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**Digital Video Broadcasting (DVB);
Next Generation broadcasting system to Handheld,
physical layer specification (DVB-NGH);
Part 4: Hybrid MIMO Profile**

Reference

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Contents

Intellectual Property Rights 4
Foreword 4
Modal verbs terminology 5
1 Scope 6
2 References 6
2.1 Normative references 6
2.2 Informative references 6
3 Definition of terms, symbols and abbreviations 6
3.1 Terms 6
3.2 Symbols 7
3.3 Abbreviations 7
4 DVB-NGH hybrid MIMO system definition 7
4.1 System overview and architecture 7
4.1.1 Overview 7
4.1.2 Hybrid MIMO SFN 7
4.1.3 Hybrid MIMO MFN 7
4.1.4 Time interleaving 8
5 Hybrid MIMO SFN 8
5.1 Transmit/receive system compatibility 8
5.2 Operational SFN modes 9
5.3 Power imbalance cases 9
6 Hybrid MIMO MFN 10
6.1 Transmit/receive system compatibility 10
6.2 Operational MFN modes 10
6.3 Spatial Multiplexing encoding for SC-OFDM waveform for rate 2 satellite MIMO 11
7 Layer 1 signalling data for the hybrid MIMO profile 11
7.1 P1 and additional P1 signalling data 11
7.2 L1-PRE signalling data 12
7.3 L1-POST signalling data 13
7.3.1 L1-POST configurable signalling data 13
7.3.2 L1-POST dynamic signalling data 14
7.3.3 In-band signalling type A 14
Annex A (informative): SC-OFDM pilot pattern 15
Annex B (informative): Rate-2 transmission with one transmit antenna 16
B.1 VMIMO 16
B.1.1 Overview 16
B.1.2 Block diagram 16
B.1.3 VMIMO processing 16
B.1.4 Parameter setting 16
B.1.5 Phase Hopping 17
B.1.6 Miscellaneous 17
Annex C (informative): Bibliography 18
History 19

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Foreword

This draft European Standard (EN) has been produced by Joint Technical Committee (JTC) Broadcast of the European Broadcasting Union (EBU), Comité Européen de Normalisation ELECtrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI), and is now submitted for the combined Public Enquiry and Vote phase of the ETSI standards EN Approval Procedure.

NOTE: The EBU/ETSI JTC Broadcast was established in 1990 to co-ordinate the drafting of standards in the specific field of broadcasting and related fields. Since 1995 the JTC Broadcast became a tripartite body by including in the Memorandum of Understanding also CENELEC, which is responsible for the standardization of radio and television receivers. The EBU is a professional association of broadcasting organizations whose work includes the co-ordination of its members' activities in the technical, legal, programme-making and programme-exchange domains. The EBU has active members in about 60 countries in the European broadcasting area; its headquarters is in Geneva.

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The DVB Project is an industry-led consortium of broadcasters, manufacturers, network operators, software developers, regulators and others from around the world committed to designing open, interoperable technical specifications for the global delivery of digital media and broadcast services. DVB specifications cover all aspects of digital television from transmission through interfacing, conditional access and interactivity for digital video, audio and data. The consortium came together in 1993.

The present document is part 4 of a multi-part deliverable. Full details of the entire series can be found in part 1 [1].

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
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Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document describes the next generation transmission system for digital hybrid (combination of terrestrial with satellite transmissions) MIMO broadcasting to handheld terminals making use of multi-aerial structures at the transmitting and receiving ends. It specifies the relationship of the hybrid MIMO profile physical layer part to the physical layer part of the other three profiles, namely the base profile ETSI EN 303 105-1 [1], the MIMO profile ETSI EN 303 105-2 [2] and the hybrid profile ETSI EN 303 105-3 [3], from the input streams to the transmitted signal. This transmission system is intended for carrying Transport Streams or generic data streams feeding linear and non-linear applications like television, radio and data services. DVB-NGH terminals might also process DVB-T2-lite signals.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI EN 303 105-1: "Digital Video Broadcasting (DVB); Next Generation broadcasting system to Handheld, physical layer specification (DVB-NGH); Part 1: Base Profile".

[2] ETSI EN 303 105-2: "Digital Video Broadcasting (DVB); Next Generation broadcasting system to Handheld, physical layer specification (DVB-NGH); Part 2: MIMO Profile".

[3] ETSI EN 303 105-3: "Digital Video Broadcasting (DVB); Next Generation broadcasting system to Handheld, physical layer specification (DVB-NGH); Part 3: Hybrid Profile".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

Not applicable.

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI EN 303 105-1 [1] apply.

3.2 Symbols

For the purposes of the present document, the symbols given in ETSI EN 303 105-1 [1] apply.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI EN 303 105-1 [1] apply.

4 DVB-NGH hybrid MIMO system definition

4.1 System overview and architecture

4.1.1 Overview

The hybrid MIMO profile - reflected by the present document - is an optional profile facilitating the use of MIMO on the terrestrial and/or satellite elements within a hybrid transmission scenario.

The ACE PAPR technique cannot be applied to frames of preamble format "NGH-MIMO".

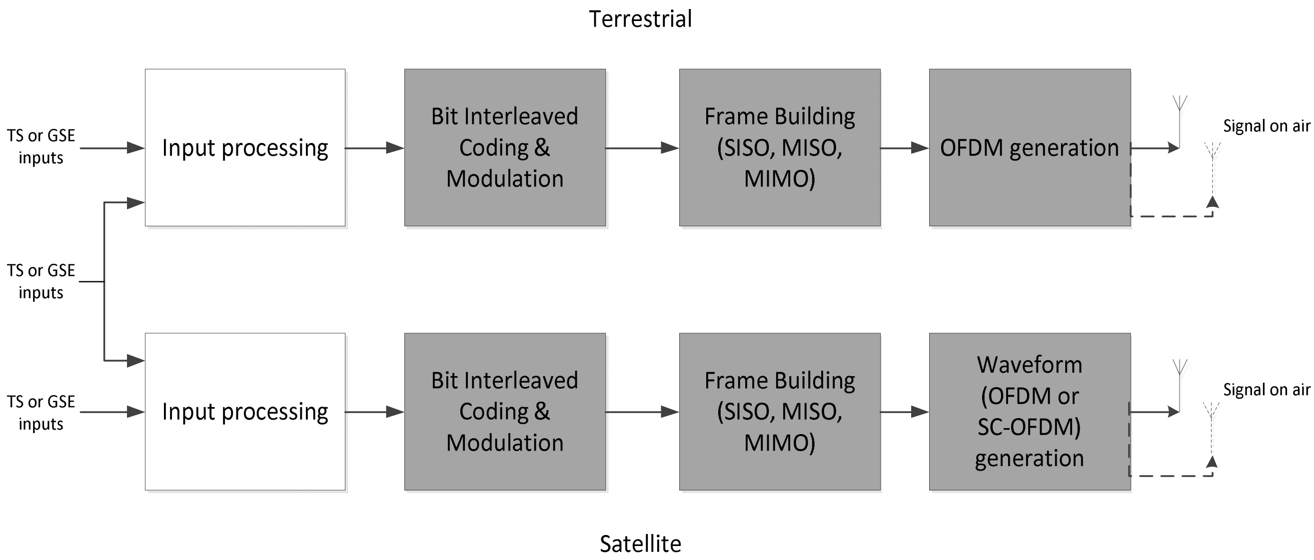
Two modes within this profile are available.

4.1.2 Hybrid MIMO SFN

The hybrid MIMO SFN describes the case where the satellite and terrestrial parts of the transmission utilize the same carrier frequency and radiate synchronized signals intended to create an effective SFN. In the case of a SISO SFN, covered in the hybrid profile, the signals are nominally identical (except for the possible application of eSFN) but in the case of a hybrid MIMO SFN MIMO pre-coding may exist in conjunction with eSFN pre-processing. The cases defined in the hybrid MIMO SFN mode are those where MIXO pre-coding is applied within or across the satellite and terrestrial transmission elements. In the case of mixed SISO/MIXO transmission the MIXO pre-coding is applicable solely during MIXO frames; during the hybrid SISO frames eSFN may be applied.

4.1.3 Hybrid MIMO MFN

The hybrid MIMO MFN describes the case where the satellite and terrestrial parts of the transmission are on different carrier frequencies, and do not necessarily share any common frame or symbol timing at the physical layer. They may however share content in terms of data payload. At least one of the transmission elements (i.e. terrestrial or satellite) shall be configured using multiple antennas, otherwise the form of transmission belongs to the Hybrid Profile ETSI EN 303 105-3 [3], not the Hybrid MIMO Profile reflected by the present document.



NOTE: Blocks differing from the Base Profile ETSI EN 303 105-1 [1] are shaded to grey.

Figure 1: High level NGH physical layer block diagram of the Hybrid MIMO Profile reflected by the present document

NOTE 1: This block diagram is common to both hybrid MIMO MFN and hybrid MIMO SFN.

NOTE 2: One of the two paths is using two transmission antennas.

4.1.4 Time interleaving

For rate 2 schemes of the Hybrid MIMO Profile reflected by the present document, both MIMO branches, i.e. the signal generation for both transmit antennas, shall use the same time interleaver configuration. The required time de-interleaver memory sizes $N_{\text{MUs,PLP}}$ and $N_{\text{MUs,PLP,1 frame}}$ per MIMO branch can be calculated in the same way as described for the SISO scheme of the Hybrid Profile in ETSI EN 303 105-3 [3], clause 6.2, when setting 1 MU corresponding always to 1 cell. The total required de-interleaver memory for both MIMO branches is twice this size. The applicable limits for the hybrid MIMO profile are still $\sum 2N_{\text{MUs,PLP}} \leq 2^{21}$ and $\sum 2N_{\text{MUs,PLP,1 frame}} \leq 2^{18}$, where the sum is taken over all PLPs in a given PLP cluster and the factor 2 comes from the fact, that the size for both MIMO branches is double that per single MIMO branch.

When two signals are transmitted that shall be (hybridly) combined in the receiver, the same rules apply as laid down in ETSI EN 303 105-3 [3], clause 6.2, i.e. the sum of the required time de-interleaver sizes (in MUs) for both signals shall not exceed the aforementioned limits.

The Receiver Buffer Model (RBM) to use for the hybrid MIMO profile is the one of the Hybrid Profile in ETSI EN 303 105-3 [3], annex B.

5 Hybrid MIMO SFN

5.1 Transmit/receive system compatibility

To make use of the hybrid MIMO SFN, the proposed transmission hardware shall include individually-fed terrestrial and satellite transmitters with suitable antennas as outlined below, delivering an OFDM waveform on both the terrestrial and satellite sides. Cases included are one or two (cross-polar, linear polarization) terrestrial antennas in combination with one or two (cross-polar, counter-rotating circular polarization) satellite antennas. In the case of rate 2 MIMO transmission (e.g. eSM) from either the satellite or terrestrial equipments the receiver shall be equipped with a dual-polarized (linear polarization or counter-rotating circular) pair of antennas. For rate 1 transmission, (e.g. Alamouti, eSFN) a cross-polar receive antenna is recommended but a single antenna is sufficient.

In all SFN cases the satellite transmission appears as 'transparent' to the receiver which sees an equivalent terrestrial transmission via an enhanced channel partly delivered by the satellite transmission. The pilot patterns for SISO/MIXO are retained on both the terrestrial and satellite transmission.

SC-OFDM is not an option for the hybrid SFN profile.

5.2 Operational SFN modes

In each of the operational mode combinations shown in tables 1 and 2, the technical descriptions of the signals specified as forming the terrestrial and satellite components can be found in one or more of the Base Profile ETSI EN 303 105-1 [1], MIMO Profile ETSI EN 303 105-2 [2] or Hybrid Profile ETSI EN 303 105-3 [3].

NOTE 1: Where a modulation is described as A+B, 'A' refers to the terrestrial part, 'B' to the satellite part.

NOTE 2: eSFN may optionally be applied to any transmission component not already having it present.

NOTE 3: The TX identifier mentioned in table 1 below is described in ETSI EN 303 105-1 [1], clause 11.5.2.

Table 1: Rate 1 transmission schemes for hybrid SFN

Terrestrial transmission	Satellite transmission	MIXO scheme(s)
Single polarization (VP or HP)	Single polarization (RHCP or LHCP)	eSFN: Terr and Sat with 2 different TX identifiers (during SISO frames)
		Alamouti code (during MIXO frames)
Dual polarization (VP and HP)	Single polarization (RHCP or LHCP)	eSFN: 2 x Terr + Sat with 3 different TX identifiers (during SISO frames)
		Alamouti+ QAM (during MIXO frames)
Single polarization (VP or HP)	Dual polarization (RHCP and LHCP)	eSFN: Terr + 2 x Sat with 3 different TX identifiers (during SISO frames)
		Alamouti+ QAM (during MIXO frames)
Dual polarization (VP and HP)	Dual polarization (RHCP and LHCP)	eSFN: 2 x Terr + 2 x Sat with 4 different TX identifiers (during SISO frames)
Dual polarization (VP and HP)	Dual polarization (RHCP and LHCP)	Alamouti + Alamouti (during MIXO frames)

Table 2: Rate 2 transmission schemes for hybrid SFN

Terrestrial transmission	Satellite transmission	MIXO scheme(s)
Dual polarization (VP and HP)	Dual polarization (RHCP and LHCP)	eSM+PH Terr + eSM+PH+eSFN Sat (during MIMO frames)

5.3 Power imbalance cases

In the case of terrestrial power imbalance, the satellite transmission maintains a fixed 0 dB imbalance, but adopts the same values of parameters θ and α as the terrestrial transmission for the chosen imbalance. Table 3 shows the corresponding set of parameters.

Table 3: eSM parameters for satellite, SFN case

Intentional power imbalance between two terrestrial Tx antennas			**0 dB**			**3 dB**			**6 dB**		
n_{bpcu}	Modulation		β	Θ	α	Β	θ	α	β	θ	α
6	f_{2i}(tx1)	QPSK	0,50	45°	0,44	0,50	0°	0,50	0,50	0°	0,50
	f_{2i+1}(tx2)	16-QAM									
8	f_{2i}(tx1)	16-QAM	0,50	$\text{atan}\left(\frac{\sqrt{2}+4}{\sqrt{2}+2}\right)$	0,50	0,50	25°	0,50	0,50	0°	0,50
	f_{2i+1}(tx2)	16-QAM									
10	f_{2i}(tx1)	16-QAM	0,50	22°	0,50	0,50	15°	0,50	0,50	0°	0,50
	f_{2i+1}(tx2)	64-QAM									

6 Hybrid MIMO MFN

6.1 Transmit/receive system compatibility

To make use of the hybrid MIMO MFN, the proposed transmission hardware shall include individually-fed terrestrial and satellite transmitters with suitable antennas, delivering an OFDM waveform on the terrestrial side and OFDM or SC-OFDM on the satellite side. Cases included are one or two (cross-polar, linear polarization) terrestrial antennas in combination with one or two (cross-polar, counter-rotating circular polarization) satellite antennas. In the case of rate 2 MIMO transmission (e.g. eSM) from either or both of the satellite or terrestrial equipments the receiver shall be equipped with a cross-polar (linear polarization or counter-rotating circular) pair of antennas in the corresponding frequency band or bands. For rate 1 transmission from either the satellite or terrestrial equipments, (e.g. Alamouti, eSFN) a dual-polarized receive antenna is recommended but a single antenna is sufficient for the corresponding satellite or terrestrial frequency band.

6.2 Operational MFN modes

Any terrestrial SISO or MIMO mode (from base and MIMO profiles respectively) may be used in conjunction with any satellite SISO mode (taken from the hybrid profile) or the MIMO modes defined in tables 1 and 2, with the following addition/exception:

- The satellite rate 2 MIMO modes add a 2 x QPSK option but exclude any use of 64-QAM.

The resulting eSM parameters for the satellite component delivering an OFDM waveform are indicated in table 4.

Table 4: eSM parameters for satellite OFDM, MFN case

n_{bpcu}	**Modulation**		**β**	**θ**	**α**
4	f_{2i}(tx1) f_{2i+1}(tx2)	QPSK QPSK	0,50	$\text{atan}(\sqrt{2}+1)$	0,50
6	f_{2i+1}(tx1)	QPSK	0,50	45°	0,44
	f_{2i+1}(tx2)	16-QAM			
8	f_{2i}(tx1)	16-QAM	0,50	$\text{atan}\left(\frac{\sqrt{2}+4}{\sqrt{2}+2}\right)$	0,50
	f_{2i+1}(tx2)	16-QAM			

NOTE 1: In the case that the satellite waveform is SC-OFDM, spatial multiplexing encoding for rate 2 MIMO is simple SM as described in ETSI EN 303 105-2 [2], clause 9.1, instead of eSM.

NOTE 2: All parameters are for 0 dB intentional power imbalance between satellite transmitting antennas.

The only constraint is that at least one transmission should be MIXO in order to qualify as hybrid MIMO; otherwise the transmission falls within the Hybrid Profile ETSI EN 303 105-3 [3].

6.3 Spatial Multiplexing encoding for SC-OFDM waveform for rate 2 satellite MIMO

The satellite SM encoding for SC-OFDM waveform is similar to the rate 2 terrestrial MIMO scheme, except that neither MIMO precoding (eSM) nor phase hopping is applied.

As for terrestrial part, MIMO processing is never applied to the preamble symbols P1, aP1 and P2.

The MIMO processing shall be applied at PLP level and consists in transmitting cell pairs (f_{2i}, f_{2i+1}) on the same SCOFDM symbol and carrier from tx-1 and tx-2 respectively.

$$\begin{pmatrix} g_{2i} \\ g_{2i+1} \end{pmatrix} = \begin{pmatrix} f_{2i} \\ f_{2i+1} \end{pmatrix}, \; i = 0, 1, \ldots, Ncells/2 - 1$$

where i is the index of the cell pair within the FEC block and $Ncells$ is the number of cells per FEC block.

The pilot patterns for each transmit antenna are derived from the one of the SC-OFDM SISO signal:

- tx1 transmits the same pilot pattern as the SC-OFDM SISO signal (see clause 5.2 of the Hybrid Profile ETSI EN 303 105-3 [3]);
- tx2 transmits the same pilot pattern as tx1, expect that the phase of the reference sequence is inverted on pilot carrier over two:

$$r_{l,k}^{tx2} = s_k^{tx2} = s_k^{tx1}$$

if k even:

$$r_{l,k}^{tx2} = s_k^{tx2} = (s_k^{tx1})^{\times} \text{ if k odd.}$$

Where l and k are the symbol and carrier indices as defined in the Hybrid Profile ETSI EN 303 105-3 [3], clause 10.3.3.

For the constellations, both the 2 x QPSK and 2 x 16-QAM schemes can be applied.

7 Layer 1 signalling data for the hybrid MIMO profile

7.1 P1 and additional P1 signalling data

The Hybrid MIMO Profile - reflected by the present document - is signalled in the preamble P1 with the values S1 = 111 (ESC code) and S2 field 1 = 011, as described in clause 8.2.2 of the Base Profile ETSI EN 303 105-1 [1].

The preamble P1 is followed by an additional P1 (aP1) symbol. The aP1 symbol has the capability to convey 7 bits for signalling and the information it carries is illustrated in figure 2.

S3 (3b)	S4 Field 1 (3b)	S4 Field 2 (1b)
Waveform	FFT/GI size	Reserved

Figure 2: aP1 signalling field

- The S3 field (3 bits) indicates the waveform used in the NGH frame in the Hybrid MIMO Profile reflected by the present document, as described in table 5.

Table 5: S3 Field

S3 field	Waveform	Description
000	OFDM	P2 and all data symbols in NGH-frame are modulated using OFDM waveform
001	SC-OFDM	P2 and all data symbols in NGH-frame are modulated using SC-OFDM waveform
010 - 111	Reserved for future use	

The combination S1 = "111", S2= "011x", and S3 = "001" shall not be used.

The S4 field 1 (3 bits): FFT and GI size:

- The first 3 bits of the S4 field are referred to as S4 field 1. According to the waveform information carried by S3 field, S4 field 1 indicates the corresponding FFT size and the guard interval for the remaining symbols in the NGH-frame. The value and meaning of S4 field 1 is given in tables 6 and 7 for OFDM and SC-OFDM waveform case respectively.

Table 6: S4 Field 1 (for OFDM waveform, S3 = 000)

S3	S4 field 1	FFT/GI size	Description
000	000	FFT Size: 1K - guard interval 1/32	Indicates the FFT size and guard interval of the OFDM symbols in the NGH-frame
	001	FFT Size: 1K - guard interval 1/16	
	010	FFT Size: 2K - guard interval 1/32	
	011	FFT Size: 2K - guard interval 1/16	
	1XX	Reserved for future use	

Table 7: S4 Field 1 (for SC-OFDM waveform, S3 = 001)

S3	S4 field 1	FFT/GI size	Description
001	000	FFT Size: 0.5K - guard interval 1/32	Indicates the FFT size and guard interval of the SC-OFDM symbols in the NGH-frame
	001	FFT Size: 0.5K - guard interval 1/16	
	010	FFT Size: 1K - guard interval 1/32	
	011	FFT Size: 1K - guard interval 1/16	
	100	FFT Size: 2K - guard interval 1/32	
	101	FFT Size: 2K - guard interval 1/16	
	110 - 111	Reserved for future use	

The S4 field 2 (1 bit): Reserved for future use.

The last 1 bit of the S4 field is referred to as S4 field 2 and it is reserved for future use.

The modulation and construction of the aP1 symbol is described in clause 11.8.3 of the Base Profile ETSI EN 303 105-1 [1].

7.2 L1-PRE signalling data

Table 8 highlights the signalling specific to the hybrid MIMO profile added to the L1-PRE signalling data defined in clause 8.2.3 of the Base Profile ETSI EN 303 105-1 [1].

Table 8: L1-PRE signalling fields specific to the Hybrid MIMO profile as reflected by the present document

…	
HYBRID_MIMO_PH_FLAG	1 Bit
…	…
L1_POST_MIMO	4 Bits
L1_POST_NUM_BITS_PER_CHANNEL_USE	3 Bits
…	

HYBRID_MIMO_PH_FLAG: This 1-bit field indicates if the Phase Hopping (PH) option is used or not. In the presence of VMIMO (see clause B.1) this flag is set to "0", because phase hopping is incompatible with VMIMO. The PH scheme is described in ETSI EN 303 105-2 [2], clause 9.3.

Table 9: Signalling format for the PH indication

Value	PH mode
0	PH not applied
1	PH applied

L1-POST_MIMO: This 4-bit field indicates the MIMO scheme of the L1-POST signalling data block. The MIMO schemes shall be signalled according to table 10.

Table 10: Signalling format for the L1-POST MIMO scheme

Value	L1-POST MIMO
0000	Alamouti
0001	eSM/PH
0010	SM
0011 to 1111	Reserved for future use

L1_POST_NUM_BITS_PER_CHANNEL_USE: This 3-bit field indicates the number of bits per channel use for the MIMO scheme used by L1-POST. The value of this field is defined in table 13.

7.3 L1-POST signalling data

7.3.1 L1-POST configurable signalling data

Table 11 highlights the signalling specific to the hybrid MIMO profile added to the L1-POST configurable signalling defined in clause 8.2.4.2 of the Base Profile ETSI EN 303 105-1 [1].

Table 11: Signalling fields of L1-POST configurable

IF S1 = "111" and S2 = "000x" or "011x" {	
PLP_MIMO_TYPE	4 Bits
IF PLP_MIMO_TYPE = "0001" or "0010" {	
PLP_NUM_BITS_PER_CHANNEL_USE	3 Bits
}	
ELSE {	
PLP_MOD	3 Bits
}	
}	
ELSE {	
PLP_MOD	3 Bits
}	
…	…
IF S1 = "111" and S2 = "001x" or "0x0x" {	
TIME_IL_LATE_LENGTH	3 Bits
NUM_ADD_IUS_PER_LATE_FRAME	4 Bits
}	
…	…

PLP_MIMO_TYPE: This 4-bit field indicates the MIMO scheme used by the given PLP. The MIMO schemes shall be signalled according to table 12.

Table 12: Signalling format for the PLP_MIMO_TYPE scheme

Value	PLP_MIMO_TYPE
0000	Alamouti
0001	eSM/PH
0010	SM
0011 to 1111	Reserved for future use

The following fields appear only if PLP_MIMO_TYPE = "0001" or "0010" (i.e. eSM/PH or SM):

PLP_NUM_BITS_PER_CHANNEL_USE: This 3-bit field indicates the number of bits per channel use for the MIMO scheme used by the given PLP. The value of this field shall be defined according to table 13.

Table 13: Signalling format for PLP_NUM_BITS_PER_CHANNEL_USE

Value	n_{bpcu}	Modulation	
000	4	f_{2i}(tx1)	QPSK
		f_{2i+1}(tx2)	QPSK
001	6	f_{2i+1}(tx1)	QPSK
		f_{2i+1}(tx2)	16-QAM
010	8	f_{2i}(tx1)	16-QAM
		f_{2i+1}(tx2)	16-QAM
011 to 111	Reserved for future use	Reserved for future use	

The following field appears only if PLP_MIMO_TYPE is neither equal to "0001" nor equal to "0010" (e.g. equal to "0000" for Alamouti):

PLP_MOD: 3-bit field indicates the modulation used by the given PLP. The modulation shall be signalled according to table 14.

Table 14: Signalling format for the modulation

Value	Modulation
000	QPSK
001	16-QAM
010 to 111	Reserved for future use

TIME_IL_LATE_LENGTH: This 3-bit field represents the length P_{late} of the late part in terms of logical frames. The Late part is the last part of the full Time Interleaver length, which is signalled by TIME_IL_LENGTH.

NUM_ADD_IUS_PER_LATE_FRAME: This 4-bit field represents the number $N_{ADD\_IU\_PER\_LATE}$ of Interleaver Units (IUs) in the late part additional to the one IU present in every logical frame.

7.3.2 L1-POST dynamic signalling data

The hybrid MIMO profile uses the same L1-Dynamic signalling defined in clause 8.2.4.4 of the Base Profile ETSI EN 303 105-1 [1].

7.3.3 In-band signalling type A

The hybrid MIMO profile uses the same in-band type A signalling defined in clause 5.2.4.2 of the Base Profile ETSI EN 303 105-1 [1].

Annex A (informative): SC-OFDM pilot pattern

This annex illustrates the scattered pilot pattern PP9 for the hybrid MIMO profile when the satellite component waveform is SC-OFDM. The pilots are sent at the same locations in SISO and MIMO modes (figure A.1).

When using the Hybrid MIMO Profile reflected by the present document, the first antenna (tx1) sends exactly the same pilot pattern as in case the SISO Hybrid Profile ETSI EN 303 105-3 [3] were used. The second antenna (tx2) sends a pilot pattern at the same locations as tx1, but with different phases, as detailed in clause 6.3.

There are no continual pilots in this profile.

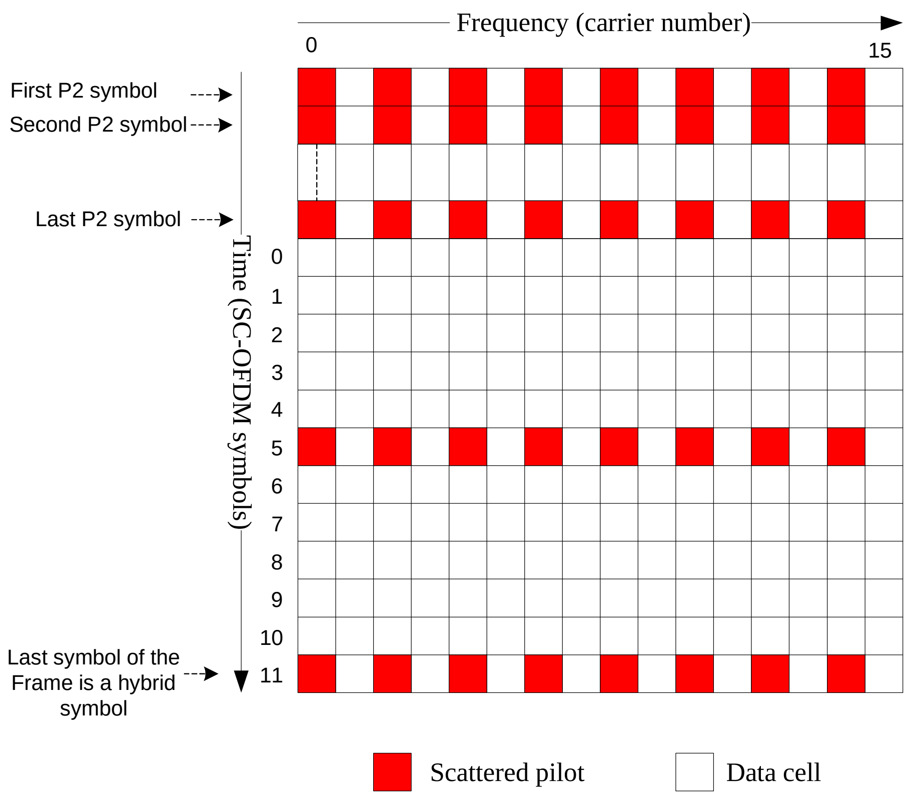


Figure A.1: Scattered pilot pattern PP9 (SC-OFDM)

Annex B (informative): Rate-2 transmission with one transmit antenna

B.1 VMIMO

B.1.1 Overview

MIMO transmission options are included in the optional MIMO profile in order to exploit the diversity and capacity advantages made possible by the use of multiple transmission elements at the transmitter and receiver. However, in an SFN network, it may happen that some terrestrial transmitters are equipped with one transmit antenna only, while the other terrestrial transmitters and the satellite transmitter are normally equipped with two transmit antennas. In such situations, one possibility would be that the 1-tx transmitters simply transmit the signal transmitted by one of the antennas of the 2-tx transmitters. From a performance point of view, a better possibility is to set up a Virtual MIMO (VMIMO) scheme, i.e. to emulate at the transmitter side an optimized 2x1 channel. This allows to send a unique signal which is representative of the two normal rate 2 signals, while optimizing performance. Another advantage is that the receiver is kept unaware of this possibility, i.e. no consequence on the receiver design is foreseen.

B.1.2 Block diagram

The block diagram illustrating the introduction of a VMIMO scheme is provided in figure B.1.

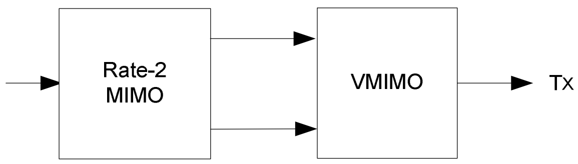


Figure B.1: VMIMO scheme

B.1.3 VMIMO processing

Basically, the VMIMO scheme consists of inserting an optimized and virtual 2x1 MISO channel prior to transmission. This virtual channel can be processed on all the input streams. Another possibility is to restrict it to the MISO and MIMO parts of the multiplex and in particular not applying it to the synchronization (P1, aP1 and P2) symbols.

The VMIMO 2x1 channel is characterized by two coefficients a_1 and a_2. The process is illustrated in table B.1, where SHS stands for synchronization, headers, signalling, etc.

Table B.1: VMIMO processing

	2-TX signal, antenna 1	**2-Tx signal, antenna 2**	**1-Tx signal (VMIMO)**
Pilot	p_1	p_2	$a_1 p_1 + a_2 p_2$
Data	d_1	d_2	$a_1 d_1 + a_2 d_2$
SHS, rate-1 signals	Sig	Sig	sig

B.1.4 Parameter setting

The a_1 and a_2 parameters do not need to be known by the receivers. The channel estimation process will simply estimate the overall channel, consisting of the juxtaposition of the VMIMO channel and the real multipath channel. Therefore they do not need to be standardized. However, some optimized values are provided in table B.2, according to the constellation used and depending on whether or not eSM is implemented.

The rationale for these values is the following: With and without eSM, the selected values ensure that a regular QAM constellation is transmitted. Without eSM, the selection of the a_i values is straightforward. With eSM, the values are modified in the following way: If φ is the eSM angle and if $a_2/a1 = tg(\varphi)$, then $tg(\theta-\varphi)=2$ for QPSK and $tg(\theta-\varphi)=4$ for 16-QAM. In table B.2, the values are provided for the 0 dB power imbalance case, i.e. $\alpha = \beta = 0,5$.

Table B.2: VMIMO parameters

	No eSM	eSM	
2 x QPSK	$a_1 = 1/\sqrt{5}$ $a_2 = 2/\sqrt{5}$	$\theta = \text{atan}\left(\sqrt{2}+1\right)$=67.5°	$a_1 = 0{,}99748$ $a_2 = 0{,}0708$
2 x 16-QAM	$a_1 = 1/\sqrt{17}$ $a_2 = 4/\sqrt{17}$	$\theta = \text{atan}\left(\frac{\sqrt{2}+4}{\sqrt{2}+2}\right)$	$a_1 = 0{,}95$ $a_2 = -0{,}312$

B.1.5 Phase Hopping

The use of VMIMO is incompatible with phase hopping (clause 9.3 of the MIMO Profile ETSI EN 303 105-2 [2]), which shall therefore be disabled when VMIMO is used.

B.1.6 Miscellaneous

For good performance with one transmit antenna only, it is assumed that the MIMO decoder is optimal (ML) or quasioptimal, whatever the values of the a_i coefficients.

Note that selecting $a_1 = 1$ and $a_2 = 0$ corresponds to the case where the transmitter equipped with one antenna simply transmits one of the signals of the rate-2 MIMO scheme.

Annex C (informative): Bibliography

- ETSI EN 302 755: "Digital Video Broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2)".
- ETSI TS 102 831: "Digital Video Broadcasting (DVB); Implementation guidelines for a second generation digital terrestrial television broadcasting system (DVB-T2)".

History

Document history		
V1.0.3	December 2021	EN Approval Procedure AP 20220324: 2021-12-24 to 2022-03-24