ATSC Standard: A/324:2024-04 Amendment No. 1, "MIMO, LDM, CB Joint Operation"

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Revision History

Version	Date
A/324:2024-04 Amendment No. 1 approved	8 January 2025

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1. OVERVIEW

1.1 Definition

An Amendment is generated to document an enhancement, an addition or a deletion of functionality to previously agreed technical provisions in an existing ATSC document. Amendments shall be published as attachments to the original ATSC document. Distribution by ATSC of existing documents shall include any approved Amendments.

1.2 Scope

This Amendment of ATSC A/324 Scheduler / Studio to Transmitter Link is for the purpose of adding signaling of joint use of Layered Division Multiplexing (LDM), Multiple Input/Multiple Output (MIMO) transmission, and Channel Bonding to both transmitters and receivers of the emitted signals. The three techniques all are described in A/322. They currently can be used individually but are precluded from joint use by language in A/322. That preclusion is being removed in A/322, and joint operation of the three techniques will be described there and permitted. To enable use of the several techniques together, new signaling values are needed. This Amendment is for the purpose(s) of adding such new values to A/324 so that the new combinations of the three signal processing methods can be applied (and for correcting the specifications and/or descriptions of certain signaling cases).

1.3 Rationale for Changes

Support the modifications being made in A/322 to enable joint use of multiple signal processing tools that hitherto was proscribed. To enable such joint use, additional signaling states are needed, and they are described in A/324.

1.4 Compatibility Considerations

The changes described in this document are backwardly compatible relative to the currently published version of the standard to which this Amendment pertains.

2. LIST OF CHANGES

Change instructions are given below in *italics*. Unless otherwise noted, inserted text, tables, and drawings are shown in blue; deletions of existing text are shown in ~~red strikeout~~. The text “[ref]” indicates that a cross reference to a cited referenced document should be inserted. Yellow highlighted references indicate the document editor should insert the appropriate internal document references.

2.1 Change Instructions

Modify Section 3.2.1 as follows:

One or more reserved bits, symbols, fields, or ranges of values (i.e., elements) may be present in this document. These elements are used primarily to enable adding new values to a syntactical structure without altering its syntax or causing a problem with backward compatibility, but they also can be used for other reasons.

Throughout this document, different bit settings (i.e., all "0's" or all "1's") are used as placeholders for reserved values, often to follow practices defined in other standards that are referenced in this document. Readers are cautioned that the values specified in each section containing a description of a structure having reserved elements are valid only for the reserved elements in that specific structure. This strategy may deviate from other ATSC practice with respect to such values for reserved bits.

The ATSC default value for reserved bits is '1.' There is no default value for other reserved elements. Use of reserved elements except as defined in ATSC Standards or by an industry standards setting body is not permitted. See individual element semantics for mandatory settings and any additional use constraints. As currently-reserved elements may be assigned values and meanings in future versions of this Standard, receiving devices built to this version are expected to ignore all values appearing in currently-reserved elements to avoid possible future failure to function as intended.

Add acronyms in Section 3.3 as follows:

PKI Public Key Infrastructure

TMP Timing and Management Protocol

Add/modify terms in Section 3.4 as follows:

Active Data Cell – A Data Cell that carries information.

ALP Generator – A function that may be within or external to a Broadcast Gateway that processes Data Source Transport Protocol (DSTP) packets arriving on its input and creates and formats a Stream of ALP Packets that is output to Scheduler processes.

ALP Packet – An individual ATSC 3.0 Link-layer Protocol packet, starting with its packet_type value (see [4]) and concluding with the last byte of its payload.

ALP Stream – A sequence of ATSC Link-layer Protocol (ALP) Packets processed in the order in which they arrive at a Broadcast Gateway, packed into Baseband Packets by the Scheduler, and passed over the STLTP to Exciter(s) for transmission in a particular PLP.

Carrier – A pure waveform frequency source, like a sine wave, that can be modulated so as to carry information. A Carrier normally is significantly higher in frequency than the information it carries.

Cell – One set of encoded I/Q components in a Constellation (per [3]).

Constellation – A set of encoded (I component/Q component) points in the I/Q plane (per [3]).

Data Cell – A Cell other than a Pilot Cell.

Data Symbol – A set of Constellations with one Constellation to be modulated onto each Carrier in a group of Carriers equally spaced across the spectrum of a communications channel.

FEC Frame – A single Baseband Packet with its associated FEC parity bits attached, having a total size of 64800 or 16200 bits (per FEC Frame).

FEC Block – A FEC Frame after mapping to cells.

Frame – A succession of Data Symbols, proceeding for a specified Period, beginning with those of a Bootstrap, followed by those of a Preamble, and concluding with those carrying both payload and Pilot Cells.

Hard Real-Time – An expression of time that defines an instant at which something is required to occur, with no opportunity to repeat and no expected opportunity to re-do. It requires a level of precision and accuracy sufficient to meet the needs of the function to be performed (e.g., with frame accuracy).

Inner Packet – A data structure that includes a header and carries a payload that is itself the payload of another packet.

Layered MIMO – The combination of LDM and MIMO.

Layered MIMO Type A – A mode of operation in which MIMO and LDM both are active and MIMO is applied to both the Core and Enhanced layers. (See Annex O in [3].)

Layered MIMO Type B – A mode of operation in which MIMO and LDM both are active and MIMO is applied only to the Enhanced layer, meaning that the associated Core layer operates in a SISO configuration. (See Annex O in [3].)

MIMO (Multiple-Input Multiple-Output) – A technique that allows a higher spectral efficiency and/or a higher transmission robustness, when compared to a single-path (i.e., SISO) system, through addition of spatial diversity and multiplexing over two distinct paths between antennas at a transmitter and a receiver. (See Annex L in [3].)

MIMO Mode – A transmission mode in which a transmission system is configured to process PLPs, demultiplexing the PLP data into two transmitter signal paths carrying those PLPs that ultimately feed a pair of cross-polarized transmitting antennas. (See Annex L in [3].)

MISO (Multiple-Input Single-Output) – A technique that allows higher transmission robustness without affecting spectral efficiency, when compared to a single-path (SISO) system, through addition of spatial diversity over multiple distinct paths between antennas at multiple transmitters and a single receiver in SFN operation. (See Section 8.2 and Annex J in [3].)

Null Cell – A Data Cell that carries no information.

Outer Packet – A data structure that includes a header and carries a payload in which the payload is one or more data structures that themselves include headers and carry payloads.

Pilot Cell – A cell within an OFDM frame that is modulated with reference information, the transmitted value of which is known to the receiver.

Polarization – The orientation of the electric field vector of a radiated electromagnetic (radio) wave with respect to the horizon as seen from the antenna, the orientation of the wave emitted from which is described. Such orientation can be fixed linear (i.e., planar) or rotating with time (i.e., circular).

Remote Public Key – A set of data that is associated with a Private/Public Key pair that is located on a Cryptographic Token other than the one where the Remote Public Key is stored and is a concatenation of the Base64-encoded Token Identifier value and the Base64-encoded Public Key value.

Security Data Packet Set – A group of Security Data Packets necessary to deliver a complete set of data that supports one of the functions provided by the Tunneled Packet Security System (see Section 6.4) of any of the CTP-based transport protocols.

SISO (Single-Input Single-Output) – A transmission system configuration in which only a single path is created between a transmitting antenna and a receiving antenna (as opposed to MIMO or MISO in which two or more paths are created between antennas).

SISO Mode – A transmission mode in which a transmission system capable of MIMO Mode operation is configured to process PLPs via a single transmitter signal path that ultimately feeds a single transmitting antenna (which may have cross-polarized elements to create circular or elliptical radiation patterns).

Subframe – A continuous portion of the Data Symbols carrying payload and Pilot Cells in a Frame that can be treated as a unit.

Subslice – A number of sequentially-indexed Data Cells, constituting a portion of the payload of a PLP, that are transported together but separately from the Data Cells of other Subslices derived from the same PLP.

System Manager – A subsystem outside the Application, Transport, and Physical Layers that is responsible for coordinating the functions of at least those layers and the static and quasistatic configurations of various system components and/or their processes, for example definition of PLPs, assignment of IP addresses and port numbers to Services, and operations of switches and servers, as well as setting the times when state changes are to occur. A System Manager does not manage Hard Real-Time activities directly but interfaces with other control functions such as traffic and automation systems plus devices providing direct control over signal flows. A System Manager also serves as the exclusive entry point for requests and the corresponding point of reply to those requests from external entities seeking services to be provided by a facility. ~~A conceptual subsystem outside the Transport and Physical Layers that is responsible for coordinating the functions of at least those two layers and the static and quasi-static configurations of various system aspects, for example definition of PLPs or assignment of IP addresses and port numbers to Services. The System Manager does not manage real-time traffic directly.~~

Time Information Position – The instant at the center of the leading edge of the first sample of the first symbol of a Bootstrap. This value is defined normatively in [3], the definition of which shall take precedence.

Tunneled Packet Security System – A service that can be provided for any of the CTP-based transport protocols to enable authentication of the payloads of data packets transported using those protocols.

Tuple – The ~~combination~~ordered sequence of Internet Protocol (IP) addresses and UDP port numbers.

Modify Section 5.1 as follows:

5.1 Relationship of Broadcast Gateway and Scheduler to the System

Figure 4.2 shows a conceptual block diagram of a Broadcast Gateway and its associated interfaces. A configuration interface allows provisioning of quasi-static aspects of Physical Layer configuration, such as PLP definitions. A Data Source Interface has two ports, one of which delivers content to the Broadcast Gateway along with Data Source Signaling that carries inter-layer information and the other of which is used for real-time control exchanges between the Broadcast Gateway and one or more Data Sources. The required message interchanges on the control interface are defined in this document. Their semantics and the protocol for their carriage are under development at the time of publication and will be documented in the future either as a revision to this standard or as a separate document. Output from the Broadcast Gateway and its Scheduler are via an STL Interface that communicates using STLTP, which carries a complete description of a Physical Layer instance on a frame-by-frame basis to one or more Transmitters.

STLTP carries, from a Broadcast Gateway to one or more Transmitters, all the content data plus signaling to control the Transmitter emissions and to use those emissions to deliver the content to receivers in the Physical Layer Pipe (PLP) structure defined in [3]. An STLTP Stream comprises a group of parallel RTP/UDP/IP multicast Streams that carry content for delivery to receivers via

PLPs, signal formatting data for both Transmitters and receivers carried in Preamble data as defined in [3]; and Transmitter control data. The Transmitter control data includes instructions for building a framing structure needed to support data delivery from Transmitter(s) to receivers, for setting the precise emission times of that structure, and for managing other Transmitter functions, all carried in Timing and Management Protocol (TMP) packets defined in Section 9.3.1 herein. Preamble and TMP packet Streams are generated in processes controlled by Schedulers in Broadcast Gateways, as shown in Figure 4.2. All the content data and the formatting data carried in the Preamble are broadcast by Transmitter(s). TMP data is sent from Broadcast Gateways to Transmitter(s) and is the only data sent over the STLTP to Transmitter(s) that is not broadcast directly to receivers. Instead, TMP data is used by Transmitter Exciters to control Framing as well as other structures and functions that enable reception. The TMP data and other fundamental structure information are communicated from Transmitters to receivers by Bootstraps, as defined in [3]. Bootstraps are generated in Transmitter Exciters based on instructions carried from Broadcast Gateways to Transmitters in TMP packet Streams, as described in Section 9.3.1.

Table 5.1 provides a listing of all the parameters used to control transmitters, their emitted waveforms, and the control and timing signals they emit. Included are parameters used in forming Bootstraps, Preambles, and PHY Frames for transmission and in communicating to receivers how to configure themselves to receive the emitted signals. Bootstraps are defined in [2]. Preambles, PHY Frame structures, and payload formatting are defined in [3]. The Timing and Management Protocol and its processes are defined below in Section 9.3, including the relevant semantic definitions. Also included herein in Annex A is a listing of all the parameters included in Table 5.1 (with the exception of those in the TMP, for which see Section 9.3.1) with descriptions of their operation. Note that the formal definitions of the respective parameters remain in the locations just cited. Note further that there is duplication of many parameters used in common by the Bootstrap and the TMP. This is to facilitate communication of parameter values from Schedulers to Transmitter Exciters that the Exciters then use in construction of Bootstraps for emission at the beginning of PHY Frames.

Replace Table 5.1 with the following table:

Table 5.1 Bootstrap, Preamble, and TMP Parameters ~~and~~Plus Their Sources

	Parameters	Instructions from System Manager	Scheduler Generated
Bootstrap Data	**bootstrap_major_version**	✓	
	bootstrap_minor_version	✓	
	ea_wake_up		✓
	min_time_to_next		✓
	system_bandwidth	✓	
	bsr_coefficient	✓	
	preamble_structure	✓	
Per Frame Data	**L1B_version**		✓
	L1B_mimo_scattered_pilot_encoding	✓	
	L1B_lls_flag		✓
	L1B_time_info_flag		✓
	L1B_return_channel_flag	✓	
	L1B_papr_reduction	✓	
	L1B_frame_length_mode	✓	

	Parameters	Instructions from System Manager	Scheduler Generated
	L1B_frame_length		✓
	L1B_excess_samples_per_symbol		✓
	L1B_time_offset		✓
	L1B_additional_samples		✓
	L1B_num_subframes	✓	
	L1B_preamble_num_symbols		✓
	L1B_preamble_reduced_carriers	✓	
	L1B_L1_Detail_content_tag		✓
	L1B_L1_Detail_size_bytes		✓
	L1B_L1_Detail_fec_type	✓	
	L1B_L1_Detail_additional_parity_mode	✓	
	L1B_L1_Detail_total_cells		✓
	L1B_crc		✓
	L1D_version		✓
	L1D_num_rf	✓	
	L1D_rf_id	✓	
	L1D_bonded_bsid	✓	
	L1D_time_sec		✓
	L1D_time_msec		✓
	L1D_time_usec		✓
	L1D_time_nsec		✓
	L1D_bsid	✓	
	L1D_crc		✓
Per Subframe Data	L1B_first_sub_mimo	✓	
	L1B_first_sub_miso	✓	
	L1B_first_sub_fft_size	✓	
	L1B_first_sub_reduced_carriers	✓	
	L1B_first_sub_guard_interval	✓	
	L1B_first_sub_num_ofdm_symbols	✓	
	L1B_first_sub_scattered_pilot_pattern	✓	
	L1B_first_sub_scattered_pilot_boost	✓	
	L1B_first_sub_sbs_first	✓	
	L1B_first_sub_sbs_last	✓	
	L1B_first_sub_mimo_mixed	✓	
	L1D_mimo	✓	
	L1D_mimo_mixed	✓	
	L1D_miso	✓	
	L1D_fft_size	✓	
	L1D_reduced_carriers	✓	
	L1D_guard_interval	✓	
	L1D_num_ofdm_symbols	✓	
	L1D_scattered_pilot_pattern	✓	
	L1D_scattered_pilot_boost	✓	
	L1D_sbs_first	✓	
	L1D_sbs_last	✓	
	L1D_subframe_multiplex	✓	

	Parameters	Instructions from System Manager	Scheduler Generated
	L1D_frequency_interleaver	✓	
	L1D_sbs_null_cells		✓
	L1D_num_plp	✓	
Per PLP Data	L1D_plp_id	✓	
	L1D_plp_lls_flag		✓
	L1D_plp_layer	✓	
	L1D_plp_start	✓	
	L1D_plp_size	✓	
	L1D_plp_scrambler_type	✓	
	L1D_plp_fec_type	✓	
	L1D_plp_mod	✓	
	L1D_plp_cod	✓	
	L1D_plp_TI_mode	✓	
	L1D_plp_fec_block_start		✓
	L1D_plp_CTI_fec_block_start		✓
	L1D_plp_num_channel_bonded	✓	
	L1D_plp_channel_bonding_format	✓	
	L1D_plp_bonded_rf_id	✓	
	L1D_plp_mimo_stream_combining	✓	
	L1D_plp_mimo_IQ_interleaving	✓	
	L1D_plp_mimo_PH	✓	
	L1D_plp_type	✓	
	L1D_plp_num_subslices	✓	
	L1D_plp_subslice_interval	✓	
	L1D_plp_TI_extended_interleaving	✓	
	L1D_plp_CTI_depth	✓	
	L1D_plp_CTI_start_row		✓
	L1D_plp_HTI_inter_subframe	✓	
	L1D_plp_HTI_num_ti_blocks	✓	
	L1D_plp_HTI_num_fec_blocks_max		✓
	L1D_plp_HTI_num_fec_blocks	✓	
	L1D_plp_HTI_cell_interleaver	✓	
	L1D_plp_ldm_injection_level	✓	
	L1D_plp_mimo	✓	
Timing & Management Protocol (TMP) Data	length		✓
	version_major		✓
	version_minor		✓
	maj_log_rep_cnt_pre	✓	
	maj_log_rep_cnt_tim	✓	
	bootstrap_major	✓	
	bootstrap_minor	✓	
	min_time_to_next		✓
	system_bandwidth	✓	
	bsr_coefficient	✓	
	preamble_structure	✓	
	ea_wakeup		✓

	Parameters	Instructions from System Manager	Scheduler Generated
	num_emission_tim	✓	
	num_xmtrs_in_group_minus_1		✓
	xmtr_group_num		✓
	maj_log_override		✓
	num_miso_filt_codes	✓	
	tx_carrier_offset	✓	
	mimo_flag		✓
	seconds		✓
	nanoseconds		✓
	tx_time_offset	✓	
	xmtr_id		✓
	txid_injection_lvl	✓	
	miso_filt_code_index	✓	
	pkt_rls_seconds		✓
	pkt_rls_a-milliseconds		✓
	crc16		✓

Do not change Section 5.5.

Move Section 5.3, "Preamble Construction," to Section 5.2 and modify new Section 5.2 as follows:

5.~~3~~2 Preamble Construction

The Preamble defined in [3] is used to control the configurations of both Transmitter(s) and off-air receivers so that the signals emitted match the decoding processes in receivers, leading to successful data recovery. The Scheduler shall construct a single Preamble Packet for each Physical Layer frame, for this purpose, which packet shall be sent to the Transmitter(s), used by them for their own configurations, and transmitted as part of the Physical Layer frame with which the Preamble Packet is associated. Multiple copies of the Preamble packet for a particular Physical Layer frame may be sent to the Transmitter(s) over a period of time to improve robustness of the Preamble data delivery to the Transmitter(s), through use of majority logic or similar techniques, under control of Timing and Management Protocol signaling as described in Section 9.3.1.

A Preamble Packet consists of two fundamental categories of data: quasi-static and dynamic, with the former changing only at infrequent intervals and the latter changing potentially on every frame. The quasi-static information comes from the System Manager, while the dynamic information is developed within the Scheduler as part of its functionality. Both types of information end up in the Preamble. The various Preamble parameters and those for construction of Bootstraps (see Section 9.3.1) are shown in Table 5.1, and their sources in either a System Manager or within ~~the~~ Scheduler processes are indicated by check marks in the two columns on the right side of the table.

Move Section 5.4, "Broadcast Gateway Management Protocol," to Section 5.3.

Move Section 5.2, "Scheduler Functionality," to Section 5.4.

Modify Section 9.3 as follows:

9.3 Timing and Management Generator

Timing and Management (T&M) information is constructed in ~~the~~a Timing and Management Generator according to instructions from ~~the~~a Scheduler or System Manager. (See Table 5.1.) It is output by the Timing and Management Generator in the form of RTP/UDP/IP multicast packets, similar to those used to carry Baseband Packets (BBPs) in PLP Streams, so that they form a Stream that can be multiplexed together with the PLP Streams in the STLTP. These Timing and Management packets are not transmitted over the air. The resulting Timing and Management Stream carries a set of instructions for controlling the emission of Physical Layer frames comprising a Bootstrap, Preamble, and Baseband Packets. Configurations of Bootstraps and certain other components of the Physical Layer frames are carried in the Timing and Management Stream. Also included in the Timing and Management Stream are the emission time of each Bootstrap and, hence, the start of each Physical Layer frame, the offset times of each Transmitter in an SFN from the Bootstrap Reference Emission Times for the Network, and other information used to control the Transmitter(s).

To set up Transmitter configurations, the Timing and Management Data for a Physical Layer frame must be sent from the Scheduler to arrive at the Transmitter(s) at least one Physical Layer frame in advance of the start of construction by the Transmitter(s) of the Physical Layer frame that it describes.

9.3.1 Timing and Management Data Stream Protocol

The Timing and Management Data shall be delivered in an RTP/UDP/IP multicast Stream conforming to RFC 3550 [6] with the constraints defined below. The maximum T&M data structure size may exceed the typical 1500-byte MTU, so a mechanism is defined herein to allow segmentation of the T&M data across multiple RTP/UDP/IP packets. Note that such segmentation is required only to conform with typical MTU sizes of 1500 bytes. If the local network allows larger multicast packets, this segmentation may not be needed.

The payload data for each T&M Stream RTP/UDP/IP packet shall be a fragment of the **TMP ()** data structure described in Table 9.3. To provide validation that the **TMP ()** structure is delivered correctly over the STL, a 16-bit cyclic redundancy check is provided as part of the **TMP ()** data. The resultant Stream of **TMP ()** packets shall have IP destination address 239.0.51.48 and destination port 30065, before application of channel number offset of the port number in the case of multichannel carriage within a single STL Tunnel Packet Stream.

The T&M Data Generator shall form the necessary **TMP ()** data structure, as detailed in Table 9.3, from the Scheduler configuration and calculated information. Once the data structure has been populated, it shall be partitioned, if necessary, into multiple RTP/UDP/IP packets, each conforming, with the necessary headers, to the local network MTU size. This process results in creation of a **TMP ()** packet set that typically consists of multiple packets of the same size followed by a smaller remainder packet. Constructing the packets in this way, however, is not normative.

The RTP header fields of the TMP packet set shall be as described below, configured with the **marker (M)** bit of the packet containing the beginning of a **TMP ()** data structure set to '1'. The **marker (M)** bits of the remaining packets shall be set to '0'. This allows the transmission system on the consumer end of the STL to reconstruct the **TMP ()** data structure after any resequencing takes place. The timestamps of the packets of a given **TMP ()** packet set shall have the same values. The timestamp values are derived from a subset of the **Bootstrap_Timing_Data ()**, providing a mechanism to uniquely associate each of the **TMP ()** packets with a specific Physical Layer frame.

The RTP header fields shall follow the syntax defined in RFC 3550 [6] with the following additional constraints:

The **Padding (P)** bit shall be set to '0', indicating no padding is present in the Timing and Management Data packet.

The **Extension (X)** bit shall be set to '0' to indicate that the header contains no extension and that the packet has not been signed. The **Extension (X)** bit shall be set to '1' to indicate that a signing (or other) extension is present. Refer to Section 6.4 for details regarding packet signing and the definition of the STLTP signing extension.

The **CSRC Count (CC)** shall be set to '0', as no **CSRC** fields are necessary.

The **marker (M)** bit shall be set to '1' to indicate that the first byte of the payload is the start of the TMP data. A '0' value shall indicate that the payload is a continuation of the TMP data from the previous packet.

The **Payload Type (PT)** shall be set to 76 (0x4c) indicating the Timing and Management Data payload type.

The **Sequence Number** shall conform to the RFC 3550 [6] specification.

The **Timestamp** shall be defined as in Table 9.2.

The **Synchronization Source (SSRC) Identifier** shall be set to '0'. There should be no other sources of Timing and Management Data carried by the STLTP. Any redundant sources can be managed using IGMP Source-Specific Multicast (SSM) mechanisms.

If the TMP packet is signed, the Header Extension of the Tunneled Packet (see Section 6.4.1) shall be placed immediately following the **SSRC** field and the **Extension (X)** bit shall be set to '1'.

Two types of data are delivered in the (TMP) (): 1) Data intended for use by all Transmitters in a Network, and 2) data addressed to each Transmitter individually. Data intended for use by all Network Transmitters is sent in every (TMP) (). Data addressed to individual Transmitters is contained within the Per_Transmitter_Data () 'for' loop. Since up to 8,192 Transmitters can be supported in a single Network, provision is made to partition portions of the data addressed to individual Transmitters into Groups containing up to 128 Transmitters each. Transmitters shall be uniquely identified by their xmtr_id values. Each Transmitter can be associated with any Group when a large enough number of Transmitters exist in a Network to benefit from partitioning of Transmitters into Groups. Each Transmitter shall be assigned to only one Group.

Table 9.2 Timing and Management Stream Packet Payload

Syntax	No. of Bits	Format
Timing and Management_Packet (TMP) () {		
Structure_Data () {		
length	16	uimsbf
version_major	4	uimsbf
version_minor	4	uimsbf
maj_log_rep_cnt_pre	4	uimsbf
maj_log_rep_cnt_tim	4	uimsbf
bootstrap_major	4	uimsbf
bootstrap_minor	4	uimsbf
min_time_to_next	5	uimsbf
system_bandwidth	2	uimsbf
bsr_coefficient	7	uimsbf
preamble_structure	8	uimsbf

ea_wakeup	2	bslbf
num_emission_tim	6	uimsbf
num_xmtrs_in_group_minus_1	6	uimsbf
xmtr_group_num	7	uimsbf
maj_log_override	3	bslbf
num_miso_filt_codes	2	bslbf
tx_carrier_offset	2	tcimsbf
mimo_flag	1	uimsbf
reserved	~~6~~5	for (i=0; i<~~6~~5; i++) '1'
}		
Bootstrap_Timing_Data () {		
for (i=0; i<=num_emission_tim; i++) {		
seconds	32	uimsbf
nanoseconds	32	uimsbf
}		
}		
Per_Transmitter_Data () {		
for (i=0; i<=num_xmtrs_in_group_minus_1; i++) {		
~~**xmtr_id**~~	~~13~~	~~uimsbf~~
tx_time_offset	16	tcimsbf
Per_Transmit_Polarization_Data () {		
for (j=0; j<=**mimo_flag**; j++) {		
xmtr_id	13	uimsbf
txid_injection_lvl	4	uimsbf
miso_filt_code_index	2	bslbf
}		
If (**mimo_flag** == 0) {		
reserved	29	for (i=0; i<29; i++) '1'
} else {		
reserved	10	for (i=0; i<10; i++) '1'
}		
}		
Packet_Release_Time () {		
pkt_rls_seconds	4	uimsbf
pkt_rls_a-milliseconds	10	uimsbf
reserved	2	'11'
}		
Error_Check_Data () {		
crc16	16	uimsbf
}		
}		

length shall indicate the number of bytes in the Timing and Management Data packet following the RTP/UDP/IP header structure. Up to 65,535 Bytes can be indicated.

version_major, in conjunction with **version_minor**, shall indicate the version of the protocol used to construct the Timing and Management Data packet. Increments in the value of **version_major** are intended to indicate changes in the structure that are not fully compatible with lower-ordered **version_major** values. The value of **version_major** can range from 0 through 15. Timing and

Management packets constructed according to this version of this standard shall have the value of **version_major** set to 0.

version_minor, in conjunction with **version_major**, shall indicate the version of the protocol used to construct the Timing and Management Data packet. Increments in the value of **version_minor** are intended to indicate changes in the structure that are fully backward compatible with lower-ordered **version_minor** values paired with the same **version_major** value. The value of **version_minor** can range from 0 through 15. Timing and Management packets constructed according to this version of this standard shall have the value of **version_minor** set to 1.

maj_log_rep_cnt_pre shall indicate the number of repetitions of Preamble data in the Preamble Stream at UDP port 30064 prior to emission of the Preamble. Permitted values shall be 1, 3, 5, 7, and 9. Note that the value of **L1B_lls_flag** may be correct only in the final copy of the Preamble data sent to Transmitters prior to emission. Consequently, majority logic error correction can be applied reliably to all portions of the Preamble Stream data except the flag value noted. See Section 10.2 for details of placement of the repeated data.

maj_log_rep_cnt_tim shall indicate the number of repetitions of Timing and Management data in the Timing and Management Stream at UDP port 30065 prior to emission of the next Bootstrap. Permitted values shall be 1, 3, 5, 7, and 9. Note that values for the **ea_wakeup** bits may be correct only in the final copy of the Timing and Management data sent to Transmitters prior to emission. Consequently, majority logic error correction can be applied reliably to all portions of the Timing and Management Stream data except the **ea_wakeup** values noted. See Section 10.1 for details of placement of the repeated data.

bootstrap_major shall indicate the value of the **bootstrap_major_version** of the Bootstrap symbols that introduce the Physical Layer frame identified by the **Bootstrap_Timing_Data ()**, which value shall be applied as the root of the Zadoff-Chu sequence of the Bootstrap symbols, as specified in [2].

bootstrap_minor shall indicate the value of the **bootstrap_minor_version** of the Bootstrap symbols that introduce the Physical Layer frame identified by the **Bootstrap_Timing_Data ()**, which value shall be applied as the seed for the pseudo-noise (PN) sequence of the Bootstrap symbols, as defined in [2].

min_time_to_next shall be the enumerated value indicating the minimum time until the next frame of the same type as defined in [2].

system_bandwidth shall be the enumerated value indicating the bandwidth of the RF Transmission channel as defined in [2].

bsr_coefficient shall be the binary value associated with the baseband sampling rate as defined in [2].

preamble_structure shall be the enumerated value indicating the Preamble configuration as defined in [3].

ea_wakeup shall signal the states of the two EA Wakeup Bits to be included in the Bootstrap signal at the start of the next frame to be emitted.

num_emission_tim shall indicate the number of sequential Bootstrap Reference Emission Times that are contained within the **Bootstrap_Timing_Data ()** 'for' loop. Up to 64 values may be indicated. Allowable values shall range from 0 thru 63 and shall be expressed as the number of values carried in the packet minus 1. At least the next Bootstrap Reference Emission Time shall be carried, and it shall be carried in index 0 of the 'for' loop.

~~**ea_wakeup** shall signal the states of the two EA Wakeup Bits to be included in the Bootstrap signal at the start of the next frame to be emitted.~~

num_xmtrs_in_group_minus_1 shall indicate the number of Transmitters minus one to which data is addressed in the **Per_Transmitter_Data ()** 'for' loop (i.e., 1 to 64 Transmitters are indexed 0 to 63). The value can be less than the total number of Transmitters in the Network, in which case data addressed to groups of Transmitters shall be sequenced in order across multiple Timing and Management Data packets.

xmtr_group_num shall indicate the ordinal number of a group of Transmitters to which information in the **Per_Transmitter_Data ()** loop is addressed. The value of the field can range from 0 through 127. Only a single value of **xmtr_group_num** shall apply to a given Timing and Management Stream data packet. Information for individual Transmitters shall be organized in groups identified by values of **xmtr_group_num** starting at 0 and incrementing by 1 from one Timing and Management Stream data packet to the next, until the highest-numbered group is reached, at which point the value shall start again at 0 in the following such packet.

Bootstrap_Timing_Data () shall contain a list of the Bootstrap Reference Emission Times of the next and, optionally, successive future frames, the list having a total number of entries equaling the value of **num_emission_tim**. The values of the Bootstrap Reference Emission Times shall strictly increase from the first entry in the list to the last.

maj_log_override shall indicate that all previous instances of Timing and Management Data and Preamble data for the next and following Physical Layer frames shall be ignored and that the information in the current Timing and Management packet and a subsequent Preamble data packet shall be used to configure the next Physical Layer frame. The non-override condition shall be indicated by a value of '000' in this field. An override condition shall be indicated by a value of '111' in this field.

num_miso_filt_codes shall be set to one less than the number of different MISO filter codes in use within an SFN, as represented by the variable '$\boldsymbol{N_{TX}}$' in Annex J of A/322. [3] For example, when $\boldsymbol{N_{TX}}$=2 is used, **num_miso_filt_codes** would be set equal to 1. The value '0' shall be reserved for future use.

tx_carrier_offset shall indicate the carrier offset of the Transmitter(s) in the frequency domain. The carrier offset shall be expressed in units of a positive or negative integer number of carriers, and it shall be a two's complement signed integer binary number having a range from –1 to +1 decimal, representing from –1 to +1 OFDM carriers. The carrier offset value shall be equal to the product of the value of **tx_carrier_offset** and the carrier frequency spacing in Hz of an 8K FFT for the value of **bsr_coefficient** and **system_bandwidth** indicated in the **Structure_Data ()** for the same frame. Carrier frequency spacing (in Hz) equals BSR (in Hz) divided by 8192. For example, in a system operating with a 6 MHz channel bandwidth and a BSR of 6.192 Mega-samples/second, **bsr_coefficient** = 2, the carrier frequency spacing of 8K carriers is 843.75 Hz, and the carrier frequency offset will be -843.75 Hz, 0 Hz, and +843.75 Hz for values of **tx_carrier_offset** of -1, 0, and +1, respectively. **tx_carrier_offset** = -2 shall be reserved for future use.

The **tx_carrier_offset** value also is used by the Scheduler to set Bootstrap Reference Emission Times as described in Section 10.3.3.2 below.

mimo_flag shall indicate that the frame identified by the BRET, identified, in turn, by the **seconds** and **nanoseconds** values in **Bootstrap_Timing_Data ()**, includes at least one PLP configured for transmission in MIMO form. When its value is set to 0, SISO form will be applied exclusively to the entire described frame. When its value is set to 1, at least one PLP within the frame will be carried by a MIMO signal.

seconds shall carry a value equal to the 32 least significant bits (LSBs) of the seconds portion of the TAI time value [15] of the associated Bootstrap Reference Emission Time, as expressed using the Precision Time Protocol (PTP) defined in [11] and [12].

nanoseconds shall carry a value equal to the nanoseconds portion of the TAI time value [15] of the associated Bootstrap Reference Emission Time. It shall be expressed as a 32-bit binary value having a range from 0 through 999,999,999 decimal.

Per_Transmitter_Data () shall contain information addressed individually to one or a group of Transmitters, with the number of Transmitters for which data is included in the loop equaling the value in **num_xmtrs_in_group_minus_1** plus 1.

~~**xmit_id** shall indicate the address of the Transmitter to which the following values are being sent and shall correspond to the seed value used by the TxID code sequence generator of that Transmitter. The value of the address shall be an unsigned integer binary number having a range of possible values from 0 through 8191 decimal.~~

tx_time_offset shall indicate the emission time offset of the Transmitter to which it is addressed relative to the Bootstrap Reference Emission Times of all frames. The Transmitter time offset shall be expressed in units of positive or negative integer steps of 100 ns and shall be a two's complement signed integer binary number having a range from –32,768 through +32,767 decimal, representing time offsets from –3,276.8 through +3,276.7 microseconds. When MIMO Mode is in use for any PLP within a PHY frame, the same **tx_time_offset** value shall be applied to both Polarizations.

Per_Transmit_Polarization_Data () contains information describing either a single set of values or two sets of values with respect to the TxID and MISO configurations of each Transmitter, depending upon the MIMO configuration of the Transmitter. When MIMO is not applied, a single set of values shall be created, while when MIMO is applied, two sets of values shall be created, one for each Polarization. Each set of values shall include **xmtr_id**, **txid_injection_lvl**, and **miso_filt_code_index**.

xmtr_id shall serve to identify either the Polarizations of Transmitter outputs in MIMO Mode or just the Transmitter itself when in SISO Mode. The values within the **Per_Transmit_Polarization_Data ()** set shall be applied to the respective transmitter outputs and also shall be used as the seed values for generation of TxID transmitter identification per [3] Annex N, with one value for SISO Mode and two values for MIMO Mode when independent identification of Polarizations is required. The value of the **xmtr_id** address shall be an unsigned integer binary number having a range of possible values from 0 through 8191 decimal. When **mimo_flag** =0, exclusively SISO Mode is indicated within the frame, and only a single **xmtr_id** value is needed; this value shall be used to indicate the transmitter to which the **Per_Transmitter_Data ()** set is addressed. When **mimo_flag** =1, indicating MIMO Mode somewhere within the frame, there shall be a single **xmtr_id** value applicable to both SISO Mode and Polarization #1 in MIMO Mode; either the same value or an additional value shall be used for Polarization #2 in MIMO Mode. Note that selection of SISO Mode or MIMO Mode is made on a per-PLP basis so that both modes may be present in a single PHY Frame. When a transmitter is capable of switching between the two modes, it is important that its RF output system be designed to accommodate such operation.[1]

[1] See "ATSC Recommended Practice: Guidelines for the Physical Layer Protocol," Doc. A/327:2024-03, Section 4.2.22, "SISO Operation of MIMO-Capable Transmitters," for detailed information.

txid_injection_lvl shall indicate the Injection Level of the TxID signal below the average power of the Preamble symbols emitted by the Transmitter (or by the specific Polarization if **mimo_flag** =1) to which its value is addressed. The Injection Level shall indicate the value in dB listed in A/322 [3] Table N.3.1 for the TxID Injection Level Code included in the **txid_injection_lvl** field (or Off for code value '0000').

miso_filt_code_index shall be set to one less than the specific MISO filter code assigned to the individual Transmitter (or to the specific Polarization if **mimo_flag** =1), as represented by the variable 'h' in A/322 [3] Annex J. For example, when h=1 is used, **miso_filt_code_index** would be set equal to 0. The same value of MISO filter code index shall apply to a particular Transmitter or Polarization regardless of whether 64-coefficient or 256-coefficient filters are in use.

pkt_rls_seconds shall be the seconds portion of the time of release from the Broadcast Gateway of the specific Timing and Management packet in which the value is found. Its value shall be expressed as 4 bits representing the 4 LSBs of the seconds value of the TAI time [15] when the first bit of the IP header of the T&M packets is released from the Broadcast Gateway.

pkt_rls_a-milliseconds shall be the milliseconds portion of the time of release from the Broadcast Gateway of the specific Timing and Management packet in which the value is found. Its value shall be expressed as 10 bits representing the 3rd through 12th MSBs of the nanoseconds value of the TAI time [15] when the first bit of the IP header of the T&M packets is released from the Broadcast Gateway. Its range will be from 0 to 953 (decimal) as a consequence of the Period of an **a-millisecond** being slightly longer than precisely a millisecond. (See the definition of an **a-millisecond** in Section 3.4.)

crc16 shall be the value resulting from application of the 16-bit cyclic redundancy check defined in [10], applied to all fields in the Timing and Management Packet payload from the **length** field through the field (and any reserved bits) immediately preceding the **crc16** field.

[Editor's Note: The above footnote number should be '2' rather than '1'. Also, inclusion of Reference Document info is intended to be temporary until completion of Revision of A/324, which currently is in drafting. This avoids the necessity to renumber practically all Reference numbering, which will be necessary when the A/324 Revision is completed.]

Modify Annex A as follows:

Annex A Physical Layer Control (Informative)

A.1 PHYSICAL LAYER RESOURCES

Operation of Physical Layers of ATSC 3.0 broadcast operations depend upon configuration data sent from Broadcast Gateways to transmitter Exciters to apply to their own operations and then to pass along to receivers for their configuration needs at the beginning of each Physical Layer frame. A Physical Layer configuration schedule is pre-determined in a System Manager to enable such operations and ~~pre-determined schedule consists of~~contains at least the control parameters listed in Section 9 of [3]. The control inputs to the Physical Layer are listed in the following sub-sections. The descriptions herein are different from the definitions in [2] and [3], as the latter are normative while those herein are for information purposes only. Note that the summaries below describe values included in the pseudo-code tables in [2] Tables 6.2, 6.4, and 6.5 and [3] Tables 9.2 and 9.8. ~~Dependency of s~~Some parameters may be ~~based~~dependent on others ~~from~~through application of formulas. Those are identified below when possible.

A.1.1 Bootstrap Signaling

bootstrap_major_version – This parameter is defined by [2] and constrained by [3]. Its purpose~~ntent~~ is to signal a ~~structure change~~version of the Bootstrap that is not backwardly~~-~~ compatible with ~~existing ~~prior version(s) of the Bootstrap.

bootstrap_minor_version – This parameter is defined by [2] and constrained by [3]. Its purpose~~ntent~~ is to signal a ~~structure change~~version of the Bootstrap that is backwardly compatible with ~~existing~~prior version(s) of the Bootstrap.

ea_wake_up – There~~is~~ are two instances of this parameter in each Bootstrap, which are~~is~~ defined by [2] to signal the presence of emergency alert information. More information applicable to their use appears in Section 7.2.2 herein.

min_time_to_next – This parameter is defined by [2] to signal ~~when~~the earliest time at which the next ~~similar ~~Physical Layer frame of the same~~Bootstrap~~ type (i.e., ~~a ~~having Bootstrap ~~that matches the same~~ major and minor version ~~number as~~values that match those of the current Bootstrap) will be available in an emission.

system_bandwidth – This parameter is defined by [2] to signal the channel bandwidth ~~of ~~in which the post-Bootstrap portion of the current Physical Layer frame is intended to be transmitted.

bsr_coefficient – This parameter is defined by [2] and constrained by Table 9.1 in [3] ~~with broadcaster-intended Baseband Sample Rate~~so as to yield the requisite Baseband Sampling Rate for the bandwidth of the emission.

preamble_structure – This parameter is defined by [2] and constrained by Table H.1.1 in [3] ~~with~~to indicate sets of settings chosen by the broadcaster for FFT size, G~~g~~uard I~~i~~nterval length, ~~and~~ Preamble P~~p~~ilot spacing, and L1- Basic FEC Mode ~~for ~~to be applied to ~~L1 Basic ~~Preamble symbols~~ chosen by the broadcaster~~. Preamble symbol~~s~~ settings should ~~be ~~result in emitted symbols at least as robust as the most robust payload symbols~~settings~~.

A.1.2 L1-Basic Signaling

L1B_version – This parameter is defined and constrained by [3]. It is capable of minor version signalinging up to eight different editions ofof the Preamble L1-Basic signaling structure over the life of the standard. It is transmitted on a per-frame basis.

L1B_mimo_scattered_pilot_encoding – This parameter is defined by [3] and signals the MIMO scattered pilot encoding scheme used by any MIMO subframes.

L1B_lls_flag – This parameter is defined by [3] to signal ifwhether Low Level Signaling (LLS) is available carried in the current frame. LLS is defined by [4] and is the starting point for finding determining which services are available on a given broadcast channel and retrieving them.

L1B_time_info_flag – This parameter is defined by [3] to signal the presence of Physical Layer timing information in the Preamble of the current frame and the precision with which it is carried.

L1B_return_channel_flag – This parameter is defined by [3] to signal the presence of adedicated return channel (DRC) data in a PLP within the current PHY frame.

L1B_papr_reduction – This parameter is defined by [3] to signal use of one or more techniques, and the technique(s) used, to reduce the peak to average power ratio within the current PHY frame.

L1B_frame_length_mode – This parameter is defined by [3] to signal that whether the current frame is time-aligned withby distribution of excess samples distribution to the guard intervals of data payload OFDM symbols or ifwhether the current frame is symbol-aligned, with no excess sample distribution.

L1B_frame_length – This parameter is defined by [3] to signal the time Period measured from the beginning of the first sampleTime Information Position of the Bootstrap associated with the current frame to the end of the final sample associated with the current frame, it is only present when time-aligned frames are used. Frame length has many considerations like the longest segment length as defined in [4], or time interleaving depth that broadcasters must choose depending on desired content and robustness. Sizes are constrained by [3] to be between 50 msec and 5000 msec in 5-msec increments.

L1B_excess_samples_per_symbol – This parameter is defined by [3] to signal the additional number of excess samples included in the guard interval of each non-Preamble OFDM symbol of the post Bootstrap portion of the current frame; it is only present when time-aligned frames are used.

L1B_time_offset – This parameter is defined by [3] to signal the number of sample periods between the nearest preceding or coincident millisecond boundary and the leading edge of the frame; it is only present when symbol-aligned frames are used.

L1B_additional_samples – This parameter is defined by [3] to signal the number of additional samples added at the end of a frame to facilitate sampling clock alignment; it is only present and is set to 0 when symbol-aligned frames are used.

L1B_num_subframes – This parameter is defined by [3] to signal the number of subframes minus 1 present within the current frame.

L1B_preamble_num_symbols – This parameter is defined by [3] to signal the total number of OFDM symbols contained within the Preamble minus 1., not including the first Preamble symbol.

L1B_preamble_reduced_carriers – This parameter is defined by in Section 7.2.3 of [3] to signal the control unit value (C_{unit}) that determines the amountnumber of carriers to be reduced (i.e., eliminated) in Preamble symbols. The carrier rReduction of the number of carriers from theits maximum number of carriersvalue (as given in Table 7.1 of [3] in the respective column for the FFT size in use, on the row having $C_{red\_coeff} = 0$) which is given by the FFT size used, produces the Number of Carriers (*NoC*) value.~~number of control units of carriers by which the maximum number of carriers for the FFT size used for the Preamble is reduced.~~ It (C_{unit}) applies to all Preamble symbols except the first one of the current frame, which uses the maximum possible carrier reduction, as represented in Table 7.1 of [3] by a value of 4 in the C_{red_coeff} column.

L1B_L1_Detail_content_tag – This parameter is defined by [3] and signals that new information is available in L1 Detail parameters other than those related to expression of the current time.

L1B_L1_Detail_size_bytes – This parameter is defined by [3] to signal the size (in bytes) of the L1-Detail information.

L1B_L1_Detail_fec_type – This parameter is defined by [3] to signal the FEC type for L1-Detail information protection. It is a combination of 16K LDPC code length with a variety of QPSK or non-uniform constellations and code rates.

L1B_L1_Detail_additional_parity_mode – This parameter is defined by [3] to signal the value of a ratio (K), expressed as the ~~Additional~~ Parity Mode, ~~which gives the ratio (K) of~~ used to calculate the number of additional parity bits ~~for the next frame's L1-Detail that are~~ carried in the current frame to be applied as error correction bits to L1-Detail of the next frame. The values of (K) are limited to 0, 1, and 2. The current and next frames are required to be of the same frame type, meaning that they have the same Bootstrap Major and Minor version values.~~to half of the number of coded bits for the next frame's L1-Detail signaling.~~ If there is no succeeding frame of the same frame type, the value 0 is sent to indicate that there are no additional parity bits carried in the current frame to be applied to a succeeding frame of the same frame type.

L1B_L1_Detail_total_cells – This parameter is defined by [3] to signal the total size (specified in data cells) of the combined coded and modulated L1-Detail data contained in the Preamble portion of the current PHY frame ~~signaling for the current frame and any modulated~~and any coded and modulated additional parity bits for L1-Detail ~~signaling~~ data for~~of~~ the ~~next~~ succeeding PHY frame.

L1B_first_sub_mimo – This parameter is defined by [3] and indicates whether MIMO is used for all PLPs in the first subframe of the current frame. When the flag is set, it indicates that MIMO processing is applied to all PLPs in the first subframe. When the flag is not set, it indicates that the first subframe includes one or more PLPs to which MIMO processing is not applied. See Table 9.8 in [3], and note that the setting of this flag is mutually exclusive with the setting of **L1B_first_sub_mimo_mixed**, as shown on the last line of the table. ~~This parameter is defined by [3] to signal whether MIMO is used for the first subframe of the current frame.~~

L1B_first_sub_miso – This parameter is defined by [3] to signal whether MISO transmit diversity code filters are ~~is used~~ applied during ~~for~~ the first subframe of the current PHY frame.

L1B_first_sub_fft_size – This parameter is defined by [3] to signal the FFT size ~~associated with~~applied to the first subframe of the current frame.

L1B_first_sub_reduced_carriers – This parameter is defined ~~by~~ in Section 7.2.3 of [3] to signal the ~~number of~~ control unit~~s~~ value (C_{unit}) that determines the number of carriers to be reduced (i.e., eliminated) in the first subframe of the current PHY frame. ~~by which the maximum number of carriers for the FFT size used for the first subframe of the current frame is reduced.~~ Reduction of the number of carriers from its maximum value (as given in Table 7.1 of [3] in the respective column for the FFT size in use, on the row having $C_{red\_coeff} = 0$), produces the Number of Carriers (*NoC*) value. It (C_{unit}) applies to all symbols of the first subframe of the current frame.

L1B_first_sub_guard_interval – This parameter is defined by [3] to signal the guard interval length used for the OFDM symbols of the first subframe of the current ~~sub~~ PHY frame.

L1B_first_sub_num_ofdm_symbols – This parameter is defined by [3] to signal a value equal to one less than the total number of data payload OFDM symbols, including any subframe boundary symbol(s), present within the first subframe of the current PHY frame.

L1B_first_sub_scattered_pilot_pattern – This parameter is defined by [3] to signal the scattered pilot pattern used for the first subframe of the current ~~sub~~ PHY frame whether it is SISO or MIMO.

L1B_first_sub_scattered_pilot_boost – This parameter is defined by [3] to signal the relative amplitude of the scattered pilots used for the first subframe of the current PHY frame.

L1B_first_sub_sbs_first – This parameter is defined by [3] to signal whether or not the first symbol of the first subframe of the current PHY frame is a subframe boundary symbol.

L1B_first_sub_sbs_last – This parameter is defined by [3] to signal whether or not the last symbol of the first subframe of the current PHY frame is a subframe boundary symbol.

L1B_first_sub_mimo_mixed – This field is defined by [3] to indicate whether the first subframe of the current PHY frame multiplexes PLPs using MIMO with other PLPs not using MIMO. When set, it indicates that PLPs using and not using MIMO are multiplexed within the first subframe, and when not set, it indicates that all PLPs in the subframe either use MIMO (i.e., with **L1B_first_sub_mimo** set) or do not use MIMO (i.e., with **L1B_first_sub_mimo** not set).

L1B_crc – This field is defined by [3] to be a CRC-32 value that encompasses the L1B Preamble data except for the CRC field itself.

A.1.3 L1-Detail Signaling

L1D_version –This parameter is defined and constrained by [3]. It is capable of signaling up to sixteen different editions of the L1-Detail signaling structure over the life of the standard~~This parameter is defined by [3]. It signals the minor version of the Preamble L1-Detail structure for the current frame~~. It is transmitted on a per-frame basis. Changes in the L1-Detail structure that make use of formerly reserved bits may not require incrementing of **L1D_version**.

L1D_num_rf – This parameter is defined by [3] to signal the number of BSIDs involved in channel bonding of the current ATSC 3.0 system, not including the BSID of the ~~present~~ current channel.

L1D_rf_id – This parameter is defined by [3] to index the implicit IDs of the other RF channels involved in channel bonding.

L1D_bonded_bsid – This parameter is defined by [3] to signal the Broadcast Stream ID of a separate RF channel that is channel bonded with the current RF channel.

L1D_time_sec – This parameter is defined by [3] to signal the seconds component of the time information. Presence of the seconds component is dependent on the value of **L1B_time_info_flag** but only is carried in conjunction with at least **L1D_time_msec**.

L1D_time_msec – This parameter is defined by [3] to signal the milliseconds component of the time information. Presence of the msec component is dependent on the value of **L1B_time_info_flag** but only is carried in conjunction with at least **L1D_time_sec**.

L1D_time_usec – This parameter is defined by [3] to signal the microseconds component of the time information. Presence of the µsec component is dependent on the value of **L1B_time_info_flag** but only is carried in conjunction with at least **L1D_time_sec** and **L1D_time_msec**.

L1D_time_nsec – This parameter is defined by [3] to signal the nanoseconds component of the time information. Presence of the nsec component is dependent on the value of **L1B_time_info_flag** but only is carried in conjunction with **L1D_time_sec**, **L1D_time_msec**, and **L1D_time_µsec**.

L1D_mimo – This parameter is defined by [3] to signal whether MIMO is used for all PLPs in the subframe referenced by the current index value of the subframe 'for' loop. ~~This parameter is defined by [3] to signal whether MIMO is used for the given subframe.~~

L1D_mimo_mixed – This field is defined by [3] to indicate whether the subframe referenced by the current index value of the subframe 'for' loop multiplexes PLPs using MIMO with PLPs not using MIMO. When set, it indicates that PLPs both using and not using MIMO are multiplexed within the subframe, and when not set, it indicates that all PLPs in the subframe either use MIMO (i.e., with **L1D_mimo** set) or do not use MIMO (i.e., with **L1D_mimo** not set).

L1D_miso – This parameter is defined by [3] to signal whether MISO is used for the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop.

L1D_fft_size – This parameter is defined by [3] to signal the FFT size associated with the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop.

L1D_reduced_carriers – This parameter is defined in Section 7.2.3 of [3] to signal the control unit value (C_{unit}) that determines the number of carriers to be reduced (i.e., eliminated) in the subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame. Reduction of the number of carriers from its maximum value (as given in Table 7.1 of [3] in the respective column for the FFT size in use, on the row having C_{red_coeff} =0), produces the Number of Carriers (*NoC*) value. It (C_{unit}) applies to all symbols of the currently indexed subframe of the current frame~~This parameter is defined by [3] to signal the number of control units of carriers by which the maximum number of carriers for the FFT size used for the given subframe is reduced~~.

L1D_guard_interval – This parameter is defined by [3] to signal the guard interval length used for the OFDM symbols of the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame.

L1D_num_ofdm_symbols – This parameter is defined by [3] to signal the value equal to one less than the total number of data payload OFDM symbols, including any subframe boundary symbol(s), present within the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame.

L1D_scattered_pilot_pattern – This parameter is defined by [3] to signal the scattered pilot pattern used for the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame, whether it is SISO or MIMO.

L1D_scattered_pilot_boost – This parameter is defined by [3] to signal the relative amplitude of the scattered pilots used for the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame.

L1D_sbs_first – This parameter is defined by [3] to signal whether or not the first symbol of the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame is a subframe boundary symbol.

L1D_sbs_last – This parameter is defined by [3] to signal whether or not the last symbol of the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame is a subframe boundary symbol.

L1D_subframe_multiplex – This parameter is defined by [3] to signal whether the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame is time-division multiplexed / concatenated in time with adjacent subframes.

L1D_frequency_interleaver – This parameter is defined by [3] to signal whether the frequency interleaver is enabled or bypassed for the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame.

L1D_sbs_null_cells – This parameter is defined by [3] to signal the number of null cells in the subframe boundary symbols of the ~~current~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame.

L1D_num_plp – This parameter is defined by [3] to signal a value equal to one less than the total number of PLPs used within the ~~given~~ subframe referenced by the current index value of the subframe 'for' loop of the current PHY frame.

L1D_plp_id – This parameter is defined by [3] to signal a value equal to the ID of the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe, with a range from 0 to 63, inclusive.

L1D_plp_lls_flag – This parameter is defined by [3] to signal whether the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe carries ~~the~~ Low Level Signaling (LLS), as defined by [4]. Multiple instances of the PLP in different subframes within a single PHY frame should indicate the same state of LLS carriage.

L1D_plp_layer – This parameter is defined by [3] to signal a value equal to the layer index of the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_start – This parameter is defined by [3] to signal a value equal to the index of the ~~d~~Data ~~c~~Cell ~~that holds~~in which the first ~~d~~Data ~~c~~Cell of the ~~current~~ PLP referenced by the current index value of the PLP 'for' loop of the current ~~in the given current s~~Subframe is located. Data Cell indexing is described in Section 7.2.6~~5~~.1~~2~~ of [3] both for subframes following the Preamble (i.e., first subframes), including the portions of last symbols carrying Preamble data not used to carry Preamble data, ~~(i.e., first subframes)~~ and for subsequent subframes.

L1D_plp_size – This parameter is defined by [3] to signal a value equal to the number of data cells allocated to the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_scrambler_type – This parameter is defined by [3] to signal the choice of scrambler type for the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_fec_type – This parameter is defined by [3] to signal the Forward Error Correction (FEC) method used for encoding the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_mod – This parameter is defined by [3] to signal the modulation characteristics used for the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe. The same code set is used to indicate modulation characteristics for both ~~whether~~ SISO ~~or~~ and MIMO.

L1D_plp_cod – This parameter is defined by [3] to signal the code rate used for the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_TI_mode – This parameter is defined by [3] to signal the time interleaving mode for the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe. The Scheduler is responsible for selecting the appropriate time interleaving mode to use for each Core PLP configured for an RF channel. ~~An~~ Enhanced PLP(s) follow~~s~~ the time interleaver modes of the Core PLP(s) with which ~~it is~~they are layered-division multiplexed.

L1D_plp_fec_block_start – This parameter is defined by [3] to signal the starting position, in indexed cells within the current subframe, of the first FEC Block that begins within the current PLP referenced by the current index value of the PLP 'for' loop of the current subframeduring the current subframe. See Section 6 *et. seq*. of [3] Tables 6.1 & 6.2 and supporting text.

L1D_plp_CTI_fec_block_start – This parameter is defined by [3] to signal the starting position, after the a CTI,, of the first cell of the first complete FEC Block, before the CTI, for the current PLP in the currentreferenced by the current index value of the PLP 'for' loop of the current subframe or the subsequent subframe. See Section 9.3.9.1 *et seq.* of [3].

L1D_plp_num_channel_bonded – This parameter is defined by [3] to signal the use of channel bonding and, if used, the number of RF channels, not including the present RF channel, involved in channel bonding of the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_channel_bonding_format – This parameter is defined by [3] to signal whether the channel bonding format for of the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe, whetheris plain channel bonding or SNR averaging channel bonding.

L1D_plp_bonded_rf_id – This parameter is defined by [3] to signal the RF IDs of the channels that are used for channel bonding with the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_mimo_stream_combining – This parameter flag is defined by [3] to signal whether the Stream combining option of the MIMO precoderprecoding process is used in the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_mimo_IQ_interleaving – This parameter flag is defined by [3] to signal whether the IQ polarization interleaving option of the MIMO precoder precoding process is used in the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_mimo_PH – This parameter flag is defined by [3] to signal whether the phase hopping option of the MIMO precoder precoding process is used in the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_type – This parameter is defined by [3] to signal when the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe is non-dispersed (i.e., when all data cells of the current PLP have contiguous logical addresses and subslicing is not used for the current PLP) or when the current PLP is dispersed (i.e., when not all data cells of the current PLP have contiguous logical addresses and subslicing is used for the current PLP).

If **L1D_plp_type** has a value of '1', the number of subslices and subslice interval are set.

L1D_plp_num_subslices – If the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe is dispersed, this parameter is defined by [3] to signal a value equal to one less than the actual number of subslices used for the given PLP within the given current subframe.

L1D_plp _subslice_interval – If the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe is dispersed, this parameter is defined by [3] to signal a value equal to the number of sequentially-indexed data cells measured from the beginning of a subslice for a given PLP to the beginning of the next subslice for the same PLP.

L1D_plp_TI_extended_interleaving – This parameter is defined by [3] to signal whether extended time interleaving is to be used for the given PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_CTI_depth – This parameter is defined by [3] to signal the number of rows used in the Convolutional Time Interleaver, as indicated by an enumerated list.

L1D_plp_CTI_start_row – This parameter is defined by [3] to signal the position of the commutator at the start of the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop within the current subframe.

L1D_plp_HTI_inter_subframe – This parameter is defined by [3] to signal the hybrid time interleaving mode for the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe, i.e., whether the specified PLP uses inter-subframe or intra-subframe hybrid time interleaving.

L1D_plp_HTI_num_ti_blocks – This parameter is defined by [3] to signal either the number of TI Blocks per interleaving frame, N_{TI}, when ~~**L1D_plp_HTI_inter_subframe** = 0~~ intra-subframe hybrid interleaving is used, or the number of subframes, ~~*P*~~N_{IU}, over which cells from one TI Block are carried when ~~**L1D_plp_HTI_inter_subframe** = 1~~ inter-subframe hybrid interleaving is used in the given PLP.

L1D_plp_HTI_num_fec_blocks_max – This parameter is defined by [3] to signal a value one less than the maximum number of FEC Blocks per interleaving frame for the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_HTI_num_fec_blocks – This parameter is defined by [3] to signal a value one less than the number of FEC Blocks contained in the current interleaving frame for the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_HTI_cell_interleaver – This parameter is defined by [3] to signal whether the Cell Interleaver is used in the ~~given~~ PLP referenced by the current index value of the PLP 'for' loop of the current subframe.

L1D_plp_ldm_injection_level – This parameter is defined by [3] to signal the Enhanced PLP injection level relative to the level of the Core PLP, as indicated by an enumerated list when LDM is applied.

L1D_bsid – This parameter is defined by [3] to signal the assigned Broadcast Stream ID (BSID) of the aggregated contents carried on the current RF ~~channel~~emission. Those same aggregated contents, if also carried on a separate RF emission, would be identified by the same BSID value. The BSID value is assigned so as to establish uniqueness of RF emission contents within a region.

L1D_plp_mimo – This parameter is defined by [3] to signal whether MIMO is used for the PLP referenced by the current index value of the PLP 'for' loop of the current subframe when the current subframe contains PLPs both using and not using MIMO.

L1D_crc – This field is defined by [3] to be a CRC-32 value that encompasses the L1D Preamble data except for the CRC field itself.

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