DM-MIMO Based GFDM Advanced Underwater Image Transmission Scheme

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Abstract. In the paper, we proposed a 2 × 2 direct mapping multi-input multi-output based generalized frequency division multiplexing (GFDM) low density parity check (LDPC) code underwater image transmission scheme (UITS). The adaptive 4 quadrature amplitude modulation (QAM) and 16 QAM modulations, were integrated into the proposed UITS. The performances of bit error rates and peak signal-to-noise ratios of the proposed UITS with perfect channel estimation (PCE) (0%) were explored. From these simulation results, we evaluated the performances of the proposed advanced UITS with PCE.

Keywords: Underwater image transmission scheme · 2 × 2 DM MIMO · GFDM · LDPC code · PSNRs

1 Introduction

In the paper, we proposed a 2 × 2 direct mapping (DM) multi-input multi-output (MIMO) based generalized frequency division multiplexing (GFDM) low density parity check (LDPC) code underwater image transmission scheme (UITS). The adaptive 4 quadrature amplitude modulation (QAM) and 16 QAM modulations, were integrated into the proposed UITS. The performances of bit error rates and peak signal-to-noise ratios of the proposed UITS with perfect channel estimation (PCE) (0%) were explored. From these simulation results, we evaluated the performances of the proposed advanced UITS with PCE. Acoustic underwater transceivers have many design challenges due to sensitive underwater acoustic channel characteristics, that is limited bandwidth, long propagation delays, extended multipath, rapid time variation, and large Doppler shifts [1]. Orthogonal

I. A. Parinov et al. (Eds.): *Physics and Mechanics of New Materials and Their Applications*, SPM 20, pp. 466–470, 2023. https://doi.org/10.1007/978-3-031-21572-8_39

frequency-division multiplexing (OFDM), and frequency-shift keying (FSK) modulations were integrated into the proposed channel-aware adaptive underwater modem. The performance of a GFDM transceiver for underwater acoustic high data-rate communication was evaluated [2]. The simulation results indicate that, for a symbol error rate of 10^{-2}, GFDM outperforms OFDM by almost 4 dB and has higher spectral efficiency, flexibility, and better error performance in an underwater acoustic channel environment. The underwater acoustic channel has multiple challenges, that is colored ambient noise, frequency-dependent attenuation, and doubly selective fading [3]. GFDM is a recently developed non-orthogonal multicarrier scheme that has been tested for underwater acoustic communication. The bit error rate (BER) performance of the proposed GFDM transceiver was evaluated under different underwater channel conditions with additive white Gaussian noise (AWGN).

The performance of the GFDM transceiver was analyzed in a shallow underwater acoustic channel (UAC) [4]. The simulation results show that the Bose–Chaudhuri–Hocquenghem (BCH) (31,6) and Reed–Solomon (RS) (15,3) give the best BER performance. The convolutional code with a code rate of 1/2 has the best BER performance. Lin et al. [5] proposed a low-power underwater acoustic (UWA) image transceiver based on GFDM modulation for underwater acoustic communication. The LDPC code error protection scheme, adaptive 4-quadrature amplitude modulation (QAM) and 16-QAM strategies, GFDM modulation, and a power assignment mechanism were integrated into the proposed GFDM-based underwater image transceiver. Lin et al. [6] also proposed a DM-based MIMO filter bank multi-carrier (FBMC) underwater acoustic multimedia communication architecture. This paper describes a DM-based GFDM underwater image transceiver.

2 Research Method

Figure 1 shows the proposed 2 × 2 DM-based GFDM-LDPC underwater image transmission scheme (UITS). It includes the following features: a 2 × 2 DM-based MIMO transmission strategy; adaptive 4-QAM or 16-QAM modulations; wireless image packet-by-packet transmission method; CSMA/CA network access method; a power assignment algorithm; (2000, 1000) LDPC code encoder with a code rate of 1/2, column weight of 3, and row weight of 6; serial-to-parallel and parallel-to-serial mechanisms. The GFDM modulation architecture [5] with a 128-point inverse fast Fourier transform (IFFT) are integrated into the UITS.

Image signals were input into the (2000, 1000) LDPC encoders, and image LDPC coding bit streams were extracted as the output. The image LDPC packets were input into the 2 × 2 DM-based MIMO mechanism using a serial-to-parallel method, and the 2 × 2 DM-based MIMO multimedia packets were extracted as outputs. Image LDPC coding packets use different spatial hardware to achieve high-speed underwater image communication in the DM-based transmission mechanism. The 2 × 2 DM-based MIMO image packets were input into adaptive 4-QAM or 16-QAM modulations, which adaptively yielded 2 × 2 DM-based MIMO image modulated packets. Those packets that were in the serial-to-parallel method, 128-point IFFT, and parallel-to-serial method; and 2 × 2 DM-based MIMO GFDM image modulated packets with power assignment schemes were extracted as final outputs. The BER limit for the image packets was 10^{-4}.

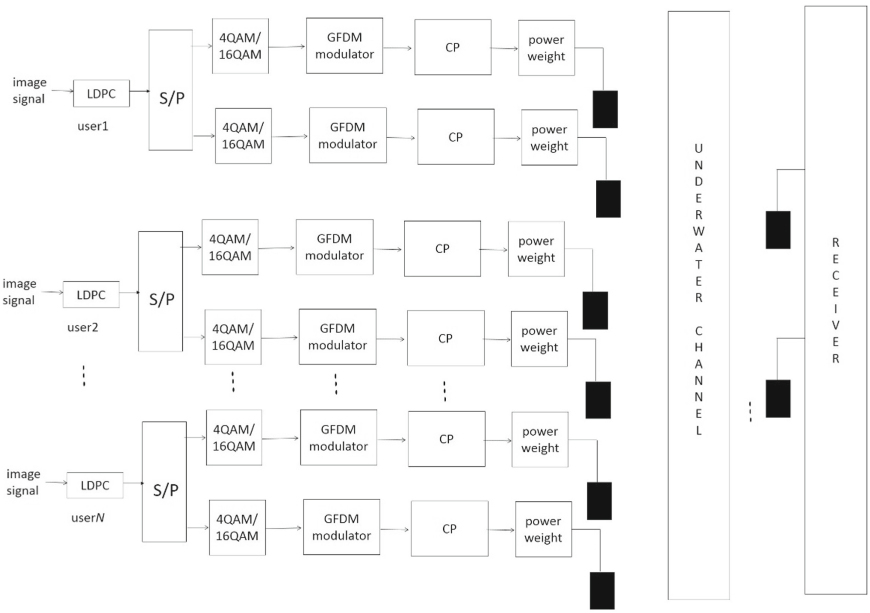

Fig. 1 The proposed DM MIMO based GFDM-LDPC advanced UITS

3 Simulation Results

The MIMO underwater channel with a model carrier central frequency of 11.5 kHz, an underwater channel bandwidth of 4 kHz, and a transmission distance of 1 km was adopted [6]. Figure 2 illustrates the BER performances of the proposed transceivers with channel estimation errors (CEEs) of 0% (perfect channel estimation), the symbols "o" and "*" denote the 4-QAM and 16-QAM modulation technology, respectively.

When using the 4-QAM strategy, the BER value of the proposed transceivers with CEEs of 0% and 11.55 dB SNR is 6.5710^{-5}. When using the 16-QAM strategy, the BER value of the proposed transceivers with CEEs of 0% and 18.54 dB SNR is 5.1410^{-5}. The results show that the 4-QAM has better SNR gain of 7 dB compared to the 16-QAM at approximately BER performance in the underwater environment.

Figure 3 shows the PSNR performance of the DM-MIMO GFDM-LDPC UITS with PCE. The symbols "o" and "*" denote the 4-QAM and 16-QAM modulation technology, respectively. The BER limit values for image packets are 10^{-4}. The received underwater image evaluation parameter is peak SNR (PSNR). The PSNR parameter in the 2 × 2 DM MIMO GFDM-LDPC UITS is given as follows.

$$IMSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left[OI(i,j) - RI(i,j)\right]^2; \tag{1}$$

$$PSNR = 10log_{10}\left[\frac{Max(OI(i,j)^2)}{IMSE}\right], \tag{2}$$

where *IMSE* is the image mean square error (MSE) of an image signal comprising of *mn* pixels; $OI(i, j)$ and $RI(I, j)$ are the matrices, containing the pixel values for the original and received image signals, respectively. Figure 3 shows the received underwater image signals using 4-QAM, and 16-QAM, with the transmission BER of 10^{-4}, in the 2×2 DM GFDM-LDPC UITS with PCE (0%). The SNRs are 11.4 dB, and 18.3 dB, respectively. The PSNRs are 61.99 dB, and 62.09 dB, respectively. The results show that the 4-QAM has better SNR gain of 7 dB compared to the 16-QAM at approximate PSNR performances of the received image signal in the underwater environment. Thus, the BER and PSNR performances of the proposed advanced UITS with PCE were evaluated.

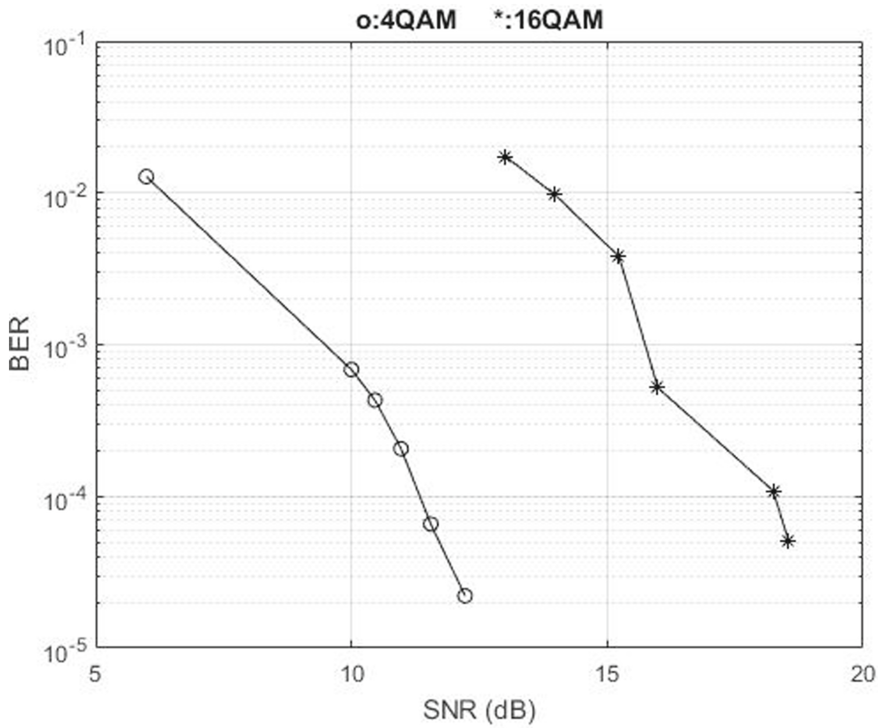

Fig. 2 BER performance of the DM-MIMO GFDM-LDPC UITS with PCE

4 Conclusion

IN this paper, we proposed a 2×2 DM MIMO GFDM-LDPC UITS in which the adaptive 4-QAM and 16-QAM modulations, the CSMA/CA multiuser communication protocol, a power assignment mechanism, DM communication strategy, LDPC channel coding, and advanced GFDM modulation scheme were adopted. We performed a simulation to evaluate the BER and PSNR performances of proposed UITS with PCE.

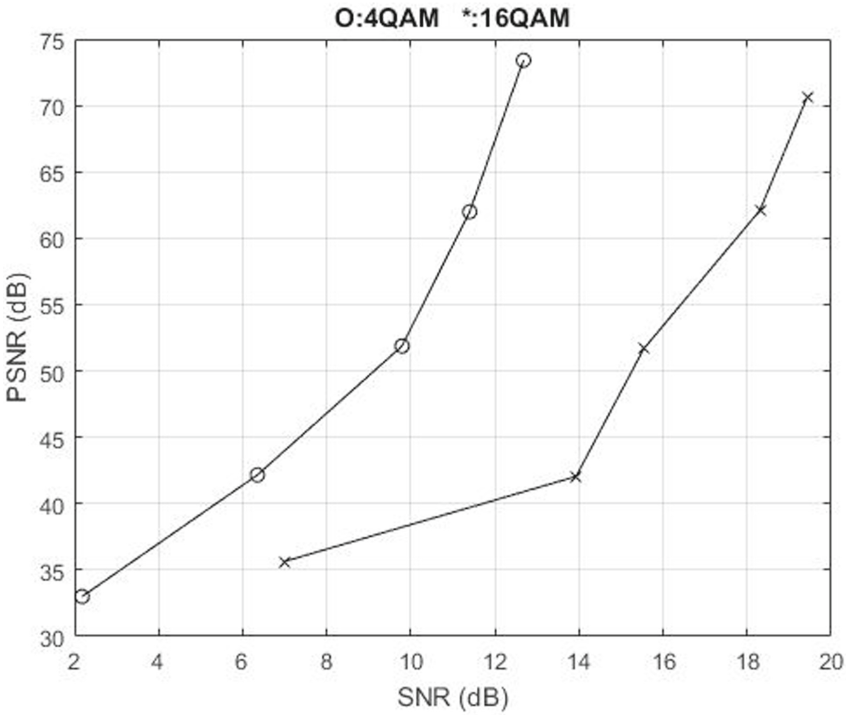

Fig. 3 PSNR performance of the DM-MIMO GFDM-LDPC UITS with PCE

Acknowledgement. The authors acknowledge the support of the grant from The Ministry of Science and Technology of Taiwan, under contract No. MOST 109-2221-E-992-091, and the valuable comments of the reviewers.

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