



Testing and Evaluation Report: TV 3.0 Project - Audio Coding

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Brazilian Digital Terrestrial Television System Forum

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1 Introduction

The SBTVD Forum was created by the Brazilian Presidential Decree # 5 820 / 2006, to advise the Brazilian Government regarding policies and technical issues related to the approval of technical innovations, specifications, development, and implementation of the Brazilian Digital Terrestrial Television System (SBTVD). The SBTVD Forum is composed of representatives of the broadcasting, academia, transmission, reception, and software industry sectors, and has the participation of Brazilian Government representatives as non-voting members.

Free-to-air terrestrial television is the main audiovisual distribution platform in Brazil, covering almost all Brazilian households and used in more than 70% of them. It secures to most of the Brazilian population a free-of-charge, universal and democratic access to information and entertainment, made by Brazilians for Brazilians. It is, therefore, an important social cohesion, national, and cultural identity factor.

For its first generation Digital Terrestrial Television system, after thorough testing and careful studies, the Brazilian Government adopted in June 2006 the ISDB-T standard, incorporating technological innovations that were deemed relevant, such as MPEG-4 AVC (H.264) video coding, MPEG-4 AAC audio coding, an appropriate closed caption character set for the Brazilian Portuguese, and a new middleware for interactive applications (Ginga).

The SBTVD Forum developed the first SBTVD standards, that were published in 2007, allowing the official opening of transmissions in that same year. Since then, the standards have been continuously revised and updated by the Forum. The technological innovations proposed by Brazil were incorporated into the International ISDB-T standard, which is currently adopted by 20 countries.

In 2016, Brazil started a safe and gradual analog TV switch-off process, that was designed to assure that no one would be deprived of the terrestrial free-to-air TV. The process was divided into two stages: in the first stage (2016 to 2019) the analog television switch-off was performed in all the state capitals, metropolitan areas, and other areas where it was required to release the 700 MHz band; on the second stage (up to 2023) the analog television switch-off would be performed in the remaining of the country. During the first stage, 1 362 cities in 47 different clusters were impacted, accounting for nearly 128 million people (62% of the population). More than 12 million Digital TV reception kits were distributed for low-income families. The analog switch-off had no significant impact on the free-to-air terrestrial TV audience. Regarding the second stage, the remaining 38% of the population (more than 79 million people) is distributed in 4 208 cities. After the implementation of Digital Terrestrial Television Brazil adopted an industrial policy that determined that all flat-panel TVs manufactured from 2012 must have an integrated Digital TV receiver and from 2013 no more CRT TVs were manufactured. Therefore, it is anticipated, based on the expected product lifetimes, that by 2023 Brazil would have nearly all its TV sets already equipped with an integrated Digital TV receiver, thus facilitating the analog television switch-off without additional Digital TV reception kits distribution.

As the Brazilian digital television switch-over began, the SBTVD Forum started considering the next steps for the evolution of the Brazilian Television. The analog TV (that we conventionally call "TV 1.0"), which started in Brazil in 1950, was black and white with monophonic sound. Then, some backward-compatible improvements (that we conventionally call "TV 1.5"), such as color (in the 1970s), stereo sound and closed caption (in the 1980s) were added to it. From 2007, the first generation of Digital Terrestrial Television (that we conventionally call "TV 2.0") was introduced in Brazil, bringing high-definition video, surround sound, mobile reception, and interactivity. Since then, the technological landscape has changed a lot. The rhythm of development and introduction of innovations is increasingly accelerated. These innovations create new consumption habits and increase the expectations of technological services users regarding the quality and convenience of these services. Since the introduction of SBTVD, new immersive audio and video formats have emerged, and are already present in the new TV sets available in the market. The TV sets currently available have resolution and contrast greater than those supported in the first generation SBTVD standard. That is the opposite of the market situation when Digital TV was launched in Brazil, as the HDTV sets offer was very low. The availability and the speed of Internet access in Brazil, especially in metropolitan areas, increased significantly, enabling the consumption of on-demand audiovisual content. This connectivity is already in use by TV sets (Smart TVs) and by broadcasters' Over-The-Top (OTT) offers. However, in the first generation SBTVD standard, there was not an integration between the broadcasting service and the Internet content offer. Furthermore, new techniques for signal coding, transport, and modulation were also developed, allowing greater efficiency in audiovisual transmission. Many Digital Terrestrial Television systems have also been evolving, including in this evolution not only enhancements in quality and efficiency but also new convergent services between the broadcasting and the Internet. Based on this technological landscape, the SBTVD Forum recognized the necessity to evolve the SBTVD. It also acknowledged that changing the physical layer, the transport layer, and/or audiovisual coding would not be backward-compatible. Nevertheless, the transition to a new generation of Digital Terrestrial Television is a long process, based on the investments required for both broadcasters and consumers and the expected life span of TV transmitters and receivers. It was, therefore, deemed necessary to increase the life span of the existing Digital Terrestrial Television system as much as possible through a backward-compatible evolution (a project we called "TV 2.5") and to start the development of the next generation Digital Terrestrial Television system (the project we called "TV 3.0").

The "TV 2.5" project comprised two aspects: broadcast-broadband integration and audiovisual quality. The first aspect involved the development of a new receiver profile for the middleware Ginga (receiver profile D, a.k.a. "DTV Play"), addressing use cases such as on-demand video, synchronized companion device, audiovisual enhancement over the Internet, and targeted content. The second aspect was addressed through the introduction of three new optional immersive audio codecs (MPEG-H Audio, E-AC-3 JOC, and AC-4) while retaining MPEG-4 AAC main audio for backward-compatibility, and through the introduction of two new optional HDR video formats (SL-HDR1 dynamic metadata and HLG "preferred transfer characteristics" signaling) while keeping MPEG-4 AVC (H.264) / 8-bit / BT.709 / 1080i for backward-compatibility. The revision of the SBTVD standards containing both "TV 2.5" aspects has already been published (available at <https://forumsbtvd.org.br/legislacao-e-normas-tecnicas/normas-tecnicas-da-tv-digital/english/>).

For the "TV 3.0" project, the SBTVD Forum, after agreeing on its requirements (use cases and corresponding technical specifications), decided to release a Call for Proposals (available at <https://forumsbtvd.org.br/wp-content/uploads/2020/07/SBTVDTV-3-0-CfP.pdf>) for any interested organization to submit its proposed candidate technologies for any of the system components or sub-components. The new system is expected to start operating in the next few years, but based on the Brazilian experience on the transition from analog to digital television, the complete transition from the current SBTVD to the TV 3.0 is expected to last at least 15+ years.

As described in the aforementioned Call for Proposals document, the response to the Call for Proposals was divided into two phases.

Phase 1 responses comprised the identification of each proposed candidate technology and appropriate contact persons and filling the compliance form of the components or sub-components corresponding to the proposed candidate technology.

Phase 2 responses comprised providing the full specification of the proposed candidate technology, adhering to the SBTVD Forum Intellectual Property Rights Policy, and the additional requirements considering general information and resources needed for evaluating and comparing the proposed candidate technologies. The “TV 3.0 CfP Phase 2 / Testing and Evaluation” document (available at https://forumsbtvd.org.br/wp-content/uploads/2021/03/SBTVD-TV_3_0-P2_TE_2021-03-15.pdf) provides further information on Phase 2, along with the test procedures for evaluating and comparing the proposals of candidate technologies.

The Call for Proposals was open from 17 July 2020 to 30 November 2020. It received in total, considering its 6 system components (Over-the-air Physical Layer, Transport Layer, Video Coding, Audio Coding, Captions, and Application Coding), 36 responses from 21 different organizations worldwide. Some similar proposals were merged for the sake of Phase 2 testing and evaluation, resulting in 30 candidate technologies.

The tests were funded by the Brazilian Ministry of Communications through the Brazilian National Council for Scientific and Technological Development (CNPq, *Conselho Nacional de Desenvolvimento Científico e Tecnológico*). The Audio Coding candidate technologies have been tested by the University of São Paulo from 05 July 2021 to 03 December 2021. This document contains the results of the tests to support, alongside the market and intellectual property evaluations, the SBTVD Forum in recommending the appropriate technologies for the next generation of digital terrestrial television in Brazil.

It is important to highlight that, in this process, the SBTVD Forum has a propositional role, with the Brazilian Government alone being responsible for making any decisions about the standards applicable to broadcasting service in Brazil.

2 Research Team

This Audio Coding report was prepared by the USP Test Lab team, which comprises the Laboratory of Audio and Music Technology (LATM) of the School of Arts, Sciences and Humanities (EACH) and the Laboratory of Art, Media and Digital Technologies (LabArteMídia) of the School of Communications and Arts (ECA) both of the University of São Paulo (USP), under the coordination of Prof. Dr. Regis Rossi Alves Faria (LATM) and Prof. Dr. Almir Antonio Rosa [Almir Almas] (LabArteMídia). The team of collaborators of LATM/LabArteMídia, participating in this project are listed below, with links to their curricula at the Lattes platform/Brazil.

Regis Rossi A. Faria, PhD in Electrical Engineering - <http://lattes.cnpq.br/9990463602315076>

Almir Antonio Rosa [Almir Almas], PhD in Communication and Semiotics - <http://lattes.cnpq.br/9279970444599822>

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We also had the collaboration of the SBTVD Forum members, in particular:

Luiz Fausto – Chair, Technical Module, SBTVD Forum

Carlos Cosme – Chair, Audio & Video Coding Workgroup, SBTVD Forum

3 Glossary

2.0	stereo (two full-bandwidth channels) sound
3D	Three-Dimensional
3DoF	Three Degrees of Freedom
5.1	surround (five full-bandwidth channels and one low-frequency effects channel) sound
5.1 + 4H	3D (five full-bandwidth channels, one low-frequency effects channel, and four overhead channels) sound
6DoF	Six Degrees of Freedom
A/V	Audio / Video
ADM	Audio Definition Model (as defined in the Recommendation ITU-R BS.2076-2)
API	Application Programming Interface
AR	Augmented Reality
BW64	Broadcast Wave 64-bit

DTH	Direct-To-Home
DTT	Digital Terrestrial Television
HDMI	High-Definition Multimedia Interface
HLG	Hybrid Log-Gamma
HOA	Higher-Order Ambisonics
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IPTV	Internet Protocol Television
ISDB-T	Integrated Services Digital Broadcasting-Terrestrial
ITU	International Telecommunications Union
MOS	Mean Opinion Score
MUSHRA	MULTiple Stimuli with Hidden Reference and Anchor
OTT	Over-the-top (internet delivery)
RF	Radio Frequency
RF64	RIFF/WAVE Format 64-bit
SBTVD	<i>Sistema Brasileiro de Televisão Digital</i> (Brazilian Digital Television System)
SDI	Serial Digital Interface
SDO	Standards Developing Organization
SDR	Standard Dynamic Range
STB	Set-Top Box

VR Virtual Reality

XR eXtended Reality

4 TV 3.0 Architecture

The TV 3.0 system components described in this document reflect the reference TV 3.0 architecture, as depicted in Figure 1.

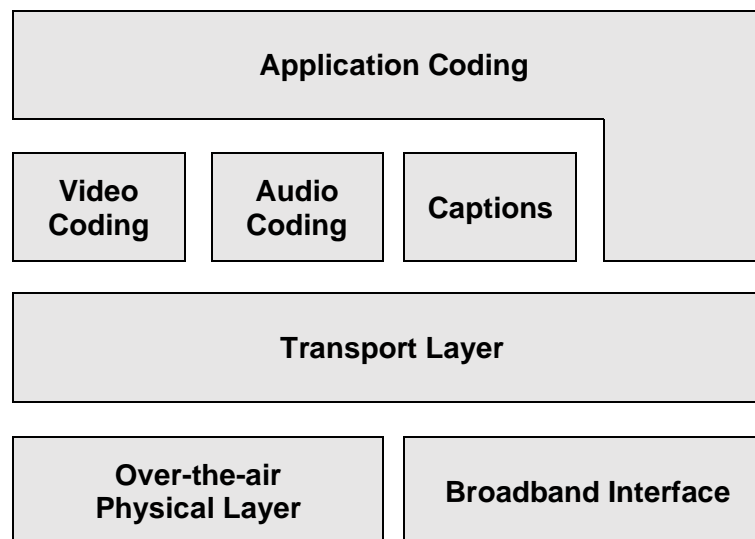


Figure 1: TV 3.0 Architecture.

For further information about TV 3.0 architecture, please refer to the TV 3.0 Call for Proposals document.

5 TV 3.0 Testing and Evaluation

Please refer to Section 4 of the “TV 3.0 CfP Phase 2 / Testing and Evaluation” document (available at https://forumsbtvd.org.br/wp-content/uploads/2021/03/SBTVD-TV_3_0-P2_TE_2021-03-15.pdf) for further information on the testing and evaluation procedures.

6 Testing and Evaluation Results

The following sections present the results of the tests executed in the laboratory and of the analysis of the documents submitted by the proponents. Additionally, it may include information of the phase of equipment reception, test setups and procedures, results data collection and processing, relevant observations taken during the tests, and final considerations from the laboratory.

The equipments described in the table below were made available by “Rede Globo de Televisão”. These equipments served as "support" for the lab testing team, to ensure that the workflow determined by the call was answered equally for all proponents and also for video recording of the performed tests.

Table 1 - Equipment from Rede Globo.

Equipment Globo		brand	model	delivery date
item	quantity			
1	1	Dell	Workstation Precision T3610	29/07/2021
2	1	Samsung	TV UN50RU7100G	29/07/2021
3	1	Blackmagic	Content Payout Hyperdeck Extreme	29/07/2021
4	1	Tektronix	Signal generator TG700	29/07/2021
5	1	Blackmagic	Smart VideoHub CleanSwitch 12x12	29/07/2021
6	1	TP-link	Ethernet switch TL-SG1024D	29/07/2021
7	1	GoPro	camera Hero 5 black	29/07/2021

The Department of Cinema, Radio and Television of the University of São Paulo, CTR/USP, also contributed with equipment and installations for carrying out the tests. In the table below, these complementary materials are described.

Table 2 - Equipment from USP.

Equipment CTR/USP		brand	model
item	quantity		
1	3	GoPro	camera GoPro 3
2	1	Apple	MacBook Pro
3	1	-	reader USB to SSD Hard Disk
4	2	-	room labs
5	-	-	furniture
6	-	-	miscellany of cables, adapters, etc

6.1 Identification of the candidate technologies

Throughout this report the candidate technologies are referred to by letters from "A" to "C". The real names of the candidate technologies cannot be publicly disclosed as this was not authorized by all proponents.

6.2 Candidate Technology A

6.2.1 Documentation Analysis

The documentation analysis consists in verifying whether the requirements set by the SBTVD CfP were met by the Candidate Technology A. For that, the following main documents provided by the proponent were used:

1. Candidate Technology A Instructions for SBTVD TV 3.0 Test (v.1.01 of 2 July 2021)
2. Candidate Technology A Proposal for SBTVD TV 3.0 Audio System Component, PHASE 2 RESPONSE – SPECIFICATION AND TECHNICAL INFORMATION (21 July 2021, 32pp.)
3. ATSC 3.0 Audio Testing Report, Doc. S34-2B-048r7 12 August 2015 FINAL
4. Listening Test Evaluation of Candidate Technology A (June 2016), issued by Aalto University (Finland), SVT AB and Norconsult AB (Sweden)
5. Proposal for ATSC 3.0 Audio System, Audio System Detailed Proposal, prepared by the proponents of Candidate Technology A

Besides these main documents, we also considered the following documents as complimentary to support the analysis: "Candidate Technology A Market Module Additional Information" (June 2021); and the corresponding ATSC Standards. Additionally, it was considered a letter from the proponent (file "Proposal for SBTVD TV 3.0 Subjective quality assessment reports.pdf") with information on listening (subjective quality) tests conducted by Aalto University (Finland) and the Swedish broadcaster SVT.

In item 6.2.1.1, which refers to "Subjective quality assessment reports", the documentation analysis of the requirement AC8.1 (audio coding efficiency) is presented. According to the SBTVD CfP, for the evaluation of the proponent's audio system, this analysis should preferably rely on technical reports of internationally recognized standardization organizations. Thus, the main considered source were the results from the Advanced Television Systems Committee (ATSC) Audio Testing Report (document 3 listed above; see item 6.2.1.1.1). However, reports from independent test labs or proponent's test labs could be submitted. The USP test lab considered that such independent reports could support the analysis, if detected a recognized methodology and attested accreditation on the issuer.

According to the CfP, the requirement AC9.2 (end-to-end latency) is addressed by analysing the documentation provided by the proponent. The information that could be retrieved about the delay chain (e.g. each module delay, audio and video encoding delay, additional video buffering (if any) before the video encoder, audio decoding and rendering delay, transcoding to a different format delay, and final decoding delay in the external sound reproduction system) is presented below in the respective note referring to AC9.2.

Following, the notes mentioned in item 6.2.1.2 (Summary of Documentation Analysis), are presented.

Note 1: The general requirement GT3 was met according to a message sent by email from the proponents of Candidate Technology A, on July 2 2021.

Note 2: The general requirement GT4 was met according to a message sent by email from the proponents of Candidate Technology A, on July 2 2021.

Note 3: The general requirement GI3 was met according to a message sent by email from the proponents of Candidate Technology A, on June 25 2021.

Note 4 - According to the proponent documentation, the requirements AC1.1.1, AC1.1.2 and AC1.1.3 were fulfilled (see p.52 of document 1, cited above).

Note 5: According to the proponent documentation, the requirements AC1.2 and AC 1.3 were fulfilled (see pp.52-53 of document 1, cited above).

Note 6: According to the proponent documentation, the requirement AC2.1 was fulfilled (see p.53 of document 1, cited above).

Note 7: According to the proponent documentation, the requirement AC2.2 was fulfilled (see pp.58-59 of document 1, cited above).

Note 8: The requirement AC2.3 was fulfilled according to the proponent documentation (see document 2, p. 17, session 4.2.6 AC2.3 – Adjust object position (Q #169) .

Note 9: According to the proponent documentation, the requirement AC2.4 was fulfilled (see p.59 of document 1, cited above).

Note 10: According to the proponent documentation, the requirements AC3.1 and AC3.2 were fulfilled (see p.60 of document 1, cited above).

Note 11: According to the proponent documentation, the requirement AC3.3 was fulfilled (see pp.61-62 of document 1, cited above).

Note 12: According to the proponent's document 2 (cited above) in item "4.1 Response Summary" (p.10), the requirement AC4.1 is fulfilled, as "audible emergency warning information is one of the standardized content classifiers that can be signaled in an audio stream, as described in the corresponding ETSI Standards. Candidate Technology A implements Emergency warning information delivery using audio description, and the way it is implemented is described in the corresponding ATSC Standard.

Note 13: According to the proponent documentation, the requirements AC5.1 and AC5.2 were fulfilled (see p.63 of document 1, cited above).

Note 14: According to the proponent documentation, the requirement AC6.1 was fulfilled (see p.65 of document 1, cited above).

Note 15: According to the proponent documentation, the requirement AC6.2 was fulfilled (see pp.65-66 of document 1, cited above).

Note 16: According to the proponent documentation, the requirement AC7.1 was fulfilled (see p.67 of document 1, cited above).

Note 17: According to the proponent documentation, the requirement AC7.2 was fulfilled (see p.68 of document 1, cited above).

Note 18: According to the proponent documentation, the requirement AC7.3 was fulfilled (see p.69 of document 1, cited above).

Note 19: According to the proponent documentation, the requirement AC7.4 was fulfilled (see pp.71-73 of document 1, cited above).

Note 20: According to the proponent documentation, for the verification of the requirement AC8.1 (audio coding efficiency) for all formats and bitrates of interest it was used the ATSC report (document 3, cited above) as a basis (see item 6.2.1.1). For further details, please refer to the item 6.2.1.1 (Subjective quality assessment reports).

Note 21: The proponent informs at session titled "Test 9 (Audio end to end latency)" (p.73), in document 1 cited above, that the system met the requirement AC9.1. Concerning the requirement AC9.2 (end-to-end latency), in the document 2, cited above, at the section 4.2.22 (p.23), the proponent states that the decoder latency is lower than 50ms at most. For the encoder, it is stated that "the lowest possible algorithmic encoder latency, not using all coding tools, ranges from 36 to 45 ms, depending on frame rate". Considering "look ahead" present, it is informed that "presently deployed emission encoders have latencies ranging from 760 ms to 876 ms of which most is used for dialog classifications in legacy content". They inform that the lowest encoder latency can be achieved using "deployed Candidate Technology A encoders" using their higher bitrate distribution mode "which has a lower latency of 6-7 frames, resulting in a latency of 240ms or lower".

At section 4.1 Response Summary, "Table 1: Summary of SBTVD Forum Audio Coding Requirements and responses" (document 2, p.9) the proponent informs that the "Theoretical Encode/Decode Algorithmic Latency, frame rate dependent" is in the range 67–95 ms, and that the Emission Low Latency is "760–876 ms <240 ms".

From these figures, it can be calculated that the maximum [encoder]+[decoder] delay is (50ms + 876ms =) 926ms. The overall end-to-end latency can only be assessed approximated from the "Figure 8: Sources of End-to-end Latency" (p.23 of the document 2) to be ~9000 ms, which leaves ~8074ms due to multiplexing (DASH) packaging, network de-jittering, and a small amount due to system audio post-processing (neither informed nor evaluable visually from the figure). For convenience, the following figure shows a reproduction of the Figure 8 of document 2 cited above.

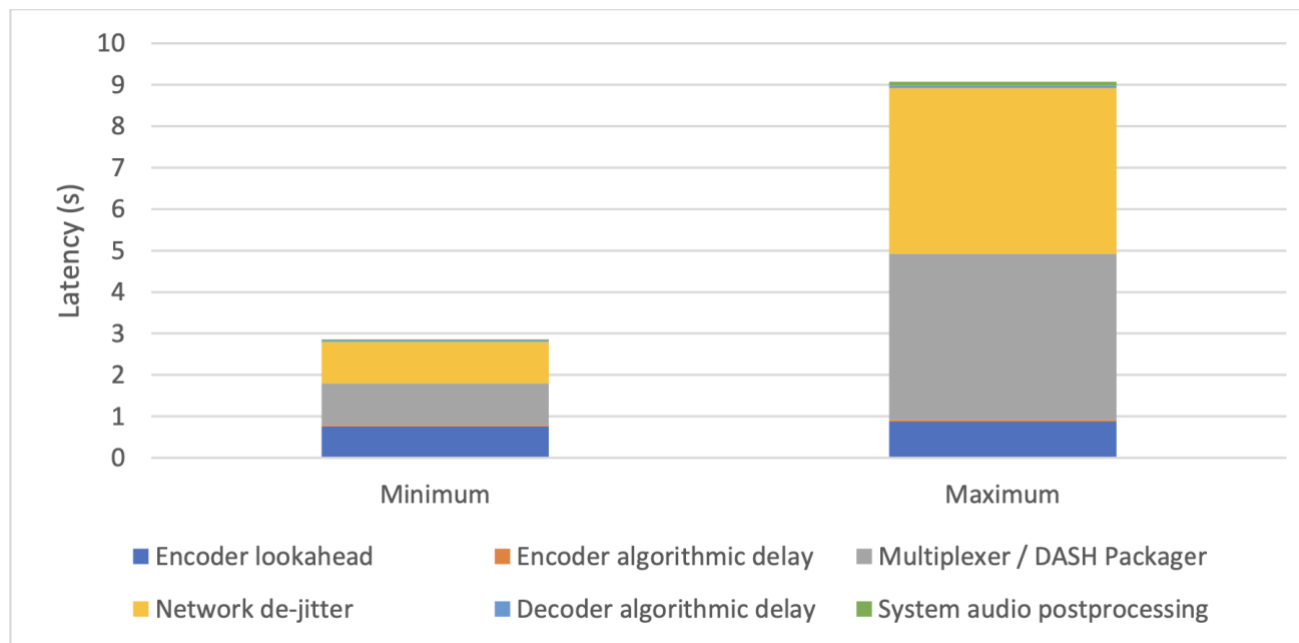


Figure 8: Sources of End-to-end Latency

Therefore, the overall delay stack comprised of $[\text{encoder}]^{\text{max.}876\text{ms}} + [\text{mux packaging} + \text{network de-jitter}] + [\text{decoder}]^{\text{max.}50\text{ms}}$ amounts to ~9000 ms.

Note 22: According to the proponent documentation, the requirement AC10.1 was fulfilled (see p.74 of document 1, cited above).

Note 23: The requirement AC11.1 (enable new immersive audio services) was not tested by the proponent; however, according to the documentation, the development stage of this requirement is considered “Possible, Subject to Industry Demand” (see p.78 of document 1, cited above).

Note 24: The requirement AC12.1 was not tested by the proponent; however, according to the documentation, the development stage of this requirement was considered “Commercially Deployed” (see p.78 of document 1, cited above).

Note 25: The requirement AC13.1 was not tested by the proponent; however, according to the documentation, the development stage of this requirement was considered “Commercially Deployed” (see p.78, of document 1, cited above).

Note 26: The requirement AC13.2 was not tested by the proponent; however, according to the documentation, the development stage of this requirement was considered “Commercially Deployed” (see p.78, of document 1, cited above).

Note 27: The additional requirement AC-AR3 was met according to the proponent document 2, cited above, in section “implementations” (see p.26 of document 2, cited above).

Note 28: The additional requirement AC-AR4 was met according to the proponent document 2, cited above, in section “implementations” (see p.26 of document 2, cited above).

Note 29: The additional requirement AC-AR5 was met according to the proponent document 2, cited above, in section “implementations” (see p.26 of document 2, cited above).

6.2.1.1 Subjective quality assessment reports

This section compiles information about the proponent's technology audio coding efficiency as retrieved from quality assessment reports provided by the proponent. The analysis of audio coding efficiency is referred to in Test 8, and addresses the requirement AC8.1 (audio coding efficiency), which is to be assessed from the aforementioned reports.

Two main sources of information were processed to assess known performance metrics of the proponent's technology coding efficiency in terms of subjective quality:

1. an official independent report released by ATSC¹ (document 1 listed in 6.2.1),
2. a listening test report produced by the Aalto University (Finland) and by the Swedish broadcaster SVT (document 4 listed in 6.2.1)

Additionally, it was considered helpful a letter from the proponent (file "Proposal for SBTVD TV 3.0 Subjective quality assessment reports.pdf") summarizing the results (mean scores values) obtained by the listening tests of document 4. The following subsections present the results of both studies above.

6.2.1.1.1 ATSC 3.0 Audio Testing Report

In august 2015, the ATSC (Advanced Television Systems Committee) issued a test report summarizing the results of a subjective listening test and feature evaluations of proposed audio systems for the ATSC 3.0 audio system. The Candidate Technology A was evaluated in it. A letter from ATSC to SBTVD Forum (dated 28 June 2021) states that Candidate Technology A satisfied all the requirements for the ATSC 3.0, which means that it achieved (in a Precertification phase of the ATSC test) a consistent BS.1116-3 score ≥ 4.0 for the following formats@bitrates: 2.0@96kbps; 5.1@192kbps; and 7.1+4H@288kbps. The ATSC report, however, did not specify minimum level requirements for MUSHRA² scoring.

¹ Advanced Television Systems Committee, "ATSC 3.0 Audio Testing Report, Doc. S34-2B-048r7", Washington, USA, August 2015.

² International Telecommunications Union, ITU-R Rec. BS.1534-2 "Method for the Subjective Assessment of Intermediate Sound Quality (MUSHRA)", Geneva, Switzerland.

The following table summarizes the results of the ATSC report, considered here as the main reference, showing the scores obtained by Candidate Technology A at two different test laboratories³. The table covers the audio formats of interest for SBTVD 3.0 CfP⁴, and shows in red the score values that do not meet a MUSHRA score > 80 ("excellent" grade).

Table 3 - ATSC3.0 report scores for Candidate Technology A. Results include metrics for mandatory loudspeaker formats specified in the CfP: 2.0, 5.1 and 5.1+4H (here approximated by the result obtained for the format 7.1+4H evaluated in the ATSC).

Audio format	Bitrates	Lab A	Lab B
		MUSHRA	MUSHRA
2.0	32	77.20	54.80
2.0	48	-	-
2.0	64	81.70	68.70
2.0	80	-	-
2.0	96	88.80	83.80
5.1	80	75.20	63.50
5.1	128	-	-
5.1	96	-	-
5.1	144	82.10	70.10
5.1	180	-	-
5.1	208	92.20	84.50
7.1+4H	144	86.70	63.80
7.1+4H	256	87.20	77.60
7.1+4H	384	88.80	85.00
7.1+4H	512	-	-
7.1+4H	768	-	-

Although for a single score value the fulfillment requirement set in the SBTVD CfP is clear in meeting a MUSHRA score > 80 ("excellent" grade) or a MOS score > 4, as a multiple scores totalization criterium was not defined to verify how the codec would meet the SBTVD AC8.1 requirement for all the formats and bitrates, this survey is only informative of the retrieved metrics from the documents.

³ Test Lab A is "Brannan A," and Test Lab B is "Mozart."

⁴ Lines with no information refer to bitrates not evaluated in the respective tests nor specified in the report.

6.2.1.1.2 Analysis combining ATSC 3.0 report and Aalto University listening tests

Although not issued by an International Organization, the listening tests conducted by the Aalto University of Finland meets the best requirements for such tests, employing a clear and well documented procedure, founded in the expected standards such as the MUSHRA methodology (ITU-R BS.1534-3 Method for the subjective assessment of intermediate quality level of audio systems), using a fine set of materials (such as high quality loudspeakers) and an adequate listening room (stated as adherent to ITU-R BS.1116-1 recommendations). Therefore, in spite of the fact that the study has collected data based on only 10 participants, we considered the results of this study relevant for the analysis of Candidate Technology A audio efficiency.

All values obtained for Candidate Technology A in the study conducted at Lab C are greater than 80.00 (in the excellent level).

The following table summarizes the scores obtained for Candidate Technology A in both listening tests: ATSC 3.0 (which includes Lab A and Lab B) and Aalto University listening tests (Lab C). The table covers the audio formats of interest for SBTVD 3.0 CfP⁵, and shows in red the score values that do not meet a MUSHRA score > 80 ("excellent" grade).

Table 4 - Combined scores obtained for Candidate Technology A based on the ATSC 3.0 report and the Aalto University listening tests report.

Audio format	Bitrates	Lab A	Lab B	LAB C
		MUSHRA	MUSHRA	MUSHRA
2.0	32	77.20	54.80	-
2.0	48	-	-	80.33
2.0	64	81.70	68.70	91.62
2.0	80	-	-	-
2.0	96	88.80	83.80	96.22
5.1	80	75.20	63.50	-
5.1	96	-	-	86.13
5.1	128	-	-	-
5.1	144	82.10	70.10	96.33
5.1	180	-	-	-
5.1	208	92.20	84.50	-
7.1+4H	144	86.70	63.80	82.57
7.1+4H	256	87.20	77.60	90.24
7.1+4H	384	88.80	85.00	93.72
7.1+4H	512	-	-	-

⁵ Lines with no information refer to bitrates not evaluated in the respective tests nor specified in the report.

Audio format	Bitrates	Lab A	Lab B	LAB C
		MUSHRA	MUSHRA	MUSHRA
7.1+4H	768	-	-	-

We would like to point out that the report from Aalto University included the MPEG AAC-LC profile as a comparative anchor in the subjective tests for stereo (2.0) format. The study found that AAC-LC at 128kbps scored higher than the Candidate Technology A codec at its highest bitrate (96kbps): the mean score obtained for Candidate Technology A for 2.0@96kbps was 96.22, and AAC-LC for 2.0@128kbps scored 98.58. However, it should be noted that the codecs were not confronted at the same bitrate, and the choice of 128kbps for AAC-LC most likely explains this prevalent result. Another result from the Aalto University listening tests included the AC-3 5.1 codec as a comparative anchor to Candidate Technology A in the subjective tests for surround (5.1) format, showing that AC-3 at 394kbps achieved practically the same performance as Candidate Technology A at 192kbps (differences statistically not-significant), that is, Candidate Technology A performs equally to AC-3 with half the bitrate used by this. It was verified that all Lab C results scored higher than the values obtained in the ATSC test. In a speculative conjecture, if the listening tests in the three test sites had been conducted with the same test content, as part of the same test procedure, and normalized accordingly, the actual values would point to an average with higher scores for the codec for all the bitrates@formats. However, only the actual values, withdrawn from the independent test reports, were informed in the table.

Again, although for a single score vale the fulfillment requirement set in the SBTVD CfP is clear in meeting a MUSHRA score > 80 ("excellent" grade) or a MOS score > 4, as a multiple scores totalization criterium was not defined to verify how the codec would meet the SBTVD AC8.1 requirement for all the formats and bitrates, this survey is only informative of the retrieved metrics from the documents.

6.2.2 Summary of Documentation Analysis

Below is the summary of documentation analysis for Candidate Technology A.

general requirements		fulfillment
GT3	All technical proposals shall be fully specified, preferably in technical standards of internationally recognized SDOs.	fulfilled [NOTE 1: see 6.2.1]
GT4	The full specification of the technical proposal shall be made available for the SBTVD Forum free of charge.	fulfilled [NOTE 2: see6.2.1]
GI3	All technical proposals licensing or any other form of commercialization shall adhere to fair, reasonable, and non-discriminatory terms, as specified in the SBTVD Forum Intellectual Property Rights Policy (see the TV 3.0 Call for Proposals document, Annex A).	fulfilled [NOTE 3: see 6.2.1]

use case		minimum technical specification			fulfillment
AC1	Enable immersive (3D) audio.	AC1.1.1	channel-based	2.0	fulfilled NOTE 4: see 6.2.1]
		AC1.1.2		5.1	fulfilled NOTE 4: see 6.2.1]
		AC1.1.3		5.1 + 4H	fulfilled NOTE 4: see 6.2.1]
		AC1.2	object-based		fulfilled NOTE 5: see 6.2.1]
		AC1.3	scene-based (HOA)		fulfilled NOTE 5: see 6.2.1]
AC2	Enable end-user interactivity/personalization when allowed by the broadcaster (e.g. switch among different languages, sports commentators, adjust the commentator loudness level and position).	AC2.1	switch components (audio objects and alternative full mix substreams)		fulfilled [NOTE 6: see 6.2.1]
		AC2.2	adjust object loudness		fulfilled [NOTE 7: see 6.2.1]
		AC2.3	adjust object position		fulfilled [NOTE 8: see 6.2.1]
		AC2.4	enable interactivity when using external sound reproduction devices		fulfilled [NOTE 9: see 6.2.1]
AC3	Enable audio description delivery in the same stream as the main audio, as an alternative full mix or as an additional audio object with associated metadata.	AC3.1	audio description delivery in the same stream as the main audio		fulfilled [NOTE 10: see 6.2.1]
		AC3.2	audio description delivery as an alternative full mix		fulfilled [NOTE 10: see 6.2.1]
		AC3.3	audio description delivery as an additional audio object with associated metadata		fulfilled [NOTE 11: see 6.2.1]
AC4	Enable emergency warning information delivery using audio description.	AC4.1	emergency warning information audio description		fulfilled [NOTE 12: see 6.2.1]
AC5	Enable a single delivery format for multiple audio playback configurations (TV loudspeakers, soundbars, home theaters, binaural).	AC5.1	flexible loudspeaker configuration render		fulfilled [NOTE 13: see 6.2.1]
		AC5.2	binaural render		fulfilled [NOTE 13: see 6.2.1]
AC6	Enable consistent loudness across programs and inside the same program.	AC6.1	consistent loudness across programs		fulfilled [NOTE 14: see 6.2.1]
		AC6.2	consistent loudness after user interaction		fulfilled [NOTE 15: see 6.2.1]

use case		minimum technical specification		fulfillment	
AC7	Enable seamless configuration changes and A/V alignment.	AC7.1	seamless playback during configuration changes (e.g. from 5.1+4H to stereo)		fulfilled [NOTE 16: see 6.2.1]
		AC7.2	seamless playback during user interaction (e.g. enable/disable several audio elements)		fulfilled [NOTE 17: see 6.2.1]
		AC7.3	seamless playback during changes in production (e.g. broadcaster removes one object)		fulfilled [NOTE 18: see 6.2.1]
		AC7.4	seamless and sample-accurate stream splicing or ad-insertion at any time instance, even if some of the streams come from different distribution platforms (e.g. switch between over-the-air and Internet delivery)		fulfilled [NOTE 19: see 6.2.1]
AC8	Provide state-of-the-art coding efficiency, to allow better quality audio in limited capacity channels (over-the-air or Internet).	AC8.1	bit rate	kbps @ MOS 4 / MUSHRA > 80 or equivalent objective metric	technical subjective results provided [NOTE 20: see 6.2.1]
AC9	Provide live audio with minimum end-to-end latency.	AC9.1	real-time encoding		fulfilled [NOTE 21: see 6.2.1]
		AC9.2	latency	ms	technical data provided [NOTE 21: see 6.2.1]
AC10	Provide audio/video synchronization.	AC10.1	A/V sync	frame-accurate	fulfilled [NOTE 22: see 6.2.1]
AC11	Enable new immersive audio services.	AC11.1	VR / AR / XR / 3DoF / 6DoF support		not fulfilled Note 23: see 6.2.1
AC12	Enable interoperability with different distribution platforms (e.g. DTT, cable, IPTV, DTH satellite, fixed broadband, 4G/5G mobile broadband, home network).	AC12.1	interoperability with different distribution platforms		not fulfilled Note 24: see 6.2.1
AC13	Enable scalability (e.g. to enhance the over-the-air audio experience with additional Internet-delivered audio content, such as new sports commentator options) and extensibility (support new settings and/or features in the future, in a backward-compatible way).	AC13.1	scalability		not fulfilled Note 25: see 6.2.1
		AC13.2	extensibility		not fulfilled Note 26: see 6.2.1

additional requirements		fulfillment
AC-AR3	Provide information about available implementations of the encoder and decoder, the latter both for professional (broadcast) and consumer electronic applications.	fulfilled [NOTE 27: see 6.2.1]
AC-AR4	Provide information about available implementations of production tools: authoring and monitoring for live and post-production.	fulfilled [NOTE 28: see 6.2.1]
AC-AR5	Provide some reference information about the decoder for TV sets manufacturing.	fulfilled [NOTE 29: see 6.2.1]

6.2.3 Test Results

Candidate Technology A presented two system setups for executing the test cases required by the SBTVD CfP, according to their test procedures instructions in the document "Instructions for SBTVD TV 3.0 Test v.1.01" of 2 July 2021.

The system setup labeled "Real-time streaming setup" on page 19 does not adhere to the real-time setup specified by the SBTVD Forum as specified in the document "TV 3.0 CfP Phase 2 / Testing and Evaluation". The system setup labeled "Real-time End to End setup" on page 6 adheres to the real-time setup specified by the SBTVD Forum (see figure 42 of SBTVD CfP). However this setup presented problems that could not be solved in time to undergo the mandatory test cases, according to the SBTVD CfP. Additionally, the proponent's setup identified as "File-based setup" on page 24 does not adhere to the non-real-time setup specified by the SBTVD Forum.

The situation with Candidate Technology A converged then as described below.

1. Candidate Technology A mandatory Test Cases setup instructions using "Real-time End to End setup" on page 6 of their documentation were not verified in laboratory tests, as the proponent did not provide a valid setup for them.
2. Candidate Technology A Test Cases setup instructions using "Real-time streaming setup" on page 19 of their documentation and "File-based setup" on page 24 were considered additional tests.
3. The proponent's test procedures instructions document does not contain Tests Cases referring to the Tests Cases TC 4.1, TC 7.4, TC 11.1 and TC12.1 as specified by the SBTVD Forum. These tests were not then verified in the laboratory.
4. The set of additional test cases, as the proponent signaled, was separated into two subsets identified as "ADDITIONAL 1" which should have execution priority over the test cases identified as "ADDITIONAL 2". The additional tests that were executed according to this deliberation are presented in the Appendix II.

To facilitate the evaluation of the proponent technology during the test cases execution, a spreadsheet was developed for each Test Case specified in the SBTVD CfP, by mapping the expected goals in each step of the sequence of test procedures into explicit questions to be answered, standardizing a model for feature analysis.

Test executions were done in rounds, each round consisting in running the test with one of the audio test content items indicated, and then collecting the results. All tests were recorded in HD video quality, for documenting and auditing purposes, as required by the SBTVD CfP. After the data collection, the overall fulfillment evaluation of the expected requirements was done confronting the noted answers to the condition(s) that would lead to the failure of the test. Observations, if any, were also collected to be informed at the final report, complementing the evaluation of the requirements with information on the behavior of the system.

The following table summarizes the equipment and software received by the Test Laboratory on 26/07/2021.

Table 5 - List of equipment and softwares of Candidate Technology A

Equipment		brand	model	delivery date
item	quantity			
1	1	Lawo	Vpro8	26/07/2021
2	1	Dell	Server PowerEdge (Ateme Titan Live)	26/07/2021
3	1	Apple	MacBook Pro	26/07/2021
4	1	Panasonic	TV TX-43HXW904	26/07/2021
5	1	Dektec	Modulator DTU-315	26/07/2021
6	1	Intel	NUC	26/07/2021
7	1	Intel	NUC	26/07/2021
8	1	RME	MADIFace and HDSP	26/07/2021
9	1	Samsung	Cellphone S215G	26/07/2021
10	1	LG	Soundbar SL9YG	26/07/2021
11	1	LG	Subwoofer SPL8-W	26/07/2021
12	1	Linksys	WRT54G2V1	26/07/2021
13	1	knup	computer monitor	26/07/2021
14	1	Onkyo	Home Theater HT-S5910 (5.1+2H)	08/11/2021
15	1	Blackmagic	Content playout UltraStudio 4K Extreme	26/11/2021
16	1	Panasonic	TV TX-43HX940E	29/11/2021

The following subsections address the test cases for Candidate Technology A.

6.2.3.1 Test 1 (Immersive audio)

The requirements AC1.1.1 (TC1.1.1), AC 1.1.2 (TC1.1.2), AC1.1.3 (TC1.1.3), AC1.2 (TC1.1.4) and AC1.3 (TC1.2) were not verified in the laboratory as the proponent's test cases were not possible to run due to problems in the provided setup.

6.2.3.2 Test 2 (Interactivity and personalization)

The requirements AC2.1 (TC2.1, TC2.2, TC2.3, TC2.4), AC2.2 (TC2.5), AC2.3 (TC2.6), and AC2.4 (TC2.7) were not verified in the laboratory as the proponent's test cases were not possible to run due to problems in the provided setup.

6.2.3.3 Test 3 (Audio description)

The requirements AC3.1 and AC3.2 (TC3.1), AC3.3 (TC3.2, TC3.3, TC3.4) were not verified in the laboratory as the proponent's test cases were not possible to run due to problems in the provided setup.

6.2.3.4 Test 4 (Audio emergency warning information)

Not verified (the proponent did not provide a test procedure for test case 4.1 which addresses the requirement AC4.1).

6.2.3.5 Test 5 (Flexible audio playback configuration)

Test 5 comprehends 2 requirements (AC5.1 and AC5.2) verified through the single Test Case 5.1 (TC5.1).

The requirement AC5.1 (Enable a single delivery format for multiple audio playback configurations - flexible loudspeaker configuration render) was not verified in the laboratory as the proponent's test case was not possible to run due to problems in the provided setup.

The requirement AC5.2 (Enable a single delivery format for multiple audio playback configurations - binaural render) was not verified in the laboratory as the proponent did not provide a valid test setup compliant to the required test procedure. The setup for testing binaural rendering was specified according to the "real-time streaming setup on page 25" of the proponent's test instructions documentation, which is not compliant with the required real-time setup as in Figure 42 of the CfP.

6.2.3.6 Test 6 (Consistent loudness)

Not verified, as the proponent did not provide a valid test procedure for test case 6.1, which addresses the requirement AC6.1 (Loudness Normalization Test - Programs), and likewise for test cases 6.2 and 6.3, which address jointly the requirement AC6.2 (Loudness Normalization Test - Preselections and Loudness Compensation Test). The test setup provided did not fulfill the non-real-time encoding requirement, just the decoding part was covered in the test procedures instructions.

6.2.3.7 Test 7 (Seamless configuration changes and A/V alignment)

Test 7 comprehends 4 requirements (AC7.1, AC7.2, AC7.3 and AC7.4) verified through 7 test cases (TC7.1, TC7.2, TC7.3, TC7.4, TC7.5, TC7.6 and TC7.7).

The requirement AC7.1 (Seamless configuration changes) and the requirement AC7.2 (Seamless content playback during user interaction) were not verified as the proponent's Test Case 7.1 and 7.2, respectively, were not possible to run due to problems in the provided setup.

The requirement AC7.3 Part 1 (Seamless content playback during changes in production) was not verified as the proponent's Test Case 7.3 was not possible to run due to problems in the provided setup. The requirement AC7.3 Part 2 (Seamless content playback during changes in production using a contribution feed) was not verified as the proponent did not provide a test procedure for the Test Case 7.4. Therefore, the requirement AC7.3 was not verified due to lack of a test procedure.

The requirement AC7.4 Part 1 (Seamless Ad-Insertion) was not verified as the proponent's Test Case 7.5 was not possible to run due to problems in the provided setup. The requirement AC7.4 Part 2 (User selection persistency after the Ad-break) was not verified as the proponent's Test Case 7.6 was not possible to run due to problems in the provided setup. The requirement AC7.4 Part 3 (Hybrid Delivery) was not verified as the proponent did not provide a valid test setup. Therefore, the requirement AC7.4 was not verified due to lack of a valid test procedure.

6.2.3.8 Test 8 (Audio coding efficiency)

Not applicable (Test 8 addresses the requirement AC8.1 which is to be assessed through documentation analysis).

6.2.3.9 Test 9 (Audio End to end latency)

The requirement AC9.1 follows the accomplishment of requirements AC1.1.1 (TC1.1.1), AC 1.1.2 (TC1.1.2) and AC1.1.3 (TC1.1.3). The result for Test Case 9.1 is, therefore, not verified, as these requirements were not verified due to problems in the setup provided by the proponent.

As defined in the CfP, the requirement AC9.2 this is not addressed in test cases, but referred to the analysis documentation of the proponent (see item 6.2.1).

6.2.3.10 Test 10 (A/V synchronization)

The requirement AC10.1 (TC10.1) was not verified in the laboratory as the proponent's test case was not possible to run due to problems in the provided setup.

6.2.3.11 Test 11 (New immersive audio services)

Test 11 was not verified (the proponent did not provide a test procedure for this test, which addresses the requirement AC11.1).

6.2.3.12 Test 12 (Interoperability with different distribution platforms)

Test 12 (TC12.1) was not verified (the proponent did not provide a test procedure for this test, which addresses the requirement AC12.1).

6.2.3.13 Test 13 (Audio scalability and extensibility)

The Test Case 13.1 addresses the requirement AC13.1, which is verified during the execution of Test Case TC12.1. Since TC12.1 was not verified, TC13.1 (and AC13.1) was not verified as well.

The requirement AC13.2 is not analyzed as a feature tested in a laboratory, but it is addressed in the Documentation Analysis phase (see section 6.2.1), based on the documentation provided by the proponent.

6.2.4 Summary of Test Results

The following table summarizes the test results for Candidate Technology A. The table is organized in terms of fulfillment of the requirements addressed in the test cases. Two distinct status for non-verification were considered:

- “not verified (01)” corresponds to test setups/procedures not provided by the proponent or to invalid test setups/procedures;
- “not verified (02)” corresponds to test setups/procedures provided by the proponent that were not possible to run due to problems that could not be solved in time.

use case		minimum technical specification			fulfillment
AC1	Enable immersive (3D) audio.	AC1.1.1	channel-based	2.0	not verified (02) [NOTE: see 6.2.3.1]
		AC1.1.2		5.1	not verified (02) [NOTE: see 6.2.3.1]
		AC1.1.3		5.1 + 4H	not verified (02) [NOTE: see 6.2.3.1]
		AC1.2	object-based		not verified (02) [NOTE: see 6.2.3.1]
		AC1.3	scene-based (HOA)		not verified (02) [NOTE: see 6.2.3.1]
AC2	Enable end-user interactivity/personalization when allowed by the broadcaster (e.g. switch among different languages, sports commentators, adjust the commentator loudness level and position).	AC2.1	switch components (audio objects and alternative full mix substreams)		not verified (02) [NOTE: see 6.2.3.2]
		AC2.2	adjust object loudness		not verified (02) [NOTE: see 6.2.3.2]
		AC2.3	adjust object position		not verified (02) [NOTE: see 6.2.3.2]
		AC2.4	enable interactivity when using external sound reproduction devices		not verified (02) [NOTE: see 6.2.3.2]
AC3	Enable audio description delivery in the same stream as the main audio, as an alternative full mix or as an additional audio object with associated metadata.	AC3.1	audio description delivery in the same stream as the main audio		not verified (02) [NOTE: see 6.2.3.3]
		AC3.2	audio description delivery as an alternative full mix		not verified (02) [NOTE: see 6.2.3.3]
		AC3.3	audio description delivery as an additional audio object with associated metadata		not verified (02) [NOTE: see 6.2.3.3]
AC4	Enable emergency warning information delivery using audio description.	AC4.1	emergency warning information audio description		not verified (01) [NOTE: see 6.2.3.4]
AC5	Enable a single delivery format for multiple audio playback configurations (TV loudspeakers, soundbars, home theaters, binaural).	AC5.1	flexible loudspeaker configuration render		not verified (02) [NOTE: see 6.2.3.5]
		AC5.2	binaural render		not verified (01) [NOTE: see 6.2.3.5]
AC6	Enable consistent loudness across programs and inside the same program.	AC6.1	consistent loudness across programs		not verified (01) [NOTE: see 6.2.3.6]
		AC6.2	consistent loudness after user interaction		not verified (01) [NOTE: see 6.2.3.6]

use case		minimum technical specification		fulfillment	
AC7	Enable seamless configuration changes and A/V alignment.	AC7.1	seamless playback during configuration changes (e.g. from 5.1+4H to stereo)	not verified (02) [NOTE: see 6.2.3.7]	
		AC7.2	seamless playback during user interaction (e.g. enable/disable several audio elements)	not verified (02) [NOTE: see 6.2.3.7]	
		AC7.3	seamless playback during changes in production (e.g. broadcaster removes one object)	not verified (01) [NOTE: see 6.2.3.7]	
		AC7.4	seamless and sample-accurate stream splicing or ad-insertion at any time instance, even if some of the streams come from different distribution platforms (e.g. switch between over-the-air and Internet delivery)	not verified (01) [NOTE: see 6.2.3.7]	
AC8	Provide state-of-the-art coding efficiency, to allow better quality audio in limited capacity channels (over-the-air or Internet).	AC8.1	bit rate	kbps @ MOS 4 / MUSHRA > 80 or equivalent objective metric	not applicable [NOTE: see 6.2.3.8]
AC9	Provide live audio with minimum end-to-end latency.	AC9.1	real-time encoding		not verified (02) [NOTE: see 6.2.3.9]
		AC9.2	latency	ms	not applicable [NOTE: see 6.2.3.9]
AC10	Provide audio/video synchronization.	AC10.1	A/V sync	frame-accurate	not verified (02) [NOTE: see 6.2.3.10]
AC11	Enable new immersive audio services.	AC11.1	VR / AR / XR / 3DoF / 6DoF support		not verified (01) [NOTE: see 6.2.3.11]
AC12	Enable interoperability with different distribution platforms (e.g. DTT, cable, IPTV, DTH satellite, fixed broadband, 4G/5G mobile broadband, home network).	AC12.1	interoperability with different distribution platforms		not verified (01) [NOTE: see 6.2.3.12]
AC13	Enable scalability (e.g. to enhance the over-the-air audio experience with additional Internet-delivered audio content, such as new sports commentator options) and extensibility (support new settings and/or features in the future, in a backward-compatible way).	AC13.1	scalability		not verified (01) [NOTE: see 6.2.3.13]
		AC13.2	extensibility		not applicable [NOTE: see 6.2.3.13]

additional requirements		fulfillment
AC-AR1	Provide free of charge test content (BW64 file with ADM metadata #1) with the required technical specification, strictly for technical evaluation of the SBTVD Forum (non-commercial usage). The content shall not make any reference to commercial brands. NOTE #1: The provided free of charge test content shall include, in addition to the BW64 (RF64 / linear PCM / 48 kHz / signed 24-bit little-endian) file with ADM metadata as informed in AC-AR1, its corresponding video content in QuickTime File Format (.mov) containing a ProRes 422 Proxy video (1080p59.94 / 10-bit / SDR / BT.2020).	fulfilled
AC-AR2	Provide free of charge reference encoder and decoder (software or hardware) with its corresponding documentation, strictly for temporary technical evaluation of the SBTVD Forum (non-commercial usage).	fulfilled

6.3 Candidate Technology B

6.3.1 Documentation Analysis

The documentation analysis consisted of verifying whether the requirements made by the Forum SBTVD were fulfilled by the Candidate Technology B. For that, the following documents were analyzed:

1. Candidate Technology B Statements_20210702.docx
2. Candidate Technology B Audio Codec Test Report.pdf
3. The corresponding IEEE Standard

In item 6.3.1.1, which refers to "Subjective quality assessment reports", the documentation analysis of requirement AC8 is presented. As mentioned by the proponents of Candidate Technology B, the results came from the report of the Candidate Technology B Audio Codec Test Report (document 2, cited above; see item 6.3.1.1).

Following, the notes mentioned in item 6.3.1.2 (Summary of Documentation Analysis) are presented:

Note 30 - The general requirement GT3 was met according to a message sent by email from the proponents of Candidate Technology B, on July 2, 2021.

Note 31 - The general requirement GT4 was met according to a message sent by email from the proponents of Candidate Technology B, on July 2, 2021.

Note 32 - The general requirement GI3 was met according to a message sent by email from the proponents of Candidate Technology B, on July 2, 2021.

Note 33 - The requirements AC1.1.1, AC1.1.2, AC1.1.3, AC1.2 and AC1.3 are considered "Ready for test" (see p.4 of document 1, cited above).

Note 34 - The requirements AC2.1, AC2.2, AC2.3, AC2.4, AC3.1, AC3.2 and AC3.3 are partially fulfilled; proponent "Intends to fulfill with system transport layer in next 3~6 months", (see p.4 of document 1, cited above).

Note 35 - The requirement AC4.1 is partially fulfilled - "System transport layer fulfilled", (see p.4 of document 1, cited above).

Note 36 - The requirement AC5.1 is considered "Ready for test" (see p.4 of document 1, cited above).

Note 37 - The requirements AC5.2, AC6.1, and AC6.2 are partially fulfilled: proponent "intends to fulfill in 1~2 months" (see p.4 of document 1, cited above).

Note 38 - The requirements AC7.1, AC7.2, AC7.3 and AC7.4 are partially fulfilled; the proponent informs: "intend to fulfill the system transport layer in the next 3~6 months" (see p.5 of document 1, cited above).

Note 39 - Concerning the requirement AC8.1 (audio coding efficiency) the proponent documentation informs that for 2.0@48kbps, and 5.1@144kbps, and 5.1+4H@256kbps the Candidate Technology B codec meets the requirement exhibiting a score > MOS 4 / MUSHRA > 80 (see pp.6-7 of document 2, cited above). According to the proponent, they are "Ready for test" (see p.5 of document 1, cited above). For further details see item 6.3.1.1 (Subjective quality assessment reports).

Note 40 - The requirements AC9.1, AC9.2, and AC10.1 are considered "Ready for test" (see p.5 of document 1, cited above). However, the requirement AC9.2 is not specified in the documents provided, as no latency technical data was informed.

Note 41 - The requirement AC11.1 is partially fulfilled; the proponent informs "Intends to fulfill in the future with more detailed requirements" (see p.5 of document 1, cited above).

Note 42 - The requirements AC12.1, AC13.1, and AC13.2 are partially fulfilled; the proponent informs "Intends to fulfill with system transport layer in next 3~6 months" (see p.5 of document 1, cited above).

Note 43 - According to document 1, cited above, the requirement AC-AR3 is fulfilled (see p.2 of document 1, cited above).

Note 44 - According to document 1, cited above, the requirement AC-AR4 is fulfilled (see p.2 of document 1, cited above).

Note 45 - According to document 1, cited above, the requirement AC-AR5 is fulfilled(see pp.2-3 of document 1, cited above).

6.3.1.1 Subjective quality assessment reports

This section compiles information about the proponent's technology audio coding efficiency as retrieved from Quality Assessment Reports provided by the proponent. The analysis of audio coding efficiency is considered in Test 8 and is to be assessed from these reports.

6.3.1.1.1 Candidate Technology B Audio Codec Test Report

In august 2021, the China Electronics Standardization Institute CESI Laboratory issued a test report summarizing the results of a subjective listening test of proposed audio systems. The Candidate Technology B was evaluated.

According to the results presented in the Candidate Technology B Audio Codec Test Report, considered here as a reference, the mono audio test with 48kbps achieved a MUSHRA score greater than 80, considered excellent; for the 2.0@48kbps, the MUSHRA score was greater than 80, considered excellent; for the 5.1.4@48kbps, the MUSHRA score was greater than 80, considered excellent, and for the 5.1@144kbps, a consistent BS.1116-3 score greater than 4.0 was achieved. Therefore, it is considered that the requirement AC8.1 was fulfilled.

6.3.2 Summary of Documentation Analysis

Below is the summary of documentation analysis for Candidate Technology B.

	general requirements	fulfillment
GT3	All technical proposals shall be fully specified, preferably in technical standards of internationally recognized SDOs.	fulfilled [NOTE 30: see 6.3.1]
GT4	The full specification of the technical proposal shall be made available for the SBTVD Forum free of charge.	fulfilled [NOTE 31: see 6.3.1]
GI3	All technical proposals licensing or any other form of commercialization shall adhere to fair, reasonable, and non-discriminatory terms, as specified in the SBTVD Forum Intellectual Property Rights Policy (see the TV 3.0 Call for Proposals document, Annex A).	fulfilled [NOTE 32: see 6.3.1]

use case		minimum technical specification			fulfillment
AC1	Enable immersive (3D) audio.	AC1.1.1	channel-based	2.0	fulfilled [NOTE 33: see 6.3.1]
		AC1.1.2		5.1	fulfilled [NOTE 33 see 6.3.1]
		AC1.1.3		5.1 + 4H	fulfilled [NOTE 33: see 6.3.1]
		AC1.2	object-based		fulfilled [NOTE 33: see 6.3.1]
		AC1.3	scene-based (HOA)		fulfilled [NOTE 33: see 6.3.1]
AC2	Enable end-user interactivity/personalization when allowed by the broadcaster (e.g. switch among different languages, sports commentators, adjust the commentator loudness level and position).	AC2.1	switch components (audio objects and alternative full mix substreams)		partially fulfilled [NOTE 34: see 6.3.1]
		AC2.2	adjust object loudness		partially fulfilled [NOTE 34: see 6.3.1]
		AC2.3	adjust object position		partially fulfilled [NOTE34: see 6.3.1]
		AC2.4	enable interactivity when using external sound reproduction devices		partially fulfilled [NOTE 34: see 6.3.1]
AC3	Enable audio description delivery in the same stream as the main audio, as an alternative full mix or as an additional audio object with associated metadata.	AC3.1	audio description delivery in the same stream as the main audio		partially fulfilled [NOTE 34: see 6.3.1]
		AC3.2	audio description delivery as an alternative full mix		partially fulfilled [NOTE 34: see 6.3.1]
		AC3.3	audio description delivery as an additional audio object with associated metadata		partially fulfilled [NOTE 34: see 6.3.1]
AC4	Enable emergency warning information delivery using audio description.	AC4.1	emergency warning information audio description		partially fulfilled [NOTE 35: see 6.3.1]
AC5	Enable a single delivery format for multiple audio playback configurations (TV loudspeakers, soundbars, home theaters, binaural).	AC5.1	flexible loudspeaker configuration render		fulfilled [NOTE 36: see 6.3.1]
		AC5.2	binaural render		partially fulfilled [NOTE 37: see 6.3.1]
AC6	Enable consistent loudness across programs and inside the same program.	AC6.1	consistent loudness across programs		partially fulfilled [NOTE 37: see 6.3.1]
		AC6.2	consistent loudness after user interaction		partially fulfilled [NOTE 37: see 6.3.1]

use case		minimum technical specification		fulfillment	
AC7	Enable seamless configuration changes and A/V alignment.	AC7.1	seamless playback during configuration changes (e.g. from 5.1+4H to stereo)		partially fulfilled [NOTE 38: see 6.3.1]
		AC7.2	seamless playback during user interaction (e.g. enable/disable several audio elements)		partially fulfilled [NOTE 38: see 6.3.1]
		AC7.3	seamless playback during changes in production (e.g. broadcaster removes one object)		partially fulfilled [NOTE 38: see 6.3.1]
		AC7.4	seamless and sample-accurate stream splicing or ad-insertion at any time instance, even if some of the streams come from different distribution platforms (e.g. switch between over-the-air and Internet delivery)		partially fulfilled [NOTE 38: see 6.3.1]
AC8	Provide state-of-the-art coding efficiency, to allow better quality audio in limited capacity channels (over-the-air or Internet).	AC8.1	bit rate	kbps @ MOS 4 / MUSHRA > 80 or equivalent objective metric	technical subjective results provided [NOTE 39: see 6.3.1]
AC9	Provide live audio with minimum end-to-end latency.	AC9.1	real-time encoding		fulfilled [NOTE 40: see 6.3.1]
		AC9.2	latency	ms	not specified [NOTE 40: see 6.3.1]
AC10	Provide audio/video synchronization.	AC10.1	A/V sync	frame-accurate	fulfilled [NOTE 40: see 6.3.1]
AC11	Enable new immersive audio services.	AC11.1	VR / AR / XR / 3DoF / 6DoF support		not fulfilled [NOTE 41: see 6.3.1]
AC12	Enable interoperability with different distribution platforms (e.g. DTT, cable, IPTV, DTH satellite, fixed broadband, 4G/5G mobile broadband, home network).	AC12.1	interoperability with different distribution platforms		partially fulfilled [NOTE 42: see 6.3.1]
AC13	Enable scalability (e.g. to enhance the over-the-air audio experience with additional Internet-delivered audio content, such as new sports commentator options) and extensibility (support new settings and/or features in the future, in a backward-compatible way).	AC13.1	scalability		partially fulfilled [NOTE 42: see 6.3.1]
		AC13.2	extensibility		partially fulfilled [NOTE 42: see 6.3.1]

additional requirements		fulfillment
AC-AR3	Provide information about available implementations of the encoder and decoder, the latter both for professional (broadcast) and consumer electronic applications.	fulfilled [NOTE 43: see 6.3.1]
AC-AR4	Provide information about available implementations of production tools: authoring and monitoring for live and post-production.	fulfilled [NOTE 44: see 6.3.1]
AC-AR5	Provide some reference information about the decoder for TV sets manufacturing.	fulfilled [NOTE 45: see 6.3.1]

6.3.3 Test Results

Candidate Technology B did not provide any setup and equipment/software for the mandatory tests, as previously indicated by e-mail. Therefore, all Test Cases of Candidate Technology B were not verified in the laboratory.

6.3.3.1 Test 1 (Immersive audio)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.2 Test 2 (Interactivity and personalization)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.3 Test 3 (Audio description)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.4 Test 4 (Audio emergency warning information)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.5 Test 5 (Flexible audio playback configuration)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.6 Test 6 (Consistent loudness)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.7 Test 7 (Seamless configuration changes and A/V alignment)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.8 Test 8 (Audio coding efficiency)

Not applicable (Test 8 addresses the requirement AC8.1 which is to be assessed through documentation analysis)

6.3.3.9 Test 9 (Audio End to end latency)

The requirement AC9.1 follows the accomplishment of requirements AC1.1.1 (TC1.1.1), AC 1.1.2 (TC1.1.2) and AC1.1.3 (TC1.1.3). The result for Test 9.1 is, therefore, not verified, as these requirements could not be verified in the laboratory.

As defined in the CfP, the requirement AC9.2 this is not addressed in test cases, but referred to the analysis documentation of the proponent (see item 6.3.1).

6.3.3.10 Test 10 (A/V synchronization)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.11 Test 11 (New immersive audio services)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.12 Test 12 (Interoperability with different distribution platforms)

Not verified for Candidate Technology B (no equipment, software, nor test procedure setups were provided).

6.3.3.13 Test 13 (Audio scalability and extensibility)

This Test Case addresses the requirements AC13.1 and AC13.2. The requirement AC13.1 is verified during the execution of Test Case TC12, and therefore it was not verified for Candidate Technology B.

The requirement AC13.2 is not analyzed as a feature tested in laboratory, but it is addressed in the Document Analysis phase (see section 6.3.1), based on the documentation provided by the proponent.

6.3.4 Summary of Test Results

The following table summarizes the test results for Candidate Technology B. The table is organized in terms of fulfillment of the requirements addressed in the test cases.

use case		minimum technical specification		fulfillment	
AC1	Enable immersive (3D) audio.	AC1.1.1	channel-based	2.0	not verified [NOTE: see 6.3.3.1]
		AC1.1.2		5.1	not verified [NOTE: see 6.3.3.1]
		AC1.1.3		5.1 + 4H	not verified [NOTE: see 6.3.3.1]
		AC1.2	object-based		not verified [NOTE: see 6.3.3.1]
		AC1.3	scene-based (HOA)		not verified [NOTE: see 6.3.3.1]
AC2	Enable end-user interactivity/personalization when allowed by the broadcaster (e.g. switch among different languages, sports commentators, adjust the commentator loudness level and position).	AC2.1	switch components (audio objects and alternative full mix substreams)		not verified [NOTE: see 6.3.3.2]
		AC2.2	adjust object loudness		not verified [NOTE: see 6.3.3.2]
		AC2.3	adjust object position		not verified [NOTE: see 6.3.3.2]
		AC2.4	enable interactivity when using external sound reproduction devices		not verified [NOTE: see 6.3.3.2]

use case		minimum technical specification		fulfillment
AC3	Enable audio description delivery in the same stream as the main audio, as an alternative full mix or as an additional audio object with associated metadata.	AC3.1	audio description delivery in the same stream as the main audio	not verified [NOTE: see 6.3.3.3]
		AC3.2	audio description delivery as an alternative full mix	not verified [NOTE: see 6.3.3.3]
		AC3.3	audio description delivery as an additional audio object with associated metadata	not verified [NOTE: see 6.3.3.3]
AC4	Enable emergency warning information delivery using audio description.	AC4.1	emergency warning information audio description	not verified [NOTE: see 6.3.3.4]
AC5	Enable a single delivery format for multiple audio playback configurations (TV loudspeakers, soundbars, home theaters, binaural).	AC5.1	flexible loudspeaker configuration render	not verified [NOTE: see 6.3.3.5]
		AC5.2	binaural render	not verified [NOTE: see 6.3.3.5]
AC6	Enable consistent loudness across programs and inside the same program.	AC6.1	consistent loudness across programs	not verified [NOTE: see 6.3.3.6]
		AC6.2	consistent loudness after user interaction	not verified [NOTE: see 6.3.3.6]
AC7	Enable seamless configuration changes and A/V alignment.	AC7.1	seamless playback during configuration changes (e.g. from 5.1+4H to stereo)	not verified [NOTE: see 6.3.3.7]
		AC7.2	seamless playback during user interaction (e.g. enable/disable several audio elements)	not verified [NOTE: see 6.3.3.7]
		AC7.3	seamless playback during changes in production (e.g. broadcaster removes one object)	not verified [NOTE: see 6.3.3.7]
		AC7.4	seamless and sample-accurate stream splicing or ad-insertion at any time instance, even if some of the streams come from different distribution platforms (e.g. switch between over-the-air and Internet delivery)	not verified [NOTE: see 6.3.3.7]
AC8	Provide state-of-the-art coding efficiency, to allow better quality audio in limited capacity channels (over-the-air or Internet).	AC8.1	bit rate kbps @ MOS 4 / MUSHRA > 80 or equivalent objective metric	not applicable [NOTE: see 6.3.3.8]
AC9	Provide live audio with minimum end-to-end latency.	AC9.1	real-time encoding	not verified [NOTE: see 6.3.3.9]
		AC9.2	latency ms	not applicable [NOTE: see 6.3.3.9]
AC10	Provide audio/video synchronization.	AC10.1	A/V sync frame-accurate	not verified [NOTE: see 6.3.3.10]
AC11	Enable new immersive audio services.	AC11.1	VR / AR / XR / 3DoF / 6DoF support	not verified [NOTE: see 6.3.3.11]

use case		minimum technical specification		fulfillment
AC12	Enable interoperability with different distribution platforms (e.g. DTT, cable, IPTV, DTH satellite, fixed broadband, 4G/5G mobile broadband, home network).	AC12.1	interoperability with different distribution platforms	not verified [NOTE: see 6.3.3.12]
AC13	Enable scalability (e.g. to enhance the over-the-air audio experience with additional Internet-delivered audio content, such as new sports commentator options) and extensibility (support new settings and/or features in the future, in a backward-compatible way).	AC13.1	scalability	not verified [NOTE: see 6.3.3.13]
		AC13.2	extensibility	not applicable [NOTE: see 6.3.3.13]

additional requirements		fulfillment
AC-AR1	Provide free of charge test content (BW64 file with ADM metadata #1) with the required technical specification, strictly for technical evaluation of the SBTVD Forum (non-commercial usage). The content shall not make any reference to commercial brands. NOTE #1: The provided free of charge test content shall include, in addition to the BW64 (RF64 / linear PCM / 48 kHz / signed 24-bit little-endian) file with ADM metadata as informed in AC-AR1, its corresponding video content in QuickTime File Format (.mov) containing a ProRes 422 Proxy video (1080p59.94 / 10-bit / SDR / BT.2020).	fulfilled
AC-AR2	Provide free of charge reference encoder and decoder (software or hardware) with its corresponding documentation, strictly for temporary technical evaluation of the SBTVD Forum (non-commercial usage).	not fulfilled [NOTE: see 6.3.3]

6.4 Candidate Technology C

6.4.1 Documentation Analysis

The documentation analysis consisted of verifying whether the requirements made by the Forum were fulfilled by the Candidate Technology C. For that, the following documents provided by the proponent were used:

1. "SBTVD TV 3.0 Call for Proposals Candidate Technology C - Test Procedures Documentation" (2_Documentation_Test_Procedures.docx)
2. "SBTVD TV 3.0 Call for Proposals Candidate Technology C" (1_Proposal.pdf)
3. "SBTVD TV 3.0 Call for Proposals Phase 2 Test Content Analysis conducted by the proponents of Candidate Technology C" (3_Test_Content_Analysis.pdf)
4. "SBTVD TV 3.0 Call for Proposals Candidate Technology C - Additional Demonstrations" (4_Documentation_Additional_Demonstrations.docx)
5. "ATSC 3.0 Audio Testing Report, Doc. S34-2B-048r7" (August 2015) (ATSC_3-0_Audio_Test_Report_(2015)_for_SBTVD_Forum.pdf)

In item 6.4.1.1, which refers to "Subjective quality assessment reports", the documentation analysis of requirement AC8 (audio coding efficiency) is presented. As considered for the proponents of Candidate Technology C, the main results came from the report of the Advanced Television Systems Committee, ATSC (item 6.4.1.1.1).

Following, the notes mentioned in item 6.4.1.2 (Summary of Documentation Analysis) are presented:

Note 46 - The general requirement GT3 was met according to a message sent by email from the proponents of Candidate Technology C, on July 2, 2021.

Note 47 - The general requirement GT4 was met according to a message sent by email from the proponents of Candidate Technology C, on July 2, 2021.

Note 48 - The general requirement GI3 was fulfilled according to a message sent by email from the proponents of Candidate Technology C, on June 21, 2021.

Note 49 - According to the proponent documentation, the requirements AC1.1.1, AC1.1.2 and AC1.1.3 were fulfilled (see p.73 of document 1, cited above).

Note 50 - According to the proponent documentation, the requirement AC1.2 was fulfilled (see p.73 of document 1, cited above).

Note 51 - According to the proponent documentation, the requirement AC1.3 was fulfilled (see p.75 of document 1, cited above).

Note 52 - According to the proponent documentation, the requirement AC2.1 was fulfilled (see pp.76,80,83,86 of document 1, cited above).

Note 53 - According to the proponent documentation, the requirement AC2.2 was fulfilled (see p.88 of document 1, cited above).

Note 54 - According to the proponent documentation, the requirement AC2.3 was fulfilled (see p.91 of document 1, cited above).

Note 55 - According to the proponent documentation, the requirement AC2.4 was fulfilled (see p.94 of document 1, cited above).

Note 56 - According to the proponent documentation, the requirements AC3.1 and AC3.2 were fulfilled (see p.97 of document 1, cited above).

Note 57 - According to the proponent documentation, the requirement AC3.3 was fulfilled (see p.99 of document 1, cited above).

Note 58 - According to the proponent documentation, the requirement AC4.1 was fulfilled (see p.104 of document 1, cited above).

Note 59 - According to the proponent documentation, the requirements AC5.1 and AC5.2 were fulfilled (see p.109 of document 1, cited above).

Note 60 - According to the proponent documentation, the requirement AC6.1 was fulfilled (see p.111 of document 1, cited above).

Note 61 - According to the proponent documentation, the requirement AC6.2 was fulfilled (see pp.114,117 of document 1, cited above).

Note 62 - According to the proponent documentation, the requirement AC7.1 was fulfilled (see p.120 of document 1, cited above).

Note 63 - According to the proponent documentation, the requirement AC7.2 was fulfilled (see p.123 of document 1, cited above).

Note 64 - According to the proponent documentation, the requirement AC7.3 was fulfilled (see pp.125,132 of document 1, cited above).

Note 65 - According to the proponent documentation, the requirement AC7.4 was fulfilled (see pp.136,138,140 of document 1, cited above).

Note 66 - According to the proponent documentation, for the verification of the requirement AC8.1 (audio coding efficiency) for all formats and bitrates of interest it used the ATSC report (document 3, cited above) as the main basis. For further details, please refer to the item 6.4.1.1 (Subjective quality assessment reports).

Note 67 - The requirements AC9.1 and AC9.2 are addressed in Test Case 9 but, according to the SBTVD Forum CfP, these requirements shall be assessed through the analysis of the proponent's documentation, no functionality testing shall be performed in the laboratory.

The proponents reports that the Candidate Technology C is designed to ensure minimal end-to-end latency in all connectivity scenarios. The Candidate Technology C encoding step is done inside the video encoder; therefore, the audio encoder delay is covered by the video encoder delay, without any audio delay. If the receiver is connected to an external sound reproduction system, Candidate Technology C decoding and rendering is done only on the final external sound reproduction system. As a result, the receiver will not introduce any additional delay, and only the external playback system introduces a constant 38.35ms rendering and decoding delay. The documentation sent by the proponent presents a text without detailed information on how the tests were performed and how they reached the value of 38.35 ms, and the absence of references is noted.

Note 68 - According to the proponent documentation, the requirement AC10.1 was fulfilled (see p.145, of document 1, cited above).

Note 69 - According to the proponent documentation, the requirement AC11.1 was fulfilled (see p.148, of document 1, cited above).

Note 70 - According to the proponent documentation, the requirement AC12.1 was fulfilled (see p.149, of document 1, cited above).

Note 71 - According to the proponent documentation, the requirement AC13.1 was fulfilled (see p.153, of document 1, cited above).

Note 72 - According to the proponent documentation, the requirement AC13.2 was fulfilled (see p.153, of document 1, cited above).

Note 73 - The additional requirement AC-AR3 was considered fulfilled, according to a message sent by email from the proponents of Candidate Technology C, on July 2, 2021.

Note 74 - The additional requirement AC-AR4 was considered fulfilled, according to a message sent by email from the proponents of Candidate Technology C, on July 2, 2021.

Note 75 - The additional requirement AC-AR5 was considered fulfilled, according to a message sent by email from the proponents of Candidate Technology C, on July 2, 2021.

6.4.1.1 Subjective quality assessment reports

This section compiles information about the proponent's technology audio coding efficiency as retrieved from quality assessment reports provided by the proponent. The analysis of audio coding efficiency is referred to in Test 8, and addresses the requirement AC8.1 (audio coding efficiency), which is to be assessed from the aforementioned reports.

To assess known performance metrics of the proponent's technology coding efficiency in terms of subjective quality, this analysis is presented in 2 parts. The first part presents the results of an official independent report released by ATSC⁶ (document 5, listed in 6.4.1). The second part combines these results with the results of another listening test conducted by the ISO/IEC MPEG WG11 working group in 2017.

6.4.1.1.1 ATSC 3.0 Audio Testing Report

In August 2015, the ATSC (Advanced Television Systems Committee) issued a test report summarizing the results of a subjective listening test and feature evaluations of proposed audio systems for the ATSC 3.0 audio system.

The following table summarizes the results of the ATSC report, considered here as the main reference, showing the scores obtained by Candidate Technology C at two different test laboratories⁷. The table covers the audio formats of interest for SBTVD 3.0 CfP⁸, and shows in red the score values for the formats@bitrates that do not meet a MUSHRA "excellent" grade.

Table 6 - ATSC3.0 report scores for Candidate Technology C. Results include metrics for mandatory loudspeaker formats specified in the CfP: 2.0, 5.1 and 5.1+4H (here approximated by the result obtained for the format 7.1+4H evaluated in the ATSC).

Audio format	Bitrates	Lab A	Lab B
		MUSHRA	MUSHRA
2.0	32	83.70	57.70
2.0	48	-	-
2.0	64	83.80	70.80
2.0	80	-	-
2.0	96	93.00	89.80

⁶ Advanced Television Systems Committee, "ATSC 3.0 Audio Testing Report, Doc. S34-2B-048r7", Washington, USA, August 2015.

⁷ Test Lab A is "Brannan A," and Test Lab B is "Mozart."

⁸ Lines with no information refer to bitrates not evaluated in the respective tests nor specified in the report.

Audio format	Bitrates	Lab A	Lab B
		MUSHRA	MUSHRA
5.1	80	78.80	62.80
5.1	128	-	-
5.1	144	84.50	72.50
5.1	180	-	-
5.1	208	94.00	87.60
7.1+4H	144	85.00	59.80
7.1+4H	256	88.70	75.40
7.1+4H	384	93.90	89.20
7.1+4H	512	-	-
7.1+4H	768	-	-

Also, according to the same report, the Candidate Technology C performance with HOA@640kbps satisfies a BS.1116-3 score ≥ 4.0 . The SBTVD CfP in the present CfP specified a test case using HOA@320kbps.

A letter from ATSC, companion to the provided report, notices that there are tools in the Candidate Technology C Low Complexity (LC) Profile codec specified in the ATSC 3.0 standard and included in the ATSC proposal that were not tested in these tests. Instead, an earlier version of the codec containing coding tools that were not part of the current Candidate Technology C LC profile was tested. Hence, these results are not fully representative of ATSC's current proposal, and, as such, ATSC believes that more modern test results would better indicate the respective systems' performance.

The Candidate Technology C standard specifies two profiles for broadcast and streaming: Baseline and Low Complexity (LC)⁹. Both profiles contain multiple levels and the proponent informs that with Level 3 the SBTVD TV 3.0 CfP requirements are fulfilled.

Although for a single score value the fulfillment requirement set in the SBTVD CfP is clear in meeting a MUSHRA score > 80 ("excellent" grade) or a MOS score > 4 , as a multiple scores totalization criterium was not defined to verify how the codec would meet the AC8.1 requirement for all the formats and bitrates, this survey is only informative of the retrieved metrics from the cited document.

⁹ The Low Complexity (LC) Profile is a superset of the Baseline Profile and includes tools for NGA as required in the SBTVD CfP.

6.4.1.1.2 ATSC 3.0 Audio Testing Report combined with Candidate Technology C Verification Test Report

In addition to the metrics above, it was retrieved scores obtained by the Candidate Technology C in a set of listening tests conducted by ISO/IEC MPEG WG11 working group in 2017, based on results from 7 different test laboratories¹⁰.

The following table summarizes the results from the ATSC 3.0 report and the Candidate Technology C report, and shows in red the score values for the formats@bitrates that do not meet a MUSHRA "excellent" grade.

Table 7 - Combined subjective listening scores for Candidate Technology C: ATSC3.0 report scores plus Candidate Technology C report scores. Results include metrics for mandatory loudspeaker formats specified in the CfP: 2.0, 5.1 and 5.1+4H (here approximated by the result obtained for the format 7.1+4H evaluated in the ATSC).

Audio format	Bitrates	Lab A	Lab B	MPEG WG11	
		MUSHRA	MUSHRA	ITU-R HQE MOS	MUSHRA
2.0	32	83.70	57.70	-	-
2.0	48	-	-	-	81.83
2.0	64	83.80	70.80	-	88.68
2.0	80	-	-	-	90.60
2.0	96	93.00	89.80	-	-
5.1	80	78.80	62.80	-	-
5.1	128	-	-	-	84.02
5.1	144	84.50	72.50	-	85.02
5.1	180	-	-	-	88.00
5.1	208	94.00	87.60	-	-
7.1+4H	144	85.00	59.80	-	-
7.1+4H	256	88.70	75.40	-	86.47
7.1+4H	384	93.90	89.20	-	90.93
7.1+4H	512	-	-	-	92.79
7.1+4H	768	-	-	4.64	-

¹⁰ Candidate Technology C Verification Test Report, ISO/IEC JTC1/SC29/WG11 (January 2017, Geneva)

The additional scores permit the evaluation of the performance of the proponent's codec in formats@bitrates of interest for SBTVD 3.0 that were not covered in the ATSC 3.0 report, such as for 2.0@48kbps. It must be noted that the studies were conducted in different locations, with different equipment, test content, and participants. Therefore, the scores of the three sources could not be normalized, checked on its statistical consistency to certify that no bias exists between the reports, and produce a combined score. The data are only informative, withdrawn from the independent test reports.

Again, although for a single score value the fulfillment requirement set in the SBTVD CfP is clear in meeting a MUSHRA score > 80 ("excellent" grade) or a MOS score > 4, as a multiple scores totalization criterium was not defined to verify how the codec would meet the AC8.1 requirement for all the formats and bitrates, this survey is only informative of the retrieved metrics from the documents.

6.4.2 Summary of Documentation Analysis

Below is the summary of documentation analysis for Candidate Technology C.

general requirements		fulfillment
GT3	All technical proposals shall be fully specified, preferably in technical standards of internationally recognized SDOs.	fulfilled [NOTE 46: see 6.4.1]
GT4	The full specification of the technical proposal shall be made available for the SBTVD Forum free of charge.	fulfilled [NOTE 47: see 6.4.1]
GI3	All technical proposals licensing or any other form of commercialization shall adhere to fair, reasonable, and non-discriminatory terms, as specified in the SBTVD Forum Intellectual Property Rights Policy (see the TV 3.0 Call for Proposals document, Annex A).	fulfilled [NOTE 48: see 6.4.1]

use case	minimum technical specification		fulfillment		
AC1	Enable immersive (3D) audio.	AC1.1.1	2.0	fulfilled NOTE 49: see 6.4.1]	
		AC1.1.2	channel-based	5.1	fulfilled NOTE 49: see 6.4.1]
		AC1.1.3	channel-based	5.1 + 4H	fulfilled NOTE 49: see 6.4.1]
		AC1.2	object-based		fulfilled NOTE 50: see 6.4.1]
		AC1.3	scene-based (HOA)		fulfilled NOTE 51: see 6.4.1]

use case		minimum technical specification		fulfillment
AC2	Enable end-user interactivity/personalization when allowed by the broadcaster (e.g. switch among different languages, sports commentators, adjust the commentator loudness level and position).	AC2.1	switch components (audio objects and alternative full mix substreams)	fulfilled [NOTE 52: see 6.4.1]
		AC2.2	adjust object loudness	fulfilled: [NOTE 53: see 6.4.1]
		AC2.3	adjust object position	fulfilled [NOTE 54: see 6.4.1]
		AC2.4	enable interactivity when using external sound reproduction devices	fulfilled [NOTE 55: see 6.4.1]
AC3	Enable audio description delivery in the same stream as the main audio, as an alternative full mix or as an additional audio object with associated metadata.	AC3.1	audio description delivery in the same stream as the main audio	fulfilled [NOTE 56: see 6.4.1]
		AC3.2	audio description delivery as an alternative full mix	fulfilled [NOTE 56: see 6.4.1]
		AC3.3	audio description delivery as an additional audio object with associated metadata	fulfilled [NOTE 57: see 6.4.1]
AC4	Enable emergency warning information delivery using audio description.	AC4.1	emergency warning information audio description	fulfilled [NOTE 58: see 6.4.1]
AC5	Enable a single delivery format for multiple audio playback configurations (TV loudspeakers, soundbars, home theaters, binaural).	AC5.1	flexible loudspeaker configuration render	fulfilled [NOTE 59: see 6.4.1]
		AC5.2	binaural render	fulfilled [NOTE 59: see 6.4.1]
AC6	Enable consistent loudness across programs and inside the same program.	AC6.1	consistent loudness across programs	fulfilled [NOTE 60: see 6.4.12]
		AC6.2	consistent loudness after user interaction	fulfilled [NOTE 61: see 6.4.1]
AC7	Enable seamless configuration changes and A/V alignment.	AC7.1	seamless playback during configuration changes (e.g. from 5.1+4H to stereo)	fulfilled [NOTE 62: see 6.4.1]
		AC7.2	seamless playback during user interaction (e.g. enable/disable several audio elements)	fulfilled [NOTE 63: see 6.4.1]
		AC7.3	seamless playback during changes in production (e.g. broadcaster removes one object)	fulfilled [NOTE 64: see 6.4.1]
		AC7.4	seamless and sample-accurate stream splicing or ad-insertion at any time instance, even if some of the streams come from different distribution platforms (e.g. switch between over-the-air and Internet delivery)	fulfilled [NOTE 65: see 6.4.1]

use case		minimum technical specification			fulfillment
AC8	Provide state-of-the-art coding efficiency, to allow better quality audio in limited capacity channels (over-the-air or Internet).	AC8.1	bit rate	kbps @ MOS 4 / MUSHRA > 80 or equivalent objective metric	technical subjective results provided [NOTE 66: see 6.4.1]
AC9	Provide live audio with minimum end-to-end latency.	AC9.1	real-time encoding		fulfilled [NOTE 67: see 6.4.1]
		AC9.2	latency	ms	technical data provided [NOTE 67: see 6.4.1]
AC10	Provide audio/video synchronization.	AC10.1	A/V sync	frame-accurate	fulfilled [NOTE 68: see 6.4.1]
AC11	Enable new immersive audio services.	AC11.1	VR / AR / XR / 3DoF / 6DoF support		fulfilled [NOTE 69: see 6.4.1]
AC12	Enable interoperability with different distribution platforms (e.g. DTT, cable, IPTV, DTH satellite, fixed broadband, 4G/5G mobile broadband, home network).	AC12.1	interoperability with different distribution platforms		fulfilled [NOTE 70: see 6.4.1]
AC13	Enable scalability (e.g. to enhance the over-the-air audio experience with additional Internet-delivered audio content, such as new sports commentator options) and extensibility (support new settings and/or features in the future, in a backward-compatible way).	AC13.1	scalability		fulfilled [NOTE 71: see 6.4.1]
		AC13.2	extensibility		fulfilled [NOTE 72: see 6.4.1]

additional requirements		fulfillment
AC-AR3	Provide information about available implementations of the encoder and decoder, the latter both for professional (broadcast) and consumer electronic applications.	fulfilled [NOTE 73: see 6.4.1]
AC-AR4	Provide information about available implementations of production tools: authoring and monitoring for live and post-production.	fulfilled] NOTE 74: see 6.4.1]
AC-AR5	Provide some reference information about the decoder for TV sets manufacturing.	fulfilled [NOTE 75: see 6.4.1]

6.4.3 Test Results

In order to facilitate the evaluation of the systems during the tests execution, a spreadsheet was developed for each Test Case specified in the SBTVD CfP, by mapping the expected goals in each step of the sequence of test procedures into explicit questions to be answered, standardizing a model for feature analysis.

Tests executions were done in rounds, each round consisting in running the test with one of the audio test content items indicated, and then collecting the results. All tests were recorded in HD video quality, for documenting and auditing purposes, as required by the SBTVD CfP. After the data collection, the overall fulfillment evaluation of the expected requirements was done confronting the noted answers to the condition(s) that would lead to the failure of the test. Observations, if any, were also collected to be informed at the final report, complementing the evaluation of the requirements with information on the behavior of the system.

Candidate Technology C submitted equipment and software to test their technology. The following table summarizes their equipment received by the laboratory on 15/07/2021.

Table 8 - Candidate Technology C list of equipment/software

Equipment		brand	model	delivery date
item	quantity			
1	1	Intel	Server NUC	15/07/2021
2	1	Intel	Control NUC	15/07/2021
3	1	Junger Audio	Multichannel Monitoring and Authoring - MMA	15/07/2021
4	1	Linear Acoustic	Authoring and Monitoring System - AMS	15/07/2021
5	1	Dell	KaiMedia KME-U4K	15/07/2021
6	1	Dell	Ateme Titan Live	15/07/2021
7	1	Dell	DigiCap DigiCaster	15/07/2021
8	1	Blackmagic	Content Playout Hyperdeck Studio 12G SDI	15/07/2021
9	1	Blackmagic	Micro converter	15/07/2021
10	1	Blackmagic	Smart VideoHub CleanSwitch 12x12	15/07/2021
11	1	DekTec	Modulator DTU-315	15/07/2021
12	5	Nvidia	Android STB Shield	15/07/2021
13	1	Senheiser	Soundbar Ambeo	15/07/2021
14	1	Denon	AVR AVC-X6700H	15/07/2021
15	1	LG	TV OLED65C1KNA	15/07/2021
16	1	Lowa SIS	Set Top Box LSA3200	15/07/2021

Equipment		brand	model	delivery date
item	quantity			
17	1	Samsung	Tablet S5e	15/07/2021
18	1	Samsung	Oculus Gear VR	15/07/2021
19	1	Samsung	Cellphone Galaxy S8	15/07/2021
20	1	Cisco	Ethernet Switch	15/07/2021
21	10	Visaton	Speakers WB10	15/07/2021

System setup

The hardware/software setup provided by the proponent for the realization of the real-time-based test cases is compliant to the specification in figure 41 of the SBTVD CfP. As considered by the proponent in their test procedures documentation, for the context of SBTVD TV 3.0 the (ISO/IEC MPEG defined) ISO/BMFF container format will be used for MMTP¹¹ broadcast for the majority of the test cases, and also DASH streaming.

According to the proponent documentation, the equipment was separated in 3 categories: one for live production; one for live emission; and one for reception and playback. For the production and emission parts, the proponent provided a rack with most of the equipment attached and plugged, containing the most relevant items:

- Two content playout units
- Two authoring units, from different manufacturers
- Two live A/V encoders, one of them making use of a MMT packer and media delivery/distributor¹²

At the reception (receiver) end the proponent provided:

- Four Android-based reception systems, three of them for receiving MMT packets and one for receiving DASH (Dynamic Adaptive Streaming over HTTP) packets
- A soundbar and a AVR audio/video receptor and reproduction systems
- A HDMI-compatible TV set

¹¹ Stands for MPEG Multimedia Transport Protocol, a IP-based transport layer protocol developed by ISO/IEC MPEG succeeding the MPEG-2 TS protocol. This is used in the ATSC 3.0 standard.

¹² A gateway solution compliant to ATSC 3.0 for OTT services (to stream Over-The-Top media content over IP)

To carry out the system evaluation tests, the proponent submitted equipment to assemble at the destination end (receivers) in 3 different configurations to receive MMT packets, compliant to the real-time configuration informed at the SBTVD CfP. The configurations are named in colors, as follows:

- Yellow: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), TV, and AVR (HDMI compliant audio receiver and distributor for speakers arranged in a setup 5.1+4H according to the document "STUDIO RECOMMENDATIONS FOR 3D-AUDIO PRODUCTIONS WITH CANDIDATE TECHNOLOGY C").
- Blue: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), TV, and Soundbar (HDMI compliant audio receiver and player for immersive audio display based on an embedded loudspeaker array).
- Green: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), and TV (image and sound player).
- White: set consisting of the items: receiver (Android-based Shield) for Hybrid Delivery test cases (DASH-based), used either with Soundbar (HDMI) and/or TV through HDMI connection.

Each configuration is customized to facilitate the tests with each of the audio reproduction systems, and has its own IP-based receiver (Shield). They only share the TV, which input can be selected to receive from each of them. An additional receiver configuration includes:

- Set-top box LowaSIS STB¹³, to receive ATSC 3.0 signals through RF connection (connected to a DekTec DTU-315 modulator) and to feed the TV through HDMI connection. Additionally, the provided TV set is compliant with Candidate Technology C and capable of directly receiving ATSC 3.0 through RF input too.

6.4.3.1 Test 1 (Immersive audio)

System setup

Test Case 1 employed most of the receiver configurations described in the system setup in item 6.4.3. The next subsections describe the actual configurations used in each part of the test.

Test planning and execution

Test Case 1 (TC 1) according to the CfP is divided in 2 parts, checking the fulfillment of the following requirements:

- Test 1.1 (immersive audio for 2.0/5.1/5.1+4H/object-based audio formats), checking compliance to requirements AC1.1.1, AC1.1.2, AC1.1.3 and AC1.2
 - Test 1.1.1 (immersive audio for 2.0 audio format), checking compliance to AC1.1.1 requirement

¹³ ATSC 3.0 enabled set-top box, with native Candidate Technology C support.

- Test 1.1.2 (immersive audio for 5.1 audio format), checking compliance to AC1.1.2 requirement
- Test 1.1.3 (immersive audio for 5.1+4H audio format), checking compliance to AC1.1.3 requirement
- Test 1.1.4 (immersive audio for object-based audio format), checking compliance to AC1.2 requirement
- Test 1.2 (immersive audio for scene-based audio format), checking compliance to the requirement AC1.3

The test cases above are presented in the items 6.4.3.1.1 through 6.4.3.1.5, numbered serially.

6.4.3.1.1 Test 1.1.1 (Immersive audio - 2.0 audio format)

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 1.1.1 used 3 validated audio test content files #1 (ac01) as described in the following table. The actual test content file format streamed in the real-time setup and received via IP by the receiver/player was a .mov video file containing the respective audio test content payload.

	Audio content type:	ac01
1	Audio test content file: ac01-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac01-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac01-globo-1	Provider: Globo

Test 1.1.1 was performed with all 3 reproduction settings: Yellow (AVR), Blue (Soundbar) and Green (TV). The test was executed using the target bitrate for 2.0 format (48kbps). The Green setting (TV sound output) can not demonstrate the system's ability to present audio in the output setups 5.1 and 5.1+4H channels. The audio content format has only 2 channels and is not binaurally rendered for earphone listening, therefore it does not permit that "sound sources positioned in the production above the listener are perceived during playback on the external sound system also above the listener".

Test result: TC1.1.1 FULFILLED

The following table summarizes observations noticed during the test execution with every audio test content.

Audio test content		Observations
1	Audio test content file: ac01-mpegH	This test file used the configuration file ac01-mpegH_AMS.xml. No anomalies were observed during the tests.
2	Audio test content file: ac01-ac4	This test file used the configuration file ac01-ac4_AMS.xml
3	Audio test content file: ac01-globo-1	It was noticed that when comparing the audio playback on TV with other audio playback systems (Soundbar and AVR), the background ambient noise sound is louder than the other audio components also present in the file.

Final considerations (TC1.1.1):

There was an issue communicated to the proponent regarding the degradation of audio quality and presence of audio artifacts that occurred intermittently and more noticed with some contents, such as, for instance, an audio click at the end of the playback of the file ac01-globo-1, and an apparently “compression” noise in the part the actress suffers a bicycle accident. The cause of this issue was appropriately tracked down with the assistance of the proponent team, accessing remotely the system configuration, who detected an incorrect firmware version of the encoder used in the tests. The issue was then solved by restoring the appropriate firmware version of the encoder, clearing the occurrence of further artifacts. The results demonstrated the ability of the system to deliver spatiality, although some contents were not adequate for spatial audio features evaluation.

6.4.3.1.2 Test 1.1.2 (Immersive audio – Surround 5.1 audio format)

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 1.1.2 used 3 validated audio test content files #4 (ac04) as described in the following table. The actual test content file format streamed in the real-time setup and received via IP by the receiver/player was a .mov video file containing the respective audio test content payload.

Audio content type:		ac04
1	Audio test content file: ac04-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac04-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac04-globo-1	Provider: Globo

Test 1.1.2 was performed with all 3 reproduction settings: Yellow (AVR), Blue (Soundbar) and Green (TV). The test was executed using the target bitrate for 5.1 format (144kbps). The Green setting (TV sound output) does not have the ability to present audio in the output setups 5.1 and 5.1+4H channels. In the test using the blue system (soundbar) the spatial sound impression was weak, with little immersive content as expected from 5.1 audio¹⁴. The audio content in 5.1 channels in a planar horizontal plane does not permit that “sound sources positioned in the production above the listener are perceived during playback on the external sound system also above the listener”.

Test result: TC1.1.2 FULFILLED

During the test, an automatic increase in the volume of the soundbar system was heard in a moment of silence (absence of audio). The following table summarizes other observations noticed during the test execution with every audio test content.

Audio test content		Observations
1	Audio test content file: ac04-mpegh	None
2	Audio test content file: ac04-ac4	None
3	Audio test content file: ac04-globo-1	In some test rounds – before the restoration of the appropriate firmware version of the system encoder (see Final considerations of TC1.1.1) – it was noticed artifacts e.g. an audio click at the end of the playback of the file, and an apparently “compression” noise in the part where the actress suffers a bicycle accident.

Final considerations (TC1.1.2):

The observed degradation of audio quality and presence of audio artifacts reported in some test rounds were equivalent to the situation verified in Test TC1.1.1 (see Final considerations of TC1.1.1). The issue was solved likewise, by the restoration of the encoder’s appropriate firmware version, clearing the occurrence of further artifacts on subsequent test rounds.

6.4.3.1.3 Test 1.1.3 (Immersive audio – Surround 5.1+4H audio format)

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 1.1.3 used 3 validated audio test content files #6 (ac06) as described in the following table. The actual test content file format streamed in the real-time setup and received via IP by the receiver/player was a .mov video file containing the respective audio test content payload.

¹⁴ This is most likely due to the lack of immersive impression in the content program itself.

Audio content type:		ac06
1	Audio test content file: ac06-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac06-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac06-globo-1	Provider: Globo

Test 1.1.3 was performed with all 3 reproduction settings: Yellow (AVR), Blue (Soundbar) and Green (TV). The test was executed using the target bitrate for 5.1+4H format (256kbps). The Green setting (TV sound output) does not have the ability to present audio in the output setups 5.1 and 5.1+4H channels. In the test using the blue system (soundbar) the spatial sound impression was weak, with little immersive content as expected from 5.1 audio¹⁵.

Test result: TC1.1.3 FULFILLED

The following table summarizes observations noticed during the test execution with every audio test content.

Audio test content		Observations
1	Audio test content file: ac06-mpegh	During the test, an automatic increase in the volume of the soundbar system was heard in a moment of silence (absence of audio).
2	Audio test content file: ac06-ac4	None
3	Audio test content file: ac06-globo-1	The presence of immersive sound components coming from the upper part (4H) was present in the tested scenario, but with poor perception.

Final considerations (TC1.1.3):

None.

6.4.3.1.4 Test 1.1.4 (Immersive audio – Surround 5.1+4H audio format + 2 mono elements)

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 1.1.4 used 2 validated audio test content files #9 (ac09) as described in the following table. The actual test content file format streamed in the real-time setup and received via IP by the receiver/player was a .mov video file containing the respective audio test content payload.

Audio content type:		ac09
1	Audio test content file: ac09-mpegh-1	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac09-globo-1	Provider: Globo

¹⁵ This is most likely due to the lack of immersive impression in the content program itself.

Test 1.1.4 was performed with all 3 reproduction settings: Yellow (AVR), Blue (Soundbar) and Green (TV). The test was executed using the target bitrate for 5.1+4H plus 2 audio mono elements (352 kbps). The Green setting (TV sound output) does not have the ability to present audio in the output setups 5.1 and 5.1+4H channels.

Test result: TC1.1.4 FULFILLED

The following table summarizes observations noticed during the test execution with every audio test content.

Audio test content		Observations
1	Audio test content file: ac09-mpegh	None
2	Audio test content file: ac09-ac4	None
3	Audio test content file: ac09-globo-1	It was observed that during the reproduction by the green system (TV) the commentator channel was at a lower volume level compared to the background ambient (carnival), this fact did not occur when the same content was reproduced by the other systems blue (soundbar) and yellow (AVR). Even though the focus is on audio analysis, the image of the reproduced content shows clear signs of failure, crashes ¹⁶ .

Final considerations (TC1.1.4):

During the tests an intermittent anomaly was observed while executing “Stream – SBTVD 3.0 Test Ate me” e.g. with the green system (TV). An error occurred with the following message: “MMTP: Didn’t receive video packets to hand on for more than 1500 ms!!!”. On subsequent attempts the tests ran successfully. This issue was verified to have the same cause of the issue reported in the Test TC1.1.1 (see Final considerations of TC1.1.1) and was solved likewise, by the restoration of the encoder’s appropriate firmware version.

6.4.3.1.5 Test 1.2 (Immersive audio for scene-based audio format)

Test 1.2 checks compliance to the requirement AC1.3. To carry out TC 1.2, the High Order Ambisonics (HOA) content is required to be encoded in a MP4 video file format. In order to execute this process it was followed the script provided by the proponent in the document “Candidate Technology C – Test Procedures Documentation”, with the following steps:

- Convert the BWF/ADM test item “ac12-mpegh.wav” into a Candidate Technology C Production Format wav-file to be fed into the encoder. This file is a validated audio test content item (see Appendix I: Audio Test Content Validation).

¹⁶ Such observations are most likely due to the mix in the content program itself.

- Encode the ProRes Proxy video into an HEVC using (the program) FFMPEG, as described in section 2.6.11.6.3 at “Candidate Technology C – Test Procedures Documentation”.
- Encode the exported MPF.wav file + HEVC video using Candidate Technology C EncMux, as described in section 2.6.11.3 at “Candidate Technology C – Test Procedures Documentation”.

The file was encoded to the desired format with a bitrate of 320 kbps, and copied to the “Blue”, “Yellow” and “Green” receivers for non-real time playback. The proponent test procedure recommended using only two of the receiver configurations (blue and white) for listening with the Soundbar reproduction device. However the test lab decided to expand the test to consider other receiver configurations (yellow and green) in order to evaluate the listening performance with the TV stereo configuration and with the AVR discrete 5.1 configuration, as required in the CfP test procedure.

Test result: TC 1.2 FULFILLED

Final considerations (TC1.2):

Sound events located to the right, left and also above the listener were verified when the system allowed it, given the player’s output settings. The system proved to be efficient when reproduced in configurations with a reduced number of channels (5.1 and stereo).

6.4.3.2 Test 2 (Interactivity and personalization)

Test planning and execution

Test Case 2 (TC 2) according to the CfP is divided in 7 parts:

- Test 2.1 (interactivity and personalization), Requirement AC2.1: Language Selection.
- Test 2.2 (interactivity and personalization), Requirement AC2.1: Selection of different preselections.
- Test 2.3 (interactivity and personalization), Requirement AC2.1: Switch between multiple commentators.
- Test 2.4 (interactivity and personalization), Requirement AC2.1: Display of textual labels.
- Test 2.5 (interactivity and personalization), Requirement AC2.2: Audio object loudness interactivity, changing the level relative to the background.
- Test 2.6 (interactivity and personalization), Requirement AC2.3: Audio object interactivity, changing the object position.
- Test 2.7 (interactivity and personalization), Requirement AC2.4: Enable Interactivity when using external sound reproduction systems.

The majority of TC2 tests require the author of the metadata to verify if the changes are read by the receiver. In tests with the proponent system, the Laboratory test authored the metadata whenever required by the test procedures. However, one should notice that the test shall demonstrate the system’s ability to allow end-users to interact with the options and selections available, according to the broadcaster settings in the production, that can be interpreted as the original options delivered for the program in a previous defined metadata file, or as a station making modifications in real time.

6.4.3.2.1 Test 2.1 – Language selection

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 2.1 used 6 validated audio test content files as described in the following table.

Audio content type:		ac03, ac05, ac08
1	Audio test content file: ac03-mpegh-1	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac03-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac05-mpegh-1	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac05-ac4	Provider: AC-4 Proponents
5	Audio test content file: ac08-mpegh-1	Provider: MPEG-H Audio Proponents
6	Audio test content file: ac08-ac4	Provider: AC-4 Proponents

Test result: TC2.1 FULFILLED

The test was plenty fulfilled with the “mpeg-h-1” audio test content. There were problems with the “ac4” audio test content. The following table summarizes observations noticed during the test execution with every audio test content.

Audio test content		Observations
1	Audio test content file: ac03-mpegh-1	None
2	Audio test content file: ac03-ac4	It was observed it did not start playback with the preferred language available in the stream
3	Audio test content file: ac05-mpegh-1	None
4	Audio test content file: ac05-ac4	It was observed it did not start playback with the preferred language available in the stream
5	Audio test content file: ac08-mpegh-1	None
6	Audio test content file: ac08-ac4	It was observed it did not start playback with the preferred language available in the stream and also it did not start the playback with the default language active given that the preferred language was not available in the stream

Final considerations (TC2.1):

The test satisfied all the procedure criteria only for the MPEG-H authored audio contents. Regarding the observations noticed with content “ac4” above, the proponent provided an explanation that it can occur when the languages are not signaled as members of a Switch Group, but instead defined in independent presets for each language, once automatic language selection in Candidate Technology C is based on Switch Groups.

6.4.3.2.2 Test 2.2 - Selection of different preselections

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 2.2 used 4 validated audio test content files as described in the following table.

Audio content type:		ac08, ac11
1	Audio test content file: ac08-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac11-mpegh	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac11-ac4	Provider: AC-4 Proponents

Test result: TC2.2 FULFILLED

The test was plenty fulfilled with the “mpeg-h” audio test content. There were some problems with the “ac4” audio test content. The following table summarizes observations noticed during the test execution with every audio test content.

Audio test content		Observations
1	Audio test content file: ac08-mpegh	None
2	Audio test content file: ac08-ac4	there are 2 beeps and 2 speaker inputs in AD / no more voice option (not relevant for testing)
3	Audio test content file: ac11-mpegh	None
4	Audio test content file: ac11-ac4	None

Final considerations (TC2.2):

The test satisfied all the procedure criteria only for all authored audio contents.

6.4.3.2.3 Test 2.3 - Switch between multiple commentators

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 2.3 used two validated audio test content files as described in the following table.

Audio content type:		ac09
1	Audio test content file: ac09-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac09-globo	Provider: Globo

Test result TC2.3: FULFILLED

The test was plenty fulfilled with the tested audio test content. The following table summarizes observations noticed during the test execution with every audio test content.

	Audio test content	Observations
1	Audio test content file: ac09-mpegh	None
3	Audio test content file: ac09-globo	None

Final considerations (TC 2.3):

The test satisfied all the procedure criteria for all authored audio contents.

6.4.3.2.4 Test 2.4 - Display of textual labels

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 2.4 used 6 validated audio test content files as described in the following table.

	Audio content type:	ac08, ac09, ac11
1	Audio test content file: ac08-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac09-mpegh	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac09-globo	Provider: GLOBO
5	Audio test content file: ac11-mpegh	Provider: MPEG-H Audio Proponents
6	Audio test content file: ac11-ac4	Provider: AC-4 Proponents

Test result TC2.4: FULFILLED

The test was plenty fulfilled with the tested audio content. The following table summarizes observations noticed during the test execution with every audio test content.

	Audio test content	Observations
1	Audio test content file: ac08-mpegh	None
2	Audio test content file: ac08-ac4	None
3	Audio test content file: ac09-mpegh	None
5	Audio test content file: ac09-globo	None
6	Audio test content file: ac11-mpegh	None
7	Audio test content file: ac11-ac4	None

Final considerations (TC 2.4):

The test satisfied all the procedure criteria for all authored audio contents.

6.4.3.2.5 Test 2.5 - Audio object loudness interactivity, changing the level relative to the background

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 2.5 used 4 validated audio test content files as described in the following table.

	Audio content type:	ac08, ac09
1	Audio test content file: ac08-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac09-mpegh	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac09-globo	Provider: Globo

Test result TC2.5: FULFILLED

The test was plenty fulfilled with the tested audio test content. The following table summarizes observations noticed during the test execution with every audio test content.

Audio content type:		observations
1	Audio test content file: ac08-mpegH	none
2	Audio test content file: ac08-ac4	Test not executed due to the absence in the authoring system of the XML file indicated in the Candidate Technology C tests procedure documentation
3	Audio test content file: ac09-mpegH	none
4	Audio test content file: ac09-globo	none

Final considerations (TC 2.5):

The test satisfied all the procedure criteria for all authored audio contents.

6.4.3.2.6 Test 2.6 - Audio object interactivity, changing the object position

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 2.6 used 3 validated audio test content files as described in the following table.

Audio content type:		ac08, ac10
1	Audio test content file: ac08-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac010-mpegH	Provider: MPEG-H Audio Proponents

Test result TC2.6: FULFILLED

The test was plenty fulfilled with the “mpeg-h” audio test content. Some problems were observed with “ac4” audio test content. The following table summarizes observations noticed during the test execution with every audio test content.

Audio content type:		observations
1	Audio test content file: ac08-mpegH	none
2	Audio test content file: ac08-ac4	Test not executed due to the absence in the authoring system of the XML file indicated in the Candidate Technology C tests procedure documentation
3	Audio test content file: ac010-mpegH	none

Final considerations (TC 2.6):

The test satisfied all the procedure criteria only for the “MPEG-H” authored audio contents.

6.4.3.2.7 Test 2.7 - Enable Interactivity when using external sound reproduction systems

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 2.4 used 6 validated audio test content files as described in the following table.

Audio content type:		ac08 ac09 ac10
1	Audio test content file: ac08-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac09-mpegH	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac09-globo	Provider: Globo
5	Audio test content file: ac10-mpegH	Provider: MPEG-H Audio Proponents
6	Audio test content file: ac10-ac4	Provider: AC-4 Proponents

Test result TC2.7: FULFILLED

The test was plenty fulfilled with the tested audio contents. The following table summarizes observations noticed during the test execution with every audio test content.

	Audio content type:	Observations
1	Audio test content file: ac08-mpeg	none
2	Audio test content file: ac08-ac4	none
3	Audio test content file: ac09-mpeg	none
4	Audio test content file: ac09-globo	none
5	Audio test content file: ac10-mpeg	none
6	Audio test content file: ac10-ac4	none

Final considerations (TC 2.7):

The test satisfied all the procedure criteria.

6.4.3.3 Test 3 (Audio description)

System setup

To carry out the Test Case 3, following the proponent's documentation, it was used the proponent's named "Blue" (receptor) system, as described in item 6.4.3.1:

- Blue: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), TV, and Soundbar (HDMI compliant audio receiver and player for immersive audio display based on an embedded loudspeaker array).

Test planning and execution

Test Case 3 (TC 3) according to the CfP is divided in 4 parts:

- TC 3.1 – Audio description, Requirement AC3.1 and AC3.2: Audio description in the same stream as the main audio
- TC 3.2 – Audio description, Requirement AC3.3 Part 1: Audio description delivered as an additional audio object.
- TC 3.3 – Audio description, Requirement AC3.3 Part 2: Audio description delivered as additional audio objects and language selection.
- TC 3.4 – Audio description, Requirement AC3.3 Part 3: Audio description delivered as additional audio objects and spatial separation of main dialog and audio description.

6.4.3.3.1 Test 3.1 – Audio description in the same stream as the main audio

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 3.1 used 3 validated audio test content files as described in the following table.

Audio content type:		ac02, ac03
1	Audio test content file: ac02-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac02-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac03-mpegh	Provider: MPEG-H Audio Proponents

Test result TC 3.1: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac02-mpegh	none
2	Audio test content file: ac02-ac4	none
3	Audio test content file: ac03-mpegh	An extra test was done with the ac03-mpeg file which contains several audio descriptions

Final considerations (TC 3.1):

The test satisfied all the procedure criteria.

6.4.3.3.2 Test 3.2 – Audio description delivered as an additional audio object

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 3.2 used 4 validated audio test content files as described in the following table.

Audio content type:		ac03, ac08
1	Audio test content file: ac03-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac03-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac08-mpegh	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac08-ac4	Provider: AC-4 Proponents

Test result TC 3.2: FULFILLED

The test was plenty fulfilled with the audio test content. The following table summarizes observations noticed during the test execution with the audio test content.

Audio content type:		Observations
1	Audio test content file: ac03-mpegH	none
2	Audio test content file: ac03-ac4	none
3	Audio test content file: ac08-mpegH	none
4	Audio test content file: ac08-ac4	none

Final considerations (TC 3.2):

The test satisfied all the procedure criteria.

6.4.3.3.3 Test 3.3 - Audio description delivered as additional audio objects and language selection

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 3.3 used 4 validated audio test content files as described in the following table.

Audio content type:		ac03, ac08
1	Audio test content file: ac03-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac03-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac08-mpegH	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac08-ac4	Provider: AC-4 Proponents

Test result TC 3.3: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac03-mpeg	none
2	Audio test content file: ac03-ac4	Audio description in only one language
3	Audio test content file: ac08-mpeg	none
4	Audio test content file: ac08-ac4	Audio description in only one language

Final considerations (TC 3.3):

The test satisfied all the procedure criteria.

6.4.3.3.4 Test 3.4 – Audio description delivered as additional audio objects and spatial separation of main dialog and audio description

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 3.4 used 4 validated audio test content files as described in the following table.

Audio content type:		ac03, ac08
1	Audio test content file: ac03-mpeg	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac03-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac08-mpeg	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac08-ac4	Provider: AC-4 Proponents

Test result TC 3.4: FULFILLED

The test was plenty fulfilled with the “mpeg-h” tested audio test content. The following table summarizes observations noticed during the test execution with the audio test content.

Audio content type:		Observations
1	Audio test content file: ac03-mpeg	none
2	Audio test content file: ac03-ac4	none
3	Audio test content file: ac08-mpeg	none
4	Audio test content file: ac08-ac4	there is no option to spatialize any object in authoring

Final considerations (TC 3.4):

The test satisfied all the procedure criteria.

6.4.3.4 Test 4 (Audio emergency warning information)**System setup**

To carry out the Test Case 4, following the proponent's documentation, it was used the proponent's named "Blue" (receptor) system, as described in item 6.4.3.1:

- Blue: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), TV, and Soundbar (HDMI compliant audio receiver and player for immersive audio display based on an embedded loudspeaker array).

Test planning and execution

Test Case 4 (TC 4) according to the CfP has only one part:

- TC 4.1 (Audio emergency warning information), Requirement AC4.1

6.4.3.4.1 Test 4.1 – Audio emergency warning information

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 4.1 used 2 validated audio test content files as described in the following table.

Audio content type:		ac03
1	Audio test content file: ac03-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac03-ac4	Provider: AC-4 Proponents

Test result TC 4.1: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac03-mpegh	none
2	Audio test content file: ac03-ac4	none

Final considerations (TC 4.1):

The test satisfied all the procedure criteria.

6.4.3.5 Test 5 (Flexible audio playback configuration)

System setup

To carry out the Test Case 5, the proponent specified the use of their provided 3 different configurations to receive MMT packets, compliant to the real-time configuration informed at the SBTVD CfP. The configurations are named in colors, as follows:

- Yellow: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), TV, and AVR (HDMI compliant audio receiver and distributor for speakers arranged in a setup 5.1+4H according to the document "STUDIO RECOMMENDATIONS FOR 3D-AUDIO PRODUCTIONS WITH CANDIDATE TECHNOLOGY C").
- Blue: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), TV, and Soundbar (HDMI compliant audio receiver and player for immersive audio display based on an embedded loudspeaker array).
- Green: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), and TV (image and sound player).

Each configuration is customized to facilitate the tests with each of the audio reproduction systems, and has its own IP-based receiver (Shield). They only share the TV, which input can be selected to receive from each of them.

Test planning and execution

Test Case 5 (TC 5) according to the CfP has only one part, checking the compliance simultaneously to 2 requirements:

- TC 5.1 – Flexible audio playback configuration, Requirement AC5.1 (flexible loudspeaker configuration render) and AC5.2 (binaural render)

6.4.3.5.1 Test 5.1 – Flexible audio playback configuration

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 5.1 used 4 validated audio test content files as described in the following table.

Audio content type:		ac08, ac11
1	Audio test content file: ac08-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac011-mpegH	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac011-ac4	Provider: AC-4 Proponents

Test result TC 5.1: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac08-mpegH	none
2	Audio test content file: ac08-ac4	none
3	Audio test content file: ac011-mpegH	none
4	Audio test content file: ac011-ac4	none

Final considerations (TC5.1):

The test satisfied all the procedure criteria.

6.4.3.6 Test 6 (Consistent loudness)

System setup

This is a non-real time test case, and it used the proponent's system setup which is compliant to the setup of Fig. 41 from the SBTVD CfP.

The setup includes an encoder and multiplexer tool, admitting audio test content ingest into a suite of authoring tools, outputting .mp4 content files that can be played by a Candidate Technology C player embedded into a A/V receiver, and transmitted to the TV/receptor/soundbar/AVR through a HDMI interface.

Test planning and execution

Test Case 6 (TC 6) according to the CfP is divided in 3 parts:

- Test 6.1 (Consistent loudness), Loudness Normalization Test – Programs, checking compliance to requirements AC6.1
- Test 6.2 (Consistent loudness), Loudness Normalization Test – Preselections, checking compliance to the requirement A6.2
- Test 6.3 (Consistent loudness), Loudness Compensation Test, also checking compliance to the requirements AC6.2

6.4.3.6.1 Test 6.1 - Loudness Normalization Test – Programs

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 6.1 used 2 validated audio test content files as described in the following table.

Audio content type:		ac08, ac11
1	Audio test content file: ac08-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac11-mpegh	Provider: MPEG-H Audio Proponents

The audio content “ac4” was not used as its ADM metadata correctness was not verified by the proponent authoring tool (see Appendix I: Audio Test Content Validation).

Test result TC 6.1: FULFILLED

The test was plenty fulfilled with the “mpeg-h” audio test content. The following table shows the result of the analysis of loudness difference between expected and measured values, using the FFMPEG program, according to the procedure.

Table 9 - Loudness difference between expected and measured values, using the FFMPEG program.

Audio Content	Generated audio file	Expected Integrated Loudness (LUFS):	Measured Integrated Loudness (LUFS):	Difference (LUFS)
AC08	TC_6.1_Estudio_C_AC08F_NUC_5_1+4_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.1_Estudio_C_AC08F_NUC_5_1+4_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.1_Estudio_C_AC08F_NUC_5_1+4_-16_21-10-2021.wav	-16	-16.8	0.8

Audio Content	Generated audio file	Expected Integrated Loudness (LUFS):	Measured Integrated Loudness (LUFS):	Difference (LUFS)
AC11	TC_6.1_Estudio_C_AC11F_NUC_5_1+4_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.1_Estudio_C_AC11F_NUC_5_1+4_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.1_Estudio_C_AC11F_NUC_5_1+4_-16_21-10-2021.wav	-16	-17.1	1.1

The maximum difference in Integrated Loudness obtained in the test was 1.1 LUFS, which is within the tolerance required of +/-3.0 dB. The following table summarizes observations noticed during the test execution with every audio test content.

	Audio test content	Observations
1	Audio test content file: ac08-mpegh	None
2	Audio test content file: ac11-mpegh	None

Final considerations:

None for TC6.1.

6.4.3.6.2 Test 6.2 – Loudness Normalization Test – Preselections

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 6.2 used 2 validated audio test content files as described in the following table.

Audio content type:	ac08, ac11
1 Audio test content file: ac08-mpegh	Provider: MPEG-H Audio Proponents
2 Audio test content file: ac11-mpegh	Provider: MPEG-H Audio Proponents

The audio content “ac4” was not used as its ADM metadata correctness was not verified by the proponent authoring tool (see Appendix I: Audio Test Content Validation).

Test result TC 6.2: FULFILLED

This test employed 15 preselections for content ac08 and 12 preselections for content ac11, that were authored using the proponent authoring tool to add the test preselections. The following table shows the result of the analysis of loudness difference between expected and measured values, using the FFMPEG program, according to the test procedure.

Table 10 - Loudness difference between expected and measured values, using the FFMPEG program.

Audio Content	Generated audio file	Expected Integrated Loudness (LUFS):	Measured Integrated Loudness (LUFS):	Difference (LUFS)
AC08	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_0_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_0_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_0_-16_21-10-2021.wav	-16	-16.8	0.8
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_1_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_1_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_1_-16_21-10-2021.wav	-16	-16.8	0.8
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_2_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_2_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_2_-16_21-10-2021.wav	-16	-16.8	0.8
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_3_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_3_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_3_-16_21-10-2021.wav	-16	-16.8	0.8
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_4_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_4_-24_21-10-2021.wav	-24	-23.9	0.1
TC_6.2_Estudio_C_AC08F_NUC_5_1+4_preset_4_-16_21-10-2021.wav	-16	-16.8	0.8	

Audio Content	Generated audio file	Expected Integrated Loudness (LUFS):	Measured Integrated Loudness (LUFS):	Difference (LUFS)
AC11	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_0_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_0_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_0_-16_21-10-2021.wav	-16	-17.1	1.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_1_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_1_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_1_-16_21-10-2021.wav	-16	-17.1	1.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_2_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_2_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_2_-16_21-10-2021.wav	-16	-17.1	1.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_3_-31_21-10-2021.wav	-31	-30.9	0.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_3_-24_21-10-2021.wav	-24	-23.9	0.1
	TC_6.2_Estudio_C_AC11F_NUC_5_1+4_preset_3_-16_21-10-2021.wav	-16	-17.1	1.1

The maximum difference in Integrated Loudness observed in the test was 1.1 LUFS, which is within the tolerance required of +/-3.0 dB. The following table summarizes observations noticed during the test execution with every audio test content.

	Audio test content	Observations
1	Audio test content file: ac08-mpegh	None
2	Audio test content file: ac11-mpegh	None

Final considerations:

None for TC6.2.

6.4.3.6.3 Test 6.3 – Loudness Compensation Test

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 6.3 used 2 validated audio test content files as described in the following table.

Audio content type:		ac08, ac11
1	Audio test content file: ac08-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac11-mpegh	Provider: MPEG-H Audio Proponents

The audio content “ac4” was not used as its ADM metadata correctness was not verified by the proponent authoring tool (see Appendix I: Audio Test Content Validation).

Test result TC 6.3: FULFILLED

Two audio test content (one ac08 and one ac11) were reauthored using the proponent authoring tool and encoded to two .mp4 test files. Loudness compensation was verified and the perceived loudness variance during the specified user interactions was not significant. The following table summarizes observations noticed during the test execution with every audio test content.

Audio test content		Observations
1	Audio test content file: ac08-mpegh	None
2	Audio test content file: ac11-mpegh	None

Final considerations:

Any noticeable difference in the overall gain between minimum and maximum voice intensity is not constant, since the program does not allow evaluating the variation as it is dynamic.

6.4.3.7 Test 7 (Seamless configuration changes and A/V alignment)

System setup

To carry out the Test Case 7, following the proponent’s documentation, it was used the proponent’s named “Blue” (receptor) system, as described in item 6.4.3 system setup:

- Blue: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), TV, and Soundbar (HDMI compliant audio receiver and player for immersive audio display based on an embedded loudspeaker array).

The part 7 of the Test 7 used the “White” receptor:

- White: set consisting of the items: receiver (Android-based Shield) for Hybrid Delivery test cases (DASH-based), used either with Soundbar (HDMI) and/or TV through HDMI connection.

Test planning and execution

Test Case 7 (TC 7) according to the CfP is divided in 7 parts:

- TC7.1 (Seamless config changes), Requirement AC7.1, seamless configuration changes
- TC7.2 (Seamless config changes), Requirement AC7.2, seamless content playback during user interaction
- TC7.3 (Seamless config changes), Requirement AC7.3 Part 1, seamless content playback during changes in production
- TC7.4 (Seamless configuration changes), Requirement AC7.3 Part 2, seamless content playback during changes in production using a contribution feed
- TC7.5 (Seamless configuration changes), Requirement AC7.4 Part 1, seamless Ad-Insertion
- TC7.6 (Seamless configuration changes), Requirement AC7.4 Part 2, user select persistency after the Ad-break
- TC7.7 (Seamless configuration changes), Requirement AC7.4 Part 3, hybrid delivery

6.4.3.7.1 Test 7.1 – Seamless configuration changes

Regarding audio test content items used in Test TC 7.1, one test item was used that concatenates four audio contents: items 01, 04, 06 and 08, from validated audio test content items (see Appendix I: Audio Test Content Validation). The concatenated audio test content file that was created is described in the following table and exhibits a total bitrate of 448kbps.

Audio content type:		Concatenation of 01, 04, 06 and 08
1	Audio test content file: TC7-1_ac01_ac04_ac06_ac08-mpegh.mov	Provider: MPEG-H Audio Proponents

Test result TC 7.1: FULFILLED

The test fulfilled the requirement AC7.1. The following table summarizes observations noticed during the test execution with the audio test content.

Audio content type:		Observations
1	Audio test content file: TC7-1_ac01_ac04_ac06_ac08-mpegh.mov	Executed only with the concatenated video file created by Candidate Technology C, that was verified to be compliant to validated individual test items

Final considerations (TC7.1):

The test satisfied all the procedure criteria.

6.4.3.7.2 Test 7.2 – Seamless content playback during user interaction

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 7.2 used 4 validated audio test content files as described in the following table.

Audio content type:		ac08, ac11
1	Audio test content file: ac08-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac011-mpegH	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac011-ac4	Provider: AC-4 Proponents

Test result TC 7.2: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac08-mpegH	none
2	Audio test content file: ac08-ac4	no authoring was provided by the proponent that allows changing audio intensity
3	Audio test content file: ac011-mpegH	none
4	Audio test content file: ac011-ac4	no authoring was provided by the proponent that allows changing audio intensity

Final considerations (TC7.2):

The test satisfied all the procedure criteria.

6.4.3.7.3 Test 7.3 – Seamless content playback during changes in production

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 7.3 used 7 validated audio test content files as described in the following table.

Audio content type:		ac08, ac09, ac11
1	Audio test content file: ac08-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac09-mpegH	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac09-ac4	Provider: AC-4 Proponents
5	Audio test content file: ac09-globo	Provider: Globo
6	Audio test content file: ac011-mpegH	Provider: MPEG-H Audio Proponents
7	Audio test content file: ac011-ac4	Provider: AC-4 Proponents

Test result TC 7.3: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac08-mpegH	none
2	Audio test content file: ac08-ac4	none
3	Audio test content file: ac09-mpegH	No Audio Description, allows position and gain adjustments
4	Audio test content file: ac09-ac4	No Audio Description, allows creating switch language, deleting and creating presets, and changing labels
5	Audio test content file: ac09-globo	No Audio Description
6	Audio test content file: ac011-mpegH	No Audio Description, allows gain but not position adjustments
7	Audio test content file: ac011-ac4	Interactivity and authoring menu present, but without gain and position adjustment options

Final considerations (TC7.3):

The test satisfied all the procedure criteria, but observations above must be taken into account.

6.4.3.7.4 Test 7.4 – Seamless content playback during changes in production using a contribution feed

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 7.4 used 4 validated audio test content files as described in the following table.

Audio content type:		ac08, ac11
1	Audio test content file: ac08-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents
3	Audio test content file: ac11-mpegh	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac11-ac4	Provider: AC-4 Proponents

Test result TC 7.4: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac08-mpegh	The player returns to the default preset whenever you change an interactivity option on the secondary authoring unit (Junger)
2	Audio test content file: ac08-ac4	none
3	Audio test content file: ac11-mpegh	none
4	Audio test content file: ac11-ac4	none

Final considerations (TC7.4):

The test satisfied all the procedure criteria.

6.4.3.7.5 Test 7.5 – Seamless Ad-Insertion

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 7.5 used 2 validated audio test content files as described in the following table.

Audio content type:		ac01, ac11
1	Audio test content file: ac01-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac11-mpegh	Provider: MPEG-H Audio Proponents

Test result TC 7.5: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac01-mpegh	none
2	Audio test content file: ac11-mpegh	none

Final considerations (TC7.5):

The test satisfied all the procedure criteria.

6.4.3.7.6 Test 7.6 – User select persistency after the Ad-break

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 7.5 used 1 validated audio test content file as described in the following table.

Audio content type:		ac01, ac11
1	Audio test content file: ac01-mpegh	Provider: MPEG-H Audio Proponents

Test result TC 7.6: FULFILLED

The test was fulfilled with the tested audio content. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac01-mpegh	none

Final considerations (TC7.6):

The test satisfied all the procedure criteria.

6.4.3.7.7 Test 7.7 – Hybrid delivery

Test 7.7 addresses the case of hybrid delivery. Although the proponent's test procedure instructions documentation cites the "blue" receptor for this test, the procedure itself and illustrations depict the usage of the "White" receptor (see item 6.4.3 system setup) for Hybrid Delivery test cases (DASH-based), connected to the Soundbar and/or TV through HDMI connection.

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 7.7 used 2 validated audio test content files as described in the following table.

Audio content type:		ac03
1	Audio test content file: ac03-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac03-ac4	Provider: AC-4 Proponents

Test result TC 7.7: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac01-mpegh	When the secondary server is disabled, the interactivity options become unavailable even after reactivating the secondary server; however, as there was no request to test the interactivity system when disabling and re-enabling the secondary server, the test was considered approved.
2	Audio test content file: ac03-ac4	none

Final considerations (TC7.7):

The test satisfied all the procedure criteria. Regarding the issue observed, after disabling the secondary server, in that the interactivity settings are preserved but the user interface on the device becomes not responsive (even after reactivating the secondary server), it was identified a bug in the Android framework that was solved later by the proponent.

6.4.3.8 Test 8 (Audio coding efficiency)

Not applicable (Test 8 addresses the requirement AC8.1 which is to be assessed through documentation analysis, see item 6.4.1.1).

6.4.3.9 Test 9 (Audio End to end latency)

The requirement AC9.1 follows the accomplishment of requirements AC1.1.1 (TC1.1.1), AC 1.1.2 (TC1.1.2) and AC1.1.3 (TC1.1.3). The result for Test 9.1 is, therefore, fulfilled, as these requirements were fulfilled.

As defined in the CfP, the requirement AC9.2 this is not addressed in test cases, but referred to the analysis documentation of the proponent. The Candidate Technology C provided in the document 1_Proposal.pdf a measurement for the latency in the Candidate Technology C chain. The figure 53 in this document shows an overview of the end-to-end latency of the Candidate Technology C chain, and in the same section it informs that “the complete decoding and rendering step for Candidate Technology C introduces a maximum delay of 38.35 ms (which is calculated for the worst-case scenario, as specified in the corresponding ISO/IEC Standard).

6.4.3.10 Test 10 (A/V synchronization)**System setup**

To carry out the Test Case 10, the proponent specified the use of their provided 3 different configurations to receive MMT packets, compliant to the real-time configuration informed at the SBTVD CfP. The configurations are named in colors, as follows:

- Yellow: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), TV, and AVR (HDMI compliant audio receiver and distributor for speakers arranged in a setup 5.1+4H according to the document “STUDIO RECOMMENDATIONS FOR 3D-AUDIO PRODUCTIONS WITH CANDIDATE TECHNOLOGY C”).
- Blue: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), TV, and Soundbar (HDMI compliant audio receiver and player for immersive audio display based on an embedded loudspeaker array).
- Green: set consisting of the items: receiver (Android-based Shield, for receiving streaming via IP), and TV (image and sound player).

Each configuration is customized to facilitate the tests with each of the audio reproduction systems, and has its own IP-based receiver (Shield). They only share the TV, which input can be selected to receive from each of them.

Test 10 included an additional configuration provided by the proponent, as follows:

- Set-top box LowaSIS STB, connected to the DekTec DTU-315 modulator (via RF) and connected to the TV set (via HDMI).

Test planning and execution

Test Case 10 (TC 10.1) according to the CfP has only one part:

- TC10.1 (A/V synchronization), Requirement AC10.1

6.4.3.10.1 Test 10.1 (A/V synchronization), Requirement AC10.1

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC10.1 used 4 validated audio test content files as described in the following table.

Audio content type:		ac03, ac05, ac07, ac09
1	Audio test content file: ac03-mpegh	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac05-mpegh	Provider: MPEG-H Audio Proponents
3	Audio test content file: ac07-mpegh	Provider: MPEG-H Audio Proponents
4	Audio test content file: ac09-mpegh	Provider: MPEG-H Audio Proponents

Test result TC 10.1: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac03-mpegh	none
2	Audio test content file: ac05-mpegh	none
3	Audio test content file: ac07-mpegh	none
4	Audio test content file: ac09-mpegh	none

Final considerations (TC10.1):

The test satisfied all the procedure criteria.

6.4.3.11 Test 11 (New immersive audio services)**System setup**

For Test 11 the following equipment were used:

- Samsung Galaxy S8 cellular phone
- Samsung GearVR glasses
- Set of headphones
- Control NUC PC

Test planning and execution

Test Case 11 (TC 11.1) addresses the demonstration of one or more demonstrations of VR / AR / XR / 3DoF / 6DoF services support. According to the CfP it has only one part:

- TC11.1 (New immersive audio services), Requirement AC11.1

6.4.3.11.1 Test 11.1 – New immersive audio services

Regarding audio test content items used in this test, it employed a set of audio test content items prepared by the proponent, as described in the following table.

Audio content type:		-
1	Audio test content file: tc11-mpeg-1.mp4	Provider: prepared by the proponent
2	Audio test content file: tc11-mpeg-2.mp4	Provider: prepared by the proponent
3	Audio test content file: tc11-mpeg-3.mp4	Provider: prepared by the proponent

The test verified the demonstration of 3D audio VR and 3DoF support. The first test round could verify only the decoding feature (playback of the audio content test files). In a second test round for TC 11.1 the proponent provided an encoder tool to prepare test content files, and it was verified the encoding feature (offline/local) followed by subsequent decoding the test items prepared by the test lab.

Test result TC 11.1: PARTIALLY FULFILLED

The test was partially fulfilled as the test scheme provided did not permit the evaluation of the capability of real-time encoding and delivering/decoding in a streaming/broadcasting fashion. The codec satisfies VR and 3DoF capabilities. It demonstrated the capability of encoding and decoding offline through the cell phone app. The test scheme presented did not allow the evaluation of the system capability in delivering the format over broadcast or broadband network.

The following table summarizes the verified results and observations collected to every test procedure step, as defined in the SBTVD CfP, and observations noticed during the test execution with the audio test contents.

Test procedure steps:		Results and observations
1	Features of the codec	It demonstrated VR and 3DoF capabilities in 3D scenes/programmes with 3D video. Status: fulfilled.
2	The readiness for real-time coding/decoding	The encoding process occurs offline on a PC and the mp4 file is copied to a mobile phone where the decoding process takes place. It was not demonstrated a complete live encoding-transmitting at one side and the receiving-decoding at another side (terminal), a process verifiable through a broadcast/streaming chain. It is our perception that the actual demonstration showed a non-real-time (offline and local) encoding and decoding process. Status: not fulfilled.
3	The readiness of delivery of the format over broadcast and broadband networks	In the provided setup it was not demonstrated a solution for delivering this format through broadcasting or live streaming. Status: not fulfilled.
4	How the application works in detail	The test procedure presented basic steps to start an app and navigate in a 3D/VR scene capable of 3DoF. Further documents provided through the process of this issue, included a demonstration of file-based local encoding capability and the API specification submitted to the Application Coding group, which is referenced in the document "2_API_Specification.pdf" enlarges the level of detail provided. Although the use of this API is not detailed in the actual demonstration provided for TC11, as the level of detail required is not specified in the CfP, we consider that all the information provided fulfills this part of the requirement. Status: fulfilled.
5	How other applications could manipulate the audio codec stream to perform the same results exhibited in the demonstration (e.g. some sort of API specification)	Additional information on the Candidate Technology C API specification was provided, this step of the requirement is fulfilled. The proposed test was aimed only for the Samsung Gear, there were no further procedures to test the capability of manipulation of audio in other applications as suggested in the test procedure. Status: fulfilled.

Final considerations (TC11.1):

The test steps 1, 4 and 5 are fulfilled, and steps 2 and 3 are not fulfilled. Therefore, for the whole requirement AC11.1, the status is classified as partially fulfilled.

6.4.3.12 Test 12 (Interoperability with different distribution platforms)

System setup

Test 12 addresses checking the system's ability to send multiple audio contents over two or more communications channels. Although the proponent's test procedure instructions inform the use of the "blue" receptor with the Soundbar and TV, the actual procedure and illustrations in the documentation make it clear to use the hybrid delivery "White" receptor for DASH streaming from the Streaming Server.

Test planning and execution

Test Case 12 (TC 12) according to the CfP has only one part:

- TC 12.1 (Interoperability with different distribution platforms), checking the compliance to the requirement AC12.1.

6.4.3.12.1 Test 12.1 – Interoperability with different distribution platforms)

Regarding audio test content items used in this test, some files were discarded due to errors encountered in either ADM metadata description or payload (see Appendix I: Audio Test Content Validation). Test TC 12.1 used 2 validated audio test content files as described in the following table.

Audio content type:		ac08
1	Audio test content file: ac08-mpegH	Provider: MPEG-H Audio Proponents
2	Audio test content file: ac08-ac4	Provider: AC-4 Proponents

Test result TC 12.1: FULFILLED

The test was fulfilled with the tested audio test contents. The following table summarizes observations noticed during the test execution with the audio test contents.

Audio content type:		Observations
1	Audio test content file: ac08-mpegH	Audio switch takes about 5 seconds
2	Audio test content file: ac08-ac4	Audio switch takes about 5 seconds

Final considerations (TC12.1):

The test satisfied all the procedure criteria. About the observations in the test, the proponent informed that such delay was expected, since the DASH protocol was used, and that for applications requiring low latency, a different protocol, such as Low Latency DASH (LL-DASH), should be used.

6.4.3.13 Test 13 (Audio scalability and extensibility)

This Test Case addresses the requirements AC13.1 (scalability) and AC13.2 (extensibility). The requirement AC13.1 is verified during the execution of Test Case TC12, and therefore it was fulfilled for Candidate Technology C (see item 6.4.3.12).

The requirement AC13.2 is not analyzed as a feature tested in laboratory, but it is addressed in the Documentation Analysis phase (see section 6.4.1), based on the documentation provided by the proponent.

6.4.4 Summary of Test Results

The following table summarizes the test results for Candidate Technology C. The table is organized in terms of fulfillment of the requirements addressed in the test cases.

Use case		minimum technical specification			fulfillment
AC1	Enable immersive (3D) audio.	AC1.1.1	channel-based	2.0	fulfilled [NOTE: see 6.4.3.1.1]
		AC1.1.2		5.1	fulfilled [NOTE: see 6.4.3.1.2]
		AC1.1.3		5.1 + 4H	fulfilled [NOTE: see 6.4.3.1.3]
		AC1.2	object-based		fulfilled [NOTE: see 6.4.3.1.4]
		AC1.3	scene-based (HOA)		fulfilled [NOTE: see 6.4.3.1.5]
AC2	Enable end-user interactivity/personalization when allowed by the broadcaster (e.g. switch among different languages, sports commentators, adjust the commentator loudness level and position).	AC2.1	switch components (audio objects and alternative full mix substreams)		fulfilled [NOTE: see 6.4.3.2]
		AC2.2	adjust object loudness		fulfilled [NOTE: see 6.4.3.2]
		AC2.3	adjust object position		fulfilled [NOTE: see 6.4.3.2]
		AC2.4	enable interactivity when using external sound reproduction devices		fulfilled [NOTE: see 6.4.3.2]

Use case		minimum technical specification		fulfillment
AC3	Enable audio description delivery in the same stream as the main audio, as an alternative full mix or as an additional audio object with associated metadata.	AC3.1	audio description delivery in the same stream as the main audio	fulfilled [NOTE: see 6.4.3.3; 6.4.3.5]
		AC3.2	audio description delivery as an alternative full mix	fulfilled [NOTE: see 6.4.3.3; 6.4.3.5]
		AC3.3	audio description delivery as an additional audio object with associated metadata	fulfilled [NOTE: see 6.4.3.3]
AC4	Enable emergency warning information delivery using audio description.	AC4.1	emergency warning information audio description	fulfilled [NOTE: see 6.4.3.4]
AC5	Enable a single delivery format for multiple audio playback configurations (TV loudspeakers, soundbars, home theaters, binaural).	AC5.1	flexible loudspeaker configuration render	fulfilled [NOTE: see 6.4.3.5]
		AC5.2	binaural render	fulfilled [NOTE: see 6.4.3.5]
AC6	Enable consistent loudness across programs and inside the same program.	AC6.1	consistent loudness across programs	fulfilled [NOTE: see 6.4.3.6]
		AC6.2	consistent loudness after user interaction	fulfilled [NOTE: see 6.4.3.6]
AC7	Enable seamless configuration changes and A/V alignment.	AC7.1	seamless playback during configuration changes (e.g. from 5.1+4H to stereo)	fulfilled [NOTE: see 6.4.3.7; 6.4.3.7.1]
		AC7.2	seamless playback during user interaction (e.g. enable/disable several audio elements)	fulfilled [NOTE: see 6.4.3.7]
		AC7.3	seamless playback during changes in production (e.g. broadcaster removes one object)	fulfilled [NOTE: see 6.4.3.7]
		AC7.4	seamless and sample-accurate stream splicing or ad-insertion at any time instance, even if some of the streams come from different distribution platforms (e.g. switch between over-the-air and Internet delivery)	fulfilled [NOTE: see 6.4.3.7]
AC8	Provide state-of-the-art coding efficiency, to allow better quality audio in limited capacity channels (over-the-air or Internet).	AC8.1	bit rate kbps @ MOS 4 / MUSHRA > 80 or equivalent objective metric	not applicable [NOTE: see 6.4.3.8]
AC9	Provide live audio with minimum end-to-end latency.	AC9.1	real-time encoding	fulfilled [NOTE: see 6.4.3.9]
		AC9.2	latency ms	not applicable [NOTE: see 6.4.3.9]

Use case		minimum technical specification			fulfillment
AC10	Provide audio/video synchronization.	AC10.1	A/V sync	frame-accurate	fulfilled [NOTE: see 6.4.3.10; 6.4.3.10.1]
AC11	Enable new immersive audio services.	AC11.1	VR / AR / XR / 3DoF / 6DoF support		partially fulfilled [NOTE: see 6.4.3.11; 6.4.3.11.1]
AC12	Enable interoperability with different distribution platforms (e.g. DTT, cable, IPTV, DTH satellite, fixed broadband, 4G/5G mobile broadband, home network).	AC12.1	interoperability with different distribution platforms		fulfilled [NOTE: see 6.4.3.12.1]
AC13	Enable scalability (e.g. to enhance the over-the-air audio experience with additional Internet-delivered audio content, such as new sports commentator options) and extensibility (support new settings and/or features in the future, in a backward-compatible way).	AC13.1	scalability		fulfilled [NOTE: see 6.4.3.13]
		AC13.2	extensibility		not applicable [NOTE: see 6.4.3.13]

additional requirements		fulfillment
AC-AR1	Provide free of charge test content (BW64 file with ADM metadata #1) with the required technical specification, strictly for technical evaluation of the SBTVD Forum (non-commercial usage). The content shall not make any reference to commercial brands. NOTE #1: The provided free of charge test content shall include, in addition to the BW64 (RF64 / linear PCM / 48 kHz / signed 24-bit little-endian) file with ADM metadata as informed in AC-AR1, its corresponding video content in QuickTime File Format (.mov) containing a ProRes 422 Proxy video (1080p59.94 / 10-bit / SDR / BT.2020).	fulfilled
AC-AR2	Provide free of charge reference encoder and decoder (software or hardware) with its corresponding documentation, strictly for temporary technical evaluation of the SBTVD Forum (non-commercial usage).	fulfilled

Appendix I: Audio Test Content Validation

The mandatory tests of the present SBTVD CfP used audio test content items provided by four (4) different sources: the proponents of three candidate technologies (MPEG-H Audio, AVSA and AC-4) and Rede Globo. The files were available for the test lab at the SBTVD Forum SFTP server, and also each proponent's system included versions of the test content. Test content files include¹⁷:

- Audio .wav files, which should be incorporated to video .mov files
- Video .mov files, to be played back by A/V content players, and
- Metadata .xml files, which describe the audio programme organization within the payload

However, as verified in the proponents' procedures and in their hardware, we noticed discrepancies in content payload, file naming conventions and diverse versions of .xml (metadata) files. In order to provide a common reference set of audio test content items, the test lab carried out a comprehensive check of all the test items in the proponents' systems against the reference files contained in the SFTP server.

The following table shows the audio content (ac) items that were checked against its audio and video content (e.g. equivalence of audio files, levels and duration/length of audio content in .mov files to the reference audio files in the SFTP server), the files structure and specified bitrate, the validation of ADM metadata according to EAR (EBU ADM Renderer) reference software¹⁸, the Channel assignment chunk (CHNA), and the conformity also to axml chunk checking using the Fraunhofer IIS ADM Info Tool¹⁹.

After this evaluation, 24 (twenty four) audio test content items were validated to be used in the Test Cases, as marked in green (validated) in the table. For all the test cases compliant to the real-time setup as specified in Figure 42 of the CfP, the test content items were loaded into a memory card and played back using the A/V playout units defined by the test laboratory. A/V players were provided by Rede Globo (a Hyperdeck from BlackMagic and Media Express v2.7 from BlackMagic). The test content items were also played using the proponent's provided players, following the proponent's procedures.

NOTE: In the nomenclature adopted for naming the content files, "ac4" refers to the test content provided by AC-4 proponents, and "mpeg-h" refers to the test content provided by MPEG-H Audio proponents, and must not be assumed that these files were encoded, respectively, by AC-4 or by MPEG-H Audio codecs.

¹⁷ This test content file set excludes .mp4 files provided by the proponents for additional/alternative tests.

¹⁸ EBU ADM Renderer (EAR), https://github.com/ebu/ebu_adm_renderer

¹⁹ Fraunhofer IIS ADM Info Tool, <https://www.iis.fraunhofer.de/en/ff/amm/dl/software/adm-info-tool.html>

Table 11 - Validated Audio Test Content Items

Audio content Structure and bitrate	Providers' content items	Validation compliant to SBTVD	Validation compliant to ITU-R BS.2076-2	Validation axml ADM Fraunhofer	Validation chna	A/V content validation	Content description	Observations regarding to EBU ADM Tool (EAR)
AC01 1: Stereo mix (Language 1) 2ch / 48kbps	ac01-ac4-1	Valid	Valid	Not Valid	Valid	OK	Aphorism on nature	
	ac01-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	OK	Panoramic cloud forest	Contains 2 AudiolD, both with trackIndex =1
	ac01-globo-1	Valid	Valid	Valid	Valid	OK	Mountain bike	
	ac01-mpeg-1	Valid	Valid	Valid	Valid	OK	Trains passing by	
AC02 1: Stereo mix (Language 1) + 2: Mix Estéreo (Language 2) + 3: Stereo Audiodescription (Language 1) 6ch / 144kbps	ac02-ac4-1	Valid	Valid	Not Valid	Valid	OK	Aphorism on nature	
	ac02-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	Not Valid	Panoramic cloud forest	Contains 2 AudiolD (lines 3 and 4), both w/ trackIndex =3. CfP requests 6 channels, chna has only 5
	ac02-mpeg-1	Valid	válido	Valid	Valid	OK	Phoenix - 2.0 German & French	
AC03 1: Channel Bed 2.0 + 2: Language 1 Mono + 3: Language 2 Mono + 4: Audiodescription Mono (Language 1) + 5: Mono Emergency Warning Information Mono 6ch / 192kbps	ac03-ac4-1	Valid	Valid	Not Valid	Valid	OK	Aphorism on nature	
	ac03-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	Not Valid	Panoramic cloud forest	Contains 2 AudiolD (lines 3 and 4), both w/ trackIndex =3. CfP requests 6 channels, chna has only 5
	ac03-mpeg-1	Valid	Valid	Valid	Valid	OK	4ever short stereo 2.0	

Audio content Structure and bitrate	Providers' content items	Validation compliant to SBTVD	Validation compliant to ITU-R BS.2076-2	Validation axml ADM Fraunhoufer	Validation chna	A/V content validation	Content description	Observations regarding to EBU ADM Tool (EAR)
AC04 1: Channel Bed 5.1 6ch / 144kbps	ac04-ac4-1	Valid	Valid	Not Valid	Valid	OK	Aphorism on nature	
	ac04-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	OK	Panoramic cloud forest	Contains 2 Audioid (lines 3 and 4), both w/ trackIndex =3. CfP requests 6 channels, chna has only 5
	ac04-globo-1	Valid	Valid	Valid	Valid	OK	Mountain bike	
	ac04-mpeg-1	Valid	Valid	Valid	Valid	OK	Record tv news report	
AC05 1: Channel Bed 5.1 + 2: Language 1 Mono + 3: Language 2 Mono 8ch / 240kbps	ac05-ac4-1	Valid	Valid	Not Valid	Valid	OK	Aphorism on nature	
	ac05-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	Not Valid	Panoramic cloud forest	Contains 2 Audioid (lines 3 and 4), both w/ trackIndex =3. CfP requests 8 channels, chna has only 5
	ac05-mpeg-1	Valid	Valid	Valid	Valid	OK	One day in berlin 5.1	Considers language channels (index= 7 and 8) as "AC_0001000X_00" (audioTrackFormatIDRef), which should be "AC_0003000X_00"
AC06 1: Channel Bed 5.1+4H 10ch / 256kbps	ac06-ac4-1	Valid	Valid	Not Valid	Valid	OK	Aphorism on nature	
	ac06-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	OK	Panoramic cloud forest	chna: Contains 2 Audioid (lines 3 and 4), both w/ trackIndex =3. CfP requests 10 channels, chna has only 5
	ac06-globo-1	Valid	Valid	Valid	Valid	OK	Mountain bike	
	ac06-mpeg-1	Valid	Valid	Valid	Valid	OK	Eurovision Sweden	
AC07 1: Channel Bed 5.1+4H + 2: Language 1 Mono + 3: Language 2 Mono 12ch / 352kbps	ac07-ac4-1	Valid	Valid	Not Valid	Valid	OK	Aphorism on nature	
	ac07-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	Not Valid	Panoramic cloud forest	Contains 2 Audioid (lines 3 and 4), both w/ trackIndex =3. CfP requests 12 channels, chna has only 5
	ac07-mpeg-1	Valid	Valid	Valid	Valid	OK	Le Mans Astray - 5.1+4H	

Audio content Structure and bitrate	Providers' content items	Validation compliant to SBTVD	Validation compliant to ITU-R BS.2076-2	Validation axml ADM Fraunhofer	Validation chna	A/V content validation	Content description	Observations regarding to EBU ADM Tool (EAR)
AC08 1: Channel Bed 5.1+4H + 2: Language 1 Mono + 3: Language 2 Mono + 4: Audiodescription Mono (Language 1) + 5: Stadium Announcer Mono 14ch / 448kbps	ac08-ac4-1	Valid	Valid	Not Valid	Valid	OK	Aphorism on nature	Contains birds sounds while the SBTVD CfP asks for human speaker "5: Stadium Announcer Mono"
	ac08-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	Not Valid	Panoramic cloud forest	Contains 2 AudiolD (lines 3 and 4), both w/ trackIndex =3. CfP requests 14 channels, chna has only 5
	ac08-mpeg-1	Valid	Valid	Valid	Valid	OK	European championship Berlin/Glasgow 2018	axml: ACO_1002 and ACO_1003 (line 72 and 80) have dialogueContentKind="5" indicating commentator, and in the call indicates 2 mono languages, following ITU-R BS.2076-2 the value should be "1". ACO_1005 (line 96) has dialogueContentKind="1" indicating (plot) dialog, and in the call it indicates stadium announcer, following ITU-R BS.2076-2 the value should be "5". Deliberation that attribution is acceptable validated the content.
AC09 1: Channel Bed 5.1+4H + 2: Commentator 1 Mono + 3: Commentator 2 Mono 12ch / 352kbps	ac09-ac4-1	Not Valid	Not Valid	Not Valid	Valid	OK	Aphorism on nature	Error identified: Lines 19 and 23: nonDialogueContentKind="5" in non-conformity with pages 38 and 39 of ITU-R BS2076-2 where values range from 0 to 2, and axml has value = 5. These contents according to the SBTVD CfP should be commentators, and so the statement in the axml should be: DialogueContentKind="5".
	ac09-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	Not Valid	Panoramic cloud forest	Contains 2 AudiolD (lines 3 and 4), both w/ trackIndex =3. CfP requests 12 channels, chna has only 5
	ac09-globo-1	Valid	Valid	Valid	Valid	OK	Rio de Janeiro carnival	
	ac09-mpeg-1	Valid	Valid	Valid	Valid	OK	Carnival 2020 - Rio de Janeiro 5.1+4H	Contains 2 extra AudiolDs (index= 11 and 12). CfP indicates 12 channels, chna has 14 channels. Ch11/12 = sing and Ch13 and Ch14 = commentators (mono): Content works correctly.

Audio content Structure and bitrate	Providers' content items	Validation compliant to SBTVD	Validation compliant to ITU-R BS.2076-2	Validation axml ADM Fraunhofer	Validation chna	A/V content validation	Content description	Observations regarding to EBU ADM Tool (EAR)
AC10 1: Channel Bed 5.1+4H + 2: Language 1 Mono + 3: Language 2 Mono + 4: Dynamic object Mono 13ch / 400kbps	ac10-ac4-1	Not Valid	Valid	Not Valid	Not Valid	OK	Aphorism on nature	CfP indicates 13 channels, chna has 12, but the content presents 13 channels.
	ac10-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid	OK	Panoramic cloud forest	chna: contains 2 AudioID (lines 3 and 4), both with trackIndex =3. The CfP indicates 13 channels, the chna reveals only 5
	ac10-mpeg-1	Valid	Valid	Valid	Valid	OK	Le Mans Astray - 5.1+4H	
AC11 1: Channel Bed 5.1+4H + 2: Language 1 Mono + 3: Language 2 Mono + 4: Mix Estéreo (Language 1) + 5: Mix Mono (Language 2) 15ch / 448kbps	ac11-ac4-1	Valid	Valid	Not Valid	Valid	OK	Aphorism on nature	
	ac11-avsa-11	Not Valid	Not Valid	Not Valid	Not Valid	OK	Panoramic cloud forest	chna: contains 2 AudioID (lines 3 and 4), both with trackIndex =3. The CfP indicates 15 channels, the chna reveals only 5
	ac11-mpeg-1	Valid	Valid	Valid	Valid	OK	European song contest Lisbon 2018 5.1+4H	Considers language channels (index= 11 and 12) as "AC_0001000X_00" (audioTrackFormatIDRef), which should be "AC_0003000X_00".
AC12 1: Higher-Order Ambisonics (3rd order, ACN channel ordering, SN3D gain normalization) 16ch / 320kbps	ac12-avsa-1	Not Valid	Not Valid	Not Valid	Not Valid: 5 AudioID	Created at test time	Panoramic cloud forest	N3D Gain Normalization divergent from expected SN3D
	ac12-mpeg-1	Valid	Valid	Not Valid	Valid	Created at test time	Clouds of franconia	No indication of normalization in ADM (EBU). audioPackFormat of type "0004" for HOA objects is no issue for BS.2076-2.

Appendix II: Additional Tests – Candidate Technology A

The proponents of Candidate Technology A have submitted equipment, software, and a test procedure documentation describing a system setup compliant to the SBTVD CfP requirements, and test procedures for the mandatory tests, as defined in the SBTVD Forum CfP. In the same documentation, the proponent also provided an alternative test setup and a set of additional test procedures to demonstrate the features required in the CfP.

Their primary system setup, aimed at the mandatory tests required by the CfP, has presented failures that could not be solved in time, and which preempted the chance of running the mandatory tests with success. In face of this, the proponent decided to authorize the execution of the additional tests using their alternative test setup.

This section presents the results and observations collected from executing the additional test set, all tests following the proponent's procedures instructions using the alternative test setup provided, according to figure 19 (for the "real-time streaming setup") in the document "Instructions for SBTVD TV 3.0 Test v1.01". The audio test content used for the tests were the test signals provided by the proponent, available in the NUC within a DASH-based directory, as specified in the test procedures.

It should be noticed that the alternative tests were performed in an environment based on file playback in the NUC and delivery to the receptor system through RF and IP connections, using a HbbTV hybrid delivery system. As for the test configuration, the laboratory had no way to check or it was not possible to assess that the specified test signals were invoked by the application.

NOTE: The discrete Surround system provided by the proponent is 5.1+2H capable (not 4H).

Table 12 - Summary of additional tests results (Candidate Technology A)

	Test Case	Result
1	<p>TC1.2 - Requirement AC1.3: Enable scene-based (HOA) immersive audio</p>	<p>Test signals: It was assumed that the video file from the NUC was AC12_HOA (MPEG-H) Receptor system used: AVR receiver and soundbar Observations: The test was executed with success. Test used the proponent's "Real-time streaming setup" as on page 19 of their instructions documentation. Receptor system used: Soundbar Observations: The system was able to reproduce 3D experience with success. We were unable to switch LG soundbar to 2.0 in order to test a stereo setup.</p>

Test Case	Result
<p>2</p> <p>TC2.1 - Requirement AC2.1: Enable end-user interactivity/personalization - Language selection</p>	<p>Test signals: It was assumed that the video files from the NUC were AC03_20_2D, AC05_51_2D and AC08_514_2D (AC-4 and MPEG-H). Receptor system used: Soundbar</p> <p>Observations: The test was partially successful. The system was not able to maintain user preferred language when the playback was restarted.</p> <p>It was not possible to do the last part of the test (Start the playback at receiver tune-in with the default language active, given that the preferred language is not available in the authored and received stream) because the system does not allow any authoring.</p>
<p>3</p> <p>TC2.2 - Requirement AC2.1: Enable end-user interactivity/personalization - selection of different preselection</p>	<p>Test signals: It was assumed that the video files from the NUC were AC08_514_2D and AC11_514_2D_20CM_10CM (AC-4 and MPEG-H) Receptor system used: Soundbar</p> <p>Observations: The system allows end-users to select between different preselections created in production. We could not check the capability of the audio system to display on the receiver side all preselections authored in production because this setup does not allow any authoring.</p>
<p>4</p> <p>TC2.3 - Requirement AC2.1: Enable end-user interactivity/personalization - switch between multiple commentators</p>	<p>Test signals: It was assumed that the video files from the NUC was AC09_514_2C (AC-4, MPEG-H and Globo). Receptor system used: Soundbar</p> <p>Observations: The system was able to allow end-users to select between multiple commentators during AC-4 and Globo video files playback. The system showed no commentators to the end-user during the MPEG-H video file presentation. There is a brief break in audio during commentators' switches.</p>
<p>5</p> <p>TC2.4 - Requirement AC2.1: Enable end-user interactivity/personalization - display of textual labels</p>	<p>Test signals: It was assumed that the video files from the NUC were AC08_514_2D, AC11_514_2D_20C_10CM (AC-4 and MPEG-H) and AC09_514_2C (AC-4, MPEG-H and GLOBO). Receptor system used: Soundbar</p> <p>Observations: The setup allows no meta-data authoring, so we could not test its ability to display to the end-users correct textual labels for all audio objects that allow interactivity options and preselections. The original meta-data authored by the proponent was able to be read on the receiver side.</p>
<p>6</p> <p>TC2.5 - Requirement AC2.2: Enable end-user interactivity/personalization - audio object loudness interactivity</p>	<p>Test signals: It was assumed that the video files from the NUC were AC08_514_2Dgain (AC-4 and MPEG-H) and AC09_514_2Cgain (AC-4, MPEG-H and GLOBO). Receptor system used: Soundbar</p> <p>Observations: The test was executed with success. AC09 MPEG-H video file presents commentator option in the menu but there is no sound when this option is chosen.</p>
<p>7</p> <p>TC2.6 - Requirement AC2.2: Enable end-user interactivity/personalization - audio object interactivity, changing object position</p>	<p>Test signals: It was assumed that the video files from the NUC were AC08_514_2Dpos and AC10_514_DO (AC-4 and MPEG-H) Receptor system used: Soundbar</p> <p>Observations: The test was executed with success. During "AC10 MPEG-H" playback, spatial object changes did not work.</p>

Test Case		Result
8	TC2.7 - Requirement AC2.4: Enable Interactivity when using external sound reproduction systems	<p>Test signals: It was assumed that the video files from the NUC were AC08_514_2Dgain, AC10_514_DO (AC-4 and MPEG-H) and AC09_514_2C (AC-4, MPEG-H and GLOBO)</p> <p>Receptor system used: Soundbar</p> <p>Observations: The test was executed with success. The "AC09 MPEG-H" video file presents comentator option in the menu but there is no sound when this option is chosen. "AC09 AC-4" and "MPEG-H" video files present object spatial options in the user-end menu but they did not work.</p>
9	TC3.1 - Requirement AC3.1: Enable audio description delivery in the same stream as the main audio. Requirement AC3.2: Enable audio description delivery as an alternative full mix	<p>Test signals: It was assumed that the video file from the NUC was AC02_20_20_20AD (AC-4 and MPEG-H).</p> <p>Receptor system used: Soundbar</p> <p>Observations: The test was executed with success. It was impossible to test the capability of the audio system to start the playback at receiver tune-in with Audio Description in the preferred language because both video files had only one AD language.</p>
10	TC5.1 - Requirement AC5.1: Enable a single delivery format for multiple audio playback configurations - flexible loudspeaker configuration render. Requirement AC5.2: Enable a single delivery format for multiple audio playback configurations - binaural render.	<p>Test signals: It was assumed that the video files from the NUC were AC08_514_2D_AD and AC11_514_2D_20CM_10CM (AC-4 and MPEG-H)</p> <p>Receptor system used: AVR receiver, soundbar, headphones and TV.</p> <p>Observations: The test was executed with success. During the tests using audio content "AC08-MPEG-H" and TV set, the female's voice in Portuguese was reproduced with a lower intensity, much closer to the bed than when it's heard during other tests. During the tests using AC08-MPEG-H file and AVR set, light noises, sounding like digital artifacts, were heard in the surround channels. Tests using audio content "AC_11_514_2D_20CM_10CM" (DOLBY) were executed with the same file indicated in the TC7.2b test page because the file was not authored on the TC 5.2b test page.</p> <p>Tests using headphones were performed with headphones attached to the AVR receiver.</p>
11	TC7.1 - Requirement AC7.1: Enable seamless configuration changes	<p>Test signals: It was assumed that the video file from the NUC was AC01468_SWITCH (AC-4 and MPEG-H)</p> <p>Receptor system used: AVR receiver</p> <p>Observations: The test was executed with success. For "mpeg-h" content, the system was able to switch from 2.0 to 5.1 and 5.1+4H (in the case of AC-4, 2H) without fail. For "ac4" content, there was an audio switch every 30 seconds as indicated by AC-4 proponents without fail.</p>
12	TC7.2 - Requirement AC7.2: Enable seamless content playback during user interaction	<p>Test signals: It was assumed that the video files from the NUC were AC08_514_2Dgain, AC08_514_2Dpos, AC11_514_2D_20CM_10CM (AC-4 and MPEG-H)</p> <p>Receptor system used: AVR receiver</p> <p>Observations: Test failed for all audio contents for all steps. The sound interrupts at each interaction and starts again.</p>

	Test Case	Result
13	TC7.3 - Requirement AC7.3 Enable seamless content playback during changes in production	<p>Test signals: It was assumed that the video files from the NUC were ac08_514_d2d_endis_lang-dlb.mov, ac08_514_d2d_endis_lang-mpegH.mov, ac08_514_2d_endis_ad-dlb.mov and ac08_514_2d_endis_ad-mpegH.mov. Receptor system used: AVR receiver</p> <p>Observations: Test failed for all audio contents for all steps. Test case 7.3 proposal is to demonstrate the system's ability to seamless playback content during changes in production during a live broadcast. Proponent real-time streaming setup did not allow authoring metadata as it was a live broadcast. There was no AD option in any video file.</p>
14	TC7.5 - Requirement AC7.4 Enable seamless Ad-insertion	<p>Test signals: It was assumed that the video file from the NUC was AC0111_ADINSERT (AC-4 and MPEG-H) Receptor system used: AVR receiver</p> <p>Observations: Test failed for all audio contents for all steps. Test case 7.5 proposal is to demonstrate the system's ability to enable seamless ad-insertion at any time instance using two different content layouts. Proponent's real-time streaming setup did not provide for a second playback unit for insertions.</p>
15	TC7.6 - Requirement AC7.4 Enable user selection persistency after the Ad-break	<p>Test signals: It was assumed that the video file from the NUC was AC0111_ADINSERT (AC-4 and MPEG-H) Receptor system used: AVR receiver</p> <p>Observations: Test failed for all audio contents for all steps. Test case 7.6 proposal is to demonstrate the system's ability to preserve user interaction settings after the ad-break using two different content layouts. Proponent's real-time streaming setup did not provide for a second playback unit for insertions.</p>
16	TC7.7 - Requirement AC7.4 Enable A/V alignment in hybrid delivery	<p>Test signals: It was assumed that the video file from the NUC was AC03_20_D_HYBRID (AC-4 and MPEG-H) Receptor system used: AVR receiver</p> <p>Observations: Test failed for all audio contents for all steps. Test case 7.6 proposal is to demonstrate the system's ability to synchronize and replace the main soundtrack delivered via broadcast for an alternative audio signal delivered via broadband utilizing Candidate Technology A audio codec. Proponent's real-time streaming setup did not provide for two different audio deliveries simultaneously.</p>
17	TC10.1 - Requirement AC10.1: Provide audio/video synchronization	<p>Test signals: It was assumed that the video files from the NUC were AC03_20_2D, AC05_51_2D, AC-7_514_2D (AC-4 and MPEG-H) and AC09_514_2C (AC-4, MPEG-H and GLOBO) Receptor system used: AVR receiver</p> <p>Observations: Test failed for all audio contents for all steps. The only video files containing lip sync were AC03 and AC07, both "MPEG-H" content. AC03 (AC-4 and MPEG-H) video files did not allow to verify the system's ability to downmix audio files from 5.1 to 2.0 because they are 2.0.</p>