Draft ETSI EN 302 550-1-3 V1.1.0 (2009-07)

European Standard (Telecommunications series)

Satellite Earth Stations and Systems (SES); Satellite Digital Radio (SDR) Systems; Part 1: Physical Layer of the Radio Interface; Sub-part 3: Inner Physical Layer Multi Carrier Modulation

Reference

DEN/SES-00312-1-3

Keywords

digital, layer 1, radio, satellite

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Sous-Préfecture de Grasse (06) N° 7803/88

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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES), and is now submitted for the Public Enquiry phase of the ETSI standards Two-step Approval Procedure.

The present document is part 1, sub-part 3 of a multi-part deliverable. Full details of the entire series can be found in part 1, sub-part 1 [i.4].

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
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

Introduction

An SDR system enables broadcast to fixed and mobile receivers through satellites and complementary terrestrial transmitters. Functionalities, architecture and technologies of such systems are described in TR 102 525 [i.5].

Several existing and planned ETSI standards specify parts of the SDR system, with the aim of interoperable implementations. The physical layer of the radio interface (air interface) is divided up into the outer physical layer, the inner physical layer with single carrier modulation, and the inner physical layer with multi carrier modulation. These parts can be used all together in SDR compliant equipment, or in conjunction with other existing and future specifications.

The present document specifies the inner physical layer with multi carrier modulation. The inner physical layer with single carrier modulation is specified in EN 302 550-1-2 [i.3], and the outer physical layer in EN 302 550-1-1 [i.4]. Guidelines for using the physical layer standard can be found in TR 102 604 [i.6].

The physical layer specifications have previously been published as "Technical Specification (TS)" type ETSI deliverables. The present document supersedes TS 102 551-2 [i.7] and is recommended for new implementations. The functional differences between the previous TS and the present document are: Exclusion of Mode 1, introduction of Mode 2s and introduction of bandwidth flexibility.

1 Scope

The present document concerns the radio interface of SDR broadcast receivers. It specifies functionality of the inner physical layer with multi carrier modulation. It allows implementing this part of the system in an interoperable way.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.
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2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area. For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] ETSI EN 300 744 (V1.5.1): "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television".

[i.2] ITU-T Recommendation O.153 (1992): "Basic parameters for the measurement of error performance at bit rates below the primary rate".

[i.3] ETSI EN 302 550-1-2 (V1.1.1): "Satellite Earth Stations and Systems (SES); Satellite Digital Radio (SDR) Systems; Part 1: Physical Layer of the Radio Interface; Sub-part 2: Inner Physical Layer Single Carrier Modulation".

[i.4] ETSI EN 302 550-1-1 (V1.1.1): "Satellite Earth Stations and Systems (SES); Satellite Digital Radio (SDR) Systems; Part 1: Physical Layer of the Radio Interface; Sub-part 1: Outer Physical Layer".

[i.5] ETSI TR 102 525 (V1.1.1): "Satellite Earth Stations and Systems (SES); Satellite Digital Radio (SDR) service; Functionalities, architecture and technologies".

[i.6] ETSI TR 102 604: "Satellite Earth Stations and Systems (SES); Satellite Digital Radio (SDR) Systems; Guidelines for the Use of the Physical Layer Standards".

[i.7] ETSI TS 102 551-2 (V2.1.1): "Satellite Earth Stations and Systems (SES); Satellite Digital Radio (SDR) Systems; Inner Physical Layer of the Radio Interface; Part 2: Multiple Carrier Transmission".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

hierarchical constellation scaling factor: constellation ratio which determines the QAM constellation for the modulation for hierarchical transmission

3.2 Symbols

For the purposes of the present document, the following symbols apply:

2k@5MHz	OFDM with 2k (i.e. 2 048 length) IFFT in 5 MHz channel spacing
α	hierarchical constellation scaling factor

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

16QAM	16 Quadrature Amplitude Modulation
C-TS	Channel Transport Stream
CU	Capacity Unit
FFT	Fast Fourier Transform
IFFT	Inverse Fast Fourier Transform
IPL	Inner Physical Layer
IPL-MC	Inner Physical Layer, Multi Carrier
IPL-SC	Inner Physical Layer, Single Carrier
OFDM	Orthogonal Frequency Division Multiplex
OPL	Outer Physical Layer
QPSK	Quaternary Phase Shift Keying
RF	Radio Frequency
RFU	Reserved for Future Use
XOR	Exclusive OR

4 Inner physical layer - Multi Carrier

The functionality of the Inner Physical Layer (Multi Carrier), in the following denoted IPL-MC, is to provide a robust modulation scheme for multi carrier modulation. The multi carrier modulation is applicable either to satellite or terrestrial transmission.

The IPL-MC is embedded between the OPL (C-TS delivery) and the RF frontend (modulation) as depicted in figure 1.

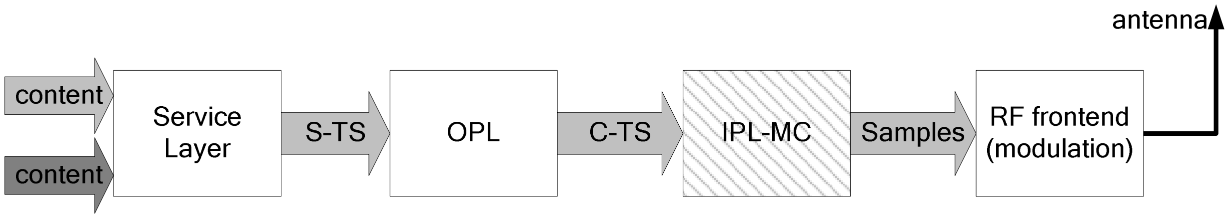

Figure 1: General block diagram of the ETSI SES SDR system concept with selection of IPL-MC

The general block diagram of the IPL-MC functionality for modes 2, 2s, 3 and 4 are given in figure 2.

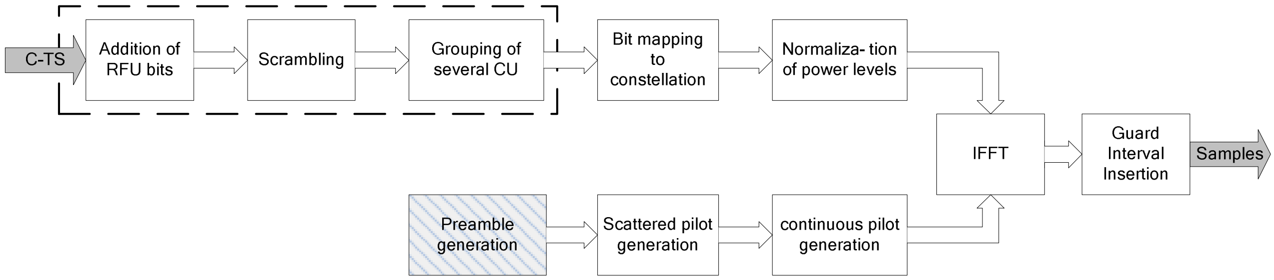

Figure 2: Block diagram of the ETSI SES SDR compliant IPL-MC in Mode 2, 2s, 3 and 4

For high robustness in rapidly changing channels or high delay spread scenarios, three modes (FFT512, FFT1024 and FFT2048) using a high pilot density together with a distinct frequency-domain preamble are introduced.

4.1 Interfacing to OPL (Outer Physical Layer)

Its interface to the OPL (Outer Physical Layer) is the C-TS (channel transport stream), which is defined in EN 302 550-1-1 [i.4]. For this special IPL-MC, the parameters which are passed to the OPL are derived within EN 302 550-1-1 [i.4].

Two types of IPL-MC exist: One providing a single-input C-TS interface, another providing double-input interface to allow hierarchical modulation. In the latter case, both C-TS need to be aligned in time, framing and throughput.

If more than one carrier needs to be supported, multiple instances of the IPL-MC need to be instantiated in parallel.

The parameters that are passed to the OPL are as follows:

- IPL-MC frame length in integer number of CU (capacity units);
- number of inputs (to distinguish between normal and hierarchical transmission).

For modes 2, 2s, 3 and 4, one IPL-MC frame is composed of five Phy sections and preceded by one preamble. Their parameters are defined in clause 4.2.2.

With these parameters, the exact throughput of the IPL-MC can be derived in CU per time. The smallest unit to be processed by the IPL-MC is one CU.

To be able to benefit from the gain of hybrid configurations (e.g. using IPL-SC together with IPL-MC), it is mandatory to have equal frame lengths on both IPLs.

If modes 2, 2s, 3 or 4 of the IPL-MC are used, a joint frame length of 432 ms is chosen.

4.2 The profile approach - different multi carrier modes

4.2.1 Profile definition

To cope with different design constraints that arise from the possible use scenarios of the IPL-MC, it has been decided within SES SDR to define different profiles. The main target frequency bands and channel bandwidths are:

Table 1: Definition of different profiles

Profile name		IPL-MC-B	IPL-MC-C	IPL-MC-D
Typical use		S-Band SDR	L-Band SDR	S-Band SDR
Supported modes		2 and 2s	3 and 4	3 and 4
Carrier frequency		2,0 GHz to 2,3 GHz	1,4 GHz to 1,5 GHz	2,0 GHz to 2,3 GHz
Channel bandwidth		4,76 MHz	1,536 MHz	1,536 MHz
Channel spacing		5 MHz	1,712 MHz	1,712 MHz

The present document does not restrict its use to the application scenarios as denoted above. Other frequency bands or channel bandwidths may be used but the parameter selection may not be optimal.

Bandwidth flexibility has been introduced to widely scale the modes 2, 2s, 3 or 4 according to different bandwidth requirements. This allows to use modes as follows:

- Mode 2 (FFT2048, guard interval 1/4): Between 6/9 and 18/9 times the specified bandwidth of 4,755 MHz with stepping of 1/9 of specified bandwidth, i.e. from 3,17 MHz up to 9,51 MHz in step sizes of 528,3 kHz.
- Mode 2s (FFT2048, guard interval 1/8): Between 6/10 and 20/10 times the specified bandwidth of 4,755 MHz with stepping of 1/10 of specified bandwidth, i.e. from 2,853 MHz up to 9,51 MHz in step sizes of 475,5 kHz.
- Mode 3 (FFT1024, guard interval 1/4): Between 4/6 and 20/6 times the specified bandwidth of 1,531 MHz with stepping of 1/6 of specified bandwidth, i.e. from 1,021 MHz up to 5,105 MHz in step sizes of 255,2 kHz.
- Mode 4 (FFT512, guard interval 1/4): Between 8/12 and 24/12 times the specified bandwidth of 1,534 MHz with stepping of 1/12 of specified bandwidth, i.e. from 1,022 MHz up to 3,067 MHz in step sizes of 127,8 kHz.

This flexibility has been introduced in a very careful way to always ensure interoperability with all specified IPL-SC modes, especially the common frame length between IPL-MC and IPL-SC of 432 ms has not been touched.

This flexibility relies purely on discrete changes in the sampling frequency.

4.2.2 Modes definition

The different modes that are defined are as follows.

Table 2: Definition of different modes

Mode 2s (guard interval 1/8) 2k@5MHz Optimized pilot pattern	Mode optimized for requirements of frequency bands using channel spacing of 5 MHz with 2k number of carriers. Parameter set recommended for networks with medium delay spread and high vehicle speed.
Mode 2 (guard interval 1/4) 2k@5MHz Optimized pilot pattern	Mode optimized for requirements of frequency bands using channel spacing of 5 MHz with 2k number of carriers. Parameter set recommended for networks with high delay spread and high vehicle speed.
Mode 3 (guard interval 1/4) 1k@1,7MHz Optimized pilot pattern	Mode optimized for requirements of frequency bands using channel spacing of 1,7 MHz. Parameter set recommended for networks with very high delay spread (e.g. SFN network with high power repeater), 1k number of carriers, preamble symbol, continuous and scattered pilots with pilot density of approximately 17 %.
Mode 4 (guard interval 1/4) 0,5k@1,7MHz Optimized pilot pattern	Similar to Mode 3. Support of higher vehicle speed (carrier spacing doubled, shorter guard interval), 0,5k number of carriers.

The parameters for all modes are denoted in table 3 and table 4.

4.2.3 Parameters for QPSK subcarrier mapping

Table 3 displays the parameters defined for the QPSK modulation of the OFDM subcarriers.

Table 3: Parameters derived in modes 2, 2s, 3 or 4 for QPSK modulation of the OFDM subcarriers

	unit	SES SDR 2k Guard 1/8	SES SDR 2k Guard 1/4	SES SDR 1k Guard 1/4	SES SDR 0,5k Guard 1/4
Mode Identifier		**2s**	**2**	**3**	**4**
FFT length		2 048	2 048	1 024	512
Used sub-carriers		1 509	1 509	729	365
Guard interval ratio		0,125	0,25	0,25	0,25
nFlx: BW flexibility (default)		10	9	6	12
nFlx: BW flexibility (range)		6…20	6…18	4…20	8…24
Sampling Frequency (fractional)	MHz	484/75 × nFlx/10	484/75 × nFlx/9	484/225 × nFlx/6	484/225 × nFlx/12
Sampling Frequency (rounded)	MHz	6,4533 × nFlx/10	6,4533 × nFlx/9	2,1511 × nFlx/6	2,1511 × nFlx/12
Pilots per OFDM symbol		262	262	127	64
Capacity unit size incl. RFU	bits	2 064	2 064	2 064	2 064
Modulation index		2	2	2	2
Signal Bandwidth	MHz	4,7549 × nFlx/10	4,7549 × nFlx/9	1,5314 × nFlx/6	1,5335 × nFlx/12
Samples per symbol		2 304	2 560	1 280	640
Symbol length incl. guard interval	µs	357,03 × 10/nFlx	396,69 × 9/nFlx	595,04 × 6/nFlx	297,52 × 12/nFlx
Guard interval length	µs	39,67 × 10/nFlx	79,34 × 9/nFlx	119,01 × 6/nFlx	59,50 × 12/nFlx
sub-carrier distance in kHz	kHz	3,15 × nFlx/10	3,15 × nFlx/9	2,10 × nFlx/6	4,20 × nFlx/12
Data sub-carriers per symbol		1 247	1 247	602	301
OFDM Symbols per Phy section		24	24	24	24
Data sub-carriers per Phy section		29 928	29 928	14 448	7 224
Bit per Phy section		59 856	59 856	28 896	14 448
CU per Phy section		**29**	**29**	**14**	**7**
Length of Phy section	ms	8,59 × 10/nFlx	9,52 × 9/nFlx	14,28 × 6/nFlx	7,14 × 12/nFlx
Padding bits		0	0	0	0
preamble per IPL-MC frame		1	1	1	1
Phy sections per IPL-MC frame		5	5	5	5
sub-carrier per IPL-MC frame		150 887	150 887	72 842	36 421
Bit per IPL-MC frame		301 774	301 774	145 684	72 842
Length of IPL-MC frame	ms	43,20 × 10/nFlx	48,00 × 9/nFlx	72,00 × 6/nFlx	36,00 × 12/nFlx
CU per IPL-MC frame		**145**	**145**	**70**	**35**
Padding bits (informative only)		0	0	0	0

4.2.4 Parameters for 16QAM subcarrier mapping

Table 4 displays the parameters defined for the 16QAM modulation of the OFDM subcarriers.

Table 4: Parameters derived in modes 2, 2s, 3 or 4 for 16QAM modulation of the OFDM subcarriers

	unit	SES SDR 2k Guard 1/8	SES SDR 2k Guard 1/4	SES SDR 1k Guard 1/4	SES SDR 0.5k Guard 1/4
Mode Identifier		**2s**	**2**	**3**	**4**
FFT length		2 048	2 048	1 024	512
Used sub-carriers		1 509	1 509	729	365
Guard interval ratio		0,125	0,25	0,25	0,25
nFlx: BW flexibility (default)		10	9	6	12
nFlx: BW flexibility (range)		6…20	6…18	4…20	8…24
Sampling Frequency (fractional)	MHz	484/75 × nFlx/10	484/75 × nFlx/9	484/225 × nFlx/6	484/225 × nFlx/12
Sampling Frequency (rounded)	MHz	6,4533 × nFlx/10	6,4533 × nFlx/9	2,1511 × nFlx/6	2,1511 × nFlx/12
Pilots per OFDM symbol		262	262	127	64
Capacity unit size incl. RFU	bits	2 064	2 064	2 064	2 064
Modulation index		4	4	4	4
Signal Bandwidth	MHz	4,7549 × nFlx/10	4,7549 × nFlx/9	1,5314 × nFlx/6	1,5335 × nFlx/12
Samples per symbol		2 304	2 560	1 280	640
Symbol length incl. guard interval	µs	357,03 × 10/nFlx	396,69 × 9/nFlx	595,04 × 6/nFlx	297,52 × 12/nFlx
Guard interval length	µs	39,67 × 10/nFlx	79,34 × 9/nFlx	119,01 × 6/nFlx	59,50 × 12/nFlx
sub-carrier distance in kHz	kHz	3,15 × nFlx/10	3,15 × nFlx/9	2,10 × nFlx/6	4,20 × nFlx/12
Data sub-carriers per symbol		1 247	1 247	602	301
OFDM Symbols per Phy section		24	24	24	24
Data sub-carriers per Phy section		29 928	29 928	14 448	7 224
Bit per Phy section		119 712	119 712	57 792	28 896
CU per Phy section		**58**	**58**	**28**	**14**
Length of Phy section	ms	8,59 × 10/nFlx	9,52 × 9/nFlx	14,28 × 6/nFlx	7,14 × 12/nFlx
Padding bits		0	0	0	0
preamble per IPL-MC frame		1	1	1	1
Phy sections per IPL-MC frame		5	5	5	5
sub-carrier per IPL-MC frame		150 887	150 887	72 842	36 421
Bit per IPL-MC frame		603 548	603 548	291 368	145 684
Length of IPL-MC frame	ms	43,20 × 10/nFlx	48,00 × 9/nFlx	72,00 × 6/nFlx	36,00 × 12/nFlx
CU per IPL-MC frame		**290**	**290**	**140**	**70**
Padding bits (informative only)		0	0	0	0

4.3 Generation of one Phy section

4.3.1 Overview

The generation of one Phy section is performed as follows:

- handling of data payload (capacity units, CU, etc.);
- handling of signalling bits (RFU: reserved for future use), applicable to modes 2, 2s, 3 and 4;
- scrambling for energy dispersal;
- accumulation of CU for one Phy section.