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

Reference

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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 3 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
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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).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

1 Scope

The present document describes the next generation transmission system for digital hybrid (combination of terrestrial with satellite transmissions) broadcasting to handheld terminals. It specifies the differences of the Hybrid 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.

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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 system definition

4.1 System overview and architecture

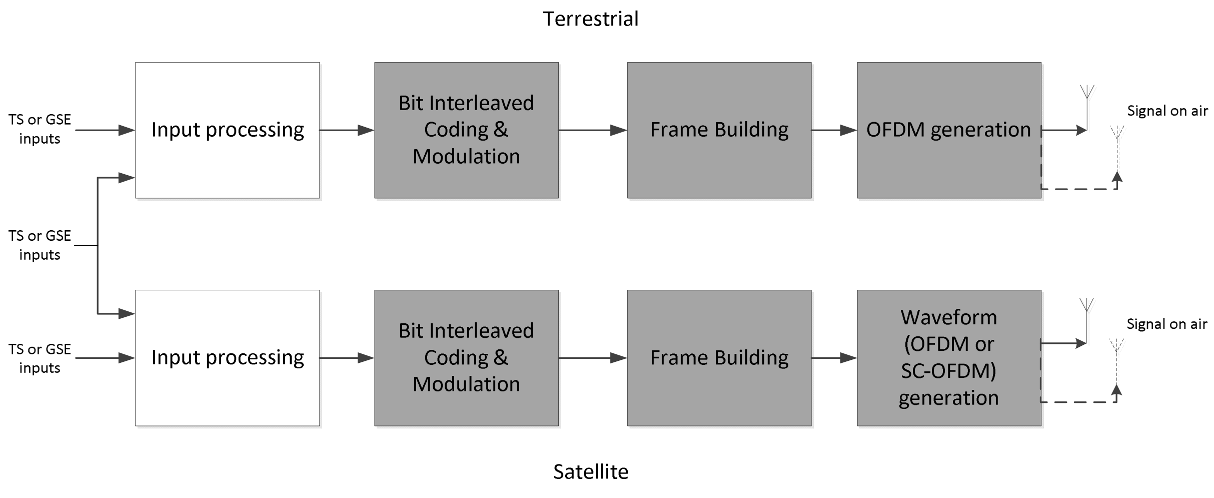
4.1.1 Overview

The Hybrid Profile - reflected by the present document - specifies the hybrid signal format, composed of a component coming from the terrestrial network, and an additional component, coming from the satellite. Hybrid signals according to the NGH profile reflected by the present document include an additional P1 symbol (aP1, see ETSI EN 303 105-1 [1], clause 11.8.3). The satellite component of the Hybrid Profile - reflected by the present document - is defined for channel bandwidths 1, 7, 2 and 5 MHz (these three bandwidths are also covered by the Base Profile [1]).

Hybrid NGH signals can also be Base Profile compliant, in which case they are covered by ETSI EN 303 105-1 [1].

Besides defining the hybrid signals, the Hybrid Profile - reflected by the present document - defines moreover the mechanisms to receive two signals simultaneously (one signal from a terrestrial transmitter and one from the satellite) and to combine their outputs to a single stream.

Figure 1 represents the high level NGH physical layer block diagram of the Hybrid Profile - reflected by the present document. Two chains are present, one for the terrestrial component and the other for the satellite component. Compared to the Base Profile, the terrestrial and satellite chains of the Hybrid Profile - reflected by the present document - present potential functional differences in the BICM, frame building and waveform generation. The system architecture of the satellite component is that of the terrestrial component, with the possibility of replacing the OFDM modulation block by the SC-OFDM modulation block, characterized additionally by the absence of particular functional blocks as explained in clause 4.1. Time frequency slicing can be applied to both, the terrestrial and the satellite components.



NOTE: Blocks differing from the Base Profile are shaded grey.

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

Both SFN and MFN configurations are possible for the Hybrid Profile - reflected by the present document. In the SFN case, when the satellite and terrestrial components share the same frequency, the signal transmitted in the two components shall be exactly the same. The system input(s) to the terrestrial and the satellite path may differ from each other in the MFN case. In the MFN case, the system architecture of the Hybrid Profile of DVB-NGH - reflected by the present document - is composed of two components: the terrestrial component, as specified in ETSI EN 303 105-1 [1], and the satellite component, as represented in figure 1.

MISO in the Hybrid Profile - reflected by the present document - is applicable to OFDM only, to both, the terrestrial and the satellite paths.

Table 1 indicates the allowed parameter settings for the Hybrid Profile - reflected by the present document. According to it, the following hybrid cases can be devised:

- SFN, OFDM: The terrestrial network and the satellite share the same frequency and the same signal is transmitted on the two components. The signal waveform is OFDM and the preambles of both components consist of a P1 plus an aP1 symbol. The OFDM parameter set is applicable to both components, terrestrial and satellite. Alternatively, the Base Profile could be adopted for both components. In that case the P1 part of the preamble of both components consists of a P1 symbol only.

- MFN, OFDM: The satellite signal is transmitted on a different frequency, OFDM is used on both components. The terrestrial component is transmitted according to the Base Profile, the satellite component according to the OFDM settings listed in table 1. The preamble of the terrestrial component consists of a P1 symbol and the preamble of the satellite component consists of a P1 plus an aP1 symbol.

- SFN, SC-OFDM: This case consists of the satellite coverage and of terrestrial gap fillers sharing the same frequency of the satellite signal. The SC-OFDM settings are applicable to both components, terrestrial and satellite. Preambles consist of P1 plus aP1 symbols for the satellite and the terrestrial component.

- MFN, SC-OFDM on the satellite component, OFDM on the terrestrial component: The terrestrial component is configured in line with the Base Profile, the satellite component using the permitted SC-OFDM settings outlined in table 1. The preamble of the terrestrial component consists of a P1 symbol and the one of the satellite component of a P1 plus an aP1 symbol.

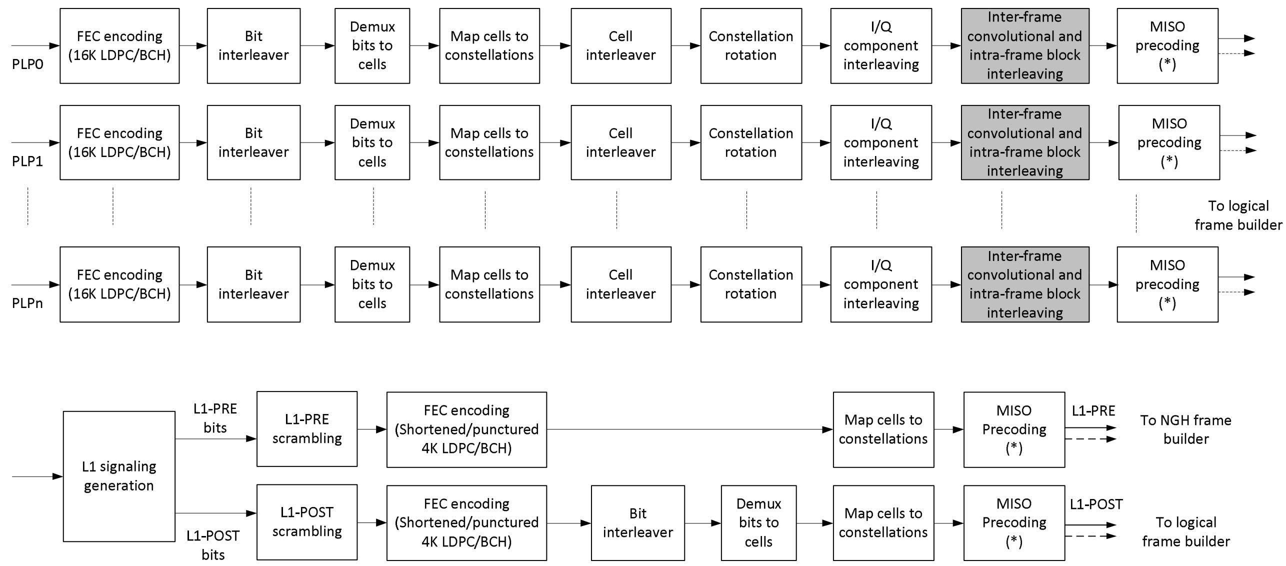
Table 1: Allowed parameter settings for the Hybrid Profile - reflected by the present document

Parameters		Hybrid waveform	
Modulation		OFDM	SC-OFDM
Bandwidths	1,7 MHz	X	X
	2,5 MHz	X	X
	5,0 MHz	X	X
	6,0 MHz		
	7,0 MHz		
	8,0 MHz		
	10,0 MHz		
	15,0 MHz		
	20,0 MHz		
Constellations	QPSK	X	X
	16-QAM	X	X
	64-QAM		
	256-QAM		
FFT sizes	0,5k		X
	1k	X	X
	2k	X	X
	4k		
	8k		
	16k		

Parameters		Hybrid waveform	
Modulation		OFDM	SC-OFDM
Guard intervals	1/128		
	1/32	X	X
	1/16	X	X
	19/256		
	1/8	X	
	19/128		
	1/4	X	
Preambles	Single P1		
	P1 + aP1	X	X
Pilot patterns	Continuous pilot symbols	X	
	PP1	X	
	PP2	X	
	PP3	X	
	PP4	X	
	PP5	X	
	PP6		
	PP7		
	PP9		X
FEC code rates	1/5 (=3/15)	X	X
	4/15	X	X
	1/3 (=5/15)	X	X
	2/5 (=6/15)	X	X
	7/15	X	X
	8/15	X	X
	3/5 (=9/15)	X	X
	2/3 (=10/15)	X	X
	11/15	X	X
	3/4	X	X
MISO		X	
Time de-interleaver size	See note 2	According to clause 6.2	According to clause 6.2
NOTE 1: Not all parameter settings listed above can be combined with each other. The exceptions are described in the following clauses. NOTE 2: In situations where a receiver needs to time de-interleave both, the terrestrial and the satellite signal, in parallel, limits for the time de-interleaver size outlined in clause 6.2 apply to the combination of both signals, i.e. they cannot simultaneously make use of the full specified time de-interleaver memory size.			

4.1.2 Bit-interleaved coding and modulation, MISO precoding

The block diagram, illustrating the functional differences in the BICM stage, is shown in figure 2. Further to the time interleaving configurations of the Base Profile, the Hybrid Profile - reflected by the present document - allows a concentration of cells at the end of the logical frame sequence over which a FEC block is spread (uniform-late interleaving).



NOTE: (*): Applicable to OFDM waveform only.

Figure 2: BICM of the Hybrid Profile - reflected by the present document (applicable to the terrestrial and the satellite path)

4.1.3 Frame building, frequency interleaving

The block diagram, illustrating the functional differences in frame building stage, is shown in figure 3. This is the same architecture as the Base Profile except for the allocation of space for the aP1 symbol. As far as the physical and the logical framing is concerned, the same mechanisms are used for the terrestrial and satellite components. These mechanisms are described in ETSI EN 303 105-1 [1], clause 9. The frequency interleaver is applicable to OFDM only.

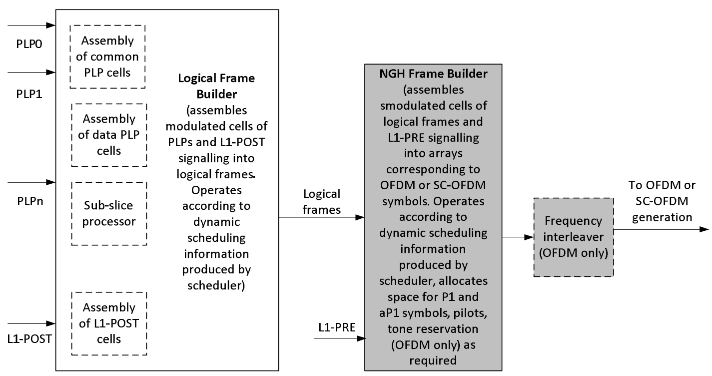


Figure 3: Frame builder of the Hybrid Profile - reflected by the present document (applicable to the terrestrial and the satellite path)

4.1.4 OFDM generation

The block diagram, illustrating the functional differences in the OFDM generation stage, is shown in figure 4. The only functional difference is the insertion of the additional preamble symbol aP1, following the preamble symbol P1, as specified in ETSI EN 303 105-1 [1], clause 11.8.3.

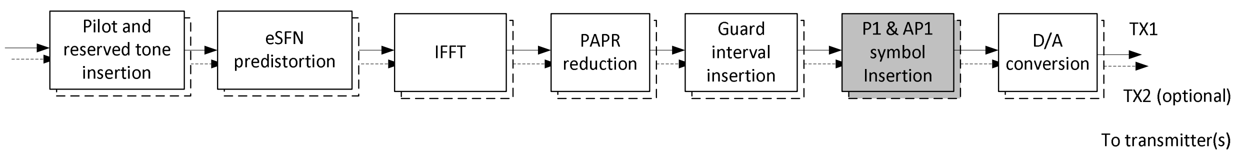


Figure 4: OFDM generation (applicable to the terrestrial and the satellite path)

4.1.5 SC-OFDM generation

The block diagram, illustrating the SC-OFM generation stage, is shown in figure 5. The functional differences to the OFDM generation are the additional spreading stage (see clause 8.1 below), a different pilot pattern, the absence of continual pilots, the absence of edge pilots, the absence of a frame closing symbol (see annex A for the latter three), the absence of PAPR reduction and the additional preamble symbol aP1 (specified in ETSI EN 303 105-1 [1], clause 11.8.3). Furthermore, the number of sub-carriers per SC-OFDM symbol is even.

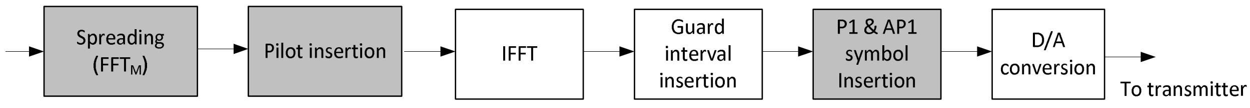


Figure 5: SC-OFDM generation (applicable to the satellite path only)

5 Input processing

Input processing follows the same mechanism as the Base Profile [1]. The compensating delay function enables the end-to-end delay of services transmitted in both the terrestrial and satellite signals to be aligned. An important use case for this is hybrid combining of a terrestrial and a satellite signal in a hybrid Multi-Frequency Network (MFN). For instance, the terrestrial signal may use time interleaving of duration 1 s for the considered input stream, while the satellite signal uses 10 s. Hence, a compensating delay of 9 s shall be used in the terrestrial modulator for this input stream, while the satellite modulator does not need any compensating delay.

6 Bit interleaved coding and modulation

6.0 Overview

The bit interleaved coding and modulation module is almost identical to the one of the Base Profile. The differences are described in this clause.

6.1 Constellation mapping

64-QAM and 256-QAM constellations (uniform and non-uniform) shall not be used for the satellite component, i.e. (NU-)64-QAM and (NU-)256-QAM are only allowed in the Hybrid Profile - reflected by the present document - for the terrestrial component in an MFN configuration.

6.2 Time interleaver

The time interleaving in hybrid signals is almost similar to the procedure described in ETSI EN 303 105-1 [1], clause 6.6 of the Base Profile. The differences are explained in this clause.

While the Base Profile ETSI EN 303 105-1 [1] spreads the IUs uniformly over the configured time interleaver length P_I, hybrid signals allow a concentration of cells at the end of the NGH logical frame sequence, over which a FEC block is spread (uniform-late interleaving). Hence it is possible to transmit fewer cells of a FEC block in the first logical frames than in the last logical frames, over which the FEC block is distributed. This group of last logical frames is referred to as the "late" part of the time interleavering frame.

There are two new hybrid-specific parameters: P_{late} = TI_LATE_LENGTH represents the length of the late part of the time interleaving in terms of logical frames inside the full time interleaver length P_I (allowed value range is 0 to 7), and $N_{\mathrm{ADD\_IU\_PER\_LATE}}$ = NUM_ADD_IUS_PER_LATE_FRAME is the number of additional IUs per logical frame in the late part (additional to the 1 IU per logical frame that is present according to ETSI EN 303 105-1 [1], clause 6.6) - its allowed values range from 0 to 15.

If multiple TI blocks are used per interleaving frame (TIME_IL_TYPE = '0'), then P_{late} = TI_LATE_LENGTH shall be 0.

In the case of hybrid signals and TIME_IL_TYPE = '1', the parameter P_I = TIME_IL_LENGTH takes a value ranging from 0 to 63 and shall be greater than or equal to P_late.

The number N_IU of IUs per FEC block (equivalent to the number of block interleavers per TI-block) is calculated by using the additional parameters P_late and $N_\mathrm{ADD\_IU\_PER\_LATE}$:

$$N_\mathrm{IU} = P_\mathrm{I} + P_\mathrm{late} \cdot N_\mathrm{ADD\_IU\_PER\_LATE}$$

The value of N_IU shall not exceed 128.

Moreover, the delays are calculated differently from clause 6.6 of the Base Profile ETSI EN 303 105-1 [1]:

For delay index $k = 0, .., P_\mathrm{I} - 1$:

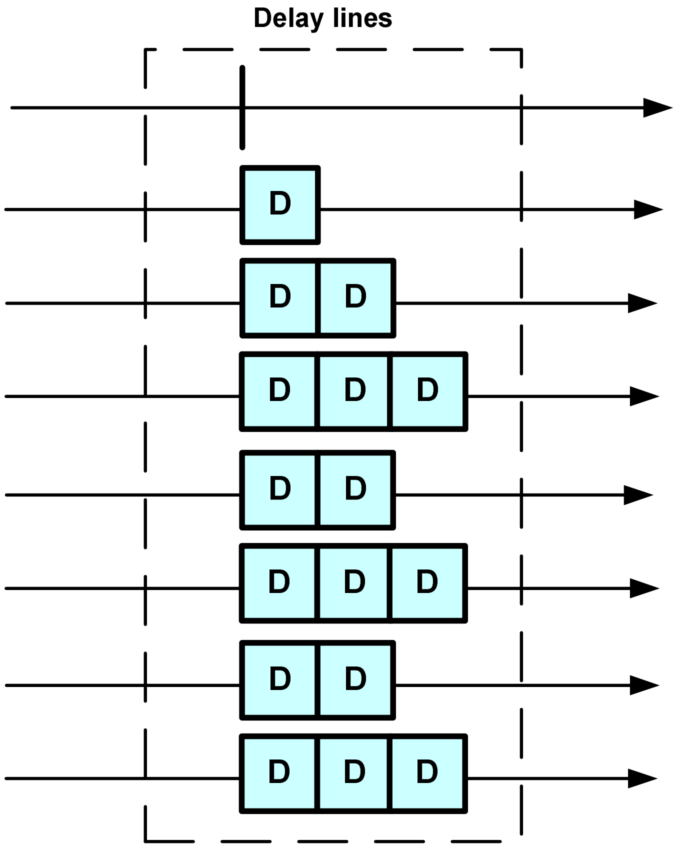
$$D(k) = k \cdot I_\mathrm{JUMP}.$$

For delay index $k = P_\mathrm{I}, .., N_\mathrm{IU} - 1$:

$$D(k) = ([k - P_\mathrm{I}] \mathrm{mod}\, P_\mathrm{late} + P_\mathrm{I} - P_\mathrm{late}) \cdot I_\mathrm{JUMP}.$$

The delay values $D(k)$ shall not exceed 128.

The same delay value may be used for several IUs in the late part, as is illustrated in figure 6. For this example, there are three times as many IUs in the last two logical frames than in the first two logical frames.



NOTE: Each delay element represents a delay of one logical frame.

Figure 6: Delay lines for $P_\mathrm{I} = 4$, $P_\mathrm{late} = 2$, $N_\mathrm{ADD\_IU\_PER\_LATE} = 2$, and $I_\mathrm{JUMP} = 1$

Hybrid receivers can make use of two levels of time de-interleaving (TDI) memory (for instance one on-chip memory and one external memory). Therefore for hybrid signals two TDI memory limits are applicable:

- The sum of $N_\mathrm{MUs,PLP}$ (as specified in ETSI EN 303 105-1 [1], clause 6.6.5) over all PLPs in a given PLP cluster shall not exceed $2^{21}\cdot$memory units (MU). As in ETSI EN 303 105-1 [1], clause 6.6.5, an MU corresponds to 2 cells for QPSK and 16-QAM, and to 1 cell for (NU-)64-QAM and (NU-)256-QAM.

- For specifying the second limit, the following definition of the number of MUs of a given PLP that can be transmitted in one TI-block applies:

$$N_{\text{MUs,PLP,frame}} = (N_{\text{large}} \cdot M_{\text{large}} + (N_{\text{IU}} - N_{\text{large}}) \cdot M_{\text{small}}) \cdot N_{\text{FEC\_TI\_MAX}}$$

where the required parameters are defined in ETSI EN 303 105-1 [1], clause 6.6.3. The second memory limit is as follows: The sum of $N_{\text{MUs,PLP,frame}}$ over all PLPs associated with the same service shall not exceed 2^{18}.

When the components (terrestrial and satellite) of a hybrid signal are combined in the receiver, its TDI memory has to allow for the simultaneous de-interleaving of PLPs from *both* received signals. Therefore, the two limits outlined above shall be observed in respect of the sum of the TDI requirements of all PLPs carrying the desired service components from *both* these signals. That means that the MU sum has to be calculated not only over the PLPs from one signal but from both.

NOTE 1: The two limits allow a first level of de-interleaving to store all relevant PLPs from one or two received signals into a first memory of size 2^{18} memory units during the current logical frame. At the end of the current logical frame, some of these stored IUs are forwarded to the decoder, while the rest can be transferred to a second memory of size 2^{21} - 2^{18} memory units that implements the required delay lines (see ETSI EN 303 105-1 [1], clause 6.6.3) representing the second level of de-interleaving.

NOTE 2: It is explicitly allowed to have, within a PLP cluster, on the one hand PLPs, which use multiple TI blocks per interleaving frame (TIME_IL_TYPE = '0') and on the other hand PLPs using multi-frame TI (TIME_IL_TYPE = '1'). Similarly, the PLPs within a PLP cluster may have different interleaver depths P_{I}.

Finally, the Receiver Buffer Model (RBM) extension to consider is the one for the Hybrid Profile building in annex B.

6.3 Distributed and cross-polar MISO

MISO is only available in the Hybrid Profile - reflected by the present document - for the terrestrial path and follows the same mechanisms as defined in ETSI EN 303 105-1 [1], clause 7.

7 Layer 1 signalling data specific for the Hybrid Profile

7.1 P1 and additional P1 signalling data

The Hybrid Profile - reflected by the present document - is signalled in the preamble P1 with the values S1 = 111 (ESC code) and S2 field 1 = 001 or 010 respectively for hybrid SISO and hybrid MISO, 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 and the information it carries is illustrated in figure 7.

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

Figure 7: aP1 signalling field for NGH Hybrid Profile - reflected by the present document

- The S3 field (3 bits) indicates the waveform used in the NGH frame in the SISO and MISO variants of the Hybrid Profile reflected by the present document, as described in table 2.

Table 2: 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= "001x" or "010x", 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 are given in tables 3 and 4 for OFDM and SC-OFDM waveform case respectively.

Table 3: 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 4: 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 ETSI EN 303 105-1 [1], clause 11.8.3.

7.2 L1-PRE signalling data

The Hybrid Profile - reflected by the present document - uses the same L1-PRE signalling as defined in clause 8.2.3 of the Base Profile [1].

7.3 L1-POST signalling data

7.3.1 L1-POST configurable signalling data

Table 5 highlights the signalling specific to the Hybrid 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 5: Signalling fields of L1-POST configurable

…	…
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_MOD: 3-bit field indicates the modulation used by the given PLP. The modulation shall be signalled according to table 6.

Table 6: 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 indicates the number $N_{ADD\_IU\_PER\_LATE}$ of interleaver units (IUs) in the late part in addition to the one IU present in every logical frame.

7.3.2 L1-POST dynamic signalling data

The Hybrid Profile - reflected by the present document - 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 Profile - reflected by the present document - 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].

8 Frame Builder

8.1 SC-OFDM

8.1.1 NGH hybrid SC-OFDM frames

8.1.1.1 Duration of the NGH hybrid SC-OFDM frame

The beginning of the first preamble symbol (P1) marks the beginning of the NGH hybrid frame.

The number of P2 symbols N_{P2} is determined by the FFT size as given in table 10, whereas the number of data symbols L_{data} in the NGH hybrid SC-OFDM frame is a configurable parameter signalled in the L1-PRE signalling, i.e. L_{data} = NUM_DATA_SYMBOLS. The total number of symbols in a frame (excluding P1 and aP1) is given by $L_F = N_{P2}+L_{data}$. The NGH SISO frame duration is therefore given by:

$$T_F = L_F \times T_s + 2 \times T_{P1},$$

where T_s is the total SC-OFDM symbol duration and T_{P1} is the duration of the P1 and aP1 symbols (see ETSI EN 303 105-1 [1], clause 11.5). For the SC-OFDM component, L_{data} shall be a multiple of 6, so as to form data sections of 6 symbols each.

The maximum value of the frame duration T_F shall be 250 ms, as for the Base Profile ETSI EN 303 105-1 [1]. Thus, the maximum number for L_F is as defined in table 7 (for 5 MHz bandwidth).

Table 7: Maximum frame length L_F in number of SC-OFDM symbols for different FFT sizes and guard intervals (for 5 MHz bandwidth) (satellite component)

FFT size	T_u [ms]	L_F for Guard interval fractions	
		1/32	1/16
2K	0,3584	670	652
1K	0,1792	1 345	1 309
512	0,0896	2 695	2 617

The minimum number of SC-OFDM symbols L_F shall be N_{P2} + 12. In all cases, the number of SC-OFDM symbols L_F shall be N_{P2} + 6xn, where n is an integer number. The values provided in the table above take this constraint into account, considering the values of N_{P2} provided with table 10.

The P1 and aP1 symbols carry only P1-specific signalling information (see clause 7.1). P2 symbol(s) carry L1-PRE signalling information (see ETSI EN 303 105-1 [1], clause 8.2.3) and, if there is free capacity, they also carry data from the common PLPs and/or data PLPs. Data symbols carry cells of the logical frame that comprises L1-POST signalling information, common PLPs and/or data PLPs as defined in [1], clause 9.2. The mapping of the logical frame onto the symbols is done at the SC-OFDM cell level, and thus, P2 or data symbols can be shared between multiple PLPs. If there is capacity left in the NGH hybrid frame, it is filled with auxiliary streams (if any) and dummy cells as defined in ETSI EN 303 105-1 [1], clauses 9.2.4 and 9.2.5. In the NGH hybrid SC-OFDM frame, the common PLPs are always located before the data PLPs. The mapping of PLPs onto the NGH hybrid SC-OFDM frame is defined in clause 8.1.1.2 below.

8.1.1.2 Capacity and structure of the NGH hybrid SC-OFDM frame

The frame builder shall map the logical frame cells and L1-PRE cells from the constellation mapper onto the data cells $x_{m,l,p}$ of each SC-OFDM symbol in each frame, where:

- m is the NGH- hybrid SC-OFDM frame number;
- l is the index of the symbol within the frame, starting at 0 for the first P2 symbol, $0 \leq l < L_F$;
- p is the index of the data cell within the symbol prior to pilot insertion.

Data cells are the cells of the SC-OFDM data symbols which are not used for scattered pilots.

The P1 and aP1 symbols are OFDM symbols, but not ordinary ones, and do not contain any active SC-OFDM data cells (see ETSI EN 303 105-1 [1], clause 11.8).

The number of active carriers, i.e. carriers not used for scattered pilots, in one P2 symbol is denoted by C_{P2} and is defined in table 8. Thus, the number of active carriers in all P2 symbol(s) is $N_{P2} \times C_{P2}$.

The number of active carriers, i.e. carriers not used for pilots, in one normal symbol is denoted by $C_{data.}$ Table 9 gives values of C_{data} for each FFT mode. These values shall be divided by two to compute the number of active carriers for the data symbols carrying also scattered pilots.

NOTE 1: Extended carrier modes are not used for the satellite component when the SC-OFDM waveform is applied.

NOTE 2: Tone reservation is not used together with frames using the waveform SC-OFDM.

In all combinations of FFT sizes and guard interval lengths, the last symbol of the NGH hybrid SC-OFDM frame is a data symbol carrying also scattered pilots.

Hence the cell index p takes the following range of values:

- $0 \leq p < C_{P2}$ for $0 \leq l < N_{\mathrm{P2}}$;
- $0 \leq p < C_{data}$ for $N_{\mathrm{P2}} \leq l < L_{\mathrm{F}} - 1$ and $(l - N_{P2})\%6 \neq (D_Y\text{-}1)$; $(D_Y = 6)$
- $0 \leq p < C_{data}/2$ for $N_{\mathrm{P2}} \leq l < L_{\mathrm{F}} - 1$ and $(l - N_{P2})\%6 = (D_Y\text{-}1)$;

Table 8: Number of available data cells C_{P2} in one P2 symbol

FFT size	C_{P2} (SISO)
512	216
1K	432
2K	864

Table 9: Number of available data cells C_{data} in one data symbol not consisting of scattered pilots

FFT size	C_{data}
512	432
1K	864
2K	1 728

Thus, the number of active SC-OFDM cells in one NGH hybrid SISO frame (C_{tot}) is given by:

$$C_{tot} = N_{P2} * C_{P2} + \frac{11}{12} * L_{data} * C_{data}$$

This formula takes into account the fact that one data symbol over six contains data for one half and pilots for the other half.

The number of P2 symbols N_{P2} is dependent on the used FFT size and is defined in table 10.

Table 10: Number of P2 symbols denoted by N_{P2} for different FFT modes

FFT size	N_{P2}
512	13
1k	7
2k	4

8.1.2 Frequency interleaver

For frames of preamble format NGH hybrid SISO and the waveform SC-OFDM there is no frequency interleaving applied.

9 OFDM Generation

The OFDM generation for the Hybrid Profile - reflected by the present document - follows the same rules as specified in ETSI EN 303 105-1 [1], clause 11 for the Base Profile, with a limitation on the number of allowed FFT sizes (see table 11 below) and bandwidths.

The satellite component of the Hybrid Profile - reflected by the present document - is defined for the following channel bandwidths: 1, 7, 2, 5 and 5 MHz (these three bandwidths are also covered by the Base Profile ETSI EN 303 105-1 [1]).

Table 11: Scattered pilot pattern to be used for each allowed combination of FFT size and guard interval for the Hybrid Profile (reflected by the present document) waveform OFDM

FFT size	Guard interval			
	1/32	1/16	1/8	1/4
2K	PP7 PP4	PP4 PP5	PP2 PP3	PP1
1K	NA	PP4 PP5	PP2 PP3	PP1

The preamble symbol P1 is followed for the Hybrid Profile by an additional preamble symbol aP1, as specified in ETSI EN 303 105-1 [1], clause 11.8.3.

10 SC-OFDM generation

10.1 Overview

The function of the SC-OFDM generation module is to take the cells produced by the frame builder, as time domain coefficients, and to spread these cells to obtain frequency domain coefficients. Next, to insert the pilots, which allow the receiver to compensate for the distortions introduced by the transmission channel, and to produce from this the basis for the time domain signal for transmission. It then inserts guard intervals in order to produce the completed NGH hybrid SISO signal of waveform SC-OFDM.

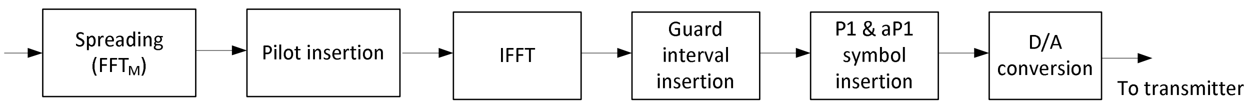


Figure 8: SC-OFDM generation

The following clauses specify values for $c_{m,l,k}$ for certain settings of m, l and k, where m and l are the NGH frame and symbol number as previously defined, and k is the SC-OFDM carrier index (see clause 8.1.1).

10.2 Spreading

This clause specifies the spreading applied to cells, prior to pilot insertion and OFDM modulation.

The transmitted signal is organized in frames. Each frame has a duration of T_F, and consists of L_F SC-OFDM symbols and two OFDM preamble symbols (P1 and aP1). Each SC-OFDM symbol is constituted by a set of K_{total} carriers transmitted with a duration T_S.

The symbols in an SC-OFDM frame (excluding P1 and aP1) are numbered from 0 to L_F-1. All SC-OFDM symbols contain data and some of them contain reference information (see clause 10.2 below).

The input cells are grouped in blocks of size M, where M is variable, and a spreading, i.e. an FFT of size M, is applied to each such group of cells.

The spreading size M_l of SC-OFDM symbol l is equal to:

$M_l = C_{data}$ if symbol l is a data-only symbol, i.e. if $l < N_{P2} \quad or \quad (l - N_{P2}) \bmod (D_Y) \neq (D_Y - 1)$

$M_l = C_{data} / 2$ if symbol l carries scattered pilots, i.e. if $(l - N_{P2}) \bmod (D_Y) = (D_Y - 1) \quad and \quad l \geq N_{P2}$

C_{data} depends on the FFT size and is described in clause 8.1.1.2.

D_Y is 6 for the SC-OFDM waveform. $X_{m,i}$ is the information to be transmitted on the SC-OFDM symbols (including P2 symbols) in the m^{th} frame.

Index i varies from 0 to $L_F \times C_{data} \times (2D_Y-1)/(2\ D_Y) - 1$

First, this complex information is mapped onto (L_F-N_{P2}) blocks of size M_l, according to clause 8.1.1.1.

$$y_{l,j} = x_i$$

The symbol index l varies from 0 to L_F -1.

The cell index j varies from 0 to M_l-1.

Then, an FFT of size M_l is applied to each block:

$$z_{l,q} = \frac{1}{\sqrt{M_l}} \sum_{j=0}^{M_l-1} y_{l,j} e^{-i2\pi qj/M_l}$$

q is the index of z in the l^{th} SC-OFDM symbol of size M_l. q varies from 0 to M_l - 1.

Then:

- if $M_l = C_{data}$, no pilot is inserted in this SC-OFDM symbol and $c_{m,l,k} = z_{l,k}$;
- if $M_l = C_{data}/2$, for k even, a pilot is inserted (see clause 10.2).

For k odd, $k = 2q+1$, $c_{m,l,k} = z_{l,q}$.

10.3 Pilot insertion

10.3.1 Introduction

Cells containing reference information are not transmitted at "boosted" power level in the SC-OFDM symbols. These cells are scattered pilot cells. The locations and amplitudes of these pilots are defined in clause 10.2.3 for SISO transmissions. The value of the pilot information is derived from a reference sequence, which is a series of values, one for each transmitted carrier on any given symbol (see clause 10.2.2).

Table 12 gives an overview of the different types of pilots and the symbols in which they appear.

Table 12: Presence of pilots in each type of symbol (X = present)

Symbol	Scattered Pilots
P1	
P2	X
Data	
Data with scattered pilots (PP9)	X

Moreover, for the SC-OFDM multiplex, the following applies:

- No continual pilots.
- No edge pilots.
- The P2 pilots are identical to the scattered pilots in the data symbols.
- Each last symbol in an SC-OFDM frame is a data symbol with scattered pilots. Therefore, no frame closing symbol is needed.
- No cell is reserved for PAPR reduction.

10.3.2 Definition of the reference NGH hybrid sequence

The pilots are modulated according to a reference complex sequence, $r_{l,k}$, where l and k are the symbol and carrier indices as previously defined. For the hybrid component, the reference sequence is fixed for each FFT size, and derived from a modified Zadoff-Chu sequence:

$$r_{l,q} = s_q = e^{-i\frac{2\pi}{n_p}\left(\frac{q^2}{2}+0.5\,q\right)}$$

Where the number of pilots in a related data symbol, n_p, is equal to $n_p = K_{total}/2 = C_{data}/2$ and q is the index of the pilot cell in the SC-OFDM symbol (q varies from 0 to $n_p - 1$).

The symbol-level sequence is mapped to the carriers such that the first output complex value (s_0) from the sequence coincides with the first active carrier ($k = K_{\min}$) in symbols of FFT size 0,5 K, 1 K, and 2 K.

10.3.3 Scattered pilot insertion

10.3.3.0 Overview

Reference information, taken from the reference sequence, is transmitted in scattered pilot cells in every P2 and every sixth data symbol of the NGH hybrid frame. The locations of the scattered pilots are defined in clause 10.2.3.1, their amplitudes are defined in clause 10.2.3.2 and their modulation is defined in clause 10.2.3.3.

10.3.3.1 Locations of the scattered pilots

A given carrier k of the SC-OFDM signal on a given symbol l will be a scattered pilot if the appropriate equations below are satisfied:

$$l < N_{P2} \text{ or } (l - N_{P2}) \bmod (D_Y) = (D_Y - 1) \text{ and } k \bmod (D_X) = 0$$

where: D_X and D_Y are defined in table 13.

$k \in [K_{\min}; K_{\max}]$; and
$l \in [0; L_F-1]$
N_{P2} is as defined in clause 8.1.1.2.
L_F is as defined in clause 8.1.1.1.

Table 13: Parameters defining the scattered pilot patterns

Pilot pattern	**Separation of pilot bearing carriers (D_X)**	**Number of symbols forming one scattered pilot sequence (D_Y)**
PP9	2	6

For the NGH hybrid SISO frames, all combinations of the scattered pilot pattern (PP9), FFT size and guard intervals are allowed. The scattered pilot pattern is illustrated in annex A.

10.3.3.2 Amplitudes of the scattered pilots

The amplitudes of the scattered pilots, A_{SP}, are shown in table 14 below.

Table 14: Amplitudes of the scattered pilots

Scattered pilot pattern	**Amplitude (A_{SP})**	**Equivalent Boost (dB)**
PP9	1	0

10.3.3.3 Modulation of the scattered pilots

The phases of the scattered pilots are derived from the reference sequence given in clause 10.2.2.

The modulation value of the scattered pilots is given by:

$$c_{m,l,k} = A_{SP}\, r_{l,q} \text{ with } k = K_{\min} + 2q$$

where A_{SP} is as defined in clause 10.2.3.2, $r_{l,k}$ is defined in clause 10.2.2, m is the NGH hybrid SISO frame index, k is the frequency index of the carriers and l is the time index of the symbols.

10.4 IFFT - SC-OFDM modulation

$$s(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \sum_{m=0}^{\infty} \left[p_1(t - mT_F) + a p_1(t - mT_F) + \frac{1}{\sqrt{K_{total}}} \sum_{l=0}^{L_F-1} \sum_{k=K_{\min}}^{K_{\max}} c_{m,l,k} \times \psi_{m,l,k}(t) \right] \right\}$$

The IFFT mechanism for the SC-OFDM mode follows the same mechanism as in the Base Profile. The SC-OFDM parameters are summarized in table 16. The values for the various time-related parameters are given in multiples of the elementary period T and in microseconds. The elementary period T is specified for each bandwidth in table 15.

Table 15: Elementary period as a function of bandwidth (SC-OFDM)

Bandwidth	1,7 MHz	2,5 MHz	5 MHz
Elementary period *T*	71/131 µs	7/20 µs	7/40 µs

Table 16: SC-OFDM parameters

Parameter	**0,5 K mode**	**1 K mode**	**2 K mode**
Number of carriers K_{total}	432	864	1 728
Value of carrier number K_{min}	0	0	0
Value of carrier number K_{max}	431	863	1 727
Duration T_U	512T	1 024T	2 048T
Duration T_U µs (see notes 1 and 2)	*89,6*	*179,2*	*358,4*
Carrier spacing $1/T_U$ (*Hz)* (see notes 1 and 2)	11 161	5 580	2 790
Spacing between carriers K_{min} and K_{max} equivalent to $(K_{total}-1)/T_U$ (see notes 1 and 2)	4,81 MHz	4,82 MHz	4,82 MHz
NOTE 1: Numerical values in italics are approximate values. NOTE 2: Values for 5 MHz channels.			

10.5 Guard interval insertion

Two different guard interval fractions (Δ/T_u) are defined. Table 17 gives the absolute guard interval duration Δ, expressed in multiples of the elementary period T (see clause 10.3) for each combination of FFT size and guard interval fraction.

Table 17: Duration of the guard interval in terms of the elementary period T

FFT size	**Guard interval fraction (Δ/T_u)**	
	1/32	**1/16**
2K	64T	128T
1K	32T	64T
0,5K	16T	32T

The emitted signal, as described in clause 10.3, includes the insertion of guard intervals.

Annex A (informative): SC-OFDM pilot pattern

This annex illustrates the scattered pilot pattern PP9 for the SC-OFDM waveform, which is used for the satellite path of the Hybrid Profile - reflected by the present document. It shows the pattern in SISO mode (figure A.1). There are no continual pilots associated with this waveform.

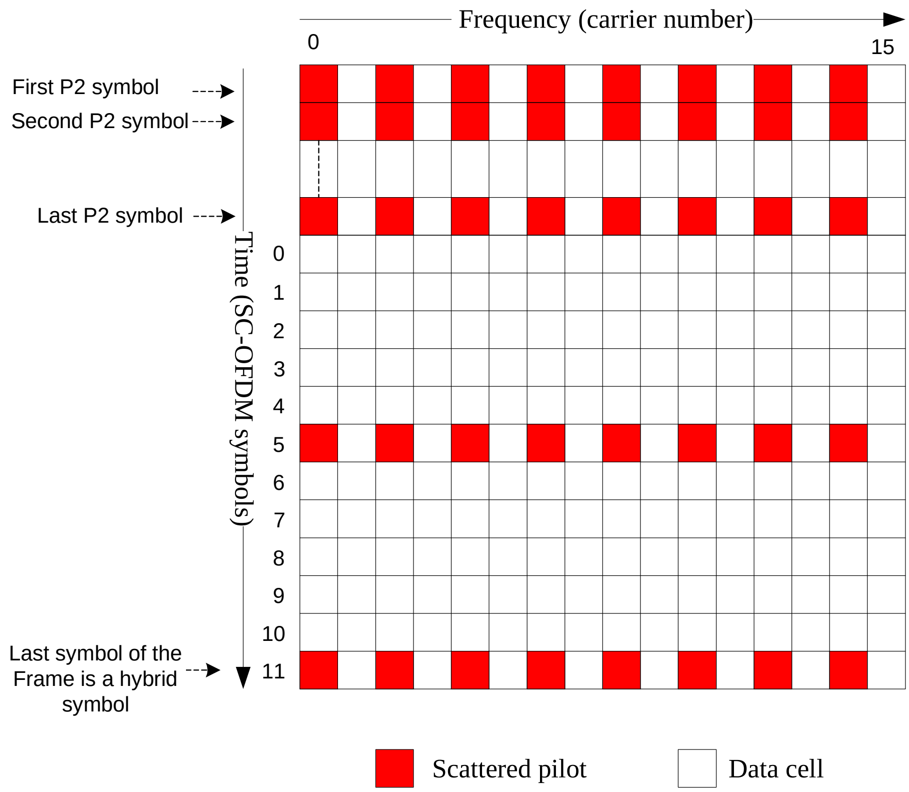


Figure A.1: Scattered pilot pattern PP9 (Hybrid Profile (reflected by the present document), SC-OFDM, SISO mode)

Annex B (normative): Receiver Buffer Model extension

For the MFN case of the Hybrid Profile reflected by the present document, the receiver buffer model described in ETSI EN 303 105-1 [1], clause C.2 applies, where the sum of the decoding rates has to be over all PLPs in a PLP cluster from the terrestrial signal and over those from the satellite signal:

$$\sum_{\mathrm{Terr}:\, i} R_{\mathrm{codebits,rec,max}}(n,i) + \sum_{\mathrm{Sat}:\, j} R_{\mathrm{codebits,rec,max}}(n,j) \leq 12\ \mathrm{Mbit/s}$$

Moreover, the total size of the de-jitter buffer for storing all PLPs in a PLP cluster from the terrestrial and satellite signals is 2 Mbits.

For the SFN case, the receiver buffer model of the Base Profile [1] applies.

Annex C (informative): Bibliography

- ETSI EN 303 105-2: "Digital Video Broadcasting (DVB); Next Generation broadcasting system to Handheld, physical layer specification (DVB-NGH); Part 2: MIMO Profile".
- 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".
- 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: "ETSI EN 102 831: "Digital Video Broadcasting (DVB); Implementation guidelines for a second generation digital terrestrial television broadcasting system (DVB-T2)".

History

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