A Weighted Multi-band Algorithm Using Estimation BER in Underwater Acoustic Communication

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Abstract**—** The multi-band UWAS communication techniques are effective in terms of performance and throughput efficiency. However, the multi-band configuration in a particular band affects the output from the entire bands. This problem can be solved through a receiving end that analyzes error rates of each band. In this paper, we proposed an estimation BER algorithm which get the reliability of received data to set the weighting value to each band. Therefore, we analyzed the efficiency of multi-band transmission scheme with estimation BER and 3 [dB] performance gain is obtained.

Keywords—multi-band; UWAS; weighting; estimation BER; turbo coding

I. INTRODUCTION

The multi-band UWAS (Underwater Wireless Acoustic Sensor) communication techniques are effective in terms of performance and throughput efficiency because it can overcome selective frequency fading by allocating the same data to different frequency bands in the environment of rapidly changing channel transfer characteristic [1-3]. However, the multi-band configuration in a particular band affects the output from the entire bands. This problem can be solved through a receiving end that analyzes error rates of each band, sets threshold values, and allocates lower weights to inferior bands. There are many methods of setting threshold values. In this paper, we proposed an algorithm to set the threshold value using an estimation BER (Bit Error Rate). Estimation BER is the method of analyzing reliability of received data based on the performance difference between demodulated and decoded data. Therefore, we analyzed the efficiency of multi-band transmission scheme with estimation BER in underwater communications by employing phase shift keying modulation and turbo pi codes with 1/3 of coding rate [4-6]. Through the simulations, the performance of multi-band is improved when the proposed threshold algorithm is applied.

II. MULTI-BAND COMMUNICATION

Fig. 1 is the block diagram of multi-band UWAS using estimation BER scheme. After K bits passed through the channel coding at the transmission unit of Fig. 2, N coded bits $\{d_0, d_1, \cdots, d_{N-1}\}$ were created. Signals that had passed through an iterative encoder passed an interleaver to change a burst error to a random error.

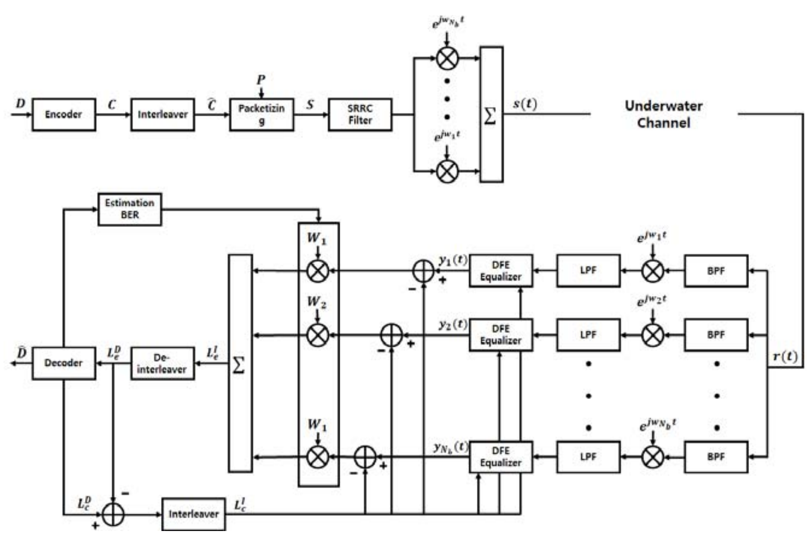


Fig. 1. Transceiver structure of multi-band communications.

After the interleaver, n preamble bits, that is, $\{p_0, p_1, \cdots, p_{n-1}\}$ were input for synchronous acquisition. The Data bit string $\boldsymbol{D}$ with $N_T = (n + N)$ bits, which was configured by the input $\{p_0, p_1, \cdots, p_{n-1}\}$, can be expressed by (1).

$$\boldsymbol{D} = \{p_0, p_1, \cdots, p_{n-1}, d_0, d_1, \cdots, d_{N-1}\} \qquad (1)$$

Multi-band signal can be expressed by (2).

$$s(t) = \sum_{k=1}^{N_b} \boldsymbol{D} e^{j w_k t} \qquad (2)$$

As for the signal received, a matched filter was used to divide each frequency and acquire the corresponding information. Then, DFE (Decision Feedback Equalizer) removed multi-path interference from each band [7], and a threshold value was determined by estimation BER in order to assign weighting value of w_k to k-th band. Proposed structure has better performance by summation of weighted bands resultant from estimation BER.

III. Weighting Assignment Using Estimation BER

Detailed structure of estimation BER block of Fig. 1 is shown in Fig. 2.

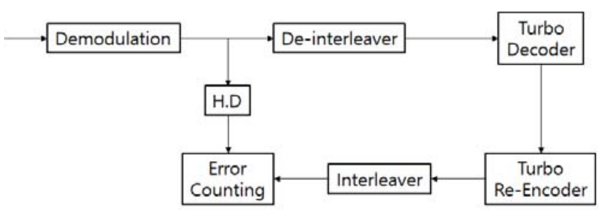
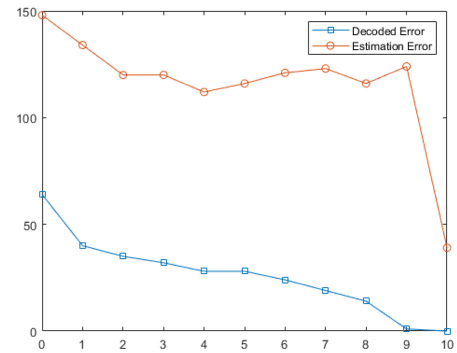
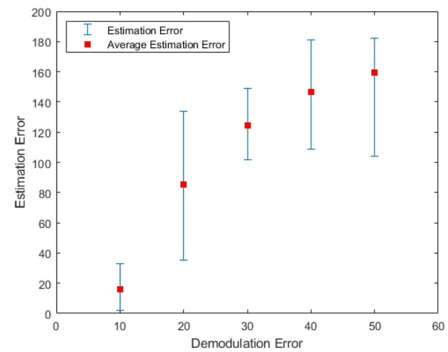


Fig. 2. Block diagram of estimation BER block.

In estimation BER block, it compares the re-encoded data of the decoded bit with hard decision (H.D) value of the demodulated data. Thus, it has close relationship with decoded performance. If the demodulation BER is low, then input error of decoder is small too. Therefore, estimation BER would also be small. The relation between estimation BER and data BER is shown in Fig. 3. Fig. 3(a) shows the relation between estimation errors and decoded errors in single band through the simulation. It shows a sharp decline of estimation error when the decoded error is perfectly corrected. Fig. 3(b) shows the distribution of estimation error when the demodulation error is less than from 10 % to 50 % of entire coded bits. To get these data, around 300 times trials are done in various SNR. The blue bar shows the range from minimum to maximum estimation error in each case, and the red marker shows the average estimation error of each data set. If the demodulation error is less than 10 %, estimation error is also small. So it shows that the estimation error has close relation with the performance of each band.



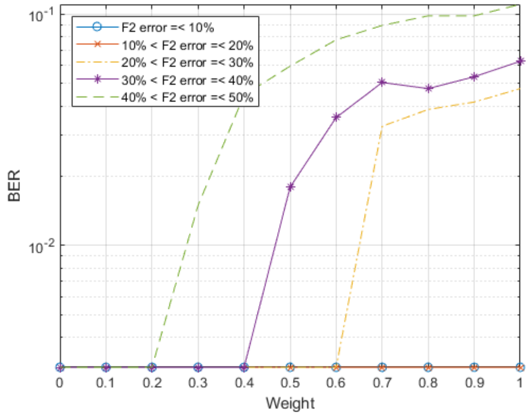
(a) Relation of decoding and estimation errors.



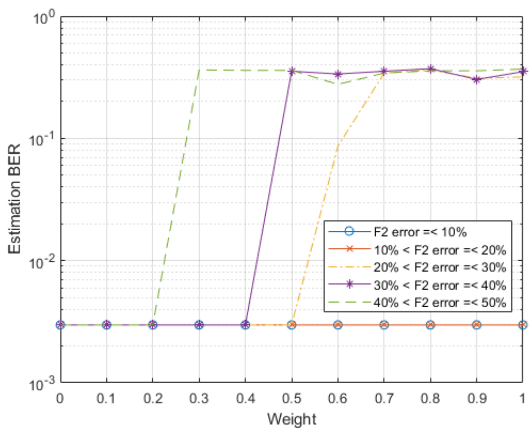
(b) Estimation error distribution according to demodulation errors.

Fig. 3. Estimation errors according to decoding and demodulation errors.

Also, according to Fig. 3(b), we can set the threshold of estimation BER for assigning weighting value. Fixed on double bands, the simulation was conducted to figure out the optimal weighting value according to the BER and estimation BER. The result is shown in Fig. 4. In this simulation, fixed on error rate of F1 band under 10 %, we changed the error rate of F2 band from 10 % to 50 %. The weight of F1 band was fixed as one all the time, and the weight of F2 bands was changed from 0 to 1 with step of 0.1. Fig. 4(a) is the decoded BER according to the error rate and weight of F2 band. In the case of 10 % and 20 % error rate, error is perfectly corrected regardless of the weight. In the case of 30 % of error rate, error is perfectly corrected when the weight is less than 0.6. In the case of 40 % and 50 % error rate, error is perfectly corrected only when the weight is less than 0.4 and 0.2 respectively. Fig. 4(b) shows the estimation BER according to the error rate and weight of F2 band. At this point, the estimation BER is not calculated by each band, but it is obtained by comparing the summation of each weighted band and re-encoded bits. Comparing Fig. 4 shows that the point at which the decoding BER increases coincides with the point at which the estimation BER increases.



(a) BER performance for various weights.



(b) Estimation BER for various weights.

Fig. 4. BER performance according various weights.

Such simulation results show the optimal weighting value according to demodulation BER and estimation BER. The optimal weight according to estimation BER, based on the result of Fig. 3 and 4, is shown in Table 1.

TABLE I. WEIGHT ACCORDING TO ESTIMATION BER

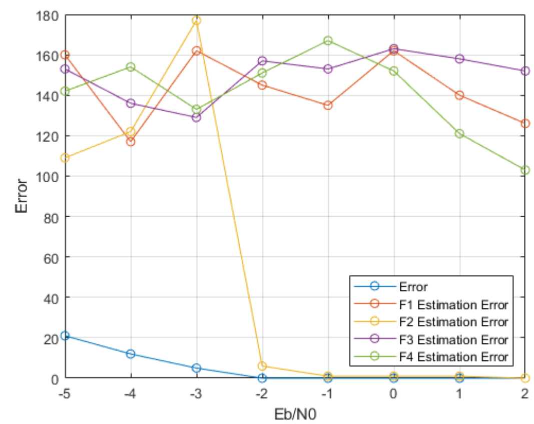
Estimation error (%)	Weight
< 10	1.0
< 31	0.8
< 37	0.6
< 44	0.4
others	0.2

IV. PERFORMANCE ANALYSIS

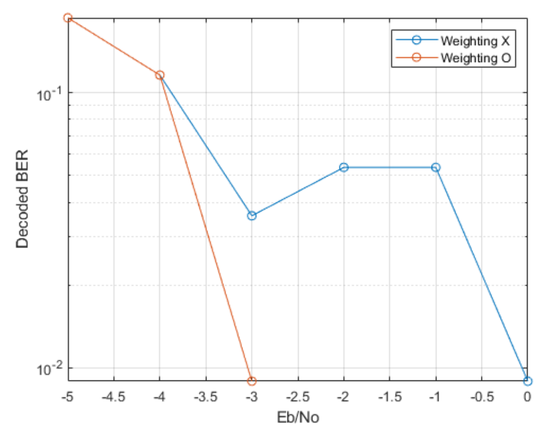
This study conducted performance analysis where the parameters shown in Table 2. As presented in Table 2, turbo codes with rate of 1/3 are employed, and total 591 bits consisted of 255 preamble bits and 336 coded bits. BPSK (Binary Phase Shift Keying) modulation was applied to form 591 symbols. The SRRC (Square Root Raised Cosine) filter with the roll-off factor of 0.35 was applied as the filters of receiving and transmitting units. The transmission rate was 100 bps. Four bands are applied, and the center frequencies of each band were 15 [kHz], 17 [kHz], 19 [kHz] and 21 [kHz] respectively, and the sampling frequency was 192 [kHz].

TABLE II. EXPERIMENT PARAMETERS

Parameters	Value
Number of bits	112 bits
Preamble bit	255 bits
Number of total iteration	5
Channel coding(coding rate)	Turbo coding (1/3)
Modulation	BPSK
Equalizer	LMS-DFE
Number of bands	4
Center frequency of each band	15 ~ 21 [kHz]
Number of samples	1920
Sampling frequency	192 [kHz]
Bit rate	100 [bps]
Roll off factor	0.35



(a) Estimation BER for multi-band.



(b) BER performance comparison between weighting and non-weighting.

Fig. 5. BER performance of weighted multi-band.

In simulation result of Fig. 5(a), to investigate how well operate weighting algorithm, specific F2 band only set to high SNR, estimation BER of F2 band decreases rapidly, it means the decoded error is perfectly corrected. Fig. 5(b) shows the performance gain when weighting is applied or not. When weighting is applied based on Table 1, errors were corrected perfectly on E_b/N_0 of -3 [dB], the other case, errors were corrected on E_b/N_0 of 0 [dB]. We know 3 [dB] of performance gain is obtained by applying weighting algorithm. Finally, we confirmed the proposed method is effective to measure the performance of each band and improved performance of multi-band transmission method in underwater channel environments.

V. Conclusion

The multi-band communication technology is effective in performance and processing efficiency because it can overcome selective frequency fading, by allocating the same data to different frequency bands, in an environment that has a rapidly changing UWAS channel transmission characteristic. However, a multi-band configuration can have poorer performance than a single band. This problem could be solved by using a receiving end that analyzed the error rates of each band, set the threshold values, and allocated the lower weights to the inferior bands. In this paper, we proposed an algorithm to set the threshold value using the estimation BER technique. Estimation BER technique can achieve estimated BER of coded data in each band by comparing received data and decoded data. Fixed on employing four bands and turbo codes, optimal weighting values are established according to error rates of estimation BER for each band through the simulation. Also, 3 [dB] of performance gain is obtained by applying weighting algorithm. In the future, proposed weighting algorithm based on estimation BER will be applied in the real oceanic experiment.

Acknowledgement

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