Overview of Channel Bonding and MIMO of ATSC 3.0 Broadcasting System

Bo-mi Lim, Hoiyoon Jung, Haechan Kwon, Sung-Ik Park, and Namho Hur

***Abstract*—This paper introduces channel bonding and multiple-input multiple-output (MIMO) technologies adopted in Advanced Television Systems Committee (ATSC) 3.0, a recently developed digital terrestrial television standard. Channel bonding and MIMO are aimed at enhancing the channel capacity, so they enable to deliver rich media services such as 8K ultra-high definition (UHD) video. Several researches to evaluate the two technologies through intensive computer simulation, laboratory tests, and field experiments are also introduced briefly, in addition to a newly conducted laboratory test of channel bonding.**

***Index Terms*—terrestrial broadcasting, channel bonding, multiple-input multiple-output, MIMO**

I. Introduction

ADVANCED television systems committee (ATSC) recently developed a new digital terrestrial television standard, ATSC 3.0, to increase the channel capacity and flexibility of spectral usages. It adopted thoroughly new technologies from video encoding to physical transmission resulting in non-backward compatibility with the previous ATSC 1.0 standard [1]-[3]. South Korea and USA successfully launched the ATSC 3.0 broadcast service, whose adoption is actively discussed in several nations. Recently, thanks to the spread of 8K display panels, the demand for rich media services beyond 4K ultra-high definition (UHD) such as 8K UHD, virtual reality (VR), and augmented reality (AR) is increased. To achieve the enhanced data rate, ATSC 3.0 adopted channel bonding and multiple-input multiple-output (MIMO) techniques.

Channel bonding combines multiple radio frequency (RF) channels as a single wide band so that the channel capacity linearly increases as the number of available RF channels increases [4]. MIMO utilizes multiple transmit and receive antennas to enhance the system capacity without additional RF channels [5]. Several studies have been published to verify and evaluate two techniques through intensive experiments [6]-[10]. This paper briefly introduces the channel bonding and MIMO techniques in ATSC 3.0 broadcast systems and considers their feasibility by reviewing the previous research and an additional laboratory performance test.

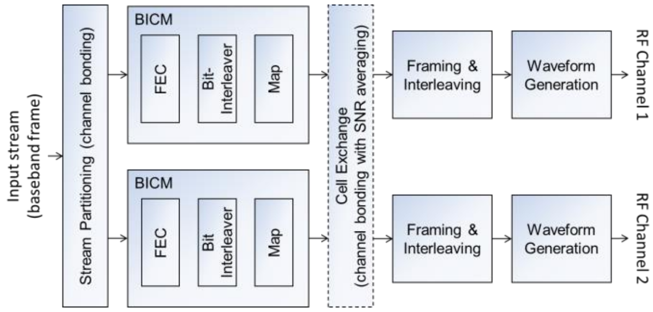

Fig. 1. Block diagram of ATSC 3.0 transmitter employing channel bonding.

II. Channel Bonding

A. Overview of ATSC 3.0 Channel Bonding

ATSC 3.0 physical layer standard includes the channel bonding techniques to combine two RF channels, which can be located contiguously or non-contiguously, achieving twice the system capacity as a single RF channel [1],[4]. Therefore, the broadcaster enables services to be allocated within two RF channels as if they are configured within a single RF channel. Fig. 1 shows the block diagram of the ATSC 3.0 transmitter employing channel bonding. The transmitter, applying channel bonding, partitions the input service streams in a baseband frame unit, which are processed in the two independent bit-interleaved coded modulation (BICM) blocks to deliver the service on two RF channels. Two different channel bonding modes can be supported: plain channel bonding and channel bonding with signal-to-noise ratio (SNR) averaging [1],[4],[6]. In plain channel bonding, the split streams can be configured with thoroughly different physical layer parameters such as modulation, code rate, time interleaving, and waveform, resulting in different data rate and robustness for each RF channel. On the other hand, in channel bonding with SNR averaging, two output streams of BICM blocks in a cell unit are exchanged in the cell exchange block. Therefore, two consecutive cells of each BICM block are transmitted using different RF channels. If two RF channels are non-contiguous, the two cells experience different propagation channels so that frequency diversity gain may be achieved, improving the reception performance. Unlike plain channel bonding, the physical layer configuration should be identical between two RF channels

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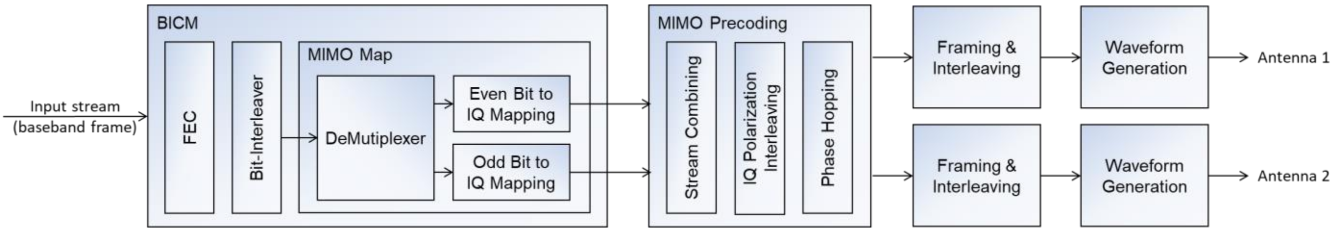

Fig. 2. Block diagram of ATSC 3.0 transmitter employing MIMO.

TABLE I
CHANNEL BONDING PERFORMANCE BASED ON THE MINIMUM RECEIVED SIGNAL STRENGTH CONSIDERING TYPES

Minimum Received Signal Strength [dBm]		Power Imbalance [dB]
RF Channel 1	RF Channel 2	
-66	-66	0 (plain channel bonding)
-67	-65	2
-67	-64	3
-68	-63	5
-68	-62	6
-68	-61	7
-68	-60	8
-68	-59	9
-68	-58	10
-68	-57	11
-69	-56	13

in the current version of the ATSC 3.0 standard to reduce the complexity of implementation.

B. *Performance of Channel Bonding*

The reception performance of channel bonding has been studied in [6]-[8]. In [6] and [7], the performance of two types of channel bonding was compared through the computer simulation with respect to the different channel conditions. In [8], the ATSC 3.0 transmitter and receiver including channel bonding were developed as hardware, and a laboratory test was conducted to verify the performance and feasibility of the 8K UHD service. If two RF channels have different channel conditions, the test results show that channel bonding with SNR averaging has better reception performance than plain channel bonding as the distance between two RF channels increases, especially in mobile receiving environments.

Additional reception performance test of the channel bonding based on the hardware was newly conducted in this paper to examine the two types of channel bonding. The physical layer parameters used in this test were the same as in [8]. TABLE I shows the measured minimum received signal strengths of two RF channels combined with channel bonding. The test result under 0 dB power imbalance was the minimum received signal strength of the plain channel bonding case. When the channel bonding with SNR averaging was applied, the two RF channels compensated each other. Therefore, if one of two RF channels acquired at least -56 dBm, 3-dB less power was allowable to decode the received signal successfully.

III. MIMO

A. *Overview of ATSC 3.0 MIMO*

MIMO increases the spectral efficiency within a single RF channel by using spatial multiplexing [5]. ATSC 3.0 allows two transmit and two receive antennas having different polarization. In general, the terrestrial broadcast system utilizes cross-polarized antennas such as horizontal and vertical polarization to guarantee spatially separated propagation paths with high cross-polarization discrimination (XPD). Therefore, the ATSC 3.0 MIMO broadcast can achieve a nearly double data rate compared to SISO broadcast systems depending on the physical layer configurations [5]. Fig. 2 shows the block diagram of the ATSC 3.0 transmitter that involves MIMO processing. The transmitter divides the bit-interleaved bit streams, generates two separated cells in the MIMO mapper, and independently processes to radiate through antenna 1 and 2. The MIMO precoding block comprises three inner blocks: stream combining, IQ polarization interleaving, and phase hopping. Since each block is individually applied to BICM output cells, any on-off combinations of three blocks are possible, including all offs. Since two polarized antennas between transmitter and receiver may interfere with each other, different pilot encoding or allocation are required to estimate the MIMO channel. Therefore, ATSC 3.0 adopts two orthogonal pilot encodings: Walsh-Hadamard and null pilot [1],[5].

B. *Performance of MIMO*

The reception performance of MIMO is provided in [9], [10]. Based on the computer simulation, laboratory test, and field test, the reception performance of the ATSC 3.0 MIMO system was evaluated concerning channel characteristics such as XPD. Also, 8K UHD service requiring 100 Mbps data rate through the MIMO broadcasting was verified in the real field environment using the Korean commercial broadcast site. As the XPD decreases or the interference between two antennas was increased, the reception performance was degraded so that tuning the direction of cross-polarized antennas should be significantly considered for extremely high data rate services.

IV. CONCLUSION

This paper considered the channel bonding and MIMO technologies in the ATSC 3.0 physical layer standard to achieve a high data rate. Their functional feasibility and reception performance were intensively verified by the developed hardware equipment in addition to the theoretical point of view. ATSC 3.0 channel bonding and MIMO are practical solutions for 8K UHD terrestrial broadcast services requiring at least 50 Mbps data rates.

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