A Study on the Performance Improvement in T-DMB System

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ABSTRACT

In this paper we propose a new turbo coded T-DMB system that replaces the existing RS code, convolutional interleaver and RCPC code by a turbo code without altering the puncturing procedure and puncturing vectors defined in the standard T-DMB system for compatibility. Simulation results show that the new turbo coded system yields considerable performance gain after just 2 iterations.

Keywords

T-DMB, RCPC, Turbo code, Compatibility

Ⅰ. Introduction

Since the T-DMB system was based on the DAB system, it includes extra functional blocks which compose of the MPEG-4 format to MPEG-2 format converter and the forward error correction (FEC) blocks to achieve better bit error rate (BER) performance[1]. With the FEC blocks which consist of the Reed-Solomon (RS) encoder/decoder and convolutional interleaver/deinterleaver, we can obtain a BER rate below 10^{-8} for video service. In this paper we propose a new turbo coded T-DMB sysem that replaces the existing RS codec, interleaver/deinterleaver block and RCPC(Rate Compatible Punctured Convolutional Code) codec by a turbo codec without modifying the puncturing procedure and puncturing vectors defined in the T-DMB system for compatibility. The performance of turbo coded system is compared with that of standard system under the Rician fading channel and the Rayleigh fading channel in conjunction with T-DMB tranmission I.

Ⅱ. T-DMB System

The DAB system provides CD quality audio and data services for fixed, portable and mobile applications with the required BER below 10^{-4}. To obtain this kind of BER, only rate compatible punctured convolutional code is used. However for the T-DMB system with the video service of MPEG-4 stream, BER should go down 10^{-8} by adding FEC blocks. The detail of additional FEC blocks as well as convolutional code block is shown in Figure 1.

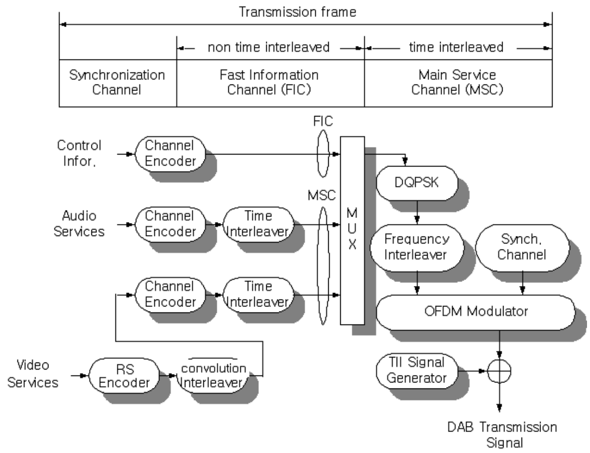

Figure 1. Block diagram of standard T-DMB system

For video service additional FEC blocks which consist of RS code and convolutional interleaver are needed to achieve lower error rate. As the RS code RS(204,188,8) is used which is a shortened form of RS(255,239,8). This RS code is defined in Galois field GF(2^8). The length of each MPEG-2 TS packet input to the RS encoder is 188 bytes and 16 parity bytes are added to make 204 bytes of output packets. The convolutional interleaver uses 12 branches and plays a role in distributing burst errors randomly at the T-DMB receiver. The structure of an RS packet is shown in Figure 2.

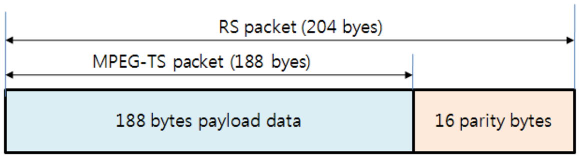

Figure 2. Structure of an RS packet

III. RCPC Codes in T-DMB system

The channel coding process for DAB system is based on RCPC coding, which allows both equal and unequal error protection (EEP, UEP), matched to bit error sensitivity characteristics. RCPC coding generates from a vector $(a_i)_{i=0}^{I-1}$ of I bits the resulting codeword $(b_i)_{i=0}^{M-1}$ of M bits. As a mother encoder, a rate 1/4 convolutional code with constraint length 7 and octal polynomial(133, 171, 145, 133) is used [2]. The mother convolutional code generates from I information and six tail bits a codeword $(x_{0,i}, x_{1,i}, x_{2,i}, x_{3,i})_{i=0}^{I+5} = (u_i)_{i=0}^{4I+23}$. The codebits generated by mother code are not transmitted by the puncturing procedure. The first 4I bits $(u_i)_{i=0}^{4I-1}$ generated from I information bits are split into consecutive blocks of 128 bits. Each block is divided into four consecutive sub-blocks of 32 bits. All sub-blocks belonging to the same block are punctured by the puncturing vector V_{PI}, given by the value of the puncturing index(PI). Each index PI corresponds to a puncturing vector V_{PI} , denoted by

$$V_{PI} = (v_{PI,0}, v_{PI,1}, \cdots\cdots, v_{PI,i}, \cdots\cdots v_{PI,31}) \qquad (1)$$

where $V_{PI,i}=1$ connotes that the corresponding bit is transmitted and $V_{PI,i}=0$ indicates a deleted position. The values of the puncturing vectors are given in Table 1, where the value of the code rate 8/(8+PI) is also given. The puncturing procedure allows the effective code rate to vary between 8/9 and 1/4. The last 24 bits $(u_i)_{i=4I}^{4I+23}$ coded by six tail bits are also punctured using the puncturing vector given by

$$V_T = (1100\ 1100\ 1100\ 1100\ 1100\ 1100) \qquad (2)$$

The resulting 12 bits are called punctured tail bits.

Table 1. Puncturing vectors

PI	Code Rate	$(v_{PI,0}, v_{PI,1}, \cdots\cdots, v_{PI,i}, \cdots\cdots, v_{PI,31})$
1	8/9	1100 1000 1000 1000 1000 1000 1000 1000
2	8/10	1100 1000 1000 1000 1100 1000 1000 1000
3	8/11	1100 1000 1100 1000 1100 1000 1000 1000
4	8/12	1100 1000 1100 1000 1100 1000 1100 1000
5	8/13	1100 1100 1100 1000 1100 1000 1100 1000
6	8/14	1100 1100 1100 1000 1100 1100 1100 1000
7	8/15	1100 1100 1100 1100 1100 1100 1100 1000
8	8/16	1100 1100 1100 1100 1100 1100 1100 1100
9	8/17	1110 1100 1100 1100 1100 1100 1100 1100
10	8/18	1110 1100 1100 1100 1110 1100 1100 1100
11	8/19	1110 1100 1110 1100 1110 1100 1100 1100
12	8/20	1110 1100 1110 1100 1110 1100 1110 1100
13	8/21	1110 1110 1110 1100 1110 1100 1110 1100
14	8/22	1110 1110 1110 1100 1110 1110 1110 1100
15	8/23	1110 1110 1110 1110 1110 1110 1110 1100
16	8/24	1110 1110 1110 1110 1110 1110 1110 1110
17	8/25	1111 1110 1110 1110 1110 1110 1110 1110
18	8/26	1111 1110 1110 1110 1111 1110 1110 1110
19	8/27	1111 1110 1111 1110 1111 1110 1110 1110
20	8/28	1111 1110 1111 1110 1111 1110 1111 1110
21	8/29	1111 1111 1111 1110 1111 1110 1111 1110
22	8/30	1111 1111 1111 1110 1111 1111 1111 1110
23	8/31	1111 1111 1111 1111 1111 1111 1111 1110
24	8/32	1111 1111 1111 1111 1111 1111 1111 1111

Protection profile contains the puncturing indices and the length of the blocks that the puncturing indices are applied. Table 2 and 3 show a protection profile applied in the FIC and MSC for transmission mode Ⅰ. For MSC we are only considering a video service transmitting at 544kbps.

Table 2. Protection profile applied in the FIC

I	M	L	L_0	L_1	$V_{PI\,0}$	V_{PI1}
768	2304	24	21	3	16	15

Table 3. Protection profile for the video bit rate 544kbits/s and protection level 3-A

I	M	L	L_0	L_1	$V_{PI\,0}$	V_{PI1}
13056	26112	408	405	3	8	7

The serial mother codeword generated from each I-bit vector is split into L consecutive blocks of 128 bits. The first L_0 blocks are punctured according to the puncturing index V_{PI0}. The remaining L_1 blocks are punctured according to the puncturing index V_{PI1}. This corresponds to a code rate of approximately 1/3. Finally, the last 24 bits of the serial mother codeword generated from the six tail bits are punctured. Therefore, the resulting punctured convolutional codeword of M bits is obtained. The same encoding procedure is applied to the four groups of I-bit vector. The encoding procedure in the MSC depends on the type of service carried, the net bit rate and the desired level of protection. The input vector of the mother convolutional encoder consists of I-bit vector, where I is a function of bit rate. Table 3 shows a protection profile for the video bit rate 544 kbits/s and protection level 3-A[2]. The serial mother codewords are split into 408 blocks of 128 bits. Using the puncturing vectors shown in Table III, we obtain the punctured convolutional codeword 26112 bits, which are transmitted in 9 OFDM symbols.

iV. Proposed T-DMB System

From the puncturing vectors defined in Table 1 we know that the first bit among the four coded bits is not punctured and always transmitted. Therefore, we can substitute the existing convolutional code with the turbo code because the information bits can be always transmitted as the systematic bits. For replacing a existing convolutional encoder by a turbo encoder, it is necessary not to modify the existing puncturing procedure and puncturing vectors for compatibility. First of all, to design a turbo encoder we must select a constraint length. The existing convolutional encoder having constraint length 7 needs six tail bits to flush the registers to zero state. Because the turbo encoder considered in this paper consists of the parallel concatenation of two constituent encoders, each constituent encoder with constraint length 4 is selected to separately flush the registers to zero state. Hence, a total of 6 tail bits which are equivalent to the standard convolutional encoder are needed to flush both of the constituent encoders. Next, we must choose a code rate for each constituent code. To obtain an overall code rate 1/4, each constituent code with code rate less than 1/2 is required. Therefore we choose a rate 1/3 code for each constituent code. It is known that maximizing the weight of output codewords corresponding to weight-2 data sequences, which weight dominates the performance characteristics, gives the best BER performance for a moderate SNR. A design for the best constituent codes for turbo codes by maximizing the effective free distance of the turbo code, in other words, the minimum output weight of codewords due to weight-2 input sequences, was reported in [3]. So, as a rate 1/3 constituent codes we use best rate 1/3 constituent codes with a maximum effective free distance. The best rate 1/3 constituent code is given by the code generator as follows

$$G = \left[1 \ , \ \frac{1+D+D^3}{1+D^2+D^3} \ , \ \frac{1+D+D^2+D^3}{1+D^2+D^3} \right] \quad (3)$$

Figure 3 shows the configuration of the designed turbo code encoder with a rate 1/3 constituent codes with constraint length of 4.

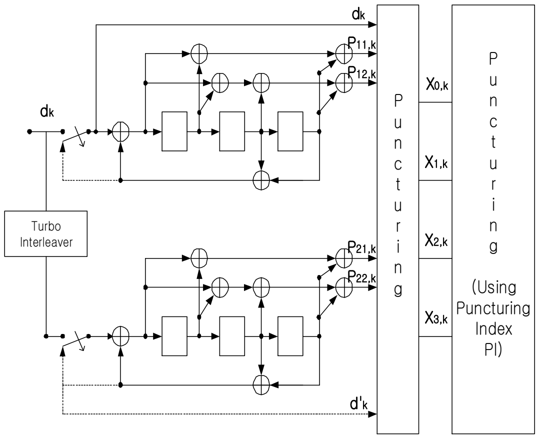

Figure 3. Configuration of the turbo encoder.

As a trellis termination, the switch allows to take input bits from register feedback. The designed turbo code results in an overall code rate 1/5. Therefore, the appropriate puncturing of the parity bits is required to obtain an overall code rate 1/4. This additional puncturing must be considered according to the puncturing vectors. Table 4 shows additional puncturing tables for each PI value. The puncturing tables for this additional puncturing are designed to transmit all the systematic bits from the first encoder and the same amount of parity bits from both encoders when the puncturing vectors are considered together.

Through this process of designing a turbo encoder we can replace the existing RS code, convolutional interleaver and RCPC code by a turbo code without altering the puncturing procedure and puncturing vectors defined in the standard T-DMB system for compatibility. Figure 4 shows the turbo coded system model substituting standard system.

V. Simulation Results

Table 4. Puncturing tables

PI	$(d_k, P_{11,k}, P_{21,k}, P_{12,k}, P_{22,k})$
1	11011 10111 10111 10111 10111 10111 10111 10111
2	11011 10111 10111 10111 10111 10111 10111 10111
3	11011 10111 10111 10111 11011 10111 10111 10111
4	11011 10111 10111 10111 11011 10111 10111 10111
5	11011 10111 11011 10111 10111 10111 11011 10111
6	11011 10111 11011 10111 10111 11011 10111 10111
7	11011 10111 11011 10111 11011 10111 11011 10111
8	11011 10111 11011 10111 11011 10111 11011 10111
9	11110 11011 10111 11011 10111 11011 10111 11011
10	11110 11011 10111 11011 11110 10111 11011 10111
11	11110 11011 11110 10111 11110 11011 10111 11011
12	11110 11011 11110 10111 11110 11011 11110 10111
13	11110 11101 11110 11011 11110 10111 11110 11011
14	11110 11101 11110 11011 11110 11101 11110 10111
15	11110 11101 11110 11101 11110 11101 11110 11011
16	11110 11101 11110 11101 11110 11101 11110 11101
17	11110 11110 11101 11110 11101 11110 11101 11110
18	11110 11110 11101 11110 11101 11101 11110 11101
19	11110 11110 11101 11101 11110 11110 11101 11110
20	11110 11110 11101 11101 11110 11110 11101 11101
21	11110 11101 11110 11110 11101 11101 11110 11110
22	11110 11101 11110 11110 11101 11110 11101 11101
23	11110 11101 11110 11101 11110 11101 11110 11110
24	11110 11101 11110 11101 11110 11101 11110 11101

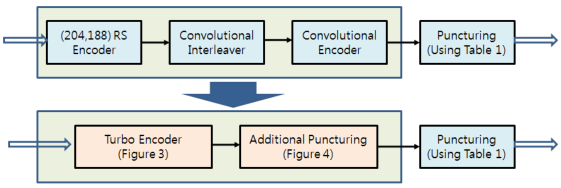

Figure 4. Turbo coded encoder

Figure 5 shows the average BER curves after Viterbi or MAP decoding in the MSC. The result corresponds to the Rayleigh fading channel. At a BER= 10^{-4}, the TCOFDM scheme offers an improvement of about 1dB and 1.7dB after 2 and 3 iterations over the COFDM scheme. More than 2.3B performance improvement can obtain after 5 iterations. With result in Figure 5, a considerable performance improvement can be obtained only after 2 iterations. But the amount of performance improvement is decreased with the increased iterations. This is because the more iterations are increased, the more correlation of encoded bits is increased.

VI. Conclusions

In this paper we propose a new turbo coded T-DMB sysem that replaces the existing RS codec, interleaver/deinterleaver block and RCPC(Rate Compatible Punctured Convolutional Code) codec by a turbo codec without modifying the puncturing procedure and puncturing vectors defined in the T-DMB system for compatibility. A range of system performance results were presented based on the standard system as well as on a turbo coded system. Simulation results indicate that the turbo coded system results in a substantial coding gain, in other words, the transmitted power requirements of the standard system employing convolutional codec can be reduced upon invoking more complexity but more powerful turbo codec.

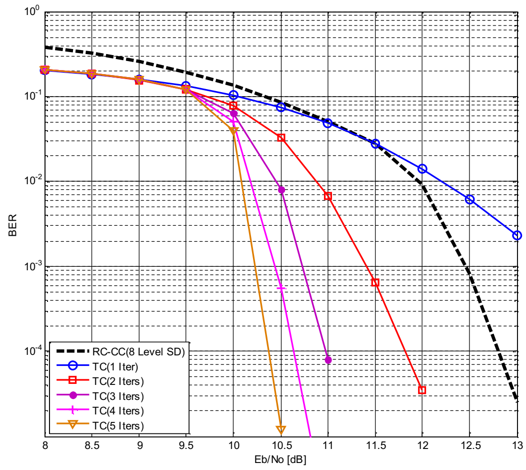

Figure 5. BER performance for 544kbps video transmission in Rayleigh channel.

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