ETSI TS 102 188-5 V1.1.1 (2004-03)

Technical Specification

Satellite Earth Stations and Systems (SES); Regenerative Satellite Mesh - A (RSM-A) air interface; Physical layer specification; Part 5: Radio transmission and reception

Reference

DTS/SES-00RSM-A-PHY-P5

Keywords

air interace, broadband, multimedia, satellite

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Important notice

Individual copies of the present document can be downloaded from:
http://www.etsi.org

The present document may be made available in more than one electronic version or in print. In any case of existing or perceived difference in contents between such versions, the reference version is the Portable Document Format (PDF). In case of dispute, the reference shall be the printing on ETSI printers of the PDF version kept on a specific network drive within ETSI Secretariat.

Users of the present document should be aware that the document may be subject to revision or change of status. Information on the current status of this and other ETSI documents is available at
http://portal.etsi.org/tb/status/status.asp

If you find errors in the present document, send your comment to:
editor@etsi.org

Contents

Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (http://webapp.etsi.org/IPR/home.asp).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

The present document is part 5 of a multi-part deliverable covering the Regenerative Satellite Mesh - A (RSM-A); Air interface; Physical Layer specifications, as identified below:

Part 1: "General description";

Part 2: "Frame structure";

Part 3: "Channel coding";

Part 4: "Modulation";

Part 5: "Radio transmission and reception";

Part 6: "Radio link control";

Part 7: "Synchronization".

1 Scope

The present document defines the Radio Frequency (RF) requirements for the Satellite Terminal (ST) transceiver of the Regenerative Satellite Mesh - A (RSM-A); Air interface operating in the Fixed Satellite System (FSS) allocations at Ka-band as follows:

- ST reception is in the Fixed Satellite Service (FSS) frequency ranges from 17,70 GHz to 19,70 GHz and from 19,70 GHz to 20,20 GHz;
- ST transmission is in the frequency ranges allocated to FSS from 27,50 GHz to 29,50 GHz and from 29,50 GHz to 30,00 GHz;

Requirements are defined for two categories of parameters:

- those that are required to provide compatibility between the radio channels, connected either to separate or common antennas, that are used in the system. This category also includes parameters providing compatibility with existing systems in the same or adjacent frequency bands;
- those that define the transmission quality of the system.

These requirements apply to all types of ST that transmit a single modulated carrier, including STs with an antenna diameter greater than 1,8 metres (or equivalent corresponding aperture).

The technical requirements of the present document apply under the environmental profile for operation of the equipment, which shall be declared by the manufacturer. The equipment shall comply with all the technical requirements of the present document at all times when operating within the boundary limits of the declared operational environmental profile.

The environmental profile for operation of the equipment shall include the ranges of humidity, temperature and supply voltage.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- 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.
- For a non-specific reference, the latest version applies.

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

[1] ETSI EN 301 459 (V1.2.1): "Satellite Earth Stations and Systems (SES); Harmonized EN for Satellite Interactive Terminals (SIT) and Satellite User Terminals (SUT) transmitting towards satellites in geostationary orbit in the 29,5 to 30,0 GHz frequency bands covering essential requirements under article 3.2 of the R&TTE Directive".

[2] ETSI TS 101 136 (V1.3.1): "Satellite Earth Stations and Systems (SES); Guidance for general purpose earth stations transmitting in the 5,7 GHz to 30,0 GHz frequency bands towards geostationary satellites and not covered by other ETSI specifications or standards".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

allocated bandwidth: width of the frequency band within ±1,25 (symbol rate/2) of the carrier frequency

carrier transmission bandwidth: width of the frequency band within ±1,4 (symbol rate/2) of the carrier frequency

necessary bandwidth: width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions

out-of-band emission: emission on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions

Received Isotropic Power (RIP): power that would be received by an isotropic antenna

Packet Loss Rate (PLR): ratio of RSM-A packets that are lost relative to total number of RSM-A packets received

NOTE: The PLR is measured after Forward Error Correction (FEC).

satellite payload: part of the satellite that provides air interface functions

NOTE: The satellite payload operates as a packet switch that provides direct unicast and multicast communication between STs at the link layer.

Satellite Terminal (ST): terminal installed in the user premises

spurious emission: emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information

NOTE: Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

unwanted emissions: consist of spurious emissions and out-of-band emissions

3.2 Symbols

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

kph	klilometre per hour
ms	millisecond (10^{-3} second)
μs	microsecond (10^{-6} second)

3.3 Abbreviations

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

ASK	Amplitude Shift Keyed
C/N	Carrier to Noise
C/No	Carrier to Noise density
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FSS	Fixed Satellite Service
G/T	Gain/Temperature
HPA	High Power Amplifier
I	In Phase
kbps	kilo bits per second (thousands of bits per second)
LHCP	Left Hand Circular Polarization
Mbps	Mega bits per second (millions of bits per second)

PHY	PHYsical
PLR	Packet Loss Rate
p-p	peak-to-peak
PTP	Point-to-Point
Q	Quadrature
RF	Radio Frequency
RHCP	Right Hand Circular Polarization
RIP	Received Isotropic Power
RSM	Regenerative Satellite Mesh
Rx	Receive
SLC	Satellite Link Control
ST	Satellite Terminal
TDM	Time Division Multiplex
Tx	Transmit
ULPC	UpLink Power Control

4 Introduction to radio transmission and reception

The functions of the physical layer are different for the uplink and downlink. The major functions are illustrated in figure 4.

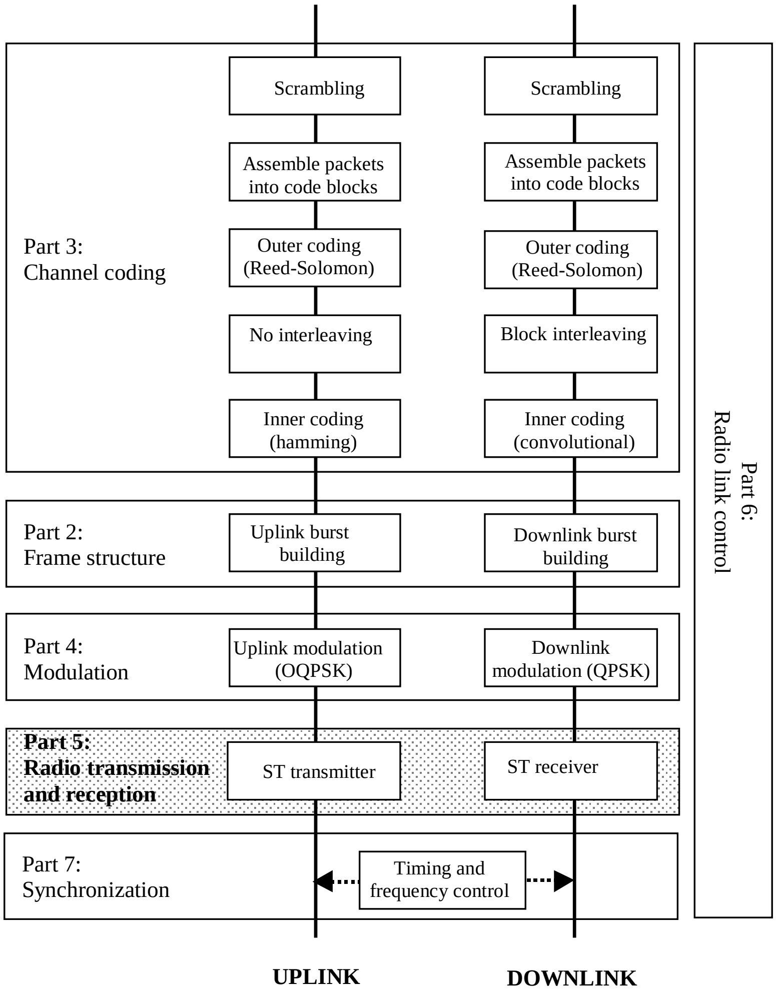

Figure 4: Physical layer functions

The present document describes the ST radio transmission and reception functions - this group of functions is highlighted in figure 4.

Clause 5 describes the frequency bands and channel arrangements for the uplink and the downlink.

Clause 6 describes the ST stability requirements.

Clause 7 describes the ST transmitter requirements.

Clause 8 describes the ST receiver requirements.

5 Frequency bands and channel arrangement

5.1 Frequency bands

The operating frequency bands are defined in table 5.1.

Table 5.1: Operating frequency bands

Band designation	Uplink frequency band	Downlink frequency band
Frequency band A	29,5 GHz to 30,0 GHz	19,7 GHz to 20,2 GHz

5.2 Downlink channel arrangement

5.2.1 Downlink TDM carriers

The downlink Time Division Multiplex (TDM) transmission uses a single carrier in one of two polarizations. The carrier transmits TDM timeslots in one of three possible operating modes. These modes are referred to as full-rate, 1/3-rate, and 1/4-rate corresponding to the burst rate of the carrier during that timeslot.

The downlink carrier centre frequencies are defined in table 5.2.1.

Table 5.2.1: Downlink carrier centre frequencies (Frequency band A)

Carrier mode	Carrier bandwidth (MHz)	Centre frequency (GHz)
Full-Rate	500	19,950
1/3-Rate	500	19,950
1/4-Rate	500	19,950

5.3 Uplink channel arrangement

5.3.1 Uplink sub-bands

An uplink sub-band is a contiguous 62,5 MHz spectrum portion within an uplink frequency band. There are eight possible 62,5 MHz sub-bands of spectrum in each polarization for the uplink frequency band. The uplink sub-bands allocated to the right-hand polarization are referred as sub-bands 0 through 7. The uplink sub-bands allocated to the left-hand polarization are referred as sub-bands 8 through 15.

The starting frequency (or the lower-band edge) and the centre frequency for each sub-band is as listed in table 5.3.1 for Uplink Frequency Band A. The sub-band starting frequency is derived from the following equation:

$$\text{Starting frequency of sub-band}(M) = 29{,}5\,\text{GHz} + K \times 62{,}5\,\text{MHz}$$

where

K = M in modulo-8

M = sub-band designator, M = 0 to 15

Centre of Frequency of Sub-band (M) = Starting Frequency of Sub-band (M) + 31,25 MHz

Table 5.3.1: Uplink sub-band starting and centre frequencies (frequency band A)

Sub-band designator		Sub-band starting frequency in uplink frequency band A (Hz)	Sub-band centre frequency in uplink frequency band A (Hz)
RHCP	LHCP		
0	8	29,500000E+09	29,531250E+09
1	9	29,562500E+09	29,593750E+09
2	10	29,625000E+09	29,656250E+09
3	11	29,687500E+09	29,718750E+09
4	12	29,750000E+09	29,781250E+09
5	13	29,812500E+09	29,843750E+09
6	14	29,875000E+09	29,906250E+09
7	15	29,937500E+09	29,968750E+09
NOTE: All frequencies are defined with respect to a satellite master oscillator that has the stability performance as specified in TS 102 188-7.			

5.3.2 Uplink FDMA carrier modes

There are four possible FDMA carrier modes. The three main carrier modes are referred to as 512 kbps, 2 Mbps and 16 Mbps modes. In addition, the unique fallback mode of 128 kbps is used for the 512 kbps. This labelling of the modes corresponds to the approximate usable information rate that can be supported in the corresponding carrier.

5.3.2.1 Uplink allocated bandwidths and configurations

The allocated bandwidth is defined as the width of the frequency band within ±1,25 (symbol rate/2) of the uplink carrier frequency. The allocated bandwidth depends on the uplink carrier mode as defined below.

The allocated bandwidth for a 128 kbps fallback carrier mode is 651 041 2/3 Hz. This value is obtained by dividing a 62,5 MHz uplink sub-band into 96 equally spaced uplink carriers. The 128 kbps carriers are labelled 0, 1, 2 to 95, corresponding to increasing operating frequency.

The allocated bandwidth for a 512 kbps carrier mode is 651 041 2/3 Hz. This value is obtained by dividing a 62,5 MHz uplink sub-band into 96 equally spaced uplink carriers. The 512 kbps carriers are labelled 0, 1, 2 to 95, corresponding to increasing operating frequency.

The allocated bandwidth for a 2 Mbps carrier mode is 2 604 166 2/3 Hz. This value is obtained by dividing a 62,5 MHz uplink sub-band into 24 equally spaced uplink carriers. The 2 Mbps carriers are labelled 0, 4, 8, to 92, corresponding to increasing operating frequency.

The allocated bandwidth for a 16 Mbps carrier mode is 20 833 333 1/3 Hz. This value is obtained by dividing a 62,5 MHz uplink sub-band into 3 equally spaced uplink carriers. The 16 Mbps carriers are labelled 0, 32, and 64 corresponding to increasing operating frequency.

5.3.2.2 Uplink carrier centre frequency

The ST shall be capable of transmitting on any of the carrier centre frequencies for each of the supported carrier mode(s).

The carrier centre frequencies relative to the sub-band starting frequency are given by the following relation:

$$\text{FDMA carrier}(P)\,\text{centre frequency relative to sub-band starting frequency} = 62{,}5\ \text{MHz} \times \left(\frac{1}{2N} + \frac{P}{96}\right)$$

where:

N = 96, 24, or 3 corresponds to a 512 kbps, 2 Mbps or 16 Mbps carrier mode, respectively

$$P = \text{the carrier designator} = \begin{Bmatrix} 0, 1, \ldots, 95 & \text{for 128 kbps and 512 kbps} \\ 0, 4, 8, \ldots, 92 & \text{for 2 Mbps} \\ 0, 32, 64 & \text{for 16 Mbps} \end{Bmatrix}$$

Refer to table 5.3.2.2 for a tabulation of the uplink carrier centre frequencies within a sub-band. The sub-band starting frequencies are defined above in table 5.3.1.

Table 5.3.2.2: Uplink carrier centre frequencies

Carrier designator	Centre frequency relative to sub-band starting frequency (Hz)		
	128 kbps or 512 kbps carriers (note 2)	2 Mbps carriers	16 Mbps carriers
0	325 520,833	1 302 083,333	10 416 666,667
1	976 562,500		
2	1 627 604,167		
3	2 278 645,833		
4	2 929 687,500	3 906 250,000	
5	3 580 729,167		
6	4 231 770,833		
7	4 882 812,500		
8	5 533 854,167	6 510 416,667	
9	6 184 895,833		
10	6 835 937,500		
11	7 486 979,167		
12	8 138 020,833	9 114 583,333	
13	8 789 062,500		
14	9 440 104,167		
15	10 091 145,833		
16	10 742 187,500	11 718 750,000	
17	11 393 229,167		
18	12 044 270,833		
19	12 695 312,500		
20	13 346 354,167	14 322 916,667	
21	13 997 395,833		
22	14 648 437,500		
23	15 299 479,167		
24	15 950 520,833	16 927 083,333	
25	16 601 562,500		
26	17 252 604,167		
27	17 903 645,833		
28	18 554 687,500	19 531 250,000	
29	19 205 729,167		
30	19 856 770,833		
31	20 507 812,500		
32	21 158 854,167	22 135 416,667	31 250 000,000
33	21 809 895,833		
34	22 460 937,500		
35	23 111 979,167		
36	23 763 020,833	24 739 583,333	
37	24 414 062,500		
38	25 065 104,167		
39	25 716 145,833		
40	26 367 187,500	27 343 750,000	
41	27 018 229,167		
42	27 669 270,833		
43	28 320 312,500		
44	28 971 354,167	29 947 916,667	
45	29 622 395,833		
46	30 273 437,500		
47	30 924 479,167		
48	31 575 520,833	32 552 083,333	
49	32 226 562,500		
50	32 877 604,167		
51	33 528 645,833		
52	34 179 687,500	35 156 250,000	
53	34 830 729,167		

Carrier designator	**Centre frequency relative to sub-band starting frequency (Hz)**		
	128 kbps or 512 kbps carriers (note 2)	**2 Mbps carriers**	**16 Mbps carriers**
54	35 481 770,833		
55	36 132 812,500		
56	36 783 854,167	37 760 416,667	
57	37 434 895,833		
58	38 085 937,500		
59	38 736 979,167		
60	39 388 020,833	40 364 583,333	
61	40 039 062,500		
62	40 690 104,167		
63	41 341 145,833		
64	41 992 187,500	42 968 750,000	52 083 333,333
65	42 643 229,167		
66	43 294 270,833		
67	43 945 312,500		
68	44 596 354,167	45 572 916,667	
69	45 247 395,833		
70	45 898 437,500		
71	46 549 479,167		
72	47 200 520,833	48 177 083,333	
73	47 851 562,500		
74	48 502 604,167		
75	49 153 645,833		
76	49 804 687,500	50 781 250,000	
77	50 455 729,167		
78	51 106 770,833		
79	51 757 812,500		
80	52 408 854,167	53 385 416,667	
81	53 059 895,833		
82	53 710 937,500		
83	54 361 979,167		
84	55 013 020,833	55 989 583,333	
85	55 664 062,500		
86	56 315 104,167		
87	56 966 145,833		
88	57 617 187,500	58 593 750,000	
89	58 268 229,167		
90	58 919 270,833		
91	59 570 312,500		
92	60 221 354,167	61 197 916,667	
93	60 872 395,833		
94	61 523 437,500		
95	62 174 479,167		
NOTE 1: All frequencies are defined with respect to a satellite master oscillator that has the stability performance as specified in TS 102 188-7. NOTE 2: 128 kbps and 512 kbps carriers shall only be assigned in groups of 2, starting with an even carrier designator.			

6 Stability requirements

6.1 Frequency and symbol timing stability

The ST transmit frequency within an uplink burst shall be maintained to within 60 Hz of the nominal transmit frequency. The nominal frequency includes any Doppler offset commanded by the network.

The ST symbol rate within an uplink burst shall be maintained to within 100 parts per billion.

6.2 Transmit signal accuracy

The uplink signal requirements are defined in table 6.2. For the reference model shown in figure 6.2.

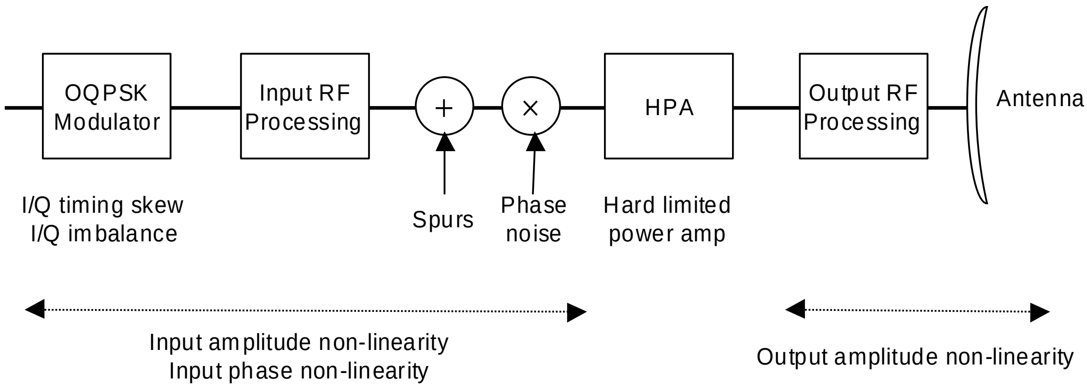

Figure 6.2: Uplink signal reference model

Table 6.2: Uplink signal requirements

Parameter	Requirement
I/Q timing skew	The ST modulator I/Q timing skew shall be less than 3 % of a symbol period.
I/Q imbalance	The ST modulator I/Q imbalance shall be below 0,5 dB (pp) in amplitude and 4° (pp) in phase.
Input phase non-linearity	The phase non-linearity for the ST at the input of the HPA shall comply with the uplink phase non-linearity mask given in figure 6.2.1 and the parameters given in table 6.2.1.
Input amplitude non-linearity	The amplitude non-linearity for the ST at the input of the HPA shall comply with the uplink input amplitude non-linearity mask given in figure 6.2.2 and the parameters given in table 6.2.2.
Output amplitude non-linearity	The amplitude non-linearity for the ST from the output of the HPA to the Antenna shall comply with the uplink output amplitude non-linearity mask given in figure 6.2.3 and the parameters given in table 6.2.3.

6.2.1 Uplink input phase non-linearity

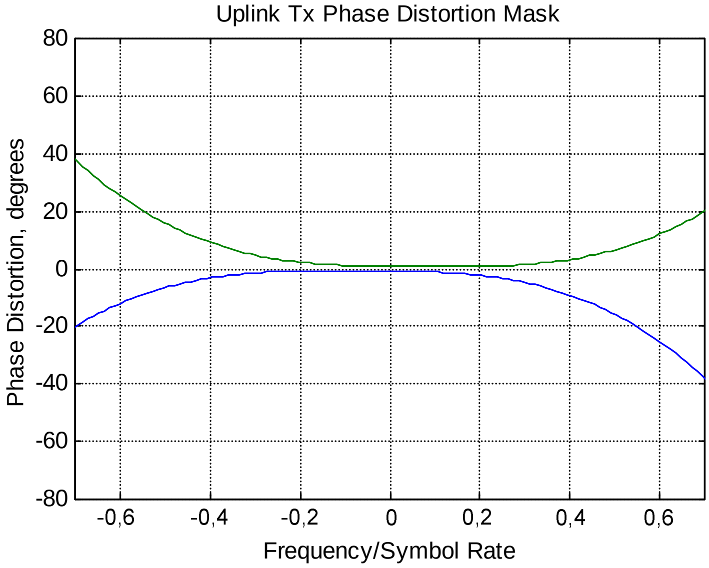

Figure 6.2.1: Uplink input phase non-linearity mask

Table 6.2.1: Uplink input phase non-linearity

Parameter	Requirement
Maximum quadratic phase	9,0°
Maximum cubic phase	56,3° p-p
Maximum ripple	1,8° p-p

6.2.2 Uplink input amplitude non-linearity

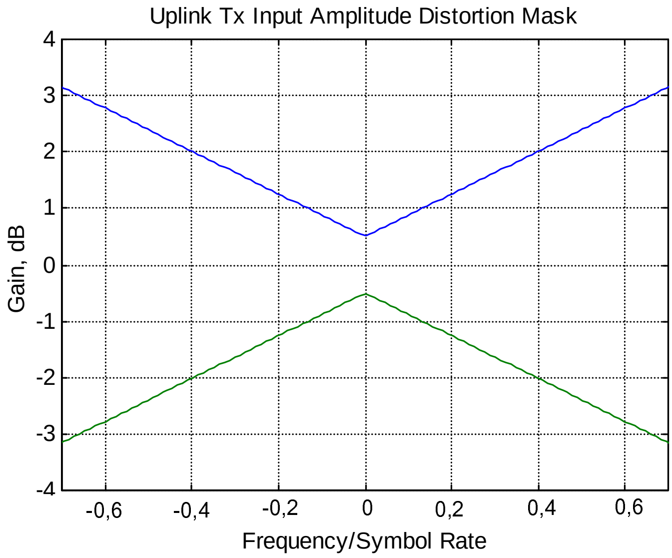

Figure 6.2.2: Uplink input amplitude non-linearity mask

Table 6.2.2: Uplink input amplitude non-linearity

Parameter	Requirement
Maximum linear variation	4,5 dB p-p
Maximum quadratic variation	0,4 dB
Maximum ripple	1,0 dB p-p

6.2.3 Uplink output amplitude non-linearity

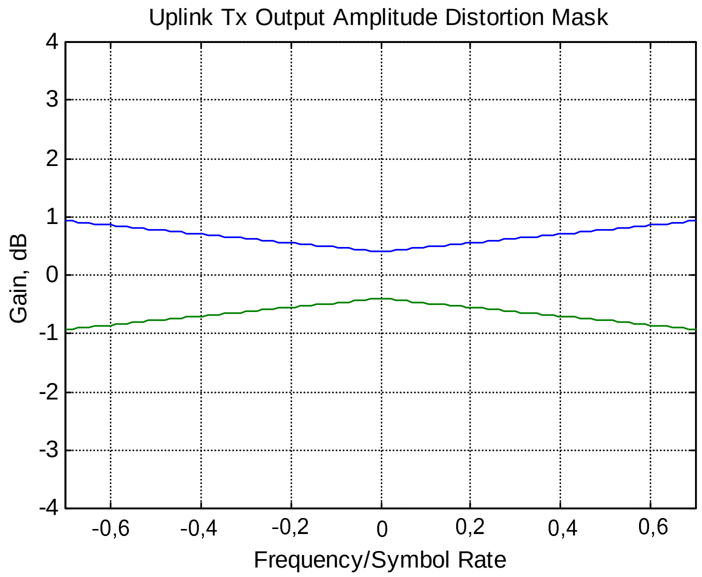

Figure 6.2.3: Uplink output amplitude non-linearity mask

Table 6.2.3: Uplink output amplitude non-linearity

Parameter	Requirement
Maximum linear variation	0,56 dB p-p
Maximum quadratic variation	0,25 dB
Maximum ripple	0,8 dB p-p

6.2.4 In-band spurs

The total integrated power of any in-band spurs shall be less than -30 dBc within the carrier transmission bandwidth, where the carrier transmission bandwidth is defined as being within ±1,4 (symbol rate/2) of the carrier frequency.

NOTE: The carrier transmission bandwidth is derived from the roll-off factor (β) of the modulation.

6.2.5 Phase noise

The ST terminal phase noise shall comply with the uplink phase noise mask shown in figure 6.2.5 and the integrated phase noise shall be less than or equal to 4 degrees when integrated from 1 % to 50 % of the symbol rate bandwidth. This mask may be exceeded by up to 3 dB, provided that the integrated phase noise within this frequency range does not exceed 4 degrees.

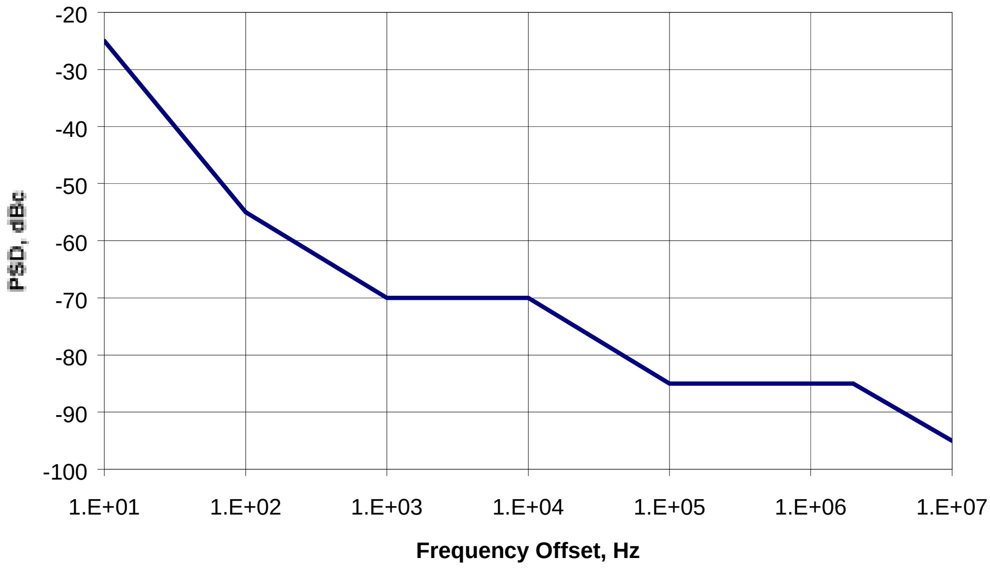

Figure 6.2.5: ST Uplink Phase Noise Mask

6.3 Frequency and mode switching

6.3.1 Transmit frequency switching

The ST carrier switching settling time shall be less than 3 ms to within 30 Hz between any two frequencies within the operational uplink band as defined in clause 5.

6.3.2 Receiver carrier mode switching

The ST shall be capable of switching between the broadcast and PTP and carrier modes within 6 µs. The ST shall also be capable of switching receiver polarization within 6 µs.

NOTE 1: Downlink carrier modes are defined in clause 5.2.1. Carrier mode switching takes place during the Idle slot and this may include a change in polarization.

NOTE 2: The ST receiver may also be required to change polarization between the beacon and broadcast slots.

7 Transmitter characteristics

7.1 Output power

7.1.1 ST power class

ST power classes are defined in table 7.1.1.

Table 7.1.1: ST power class

ST power class	EIRP (dBW) (notes 1 and 4)	Carrier modes (note 2)	Nominal effective antenna diameter (note 3)
Class 1	47,9	128 kbps; 512 kbps	0,7 m
Class 2	52,0	128 kbps; 512 kbps	1,2 m
Class 3	52,5 to 54,2	512 kbps; 2 Mbps	1,0 m / 1,2m
Class 4	57,8	512 kbps; 2 Mbps	1,8 m
Class 5	66,9	512 kbps; 2 Mbps; 16 Mbps	3,5 m
NOTE 1: EIRP refers to the capability of the ST. This shall be the minimum eirp that the ST can emit when operating at maximum output power. NOTE 2: The carriers modes indicates the minimum set of carrier modes that shall be supported. NOTE 3: The nominal effective antenna diameter is a non-normative (informative) figure that indicates the nominal aperture of antenna that is expected. Where multiple figures are given, the lowest figure corresponds to typical locations and the higher figure corresponds to locations with higher rain fade or locations where higher availability is required. NOTE 4: The EIRP includes an allowance for initial pointing losses and station keeping losses.			

7.1.2 Power control range

The Uplink Power Control (ULPC) function is used to control ST transmit power to attain the following objectives:

1) Assure adequate margins against interference and atmospheric effects to meet the uplink packet loss rate and power control error objectives.

2) Compensate for the ST RF imperfections such as power versus frequency variation.

The ULPC process is distributed between the satellite and STs. The STs adjust their transmit uplink power per carrier frequency based on beacon power measurements and satellite power measurement feedback of uplinked packets.

The STs independently adjust their transmit power for each uplink carrier. More details of the uplink power control are described in TS 102 188-6.

The ST shall provide a minimum eirp dynamic range as defined in table 7.1.2.

Table 7.1.2: ST power control range

ST power class	Carrier mode	Minimum EIRP dynamic range (dB) (note)
Class 1, 2	128 kbps; 512 kbps	18,0 dB
Class 3, 4	512 kbps; 2 Mbps	24,0 dB
Class 5	512 kbps; 2 Mbps; 16 Mbps	33,0 dB
NOTE: The minimum EIRP dynamic range includes the range of EIRP that is required for the ST to operate in the different carrier modes.		

7.1.3 Off-axis eirp

7.1.3.1 Co-polar limits

The uplink off-axis eirp spectral density for co-polarized signals in any 40 kHz band shall not exceed the values defined in table 7.1.3.1a. For all directions within ±3 degrees of the GSO arc, under clear-sky conditions.

Table 7.1.3.1a: Co-polar off-axis eirp for directions within ±3 degrees of the GSO arc

Off-axis eirp (dBW/ 40 kHz)	Angle (degrees)
18,5 - 25 log(Φ)	2,0° ≤ Φ ≤ 7,0°
-2,63	7,0° < Φ ≤ 9,23°
21,5 - 25 log(Φ)	9,23° < Φ ≤ 48,0°
-10,5	48,0° < Φ ≤ 180,0°
NOTE: Φ is the angle, in degrees, between the main beam axis and the direction considered.	

The uplink off-axis eirp spectral density for co-polarized signals in any 40 kHz band shall not exceed the values defined in table 7.1.3.1b. For all directions other than within ±3 degrees of the GSO arc, under clear-sky conditions.

Table 7.1.3.1b: Co-polar off-axis eirp for directions not within ±3 degrees of the GSO arc

Off-axis eirp (dBW/ 40 kHz)	Angle (degrees)
21,5 - 25 log(Φ)	3,5° ≤ Φ ≤ 7,0°
+0,37	7,0° < Φ ≤ 9,23°
24,5 - 25 log(Φ)	9,23° < Φ ≤ 48,0°
-7,5	48,0° < Φ ≤ 180,0°
NOTE: Φ is the angle, in degrees, between the main beam axis and the direction considered.	

The above co-polar limits may be exceeded by up to A dB during fade conditions, where A is the attenuation of the transmit signal relative to clear sky conditions.

The off-axis eirp shall also comply with the limits specified in EN 301 459 [1] for antennas with a diameter that does not exceed 1,8 m, or equivalent corresponding aperture. In the event of any conflict, the more stringent requirement shall apply.

For larger aperture antennas the off-axis eirp should comply with the limits specified in TS 101 136 [2].

7.1.3.2 Cross-polar limits

The uplink off-axis eirp spectral density for cross-polarized signals in any 40 kHz band shall not exceed the values defined in table 7.1.3.2. For all directions relative to the GSO arc, under clear-sky conditions.

Table 7.1.3.2: Cross-polar off-axis eirp for all directions

Off-axis eirp (dBW/ 40 kHz)	Angle (degrees)
8,5 - 25 log(Φ)	2,0° ≤ Φ ≤ 7,0°
-12,63	7,0° < Φ ≤ 9,23°
NOTE: Φ is the angle, in degrees, between the main beam axis and the direction considered.	

The above cross-polar limits may be exceeded by up to A dB during fade conditions, where A is the attenuation of the transmit signal relative to clear sky conditions.

The off-axis eirp shall also comply with the limits specified in EN 301 459 [1] for antennas with a diameter that does not exceed 1,8 m, or equivalent corresponding aperture. In the event of any conflict, the more stringent requirement shall apply.

For larger aperture antennas the off-axis eirp should comply with the limits specified in TS 101 136 [2].

7.2 Transmit antenna characteristics

7.2.1 Antenna radiation pattern

The peak gain for any individual sidelobe shall not exceed the envelope defined in table 7.2.1 between 1° and 7°.

For angles greater than 7°, the envelope defined in table 7.2.1 may be exceeded by no more than 10 % of the sidelobes provided that no individual sidelobe exceeds the gain envelope by more than 3 dB.

Table 7.2.1: Antenna transmit gain

Peak gain (dBi)	Angle (degrees)
29 - 25 log(Φ) dBi	1,8° ≤ Φ ≤ 7,0°
8 dBi	7,0° < Φ ≤ 9,0°
32 - 25 log(Φ) dBi	9,0° < Φ ≤ 48,0°
-10 dBi	48,0° < Φ ≤ 180,0°
NOTE: Φ is the angle, in degrees, between the main beam axis and the direction considered.	

The antenna axial ratio shall be less than 1 dB.

7.2.2 Transmit polarization

The transmit polarization shall be either Left Hand Circular Polarized (LHCP) or Right Hand Circular Polarized (RHCP) depending upon the uplink cell.

The STs have the capability to transmit RHCP or LHCP and this capability shall be selectable.

The polarization of each uplink cell is specified in TS 102 188-7.

7.2.3 Transmit antenna losses

7.2.3.1 Wet antenna losses

The wet antenna losses due to rain rates up to 10 mm/hour rain rate, at elevation angles of 30° or above, shall be less than 1,0 dB.

7.2.3.2 Pointing losses

The transmit antenna pointing losses due to initial depointing shall be less than 0,45 dB.

The transmit antenna pointing losses due to depointing for wind speeds up to and including 80 kph shall be less than 0,5 dB.

7.2.4 Pointing accuracy

The transmit pointing accuracy for antennas with a diameter that does not exceed 1,8 m, or equivalent corresponding aperture, shall comply with the antenna pointing requirements specified in EN 301 459 [1]. In the event of any conflict with the requirements of clause 7.2.3.2, the more stringent requirement shall apply.

The Tx beam to Rx beam squint (from Tx peak to Rx peak) shall be less than 0,1 dB pointing loss in Tx beam gain, when the antenna is peaked with zero degrees pointing error on Rx beam.

7.3 Ramp-up and ramp-down

The ST shall meet the RF output envelope timing illustrated in figure 7.3 and defined in table 7.3.

Each time slot includes a ramp-up and a ramp-down period. Waveforms are measured in a linear voltage sense and are referred to the 10 % and 90 % points of the Amplitude Shift Keyed (ASK) RF transmit envelope.

The rise and fall of the ST RF transmit envelope, when measured on the linear scale of a spectrum analyzer (voltage), shall be between 1,0 µs and 5,68 µs between 10 % to 90 % of its final value.

The STs shall modulate data onto the TX reference starting at 9,6 µs after the 'start of burst' rising edge and ending 1,92 µs before the falling edge of the 'carrier on' signal.

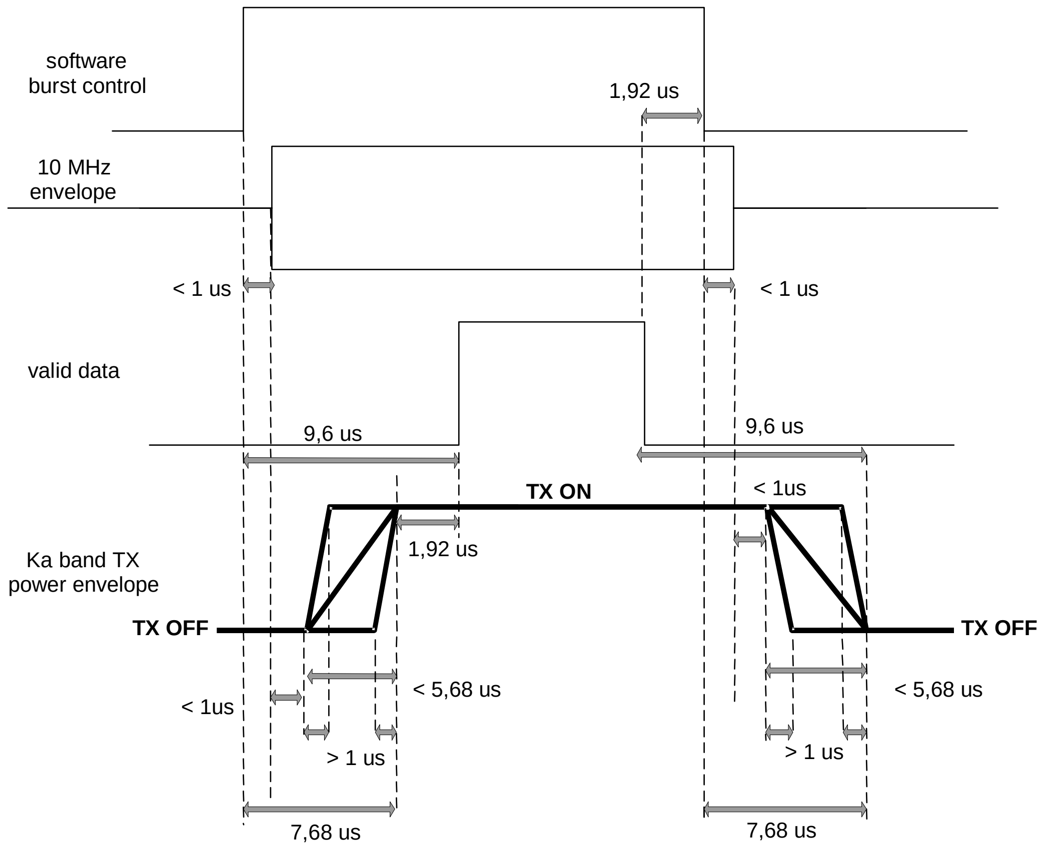

Figure 7.3: Ramp up and ramp down times

Table 7.3: ST RF envelope timing

Region	Minimum µs	Maximum µs
ASK Leading Edge to RF 10 %	≥ 0,1	≤ 6,68
Rise time	≥ 1,0	≤ 5,68
ASK Leading Edge to RF 90 %	≥ 1,1	≤ 7,68
ASK Trailing Edge to RF 90 %	≥ 0,1	≤ 6,68
Fall Time	≥ 1,0	≤ 5,68
ASK Trailing Edge to RF 10 %	≥ 1,1	≤ 7,68

7.4 Output RF spectrum

7.4.1 Emissions due to modulation

The mean out-of-band emissions in any 4 kHz bandwidth shall be less than or equal to the limits defined in table 7.4.1.

Table 7.4.1: Out of band emissions due to modulation

Frequency offset (% of allocated bandwidth)	Emission limit (dBc)	Measurement bandwidth (kHz)
50 % to 100 %	-25 dBc	4 kHz
100 % to 250 %	-35 dBc	4 kHz

Where the allocated bandwidth depends on the uplink carrier mode as defined in clause 5.3.2.1.

7.4.2 Adjacent channel interference

The total aggregate power of the ST transmitted signal outside its allocated bandwidth of ±1,25 (symbol rate/2) shall be less than -16,5 dBc. The power shall be measured using a measurement bandwidth equal to the allocated bandwidth of (1,25 x symbol rate). This limit includes the effects of pulse shaping, phase noise, transmitter distortion, and spurs and in the event of any conflict with the requirements in clause 7.4.1, the more stringent limit shall apply.

7.4.3 Carrier-off conditions

The carrier on/off ratio shall equal or exceed the limits defined in table 7.4.3.

Table 7.4.3: ST carrier-off limits

ST Power Class	Carrier on/off ratio (dB)
Class 1, 2, 3	≥ 60,0 dB
Class 4, 5	≥ 50,0 dB

7.5 Spurious emissions

7.5.1 Transmitter spurious emissions

The uplink spurious emissions from the ST shall be attenuated relative to the carrier by the following limits:

$$\text{Attenuation relative to carrier power} = MIN\left\{43 + 10\log(P), 60\right\} dBc$$

where P is the total mean carrier power supplied to the antenna.

The spurious emissions regions are defined as the frequencies below (fc1 - 2,5 Bn) and the frequencies above (fc2 + 2,5 Bn) where:

- fc1 is the carrier centre frequency of the lowest carrier in the operating band;
- fc2 is the carrier centre frequency of the highest carrier in the operating band;
- Bn is the necessary bandwidth of the uplink carrier.

7.5.2 Off-axis spurious radiation

The off-axis spurious radiation shall comply with the limits specified in EN 301 459 [1] for antennas with a diameter that does not exceed 1,8 m, or equivalent corresponding aperture. In the event of any conflict, the more stringent requirement shall apply.

For larger aperture antennas the off-axis spurious radiation shall comply with the limits specified in TS 101 136 [2].

7.5.3 On-axis spurious radiation

The on-axis spurious radiation shall comply with the limits specified in EN 301 459 [1] for antennas with a diameter that does not exceed 1,8 m, or equivalent corresponding aperture. In the event of any conflict, the more stringent requirement shall apply.

For larger aperture antennas, the eirp spectral density of the spurious radiation shall not exceed 18 dBW in any 100 kHz band.

8 Receiver characteristics

8.1 Receive antenna characteristics

8.1.1 Receiver figure of merit

The ST receiver clear sky G/T performance, including any pointing losses at a 30° elevation angle shall be as defined in table 8.1.1. These values shall apply at the midband downlink frequency of 19,95 GHz.

Table 8.1.1: ST Receiver G/T performance

Nominal effective antenna diameter (m) (note 1)	G/T (dB/K) (notes 2 and 3)
0,74	≥ 18,2
1,0	≥ 20,5
1,2	≥ 22,3
1,8	≥ 25,9
3,5	≥ 29,2
NOTE 1: The defined performance also applies to a non-circular antenna of equivalent aperture. NOTE 2: The background noise temperature is assumed to be 44° K for the purposes of G/T calculations. NOTE 3: The G/T figure includes an allowance for initial pointing losses and station keeping losses.	

8.1.2 Receiver discrimination

The ST aggregate adjacent satellite discrimination from satellites located ±2°, ±4°, ±6° from the wanted satellite orbital position shall be as defined in table 8.1.2.

Table 8.1.2: ST adjacent satellite discrimination

Nominal effective antenna diameter (m) (note)	Discrimination (dB)
0,74	≥ 22,0
1,0	≥ 27,0
1,2	≥ 27,0
1,8	≥ 27,0
3,5	≥ 29,0
NOTE: The defined performance also applies to any antenna of equivalent aperture.	

8.1.3 Receive polarization

The receive polarization shall be either Left Hand Circular Polarized (LHCP) or Right Hand Circular Polarized (RHCP). The ST shall be capable of receiving both polarizations; the polarization shall be electronically selectable during normal operation.

The ST shall be capable of switching between the downlink polarizations within 6 μs.

8.1.4 Receive antenna losses

8.1.4.1 Wet antenna losses

The wet antenna losses due to rain rates up to 10 mm/hour rain rate, at elevation angles above 30° shall be less than or equal to 0,5 dB.

8.1.4.2 Depointing losses

The receive antenna pointing losses due to initial depointing shall be less than 0,2 dB.

The receive antenna pointing loss due to depointing for wind speeds up to and including 80 kph shall be less than 0,25 dB.

8.2 Receiver performance

8.2.1 Definitions

8.2.1.1 Received Isotropic Power (RIP)

The Received Isotropic power (RIP) is the power that would be received by an isotropic antenna.

NOTE: An isotropic antenna is a theoretical antenna that receives energy uniformly in all directions with unit gain. The actual received power for a perfectly aligned real antenna is increased by the gain of the antenna.

8.2.1.2 Packet Loss Rate (PLR)

The Packet Loss Rate (PLR) is the ratio of RSM-A packets that are lost relative to total number of RSM-A packets received. The PLR is measured after Forward Error Correction (FEC).

NOTE: RSM-A packets are transmitted in pairs and the FEC is applied over both packets. An FEC failure therefore normally results in the loss of 2 packets.

8.2.2 Receiver sensitivity

8.2.2.1 Receiver packet loss rate for PTP transmissions

The ST shall provide a downlink Packet Loss Rate (PLR) of 2,5 x 10^{-7} or less, at an Eb_t /No of 2,85 dB in an AWGN channel environment with a maximum integrated telemetry RIP as defined in annex A.

8.2.2.2 Receiver packet loss rate for Broadcast transmissions

The ST shall provide a downlink Packet Loss Rate (PLR) of 2,5 x 10^{-7} or less, at an Eb_t /No of 2,6 dB in an AWGN channel environment with a maximum integrated telemetry RIP as defined in annex A.

8.2.2.3 Receiver dynamic range

The ST shall meet the PLR requirements with a dynamic RIP variation from burst to burst of up to 15 dB for PTP and Broadcast modes and up to 17 dB for Beacon modes.

The ST shall also operate with no damage with a maximum downlink RIP less than or equal to -100 dBW.

8.3 Receive signal quality

8.3.1 Beacon measurements

The ST shall measure the C/N of the beacon every frame with a standard deviation of 0,2 dB after averaging for 96 ms at a C/No of 80 dB-Hz.

The terminal shall measure the beacon C/N over a dynamic range of 18 dB.

The terminal shall compute a windowed average of the beacon C/N over the last t seconds, where t is less than 1 s. The ST shall collect statistics on the beacon observations in 100 bins, where each bin is 0,25 dB wide.

The ST shall store the last 10 beacon measurements that are time correlated with the last 10 stored PTP measurements, each with a resolution of 0,25 dB.

8.3.2 PTP measurements

The ST shall measure the C/N of every PTP burst directed to its microcell with a standard deviation of 0,5 dB at a C/No of 93 dB-Hz.

The ST shall store the last 10 PTP measurements, each with a resolution of 0,25 dB.

The terminal shall compute the difference between the measured PTP C/N and the C/N of the beacon observation made in the same frame with a resolution of 0,20 dB. The terminal shall collect statistics on the PTP-beacon error in 100 bins, where each bin is 0,25 dB wide.

Annex A (normative): Downlink telemetry signals

A.1 General

This annex defines the downlink telemetry signals that shall apply to the ST receiver performance specifications in clause 8 of the present document.

A.2 Downlink telemetry signals

The ST shall be capable of receiving the wanted downlink signals in the presence of a telemetry signals with a maximum integrated RIP of -165,9 dBW.

The characteristics of the telemetry signals are defined in table A.2.

Table A.2: Downlink telemetry signal

Parameter	LHCP	RHCP
Centre frequency	F1: 19,700250 GHz F2: 19,700750 GHz F3: 19,701250 GHz	F1: 19,701750 GHz F2: 19,702250 GHz F3: 19,702750 GHz

Annex B (informative): Bibliography

ETSI TS 102 188-1: "Satellite Earth Stations and Systems (SES); RSM-A Air Interface; Physical Layer specification; Part 1: General description".

ETSI TS 102 188-2: "Satellite Earth Stations and Systems (SES); RSM-A Air Interface; Physical Layer specification; Part 2: Frame structure".

ETSI TS 102 188-3: "Satellite Earth Stations and Systems (SES); RSM-A Air Interface; Physical Layer specification; Part 3: Channel coding".

ETSI TS 102 188-4: "Satellite Earth Stations and Systems (SES); RSM-A Air Interface; Physical Layer specification; Part 4: Modulation".

ETSI TS 102 188-6: "Satellite Earth Stations and Systems (SES); RSM-A Air Interface; Physical Layer specification; Part 6: Radio link control".

ETSI TS 102 188-7: "Satellite Earth Stations and Systems (SES); RSM-A Air Interface Physical Layer specification; Part 7: Synchronization".

ETSI TS 102 189-1: "Satellite Earth Stations and Systems (SES); Regenerative Satellite Mesh - A (RSM-A) air interface; MAC/SLC layer specification; Part 1: General description".

ETSI TS 102 189-2: "Satellite Earth Stations and Systems (SES); Regenerative Satellite Mesh - A (RSM-A) air interface; MAC/SLC layer specification; Part 2: MAC layer".

ETSI EN 301 360 (V1.1.3): "Satellite Earth Stations and Systems (SES); Harmonized EN for Satellite Interactive Terminals (SIT) and Satellite User Terminals (SUT) transmitting towards geostationary satellites in the 27,5 GHz to 29,5 GHz frequency bands covering essential requirements under article 3.2 of the R&TTE Directive".

History

Document history		
V1.1.1	March 2004	Publication