

Performance Improvement for 3D HDTV Service using Block LDPC Codes

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Abstract

There has been active research on 3D broadcasting service with HD resolution (3D HDTV) in ATSC system. The 3D HDTV broadcasting system requires more bandwidth efficient transmission schemes because it should convey both left and right HD resolution images simultaneously in the finite 6MHz bandwidth. Recently more bandwidth efficient modulation and more reliable error correction codes have been considered for the 3D HDTV service. A modified ATSC transmitting system using the BCH and Irregular Repeat Accumulate (IRA) LDPC codes in [3]. The modified ATSC system has SNR gain over the conventional ATSC system but is not sufficient for 3D HDTV service. In this paper, we propose more advanced ATSC transmission schemes that use higher modulation such as 16-QAM and concatenated RS code and block LDPC codes. Compared with conventional ATSC system and the modified ATSC system in [3], the proposed system has about 2.97dB and 1.12dB SNR gain at the payload data rate of 19.44Mbps compared with the existing ATSC system and the modified ATSC system [3]. Also, the proposed scheme requires only 1.05dB power increase for the 3D HDTV service, which is reasonable SNR increase value and applicable to the advanced 3D high definition broadcasting realization in limited 6MHz bandwidth.

Keywords: 3D HDTV; Reed Solomon Code; ATSC; Block LDPC; 16QAM

1. Introduction

There has been active research on 3D broadcasting service in accordance with increasing interest on the realistic media. In the traditional 3D broadcasting system, left and right images are transmitted alternatively such as side-by-side, top and bottom, and line/column interleaved method. However those 3D broadcasting systems have difficulty in realizing HD resolution because they truncate the image information. For more realistic media the 3D broadcasting service with HD resolution (3D HDTV) is indispensable. Recently the dual-stream 3D system for HD resolution was proposed and accepted as ATSC standardization [1]. The dual-stream 3D system transmits two streams which consist of left image with conventional MPEG-2 coding and right image with H.264 coding and it can provide 3D HDTV service in a finite 6MHz bandwidth. Also, it has advantage of backward compatibility with conventional 2D service. For the conventional 2D service, TV terminal has only to decode the left image.

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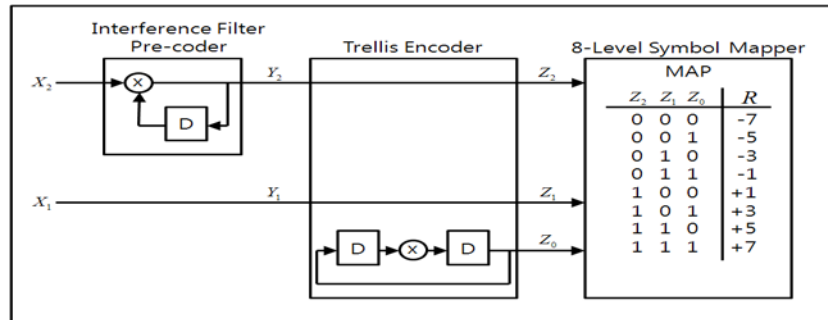


Figure 1. Trellis Encoder and Symbol Mapper in Conventional ATSC System

The 3D broadcasting service with HD-quality requires higher data transmission rate than the existing 2D HD broadcasting service (19.33Mbps) because it should convey both left and right HD resolution images simultaneously in the finite 6MHz bandwidth. Currently 2D HD broadcasting service in ATSC [2] uses Trellis code and 8-VSB modulation in which one of the two information bits is encoded with convolution code and then encoded two bits and the other information bit are modulated to a 8-level symbol as shown in Figure 1. This modulation and error correction techniques were introduced 20 years ago and not so efficient in terms of data rate and error correction capability. Recently more bandwidth efficient modulation and more reliable error correction codes have been considered for the 3D HDTV service. In [3], a modified ATSC transmission system was presented using the BCH code and the Irregular Repeat Accumulate (IRA) LDPC code which are adopted in the DVB-S and DVB-T2 [4]. With more improved error correction codes the modified ATSC system can have SNR gain over the conventional ATSC system. However, it is not sufficient for the 3D HDTV services.

In this paper, we propose more advanced ATSC transmission schemes that use higher modulation such as 16-QAM and concatenated RS code and block LDPC codes. With the proposed transmission scheme we can improve the data transmission rate which is adaptable for 3D HDTV service with only 1dB signal power increase.

This paper is organized as follows. In Section II, we consider the transmission structure for 3D HDTV service and present the proposed system model. In Section III and IV, simulation results and the conclusions are presented.

2. System Model and Proposed Method for Transmitting High-performance 3D HDTV

Basically, HDTV service requires 17~18Mbps with MPEG-2 compressed code and 8~9Mbps with H.264 compressed code, respectively. In the current 2D HDTV service the data transmission rate of 19.2Mbps is required for MPEG2 video stream and elementary audio stream in the finite 6MHz bandwidth. So the bandwidth efficiency is about 3.2bps/Hz. In this Section, we consider four transmission structures for 3D HDTV service which are shown in Figure 2. Each transmission scheme has Pros and Cons. We present a system model for 3D HDTV service considering the backward compatibility and system performance.

Based on the system model, we propose advanced ATSC transmission system with more reliable and bandwidth efficient modulation and error correction techniques.

2.1. Transmission Structure for 3D HDTV Service

In the 1st transmission structure shown in the Figure 2 (a), each of two channels (left and right images) is compressed with the conventional MPEG-2 coding scheme. This method can ensure the backward compatibility, but is difficult to transport many programs because of inefficiency.

The 2nd transmission structure shown in the Figure 2 (b) uses 12Mbps for the conventional 2D or left video stream with MPEG2 coding and 5.5~6Mbps for 3D depth or right video stream with H.264 coding. Since this method can guarantee backward compatibility, it is used for 3D HDTV experimental broadcasting. However it cannot avoid the degradation of HD image quality due to the decrease of data rates from 18Mbps to 12Mbps. Also the quality difference between left and right image may cause the viewer to feel vomiting, dizziness.

In the 3rd transmission structure in Figure 2 (c), both left stream and right stream are compressed using H.264 coding with 8~9Mbps and multiplexed via one channel. This method uses more efficient video compression coding, *e.g.*, H.264, and can transmit both left and right HD quality video streams with the same data transmission rate of 19.2Mbps in 6MHz bandwidth. However, if you receive only 2D service it needs to change the receiver system which supports 2D decoding of H.264. That is a disadvantage of the (c).

Finally, last transmission structure shown in Figure 2 (d) is similar to the 2nd transmission structure in which the left video stream (or 2D stream) is compressed with MPEG2 and the right video stream (or 3D depth) is compressed with H.264. However this method increases the data transmission rates from 19.2Mbps to 27Mbps in order to have no degradation in HD quality images. If we use this method, we can guarantee the complete backward compatibility but data transmission rate is required to increase about 1.5 times than the conventional transmission scheme. The bandwidth efficiency should be more than 4.5bps/Hz (27Mbps/6MHz). Since the 8-VSB modulation in conventional ATSC transmission system is difficult to achieve 27Mbps in the 6MHz bandwidth, higher modulation scheme is necessary.

Among the four transmission structures, we consider the scheme (d) for 3D HDTV service considering the backward compatibility and the system performance.

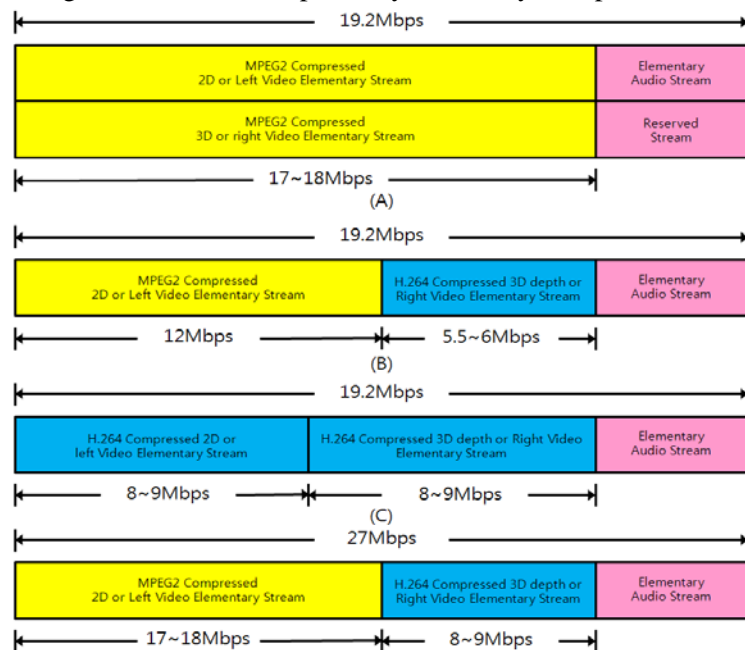


Figure 2. Transmission Schemes for providing 3D HDTV Service

2.2. Proposed ATSC Transmission System for 3D HD Service

For the transmission structure (d), more bandwidth efficient modulation and reliable error correction codes should be considered. In [3], a modified ATSC transmission system was presented using the BCH code [9] and the Irregular Repeat Accumulate (IRA) LDPC code which are adopted in the DVB-S and DVB-T2 [4]. Also the modified ATSC system adopted 4-PAM and 8-PAM rather than 8VSB modulation. In case of 4-PAM, the

modified ATSC system [3] has as same bandwidth efficiency as the conventional ATSC system. Also it provides 1.5 times higher bandwidth efficiency using 8-PAM modulation. In other words, it achieves a data rate of 19.33Mbps and 28.99Mbps in the 6MHz using 4-PAM and 8-PAM respectively. The simulation results in [3] showed that the modified ATSC system can have 1.85dB SNR gain over the conventional ATSC system for the data rate of 19.2Mbps. However it requires more signal power of 3.91dB for the data rates of 27Mbps which is the required data transmission rate for the 3D HDTV system model.

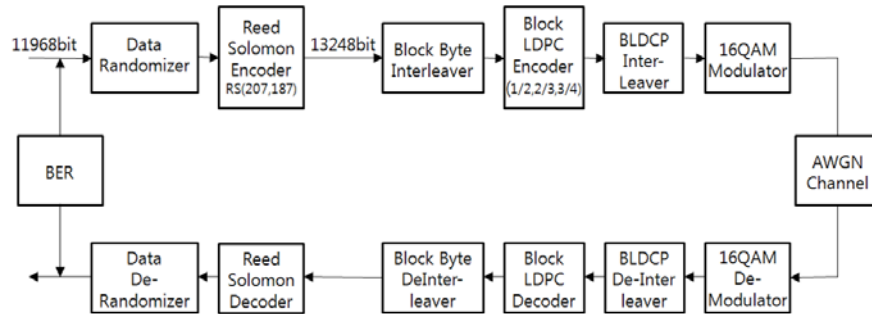


Figure 3. The Advanced ATSC Transmission System for 3D HDTV Service using Concatenated RS and Block LDPC Codes

In this paper, we propose more advanced ATSC transmission schemes that use higher modulation such as 16-QAM and concatenated RS code and block LDPC codes. The proposed ATSC transmission system for 3D HDTV service is shown in Figure 3. The proposed scheme is based on the conventional ATSC transmission scheme minimizing the modification of system structure such as data randomizer and RS code and block byte interleaver. In the proposed scheme, we consider block LDPC (BLDPC) which has more error correction capability and flexibility than IRA LDPC code. The IRA LDPC code in DVB-S and DVB-T is somewhat rigid and the code length is fixed as 64800bits.

On the other hand, the BLDCP code support various code rates (1/2, 2/3, 3/4) and code length. Also, the BLDCP has better performance than IRA LDPC code and is adopted in IEEE 802.11n and 802.16e systems.

As shown in Figure 3, elementary stream packet of 8 segments with 11968 bits is encoded with RS (207,187) outer code. After RS coding, 13248 bits are block interleaved and encoded with the BLDCP encoder. Parity check matrix H of BLDCP is designed newly using similar method in IEEE 802.16e and 802.11n [10]. The parity check matrix H has size of (48zx96z) where z is a parameter corresponding to a code length and code rate. For example the parameter z is 207 for the code rate 1/2. In the proposed method, we use 16-QAM modulation rather than 8VSB or 8PAM and achieve higher data transmission rate. The performance degradation due to 16-QAM modulation can be compensated with the powerful error correction codes, i.e. concatenated RS and BLDCP codes.

3. Simulation Results and Performance Comparison

In this Section we present simulation results. We assume an AWGN channel. Also we assume that the field sync and the segment sync are perfect.

Figure 4 shows the BER performance of the existing ATSC system (i.e., RS code, TCM, 8PAM) and the modified ATSC system (i.e., BCH code, LDPC, 4PAM) in [3] and the advanced ATSC system (i.e., RS code, BLDCP, 16QAM) which is proposed in this paper. In the performance comparison, the threshold of visibility (TOV) is important measure which is SNR value for successful transmission of video stream. In Table I, we present the performance comparison parameters such as E_b/N_0 threshold, bandwidth efficiency, data transmission rate and TOV gain or loss.

The TOV of the conventional ATSC system is known as 8.92dB. The TOV of the modified ATSC system [3] is 7.1dB in case of 4-PAM. As mentioned above, since the modified ATSC with 4-PAM has same bandwidth efficiency and data transmission rate, it has about 1.85dB SNR gain over the conventional ATSC system. The modified ATSC system [3] with 8-PAM has a data transmission rate of 28.99Mbps which satisfies the requirement of 3D HDTV service but requires 3.91dB more signal power.

The performances of the proposed system are simulated with BLDPCC code rate 1/2, 2/3, and 3/4 and TOVs are 5.95dB, 8.73dB and 10.17dB respectively. The proposed transmission scheme with 16-QAM and BLDPCC with code rate of 1/2 has same payload data rate as the existing ATSC system. In that case, the proposed scheme is 2.97dB and 1.12dB better than the existing ATSC transmission system and the modified ATSC system [3]. Also, TOV of SNR is converted with Eq. (1).

$$\frac{S}{N} = \frac{E_b}{N_o} + 10\log_{10}\left(\frac{187}{207} \times \frac{1}{2} \times 4 \times 2\right) = 11.53 \quad (1)$$

The proposed scheme with code rate 2/3 has data transmission rate of 25.92Mbps which is slightly lower than the requirement of 3D HDTV service. In that case, the proposed scheme requires only 1.05dB power increase, which is reasonable SNR increase value and we think that the 16-QAM BLDPCC with code rate 2/3 are applicable to the advanced 3D HDTV system.

Also the proposed system using RS code (n,k)=(207,187), BLDPCC with code rate 3/4 and 16QAM has the bandwidth efficiency of 5.42. In that case, the data transmission rate is 29.16Mbps and satisfies the requirement of 3D HDTV service. As shown in Table I, the proposed scheme has about 0.9dB SNR gain compared with the modified ATSC system [3].

Table 1. Performance Comparison between Conventional ATSC System and RS and Block LDPC Code and 16QAM System

Method	Coding and Modulation	Eb/No (dB)	Bandwidth efficiency	SNR (dB)	Data rate	TOV gain/loss
Current ATSC	RS+Trellis +8PAM	8.92	3.61	14.5	19.44	Reference
BCH+ LDPC	4PAM	7.1	3.59	12.65	19.33	+1.85
	8PAM	11.1	5.40	18.41	28.99	-3.91
RS+ BLDPCC +16QAM	r=1/2	5.95	3.61	11.53	19.44	+2.97
	r=2/3	8.73	4.82	15.55	25.92	-1.05
	r=3/4	10.17	5.42	17.51	29.16	-3.01

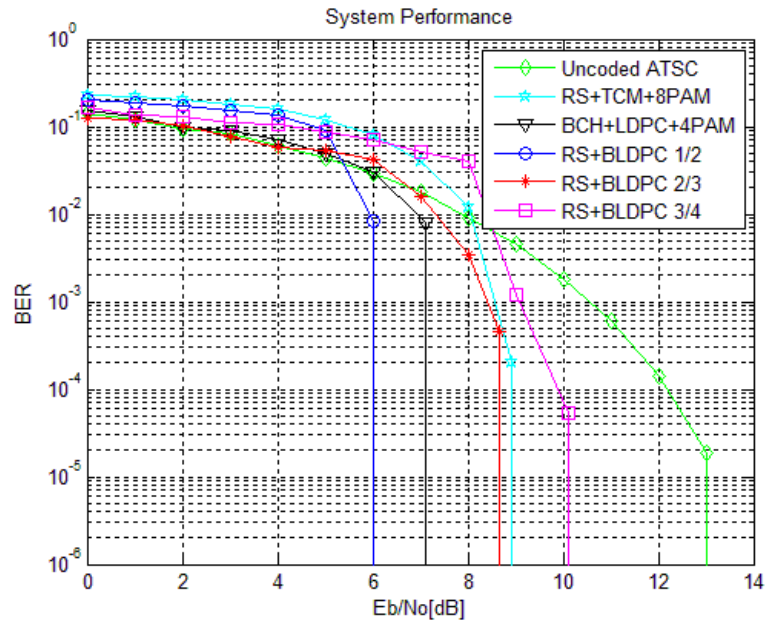


Figure 4. BER Performance Comparison with ATSC and the Modified ATSC [3] and Proposed ATSC

4. Conclusion

In this paper, we considered the system model for providing 3D broadcasting of HD quality in accordance with the increasing attention for realistic media. Based on the system model we proposed the advanced ATSC transmission system with powerful concatenated RS and BLDPC code and higher order modulation.

Compared with conventional ATSC system and the modified ATSC system in [3], the proposed system has performance improvement in terms of SNR gain. The proposed transmission system has about 2.97dB and 1.12dB SNR gain at the payload data rate of 19.44Mbps compared with the existing ATSC system and the modified ATSC system [3]. In addition, the proposed system using BLDPC with code rate of 3/4 has approximately payload rate of 29Mbps and achieves 0.9dB performance improvement compared with the modified ATSC system [3]. Finally the proposed scheme with code rate 2/3 has data transmission rate of 25.92Mbps which is slightly lower than the requirement of 3D HDTV service. In that case, the proposed scheme requires only 1.05dB power increase, which is reasonable SNR increase value and we think that the 16-QAM BLDPC with code rate 2/3 are applicable to the advanced 3D HDTV system.

Acknowledgments

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