Performance of MIMO Bit Division with Polarized MIMO DVB-T2

In-Woong Kang, Suk Chan Kim, Ki-Hwan Suh, Heung Mook Kim, Jae Hyun Suh, Youngmin Kim, and Hyoung-Nam Kim

***Abstract*—**This paper introduces a principal concept of MIMO bit division and presents its performance with corresponding simulation results. When multiple antenna technique is applied to enhance the spectral efficiency, the original data stream should be divided in a proper way. We found that the way of dividing original data stream, if it is not cooperating well with the originally structured system, may lead to performance degradation. The key idea is dividing the original data bit stream without causing an undesired change of bit order at the output of bit-to-cell demux..

***Keywords*—**MIMO, MIMO bit division, DVB-T2, UHDTV.

I. Introduction

UHD(Ultra High Definite) TV standard supports 16 times bigger pixels per frame and about 4 times greater audio channels compared to HD(High Definite) TV standard. In addition, higher frame rate, greater number of bits per pixel and advanced color sampling result in an increase of amount of video and audio content. Even with an assistance of important progress in data compressing techniques, the required transmission data rate is still big, thus leading to the strong requirement of developing digital data transmission system. 256~4096 QAM modulation, Turbo codes or LDPC codes, and multiple antenna techniques are taken into account as some of key parts of such a development[1].

DVB-T2, known as one of the most advanced digital terrestrial transmission (DTT) system offering higher spectral efficiency, robustness and flexibility developed upon the DVB-T system[2],[4]. Even though this digital broadcasting system can provide transmission rate enough for SD TV and HD TV contents, still the transmission data rate is not sufficient for UHDTV service. Due to the lack of transmission data rate, researches and tests to achieve UHDTV-grade transmission data rate with new generation of broadcasting system already has been going on [6],[7]. Among possible system options, NHK and BBC adopts Multiple-Input Multiple-Output(MIMO) system, like other wireless communication systems have tried and resulted in a phenomenal development in spectral efficiency using additional transmitter and/or receiver antennas.

MIMO technique that NHK adopted to develop next generation broadcasting system uses dipole antenna at the both side of transmitter and receiver. The dipole antenna utilizes polarization and it opens up two transmission channels, vertical channel and horizontal channel, increasing the system throughput allowing two independent data stream to be transmitted at the same time.

When MIMO technique, especially designed to enhance the spectral efficiency, is applied to a system, the MIMO system will include dividing process that divides the original data stream into multiple streams either in bit or subcarrier level. As this MIMO system is considered to be structured with bit-interleaved coded modulation(BICM), the dividing process should not affect on the performance of BICM. In this paper a proper bit level MIMO processing with DVB-T2 system is explained and its performance is provided.

The rest of this paper is organized as follows: In section II, DVB-T2 system is described. In section III, MIMO bit division processing is explained. Corresponding simulation results are presented in section IV and this paper is concluded in section V.

II. DVB-T2 System

A. Basic features of OFDM system

DVB-T2 system is one of the digital terrestrial transmission systems that Orthogonal Frequency Division Multiplexing(OFDM) is used as a modulation function. OFDM technique loads data on a big number of subcarriers into which the assigned bandwidth is divided. The subcarriers are designed to overlap over adjacent ones to increase spectral efficiency and the interference between subcarriers caused by the overlap, namely Inter-Carrier Interference(ICI), is prevented by using orthogonality between subcarriers.

Using a number of subcarriers over a broadcasting channel assigns a small frequency band to each of subcarriers and its bandwidth is highly likely much less than the coherence bandwidth of the frequency selective fading channel which the transmitted signal is propagating through. In this manner, the

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TABLE I
DVB-T2 DEMUX PARAMETERS

Modulation Format	LDPC Code Rates	Output bit number
64QAM	3/5	[2,7,6,9,0,3,1,8,4,11,5,10]
	5/6	[11,7,3,10,6,2,9,5,1,8,4,0]
256QAM	3/5	[2,11,3,4,0,9,1,8,10,13,7,14,6,15,5,12]
	5/6	[7,3,1,5,2,6,4,0]

frequency selective fading channel turns into a set of frequency flat fading sub-channels, therefore the task of data processing in frequency domain, such as channel estimation in frequency domain and equalization, is drastically reduced. In time domain, since generating an OFDM symbol is implemented by Inverse Fast Fourier Transform(IFFT), the bigger the size of the IFFT is, which is the number of the subcarriers, the longer the size of one OFDM symbol becomes. A long OFDM symbol is able to cope with the multipath fading channel that has a long delay spread by appending Cyclic Prefix(CP) at the beginning of the OFDM symbol.

As UHDTV service requires higher transmission data rate compared to other current broadcasting systems, some features of OFDM modulation technique, which are proper to achieve high data rate, have been considered as one legitimate system. For example, DVB-T2 system supports big FFT size up to 32K, high constellation mapping level up to 256 QAM for greater data rate.

B. Forward Error Correction

DVB-T2 system is equipped with very strong error correction codes, which are Low Density Parity Check(LDPC) codes. LDPC codes are basically linear block code with very sparse parity-check matrices meaning a very small number of ones are placed in the matrices. Decoding procedure of LDPC codes differ from conventional linear block code. Iterative decoding technique of LDPC codes approach the Shannon limit over noisy channel[10], [11].

LDPC codes used in DVB-T2 standard are classified as irregular LDPC codes whose parity check matrix has different number of ones in columns and rows leading to unequal error protection property. Generally, the non-uniform bit reliabilities inherent to the high-order modulation and irregular LDPC code imply the mismatch between the decoder and the demodulator. Hence, the bit mapping is plugged between the two modules, specifically bit-to-cell demux in DVB-T2 chain, to match the unequal error protections of different coded bits to different modulation level[10]. The mapping operation is basically performed in one or two QAM symbol unit and the bit mapping rules are different with different QAM modulation level and LDPC code rates as explained in Table I.

C. Maximum-Likelihood Decoding

At the receiver side, Maximum-Likelihood(ML) decoding calculates the reliabilities of all bits received based on the maximum a posteriori probability decoding method expressed in (1). Log-Likelihood Ratio(LLR) value of each of bits is calculated and used as a measure of the reliability.

TABLE II
MODIFIED ALAMOUTI SPACE FREQUENCY BLOCK CODING

	Antenna 1	Antenna 2
Subcarrier i	S_i	$-S_{i+1}^*$
Subcarrier i+1	S_{i+1}	S_i^*

$$L(b_k) = \ln \frac{\sum_{s_i|b_k=1} \Pr\left(\mathbf{s}_i|\mathbf{r}\right)}{\sum_{s_i|b_k=0} \Pr\left(\mathbf{s}_i|\mathbf{r}\right)}. \tag{1}$$

Where b_k is the k-th bit of the transmitted vector, and $\boldsymbol{s}_i$ is the vector from the ensemble $\{\boldsymbol{s}_1, ..., \boldsymbol{s}_l\}$.

III. MIMO PROCESSING

A. Spatial Multiplexing

Multiple antennas at the both side of a transceiver imply that the system can utilize new resource, which is spatial resource, for certain designated purposes. Among those purposes, spatial multiplexing technique is designed to use the added antennas to increase spectral efficiency by transmitting independent data via multiple transmit antennas. It is known that an increase in capacity is proportional to the minimum number out of the number of transmit antennas and the number of receive antennas. This capacity increase by spatial multiplexing technique can be fully achieved under the assumption that the propagating channel is richly-scattering[8].

B. 2X2 MIMO Using Dipole Antenna

Research teams who are dedicated in developing UHDTV-grade digital transmission system have been working on adding multiple antenna technique to enlarge the capacity. However, using multiple antennas at the both sides of the broadcasting links directly leads to additional cost, and the target transmission data rate doesn't require a big number of additional antennas. For these reasons, the next generation terrestrial broadcasting systems are expected to have two antennas at transmitter and receiver[3], [6].

Moreover, dipole antennas are considered to be included in new broadcasting systems pursuing better data rate because of its polarization property that is very helpful to make each transmitted signal travel through different channels, vertical and horizontal channels, with very low cross antenna discrimination[5].

C. Proposed MIMO Bit Processing

Current DVB-T2 standard supports Multiple-Input Single-Output(MISO) technique optionally. Based on the Alamouti space-frequency block coding(SFBC) explained in Table II, the MISO processing of DVB-T2 system encodes the QAM symbols that the same QAM symbols are repeated once in the next frequency index before they are modulated by OFDM modem[2], [9]. In this way the transmitted signal obtains

TABLE III
SIMULATION PARAMETERS

Parameters	
FFT size	4 K mode
Guard Interval	1/4
LDPC Code Rate	5/6
Modulation Depth	64QAM, 256QAM
Channel Model	Modified DVB-NGH Model Identity Matrix AWGN Model

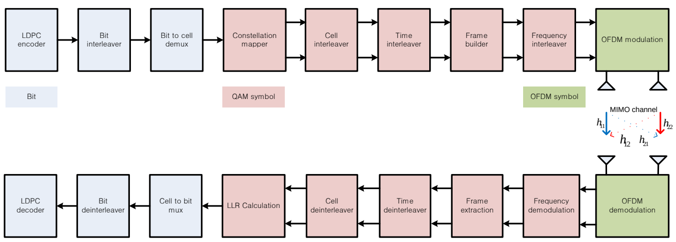

Fig. 1 Block Diagram of Polarized MIMO DVB-T2 System

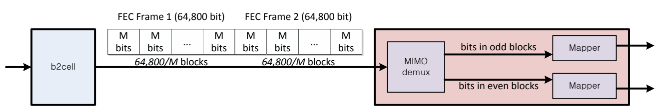

Fig. 2 MIMO bit division in every M bits

diversity gain and it follows that the receiver shows better error performance compared to the SISO DVB-T2 system.

Contrary to the MISO processing, spatial multiplexing MIMO technique necessarily divides the original data stream in a certain way and the divided data flows will be going through different path that has same data processing modules as Fig. 1 depicts. Fig. 1 shows that after the original bit data stream is processed by bit-to-cell demux module, this bit stream at the output of bit-to-cell demux is divided into two streams and further data processing is followed.

When the original data stream is divided by MIMO demux as shown in Fig. 2, the way MIMO demux works should take the function of bit-to-cell demux into account. In order to do so, we propose that MIMO demuxing also should be performed in the same unit in which the bit-to-cell demux is performed. In this manner, MIMO demux can divide bit-to-cell demux output without causing degradation in the performance of the combination of LDPC codes and bit-to-cell demux.

IV. SIMULATION RESULTS

In this section, we demonstrate the MIMO bit processing under the presented simulation environment. Important simulation parameters are given in Table III. We checked the performance of the MIMO bit mapping over Additive White Gaussian Noise(AWGN) channel implemented by 2X2 identity matrix because the channel we currently focus on is the dipole antenna MIMO channel with small cross polarization discrimination.

Fig. 3 and Fig. 4 are bit error rate performance at the output of ML decoding and at the output of LDPC decoder when only AWGN impairs the received signal. Bit error performance before LDPC decoder, Uncoded BER, is determined by

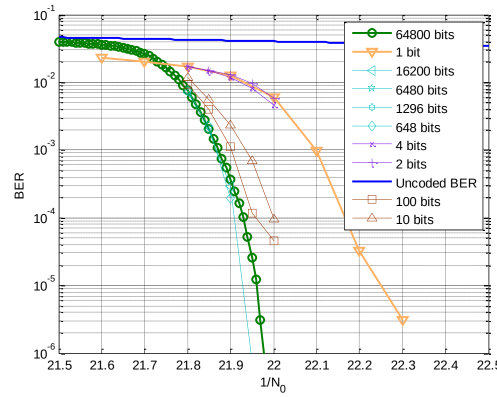

Fig. 3 Bit error ratio performance of different MIMO bit divisions with 256QAM in AWGN

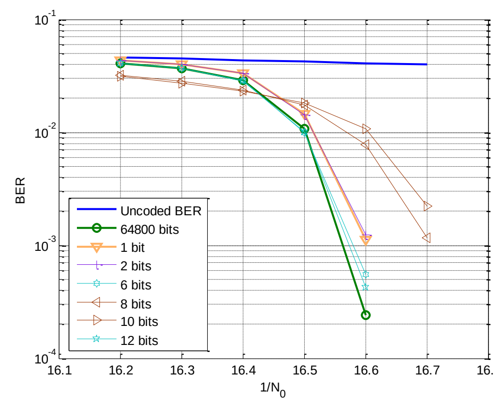

Fig. 4 Bit error ratio performance of different MIMO bit divisions with 64QAM in AWGN

comparing the signs of ML decoding output bits with LDPC encoder output and it is marked as a blue plot. As shown in figures, Uncoded BER of different MIMO bit mappings presents no difference since MIMO bit mapping methods do not actually affect the ML decoding itself. However the error performance after LDPC decoding indicates that MIMO bit mapping can definitely change the result. The performance is the best when the bit division is performed keeping the output of bit-to-cell demux from being scrambled again. For example in Fig. 3, when the bit division is done in every multiple of eight bits, bit error rate graphs fall before the graphs in the other cases and the same results are given in Fig. 4 as well in case of 64 QAM modulation.

V. CONCLUSION

We introduced a concept of proper MIMO bit division. Our results show that MIMO bit division in the same level, in which bit-to-cell demux performs, presents the best performance with the BICM of DVB-T2 system. The bit division design can be extended directly to other MIMO broadcasting systems in the future.

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