Modulation	6.3 KHz	Mapping scheme	QPSK
Duration of symbol	40.65 ms	CP length	0.25*IFFT
Frequency response	12-19 KHz	CRC	(11.19)

The model flowchart in Figure 1 is demonstrating the functions of under-water communication by means of our proposal. Matlab is used to establish the system with above parameters with efforts to minimize the negative effects of under-water medium on the radio wave transmission (deep fading with time variant multipath).

II. TRANSCEIVER DESIGN

As given in Table 1, Symbol period is vital parameter in the settings of underwater channel; however, tradeoff is recovered between the spreading delay and symbol period so that, symbol period must be chosen in accordance with spreading delay which is highly responded to the surrounding medium. Ten milliseconds of Symbol period are found optimum for occasion's environments. For designing this paradigm 1/6, 1/3, 2/3 Polar code rate is being implemented with constraint length of 7 to be used with CRC (11,19) of polynomial sequence. In order to map each bit into the respected symbol, QPSK mapper in being used and for averting the block error we have employed a random inter-leaver. Time domain information is retrieved wherever required using the concept of Inverse Fast Fourier Transform (IFFT). The produced symbols are up sampled by 12 KHz to 19 KHz passband frequency for making it more combatable to inter-symbol-interface, hence seven times up samples are performed on the symbols prior to their conversion into analogue version. The advantage of orthogonality in frequency multiplexing lies on guard appendix on the head of each symbol which form the so-called cyclic prefix as demonstrated in Figure 1. The guard interval is set to 10.2 milliseconds as in Table 1. Shaping process is performed using cosine raised filter so each pulse is reshaped during this stage. For synchronization purpose, LFM signal of duration (1 millisecond) is been employed. Signal transmission was kept undergoing a noisy channel (AWGN) and Rayleigh fading on top of deep fading of under-water environments. Figure 2 is depicting the process of demodulation (receiving) of the under-water channel's

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signal. Receiver deploys successive cancelation decoder with DQPSK module to retrieve the original signal; whereas, signal is down-converted to the level of the original frequency with IQ transformation.

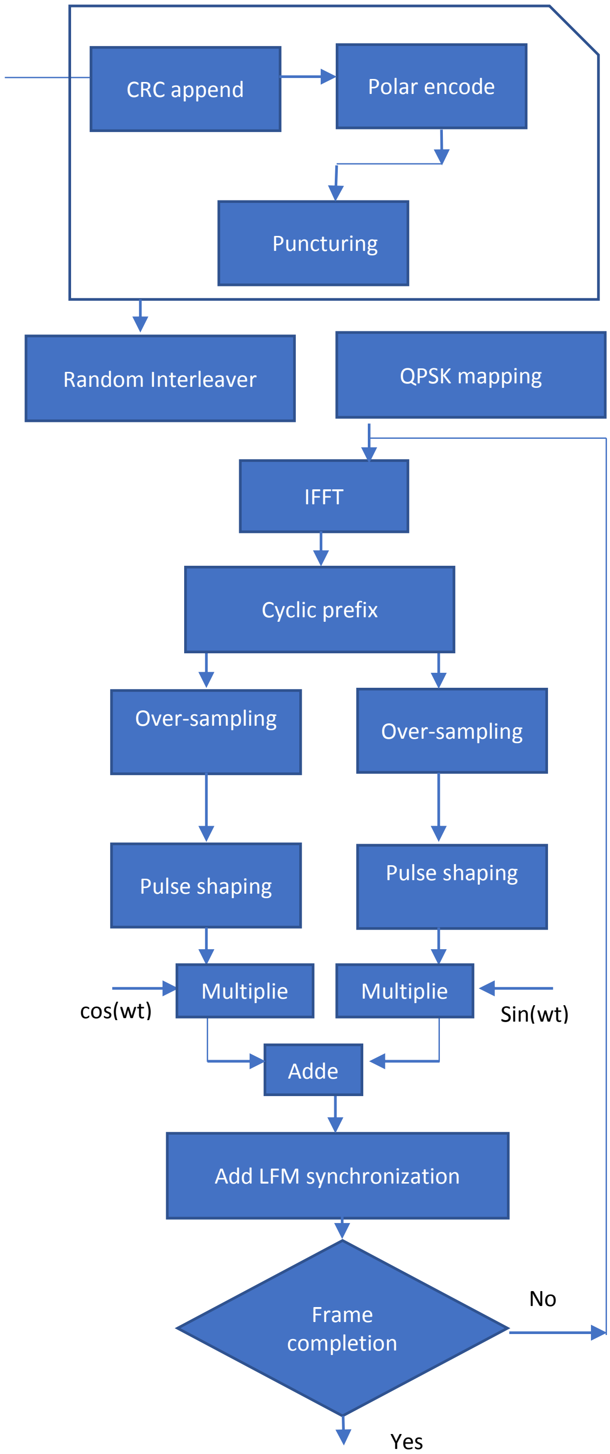

Figure 1: The transceiver design of OFDM based Polar code in under-water communication system.

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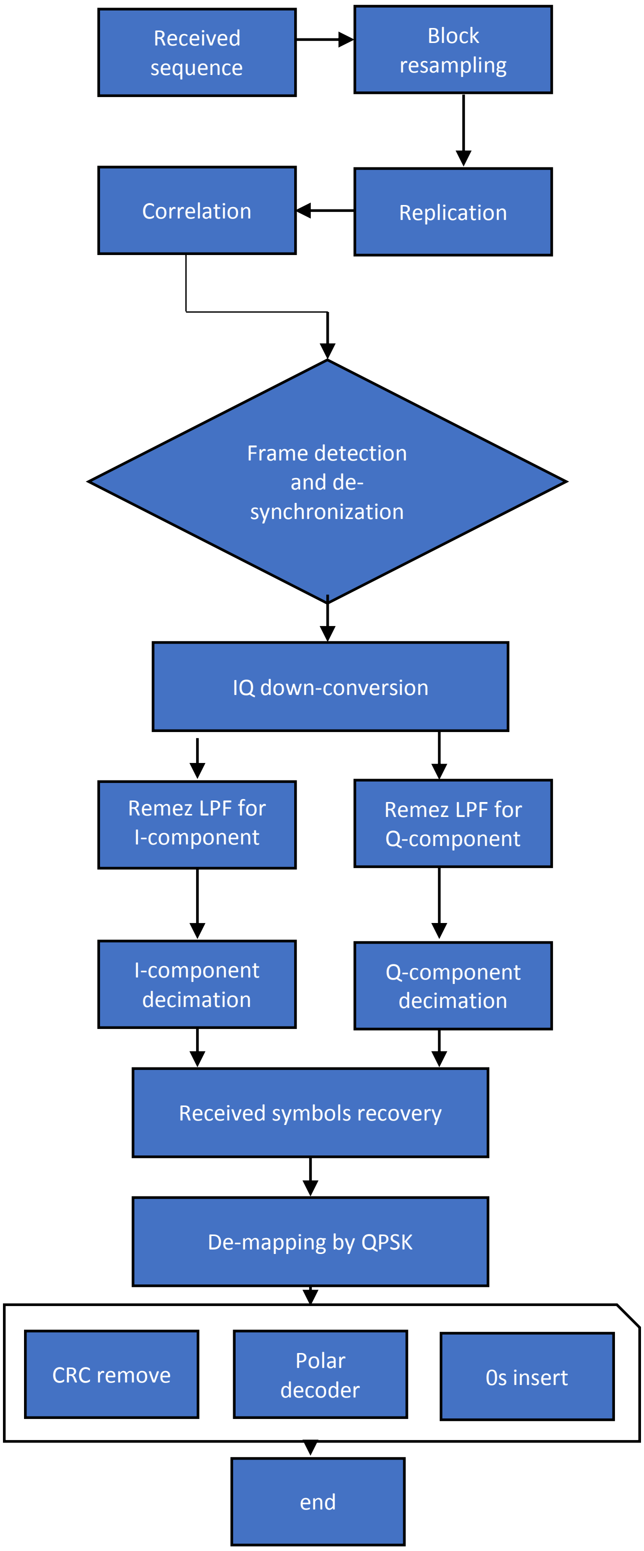

Figure 2: Receiver end system of OFDM-PC paradigm.

This work involves the use of polar code on the top of frequency division multiplexing to enhance the reliability of the underwater communication system. However, system is expected to perform a better noise immunity over AWGN under-sea environments.

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III. MATHEMATICAL INTERPRETATION

Firstly; as diagram reveals, polar coding is performed as pyramid top step. However, equation (2) is describing the process of polar coder.

$$F^{\otimes n} = F^{\otimes n-1} \otimes F \qquad (2)$$

The note ⊗ refers to Kronecker product on equation (2). Furthermore, the ratio of log likelihood of the respective channel [8] is given in (3).

$$LLR(y_i) = ln(\frac{p(y_i|x_i=0)}{p(y_i|x_i=1)}) \qquad (3)$$

Successive cancelation decoder (SC) may return the decision output as follow.

$$\widehat{U}_i = \begin{cases} 0 & LLR(y_1^N, U_1^{i-1}) \geq 0 \\ 1 & LLR(y_1^N, U_1^{i-1}) < 0 \end{cases} \qquad (4)$$

The output decision likelihood ratio from successive cancelation decoder with consideration of previous state of output ($U_1^{\,i-1}$) [9][10].

$$LLR(y_1^N, U_1^{i-1}) \qquad (5)$$

As the coder generates a decision of output, orthogonal frequency multiplexing procedure may take place on then. The OFDM paradigm could produce the form (modulator output of transmitter)) of equation (6) and the receiver may demodulate this sequence as per the equation (7).

$$\boldsymbol{x_n = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_k \, exp(\frac{j2\pi nk}{N})} \qquad (6)$$

$$\boldsymbol{Y_k = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} y_n \, exp(-\frac{j2\pi nk}{N})} \qquad (7)$$

For up conversion of OFDM symbols, Inverse Fourier Transform is being used in transmitter. Such is followed by Fourier transform to recover the original information format in the receiver[11].

$$X = IFFT(x) \qquad ,Y = FFT(y)$$

The approximation of noise variance can be performed to cover the required accuracy of FFT.

$$\boldsymbol{\sigma_Z^2 = \sigma_G^2 (1 + \frac{1}{\Gamma})} \qquad (8)$$

$$\boldsymbol{LLR(Y_i) = ln\left[exp\left(\frac{2y_i}{\sigma_Z^2}\right)\right] = \frac{2y_i}{\sigma_Z^2}} \qquad (9)$$

The equation (9) reveals the approximation of LLR due to noise variance approximation of (8).

More specifically, the output of underwater channel pulses that produced by QPSK modulator can be given as:

$$g(t) = \sum_{n=0}^{k-1} d_n s(t) exp(j2\Pi f n^t) \qquad (10)$$

Where this sequence is passed through OFDM modulator, the new sequence can be yielded as below:

$$\mathrm{g(t) = exp(j2\Pi f_c) \sum_{n=0}^{k-1} d_n s(t) exp(j2\Pi fn^t)} \quad (11)$$

For orthogonality insurance in the system, d_n is kept as zero as in below equation [12][13].

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$$\int_{-\infty}^{\infty} s(t)\exp\left(j2\pi\langle f_i - f_j\rangle t\right)dt = \begin{Bmatrix} 1, & \text{if } i = j \\ 0, & \text{if } i \neq j \end{Bmatrix}$$

IV. RESULTS AND DISCUSSION

With three key performance, system is established to measure the Block Error Rate (BER) as respect to signal to noise ratio (SNR). By changing the constraint length of symbol in polar code to be either 120 or 240 and varying the CRC to be 11 and 19 respectively; Signal to noise ratio is plotted on basis of block error rate with different code rates R (1/6, 1/3, ½, 2/3). The results is given by Figures (3 through 5).

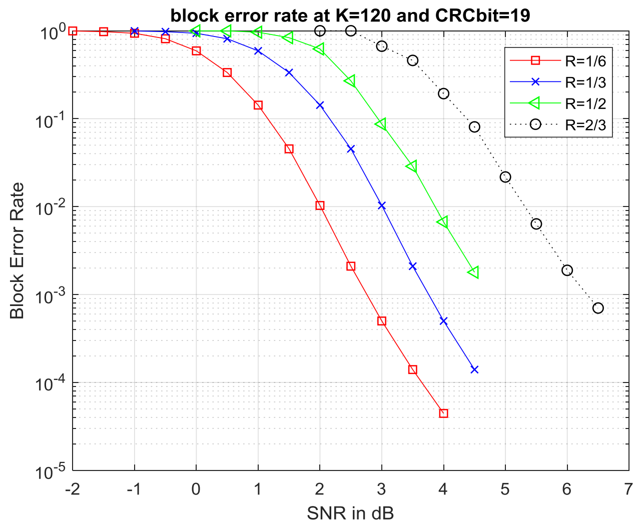

Figure 3: Block error rate versus the signal to noise ratio, figure depicts good performance with low constraint length.

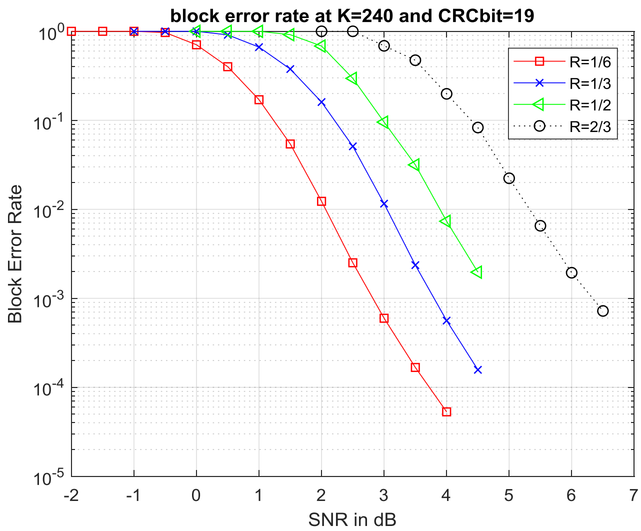

Figure 4: Block error rate versus the signal to noise ratio, figure depicts low performance with higher constraint length.

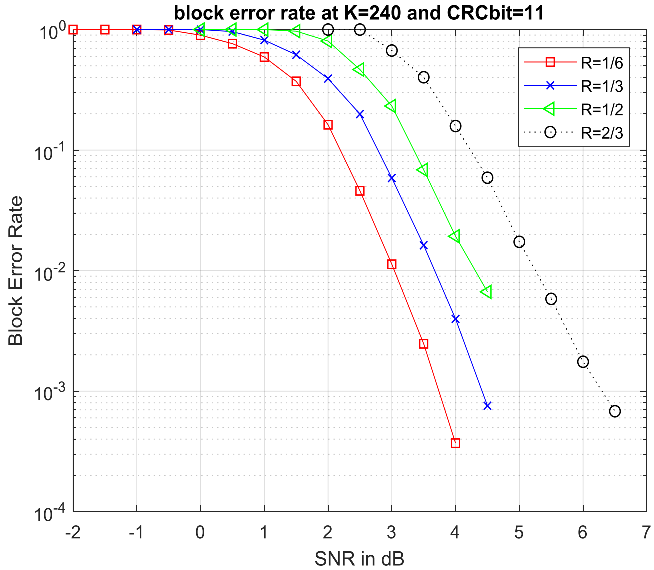

Figure 5: Block error rate versus the signal to noise ratio, figure depicts very-low performance with higher constraint length and lower CRC bit.

V. CONCLUSION

For under-water communications system, it been notice that high fading can hit the radio transmission due to severe multipath reflection. However, coding schemes followed by strong multiplexing technique is found suitable to combat such negative effects. In this study, we used the Polar code with orthogonally scheme to enhance the block error rate. Polar code with two possibilities of constraint lengths (120, 240) are used over OFDM system. Results reveals that constraint length of 120 and cyclic redundancy check bit of 19 will return the optimum results of block error rate with respect to signal to noise ratio at code rate of 1/6. Whereas different block error rates are yielded by varying the code rate as 1/3, 1/2 and 2/3. The following experiment stage of this study involves increasing the constraint length of polar code to be 240 and two possibilities of cyclic redundancy check bits are tested with the same constraint length (CRC-bit) i.e. 11 and 19; hence then, results reveal that high constraint length may degrade the performance of the system. At such condition when big constraint length is imposed to the paradigm, cyclic redundancy check (CRC-bit) bit may mitigate the negative outcomes, maximizing the CRC-bit is proved to reduce the block error rate.

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