Designing A Concatenated Code To Improve The Error Performance Of Low-Priority Data In T-DMB System With The Hierarchical Modulation

Li Erke*, Sung-Gaun Kim**, Hanjong Kim***

*,*** Korea University of Technology and Education

** Kongju University

E-mail : *marcheol83@hotmail.com, **kimsg@kongju.ac.kr, ***hjkim@kut.ac.kr

ABSTRACT

Hierarchical modulation has been considered for achieving higher data rates in Terrestrial-DMB(T-DMB) systems. And for achieving a higher data rates transmission, the low-priority (LP) data, which is used to carry additional data, such as video data, audio data and textual data, should be perfectly decoded in a certain value of E_b/N_o. Unfortunately, the man-made noise badly affects the high-priority (HP) symbol, which is used to carry the conventional data in the existed T-DMB system; and since the advanced T-DMB system is proposed to fit for the legacy T-DMB receivers, the low-priority symbols in the hierarchical modulation are much worse affected by the neighbors, who are both in the same quadrant. Because of the feature that mentioned previously, the turbo code has been considered to deal with the LP data. And due to the degradation which caused by the shortened symbol distance, the error performance of LP data is not sufficient by only using the turbo code. In this paper, we propose a Reed-Solomon code used outside of turbo code, and with the turbo code, it becomes a concatenated code. In this paper, there are some simulation results, within the comparison of those performances, we can see how a Reed-Solomon code is utilized for degradation of error performance which is caused by the hierarchical constellation, and how to design a Reed-Solomon code which is suitable for improving the degradation of error performance.

Keyword

T-DMB, Turbo Code, Reed-Solomon Code, Concatenated Code

Ⅰ. Introduction

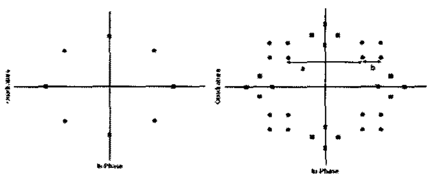
Korea T-DMB system (Terrestrial-Digital Multimedia Broadcasting system) is based on Eureka-147, which is used as a transmission standard for digital audio broadcasting in Europe [1]. And there are four transmission modes described in [1], but in Korea, only the transmission mode 1 was adopted for digital multimedia broadcasting services [2]. Since T-DMB system has been considered as an extended version of European DAB system, and its transmission rate should follow the European version [1]. However, as new sorts of services are provided, such transmission rate is not sufficient. Then the study of new technique for higher data rate transmission is placed on the agenda.

Facing to the problem for upgrading the broadcasting transmission rate, the hierarchical modulation has been considered as a good solution. Because, when the values of distance between two symbols in hierarchical constellation, are properly selected, the compatibility between advanced T-DMB system and conventional T-DMB system, and the promotion of transmission rate, can both be implemented. For the promotion of transmission rate, turbo code has been recommended. However, the degradation caused by the shortened symbol distance in one quadrant of hierarchical constellation, is much worse than we have imagined, and even using the turbo code, we can not get a good performance of bit error rate at low E_b/N_o. Hence, in this paper we propose a Reed-Solomon code which is combined with the turbo code to form a concatenated code.

The outline of this paper is as the following shown. A review of hierarchical modulation is given in section 2. The value of hierarchy parameter is discussed in section 3. Section 4 is showing how to combine the turbo code with Reed-Solomon code, and some comparisons of simulation results. Section 5 is the conclusion.

II. Brief Review of Hierarchical Modulation

In the hierarchical constellation, the data symbols can be separated into two kinds of symbols, high-priority (HP) symbols and low-priority (LP) symbols [3]. The HP symbol is defined for carrying the information generated by the conventional T-DMB system, and the LP symbol is defined for carrying the additional data. Fig.1 (a) shows the constellation of transmitted HP symbols in the conventional T-DMB system. And Fig.1 (b) shows the constellation of the symbols, each of which is combined by both HP symbol and LP symbol, in the advanced T-DMB system. In this paper, we should notice that the LP data has been only inserted into the Main Service Channel (MSC), but not the Synchronization Channel or Fast Information Channel (FIC).



(a) (b)

Fig. 1. (a) π/4-DQPSK constellation used in the conventional T-DMB system. (b) Hierarchical constellation used in the proposed T-DMB system

In [3], there is an important parameter called hierarchy parameter α, which is given by:

$$\alpha = \frac{a}{b} \tag{1}$$

Where **a** represents the minimum distance between two symbols in adjacent quadrants whereas **b** represents the distance between two neighboring symbols in one quadrant. Parameter **a** and **b** have shown in Fig.1 (b). Considering the compatibility of advanced T-DMB system and conventional T-DMB system, the option of the value of hierarchy parameter α should be noticed.

III. Option of Hierarchy Parameter

As we known, the different values of hierarchy parameter could cause different effects on HP symbols and LP symbols, but we want to design a new DMB transmitter, from which the signal can also be decoded at the legacy T-DMB receiver. Based on such a purpose, many researchers have done lots of work on figuring out the best value α. Fig.2 shows the block diagram of the conventional T-DMB system with the hierarchical mode, which we have used for our work, and Fig.3 shows the performance results. Fig.3 (a) shows BER of HP data in AWGN channel, and Fig.3 (b) shows BER of HP data in time-invariance Rayleigh channel. From Fig.3, α=4 can be selected to solve the problem of compatibility. In the following simulations, we fixed the α value equals 4, which will not be mentioned again.

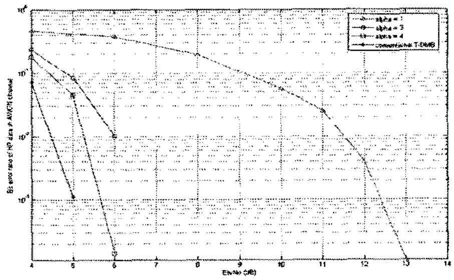


Fig. 3. (a) Bit error performance of HP data under the AWGN channel

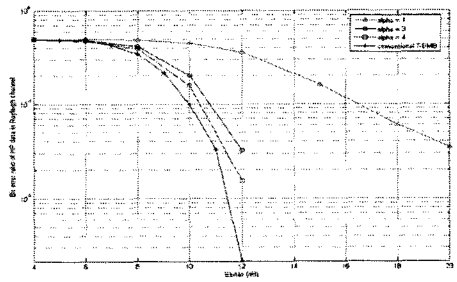


Fig. 3. (b) Error performance of HP data under the time-invariance Rayleigh channel.

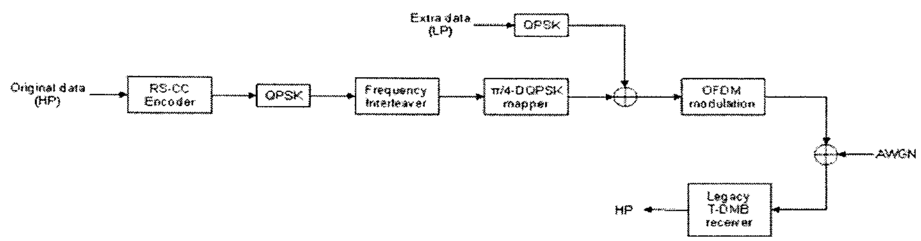


Fig. 2. Block diagram of the T-DMB system with hierarchical mode.

Ⅳ. The Proposed Concatenated Code

4.1 Block Diagram of The Proposed T-DMB With The Concatenated Code

For achieving the higher data rate transmission in the advanced T-DMB system, the LP data processing is the vital part. To deal with the LP data, the most efficient turbo code has been considered as a solution. However, the degradation of error performance of LP symbol transmission is still not acceptable, since the distance between two symbols in one quadrant of hierarchical constellation has been shortened a lot, in other words, in the hierarchical constellation each LP symbol was badly affected by another. In Fig.4, without the two yellow blocks, the block diagram formed by the remained blocks is the one that uses the turbo code only to deal with LP symbols, and the black curve shown in Fig.6, is the simulation result under the time-invariance Rayleigh channel. By the way, in this paper, the turbo code algorithm is following [4] and [5], and some parameters are shown as: code rate R=1/2, constraint length K=5, generators G1=37, G2=21, and parallel concatenation R1=R2=2/3. To fit for the number of symbols in one CIF, the size memory of random interleaver is changed into a 96x96 matrix. As the black curve shown in Fig.6, we can see that even the most efficient turbo code could decode the LP data, whose BER is under the expectant value 10^{-4}, but at a large E_b/N_o. So we should find a new way to save the E_b/N_o.

From [2], we can get that the concatenated code has an advanced improvement in decoding the video data, and combining the feature of Reed-Solomon code, we suggest that the concatenated code would improve the degradation of error performance of LP data transmission. Fig.4 shows the block diagram of the proposed T-DMB system with the concatenated code.

In our simulation, the Reed-Solomon code (192, 176, t=8), which is similar with RS(204, 188, t=8) derived from the original systematic RS(255, 239, t=8) [6], has firstly been used as an outer code for decoding LP data. In Fig.5, the performance result under the AWGN channel, is shown in pairs, each of which has been shown in the same color. In each pair, the difference is the method of decoding LP data, and between two different pairs, the difference is the value of iteration in turbo code. From the Fig.5, we can see that the concatenated code surely improves the degradation of bit error rate. And when we use the iteration value larger than 6, the coding gain changes only a little, so the iteration=6 can be considered as the best iteration in those three pairs.

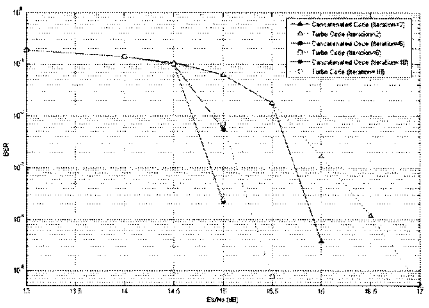


Fig. 5. The performance result of three pairs of concatenated code and turbo code under the AWGN channel, in three different iteration levels.

4.2 Performance Results of The Concatenated Code With Different Reed-Solomon Code

In the above part, we had selected the level of iteration used in turbo code, and in this part we'd like to show you the different performance results, which were got from different Reed-Solomon codes under the

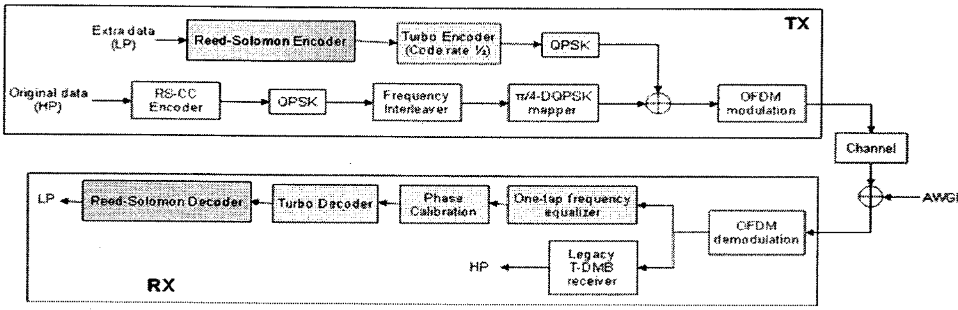


Fig. 4. Block diagram of the proposed T-DMB system with concatenated code.

time-invariance Rayleigh channel. The block diagram is still as the Fig.4 shown, and the Fig.6 shows the simulation result of turbo code only and the simulation results of three different concatenated codes (turbo code iteration all equals 6). From Fig.6, we can get that, by using the concatenated code within the RS(192, 176, t=8), we can nearly save 7dB E_b/N_o more than by using turbo code only, to obtain BER = 10^{-6}. And when we reduce the code rate of RS, we can save more energy. However, there is a trade-off, when we reduced the code rate, the number of redundant bits increases, in other words, the LP data rate reduces. So according to the required LP data rate, we can properly design the concatenated code.

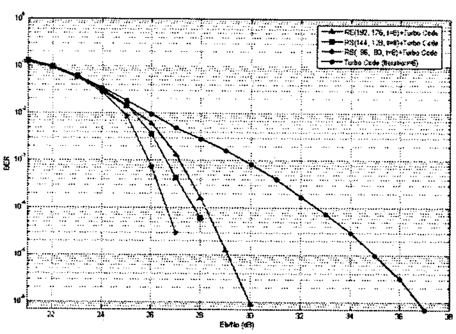


Fig. 6. Comparison between the performance result of LP data processing with the turbo code and the performance results of LP data processing with three different concatenated codes.

V. Conclusion

When the hierarchical modulation is applied to the conventional T-DMB system for achieving higher data rate transmission, the LP data processing should be considered. To decode the LP data, the turbo code has been recommended. However, the performance result within the turbo code is still not acceptable, so we propose the concatenated code for improving the degradation. As the Fig.5 and Fig.6 show, the proposed code surely improves the performance of bit error rate, and according to the different requirements of LP data transmission rate, we can properly change the code rate of Reed-Solomon code which is one part of the proposed code.

References

[1] ETSI EN 300 401 v1.3.3 (2001-05), "Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers".

[2] ETSI TS 102 428 v1.1.1 (2005-06), "Digital Audio Broadcasting (DAB); DMB video service; User Application Specification".

[3] ETSI TR 102 377 v1.2.1 (2005-11), "Digital Video Broadcasting (DVB); DVB-H Implementation Guidelines".

[4] Berrou, C., Glavieux, A., and Thitimajshima, P. "Near Shannon Limit Error-Correcting Coding and Decoding: Turbo Codes, " IEEE Proceedings of the Int.conf. on Communications, Geneva, Switzerland, May 1993(ICC'93), pp.1064-1070.

[5] Berrou, C., and Glavieux, A. "Near Optimum Error Correcting Coding and Decoding: Turbo-Codes," IEEE Trans. On Communications, vol. 44, no. 10, October 1996, pp.1261-1271.

[6] ETSI TS 102 427 v1.1.1 (2005-07), "Digigal Audio Broadcasting (DAB); Data Broadcasting - MPEG-2 TS streaming".