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**Digital Video Broadcasting (DVB);
Next Generation broadcasting system to Handheld,
physical layer specification (DVB-NGH);
Part 2: MIMO Profile**

EBU DVB[®]

Reference

DEN/JTC-DVB-373-2

Keywords

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Foreword

This 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).

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 2 of a multi-part deliverable. Full details of the entire series can be found in part 1 [1].

National transposition dates	
Date of adoption of this EN:	24 March 2022
Date of latest announcement of this EN (doa):	30 June 2022
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	31 December 2022
Date of withdrawal of any conflicting National Standard (dow):	31 December 2022

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 terrestrial MIMO broadcasting to handheld terminals making use of multi-aerial structures at the transmitting and receiving ends. It specifies the differences of the MIMO Profile physical layer part to the physical layer part of the Base Profile ETSI EN 303 105-1 [1] - from the input streams to the transmitted signals. 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".

2.2 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.

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

- [i.1] ETSI EN 303 105-4: "Digital Video Broadcasting (DVB); Next Generation broadcasting system to Handheld, physical layer specification (DVB-NGH); Part 4: Hybrid MIMO Profile".

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 MIMO system definition

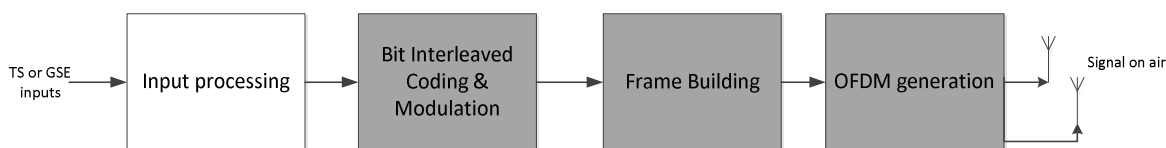
4.1 System overview and architecture

4.1.1 Overview

MIMO transmission options are included in the optional MIMO Profile - reflected by the present document - in order to exploit the diversity and capacity advantages made possible by the use of multiple transmission elements at the transmitter and receiver. Channel estimation suitable for MIMO is provided by an appropriate pilot structure, identical to that provided in the Base Profile ETSI EN 303 105-1 [1] for MISO frames. The term 'MIXO frames' encompasses all frames containing such pilots. MIMO may hence form part of a transmission including MISO PLPs as well as SISO frames as defined in the Base Profile [1]. Within MIXO frames, different schemes may be applied to constituent PLPs according to the desired transmission characteristics; for instance MISO is specified for L1 signalling and may also be used for any other low-rate high-robustness transmission. Rate 2 MIMO, which increases the data multiplexing rate by sending distinct information from each transmit element, can be chosen where high data throughput efficiency is the primary goal.

In the following clauses, the differences to the Base Profile ETSI EN 303 105-1 [1] are outlined with reference to their Base Profile [1] counterparts.

Compared to the Base Profile [1], only the BICM and the OFDM generation stage contains functional differences.



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 MIMO Profile

4.1.2 Bit interleaved coding and modulation, MISO and MIMO precoding

The block diagram illustrating the functional differences in the BICM stage is shown in figure 2.

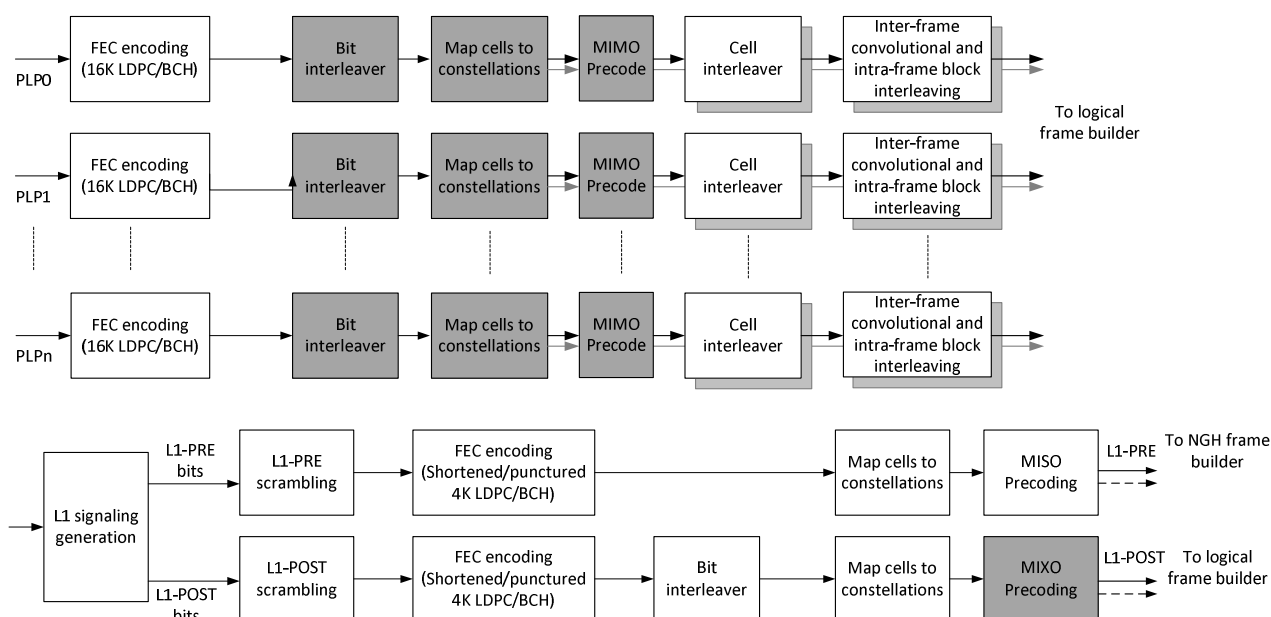
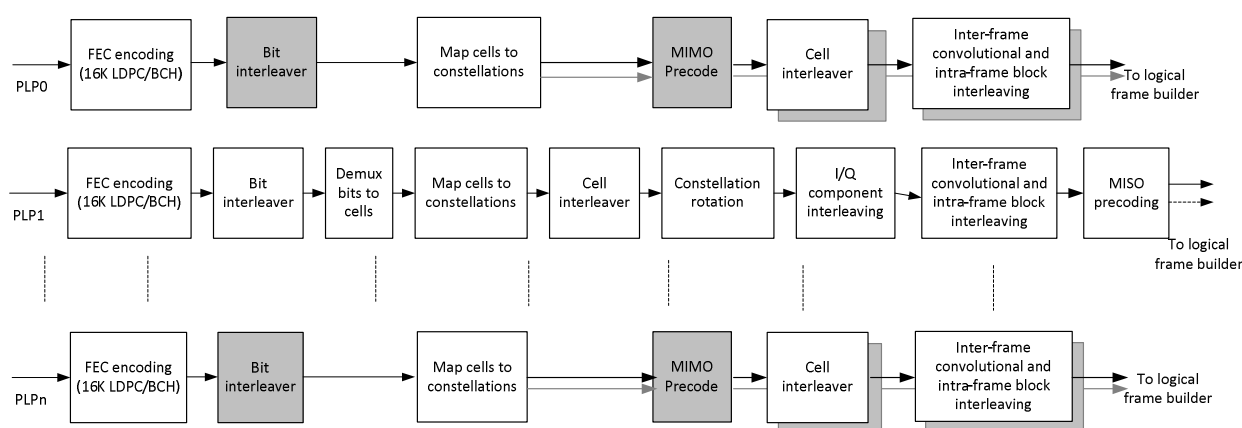


Figure 2: Bit Interleaved Coding and Modulation (BICM) of the MIMO Profile



NOTE: Layer 1 signalling as in figure 2 above.

Figure 3: Bit Interleaved Coding and Modulation (BICM) with mixed MIMO and MISO PLPs

4.1.3 FEC encoding and interleaving inside a FEC block

MIMO PLPs within the MIMO Profile - reflected by the present document - employ a revised bit interleaver intended to simplify iterative MIMO decoding at the receiver. The Base Profile ETSI EN 303 105-1 [1] bit to cell demultiplexing is no longer explicitly present.

4.1.4 Modulation and component interleaving

The constellation is non-rotated QPSK, 16-QAM and 64-QAM. The constellation may be the same or different on the output MIMO pair depending on the chosen operational mode.

4.1.5 Time interleaving (inter-frame convolutional interleaving plus intra-frame block interleaving)

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 is identical. To keep the total memory requirement the same, each of these MIMO streams has half the maximum depth as the Base Profile [1].

4.1.6 Frame building, frequency interleaving

MIMO frames are built according to figure 4. This is the same architecture as the Base Profile [1] except for the allocation of space for the aP1 symbol.

The frequency interleaver is a pairwise interleaver defined in Base Profile [1], clause 9.10.

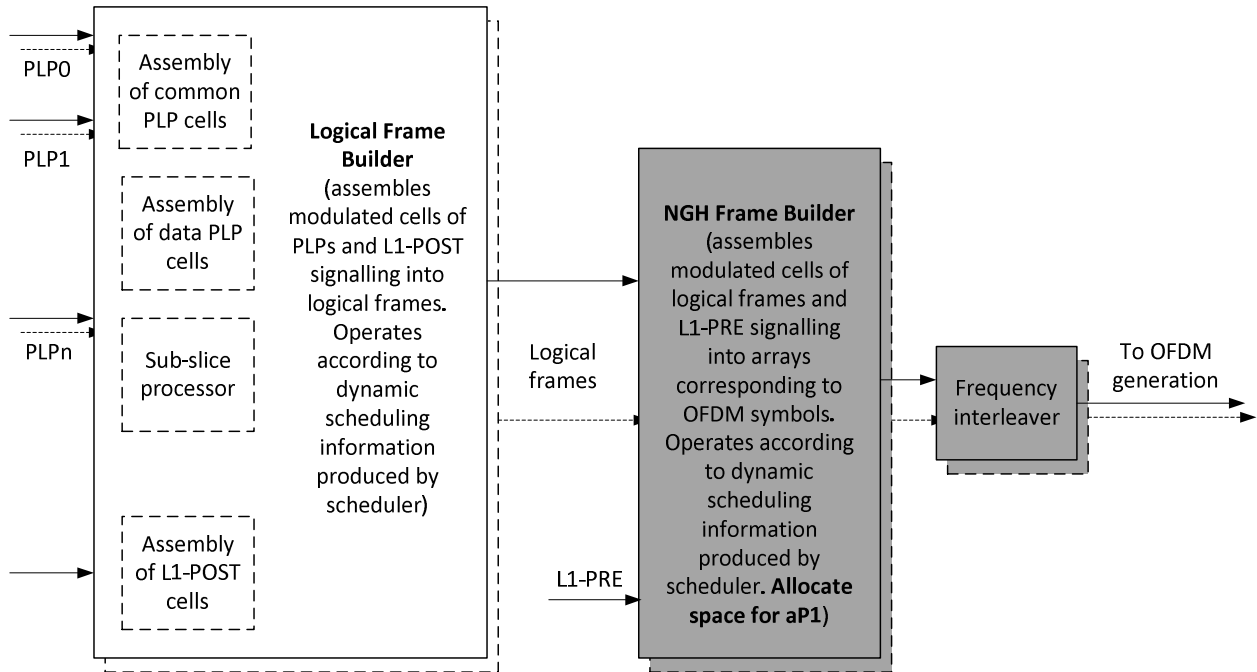


Figure 4: MIMO Frame Builder

4.1.7 OFDM generation

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

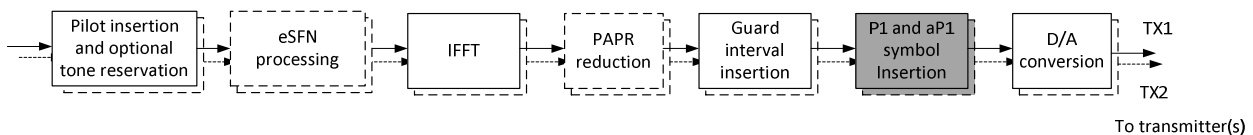


Figure 5: OFDM generation

5 Transmit/receive system compatibility

To make use of the MIMO Profile reflected by the present document, the proposed transmitter hardware shall include individually-fed cross-polar antennas (Horizontal (HP) and Vertical POLARIZATION (VP)). In addition, to receive and decode the MIMO signal, a cross-polar pair of antennas is necessary at the receive terminal.

In a given PLP, only one of MISO or MIMO encoding may be used, i.e. they are not cascable.

The bit interleaver for the MIMO Profile described below in clause 6 is a replacement for that described in ETSI EN 303 105-1 [1].

6 Bit interleaver

The bit interleaver used for MIMO PLPs is different from the one used in the Base Profile [1]. Figure 6 shows the basic block diagram.

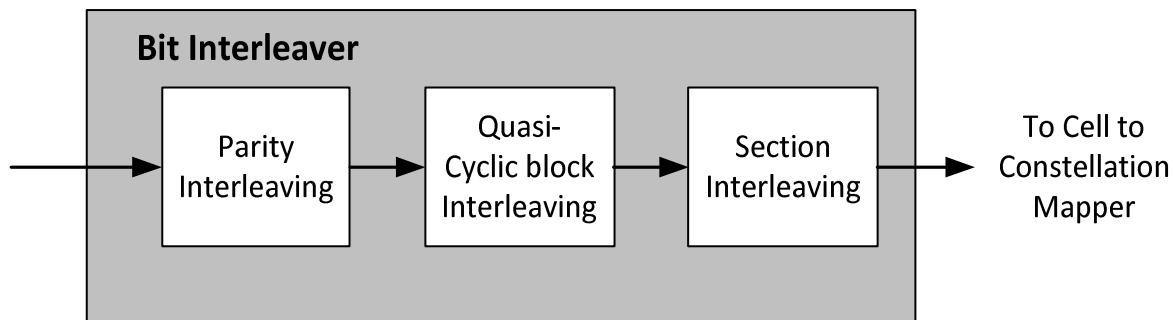


Figure 6: Bit Interleaver of the MIMO Profile

In order to allow for a more efficient receiver implementation, the new bit interleaver is adapted to the quasi-cyclic structure of the LDPC code. The new bit interleaver for MIMO consists of two components: a parity interleaver and a parallel bit interleaver.

The parity interleaver is identical to the one used in the bit interleaver of the Base Profile (see ETSI EN 303 105-1 [1], clause 6.1.4). Its role is to convert the staircase structure of the parity-part of the LDPC parity-check matrix into a quasi-cyclic structure similar to the information-part of the matrix. At the output of the parity interleaver the LDPC codeword consists of 45 adjacent Quasi-cyclic Blocks (QB), each block consisting of 360 bits (note also the Q_{ldpc} parameter in ETSI EN 303 105-1 [1], clause 6.1.2). The parity-interleaved codeword is interleaved by the parallel bit interleaver and then mapped to a sequence of Spatial-Multiplexing (SM) blocks of N_{bpcu} bits each, as shown in figure 7 for $N_{\text{bpcu}} = 8$.

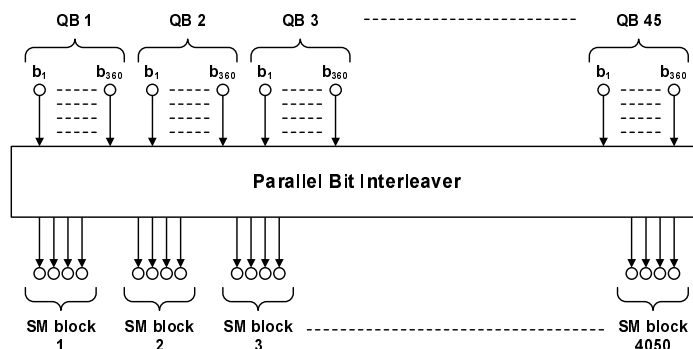


Figure 7: Parallel bit interleaver, QB and section interleaver part

The parallel interleaver in turn comprises two stages: a QB interleaver and a section interleaver.

The QB interleaver permutes the order of the 45 Quasi-cyclic Blocks (QBs) of the LDPC codeword. The corresponding QB permutation is optimized for each combination of N_{bpcu} , code rate, and power imbalance. Tables 1 to 3 show these permutations for $N_{\text{bpcu}} = 6, 8$ and 10 , respectively, each table containing the permutations for all code rates and power imbalances. The QB indices range from 1 to 45.

Table 1: QB permutations for 6 bits per channel use

Code rate	Power imbalance	QB permutations for 6 bits per channel use																																													
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14	Section 15																															
1/3	1:1	17	5	34	33	28	38	22	13	32	14	44	7	27	23	18	41	10	35	21	15	45	42	26	31	39	29	12	4	1	2	40	36	19	20	43	9	16	3	24	11	37	25	30	8	6	
	1:2	20	23	40	15	19	21	27	44	9	10	11	36	18	38	32	35	39	31	16	33	42	30	1	7	34	43	45	17	28	22	8	4	2	14	24	41	37	25	12	26	5	3	6	13	29	
	1:4	6	27	36	3	19	1	28	38	16	8	32	24	33	13	35	15	2	7	41	43	31	42	25	22	11	30	44	23	18	21	4	26	39	5	29	45	20	34	40	37	14	17	10	9	12	
2/5	1:1	20	16	34	41	28	36	19	35	42	45	43	2	1	8	30	12	9	14	10	38	15	22	6	5	24	13	31	32	23	27	40	39	18	33	3	29	25	7	21	44	17	26	37	11	4	
	1:2	20	16	34	41	28	36	19	35	42	45	43	2	1	8	30	12	9	14	10	38	15	22	6	5	24	13	31	32	23	27	40	39	18	33	3	29	25	7	21	44	17	26	37	11	4	
	1:4	20	16	34	41	28	36	19	35	42	45	43	2	1	8	30	12	9	14	10	38	15	22	6	5	24	13	31	32	23	27	40	39	18	33	3	29	25	7	21	44	17	26	37	11	4	
7/15	1:1	13	11	44	41	24	12	16	27	14	22	32	5	17	29	39	6	35	30	10	8	37	3	38	1	7	42	26	15	28	34	9	23	43	4	40	2	20	25	36	21	33	31	18	19	45	
	1:2	34	13	24	16	40	19	23	38	1	28	36	21	9	6	2	42	44	8	43	33	5	22	41	32	29	45	15	18	26	37	27	31	10	17	30	11	14	20	7	3	35	4	39	25	12	
	1:4	34	13	24	16	40	19	23	38	1	28	36	21	9	6	2	42	44	8	43	33	5	22	41	32	29	45	15	18	26	37	27	31	10	17	30	11	14	20	7	3	35	4	39	25	12	
8/15	1:1	12	27	14	35	13	38	7	39	9	19	43	33	24	25	10	6	45	21	2	28	4	3	17	15	40	42	22	8	41	11	32	16	18	44	31	37	30	26	29	34	36	23	5	20	1	4
	1:2	8	25	22	18	28	20	3	23	4	33	38	19	27	31	11	6	45	24	29	39	7	26	41	2	10	40	32	13	14	9	1	34	5	35	36	21	42	37	12	16	30	17	15	44	43	
	1:4	34	13	24	16	15	18	23	32	1	28	36	21	9	6	2	42	44	8	37	33	5	22	19	14	29	45	40	41	26	43	27	31	10	17	30	11	14	20	7	3	35	4	39	25	12	
3/5	1:1	32	38	25	18	28	34	7	39	15	20	40	44	19	12	29	14	17	21	33	5	24	36	41	31	10	6	27	45	42	37	13	43	11	26	16	22	2	1	3	8	30	9	23	4	35	
	1:2	31	43	26	20	44	39	18	28	11	37	12	36	34	42	40	9	7	21	22	6	16	27	29	13	8	30	19	38	45	32	4	2	10	5	1	14	17	41	24	35	3	23	15	33	25	
	1:4	23	5	22	42	45	20	43	18	11	27	39	34	41	37	6	24	16	8	30	40	12	35	21	31	96	10	33	44	38	14	4	3	13	9	29	19	32	15	25	28	26	17	1	2	7	
2/3	1:1	19	33	39	10	14	34	27	3	40	20	36	32	16	17	43	7	9	26	11	44	21	5	42	31	6	41	8	4	24	13	25	15	18	23	1	45	30	2	38	12	29	22	35	28	37	
	1:2	10	24	31	4	5	43	22	34	21	18	36	12	11	9	13	35	41	15	20	29	8	16	2	40	27	25	39	6	33	45	30	28	37	23	1	14	7	3	26	42	44	38	19	17	32	
	1:4	45	39	28	38	16	20	10	8	14	44	35	4	24	34	12	26	32	15	30	22	11	21	43	17	19	13	6	2	5	37	31	42	9	7	40	18	25	1	27	23	3	29	33	41	36	
11/15	1:1	5	35	39	3	25	16	44	17	4	32	13	12	8	26	45	10	6	15	21	40	43	27	24	33	2	28	41	29	19	38	14	20	30	36	7	23	34	1	18	22	42	11	9	37	31	
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	1:4	45	1	39	13	34	18	22	3	19	20	37	17	36	30	27	16	31	2	8	42	35	6	38	33	28	23	9	21	43	4	12	15	29	32	40	24	14	7	5	10	41	44	25	11	26	

Table 2: QB permutations for 8 bits per channel use

Code rate	Power imbalance	QB permutations for 8 bits per channel use																																												
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11																																		
1/3	1:1	9	37	33	39	38	28	14	3	43	36	1	20	4	7	12	6	13	35	8	23	19	32	42	25	41	10	44	30	24	31	40	27	15	26	21	29	5	17	11	34	22	16	18	2	45
	1:2	4	16	25	1	19	42	36	8	13	34	41	6	37	9	12	17	3	35	32	22	2	39	11	21	14	33	15	23	44	18	26	40	43	24	10	5	28	20	29	31	7	27	30	38	45
	1:4	4	16	25	1	19	42	36	8	13	34	41	6	37	9	12	17	3	35	32	22	2	39	11	21	14	33	15	23	44	18	26	40	43	24	10	5	28	20	29	31	7	27	30	38	45
2/5	1:1	7	21	43	35	27	4	24	5	16	20	30	10	17	42	41	44	15	13	31	36	23	12	37	18	1	19	40	22	29	9	38	8	6	34	14	26	39	3	25	32	28	33	11	2	45
	1:2	7	21	43	35	27	4	24	5	16	20	30	10	17	42	41	44	15	13	31	36	23	12	37	18	1	19	40	22	29	9	38	8	6	34	14	26	39	3	25	32	28	33	11	2	45
	1:4	38	3	28	4	17	9	16	12	36	29	19	6	8	35	7	40	37	10	44	34	2	15	14	39	32	5	42	20	1	26	18	13	23	33	11	22	31	25	43	21	27	24	41	30	45
7/15	1:1	8	12	38	21	28	19	24	6	31	17	27	20	32	5	35	2	37	1	4	3	43	9	41	33	26	15	39	18	29	11	30	7	44	23	25	16	14	10	34	36	22	42	13	40	45
	1:2	41	14	33	22	27	10	21	12	35	19	34	8	37	15	5	20	28	24	29	32	11	4	1	3	30	44	6	7	23	42	25	17	26	2	36	13	39	43	38	16	40	9	31	18	45
	1:4	35	15	8	5	40	20	42	1	2	11	31	3	41	37	6	10	36	14	34	28	44	22	12	30	29	17	26	27	23	43	9	4	38	18	24	21	32	16	13	39	33	19	25	7	45
8/15	1:1	17	39	38	26	41	10	33	6	28	5	14	3	42	22	31	43	25	40	44	24	8	1	12	4	29	15	7	20	34	2	36	23	37	16	11	9	30	27	32	21	35	13	18	19	45
	1:2	28	29	19	22	35	43	44	16	21	38	41	5	27	37	15	42	7	18	9	20	25	10	40	4	34	3	31	2	12	14	6	17	26	8	30	1	33	39	23	13	36	11	32	24	45
	1:4	16	24	44	3	39	34	8	11	37	25	26	7	29	43	42	1	35	22	21	17	4	2	33	5	27	10	13	14	36	19	23	9	41	40	32	20	28	18	31	15	30	12	6	38	45
3/5	1:1	24	3	15	2	40	11	29	18	42	12	34	16	31	21	41	19	44	14	38	25	37	36	32	7	1	28	5	10	33	9	6	17	4	13	39	23	30	26	43	8	35	20	27	22	45
	1:2	27	20	32	18	41	33	6	12	35	21	14	9	31	37	23	16	42	40	43	13	36	34	26	22	30	28	8	19	1	44	3	38	11	39	10	24	29	25	17	7	5	15	4	2	45
	1:4	27	20	32	18	41	33	6	12	35	21	14	9	31	37	23	16	42	40	43	13	36	34	26	22	30	28	8	19	1	44	3	38	11	39	10	24	29	25							

Table 3: QB permutations for 10 bits per channel use

Code rate	Power imbalance	QB permutations for 10 bits per channel use																																																			
		Section 1						Section 2						Section 3						Section 4						Section 5						Section 6						Section 7						Section 8						Section 9			
1/3	1:1	27	17	42	8	30	38	6	15	32	36	22	18	40	26	14	41	45	29	23	9	20	4	44	37	2	43	12	11	10	28	21	16	5	13	31	33	3	1	35	7	39	34	24	19	25							
	1:2	27	17	42	8	30	38	6	15	32	36	22	18	40	26	14	41	45	29	23	9	20	4	44	37	2	43	12	11	10	28	21	16	5	13	31	33	3	1	35	7	39	34	24	19	25							
	1:4	42	30	27	8	17	38	32	36	6	15	26	14	40	18	22	9	45	23	41	29	20	4	44	37	2	43	12	11	10	28	21	16	5	13	31	33	3	1	35	7	24	25	39	34	19							
2/5	1:1	30	35	13	26	38	22	14	1	10	19	7	21	24	45	33	41	3	43	20	31	9	16	11	34	4	17	32	42	23	36	28	15	44	5	2	40	18	12	39	29	27	25	8	37	6							
	1:2	30	35	13	26	38	22	14	1	10	19	7	21	24	45	33	41	3	43	20	31	9	16	11	34	4	17	32	42	23	36	28	15	44	5	2	40	18	12	39	29	27	25	8	37	6							
	1:4	44	23	13	45	1	2	21	14	4	25	41	20	22	29	19	30	24	17	42	33	27	5	36	11	3	40	8	18	7	35	16	10	38	31	28	43	34	6	12	9	39	26	37	15	32							
7/15	1:1	9	1	33	4	20	16	29	41	38	6	19	14	35	30	39	43	15	27	44	10	11	3	24	18	7	45	8	37	34	22	31	2	40	36	12	32	13	42	25	17	28	21	26	5	23							
	1:2	43	20	44	31	7	28	19	26	23	3	40	35	42	22	16	34	21	27	17	4	33	32	2	38	1	39	10	36	11	8	6	24	41	15	5	18	25	45	13	29	14	9	30	37	12							
	1:4	39	32	44	31	10	33	19	36	11	4	28	7	18	22	1	41	35	14	13	29	34	2	3	24	9	40	25	30	6	23	43	16	42	37	5	38	21	26	17	12	45	20	27	15	8							
8/15	1:1	27	3	43	12	17	18	8	40	22	15	31	7	41	29	21	30	6	26	28	36	39	9	19	16	32	5	13	24	1	4	10	23	14	35	2	42	37	44	38	34	33	11	45	25	20							
	1:2	31	43	28	25	10	36	16	35	38	13	44	20	21	30	15	12	4	24	1	5	7	14	34	45	18	33	11	42	27	9	39	17	26	40	23	32	3	22	41	6	8	19	29	37	2							
	1:4	28	25	44	37	8	2	10	38	3	6	13	42	39	35	1	16	41	18	9	17	34	19	27	11	4	33	24	30	23	7	12	14	45	32	15	40	21	36	22	29	43	20	26	31	5							
3/5	1:1	17	28	39	7	14	29	16	35	41	45	2	5	18	1	32	42	13	37	34	21	33	25	40	12	6	30	31	24	8	20	23	4	3	9	11	27	22	38	44	15	10	19	43	36	26							
	1:2	17	28	39	7	14	41	16	35	29	45	2	5	18	1	32	37	13	34	42	21	33	12	40	25	6	30	31	24	8	20	23	4	3	9	11	15	27	38	44	22	43	26	36	10	19							
	1:4	95	12	38	32	24	28	11	45	23	33	42	14	40	6	31	3	8	17	2	15	19	43	37	20	22	5	18	1	9	4	10	30	41	21	13	44	25	36	34	26	29	39	16	27	7							
2/3	1:1	14	6	24	15	23	39	28	36	30	11	13	8	22	34	10	9	44	33	41	5	12	31	2	3	29	40	43	32	7	18	16	20	38	45	4	26	27	21	19	25	37	35	1	17	42							
	1:2	17	23	45	21	6	42	24	3	29	16	32	27	1	25	38	26	7	18	39	20	37	44	41	43	12	5	10	11	35	33	28	40	34	4	8	30	13	19	2	22	9	14	31	15	36							
	1:4	38	30	11	27	17	16	22	45	21	44	1	23	3	2	35	7	8	12	39	13	40	6	42	36	14	18	34	31	28	24	10	5	15	26	9	20	19	37	32	29	25	33	4	43	41							
11/15	1:1	45	43	10	35	16	24	29	1	41	27	26	5	25	23	44	8	13	30	12	9	17	39	22	4	38	21	28	19	20	37	14	31	34	6	3	32	11	15	7	42	33	40	36	2	18							
	1:2	27	11	10	37	45	25	6	32	28	5	18	4	23	22	9	36	30	41	34	43	35	29	1	31	38	7	3	16	44	12	2	40	33	39	20	17	26	8	42	15	24	19	13	21	14							
	1:4	1	30	15	7	35	26	22	27	21	44	17	23	37	31	39	9	8	13	36	24	4	42	34	20	28	16	41	6	45	2	29	10	19	33	40	14	18	12	38	5	43	32	3	25	11							

Following the QB interleaver, the LDPC codeword is divided into parallel sections, each section containing $N_{\text{bpcu}}/2$ adjacent quasi-cyclic blocks. Each section is interleaved independently by a section interleaver. The number of sections per LDPC codeword for $N_{\text{bpcu}} = 6, 8$ and 10 is $15, 11$ and 9 , respectively. For $N_{\text{bpcu}} = 8$, since 4 is not a divisor of 45 the last quasi-cycle block does not belong to any section and shall not be permuted by a section interleaver.

The section interleaving consists in writing the bits of each section row by row into a matrix with 360 columns and $N_{\text{bpcu}}/2$ rows and reading them out column by column. Such an interleaving strategy ensures that each spatially multiplexed block contains 2 adjacent bits from each quasi-cyclic block in the corresponding section, as shown in figure 8 for $N_{\text{bpcu}} = 8$. The bits from all sections are then merged into an interleaved LDPC codeword.

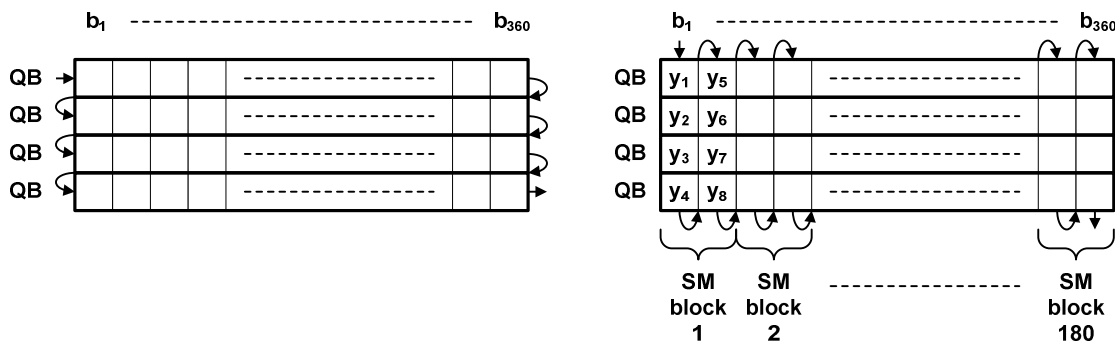


Figure 8: Section interleaver, write and read sequences

7 Complex symbol generation

The N_{bpcu} bits of each SM block modulate two complex symbols (s_1 and s_2), which are spatially multiplexed over the two antennas. The mapping of the bits to complex symbols is shown in figure 9 for $N_{\text{bpcu}} = 6, 8$ and 10 , the corresponding bit encoding/labelling of the real pulse-amplitude modulation symbols being illustrated in figure 10. Bit b_1 is always the least significant.

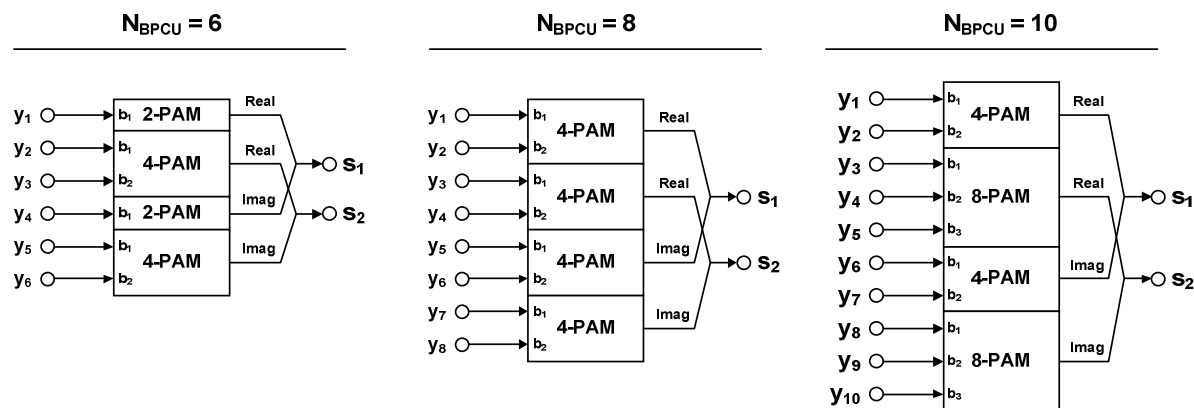


Figure 9: Mapping of SM blocks to pairs of complex symbols

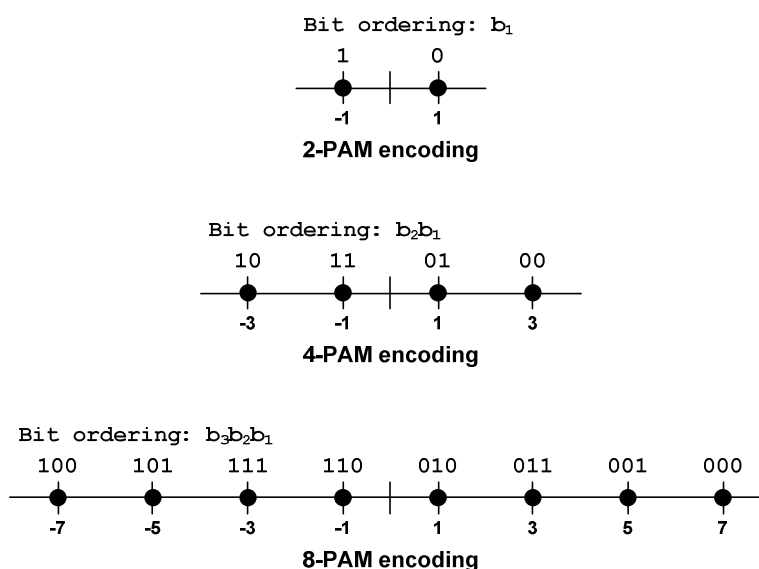


Figure 10: Bit encoding/labelling for real PAM symbols

The resulting constellations for the symbols s_1 and s_2 are summarized in table 4.

Table 4: Constellations sizes

	$N_{\text{BPCU}} = 6$	$N_{\text{BPCU}} = 8$	$N_{\text{BPCU}} = 10$
s_1	QPSK	16-QAM	16-QAM
s_2	16-QAM	16-QAM	64-QAM

NOTE: 64-QAM is using uniform constellation mapping only (see clause 6.2.3 in ETSI EN 303 105-1 [1]).

8 Power imbalance

The MIMO Profile - reflected by the present document - is specified for use with one of three fixed power imbalances (HP/VP or VP/HP), in order to facilitate time-sharing with SISO services without undesired station envelope power fluctuations or excessive SISO link budget loss.

The available power imbalances are 0 dB, 3 dB and 6 dB.

The imbalance may be optionally applied during all PLP and frame types, SISO, MISO and MIMO. So where Alamouti coding is used in a cross-polar context (see ETSI EN 303 105-1 [1], clause 7.2) an imbalancing matrix may be introduced as follows, the value of β taken from ETSI EN 303 105-1 [1], table 30.

$$\begin{bmatrix} g'_q(Tx1) \\ g'_q(Tx2) \end{bmatrix} = \begin{bmatrix} \sqrt{\beta} & 0 \\ 0 & \sqrt{1-\beta} \end{bmatrix} \begin{bmatrix} g_q(Tx1) \\ g_q(Tx2) \end{bmatrix}$$

$$q = 0 \dots N_{data} - 1$$

In the case of cross-polar transmission, during SISO frames, the two transmission elements may be generated as:

$$\begin{bmatrix} g'_q(Tx1) \\ g'_q(Tx2) \end{bmatrix} = \begin{bmatrix} \sqrt{\beta} & 0 \\ 0 & \sqrt{1-\beta} \end{bmatrix} \begin{bmatrix} g_q \\ g_q \end{bmatrix}$$

$$q = 0 \dots N_{data} - 1$$

NOTE: If the specified options for fixed power imbalance are not used, and envelope power fluctuations are acceptable, then the MIMO frames are transmitted with 0 dB power imbalance and the SISO on a single polarization (infinite imbalance).

9 MIMO precoding

9.1 Overview

MIMO processing is intended for a 2x2 MIMO system which means that at least two antenna aeriels are equipped at both transmitter and receiver side. MIMO processing acts on a pair of input constellation points (not necessarily drawn from the same constellation) and creates a pair of outputs intended for the two elements of a dual-polar transmitter. MIMO processing is never applied to the preamble symbols P1, aP1 and L1-PRE and the pilots are processed as described in ETSI EN 303 105-1 [1], clause 11.2.

The MIMO precoding shall be applied at PLP level and consists in multiplying cell pairs (f_{2i}, f_{2i+1}) by a variable precoding matrix $\mathbf{W}(i)$. Encoded cell pairs (g_{2i}, g_{2i+1}) shall be transmitted on the same OFDM symbol and carrier from tx1 and tx2 respectively.

$$\begin{pmatrix} g_{2i} \\ g_{2i+1} \end{pmatrix} = \mathbf{W}(i) \begin{pmatrix} f_{2i} \\ f_{2i+1} \end{pmatrix}, i = 0, 1, \dots, N_{cells}/2 - 1$$

where i is the index of the cell pair within the FEC block and N_{cells} is the number of cells required to transmit one LDPC block by using MIMO encoding which is calculated by N_{ldpc}/N_{bpcu} .

The MIMO precoding process consists of a spatial-multiplexing precoding followed by an additional phase-hopping, as shown in figure 11. The combined precoding matrix $\mathbf{W}(i)$ is the product of the fixed spatial-multiplexing precoding matrix \mathbf{F} and the variable phase-hopping matrix $\mathbf{X}(i)$.

For rate 2 MIMO schemes, 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 size $N_{MUS,PLP}$ per MIMO branch can be calculated in the same way as described for the SISO scheme of the Base Profile in ETSI EN 303 105-1 [1], clause 6.6.5, when setting 1 MU corresponding always to 1 cell (for any signal constellation - QPSK, 16-, 64- and 256-QAM). The total required de-interleaver memory for both MIMO branches is twice this size. The applicable limit for the MIMO Profile - reflected by the present document - is still $\sum 2N_{MUS,PLP} \leq 2^{18}$ MUs, 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.

If MIMO precoding is not used, only transmit antenna 1 (tx1) path is used and the input QAM symbols shall be copied directly to the output, i.e. $g_k = f_k$ for $k=0,1,2,\dots,N_{data}-1$.

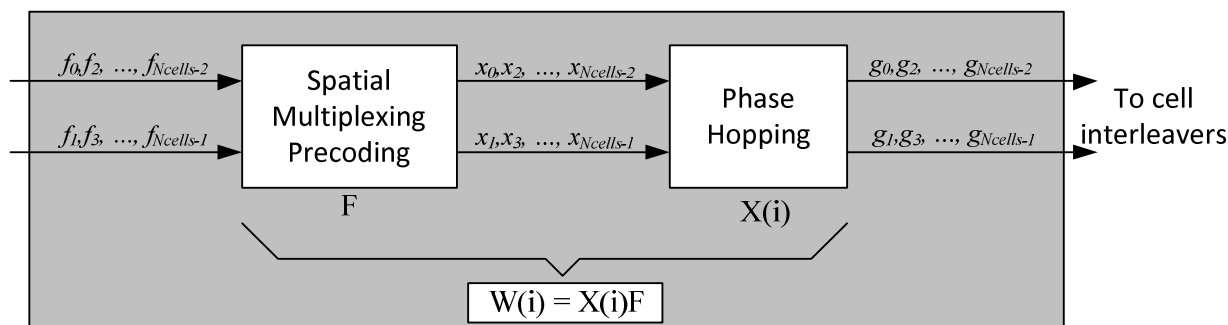


Figure 11: Block diagram of the MIMO precoding

9.2 Spatial-multiplexing encoding

The spatial multiplexing encoding process is carried out on pairs of normalized QAM symbols ($f_{2i}(tx1)$, $f_{2i+1}(tx2)$) from the output of the constellation mapper. These payload cells, prior to the application of phase hopping, are $x_{2i}(tx1)$ for transmit antenna 1 and $x_{2i+1}(tx2)$ for transmit antenna 2 and shall be generated from the input symbols according to:

$$\begin{bmatrix} x_{2i}(tx1) \\ x_{2i+1}(tx2) \end{bmatrix} = \sqrt{2} \begin{bmatrix} \sqrt{\beta} & 0 \\ 0 & \sqrt{1-\beta} \end{bmatrix} \begin{bmatrix} \cos \theta & \sin \theta \\ \sin \theta & -\cos \theta \end{bmatrix} \begin{bmatrix} \sqrt{\alpha} & 0 \\ 0 & \sqrt{1-\alpha} \end{bmatrix} \begin{bmatrix} f_{2i}(tx1) \\ f_{2i+1}(tx2) \end{bmatrix}$$

$$i = 0, \dots, (N_{cells} / 2) - 1$$

N_{cells} is the number of cells required to transmit one LDPC block by using MIMO encoding which is calculated by N_{ldpc}/N_{bpcu} .

MIMO processing may be applied for 6, 8 or 10 bpcu and also for intentional power imbalance of 0, 3, 6 dB between two transmit antennas. MIMO encoding process shall use defined parameter values for each case according to table 5.

Table 5: eSM parameters

Intentional power imbalance between two Tx antennas			0 dB			3 dB			6 dB		
n_{bpcu}	Modulation		β	Θ	α	β	Θ	A	B	θ	α
6	$f_{2i}(tx1)$	QPSK	0,50	45°	0,44	1/3	0°	0,50	0,20	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	1/3	25°	0,50	0,20	0°	0,50
	$f_{2i+1}(tx2)$	16-QAM									
10	$f_{2i}(tx1)$	16-QAM	0,50	22°	0,50	1/3	15°	0,50	0,20	0°	0,50
	$f_{2i+1}(tx2)$	64-QAM									

NOTE: $-\pi/2 < \text{atan} < \pi/2$.

The encoding process is repeated for each pair of QAM symbols in turn.

9.3 Phase hopping

Except in the case of the hybrid MIMO Profile where VMIMO has been used (see ETSI EN 303 105-4 [i.1], clause B.1), phase hopping shall be applied to the output of the spatial-multiplexing precoding and consists of applying an incremental phase change to the complex cells transmitted on tx2. The phase change is performed by multiplying each cell pair (x_{2i} , x_{2i+1}) by a variable matrix $\mathbf{X}(i)$, resulting in a cell pair (g_{2i} , g_{2i+1}), i.e. the encoded OFDM payload cells:

$$\begin{pmatrix} g_{2i} \\ g_{2i+1} \end{pmatrix} = \mathbf{X}(i) \begin{pmatrix} x_{2i} \\ x_{2i+1} \end{pmatrix}, \quad i = 0, 1, \dots, N_{cells}/2 - 1$$

where $X(i)$ has the following expression:

$$X(i) = \begin{pmatrix} 1 & 0 \\ 0 & e^{j\Phi_{PH(i)}} \end{pmatrix}, i = 0, 1, \dots, N_{cells}/2 - 1$$

The phase change for cell pair i is $\Phi_{PH(i)} = 2\pi i/9$, i.e. it is initialized to 0 at the beginning of each FEC block and is incremented by $2\pi/9$ for every cell pair. The resulting hopping pattern is periodic with a period of 9 cell pairs, i.e. $\mathbf{X}(i+9) = \mathbf{X}(i)$. Since the number of cell pairs per FEC block is a multiple of 9 for all modulations, there is always an integer number of phase-hopping periods in each FEC block.

The phase-hopping matrix $\mathbf{X}(i)$ is independent of the modulation and the power imbalance.

10 eSFN processing for MIXO

The principle role of eSFN with MIMO (also MISO, see ETSI EN 303 105-1 [1], clause 7) is to carry SISO frames as part of transmission containing both SISO and MIXO frames. The eSFN signal power is split in the same way as the MIXO power over different transmission components (e.g. the HP/VP parts in case of crosspolar transmission), to achieve the corresponding power imbalance, such that the average power is the same on each transmission component during SISO and MIXO transmission. Thus eSFN is applied within the MIMO Profile at frame level to modulate the OFDM symbols using the eSFN predistortion term Φ_k as described in ETSI EN 303 105-1 [1], clause 11.5.2.

If continuity of the transmitter identification property of eSFN is required during MIMO frames as well as SISO, then eSFN may optionally be continuously applied over all frame types.

11 SISO/MIXO options for P1, aP1 and P2 symbols

Table 6 specifies the SISO/MIXO coding options applicable to P1, aP1 and P2 symbols.

Table 6: SISO/MIXO coding options for P1, aP1 and P2 symbols

Symbol type PLP type	P1/aP1	P2	P2	P2	Data Symbols
		L1-pre	L1-post	Data	
SISO	Uncoded SISO or eSFN	Uncoded SISO or eSFN	Uncoded SISO or eSFN	Uncoded SISO or eSFN	Uncoded SISO or eSFN
MISO	Uncoded SISO or eSFN	Alamouti	Alamouti	Alamouti	Alamouti
MIMO	Uncoded SISO or eSFN	Alamouti	Alamouti or eSM/PH	Alamouti or eSM/PH	Alamouti or eSM/PH

NOTE 1: The SISO row is shown for information only.
NOTE 2: When Alamouti or eSM/PH is used, eSFN may be optionally added with a unique tx code applied per station or per-antenna.

12 Layer 1 signalling data specific for the MIMO Profile

12.1 P1 and additional P1 signalling data

The MIMO Profile - reflected by the present document - is signalled in the preamble P1 with the values $S1 = 111$ (ESC code) and $S2$ field 1 = 000, as described in ETSI EN 303 105-1 [1], clause 8.2.2.

The preamble P1 is followed by an additional P1 (aP1) symbol. The aP1 symbol has the capability to convey 7 bits for signalling, as illustrated in figure 12 below.

S3 (3b)	S4 (4b)
FFT size/GI	Reserved

Figure 12: aP1 signalling format for the MIMO Profile

- The S3 field (3 bits) indicates the FFT size and gives partial information about the guard interval for the remaining symbols in the NGH frame in the MIMO Profile reflected by the present document - as described in table 7.

Table 7: S3 (3 bits) for NGH MIMO preamble type

S3 field	FFT/GI size	Description
000	FFT Size: 1K - any allowed guard interval	Indicates the FFT size and guard interval of the symbols in the NGH frame of the MIMO Profile
001	FFT Size: 2K - any allowed guard interval	
010	FFT Size: 4K - any allowed guard interval	
011	FFT Size: 8K - guard intervals 1/32; 1/16; 1/8 or 1/4	
100	FFT Size: 8K - guard intervals 1/128; 19/256 or 19/128	
101	FFT Size: 16K - guard intervals 1/128; 19/256 or 19/128	
110	FFT Size: 16K - guard intervals 1/32; 1/16; 1/8 or 1/4	
111	Reserved for future use	

- The S4 field (4 bits): 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].

12.2 L1-PRE signalling data

Table 8 highlights the signalling specific to the MIMO Profile - reflected by the present document - 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 MIMO Profile

...	
L1_POST_MIMO	4 Bits
L1_POST_NUM_BITS_PER_CHANNEL_USE	3 Bits
...	

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 9.

Table 9: Signalling format for the L1-POST MIMO scheme

Value	Constellation
0000	Alamouti
0001	eSM/PH
0010 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 12.

12.3 L1-POST signalling data

12.3.1 L1-POST-configurable signalling data

Table 10 highlights the signalling fields specific to the MIMO Profile - reflected by the present document - 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 10: The signalling fields of configurable L1-POST signalling

IF S1 = "111" and S2 = "000x" or "011x" {	
PLP_MIMO_TYPE	4 Bits
IF PLP_MIMO_TYPE = "0001" {	
PLP_NUM_BITS_PER_CHANNEL_USE	3 Bits
}	
ELSE {	
PLP_MOD	3 Bits
}	
}	
ELSE {	
PLP_MOD	3 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 11.

Table 11: Signalling format for the PLP_MIMO_TYPE scheme

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

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

- **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 8.

Table 12: Signalling format for PLP_NUM_BITS_PER_CHANNEL_USE

Value	N _{bpcu}	Modulation	
		$f_{2i}(tx1)$	QPSK
000	6	$f_{2i+1}(tx2)$	16-QAM
		$f_{2i}(tx1)$	16-QAM
001	8	$f_{2i+1}(tx2)$	16-QAM
		$f_{2i}(tx1)$	16-QAM
010	10	$f_{2i+1}(tx2)$	64-QAM
		$f_{2i}(tx1)$	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 62 of the Base Profile ETSI EN 303 105-1 [1].

12.3.2 L1-POST-dynamic signalling data

The MIMO Profile - reflected by the present document - uses the same L1-POST-dynamic signalling defined in clause 8.2.4.4 of the Basic Profile ETSI EN 303 105-1 [1].

12.3.3 In-band signalling type A

The MIMO Profile - reflected by the present document - uses the same in-band type A signalling defined in clause 5.2.4.2 of the Basic Profile ETSI EN 303 105-1 [1].

Annex A (informative): Bibliography

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

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