

Field Testing of HEVC based Terrestrial UHD 3D Broadcast in ATSC 3.0

Yeonjun Choi*, Sung-Hoon Kim*, Hongkyw Choi*, Seongwon Jung*

* ETRI(Electronics and Telecommunications Research Institute), Korea

june@etri.re.kr, steve-kim@etri.re.kr, hk-choi@etri.re.kr, jsw@etri.re.kr

Abstract— ATSC 3.0 is the first Internet Protocol (IP) integrated standard with a flexible structure suitable for simultaneous transmission and reception of various formats of media on both broadcasting and broadband. The user-selectable Ultra High Definition (UHD) stereoscopic 3D media system is the head-end system for selectively receiving immersive media, i.e., 3D media, virtual reality (VR), etc., not using more bandwidth but e maintaining compatibility with the current mobile 2D High Definition (HD) and fixed 2D UHD media transmission and reception services in ATSC 3.0. In this paper, we describe the field test results of High-Efficiency Video Coding (HEVC)-based media transmission and reception techniques developed for stereoscopic media service compatible with the existing 2D media service. We performed the world's first field test for simultaneous transmission and reception of 2D and 3D videos on HEVC encoding in ATSC 3.0.

Keywords— ATSC 3.0, stereoscopic 3D video, UHD 3D TV, HEVC, 2D-3D simulcast, broadcasting field test

I. INTRODUCTION

The COVID-19 pandemic has narrowed the scope of people's activities in real life and expanded them in virtual spaces. In order to satisfy the demand for cultural enjoyment and various economic activities, entertainment performances such as K-Pop, classical music, musicals, and fashion shows using non-fungible token (NFT) began to be supplied through digital media and networks with up-to-date technologies such as live streaming, metaverse, and VR[1]. Accordingly, several technologies based on ATSC 3.0 have been introduced to service large-scale immersive media such as 3D and VR broadcasting[2].

ATSC 3.0, the next-generation terrestrial digital broadcasting standard, is the first broadcasting standard to enable simultaneous broadcasting and broadband service a variety of media formats on high-quality fixed and mobile devices[3]. As a way to make this possible, ATSC 3.0 adapts Real-time Objective Delivery over Unidirectional Transport (ROUTE) protocol for broadcasting transportation and Dynamic Adaptive Streaming over HTTP (DASH) protocol for both ROUTE and IP-based broadband network delivery. ATSC 3.0 standard allows both MPEG Media Transport Protocol (MMTP) and ROUTE protocol as transport protocol[4]. ATSC 3.0's video encoding standard, High-Efficiency Video Coding (HEVC), includes HD and other

kinds of video format[5]. It also includes more complex techniques that are bandwidth-efficient but decoding-overhead, i.e., Scalable HEVC (SHVC) and other extended encoding technologies, considering delivery of large amounts of immersive contents. These technologies can replace Digital TV (DTV) for fixed HD broadcasting and Digital Multimedia Broadcasting (DMB) for mobile broadcasting with different frequency bandwidths at the same time, enabling frequency-efficient UHD services that combine UHD and mobile HD broadcasting into one frequency bandwidth.

There are some researches and field tests on up-to-date technologies in ATSC 3.0. In South Korea, ATSC 3.0 broadcasting technology was adopted as the domestic terrestrial UHD broadcasting standard in 2016. Main broadcasting stations began to provide ATSC 3.0-based terrestrial UHD broadcasting services from May 2017, and some events were broadcast in ATSC 3.0 live broadcasting pilot service of 4K UHD and mobile HD simultaneously to the world during the 2018 Pyeongchang Winter Olympics. In the United States, the Federal Communications Commission (FCC) approved the use of ATSC 3.0 as an additional broadcasting standard in November 2017. Accordingly, Consumer Technology Association (CTA) and National Association of Broadcasters (NAB) began joint field tests in Cleveland and other places in November 2017, and in October 2018, the FCC additionally authorized broadcasters to test ATSC 3.0 broadcasting, which enabled the test for the next-generation terrestrial broadcasting standard in the United States. As of 2021, the broadcasting infrastructure has been built so that more than 75% of viewers in about 62 Designated Market Areas (DMAs) can receive ATSC 3.0 broadcasting. Pearl, the American broadcasting corporation, defined the ATSC 3.0 Physical layer transfer profile with two single capacity setups of at least 3 Mbps, up to 24.9 Mbps, and one two capacity setup on one channel, and Sony also defined the same physical layer transfer profile the same as Pearl to conduct a field test in Phoenix and Santa Barbara[6][7]. Although there have been several field tests, there is no test case of broadcasting immersive media contents such as 3D with existing 2D simultaneously based on ATSC 3.0 standard yet.

In this paper, we introduce a field test conducted by implementing HEVC-based terrestrial UHD 3D media delivery technology that provides UHD stereoscopic media

with efficient frequency bandwidth while maintaining compatibility with Over-the-top (OTT) media service and mobile environments under the ATSC 3.0 standard.

The remainder of the paper consists of the following. An overview of the field tests and the introduction of the test bed system are described in Section II. The performance and results of the field test experiment are described in section III. Finally, section IV states the conclusion.

II. OVERVIEW OF TESTBED SYSTEM FOR FIELD TEST

In this paper, the field test was conducted to confirm whether ATSC 3.0 transmission and reception is possible in a real-time broadcast environment by establishing an ATSC 3.0 transmission and reception system in preparation for the ATSC 3.0 2D/3D simulcast pilot deployment planned next year in Busan.

Before the field test, we built ATSC 3.0 based stereoscopic 3D broadcasting service testbed system and performed a lab test[8]. Our HEVC-based stereoscopic 3D media transmission and reception testbed system is configured to follow the UHD 3D TV Service illustrated in ATSC 3.0 as shown in Figure 1.

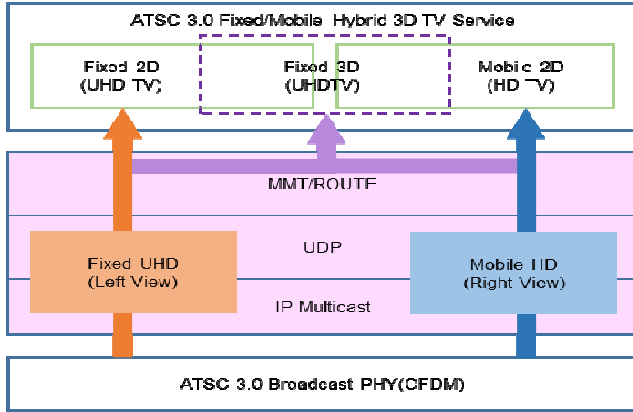


Figure 1. Conceptual configuration of ATSC 3.0 3D TV Service. This diagram represents our testbed system by modifying an example configuration presented in the ATSC 3.0 HEVC standard[3]

Each view is packaged in a different Physical Layer Pipe(PLP) and transmitted in a different subframe, which is decoded and displayed by the reception side depending on the display type of the receiver. Video streams for Mobile HD are placed on the front PLP and subframe 0, and video streams for fixed UHD are placed on the next PLP and subframe 1. HEVC-based 2D/3D simulcast mechanism is shown in Figure 2. HEVC encoder encodes the UHD-class left view video the same as the original and downsamples the UHD-class right view video into HD video stream. The former applies higher-order modulation construction, i.e. 256QAM, to send a larger amount of stream, and the latter applies lower-order modulation construction, i.e. QPSK or 16QAM, to ensure stable reception on the move. On the receiver side, it decodes streams and displays 2D/3D depending on its display type. In the case of the mobile receiver, it decodes and displays the HD video of the right view. In the case of the fixed UHD

receiver, it decodes and displays the fixed UHD video of the left view. Finally, in the case of the fixed 3D receiver, it obtains both videos of the left view and the right view from the PHY layer, and restores them to the 3D video.

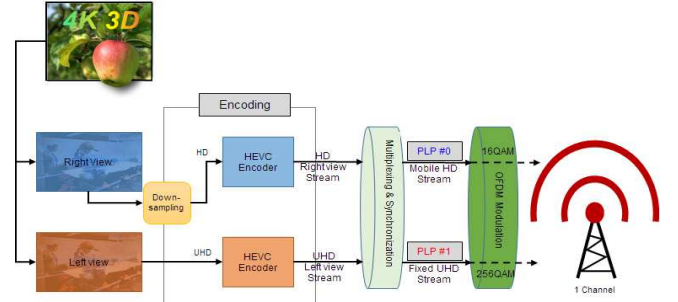


Figure 2. HEVC-based video encoding process for multi-formatted video simulcast

The system proposed in this paper is a head-end system that guarantees existing fixed UHD/mobile HD broadcasting currently in service while simultaneously providing UHD 3D services to TV users at one channel frequency without separate frequency or additional data bandwidth allocation. Figure 3 shows the encoding and decoding mechanism for transmitting and receiving HEVC- based stereoscopic UHD 3D contents of the system.

As shown in Figure 3, the head-end system consists of a transmission part and a reception part. The process of transmission part starts with acquisition of stereoscopic 3D, and separates video and audio from the 3D, then encodes them, multiplexes them, packages them with ATSC 3.0 signal information at ATSC 3.0 G/W, and finally transmits the modulated RF signal through the transmitter antenna. The reception part demodulates and decodes the received RF signal according to conditions such as RF reception quality and display type, and displays it in mobile 2D, fixed UHD 2D, and fixed UHD 3D. The downsampled right HD video and the left UHD video of an original 3D video are encoded with HEVC. For mobile HD reception, the receiver decodes and displays the received right HD video. In case of UHD reception, the receiver decodes and displays the received left UHD video. For 3D reception, the receiver uses both the right HD and the left UHD videos which it receives. The right HD video is upsampled to the original resolution, and the original 3D stereoscopic video is reconstructed with the left UHD video and the upsampled right UHD video.

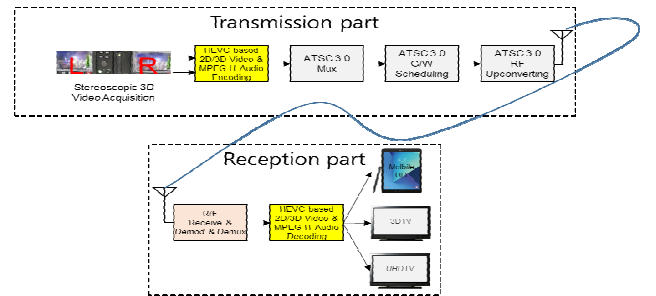


Figure 3. Functional flow of HEVC-based 3D broadcasting testbed system

III. FIELD TEST EXPERIMENT

The ATSC 3.0 compliant head-end system for stereoscopic 3D broadcasting service described in section II was configured as shown in Figure 4 in order to test whether HEVC encoded stereoscopic 3D video transmission and reception was possible in the environment similar to the actual transmission and reception environment with appropriate transmission parameters.

The field test was carried out from the end of June to the first week of July 2022 by mounting a testbed system in the facility of Jeju Techno Park (TP) in Jeju Island as shown in Figure 5. After the original video was extracted and encoded to HEVC stream by the testbed system, that stream was transmitted using a transmitter provided by the Jeju TP for broadcast transmission and reception test. Among the test frequencies/channels held by Jeju TP, channel number 50 with the center-frequency of 689 MHz and the transmission power of about 400 watts was used for field testing through the experimental transmission antenna shown in Figure 6.

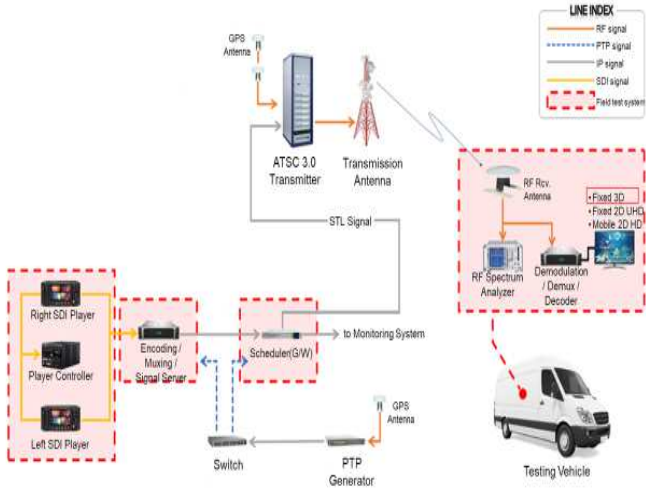


Figure 4. Field test configuration of HEVC-based UHD 3D broadcasting head-end system

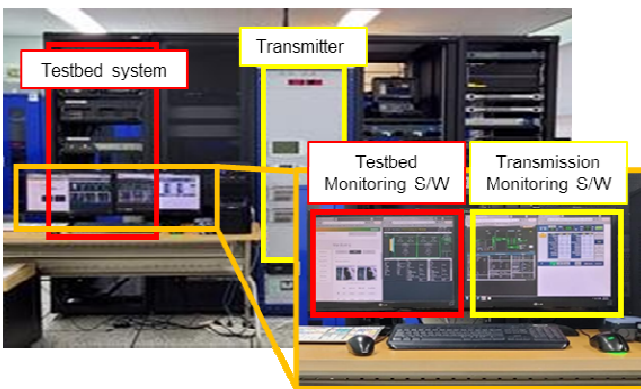


Figure 5. UHD 3D transmission head-end testbed system deployed at transmitter site. The systems in the red box are newly configured testbeds for HEVC-based 2D/3D simulcast field test and the ones in the yellow box that Jeju TP has are the systems for broadcast transmission test purposes. The orange box indicates real-time field test monitoring S/W

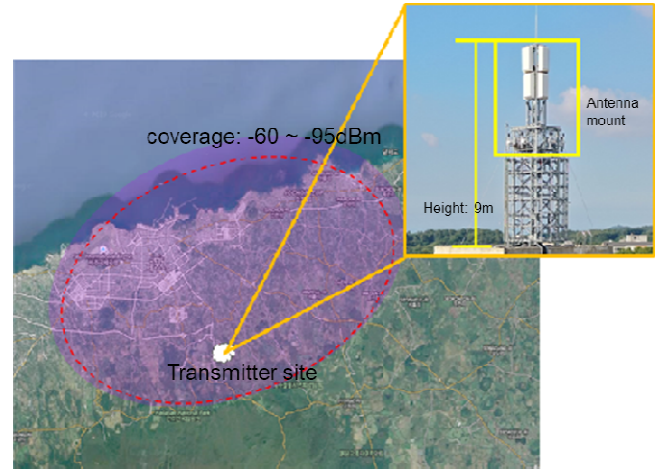


Figure 6. Transmission antenna and reception coverage

TABLE 1. MAJOR FIELD TEST PARAMETERS

	Fixed 3D	
	Mobile 2D	Fixed 2D
System bandwidth	6MHz	
FFT Size	8k	32k
# of OFDM Symbol	64	24
Pilot Pattern	4_2	8_2
PLP Size	384124	611716
FEC Type	BCH + 16k LDPC	BCH + 64k LDPC
Modulation	16QAM	256QAM
Code Rate	7/15	11/15
Transmission Capacity	3.262Mbps	16.691Mbps

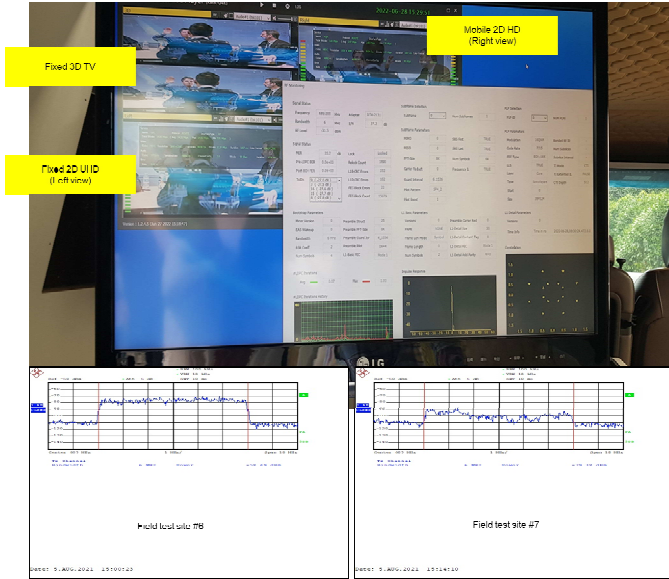
The purpose of the test was to find out whether 3D broadcasting transmission and reception can be serviced in real-time at the several receiving test sites by displaying transmitted 3D on a screen and measuring signal strength at the same time using equipment installed in the receiving test vehicles.

In order to field test the developed system, we encoded video as HEVC and audio as MPEG-H according to the ATSC 3.0 standard, and then packaged the output bitstream as two subframes and two PLPs. The main parameters are shown in Table 1. The location of the field test was selected in the dotted line area with a signal strength of -85 dBm or more among the areas within the reception coverage at the transmission station as shown in Figure 6.

Field tests were conducted using a reference receiver for fixed 3D reception, and were monitored while receiving mobile HD and fixed UHD together to assist reception verification. During the field test, equipment was mounted in the field test vehicle and moved to each reception location. The reception status was monitored and the signal was measured at each location as shown in Figure 7. Figure 7(a) shows moving routes and location for 11 field test sites, and Figure 7(b) is an example of a fixed 3D simulcast field test monitoring screen and some of the received signal spectrum measurements at the fixed test sites.



(a) Fixed 3D reception test sites with moving routes



(b) Monitoring screen and RF spectrum measurement results of fixed 3D broadcasting field test

Figure 7. Field test sites and reception signal parameter measurements

TABLE 2. FIXED 3D RECEPTION RESULTS: OUTDOOR ROOFTOP

Test site #	1	2	3	4	5	6
Rx Power (dBm)	-24.90	-82.30	-63.19	-72.96	-72.14	-58.49

Test site #	7	8	9	10	11
Rx Power (dBm)	-79.38	-64.74	-54.19	-58.71	-29.46

The success of 3D reception in ATSC 3.0 HEVC-based 2D/3D simultaneous service test environment, which is the objective of this paper, was verified by measuring the received signal strength of 11 fixed 3D reception sites measured with a

reference receiver. The results are shown in Table 2. Success of each fixed reception measurement in the analysis was based on whether 3D media can be received, which was the purpose of the field test, and a positive judgment can be made based on -85 dBm, which is acceptable ToV(Threshold of Visibility) of the receiver. According to the criteria, all 11 reception points were judged to have good 3D reception.

IV. CONCLUSIONS

This paper constructed a testbed system capable of 3D simultaneous broadcasting service with ATSC 3.0 standard using HEVC-based image encoding technique and introduced a successful use case by performing the world's first 2D/3D simultaneous broadcasting field test. Field testing of other methods to provide more efficient 3D broadcasting services, such as SHVC-based encoding techniques, and further standardization and development of more efficient encoding techniques than SHVC are also in progress. Based on the success of this field test, the world's first ATSC 3.0 2D/3D pilot broadcasting will start in 2023 with two broadcasting companies in Busan. It is expected to contribute to popularizing immersive contents such as 3D and VR and to expand the base of next-generation media services.

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YeonJun Choi received the B.S., M.S. degrees in computer science from Pusan National University, Busan, South Korea, in 1996, 1998, respectively, the Ph.D. degree from Chungnam National University, Daejeon, South Korea, in 2020. Since 2001, she has been a Principal Researcher at the Electronics and Telecommunications Research Institute (ETRI), South Korea. Her research interests include big data processing, VR/AR and 3DTV broadcasting systems.



Sung-Hoon Kim received his B.S., M.E., and Ph.D. degrees in electronics engineering from Kookmin University in Seoul, KOREA in 1994, 1996 and 2008, respectively. Since 2000, he has been a Principal Researcher at the Electronics and Telecommunications Research Institute (ETRI) in Korea. His research interests are digital signal processing in the fields of Terrestrial & Mobile DTV, 3DTV, VR and UHD TV broadcasting systems



HongKyw Choi received his B.S., M.E. degrees in Electrical and Electronics Engineering from Korea Maritime & Ocean University in Busan KOREA in 2007, 2009 and Ph.D. degrees in Advanced device technology from University of Science and Technology in Daejeon, KOREA in 2014. Since 2014, he has been a Senior Researcher at the Electronics and Telecommunications Research Institute (ETRI) in Korea. His research interests are van der Waals materials, sensors, 3D, and video composition.



Seongwon Jung received the B.S. degree in computer information and communication engineering from Kyungnam University, Changwon, South Korea, in 2020, and the M.S. degrees in computer engineering from Dong-A University, Busan, South Korea, in 2022. In 2022, he joined the Intelligent Convergence Research Lab, the Electronics and Telecommunications Research Institute (ETRI), Busan, where he is currently a Researcher. His research interests include image/video computing systems, video compression, real-time processing, and deep learning-based image processing.