Chapter 49
Direct Mapping Based FBMC-LDPC Advanced Underwater Acoustic Transmission Scheme for Data Signals

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Abstract This paper proposes a 2 × 2 direct mapping (DM) based of an underwater acoustic transmission (UAT) scheme for data signals based on filter bank multicarrier (FBMC)-low density parity check (LDPC). The 2 × 2 DM multiple-input multiple-output (MIMO) transmission mechanism, FBMC modulation, LDPC channel coding, adaptive binary phase shift keying (BPSK) modulation and four offset quadrature amplitude modulation (4-OQAM), and power assignment mechanism are integrated. The performances of bit error rates (BERs) and data error rates (DERs) of the proposed underwater data transmission scheme with perfect channel estimation (PCE) (0%), and the channel estimation errors(CEEs) of 5%, 10%, and 20% are investigated. The bit error rates (BERs) of data signals for underwater transmission must be less than 10^{-5}. The transmission power weightings and ratios of power saving (PS) for the proposed underwater acoustic transmission system are explored through simulations. From these simulation results, we evaluate the performances of the proposed advanced data UAT scheme.

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49.1 Introduction

Underwater multimedia sensor networks (UMSNs) are a compelling interest of the research topic, and UMSNs can be applied to undersea monitoring, and advanced coastal surveillance. Sarisaray-Boluk et al. [1] adopt different combinations of multipath transport, watermarking-based error concealment, forward error correction, and adaptive retransmission mechanisms to achieve reliable and quality aware image transmission in underwater channel impairments. Singh et al. [2] propose a two-step preamble-based approach using a novel frame structure to estimate carrier frequency offset (CFO) and channel in multiple-input multiple-output (MIMO) filter bank multicarrier (FBMC) scheme with offset quadrature amplitude modulation (OQAM). At the first step, the coarse CFO estimator without channel information was developed, and the fine CFO can be draw on a constant carrier phase. At the second step, the minimum mean square error estimator is designed for effective channel estimation in time domains. Singh et al. [3] propose a post-processing signal-to-noise-plus-interference-ratio (PP-SNIR) method in a MIMO FMBC-OQAM scheme with imperfect channel state information, and PP-SNIR derived to calculate symbol error rate.

Amini et al. [4] investigated a FBMC transmission scheme in an underwater communication application, and Lin et al. [5] demonstrated a FBMC-based low density parity check (LDPC) code underwater acoustic transmission (UAT) scheme for voice and image signals. In previous study [6], the proposed direct mapping (DM) FBMC-based underwater transmission scheme (UTS) was demonstrated. The performances of transmission bit error rates (BERs) of the UTS, the mean square error (MSE) performances and the power saving ratios of the DM FBMC UTS scheme, for audio signals transmission with perfect channel estimation (PCE) were explored. The paper examines the BERs and data error rates (DERs) performances of the DM-based FBMC-LDPC UAT scheme. The power saving ratios of the DM-based FBMC-LDPC UAT scheme, and data signals received using BPSK modulation in the DM-based FBMC-LDPC UAT scheme, for a BER of 10^{-5}, were discussed.

49.2 Research Method

Figure 49.1 deplicts the proposed DM-based FBMC-LDPC UAT scheme for data signals. The transmission architecture has been demonstrated for voice signals [6], and the transmission performances of the proposed DM-based FBMC-LDPC UAT scheme is discussed for data signals. The underwater channel model with an underwater channel bandwidth of 3.9 kHz, a carrier central frequency of 11.5 kHz, and a transmission distance of 1 km was used [7]. The BER requirement of underwater transmission data signals is 10^{-5}, and the DER of the DM-based FBMC-LDPC UAT scheme with a BER of 10^{-5} is demonstrated. The DER is defined as follows:

$$\mathrm{DER} = \frac{D_e}{D_t} \tag{1}$$

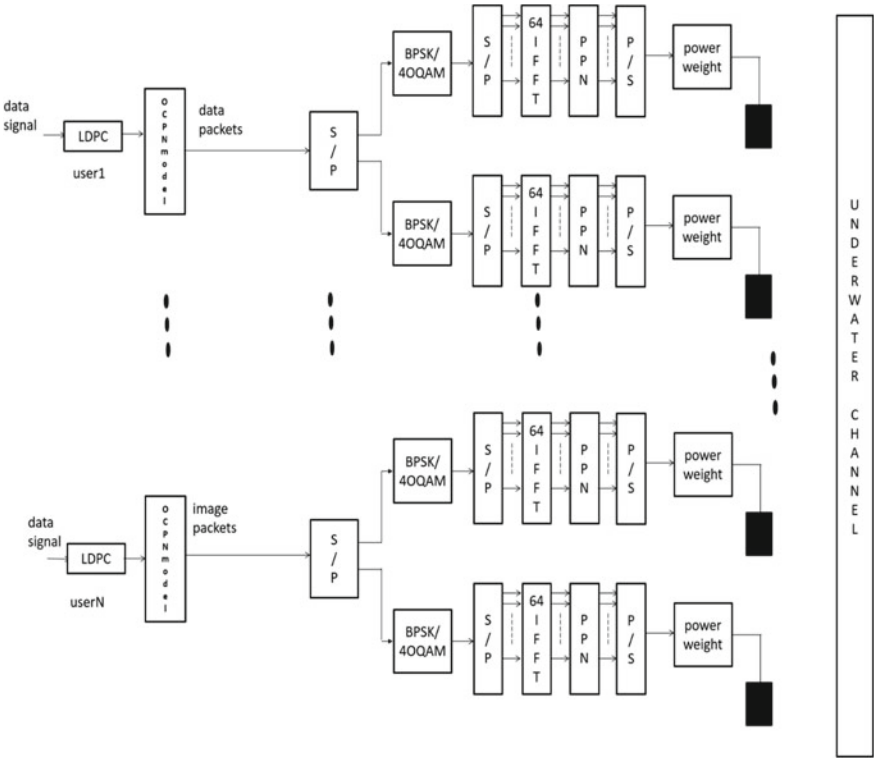


Fig. 49.1 Proposed the DM-based FBMC-LDPC UAT scheme for data signals

D_e and D_t denote the number of the transmission error data symbols, and the number of transmission data symbols, respectively. The performances of BERs and DERs of the proposed DM-based FBMC-LDPC UAT scheme with PCE) (0%) and CEEs of 5%, 10%, and 20% are investigated. With the CEEs increased, the BERs and DERs increased.

49.3 Simulation Results

Figure 49.2 shows that DER performances of the DM-based FBMC-LDPC UAT scheme, using BPSK modulation, with PCE (0%) and CEEs of 5%, 10%, and 20%, respectively. The 10^5 data symbols were simulated in the underwater data transmission. The colors ‘black’, ‘red’, ‘blue’, and ‘purple’, in Figs. 49.2 and 49.3, denote the DM-based FBMC-LDPC UAT scheme with a PCE, the DM-based FBMC-LDPC UAT scheme with a CEE of 5%, the DM FBMC UTS scheme with a CEE of 10%, and the DM-based FBMC-LDPC UAT scheme with a CEE of 20%, respectively. Using the BPSK modulation with a PCE, and CEEs of 5%, 10%, and 20%, respectively,

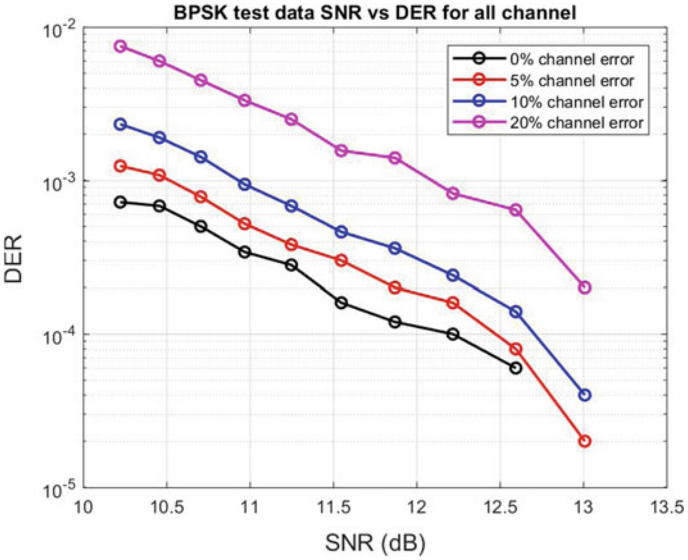


Fig. 49.2 DER performances of the DM-based FBMC-LDPC UAT scheme, using BPSK modulation, with PCE (0%) and CEEs of 5%, 10%, and 20%, respectively

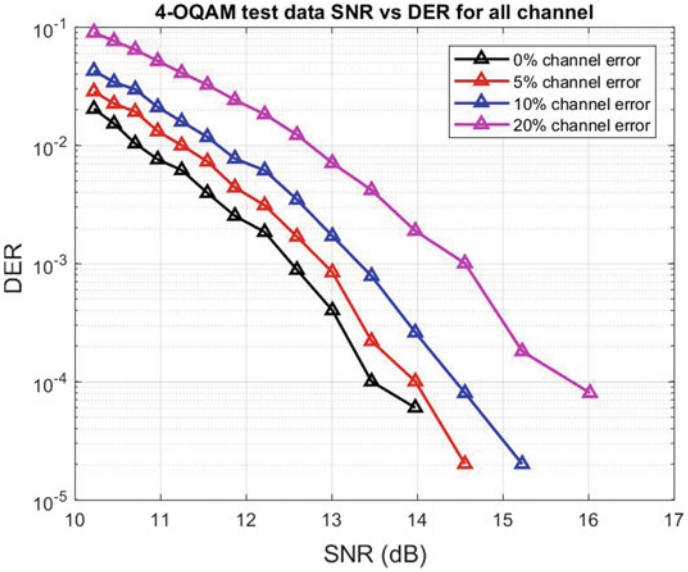


Fig. 49.3 DER performances of the DM-based FBMC-LDPC UAT scheme, using 4-OQAM modulation, with PCE (0%) and CEEs of 5%, 10%, and 20%, respectively

for signal to noise ratios (SNRs) of 12.59 dB, with the corresponding DERs of the received data signals were 6×10^{-5}, 8×10^{-5}, 1.4×10^{-4}, and 6.4×10^{-4}. Using the BPSK modulation with a PCE, and CEEs of 5%, 10%, and 20%, respectively, for SNRs of 12.59 dB, with the corresponding BERs of the received data signals were 2×10^{-6}, 2.67×10^{-6}, 4.67×10^{-6}, and 2.13×10^{-5}. With the CEEs increased, the BERs and DERs increased.

Figure 49.3 shows the DER performances of the DM-based FBMC-LDPC UAT scheme, using 4-OQAM modulation, with PCE (0%) and CEEs of 5%, 10%, and 20%, respectively. The data signals received using the 4-OQAM modulation with a PCE, and CEEs of 5%, 10%, and 20%, respectively, for signal to noise ratios (SNRs) of 12.59 dB, with the corresponding DERs of the received data signals were 8.8×10^{-4}, 1.68×10^{-3}, 3.46×10^{-3}, and 1.22×10^{-2}. Data signals were received using the 4-OQAM modulation with a PCE, and CEEs of 5%, 10%, and 20%, respectively, for signal to noise ratios (SNRs) of 12.59 dB, with the corresponding BERs of the received data signals 2.93×10^{-5}, 5.73×10^{-5}, 1.11×10^{-4}, and 4.1×10^{-4}. Simulation results show that the BERs and DERs performances of the DM-based FBMC-LDPC UAT scheme, using BPSK modulation, are better than that of the DM-based FBMC-LDPC UAT scheme, using 4-OQAM modulation.

Figure 49.4 demonstrates the power saving ratios of the DM-based FBMC-LDPC UAT scheme with a BER of 10^{-5}, for PCE. The maximum acceptable transmission

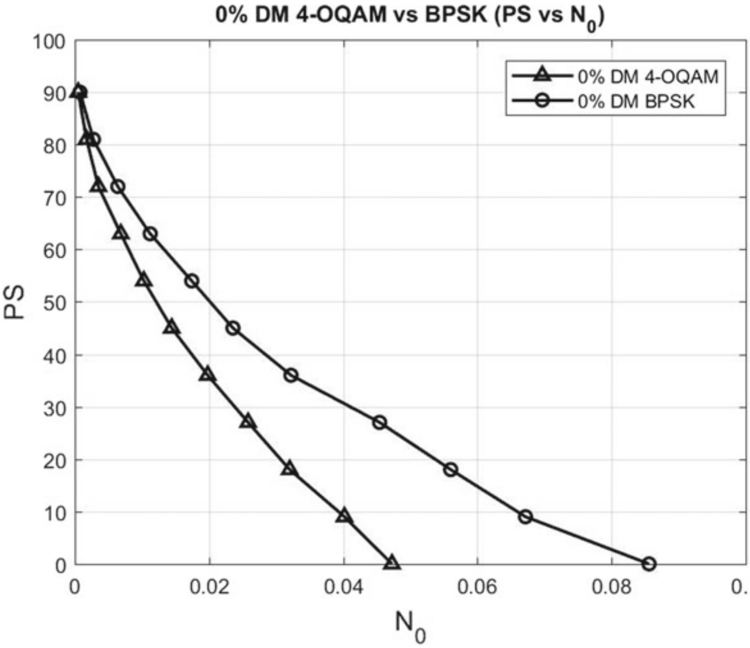
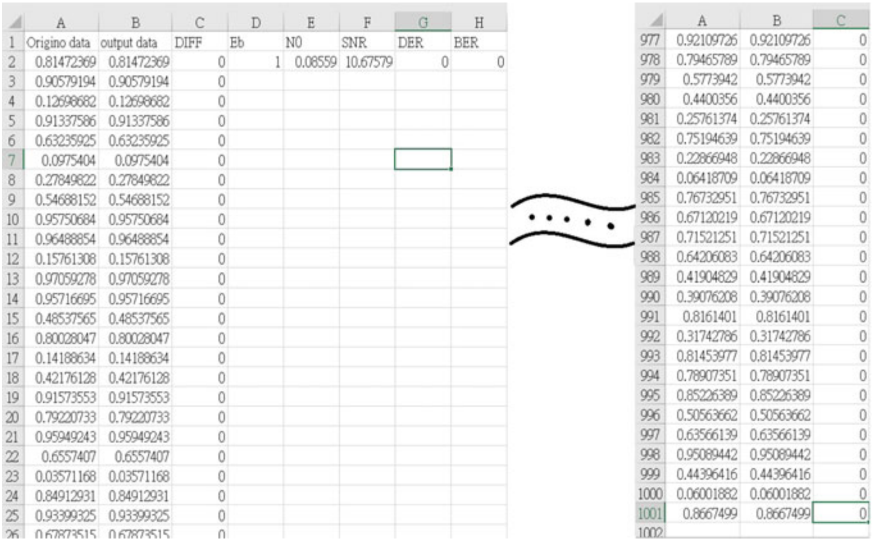


Fig. 49.4 Power saving ratios of the DM-based FBMC-LDPC UAT scheme with a BER of 10^{-5}, for PCE



	A	B	C	D	E	F	G	H
1	Origino data	output data	DIFF	Eb	N0	SNR	DER	BER
2	0.81472369	0.81472369	0	1	0.08559	10.67579	0	0
3	0.90579194	0.90579194	0					
4	0.12698682	0.12698682	0					
5	0.91337586	0.91337586	0					
6	0.63235925	0.63235925	0					
7	0.0975404	0.0975404	0					
8	0.27849822	0.27849822	0					
9	0.54688152	0.54688152	0					
10	0.95750684	0.95750684	0					
11	0.96488854	0.96488854	0					
12	0.15761308	0.15761308	0					
13	0.97059278	0.97059278	0					
14	0.95716695	0.95716695	0					
15	0.48537565	0.48537565	0					
16	0.80028047	0.80028047	0					
17	0.14188634	0.14188634	0					
18	0.42176128	0.42176128	0					
19	0.91573553	0.91573553	0					
20	0.79220733	0.79220733	0					
21	0.95949243	0.95949243	0					
22	0.6557407	0.6557407	0					
23	0.03571168	0.03571168	0					
24	0.84912931	0.84912931	0					
25	0.93399325	0.93399325	0					
26	0.67873515	0.67873515	0					

	A	B	C
977	0.92109726	0.92109726	0
978	0.79465789	0.79465789	0
979	0.5773942	0.5773942	0
980	0.4400356	0.4400356	0
981	0.25761374	0.25761374	0
982	0.75194639	0.75194639	0
983	0.22866948	0.22866948	0
984	0.06418709	0.06418709	0
985	0.76732951	0.76732951	0
986	0.67120219	0.67120219	0
987	0.71521251	0.71521251	0
988	0.64206083	0.64206083	0
989	0.41904829	0.41904829	0
990	0.39076208	0.39076208	0
991	0.8161401	0.8161401	0
992	0.31742786	0.31742786	0
993	0.81453977	0.81453977	0
994	0.78907351	0.78907351	0
995	0.85226389	0.85226389	0
996	0.50563662	0.50563662	0
997	0.63566139	0.63566139	0
998	0.95089442	0.95089442	0
999	0.44396416	0.44396416	0
1000	0.06001882	0.06001882	0
1001	0.8667499	0.8667499	0
1002			

Fig. 49.5 Data signal received using BPSK modulation in the DM-based FBMC-LDPC UAT scheme with a BER and DER of zero, for PCE

BER value for the data signal is 10^{-5}. The data signals received using the BPSK modulation for the SNRs of 15.18 dB, 16.41 dB, and 18.40 dB, with the corresponding power saving ratios of 63%, 72%, and 81%, respectively. The data signals received using the 4-OQAM modulation for the SNRs of 17.33 dB, 19.04 dB, and 20.42 dB, with the corresponding power saving ratios of 63%, 72%, and 81%, respectively. At the same power saving ratio, the SNRs of the BPSK modulation are lower than that of 4-OQAM modulation. Figure 49.5 illustrates that the 1000 data symbols with EXCEL format received using the BPSK modulation in the DM-based FBMC-LDPC UAT scheme with a BER and DER of zero, for PCE. The received data signals are accurate, and the DM-based FBMC-LDPC UAT scheme can be applied to underwater data transmission.

49.4 Conclusion

In this paper, a DM-based FBMC-LDPC UAT scheme for data signals was dissicussed. The BERs and DERs performances of the DM-based FBMC-LDPC UAT scheme, using BPSK and 4-OQAM modulations, with PCE (0%) and CEEs of 5%, 10%, and 20%, respectively, were demonstrated. The BERs and DERs performances of the DM-based FBMC-LDPC UAT scheme using BPSK modulation is superior to the DM-based FBMC-LDPC UAT scheme using 4-OQAM modulation. With CEEs increased, the BERs and DERs performances decreased. Power saving ratios of the

DM-based FBMC-LDPC UAT scheme with a BER of 10^{-5}, for PCE, are explored. Simulation results show that the proposed DM-based FBMC-LDPC UAT scheme is suitable for underwater data transmission.

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