ATSC Standard: A/322:2024-09 Amendment #1, "ATSC 3.0 Errata"

A/322-2024-09a Amend. No. 1
28 July 2025

Advanced Television Systems Committee
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Revision History

Version	Date
Amendment approved	28 July 2025
Editorial updates to definitions of Frame and Subframe in Section 3.4, and clarification of change instructions in Section L.11.2.	20 November 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 document mainly corrects errata items found in the MIMO, Channel Bonding, LDM combinations in the physical layer. This amendment also fixes errata items for Subframe and Frame term additions, and LDM Core layer <= Enhanced Layer SNR description. This amendment is in response to New Project Proposal N-074r0, "ATSC 3.0 MIMO Extension".

1.3 Rationale for Changes

In A/322, optional combinations among LDM, MIMO, and Channel Bonding are being implemented and clarifications, typos and optimizations are proposed to fix errata items. This amendment fixes all items found to date in these combinations, along with clarifications in Subframe and Frame term additions and LDM Core Layer <= Enhanced Layer SNR. These fixes clarify meanings and intent of LDM, MIMO, and CB combinations along with some optimizations for implementation ease.

1.4 Compatibility Considerations

The changes described in this document are backward-compatible to the currently published version of the standard to which this Amendment pertains and any previously approved Amendments for that standard; however, currently deployed receivers would not have the capability of decoding the signal generated by this amendment. These changes would not affect any receiver's ability to demodulate signals not encoded using MIMO, LDM, or Channel Bonding.

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~~. 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 Normative References

2.2 Acronyms, Abbreviations and Mathematical Operators

2.3 Terms

2.4 Change Instructions

Search and replace term subframe to Subframe.

It should be noted that the terms "Frame" and "Subframe" should be defined and then capitalized throughout the A/322 standard to help differentiate them from "FEC Frame," which is defined in the Terms. There likely are other terms that should get the same treatment. Requires detail review of redline changes prior to publication.

Search and replace term frame to Frame.

It should be noted that the terms "Frame" and "Subframe" should be defined and then capitalized throughout the A/322 standard to help differentiate them from "FEC Frame," which is defined in the Terms. There likely are other terms that should get the same treatment. Requires detail review of redline changes prior to publication.

Add terms to Section 3.4 as follows

Frame – A series of bootstrap and post-bootstrap OFDM symbols (consisting of Preamble and one or more subframes) extending from the center of the leading edge of the first sample of the first symbol of a bootstrap to the identical point in the immediately succeeding bootstrap.[1]

Subframe – A series of post-bootstrap, non-Preamble OFDM symbols having the same FFT size, GI length, and number of useful carriers (*NoC*), and sharing a common scattered pilot pattern, all of which may be placed between optional boundary symbols.

Modify Section 6.4.1 as follows:

A two-layer LDM system shall combine two or more PLPs before time interleaving. Each layer shall consist of one or more PLPs. The Core Layer shall ~~use an~~have equal or ~~more~~greater robustness ~~ModCod combination~~ than the Enhanced Layer. Each PLP may use a different FEC encoding (including code length and code rate) and constellation mapping. For example the Core Layer might use N_{inner}=64800, code rate=4/15 and QPSK while the Enhanced Layer might use N_{inner}=64800, code rate=10/15 and 64QAM.

Add text to Section 8.6 as follows:

The bootstrap symbol construction is defined in detail in [2]. Section 9.1 establishes constraints on the payload contents of the bootstrap to represent the set of capabilities that this standard supports.

[1] Note: post-bootstrap OFDM symbol constituents (i.e., a Preamble and one or more Subframes) included in the Frame definition herein relate specifically to the post-bootstrap Frame structure described in this standard. Other post-bootstrap structures are possible if signaled by different parameter values in the bootstrap.

When MIMO or Layered MIMO is applied, the bootstrap symbols prefixed to a frame shall be identical between the Polarizations, while the amplitudes may differ. In each Polarization, amplitude of the bootstrap symbol should conform to that of the following Preamble symbol.

Modify Section 9.2.3 as follows:

The parameters of the first subframe of the current frame are signaled within L1-Basic to facilitate the immediate initial OFDM processing of this first subframe at a receiver without needing to wait until L1-Detail is decoded.

~~**L1B_first_sub_mimo** – This field shall indicate whether MIMO (see Annex L) is used for the first subframe of the current frame. A value of 1 shall indicate that MIMO is used, and a value of 0 shall indicate that MIMO is not used.~~

L1B_first_sub_mimo – This field shall indicate whether MIMO (see Annex L and Annex O) is used for all PLPs in the first subframe of the current frame. A value of 1 shall indicate that MIMO processing is applied to all PLPs in the first subframe. A value of 0 shall indicate that the first subframe includes one or more PLPs to which MIMO processing is not applied. See Table 9.8 and note that the setting of this field to 1 is mutually exclusive with the setting of **L1B_first_sub_mimo_mixed** to 1, as shown on the last line of the table.

L1B_first_sub_mimo_mixed – This field shall indicate whether the first subframe of the current frame multiplexes PLPs using MIMO with other PLPs not using MIMO. A value of 1 shall indicate that PLPs using and not using MIMO are multiplexed within the subframe, and a value of 0 shall indicate that all PLPs in the subframe either use MIMO (i.e., **L1B_first_sub_mimo** =1) or do not use MIMO (i.e., **L1B_first_sub_mimo** =0).

When LDM is applied to the first subframe in a frame (i.e., when PLPs having **L1D_plp_layer values** >0 are present in the subframe), the values of **L1B_first_sub_mimo_mixed** indicate the following: When set to 1, MIMO processing shall be applied to all Enhanced PLPs (i.e., **L1D_plp_layer** >0) in the described subframe, and MIMO processing shall not be applied to all Core PLPs (i.e., **L1D_plp_layer** =0) in the described subframe. See Table 9.8, and note that the setting of this field to 1 is mutually exclusive with the setting of **L1D_first_sub_mimo** to 1, as shown on the last line of the table.

Table 9.1 Use Cases and Indications Related to MIMO: Signaling Format for **L1B_first_sub_mimo_mixed** in Conjunction with **L1B_first_sub_mimo**

MIMO Configurations	Related L1-Basic Signaling Assignment	
	L1B_first_sub_mimo	L1B_first_sub_mimo_mixed
All PLPs in first subframe use SISO	0	0
PLPs of both types in first subframe	0	1
All PLPs in first subframe use MIMO	1	0
Invalid Combination	1	1

Note: In cases of all-SISO and all-MIMO PLPs within the first subframe, any of the available multiplexing types (i.e., TDM, FDM, LDM, and combinations thereof) can be applied. In cases in which MIMO is to be applied differently to the PLPs on the respective layers (i.e., Core and Enhanced) within a subframe, LDM multiplexing is required to be applied to the subframe (potentially along with TDM, FDM, and combinations thereof on either or both of the layers).

L1B_first_sub_miso – This field shall indicate the MISO (see Section 8.2) option used for the first subframe of the current frame as given in Table 9.11.

…

L1B_first_sub_sbs_last – This field shall indicate whether or not the last symbol of the first subframe of the current frame is a subframe boundary symbol. **L1B_first_sub_sbs_last** =0 shall indicate that the last symbol of the first subframe of the current frame is not a subframe boundary symbol. **L1B_first_sub_sbs_last** =1 shall indicate that the last symbol of the first subframe of the current frame is a subframe boundary symbol.

~~**L1B_first_sub_mimo** – This field shall indicate whether MIMO (see Annex L and Annex O) is used for all PLPs in the first subframe of the current frame. A value of 1 shall indicate that MIMO processing is applied to all PLPs in the first subframe. A value of 0 shall indicate that the first subframe includes one or more PLPs to which MIMO processing is not applied. See Table 9.8 and note that the setting of this field to 1 is mutually exclusive with the setting of **L1B_first_sub_mimo_mixed** to 1, as shown on the last line of the table.~~

~~**L1B_first_sub_mimo_mixed** – This field shall indicate whether the first subframe of the current frame multiplexes PLPs using MIMO with other PLPs not using MIMO. A value of 1 shall indicate that PLPs using and not using MIMO are multiplexed within the subframe, and a value of 0 shall indicate that all PLPs in the subframe either use MIMO (i.e., **L1B_first_sub_mimo** =1) or do not use MIMO (i.e., **L1B_first_sub_mimo** =0).~~

~~When LDM is applied to the first subframe in a frame (i.e., when PLPs having **L1D_plp_layer** values >0 are present in the subframe), the values of **L1B_first_sub_mimo_mixed** indicate the following: When set to 1, MIMO processing shall be applied to all Enhanced PLPs (i.e., **L1D_plp_layer** >0) in the described subframe, and MIMO processing shall not be applied to all Core PLPs (i.e., **L1D_plp_layer** =0) in the described subframe. See Table 9.8, and note that the setting of this field to 1 is mutually exclusive with the setting of **L1D_first_sub_mimo** to 1, as shown on the last line of the table.~~

~~**Table 9.2** Use Cases and Indications Related to MIMO: Signaling Format for **L1B_first_sub_mimo_mixed** in Conjunction with **L1B_first_sub_mimo**~~

~~**MIMO Configurations**~~	~~**Related L1-Basic Signaling Assignment**~~	
	~~**L1B_first_sub_mimo**~~	~~**L1B_first_sub_mimo_mixed**~~
~~All PLPs in first subframe use SISO~~	~~0~~	~~0~~
~~PLPs of both types in first subframe~~	~~0~~	~~1~~
~~All PLPs in first subframe use MIMO~~	~~1~~	~~0~~
~~Invalid Combination~~	~~1~~	~~1~~

~~Note: In cases of all-SISO and all-MIMO PLPs within the first subframe, any of the available multiplexing types (i.e., TDM, FDM, LDM, and combinations thereof) can be applied. In cases in which MIMO is to be applied differently to the PLPs on the respective layers (i.e., Core and Enhanced) within a subframe, LDM multiplexing is required to be applied to the subframe (potentially along with TDM, FDM, and combinations thereof on either or both of the layers).~~

Modify Table 9.9 as follows:

…

```
L1D_bsid
for (i=0 .. L1B_num_subframes) {
    if (i > 0) {
        L1D_mimo_mixed
```

```
        }
        if (i = 0 && L1B_first_sub_mimo_mixed = 1) || (i >0 && L1D_mimo_mixed = 1) {
            for (j = 0 .. L1D_num_plp) {
                L1D_plp_mimo

            If (L1D_plp_mimo = 1) {
                L1D_plp_mimo_stream_combining
                L1D_plp_mimo_IQ_interleaving
                L1D_plp_mimo_PH
                }
            }
        }
    }
    L1D_reserved
    L1D_crc
```

Add text to the footnote on page 115 (above Table 9.9) as follows:

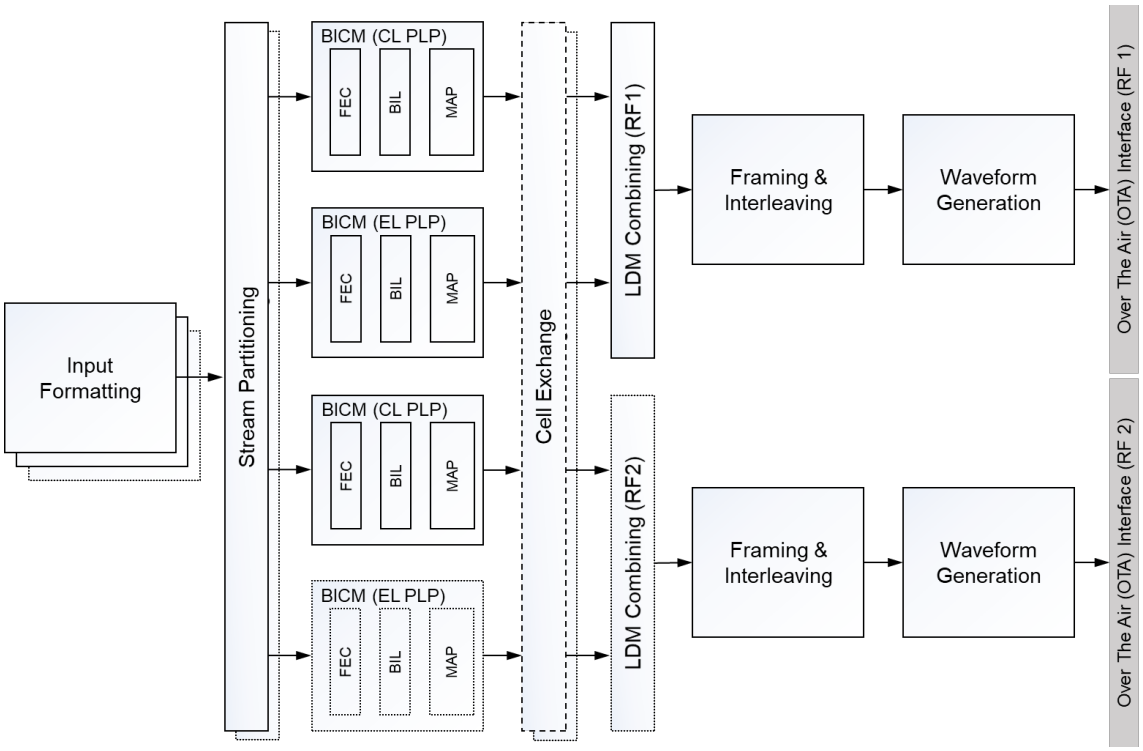
1 The splitting of the 'i' and 'j' 'for' loops into two sections each was necessitated by the evolution of functions described in the table to enable simultaneous use of multiple signal processing methods while maintaining backward compatibility. The first section 'for' loop is called the '**L1D_version** >= 1 loop' and the second section 'for' loop is called the 'L1D_version >= 2 loop'.

Add text to Section K.4 as follows:

When plain channel bonding is used, two PLPs in different RF channels can be bonded while having different scheduling parameters including layer setting, multiplexing scheme, and framing information such as PLP size, PLP start, PLP type, and so on. When channel bonding with SNR averaging is used, the two mutually bonded PLPs shall be configured with the same scheduling parameters, including the layer indices of PLPs, in order to achieve low complexity. This means that Core PLP shall be channel-bonded only with Core PLP, and Enhanced PLP shall be channel-bonded only with Enhanced PLP, respectively.

When channel-bonded and nonbonded PLPs assemble a complete delivered product, while all involved PLPs use SISO, the total TI memory required for the complete delivered product shall be twice the amount specified in Section 7.1.2. Simultaneously, for each RF channel, the group of PLPs consisting of all nonbonded PLPs within this complete delivered product shall individually satisfy the TI memory constraint specified in Section 7.1.2. When any MIMO PLP is included in the complete delivered product consisting of channel-bonded and nonbonded PLPs, the overall TI memory increases to four times the amount described in Section 7.1.2.

Modify Section K.4 as follows (changing Figure K.4.1):



Modify Section L.4.1 as follows:

The MIMO demultiplexer is composed of two stages. The first stage is exactly the same as the SISO demultiplexing described in Section 6.3.3. The second stage ~~evenly~~alternately spreads the output vectors of the first stage SISO demultiplexer into two constellation mappers, one for each transmitting Polarization.

Modify Figure L.1.2 as follows:

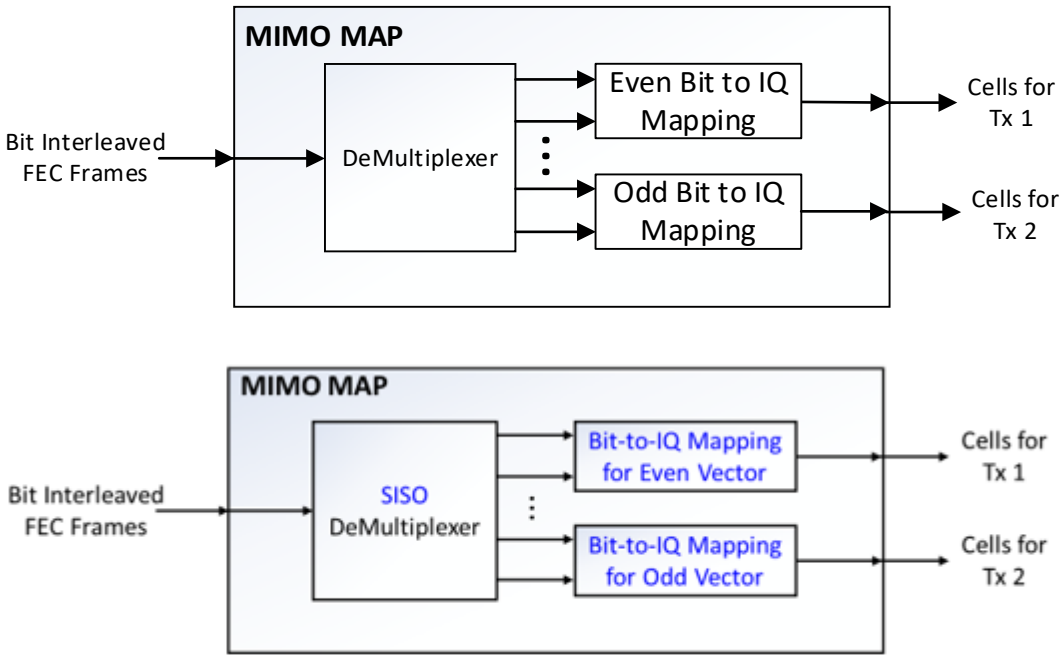


Figure L.1.2 MIMO MAP block diagram.

Add text to Section L.6 as follows:

L.6 TIME INTERLEAVER

The same time interleavers as in Section 7.1 shall be used for MIMO. Since the time interleaving is carried out after the generation of two MIMO streams there are two parallel time interleavers. The time interleaving applied to both MIMO streams shall be identical. The total memory requirement as described in Section 7.1.2 applies to each time interleaver for each Polarization. Hence, time interleaving for MIMO requires twice the memory as is required for SISO. When MIMO is used with channel bonding, the total memory requirement is proportional to the number of combined RF channels compared to the memory required for MIMO transmission within a single RF channel. In this version of the specification, the total memory requirement for MIMO with channel bonding is twice and four times that of MIMO and SISO transmissions within a single RF channel, respectively.

When SISO and MIMO PLPs assemble a complete delivered product, the total TI memory required for the complete delivered product shall be twice the amount specified in Section 7.1.2. Simultaneously, the group of PLPs comprising all SISO PLPs within this complete delivered product shall individually satisfy the TI memory constraint specified in Section 7.1.2.

Extended interleaving mode as defined in Section 7.1.3 may be optionally enabled. Extended interleaving shall only be used when the modulation is QPSK and MIMO precoding is disabled (**L1D_plp_mimo_stream_combining** == 0 and **L1D_plp_mimo_IQ_interleaving** == 0 and **L1D_plp_mimo_PH** == 0).

Add text to Section L.7 as follows:

MIMO frames shall be built according to Section 7.2.

The specific multiplexing techniques allowed for MIMO shall be the following:

- Time division multiplexing (TDM), as described in Section 7.2.7.3.
- Frequency division multiplexing (FDM), as described in Section 7.2.7.5.
- Time and frequency division multiplexing (TFDM), as described in Section 7.2.7.6.

The number of available data cells for cell multiplexing can be obtained from tables in Section 7.2.6. Equivalent SISO pilot patterns that have the same number and position as those of MIMO scattered pilot patterns shall be used for a table lookup. Equivalent SISO scattered pilot patterns are shown in Table L.9.2.

Data cell indexing described in Section 7.2.6.1 is applied individually to Polarizations #1 and #2. Initialization of data cells accordingly proceeds independently for each Polarization. For available data cells in a MIMO subframe, dummy modulation values shall be generated in parallel for each Polarization, following the same process defined in Section 7.2.6.5. Each Polarization shall initialize its available data cells with those generated dummy modulation values before overwriting them with actual PLP data. With parallel data cell indexing, an identical sequence of dummy modulation values shall be independently allocated to each Polarization.

MIMO PLP data cells shall not be allocated to any cells in Preamble symbol(s), even if there are available cells remaining in the last Preamble symbol. SISO PLP data cells may be allocated to any remaining cells in the last Preamble symbol.

This version of the specification specifies the multiplexing between MIMO and SISO PLPs as follows: TDM between MIMO and SISO PLPs is allowed on a subframe basis, but not within a single subframe; LDM of MIMO and SISO PLPs is allowed as described in Annex O.

Modify Section L.11 as follows:

The same OFDM structures as in Section ~~**Error! Bookmark not defined.**~~8.3 shall be used for each Polarization stream in MIMO transmission.

IFFT for MIMO follows the definitions and descriptions in Section 8.3 but includes a partial augmentation. Since MIMO introduces an extra transmission path in addition to a SISO setup, the waveform expression for MIMO shall render the following two framing scenarios explainable:

- Case 1: Pure MIMO frame consisting solely of MIMO subframe(s)
- Case 2: Coexistence of MIMO and SISO subframes based on TDM

If MIMO is in use, the baseband time domain signal after IFFT shall be described in a Polarization-specific fashion as follows:

$$\sum_{l=0}^{L_{Fp}-1} \frac{1}{\sqrt{P_{preamble,l}}} \sum_{k=0}^{NoC_{P,l}-1} c_{l,k} \times \psi_{l,k}(t) + \sum_{\substack{m=0,\\ m \in S_{M,a}}}^{N_{SF}-1} \frac{1}{\sqrt{P_{data,m}}} \sum_{l=0}^{L_{SFm}-1} \sum_{k=0}^{NoC_m-1} c_{a,m,l,k} \times \psi_{m,l,k}(t)$$

where $\psi_{l,k}(t)$ and $\psi_{m,l,k}(t)$ shall follow the same definitions as in Section 8.3 and:

<tab> a denotes the Polarization index, where $a = 0$ and $a = 1$ indicate~~s~~ Polarizations #1 and #2, respectively;

<tab> k denotes the carrier number;

<tab> l denotes the OFDM symbol number starting from 0 for the first Preamble symbol of a frame and being reset at the first OFDM symbol of each subframe;

<tab> m denotes the subframe number, $0 \leq m < N_{SF}$;

<tab> $c_{l,k}$ is the complex modulation value for carrier k of the Preamble symbol number l;

<tab> $c_{a,m,l,k}$ is the complex modulation value for carrier k of the OFDM symbol number l in subframe number m associated with Polarization a;

<tab> $S_{M,a}$ denotes the set of subframe numbers, for which Polarization a is active during the ~~corresponding~~ transmission of those subframes;

<tab> $NoC_{P,l}$ denotes the number of carriers in the $(l + 1)^{th}$ Preamble symbol. The first Preamble symbol ($l = 0$) always has the minimum NoC and the following Preamble symbols ($0 < l < L_{Fp}$) share the same NoC value that is signaled in L1-Basic as explained in Sections 7.2.5.1 and 9.2.2;

<tab> NoC_m denotes the number of carriers of subframe m as defined in Table 8.8;

<tab> L_{SFm} is the number of data and subframe boundary symbols in subframe m;

<tab> L_{Fp} is the number of OFDM symbols in the Preamble;

<tab> N_{SF} is the number of subframes in a frame;

<tab> $P_{preamble,l}$ is the per-Polarization frequency domain total power of $(l + 1)^{th}$ Preamble symbol summarized in Table I.1.1;

<tab> $P_{data,m}$ is the per-Polarization frequency domain total power of each data and subframe boundary symbol in subframe m. Allowed values of $P_{data,m}$ are summarized in Table I.2.1 to Table I.2.5.

The MIMO transmitter shall transmit the same Preamble symbols over Polarizations #1 and #2. The presented signal expression shares a common value $c_{l,k}$ irrespective of the Polarization index a. Carrier signals in data and subframe boundary symbols can differ between Polarization, and hence the corresponding carrier modulation value $c_{a,m,l,k}$ is defined as Polarization-specific.

…

Modify Section L.11.2 as follows:

TDM of MIMO and SISO subframes involves transmission of SISO signals at MIMO transmitters. In the current version of the specification, transmission of SISO signals from MIMO transmitters can take one of the following forms:

- Option 1: Polarization #1 transmits SISO subframes and Polarization #2 is inactive during ~~then~~those subframes.
- Option 2: Polarizations #1 and #2 transmit the same signal copies of SISO subframes.

~~If only Polarization #1 is active during the subframe duration using SISO and Polarization #2 is inactive during then~~If Option 1 is applied, $S_{M,a}$ shall be defined accordingly as follows:

<tab> $S_{M,a}$ ~~shall be determined as follows.~~ If $a = 0$, $S_{M,a} = \{0, \ldots, N_{SF} - 1\}$. If $a = 1$, $S_{M,a}$ consists of the subframe numbers that use MIMO.

For example, if subframe 2 and subframe 3 apply MIMO processing out of total $N_{SF} = 4$ subframes, $S_{M,1}$ equals {2, 3}, while $S_{M,0}$ equals {0, 1, 2, 3}.

~~If Polarizations #1 and #2 are both active during the subframe duration using SISO~~If Option 2 is applied, ~~the notions~~ $S_{M,a}$ and $c_{a,m,l,k}$ shall satisfy the following:

<tab> $S_{M,a}$ shall consist of every subframe number within $0 \leq m < N_{SF}$, regardless of the value of a. That is, $S_{M,a} = \{0, \ldots, N_{SF} - 1\}$;

<tab> $c_{a,m,l,k}$ shall satisfy $c_{0,m,l,k} = c_{1,m,l,k}$ if m indicates a SISO subframe

Modify Section L.13 as follows:

Channel bonding (see Annex K) may be used with MIMO and shall conform to this section when used. Channel bonding described in this section is defined for two RF channels. A block diagram in Figure L.13.1 shows the system architecture when channel bonding is used with MIMO. Following the stream partitioning process described in Section K.1, a single input data packet stream is partitioned into two separate Baseband Packet streams, each fed into the BICM chain for each RF channel. MIMO with channel bonding can also operate in two modes, plain channel bonding and SNR averaging, which can be selected by **L1D_plp_channel_bonding_format**. ~~Dashed lines in Figure L.13.1 show blocks enabled by MIMO precoding setting, and dotted lines indicate blocks activated only when SNR averaging is applied.~~ In Figure L.13.1, the solid lines depict blocks and arrows common to all configurations, while dashed lines denote blocks and arrows that may be disabled depending on the configuration settings related to MIMO and channel bonding.

Modify Figure L.13.1 as follows:

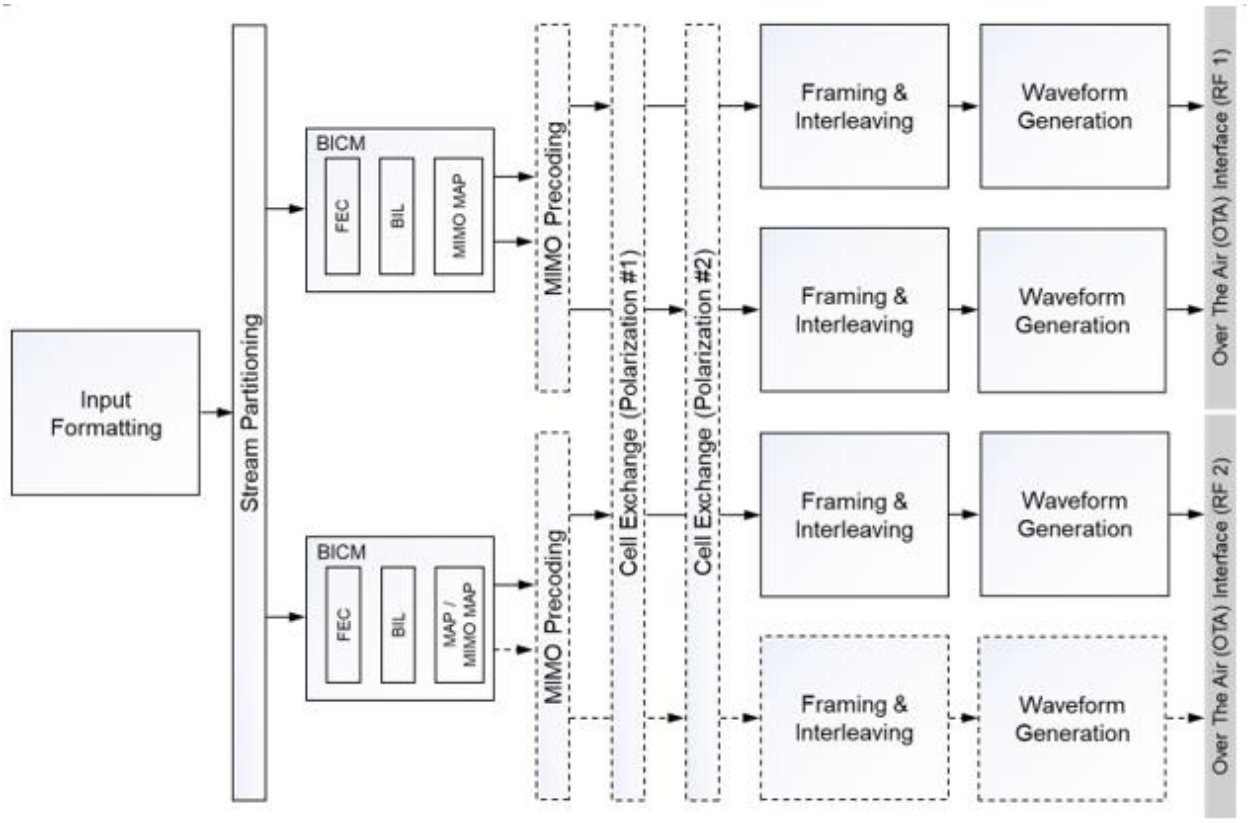


Figure L.13.1 Block diagram of the channel bonding with MIMO system architecture.

Add text to Section L.14 as follows:

This section highlights the L1 signaling data specific to MIMO defined in Section 9.

The use of MIMO in the first subframe of the current frame is signaled in the Preamble with the L1-Basic parameter **L1B_first_sub_mimo**.

The use of MIMO in subframes after the first subframe of the current frame is signaled in the Preamble with the L1-Detail parameter **L1D_mimo**.

The configuration of the MIMO precoding is signaled with the L1-Detail parameters **L1D_plp_mimo_stream_combining**, **L1D_plp_mimo_IQ_interleaving**, and **L1D_plp_mimo_PH**.

The choice of scattered pilot encoding scheme is signaled by **L1B_mimo_scattered_pilot_encoding**, which applies to all MIMO subframes in the current frame. When both SISO and MIMO subframes are present in the current frame, the SISO subframe shall conform to the pilot insertion process as detailed in Section 8.1 regardless of the value of **L1B_mimo_scattered_pilot_encoding**.

The choice of the scattered pilot pattern for MIMO is signaled with the L1-Basic parameter **L1B_first_sub_scattered_pilot_pattern** if MIMO is used in the first subframe of the current frame, and with the L1-Detail parameter **L1D_scattered_pilot_pattern** for subframes after the first subframe. These signaling parameters are also used for SISO but with a different interpretation.

Modify Section N Page Header as follows:

ATSC A/322:2024-09 Physical Layer Protocol, Annex ~~O~~N 13 September 2024

Modify Section O.6.2 as follows:

LDM Combiner for Layered MIMO Type B shall use a single pair of injection level controller and power normalizer. The injection level controller and power normalizer associated with Polarization #1 stream operate the same as which described in Section O.6.1.

The scaling factor for the injection level controller, α, and the normalizing factor for the power normalizer, β, depend on the injection level of the Enhanced Layer. Values allowed and the correspondence among the parameters shall conform with the same lookup tables as in Table 6.15 and Table 6.16. For the use of Layered MIMO Type B, descriptions for CL power, EL power, total power, and their ratios in Table 6.15 and Table 6.16 shall be interpreted as the quantities confined to ~~each dedicated~~ Polarization #1 transmission.

Add text to Section O.7 as follows:

The same time interleavers as in Section 7.1 shall be used for Layered MIMO.

In both Layered MIMO Type A and B, time interleaving mode is defined for Core PLPs. The Enhanced PLP(s) follows the same time interleaving as defined for the associated Core PLP(s). The total memory requirement conforms to the description in Section L.6. Overall, time interleaving for Layered MIMO requires twice the total memory as is required for SISO.

When Combined PLP(s) applying Layered MIMO form a complete delivered product with other SISO or MIMO PLP(s) that do not use Layered MIMO, the total TI memory required for the complete delivered product shall be twice the amount specified in Section 7.1.2. Simultaneously, the group of PLPs comprising all SISO PLPs (including Core PLPs in Layered MIMO Type B), within this complete delivered product shall individually satisfy the TI memory constraint specified in Section 7.1.2.

Extended interleaving mode shall not be used for Layered MIMO.

Add text to Section O.8 as follows:

Layered MIMO frames shall be built in the same manner with MIMO frames, according to Section 7.2. The LDM-combined cells in Layered MIMO are treated identically to cells in SISO or non-LDM MIMO systems.

Every data cell in a Layered MIMO PLP shall not be allocated to any cells in Preamble symbol(s), even if there are available parts remaining in the last Preamble symbol.

The cell multiplexing in Layered MIMO shall follow the same process as MIMO cell multiplexing described in Section L.7. The number of available data cells for cell multiplexing can be obtained from tables in Section 7.2.6. Equivalent SISO pilot patterns that have the same number and position as those of MIMO scattered pilot patterns shall be used for table lookup. Equivalent SISO scattered pilot patterns are shown in Table L.9.2.

Dummy modulation value insertion for Layered MIMO subframes shall comply with Section 7.2.6.5 and Section L.7. The power of dummy modulation values shall match that of the actual PLP data assigned to the respective Polarizations. With Layered MIMO Type B in use, the level of dummy modulation value's transmission power shall differ between Polarizations, according to power scaling at the IFFT stage.

Subframes using Layered MIMO Type B shall not contain any Core PLP(s) that are not associated with Enhanced PLP(s).

As noted in Section 7.2.7.4.6, Core and Enhanced PLPs in a PLP group may differ in total cell count (i.e., Enhanced PLPs may not fully span the PLP group), especially when HTI mode time interleaving is in use. Layered MIMO subframes in such cases shall insert Enhanced Layer dummy modulation values to the data cell indices specified in Section 7.2.7.4.6. The insertion of Enhanced Layer dummy modulation values for Layered MIMO shall be specifically performed between the MIMO precoding and LDM Combining stages. That is, the insertion shall be applied over the cells produced at the end of the MIMO precoding stage.

The Baseband Packet scrambling sequence defined in Section 5.2.3 is used to generate Enhanced Layer dummy modulation values. This scrambling sequence shall be reinitialized for each relevant PLP group. Taken as input to the MIMO mapping block (see Section L.4), a single scrambling sequence shall be modulated into two parallel cell streams, each mapped onto the respective Polarization. Enhanced Layer dummy modulation values shall use the same constellation as the last Enhanced PLP in the PLP group. Note that indexing of the produced cells follows Section L.4.1, except that it continues until the end of each scrambling sequence. The produced cell pairs shall then undergo MIMO precoding, applying the same configuration as the last Enhanced PLP in the PLP group. Subsequent system procedures applied to the precoded cells (e.g., LDM Combining and IFFT) shall use the same parameters and configurations, including the injection level, as used for the preceding Enhanced PLP.

Modify Section O.10.1 as follows:

Pilot encoding for Layered MIMO shall be organized according to Section L.9.2.11.

For Layered MIMO Type A, either Walsh-Hadamard encoding or null pilot encoding can be used. Pilot signals shall be shared Polarization-wise between the Core Layer and Enhanced Layer.

For Layered MIMO Type B, only Walsh-Hadamard encoding is allowed. If superposed by means of Layered MIMO Type B, SISO PLP(s) and MIMO PLP(s) shall share the pilot cells transmitted in Polarization #1. Pilot schemes using Walsh-Hadamard encoding achieve such pilot compatibility, as summarized in Table L.9.1. The L1 signaling parameter

L1B_mimo_scattered_pilot_encoding shall hence be identified as 0, indicating both the MIMO pilot pattern with Walsh-Hadamard encoding and the SISO pilot pattern simultaneously (see Table 9.3). This indication may be interpreted differently depending on which PLP(s) is being received.

Modify Section O.12 as follows:

IFFT in Layered MIMO follows the definitions and descriptions in Sections 8.3 and L.11 but with a partial modification. The same OFDM structures as in Section 8.3 shall be used for each Polarization stream in MIMO transmission.

To embrace MIMO formulation and different types of LDM Combining, Layered MIMO uses a post-IFFT signal description modified from that in Section 8.3. In a Layered MIMO system, the baseband time domain signal after IFFT shall be described for each Polarization by the following expression:

$$\sum_{l=0}^{L_{Fp}-1} \frac{K_0[a]}{\sqrt{P'_{preamble,a,l}}} \sum_{k=0}^{NoC_{P,l}-1} c_{l,k} \times \psi_{l,k}(t) + \sum_{m=0}^{N_{SF}-1} \frac{K_m[a]}{\sqrt{P'_{data,a,m}}} \sum_{l=0}^{L_{SFm}-1} \sum_{k=0}^{NoC_m-1} c_{a,m,l,k} \times \psi_{m,l,k}(t)$$

where $\psi_{l,k}(t)$ and $\psi_{m,l,k}(t)$ follow the definitions in Section 8.3, and:

<tab> a denotes the Polarization index, where $a = 0$ and $a = 1$ indicate~~s~~ Polarizations #1 and #2, respectively;

<tab> k denotes the carrier number;

<tab> l denotes the OFDM symbol number starting from 0 for the first Preamble symbol of a frame and being reset at the first OFDM symbol of each subframe;

<tab> m denotes the subframe number, $0 \leq m < N_{SF}$;

<tab> $K_m[a]$ is the scaling coefficient subject to subframe number m and Polarization index a. The value of $K_m[a]$ is related to the injection level information as summarized in Table O.12.1;

<tab> $c_{l,k}$ is the complex modulation value for carrier k of the Preamble symbol number l;

<tab> $c_{a,m,l,k}$ is the complex modulation value for carrier k of the OFDM symbol number l in subframe number m associated with Polarization a;

<tab> $NoC_{P,l}$ denotes the number of carriers in the $(l + 1)^{th}$ Preamble symbol. The first Preamble symbol ($l = 0$) always has the minimum NoC and the following Preamble symbols ($0 < l < L_{Fp}$) share the same NoC value that is signaled in L1-Basic as explained in Sections 7.2.5.1 and 9.2.2;

<tab> NoC_m denotes the number of carriers of subframe m as defined in Table 8.8;

<tab> L_{SFm} is the number of data and subframe boundary symbols in subframe m;

<tab> L_{Fp} is the number of OFDM symbols in the Preamble;

<tab> N_{SF} is the number of subframes in a frame;

<tab> $P'_{preamble,a,l}$ is the frequency domain total power of the $(l + 1)^{th}$ Preamble symbol, derived from the input to the IFFT block associated with Polarization a;

<tab> $P'_{data,a,m}$ is the frequency domain total power of each data and subframe boundary symbol in subframe m, derived from the input to the IFFT block associated with Polarization a.

Two parallel IFFT functional blocks shall generate baseband time domain signals for each Polarization stream.

Add text to Section O.12.1 as follows:

O.12.1 Coexistence with SISO or MIMO Subframes

Layered MIMO subframes can be time division multiplexed with other types of subframes not using Layered MIMO. In this TDM case, the baseband time domain signal after IFFT shall be described by the following per-Polarization expression:

$$\sum_{l=0}^{L_{Fp}-1} \frac{K_{\text{~~}S_{M,a}(0)}[a]}{\sqrt{P'_{preamble,a,l}}} \sum_{k=0}^{NoC_{P,l}-1} c_{l,k} \times \psi_{l,k}(t) + \sum_{\substack{m=0 \\ m \in S_{M,a}}}^{N_{SF}-1} \frac{K_m[a]}{\sqrt{P'_{data,a,m}}} \sum_{l=0}^{L_{SFm}-1} \sum_{k=0}^{NoC_m-1} c_{a,m,l,k} \times \psi_{m,l,k}(t)$$

where:

<tab> $S_{M,a}$ denotes the set of subframe numbers, for which Polarization a is active during the ~~corresponding~~ transmission of those subframes;

and the other related parameters share definitions in the previous expression in Section O.12.

To clarify the processing on SISO and non-LDM MIMO elements, the following conditioned descriptions for related parameters are specified:

<tab> $K_m[a]$ satisfies $K_m[a] = 1$ if subframe m is not Layered MIMO;

<tab> For each Polarization, the power of Preamble symbol references the data symbol power of the first subframe activating the corresponding Polarization. This is indicated by the scaling factor $K_{S_{M,a}(0)}[a]$, where $S_{M,a}(0)$ denotes the first element of $S_{M,a}$. The subframes shall be arranged in descending order of the scaling factor ~~K_m~~$K_m[1]$.

Transmission of pure SISO subframes at the Layered MIMO transmitter can choose between two different Polarization selection schemes summarized in Section L.11.2. The possible options for Polarization selection are as follows:

- Option 1: Polarization #1 transmits SISO subframes while Polarization #2 is inactive during ~~then~~those subframes.
- Option 2: Polarizations #1 and #2 transmit identical signal copies of SISO subframes.

The realization of $S_{M,a}$ shall vary depending on the selected Polarization mapping option. If Option 1 is applied, $S_{M,a}$ shall be determined as follows:

<tab> $S_{M,0}$ consists of every integer within $0 \le m < N_{SF}$, i.e., $S_{M,a} = \{0, \ldots, N_{SF} - 1\}$;

<tab> $S_{M,1}$ consists of the subframe numbers that use MIMO or Layered MIMO.

If Option 2 is applied, $S_{M,a}$ and $c_{a,m,l,k}$ shall be determined as follows:

<tab> $S_{M,a}$ consists of every integer within $0 \le m < N_{SF}$, i.e., $S_{M,a} = \{0, \ldots, N_{SF} - 1\}$, irrespective to the value of a.

<tab> $c_{a,m,l,k}$ satisfies $c_{0,m,l,k} = c_{1,m,l,k}$ if subframe m is SISO.

Modify Section O.13 as follows:

Not all blocks are used in every configuration. In Figure O.13.1, solid lines denote blocks common to all configurations, while dashed lines indicate blocks that can be disabled depending on configurations related to LDM, MIMO, and channel bonding. Solid arrows represent signal flows common to all configurations, whereas dashed arrows denote optional signal flows that may be absent depending on the configuration.

For a channel-bonded PLP, all data packets engaged shall pass through a common Input Formatting block (utilizing the same **L1D_plp_id** value on every associated RF channel), as described in Section K.1. Baseband Packets generated by the Input Formatting block dedicated to a channel-bonded PLP shall be ~~divided into~~split across two parallel streams at the Stream Partitioning block. Baseband Packets unrelated to channel bonding shall bypass Stream Partitioning.

Plain channel bonding and SNR averaging are both available for channel bonding with Layered MIMO. The related cell/PLP multiplexing shall follow Section K.4. Whenever channel bonding with SNR averaging is used, the bonded streams originating in the same Input Formatting block shall be contained in the same LDM layer.

If enabled, cell exchange processing shall be applied over the cells produced at the end of the MIMO precoding stage: MIMO-precoded (regardless of whether the MIMO precoding functions are active or not) cells for MIMO PLP(s) and post-BICM cells for SISO PLP(s). The cell exchange processing described in Section L.13 and Section K.3 shall be applied to MIMO PLP's and SISO PLP's cells, respectively.

The output streams from cell exchange blocks shall go through LDM Combining between each coupled stream pair, i.e., Core and Enhanced Layer cells that belong to the same Polarization. The LDM Combining process shall conform to the specifications in Sections 6.4 and O.6.

When a channel-bonded PLP with SNR averaging is included, Layered MIMO configurations for the bonded RF channels shall be identical between the corresponding subframes (each in a different RF channel). The type of Layered MIMO (i.e., whether Type A or B)~~,~~ and injection level~~, and MIMO parameters~~ shall be identical. MIMO parameters and layer indices shall be identical as well. Note that individual PLPs in a Combined PLP can independently configure the use and format of channel bonding, meaning it does not need to be applied simultaneously. Other configuration constraints under the use of SNR averaging shall follow the same specification in Section K.3.

When plain channel bonding is used, the type of Layered MIMO, layer index, injection level, and other Layered MIMO parameters may differ between the engaged PLPs in different RF channels. Other scheduling parameters may also differ, as described in Section K.3. Accordingly, ~~P~~plain channel bonding with Layered MIMO does not restrict channel bonding to a homogeneous PLP pair. A channel-bonded PLP may comprise a SISO PLP and a MIMO PLP, and part of a Layered MIMO subframe may be bonded with one not using Layered MIMO.

Add text to Section O.14 as follows:

This section highlights the L1 signaling data specific to Layered MIMO defined in Section 9.

L1B_first_sub_mimo indicates whether MIMO is applied to every Core PLP in the first subframe of the current frame.

L1D_mimo indicates whether MIMO is applied to every Core PLP in the current subframe, which is the second or later in the given frame.

For the first subframe of the current frame, the type of Layered MIMO is signaled by **L1B_first_sub_mimo_mixed** in conjunction with **L1B_first_sub_mimo** when PLP(s) with **L1D_plp_layer** >0 are present in the subframe. Layered MIMO Type A is indicated when the two parameters are signaled as **L1B_first_sub_mimo_mixed** =0, **L1B_first_sub_mimo** =1. Layered MIMO Type B is indicated when the two parameters are signaled as **L1B_first_sub_mimo_mixed** =1, **L1B_first_sub_mimo** =0.

For subframes that are not the first in the current frame, the type of Layered MIMO is signaled by **L1D_mimo_mixed** in conjunction with **L1D _mimo** when PLP(s) with **L1D_plp_layer** >0 are present in the subframe. Layered MIMO Type A is indicated when the two parameters are signaled as **L1D_mimo_mixed** =0, **L1D _mimo** =1. Layered MIMO Type B is indicated when the two parameters are signaled as **L1D_mimo_mixed** =1, **L1D _mimo** =0.

The parameters in the **L1D_version** >= 2 loop (**L1D_plp_mimo**, **L1D_plp_mimo_stream_combining**, **L1D_plp_mimo_IQ_interleaving** and **L1D_plp_mimo_PH**) shall apply to the **L1D_plp_mimo** in the same order as signaled in the **L1D_version** >= 1 loop.

Note: This version of the specification allows only LDM-based mixing of SISO and MIMO PLPs for subframes with **L1B_first_sub_mimo_mixed** =1 and **L1B_first_sub_mimo** =0, or **L1D_mimo_mixed** =1 and **L1D _mimo** =0 (as appropriate for the given subframe). Future versions may specify additional multiplexing options for mixed use of MIMO mode (e.g., all PLPs having **L1D_plp_layer** =0) within a subframe (see Table 9.8 and Table 9.10).

In subframes using Layered MIMO Type B, every Core PLP shall be associated with one or more Enhanced PLPs. Specifically, in any subframe indicated by **L1D_mimo_mixed** or **L1B_first_sub_mimo_mixed**, no Core PLP shall have its **L1D_plp_start** equal to or greater than the maximum value of **L1D_plp_start** + **L1D_plp_size** among all Enhanced PLPs present in the subframe; and no Core PLP shall have its **L1D_plp_start** + **L1D_plp_size** equal to or less than the minimum **L1D_plp_start** among all Enhanced PLPs present in the subframe.

In subframes using Layered MIMO Type B, **L1D_plp_mimo** indicates whether each PLP is in MIMO mode. For the current version of the specification, Layered MIMO Type B shall assign **L1D_plp_mimo** =0 to Core PLPs and **L1D_plp_mimo** =1 to Enhanced PLPs.

The layer index of each PLP is signaled by **L1D_plp_layer**. Core and Enhanced PLPs are identified by **L1D_plp_layer** =0 and **L1D_plp_layer** >0, respectively. The use of Layered MIMO involves the presence of PLP(s) having **L1D_plp_layer** >0 in the corresponding subframe.

Within a subframe using Layered MIMO Type B, all Enhanced PLPs shall apply the same value **L1D_plp_ldm_injection_level**.

The choice of scattered pilot encoding scheme is signaled by **L1B_mimo_scattered_pilot_encoding**, which applies to every Layered MIMO subframe in the current frame. The interpretation of this field is defined in Table 9.3. If Layered MIMO Type A is used, **L1B_mimo_scattered_pilot_encoding** can either be 0 or 1. If Layered MIMO Type B is used, **L1B_mimo_scattered_pilot_encoding** shall be signaled as 0. When both SISO and Layered MIMO subframes are present in the current frame, the SISO subframe shall conform to the pilot insertion process as detailed in Section 8.1 regardless of the value of **L1B_mimo_scattered_pilot_encoding**.

The configuration of MIMO precoding is signaled by a set of L1-Detail parameters, **L1D_plp_mimo_stream_combining**, **L1D_plp_mimo_IQ_interleaving**, and **L1D_plp_mimo_PH**.

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