ATSC Implementation Guide: Emissions Testing Process

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The Advanced Television Systems Committee, Inc. is an international, non-profit organization developing voluntary standards and recommended practices for broadcast television and multimedia data distribution. ATSC member organizations represent the broadcast, professional equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries. ATSC also develops implementation strategies and supports educational activities on ATSC standards. ATSC was formed in 1983 by the member organizations of the Joint Committee on Inter-society Coordination (JCIC): the Consumer Technology Association (CTA), the Institute of Electrical and Electronics Engineers (IEEE), the National Association of Broadcasters (NAB), the Internet & Television Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE). For more information visit www.atsc.org.

Implementers with feedback, comments, or potential bug reports relating to this document may contact ATSC at https://www.atsc.org/feedback/.

Revision History

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1. CONFORMANCE IMPLEMENTATION TEAM (IT-3)

Conformance testing is a key factor in enabling the market introduction of systems and devices that are compliant to a new standard. This testing facilitates the introduction of high-quality systems and devices meeting the specification which drives the adoption and conformance of the standard. It is based on the existence of common test procedures, covering technology specifications and a key component to ensure interoperability among services and devices of different broadcasters and equipment vendors.

The ATSC Conformance Implementation Team (IT-3) provides a venue to scope and plan for formal and informal testing approaches for both emission and reception. The ATSC 3.0 IT-3 may address business, regulatory, and technical requirements for the successful roll-out of ATSC 3.0.

This Guide was authored by IT-3. It is not an ATSC Standard or Recommended Practice. As such, this Guide was not subject to the ATSC procedures that govern the development of ATSC Standards and Recommended Practices. However, the information contained herein represents the consensus agreement of the members of IT-3, which comprise a variety of stakeholders within the ATSC 3.0 ecosystem, including broadcasters, consumer electronics manufacturers, and equipment and technology vendors.

2. OVERVIEW

2.1 Scope

This document describes an Emissions Testing Process for ATSC 3.0 Broadcasts. The testing program includes two parts. First, there is a test checklist to ensure that the emission is functional, and second this document describes a methodology for quickly responding to interoperability issues with receivers.

The emissions checklist is intended as a tool to assist in launching a new station or deploying a new configuration. It is not intended for ensuring regulatory compliance or as an emissions conformance program, nor is it intended to require any specific feature set.

The methodology for quickly responding to interoperability issues with receivers is provided in order to help stations to capture streams and provide them for analysis by various third parties. This section includes points at which streams can be captured, test formats and equipment, and stream capture and sharing processes.

3. REFERENCES

All referenced documents are subject to revision. Users of this guide are cautioned that newer editions might or might not be compatible. For the ATSC 3.0 family of Specifications, users are recommended to use the latest version of A/300 [1] and all referenced specifications but should note the applicable version may differ for their own station set up.

3.1 Informative References

The following documents contain information that may be helpful in applying this document.

[1] ATSC: "ATSC Standard: ATSC 3.0 System," Doc. ATSC A/300:2022-04, Advanced Television Systems Committee, Washington, DC., 8 April 2022.

[2] IEEE: "Use of the International Systems of Units (SI): The Modern Metric System," Doc. SI 10, Institute of Electrical and Electronics Engineers, New York, NY.

[3] ATSC: "ATSC Standard: Audio Watermark Emission," Doc, A/334:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[4] ATSC: "ATSC Recommended Practice: Guidelines for the Physical Layer Protocol," Doc. A/327:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[5] ATSC: "ATSC Recommended Practice: ATSC 3.0 PHY Lab Performance Test Plan," Doc. A/325:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[6] ATSC: "ATSC Recommended Practice: ATSC 3.0 Field Test Plan," Doc. A/326:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[7] CTA "Recommended Practice for ATSC 3.0 Television Sets, Physical Layer", Doc CTA-CEB32.2 Consumer Technology Association, Arlington, VA.

[8] ATSC: "ATSC Standard: Physical Layer Protocol," Doc/ A/322:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[9] ATSC: "ATSC Standard: Link Layer Protocol," Doc. A/330:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[10] ATSC: "ATSC Standard: Signaling, Delivery, Synchronization, and Error Protection," A/331:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[11] ATSC: "ATSC Standard: Service Announcement," Doc, A/332:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[12] ATSC: "ATSC Standard: ATSC 3.0 Security and Service Protection," Doc. A/360:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[13] ATSC: "ATSC Standard: Video – HEVC," Doc. A/341:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[14] ATSC: "ATSC Standard: Audio Common Elements," Doc. A/342-1:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[15] ATSC: "ATSC Standard: Captions and Subtitles," Doc. A/343:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[16] W3C: "TTML Profiles for Internet Media Subtitles and Captions 1.0.1 (IMSC1)", Recommendation, W3C.
https://www.w3.org/TR/ttml-imsc1.0.1/

[17] ATSC: "ATSC Technology Group Report: ATSC 3.0 Launch – DASH Timeline and IMSC1," Doc T/300, Advanced Television Systems Committee, Washington, DC, 9 October 2020.
https://www.atsc.org/atsc-documents/type/3-0-technology-group-reports/

[18] CTA: "Recommended Practice for ATSC 3.0 Television Sets, Video," Doc. CTA-CEB32.4, Consumer Technology Association, Arlington, VA.

[19] ATSC: "ATSC Standard: Content Recovery in Redistribution Scenarios," Doc. A/336:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[20] ATSC: "ATSC Standard: Scheduler / Studio to Transmitter Link," Doc. A/324:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.

[21] ATSC: "ATSC Recommended Practice: Receiver Performance Guidelines," Doc. A/74, Advanced Television Systems Committee, Washington, DC, 7 April 2010.
[22] Pearl: "Host Station Manual." https://pearltv.com/station-resources/
[23] Dolby: "AC-4 Audio Handbook." https://professional.dolby.com/siteassets/tv/home/dolby-vision/dolby_atsc3_hdbk_digi_v04_share.pdf.
[24] ATSC: "ATSC Technology Group Report: ATSC 3.0 Initial AC-4 Implementation," Doc. T/301, Advanced Television Systems Committee, Washington, DC, 24 May 2019.
[25] SMPTE "Timed Text Format (SMPTE-TT)", Doc. ST 2052-1, Society of Motion Picture and Television Engineers, White Plains, NY.
[26] ATSC: "ATSC Standard: Video Watermark Emission," Doc, A/335:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.
[27] CTA: "Recommended Practice for ATSC 3.0 Television Sets, Watermarking and Content Recovery," Doc. CTA-CEB32.10, Consumer Technology Association, Arlington, VA.
[28] IEEE: "Development of the MPEG-H TV Audio System for ATSC 3.0," in IEEE Transactions on Broadcasting, vol. 63, no. 1, March 2017. https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7874294
[29] ATSC: "ATSC Standard: ATSC 3.0 Security and Service Protection," Doc. A/360:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.
[30] ATSC: "ATSC Recommended Practice: Security and Content Protection," Doc. A/361:2022-03, Advanced Television Systems Committee, Washington, D.C., 31 March 2022.
[31] ATSC: "ATSC Recommended Practice: Digital Rights Management (DRM)," Doc. A/362:2022-03, Advanced Television Systems Committee, Washington, DC, 31 March 2022.
[32] CTA: "Recommended Practice for ATSC 3.0 Television Sets, Security and Protected Services" Doc. CTA-CEB32.9, Consumer Technology Association, Arlington, VA.

4. DEFINITION OF TERMS

With respect to definition of terms, abbreviations, and units, the practice of the Institute of Electrical and Electronics Engineers (IEEE) as outlined in the Institute's published standards [2] shall be used. Where an abbreviation is not covered by IEEE practice or industry practice differs from IEEE practice, the abbreviation in question will be described in Section 4.1 of this document.

4.1 Acronyms and Abbreviations

The following acronyms and abbreviations are used within this document.

16K 16384 point FFT size

3D Three dimensional

8K 8192 point FFT size

AFD Active Format Description

ALP ATSC 3.0 Link-Layer Protocol

ATSC Advanced Television Systems Committee

bps	bits per second
BSID	Broadcast Stream ID
CTA	Consumer Technology Association
DASH	Dynamic Adaptive Streaming over HTTP
DASH-IF	DASH Industry Forum
DNS	Domain Name System
DRM	Digital Rights Management
EFDT	Extended File Delivery Table
ESG	Electronic Service Guide
FEC	Forward Error Correction
FFT	Fast Fourier Transform
GI	Guard Interval
GNSS	Global Navigation Satellite System
GOP	Group of Pictures
GPS	Global Positioning System
HD	High Definition
HDR	High Dynamic Range
HELD	HTML Entry pages Location Description
HEVC	High Efficiency Video Coding
HLG	Hybrid Log-Gamma
HTI	Hybrid Time Interleaver
IEEE	Institute of Electrical and Electronic Engineers
IMSC1	Internet Media Subtitles and Captions 1.0
ISO	International Organization for Standardization
ISO BMFF	ISO Base Media File Format
ISO/IEC	International Organization for Standardization /International Electrotechnical Commission
IT-3	ATSC Implementation Team 3: Conformance
L1	Layer 1
LCT	Layered Coding Transport
LLS	Low Level Signaling
LMT	Layer Mapping Table

M&E	Music and Effects
MBMS	Multimedia Broadcast/Multicast Services
Mbps	megabits per second
MHz	Megahertz
MIME	Multipurpose Internet Mail Extensions
MMT	MPEG Multimedia Transport
MMTP	MPEG Media Transport Protocol
MPD	Media Presentation Description
MPEG	Moving Picture Experts Group
msec	milliseconds
Mux	Multiplexer
MVPD	Multichannel Video Programming Distributor
MPLP	Multiple Physical Layer Pipes
NTP	Network Time Protocol
PCAP	Packet Capture
PHY	Physical Layer
PKI	Public Key Infrastructure
PLP	Physical Layer Pipe
PQ	Perceptual Quantization
PTP	Precision Time Protocol
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency / Right Front (audio Channel)
ROUTE	Real-time Object delivery over Unidirectional Transport
SAP	Segment Access Point
SD	Standard Definition
SDR	Standard Dynamic Range
SFN	Single Frequency Network
SFR	Standard Frame Rate
SHVC	Scalable High Efficiency Video Coding
SID	Sub-stream Identifier
SL-HDR1	Single Layer High Dynamic Range part 1
SLS	Service Layer Signaling

SLT	Service List Table
SMPTE	Society of Motion Picture and Television Engineers
SPS	Sequence Parameter Set
STL	Studio-to-Transmitter Link
S-TSID	Service-based Transport Session Instance Description
TDCFS	Time Diversity Code Filter Set
TDM	Time Division Multiplexing
TI	Time Interleaver
TOI	Transport Object Identifier
TSI	Transport Session Identifier
TT	Timed Text
TTML	Timed Text Markup Language
TV	Television
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
USBD	User Service Bundle Description
UTC	Universal Coordinated Time
VDS	Video Description Service
VP1	The audio watermarking technology specified in A/334, "ATSC Standard: Audio Watermark Emission" [3].
W3C	World Wide Web Consortium

5. EMISSION CHECKLISTS

5.1 General

Figure 5.1 represents the elements of the ATSC 3.0 emissions system and the items that warrant consideration in this checklist:

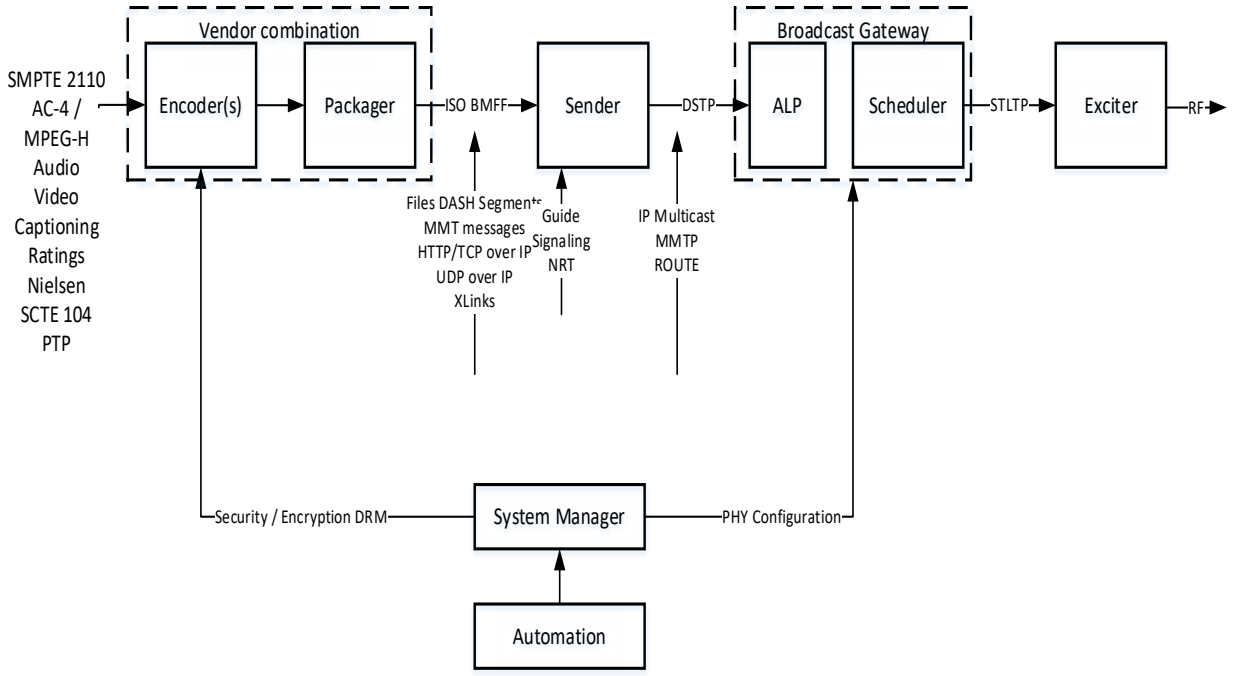

Figure 5.1 ATSC 3.0 emissions system overview**.**

5.2 Checklist 1 – PHY

Readers are encouraged to look at:

- ATSC A/327, "Guidelines for the Physical Layer Protocol," [4] provides guidance on possible configurations of the PHY.
- Procedures for testing of ATSC 3.0 PHY in the lab are described in A/325, "ATSC 3.0 Lab Performance Test Plan" [5].
- Procedures for testing of ATSC 3.0 PHY in the field are described in A/326, "ATSC 3.0 Field Test Plan" [6].
- CEB32.2 Recommended Practice for ATSC 3.0 Television Sets, Physical Layer [7].

Familiarity with these documents is highly recommended.

A list of items to check in PHY configurations are:

☐ Bootstrap signaling, e.g., for 6 MHz channel set bsr_coefficient (N) =2.

For each PLP or subframe:

☐ Select FFT size based on Doppler considerations of the Service, e.g., automotive Service should be lower order FFT (8K or 16K), stationary Service can be any FFT size.

☐ Select Guard Interval based on echo patterns of environment and SFN considerations, e.g., San Francisco can have naturally occurring echoes up to 147 μsec, SFN coverage depends on distance between towers.

☐ Find pilot pattern Dx basis given FFT size and GI in Table 8.9 of A/322, "Physical Layer Protocol," [8] (either 3 or 4).

☐ Select pilot pattern in Table 8.3 of A/322 [8].

- ☐ Select FEC codeword length of either 64800 or 16200, e.g., 64800 is popular for higher bit protection.
- ☐ Select modulation order and Code Rate to accommodate desired payload size. Note: an upper limit estimate of payload calculation is provided below.
- ☐ Select pilot boost value to adjust payload size / desired robustness level.
- ☐ Ensure subframe boundary symbols First and Last are enabled.
- ☐ Ensure Frequency Interleaver is enabled. Off is not recommended.
- ☐ Select Time Interleaver mode. 'None' is not recommended.
- ☐ Adjust Time Interleaver settings, e.g., CTI Depth or HTI # of TI-blocks, # of FEC blocks to meet desired payload sizes.
- ☐ For MPLP configurations, HTI is required for a Service that spans MPLP. Proper configuration of HTI can be exercised with a table (see Table 5.1). The total number of cells must be <524288. Note that in this example, PLP3 is "OFF" given the number of FEC blocks is zero.

Table 5.1 MPLP Configurations

PLP	**0**	**1**	**2**	**3**
codelength	64800	64800	64800	64800
log2(modulation order)	4	8	8	8
blocksize	16200	8100	8100	8100
#FEC blocks	15	28	32	0
#TI Blocks	3	2	1	1
Cell Interleaver (1=on, 0=off)	1	1	0	0
# cells	97200	121500	259200	0
Total # cells (Valid if Green)	477900			

- ☐ Select the number of symbols so that entire frame is less than 250 msec as suggested in CTA CEB32.2 [7].

$$symbol\ duration = \frac{FFT\ size + GI\ samples}{0.384 * (N + 16)}; N = 2\ for\ 6MHz\ channel$$

$$\#\ symbols/frame \leq \frac{Max\ Frame\ duration - Bootstrap\ duration}{symbol\ duration}$$

$$\#\ symbols/frame \leq \frac{250msec - 2.0msec}{symbol\ duration}$$

- ☐ Ensure LMT is sent for each Service. As per A/330, "Link Layer Protocol" [9], Section 7.1.1, if multiple PLPs, LMT must be in the PLP(s) with LLS as indicated with L1D_plp_lls_flag being set to '1'. Each instance of LMT describes mappings between PLPs and any IP address/port associated with any multicast referenced in the identified PLP with LLS tables.

Upper Limit estimate on payload calculation is below. It does not account for fewer available data cells in Preamble and Subframe Boundary Symbols. An accurate payload value requires use of data cell counts available in tables in A/322 [8], Section 7.2.6.

$$M = QAM\ Modulation \in \{4, 16, 64, 256, 1024, 4096\}$$

$$FFT = FFT\ size \in \{8192, 16384, 32768\}$$

$$Fs = sampling\ frequency\ [Hz] = 384000 * (N + 16); N = 2\ for\ 6\ MHz\ channel$$

$$carrierReduction = coefficient\ of\ fewer\ carriers \in \{0, 1, 2, 3, 4\}$$

$$NoC = \#of\ active\ carriers = 6913 - (196 * carrierReduction)\ for\ 8K\ FFT$$

$$NoC = 13825 - (192 * carrierReduction)\ for\ 16K\ FFT$$

$$NoC = 27649 - (384 * carrierReduction)\ for\ 32K\ FFT$$

$$carrierSpacing = \frac{Fs}{FFT}$$

$$signalBW = carrierSpacing * NoC\ [Hz]$$

$$CP = continualPilots \in \{48, 96, 192\}\ for\ 8K, 16K\ and\ 32K\ FFT\ respectively$$

$$Dx = scatteredPilot\ symbol\ spacing\ as\ listed\ in\ A/322\ Table\ 8.3$$

$$Dy = scatteredPilot\ frequency\ spacing\ as\ listed\ in\ A/322\ Table\ 8.3$$

$$pilotOverhead = \frac{\left\lceil \frac{NoC}{\frac{Dx}{Dy}} + CP \right\rceil}{NoC}$$

$$Estimate\ payload_{UpperLimit} = log_2(M) * \left[\frac{codelength * coderate - 12 * 16}{codelength}\right] * signalBW * [1 - pilotOverhead]$$

Example with 8K FFT, no carrier reduction, 256 QAM, codelength=64800bits, coderate =9/15, scattered pilot pattern with Dx=8, Dy=4:

$$Estimate\ payload_{UpperLimit} = log_2(256) * \left[\frac{64800 * 0.6 - 12 * 16}{64800}\right] * 5832843.75 * [1 - 0.0383335]$$

$$Estimate\ payload_{UpperLimit} = 26791442\ bits/sec$$

This is the physical layer pipe payload of ATSC Link-layer Protocol (ALP) packets [9]. For IP payloads, ALP header overhead must be taken into account.

For an accurate payload value please see ETRI's ATSC 3.0 PHY simulator: https://atsc.agos.co.kr/ (email required to register, but free to use).

5.3 Checklist 2 – Signaling and Scheduling

A/331, "Signaling, Delivery, Synchronization, and Error Protection," has two signaling protocols, ROUTE and MMT [10]. For ROUTE/DASH operations, the major signaling items to check are as follows:

- For ROUTE Signaling:

☐ Ensure LLS Table 1(SLT) and Table 3(ST) is present on 224.0.23.60:4937

- ☐ Ensure the SLT has proper BSID, e.g., the broadcaster NTSC-TSID found at https://enterpriseefiling.fcc.gov/dataentry/public/tv/publicFacilitySearch.html.
- ☐ Ensure the SLT has proper globally unique URI `globalServiceID` as indicated in A/332, "Service Announcement" [11],
  e.g., `urn:atsc:serviceid:usc32` or `https://doi.org/10.5239/955B-6DEE`.
- ☐ Ensure the SLT has proper `slsProtocol`="1" for ROUTE.

☐ Ensure SLT indicates `serviceId` and version (`sltSvcSeqNum`).

☐ Ensure SLT indicates the service category as in Table 6.4 in A/331 [10].

☐ Ensure SLS is located on TSI = 0 of the Service Route Session.

☐ Ensure SLS contains the USBD, MPD, and S-TSID

- ☐ If a Broadcaster Application is sent, HELD should also be present.

☐ Ensure USBD provides the base URL for the Service.

☐ Ensure the SLS signals that each ROUTE Session is assigned to a maximum of one PLP via ALP stream.

☐ Ensure S-TSID signals the ROUTE Session, e.g., (Destination Address: Port # and Source Address)

- ☐ Ensure S-TSID signals the LCT channels for each component (video/audio/captions) with separate TSI values
  - ☐ Ensure each LCT channel has source flow (optionally Repair Flow) with real time value = true
    - ☐ Ensure each source flow has EFDT instance to signal the initialization segment name and TOI value.

☐ SLS tables should be signed according to A/360, "ATSC 3.0 Security and Service Protection," [12] with PKI. Verify presence of SMT and CDT.

☐ Verify sufficient headroom (padding), preventing overflow in the Scheduler. This means not to completely fill the PLP with 100% utilization. If the input is 10 Mbps, setup the PLP for, e.g., 10.5 Mbps. As a recommendation, try to avoid dropped packets.

- For DASH-IF Signaling:

DASH-IF provided ATSC with interoperability points for ATSC 3.0. Familiarity with DASH-IF-IOP-for-ATSC3-0-v1.1.pdf document is highly recommended.

- ☐ Ensure broadcast TV profile is used.
- ☐ Select Segment size to balance video codec efficiency vs. channel change time. A popular choice is 2 seconds. Verify channel change (service acquisition) time is reasonable. This is a subjective measurement, but is directly impacted by segment size and GOP (below).
- ☐ Select closed GOP structure (SAP type 1 or 2).
- ☐ Ensure MPD Availability Start Time (AST) + Period start time indicates (relatively) current time in UTC.
- ☐ Ensure MPD Adaptation set for video is correct
  - ☐ Video formats follow A/341, "Video – HEVC" [13].
  - ☐ Codec = hev1.2.4.L120.x (HEVC Main 10 profile).
  - ☐ mimeType="video/mp4".
  - ☐ startWithSAP="1".
- ☐ Ensure MPD Adaptation set for audio[1] is correct
  - ☐ Audio formats follow A/342, "Audio Common Elements" [14].
  - ☐ Codec = ac-4.02.01.x (AC-4) or mhm1.0x0D (MPEG-H Audio).
  - ☐ mimeType="audio/mp4".
  - ☐ startWithSAP="1".
- ☐ Ensure MPD Adaptation set for closed captions is correct
  - ☐ Caption formats follow A/343, "Captions and Subtitles" [15], and W3C IMSC 1.0.1 [16]. Please refer to ATSC T/300, "ATSC Technology Group Report: ATSC 3.0 Launch – DASH Timeline and IMSC1" [17].
  - ☐ Codec = stpp.ttml.im1t.
- ☐ Ensure either Segment Template ($NUMBER$) or Segment Timeline ($TIME$) is used.
- ☐ Caption signaling should follow DASH-IF-IOP-v4.3 and W3C IMSC1 TTML1 specifications.
- ☐ Service Guide. Verify presence of ESG data (serviceFragments and guideFragments in LCT channel).

[1] Noting that A/300 [1] Section 5.1.15 states "All ATSC 3.0 terrestrial and hybrid television services emitted within a given region shall use one audio system selected for that region from those defined in A/342 Parts 2 and higher. For example, broadcast organizations in North America have selected the audio system defined in A/342, Part 2 as the audio system for use in Mexico, Canada and the U.S., and the Telecommunication Technology Association (TTA) has selected the audio system defined in A/342, Part 3 for use in the Republic of Korea."

5.4 Checklist 3 – Video

This document assumes that the service is based on a single Video House Format that is static and would only be changed during major reconfigurations. Dynamically switched formats are outside the scope of this document.

Follow this checklist:

☐ Determine the preferred Video House Format. The Video House Format would typically be one of the formats listed in A/341 [13] Table 5.1; however, ATSC 3.0 Standards do not constrain the Video House Format to the items this table.

☐ Ensure that the encoder is capable of ISO/IEC 23008-2 (HEVC) encoding and that such encoding is selected (A/341 [13], Section 6.1).

☐ Ensure that each SPS has bit_depth_luma_minus8 and bit_depth_chroma_minus8 both equal to 0 or both equal to 2. This constrains the bit depth of luma and chroma to be 8 or 10 bits and the bit depth of luma and chroma to be identical (A/341 [13], Section 6.1).

☐ Determine the classification of video from the following options:

- Legacy SD video – A/341 [13], Section 6.2.1. Note that CTA-CEB32.4 [18], Table 1 shows the recommended Legacy SD video formats.
  - Ensure that the encoded video meets all requirements in A/341 [13], Section 6.2.1.
- Interlaced HD video – A/341 [13], Section 6.2.2. Note that CTA-CEB32.4 [18], Table 2 shows the recommended Interlaced HD video formats.
  - Ensure that the encoded video meets all requirements in A/341 [13], Section 6.2.2.
- Progressive video – A/341 [13], Section 6.2.3. Note that CTA-CEB32.4 [18], Table 3 shows the recommended Progressive video formats.
  - Ensure that the encoded video meets all requirements in A/341 [13], Section 6.2.3.

☐ If Progressive video is selected, determine if HEVC Spatial Scalable Coding will be used.

  ☐ If HEVC Spatial Scalable Coding (SHVC) will be used, ensure that the encoded video meets all requirements in A/341 [13], Section 6.3.1.

☐ If Progressive video is selected, determine the transfer characteristics from the following options:

- SDR – A/341 [13], Section 6.3.2.1
  - Ensure that the encoded video meets all requirements in A/341 [13], Section 6.3.2.1.
- PQ – A/341 [13], Section 6.3.2.2
  - Ensure that the encoded video meets all requirements in A/341 [13], Section 6.3.2.2.
- HLG – A/341 [13], Section 6.3.2.3
  - Ensure that the encoded video meets all requirements in A/341 [13], Section 6.3.2.3.

☐ If the SDR transfer function is selected, determine if SL-HDR1 will be used

  ☐ Ensure that the metadata meets all requirements in A/341 [13], Section 6.3.2.1.1.

☐ If the SL-HDR1 is selected, determine if HEVC Spatial Scalable Coding (SHVC) will also be used

  ☐ Ensure that the metadata meets all requirements in A/341 [13], Section 6.3.2.1.2.

- ☐ If the PQ transfer function is selected, determine if SMPTE ST 2094-10 will be used
  - ☐ Ensure that the metadata meets all requirements in A/341 [13], Section 6.3.2.2.1.
- ☐ If Progressive video is selected, determine if 3D video will be used
  - ☐ Ensure that the encoded video meets all requirements in A/341 [13], Section 6.3.3.
- ☐ If Progressive video is selected and high frame rate video is to be used, determine if high frame rate temporal sub-layering will be used
  - ☐ Ensure that the encoded video meets all requirements in A/341 [13], Section 6.3.4.
- ☐ If carried, ensure that AFD and bar data are as specified in A/341 [13], Sections 6.4.1 and 6.4.2.
- ☐ If closed captions are carried in the video stream, ensure that they conform to A/341 [13], Section 6.4.3. (Note that closed captions in video are optional. IMSC1 closed captions as described in Section 5.6 are required.)
- ☐ Ensure that picture timing information is carried as specified in A/341 [13], Section 6.4.4.
- ☐ Ensure that the video characteristics listed in A/341 [13], Table 7.1 and the associated signaling are aligned.

5.5 Checklist 4 – Audio

- ☐ Make sure the audio encoder configuration matches the incoming audio
  - Know the loudness measured in LKFS of incoming content.
  - Know the channel configuration of incoming content.
  - Know the Presentation set for the incoming content.
  - Know what Presentation number corresponds with an intended program, i.e., Presentation 1 is default, English; Presentation 2 is M&E+D+VDS…etc.
  - If the incoming input to the encoder already carries the metadata describing the audio (e.g., loudness, channel configuration, Audio Presentations, etc.), the encoder should use the incoming metadata.
    - MPEG-H Audio metadata is provided together with the audio signals as Control Track and synchronized with the video signal [28].
- ☐ The audio frame rate and the video frame rate match
  - AC-4 uses an adjustable audio frame rate.
  - MPEG-H Audio does not require any adjustment of the audio frame rate.
- ☐ Ensure that audio and video Random Access Points (RAPs) are aligned
  - AC-4 is the first Dolby codec with i-frames that can be aligned to the video I-Frames.
  - MPEG-H Audio allows for sample-accurate alignment at each RAP by introducing Immediate Play-out Frames (IPFs at arbitrary positions in the audio stream).

5.6 Checklist 5 – Captions

Familiarity with the following documents is recommended:

- A/343, “Captions and Subtitles” [15].

- T/300, "ATSC Technology Group Report: ATSC 3.0 Launch – DASH Timeline and IMSC1" [17].
- SMPTE-TT (ST 2052-1) [25].
- W3C "TTML Profiles for Internet Media Subtitles and Captions 1.0.1 (IMSC1)" [16].

An ATSC 3.0 emission typically includes closed captions and an ATSC 3.0 broadcast encoder should follow the reference documents above. While there are many aspects of caption encoding for ATSC 3.0, it is important that a broadcast station use a workflow and encoder that comply with the requirements in A/343 [15] and the recommendations provided in T/300 [24]. The brief checklist below should help an ATSC 3.0 broadcast station adequately confirm the proper setup for captions.

☐ A/343 [15] relevant sections:

- Section 5, Content Essence Specification
- Section 6. Packaging and Timing in ISO Base Media File Format (ISO BMFF)
- Section 7, Signaling

☐ T/300 [17] relevant sections:

- Section 5, Station Model
- Section 6, IMSC1 Segment Encoding
- Section 7, MPD Updates
- Section 8, MPD Timing and Versioning

It is worth noting that T/300 [17] provides both background information plus guidance in the form of bold "Recommendation:" statements in virtually all of the relevant sections noted above. Those Recommendations can assist in providing a quick check of caption related settings in a broadcast station.

5.7 Checklist 6 – Audio Watermarks

Audio watermarks are optional, and readers are encouraged to look at:

- ATSC A/334, "Audio Watermark Emission," [4].
- ATSC A/336, "Content Recovery in Redistribution Scenarios," [4].
- CEB32.10 Recommended Practice for ATSC 3.0 Television Sets, Watermarking and Content Recovery [7].

Audio Watermark payload format checklist:

☐ Validate Embedder Configuration – check the configuration of the watermark embedding equipment to

- ☐ Confirm the Server Code (`serverCode`) is the unique Server Code assigned to the station by the ATSC Registrar.
- ☐ Confirm that all audio channels intended for synchronous output (i.e., 5.1, 2.0, etc.) are being watermarked.
- ☐ Confirm the embedder is synchronized to the station master clock (e.g., NTP, PTP, GPS, etc.).

☐ Validate VP1 Payload – decode the watermarked audio to

- ☐ Confirm serverCode matches that configured by embedder
  - ☐ Confirm domain_type.
  - ☐ Confirm server_field.
- ☐ Confirm intervalCode
  - ☐ Increments sequentially every 1.5 s.
  - ☐ Is aligned with playout system timestamp within +/– 3 seconds.
- ☐ Confirm query_flag value matches that configured by the embedder
  - ☐ Confirm query_flag value changes between 0 and 1 when toggled at the embedder.
- ☐ Verify that the same payload is embedded into each audio channel that is intended to be synchronously output.

☐ Display Override – if supported

- ☐ Confirm the use of inverse signaling as defined by A/334 [3] only during the time when the Display Override feature was enabled within the watermark embedding equipment.

5.8 Checklist 7 – Video Watermarks

Video watermarks are optional, and readers are encouraged to look at:

- ATSC A/335, "Video Watermark Emission," [4].
- ATSC A/336, "Content Recovery in Redistribution Scenarios," [4].
- CEB32.10 Recommended Practice for ATSC 3.0 Television Sets, Watermarking and Content Recovery [7].

Video Watermark payload format checklist:

☐ Validate Embedder Configuration – check the configuration of the watermark embedding equipment to

- ☐ Confirm the Server Code (`serverCode`) is the unique Server Code assigned to the station by the ATSC Registrar.
- ☐ Confirm the embedder is synchronized to the station master clock (e.g., NTP, PTP, GPS, etc.).

☐ Validate VP1 Payload – decode the watermarked video to

- ☐ Confirm serverCode matches that configured by embedder
  - ☐ Confirm domain_type.
  - ☐ Confirm server_field.
- ☐ Confirm intervalCode
  - ☐ Increments sequentially every 1.5 s.
  - ☐ Is aligned with playout system timestamp within +/– 3 seconds.
- ☐ Confirm query_flag value matches that configured by the embedder
  - ☐ Confirm query_flag value changes between 0 and 1 when toggled at the embedder.
- ☐ Verify that the same payload is embedded into each video frame that carries the VP1 Message Group as defined by A/335.

5.9 Watermark Recovery Process

The ATSC 3.0 audio and video watermark can be used to deliver signaling and supplemental information to receivers via broadband through the content recovery process described in A/336, "Content Recovery in Redistribution Scenarios" [19]. Broadcasters utilizing the content recovery process to deliver signaling information should confirm that their Recovery File Servers respond to properly formed data requests and that Recovery and Dynamic Event files being delivered to receivers are valid.

This can be achieved by performing data requests to the Recovery File Server and reviewing the returned information using "common off the shelf" tools such as POSTMAN or an Internet Browser.

1) Determination of named elements in Recovery file and Dynamic Event file URL:
   a) Determination of {`hostname`}
      i. Confirm the `hostname` has the proper DNS registration as the first CNAME obtained during DNS resolution of the intermediate name (`intName`).
      ii. Confirm the `intName` as follows
         1 If domain_type = 0, `intName` has the value
            a. `a336.{serverCode1}.{serverCode2}.{serverCode3}.{serverCode4}.0.vp1.tv`.
         2 If domain_type = 1, `intName` has the value
            b. `336.{serverCode1}.{serverCode2}.{serverCode3}.1.vp1.tv`.
   b) Determination of {`subdName`}
      i. Confirm the `subdName` as follows
         1 If domain_type = 0, `subdName` has the value of
            a. `{serverCode4}{serverCode3}/{serverCode2}/{serverCode1}`.
         2 If domain_type = 1, `subdName` has the value of
            a. `{serverCode3}{serverCode2}/{serverCode1}`.
   c) Determination of {`serverCode`}
      ii. Confirm the `serverCode` value (where `serverCode1`, `serverCode2`, `serverCode3`, and `serverCode4` are the least-to-most significant bytes of the server_field of the VP1 payload) as follows
         1 If domain_type = 0, `serverCode` has the value of
            a. `{serverCode4}{serverCode3}{serverCode2}{serverCode1}`.
         2 If domain_type = 1, `serverCode` has the value of
            a. `{serverCode3}{serverCode2}{serverCode1}`.
2) Recovery File Retrieval via Broadband:
   a) Confirm a recovery data request can be made to the broadcaster's Recovery File Server with the following URL
      `https://{hostName}/a336/rdt/{subdName}/{serverCode}-{intervalCode}.rdt`
   b) Confirm the hostname is the URL of the Recovery File Server as specified by the station.
3) Dynamic Event Retrieval via Broadband:
   a) Confirm a Dynamic Event request can be made to an Event Server with the following URL when there is a change in query_flag value between successive VP1 payloads:
      `https://{hostName}/a336/dyn/{subdName}/{serverCode}-{intervalCode}.dyn`
   b) Confirm the hostname is the URL of the Event Server as specified by the station.

4) Recovery Response Files:
   a) Confirm Recovery Response Files served by the Recovery File Server are delivered as a multi-part MIME message encapsulated in an MBMS "metadata envelope" as defined by Section 6.6. of A/331 [10].
   b) Confirm Recovery Files contained within the Recovery Response conform to the format defined by Section 5.4.3 of A/336 [19]
      i. Confirm the queryFlag value is equivalent to that configured within the embedding equipment.
      ii. Confirm the displayOverride value is equivalent to that configured within the embedding equipment.
   c) Confirm Dynamic Events contained within the Recovery Response conform to the format defined by Table 5.1.4 of A/336 [19].
   d) Confirm Signaling Metadata Objects (Signaling Objects) contained within the Recovery Response conform to the format defined by A/331 [10], Table 6.17.

5.10 Checklist 8 – Security and Service Protection

Readers are encouraged to look at:

- ATSC A/350, "ATSC 3.0 Security and Service Protection" [29]
- ATSC A/361, "ATSC Recommended Practice: Security and Content Protection" [30]
- ATSC A/362, "ATSC Recommended Practice: Digital Rights Management (DRM)" [31]
- CEB32.9 Recommended Practice for ATSC 3.0 Television Sets, Security and Protected Services [32]

A checklist for security and service protection elements is beyond the scope of this revision of this document, but readers should refer to A3SA (https://a3sa.com/) for information about obtaining licenses and certificates, and their use within an emissions system.

6. METHODOLOGY FOR RESPONDING TO INTEROPERABILITY ISSUES

6.1 General

The following section provides some guidance for responding to interoperability issues. Primarily it is concerned with the situation where an apparently compliant (according to the checklists above) stream does not work with receivers in the field.

The receiver could be a production unit in viewers' households, in the station's lab, or at an MVPD location.

Note that adherence to the checklists in this document does not guarantee compliance and steps should be taken locally to analyze issues in the stream. A number of commercial tools are available for this.

6.2 Stream Capture Points

Figure 6.1 illustrates the stream capture points possible with the ATSC 3.0 system.

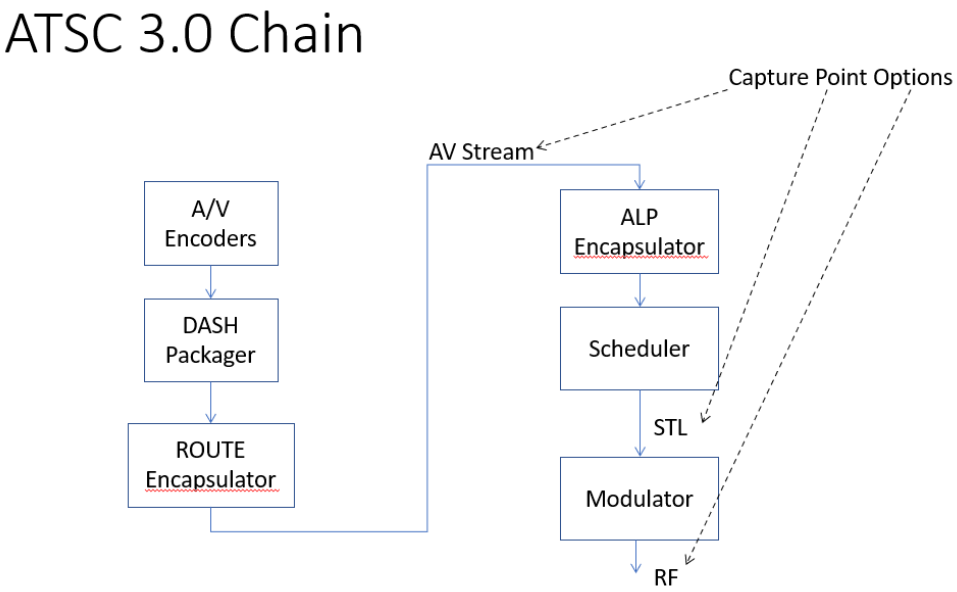

Figure 6.1 ATSC 3.0 emissions capture points.

The following characteristics are noted about the Capture Point Options:

- AV Stream:
  - Includes Audio, Video, Signaling
    - Modulation agnostic
    - Includes all program content
    - Includes all table info
  - Adding gateway config file completes the modulation characteristics
    - Equivalent to STL capture
    - Multiple file formats are in use by different modulator vendors.
- STL:
  - Includes above plus Modulation
    - Frame and PLP structure
    - About 30 Mbps
  - Includes all transmission characteristics
  - Must be captured at the station, cannot be obtained over the air
  - Exciter may require extremely disciplined data rate
  - Check A/324, "Scheduler / Studio to Transmitter Link" [20], for latest revisions to this format
- RF:
  - Includes above at 350 Mbps
  - Multiple file formats
    - Many RF Capture devices are available
    - RF implies extremely high data rates, i.e., very large files
    - Preference is to capture at or as close as possible to the TX, to eliminate channel effects

- "At receiver" capture (including channel effects) might eventually be needed in some cases

The AV Stream Capture with the Gateway configuration file is the most versatile and stable test capture configuration. There may be occasional benefits to the other capture options, e.g., RF Capture may be necessary to replicate some scenarios accurately.

6.3 Test Formats and Equipment

For AV IP Streams, a PCAP is a practical format that is widely used and can be fed into a modulator in a lab setting. One option is to capture the IP stream using Wireshark. Several formats are possible with Wireshark, but the .pcap format is compatible with the DecTek and Enensys inputs.

For STL the preferred format is STL-TP, as an IP-based transport its suitable for capture with a range of tools such as Wireshark. However, not all tools are yet able to replay these.

For RF, the A/74 ("Receiver Performance Guidelines") [21] file format is the preferred format for sharing and analysis. Many tools are available, for example, Test Tree's RF-Catcher with the additional IQ-to-A/74 file conversion application.

In this document, no preference for a specific device or vendor is expressed, however many tools are available to capture and analyze ATSC 3.0 streams. These are evolving with the market and may not be currently capable of identifying all parameters in this document.

At present, this document recommends providing stream examples at multiple capture points (PCAP and STL-TP, and RF, if possible).

Note that the DASH-IF provide a Conformance Checker at https://conformance.dashif.org though at time of writing this needs to be extended for the ATSC 3.0 IOP.

6.4 Stream Capture and Sharing Processes

If any stream/issue under investigation affects only one equipment vendor/receiver manufacturer, the station engineers are strongly advised to contact that entity directly to investigate. The CTA, NAB, and the ATSC Conformance Implementation Team (IT-3) can provide contacts for most organizations but cannot discuss specific manufacturers or equipment vendors directly.

If the stream issue affects multiple vendors/receiver manufacturers, and if the entity has the rights to share the content for test purposes, then the following steps are suggested:

1) Capture Stream at Station site (see previous section) — either stations provide, or someone with a capture tool can get recordings. Contact ATSC for support if necessary (admin@atsc.org).
2) Upload to https://atsc3.cta.tech/ using the "upload form" as "interoperability material", providing as much information as possible about the nature of the capture. Note the license grant notice.
3) The stream is then shared with all users of the portal, which is open to ATSC, CTA, and NAB member companies.
4) The ATSC Conformance Implementation Team provides a forum for open discussion with manufacturers and contributors are strongly advised to join this group and notify them of the provided material. For additional information see the ATSC web site, https://www.atsc.org/subcommittees/atsc-3-0-conformance-implementation-team/.
5) The stream can then be inspected, with issues raised in the online issue tracker: https://redmine.cta.tech/.

Optionally, CTA may choose to consider a stream for inclusion in the NEXTGEN TV logo test suite as “Recommended” or even “Approved” for certification. This is at the complete discretion of CTA.

7. ADDITIONAL RESOURCES

The following documents are recommended for additional reading:

- Pearl “Host Station Manual” [22].
- Dolby “AC-4 Audio Handbook” [23].
- ATSC T/301, “ATSC Technology Group Report: ATSC 3.0 Initial AC-4 Implementation” [24].
- SMPTE “Timed Text Format (SMPTE-TT)”, Doc. ST 2052-1 [25].
- IEEE "Development of the MPEG-H TV Audio System for ATSC 3.0" [28].

– End of Document –