FEC PERFORMANCE EVALUATION OF ISDB-T AND DTMB SYSTEMS FOR TERRESTRIAL DIGITAL TV

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ABSTRACT

In this paper, the forward error decoding scheme of terrestrial multimedia broadcasting are compared between Japan and China standard. To provide a reliable comparison, the decoding performance of three similar data rate codes are compared, which are included in Japan and China standard. In addition, the decoding performance of LDPC codes in China standard are evaluated with quantized data.

Index Terms— FEC, DTMB, ISDB-T, LDPC, BCH

1. INTRODUCTION

The FEC for terrestrial multimedia broadcasting of Japan, known as ISDB-T [1] , uses Convolutional codes concatenated Reed-Solomon codes. In China standard, called as DTMB [2] , the FEC uses different coding scheme from ISDB-T. It includes a concatenation of LDPC codes and BCH codes. To allow selection of the most appropriate property of error correction for a given service, different data rate codes are addressed in the two standards. For ISDB-T, the Convolutional codes are optionally punctured into $1/2, 2/3, 3/4, 5/6$ and $7/8$ data rates. In DTMB, the LDPC codes are constructed as three different data rates with $0.4, 0.6$ and 0.8 respectively. In the two standards, the outer codes, RS codes in ISDB-T and BCH codes in DTMB, are constructed as fixed data rate.

The objective addressed in this paper, is the evaluation and comparison of the decoding performance between ISDB-T and DTMB. The bit error rate (BER) performance and decoding complexity of the FEC in the two standards are compared. In order to provide reliable comparison, the decoding performance of ISDB-T is evaluated with data rate $0.46, 0.61, 0.69$ which correspond to Convolutional codes with $1/2, 2/3, 3/4$ respectively. The decoding performance of DTMB is evaluated with data rate $0.4, 0.6$ and 0.8 respectively.

It is noticed that the decoding of LDPC codes are emphasized in this paper since the following reason. The sum-product algorithm (SPA) [3] is known as optimal decoding algorithm based on belief propagation method for LDPC codes. Since the complex calculation of SPA, it is impossible for direct implementation. In this paper, the BER performance of LDPC codes in DTMB is evaluated in log-SPA algorithm [4] which operates on quantized data.

This paper is organized as follows. Section 2 presents the specification of FEC in DTMB and ISDB-T. Section 3 presents the decoding algorithm for LDPC codes of DTMB. The BER performance of LDPC codes is evaluated by log-SPA with quantized data. Section shows the comparison of decoding performance of ISDB-T and DTMB in terms of BER performance and throughput with the use of software realization. Finally, section 5 offers the conclusion of this paper.

2. SPECIFICATION OF FEC IN DTMB AND ISDB-T

2.1. ISDB-T

The channel coding stage in ISDB-T is based on a concatenated coding system. The coding system has (204,188) Reed-Solomon (RS) code as outer code and convolutional code (CC) with constraint length 7 as inner code. A byte-level interleaver is used between outer code and inner code. In the receiver, a decoder for this concatenated coding system consists of an inner decoder based upon Viterbi decoding (VD) for CC code and an outer decoder relying on Berlekamp-Massey (BM) decoding for RS code. The byte-interleaver is used to spread any error bursts that might happened at the output of the VD. As a result, it can achieve a significant coding gain by utilizing RS block decoder as the outer decoder. Fig. 1 shows FEC of ISDB-T. Fig. 2 shows encoder of CC. The generator polynomials of the mother code are $G_1 = 171_{oct}$ for X output, $G_2 = 133_{oct}$ for Y output.

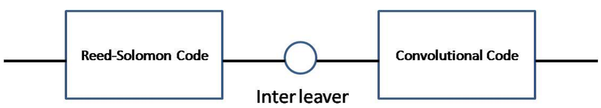

Fig. 1. FEC of ISDB-T

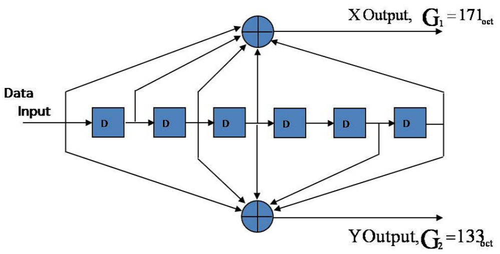

Fig. 2. Convolutional Code

2.2. DTMB

In DTMB, FEC of this system adopted LDPC codes as inner code and BCH code as outer code. Fig. 3 shows FEC of DEMB, and Fig. 4 shows configuration of FEC. k_{cBCH} is bits before the coding, n_{cBCH} means bits after the coding. And K_{LDPC} indicate bits before the coding, N_{LDPC} is bits after the coding.

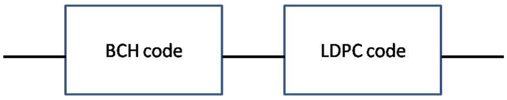

Fig. 3. FEC of DTMB

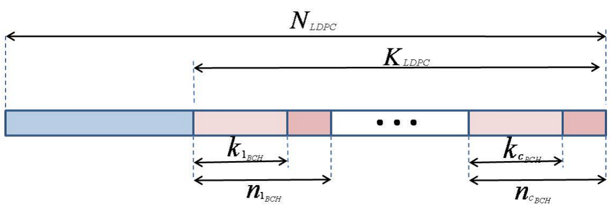

Fig. 4. Configuration of LDPC and BCH

The outer code uses BCH(762, 752). This code is derived from BCH(1023, 1013), 261 bits 0 are added in front of 752 information bits before scrambler to get 1013 information bits. After BCH(1023, 1013) coding, 1023 bits was constructed. Remove the first 261 bits 0, 762 coded bits are then left. All three FEC codes use the same BCH encoder.

The inner code in DTMB uses irregular quasi-cyclic (QC) LDPC codes, which is a class of array-structured LDPC codes. The parity check matrix of QC-LDPC(m, n) is an ($m/b, n/b$) array of circulants. Then, array of circulants is zero matrices or shifted identity matrices, which $b \times b$ matrix. In the standard, three code rate is defined. Tab. 1 shows Rate of DTMB and ISDB-T.

FEC	DTMB	ISDB-T
Rate	0.4	0.46
		0.61
	0.6	0.69
		0.77
	0.8	0.81
		—

Table 1. Rate of FEC in DTMB and ISDB-T

3. SOFT DECISION DECODING OF DTMB ON QUANTIZED DATA

3.1. SPA Algorithm

SPA algorithm is assumed as optimal decoding method for LDPC code. The SPA algorithm consists of check node processing and bit node processing as shown in Figure 5 .

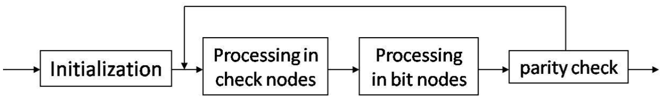

Fig. 5. The flow of LDPC decoding

In the step of check node processing, the check node information L_{mn} is calculated as eq. (1) . The Z_{mn} is LLR information propagated from bit nodes. For eq. (1) , it need multiplication and $tanh$ calculation, which is difficult for real implementation.

$$L_{mn_X} = 2tanh^{-1}\{\Pi_{n' \in N(m) \backslash n_X} tanh(\frac{Z_{mn'}}{2})\} \quad (1)$$

Where, $v(X) = tanh(\frac{X}{2}) = ln\frac{exp(X)-1}{exp(X)+1}$. And the inverse function $v^{-1}(t) = ln\frac{1+t}{1-t}$.

Fig. 6 is indicated check node process.

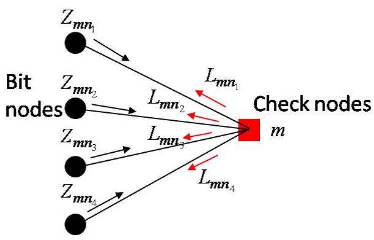

Fig. 6. Processing in check nodes

In the step of bit node processing, the bit node information Z_{mn} is calculated as eq. (2) .

$$Z_{m_X n} = Z'_n + \sum_{m' \in M(n) \backslash m_X} L_{m'n} \quad (2)$$

For each bit nodes n update Z_n for hard decision by (3) .

$$Z_n = Z'_n + \sum_{m \in M(n)} L_{mn} \quad (3)$$

The figure of processing in bit nodes is shown in following.

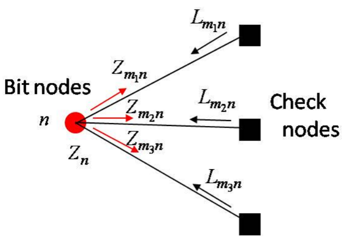

Fig. 7. Processing in bit nodes

3.2. Log-SPA Algorithm

In this paper, we present a log-SPA algorithm for LDPC decoding. In order to eliminate the complex calculation of multiplication in eq. (1) , the property of exponential function as shown in eq. (4) can be used for the simplication of eq. (1) .

$$\Pi_{i=1}^{n} X_i = exp\{\sum_{i=1}^{n} ln(X_i)\} \quad (4)$$

The eq. (1) can thus be written as following,

$$L_{mn_X} = 2tanh^{-1}[exp\{-\sum_{n' \in N(m) \backslash n_X} -ln(tanh(\frac{|Z_{mn'}|}{2}))\} \times \Pi_{n' \in N(m) \backslash n_X} sign(Z_{mn'})] \quad (5)$$

Assuming, $\Gamma(X) = ln(tanh(\frac{|X|}{2}))$, then the eq. (5) can be further submitted by following formula,

$$L_{mn_X} = \Gamma^{-1}(\sum_{n' \in N(m) \backslash n_X} \Gamma(|Z_{mn'}|))\Pi_{n' \in N(m) \backslash n_X} sign(Z_{mn'}) \quad (6)$$

For real implementation, the $\Gamma(X)$ can be precomputed and saved on a look-up table (LUT).

Fig. 8 shows the process that r (received data) is received and LLR is received after r is demodulated by demodulator, then LLR is quantized. In SPA, LLR indicate the next expression.

$$LLR = \frac{2}{\sigma^2} r \quad (7)$$

σ means variance ($= Eb/No$).

While this paper uses noise power when Eb/No is $2dB$. $\Gamma(X) = ln(tanh(\frac{|X|}{2}))$ figure Fig. 9 . In Log-SPA, $\Gamma(X)$ is quantized and retained as LUT.

Fig. 8. Flows of quantization

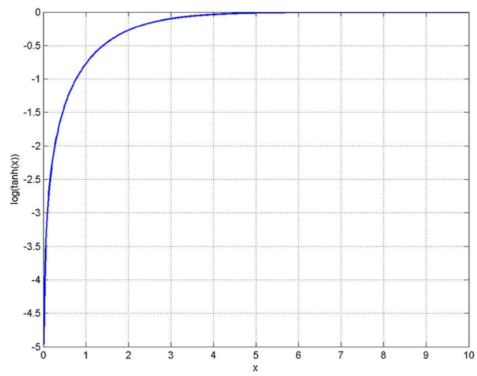

Fig. 9. The figure of $\Gamma(X)$

4. COMPARISONS OF DECODING PERFORMANCE

The Comparisons of BER performance and decoding complexity between ISDB-T and DTMB are shown in this section. In our simulation, the signal is assumed as modulated by QPSK and propagated through AWGN channel.

4.1. Comparison of BER performance

In Fig. 10, the SPA algorithm for LDPC decoding that operates on infinite precision data is set as optimal reference for DTMB. Based on this figure, we can find that the log-SPA algorithm operating on 6bits quantization level is close to decoding performance of optimal scheme.

Fig. 11 shows the BER performance comparison between ISDB-T and DTMB. The error decoding capability is similar for ISDB-T and DTMB when the data rate is low($r = 0.46$ for ISDB-T and $r = 0.4$ for DTMB). The DTMB has $0.5dB$ coding gain than ISDB-T if data rate is set as 0.6. In addition, DTMB with data rate equaling to 0.8 has similar error decoding capability, compared to ISDB-T with data rate equaling to 0.69 .

Fig. 12 shows the needed Eb/No of the two standands if BER=10-5. Code rates in horizontal axis for ISDB-T are set as $0.46, 0.61, 0.69$ and so are $0.4, 0.6$ and 0.8 respectively for DTMB. It is easily found that the decoding performance of DTMB is better than ISDB-T if the data rate is high.

4.2. Comparison of decoding complexity

The decoding complexity is compared on the testing of throughput with the use of software realization for the FEC

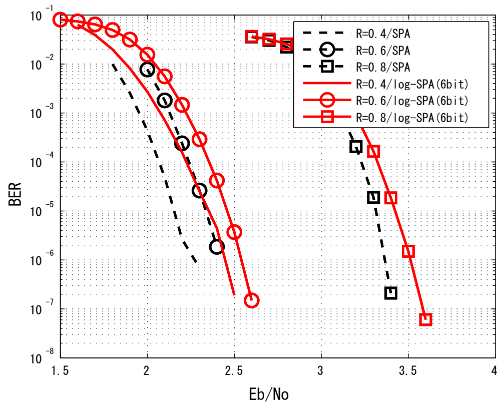

Fig. 10. BER performance of SPA and Log-SPA

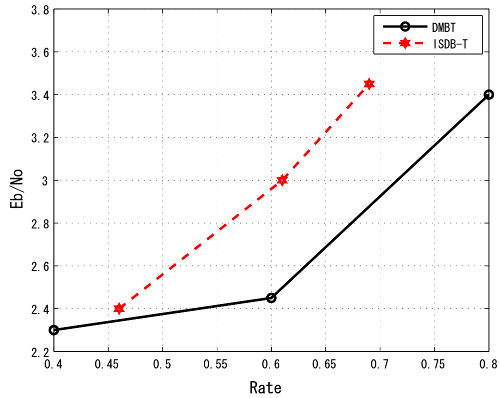

Fig. 12. (b).The BER performance of the two systems

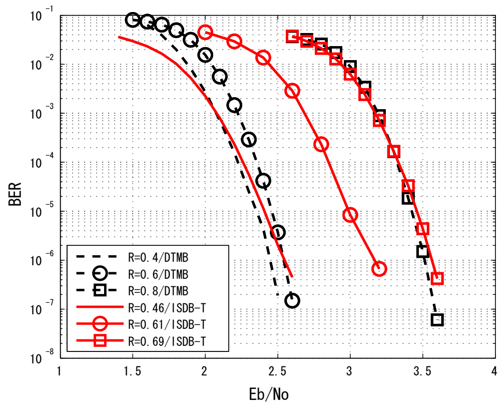

Fig. 11. (a).The BER performance of the two systems

	Code rate	Throughput(kbits/sec)
ISDB-T	0.46	745.6
	0.61	751.1
	0.69	763.7
DTMB	0.4	123.9
	0.6	180.0
	0.8	241.9

Table 2. Comparison of decoding complexity

decoding of ISDB-T and DTMB. The simulation environment is shown in following. And the Tab. 2 shows that the decoding of DTMB is more complex than ISDB-T. As shown in Tab. 2 . The code rate of ISDB-T are set as $0.46, 0.61, 0.69$ and so are $0.4, 0.6, 0.8$ respectively for DTMB. Throughput is shown kiro bits per second (kbps).

Simulation environment

- OS : ubuntu 9.04 Memory : 2Gbyte
- CPU : Intel Core 2 Duo CPU E6750@2.66GHz
- C language : gcc as compiler

5. CONCLUSION

In this paper, the decoding performance in terms of BER performance and decoding complexity of ISDB-T and DTMB are compared. It is shown that the log-SPA algorithm is effective for LDPC codes of DTMB, since it gives good BER performance and possible solution of implementation. In addition, the error decoding capacity of two standards are similar on low data rate ($r = 0.46$ for ISDB-T and $r = 0.4$ for DTMB). For high data rate, the error decoding capacity of DTMB is distinctly higher than ISDB-T. As regards the decoding complexity, the ISDB-T is apparently better than DTMB.

6. REFERENCES

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