HERSCHEL / PLANCK

Herschel/Planck Space / Ground Interface Control Document

SCI-PT-ICD-07418

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ENREGISTREMENT DES EVOLUTIONS / *CHANGE RECORD*

Date	*Issue/Rev*	*Pages Affected*	*Description*
11 July 2001	2 / 0	All	Rename "FIRST" "Herschel". Rename "Perth" "New Norcia" Delete high rate TC option Changes related to frequency management (centre frequency,bandwidth), increase Planck information rate Update to reference documents TC via MGA: baseline
8 May 2002	2/1	3	New issue of ECSS RF and modulation standard RD11 draft 9.4
		5,33	Medium bit rate is 150 kbps
		5,33	GMSK high rate modulation scheme
		7	Ranging tone frequency is 600 kHz-700 kHz
		6,7,20	Turbo code deleted
		10	antenna polarisation sense to use will be RHC (Right Hand Circular).
		24	Introduce VC4 HK and change VC naming convention according to email S.Thuerey 1.7.2002
		21	MGA required for New Norcia medium data rate
			Planck spin axis – earth angle is up to 10 deg. Note included
			Note added about nominal acquisition sequence at NNO
29 Nov 2002	3/0	General	Introduction of requirement identifications according to ASP/DOORS rules and rewording text into requirements.
		1.3	AD-5: PSS replaced by ECSS (RD-11), RD-11 deleted
		1.4	New: RD-12 (IEEE Std 149), RD-13 (CReMA)
		2.1.1	Emission bandwidth reduced to 4.2 MHz
		2.1.4	500 bps called “lowK”, 5 kbps called “lowN”
			Subcarrier frequency deleted for turbo encoding
		2.1.7	New section: Frame synchronisation
		2.1.8	New section: Bitstream pseudo randomiser
		2.2.1	Max Rx Doppler rate 500 Hz/sec
		2.2.3	Ranging tone frequency fixed to 687260 Hz with 1 kHz offset from SPL-null

Date	*Issue/Rev*	*Pages Affected*	*Description*
		2.2.6	New section: Uplink sweep
		3.1.3	New text for switching, figure updated
		4.1.1 & 4.1.2	Transponder characteristics updated
		4.2.2	Villafranca characteristics added
		4.2.1 &4.2.2	Addition of atmospheric and ionospheric losses
		4.3.3	4 kbps LGA uplink from Kourou until 350000 km
		4.3.3	5 kbps LGA downlink to Kourou until 750000 km
		4.3.3	MGA range clarified
		4.4	RF suitcase required L-24 months
		10.2	Delete, no turbo encoding
		Fig A4.1	Updated to include pseudo randomiser box
1 Dec. 2003	3/1	2.1.1	HP-SGICD-COM-TM-005/007: - dedicated emission bandwidth introduced for each data rate - TBC removed from frequency values
		2.1.4	HP-SGICD-COM-TM-020: LowK changed to Low-1 and LowN changed to Low-2
		2.2.1	HP-SGICD-COM-TC-005: TBC removed from frequency values
		2.2.3	HP-SGICD-COM-TC-025: tone frequency corrected to provide 10kHz offset
		2.2.7.1	HP-SGICD-COM-TC-045: TBC removed
		2.2.7.2	HP-SGICD-COM-TC-050: TBC removed
		4.2.2	Updated antenna gain figures for Vilspa
		5.2.1.3	HP-SGICD-STR-TM-025: S/C Ids assigned for Herschel, Planck and common AVM
		6.3.1	HP-SGICD-STR-TC-045: S/C Ids assigned for Herschel, Planck and common AVM
1 Dec. 2004	3/2	4.1.2	Table 4-3 and 4-4: dBm > dBW
		4.2.1 – 4.2.3	Update of ground station equipment information

Date	*Issue/Rev*	*Pages Affected*	*Description*
		5.2.1.14	Table in HP-SGICD-STR-TM-125 aligned with AD-2
		5.2.1.14	HP-SGICD-STR-TM-135 made more precise
		6.2.2	Table added to define MAP Ids
		6.3	Table in HP-SGICD-STR-TC-040 aligned with AD-2
		6.3.2	Table added to define Virtual Channel Ids

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1. INTRODUCTION AND SCOPE

1.1 Scope

The ESA Radio Frequency and Modulation Standard **[AD-5]**, requires to control the spacecraft/ground station interface a) in a definitive and formal specification of the RF interface; b) by means of Link Budget Tables regularly updated to keep track of the development of the spacecraft and ground station(s). The hardware interface compatibility will be demonstrated by Spacecraft/Ground station compatibility tests, to be documented by the Compatibility Test Plan and the related Compatibility Test Results Report.

This Space / Ground Interface Control Document (SGICD) defines the relevant ***parameters for the interface between the Herschel/Planck spacecraft and the ground station(s),*** as well as the list of standards and other documents applicable to this interface, and shall act as the source document for all data to be used in the preparation of the Link Budget Tables.

The ESA Packet Telemetry and Telecommand Standards (**[AD-1]** and **[AD-2]**) address the transport of telemetry and telecommand data between user applications on the ground and user applications on-board the satellite, and the intermediate transfer of this data through the different elements of the ground and space segments.

The Space/Ground ICD serves to complement and extend the Packet Telemetry and Telecommand Standards by defining all the mission specific details of the various interface levels, and in addition the ***Application-Level*** interface between ground and on-board applications.

The document will be agreed between the ESA Herschel/Planck Project Manager, the appointed ESOC representative and the Prime Contractor. Upon approval the document will be controlled by the ESA Herschel/Planck Project Manager to whom any updates or changes to any parameters contained in it shall be submitted.

For each of the major project reviews, the Prime Contractor (in association with his subcontractors) shall supply ESA with updated information concerning the spacecraft performance or confirmation that no change has occurred from the previous review. This shall be achieved through submittal of respective compliance tables.

1.2 Operations Scenario

1.2.1 Nominal Mission Operations

The mission operations of the Herschel/Planck spacecraft and its payload will be conducted under control of the Herschel/Planck Mission Operations Centre (MOC) at the European Space Operations Centre (ESOC). Throughout the complete mission duration (from launch up to the end of mission, when ground contact to the spacecraft/payload is terminated), facilities and services will be provided to the Herschel/Planck Science Users for planning and execution of astronomical observations, and provision of the necessary data sets

Interaction with the spacecraft will be by monitoring and analysis of telemetered data and the uplink of commands to effect the necessary operations. Most commands will be stored on board for later execution at a defined time, others may be intended for execution in «near-real-time». In both cases, it may also be necessary to control subsystem and experiment equipment using low-level commands or high-level commands (i.e. via on-board applications or On-Board Control Procedures).

Telemetry and telecommands will also be required for on-board software management functions, including:

- control of, and communication with, on-board processes (such as an on-board telemetry monitor)
- loading and dumping of on-board memories
- control of on-board mission time line.

All telecommands must be appropriately verified by telemetry at acceptance and execution.

Telemetry data will be required in order to verify the execution of all mission operations and will also be required for:

- routine on ground health monitoring of the subsystems and the experiments;
- reporting to the ground any anomalous events detected on-board and any actions taken autonomously by the on-board systems;
- performance evaluation on the ground for the purposes of long-term trend analysis and feedback into the mission planning cycle.

1.2.2 Contingency Operations

In the event of unforeseen on-board events, actions will be necessary to investigate and correct anomalies utilising the available telemetry and command functions. In addition, it may be necessary to modify on-board software in order to compensate for on-board failures or anomalous performance.

1.2.3 Packet Distribution

The following telemetry and telecommand packet categories exist:

- those generated on the ground and up linked to the spacecraft
- those generated by on board applications and down linked to the ground
- those generated on board and routed to other on board applications (and to the ground if necessary)

1.3 Applicable Documents

AD 1. Packet Telemetry Standard,
PSS-04-106, Issue 1, January 1988

AD 2. Packet Telecommand Standard,
PSS-04-107, Issue 2, April 1992

AD 3. Telemetry Channel Coding Standard,
PSS-04-103 Issue 1, September 1989

AD 4. Ranging Standard,
PSS-04-104, Vol. I, Issue 2, March 1991

AD 5. ECSS Radio Frequency and Modulation Standard,
ECSS E-50-05, Draft 9.4, April 2002

1.4 Reference Documents

RD 1. Herschel/Planck Operations Interface Requirements Document (H/P-OIRD),
SCI-PT-RS- 07360, Issue 2.1, December 2001

RD 2. ESA Telecommand Decoder Specification,
PSS-04-151

RD 3. Herschel/Planck Suitcase Requirements Specification, H-P-1-ASPI-SP-0252

RD 4. CCSDS Packet Telemetry, CCSDS 102.0-B-4, November 1995

RD 5. ECSS Telemetry and Telecommand Packet Utilisation Standard, ECSS-E-70/41 Draft 04, April 1999

RD 6. Herschel/Planck Transponder Specifications, H-P-SP-AI-0012

RD 7. CCSDS Telemetry Channel Coding, CCSDS 101.0-B-5 blue book, June 2001

RD 8. CCSDS Telecommand Part 2 Data Routing Service, CCSDS 202.0-B-2, November 1992

RD 9. Herschel/Planck Packet Structure ICD (H/P PS-ICD), SCI-PT-IF-07527

RD 10. Herschel/Planck Radio Frequency Test Procedure and Report, Issue TBD, Date TBD

RD 11. Deleted

RD 12. IEEE Standard 149, 1979

RD 13. Consolidated Report on Mission Analysis, FP-MA-RP-0010-TOS/GMA

RD 14. Herschel/Planck System Requirements Specification, SCI-PT-RS-05991

2. TELECOMMUNICATION SYSTEM

The telecommunication system supports the functions of tracking, telecommand and telemetry for each phase of the mission.

The spacecraft telecommunication subsystem consists of a redundant set of transponders using X-Band for the uplink, and X-Band for the downlink. Depending on the mission phase, the transponder can be routed via RF switches to different antennas. The telecommunication subsystem provides hot redundancy for the receiving function and cold redundancy for the transmitting function.

The associated ground network consists of a number of stations, which support some or all of the mission phases. A full description of the station utilisation will be found in Section 4 together with the appropriate specification of spacecraft and ground stations.

The satellite telecommunication subsystem will be allocated with its dedicated frequency in the X-Band frequency range. The frequency assignment has been requested from the Frequency Management Office.

2.1 Down Link

2.1.1 Frequencies

Reference **HP-SGICD-COM-TM-005**

Each satellite is allocated a frequency for a Category A (non Deep Space) Mission and its telecommunication subsystem shall support a down link frequency in the 8450 – 8500 MHz frequency band (X-band) as follows:

Herschel

8468.5 MHz

Planck

8455.0 MHz

*

Reference **HP-SGICD-COM-TM-007**

The emission bandwidths shall be as follows:

Low rate: 340 kHz

Medium rate: 6.2 MHz

High rate: 4.2 MHz

Ranging: 2.0 MHz

*

Reference **HP-SGICD-COM-TM-010**

The antenna polarisation sense shall be RHC (Right Hand Circular) in accordance with RD-12.

*

2.1.2 Telemetry Channel Formats

Reference HP-SGICD-COM-TM-015

The telemetry shall follow the Packet Telemetry Standard **[AD-1]** without Source Packet segmentation, as mentioned in **[RD-4]**.

*

2.1.3 Ranging Signal

The ranging signal is defined in section 2.2.3.

2.1.4 Modulation

Reference HP-SGICD-COM-TM-020

The telemetry modulation scheme and the bit rates to be transmitted shall be as follows (see section 2.1.5 for details on bit rates):

Herschel/Planck

Rate	Information rate	Modulation scheme	Subcarrier frequency
Low-1	500 bps	PCM(NRZ-L)/PSK/PM	45884.000 Hz (sine)
Low-2	5 kbps	PCM(NRZ-L)/PSK/PM	45884.000 Hz (sine)
Medium	150 kbps	PCM(SP-L)/PM	Not applicable
High	1.5 Mbps	GMSK	Not applicable

*

The modulation scheme to be used for high rate transmission is GMSK (with BTb=0.25.) as defined in **[AD-5]**.

Both medium rate and high rate telemetry transmissions have to comply with the emission masks stipulated by the Space Frequency Co-ordination Group (SFCG) in recommendation REC 17-2R1 which are reported in Appendix 5. While the proposed high rate modulation schemes may meet the mask with no special precautions, the medium rate modulation scheme PCM(SP-L)/PM requires that a pre-modulation filter be used.

The ranging signal in the ranging channel of the transponder directly phase modulates (PM) the downlink carrier. When simultaneous ranging and telemetry is performed, the two signals are added prior to phase modulation of the downlink carrier. Ranging is not possible simultaneously with high rate telemetry. During these phases, Doppler tracking only will be used instead of Ranging.

2.1.5 Telemetry Bit Rates

Reference **HP-SGICD-COM-TM-025**

The information rates (fb) and transmitted symbol rates fs') listed below shall be supported. The information rates refer to the transfer layer with its associated data structure (Transfer Frames). The symbol rates results from the applied concatenated encoding.

Herschel/Planck

Concatenated encoding

fb = information rate [bps]

fs = data rate at convolutional encoder input [bps]

fs' = transmitted symbol rate [sps]

fsc = subcarrier frequency [Hz]

N = subcarrier frequency/transmitted symbol rate ratio

fs'	fs	fb	fsc	N
1147.1000	573.5500	500.0065	45884.000	40
11471.0000	5735.5000	5000.0645	45884.000	4
344130.0000	172065.000	150001.9500	N/A	N/A
3441300.0000	1720650.0000	1500019.3511	N/A	N/A

*

For details on the above mentioned bit/symbol rate definition, see Appendix 4.

For details on the above mentioned bit/symbol rate definition, see Appendix 4.

2.1.6 Coding

Reference **HP-SGICD-COM-TM-030**

The baseline coding shall be concatenated encoding (Reed Solomon R-S 255,223 with interleaving depth I = 5, and convolutional rate ½ with constraint length k = 7) in accordance with **[AD-3]**.

*

2.1.7 Frame Synchronisation

Reference **HP-SGICD-COM-TM-035**

To allow a proper frame synchronisation on ground, a synchronisation marker 1ACFFC1D shall be inserted at the first bit of the code block of each transfer frame inline with [AD-3].

*

2.1.8 Bitstream Pseudo Randomiser

In order to maintain symbol synchronisation with the received telemetry signal, a minimum bit and symbol transition density must be ensured as per §5.2.5 of **[AD-5]**. Depending on the data content, the use of quadrature phase modulation and convolutional encoding may lead to the absence of transition at symbol level.

Reference **HP-SGICD-COM-TM-040**

An on-board pseudo randomiser shall be implemented. The requirements for the pseudo randomiser are given in **[AD-3]**.

*

2.2 Up-Link (On-Board Reception)

2.2.1 Frequencies

Reference **HP-SGICD-COM-TC-005**

Each satellite is allocated a frequency for a Category A (non Deep Space) mission and its telecommunication subsystem shall support an uplink frequency in the 7190 - 7235 MHz frequency band (X-Band) as follows:

Herschel

7207.8483 MHz

Emission bandwidth: 3 MHz

Planck

7196.3580 MHz

Emission bandwidth: 3 MHz

*

The ratio of uplink and downlink frequencies for the transponders will be as follows:

fu/fd = 749/880 (X-/X- Band)

Reference **HP-SGICD-COM-TC-010**

The maximum Rx Doppler rate shall be 500 Hz/sec.

*

Reference HP-SGICD-COM-TC-015

The antenna polarisation sense shall be RHC (Right Hand Circular) according to RD-12.

*

2.2.2 Telecommand Format Standard

Reference HP-SGICD-COM-TC-020

The telecommand format shall follow the Packet Telecommand Standard, PSS-04-107 **[AD-2]**.

*

2.2.3 Ranging Signal

For the ESA ground station(s) the ranging signal is in accordance with the Ranging Standard **[AD-4]**.

Reference HP-SGICD-COM-TC-025

The selected tone frequency shall be 698260 Hz, providing 10 kHz offset from SPL-null.

*

2.2.4 Modulation

Reference HP-SGICD-COM-TC-030

The telecommand modulation scheme shall be PCM(NRZ-L)/PSK/PM on a sinusoidal sub-carrier. The selected subcarrier frequency is 16 kHz.

*

The ranging signal directly phase modulates (PM) the uplink carrier. For simultaneous ranging and telecommand, the two signals are added prior to phase modulation of the uplink carrier.

2.2.5 Telecommand Bit Rates

Reference HP-SGICD-COM-TC-035

The following telecommand bit rates shall be used. These bit rates refer to the digital bit stream at the physical layer, consisting of CLTUs and Idle/Acquisition sequences.

Herschel/Planck

125 bps

4 kbps

*

2.2.6 Uplink Sweep

Reference **HP-SGICD-COM-TC-040**

The uplink sweep shall be implemented according to the following limitations:

- The range shall cover the maximum doppler shift of +/- 130 kHz
- The rate shall be 500 Hz/s
- The telecommand sweep shall be possible to complete within 3 minutes (TBC)
- The maximum sweep discontinuity shall be 1 Hz

*

2.2.7 Telecommand Specific Requirements

The following requirements have been defined based on the telecommand rejections observed in orbit with the XMM satellite, namely related to:

- Telecommand chain selection with multiple channels
- Loss of bit synchronisation with telecommands containing long series of " Zeroes ".

2.2.7.1 Telecommand Chain Selection

Reference **HP-SGICD-COM-TC-045**

When the on-board telecommand chain features multiple input channels, the selection process of the active input channel shall insure that the probability of maximum length frame rejection (or abandonment of CLTU) is less than 10^{-3}. This probability of rejections is defined:

- in worst case conditions (spacecraft attitude, distance from ground station);
- when the Bit Error Rate at any input of the telecommand decoder is less than 10^{-5};
- when the same valid CLTU is arriving quasi-simultaneously at several inputs of the telecommand decoder, with different signal to noise ratios;
- when the A/D commanding service is enabled

*

2.2.7.2 Loss of Bit Synchronization

Reference **HP-SGICD-COM-TC-050**

Telecommands with a minimum bit transition density of 3 % at code-block level (coding layer) and uplinked at a the Herschel/Planck bit rates of section 2.2.5 shall be decoded and distributed on-board with a rejection rate of less than 10^{-3}, in worst case conditions (spacecraft attitude, distance from ground station, etc.)

Note: The Telecommand delivery system shall be able to handle CCSDS CLTUs **[RD-8]** containing the lowest allowed transition density. This worst case condition shall not cause a loss in the demodulation process exceeding 0.2 dB when compared with 50% transition density.

*

3. OPERATIONAL UTILISATION

3.1 Operational Modes

3.1.1 Modulation Modes

Reference **HP-SGICD-COM-OPS-005**

The telecommunication subsystem shall support the following modes for the up link:

- unmodulated carrier
- command
- ranging
- command and ranging

*

Reference **HP-SGICD-COM-OPS-010**

The following operational modes shall be supported for the downlink:

- unmodulated carrier
- telemetry
- ranging
- telemetry and ranging

*

3.1.2 Transponder Modes

Reference **HP-SGICD-COM-OPS-015**

The transponder shall be operable both in coherent and in non-coherent mode depending on the lock status of the receiver. The transponder mode shall be capable of being set by telecommand.

*

In the coherent mode, the transmitter shall operate coherent to the receiver as soon as the receiver is locked. If the receiver loses lock, the transmitter shall go to non-coherent and return to the coherent mode, after the receiver gets locked.

In the non-coherent mode, the transmitter shall remain non-coherent, until it receives a telecommand to go coherent and the receiver indicates the lock of the uplink signal.

3.1.3 Antenna Switching

The transmitter, the HPA and the antenna shall be able to be independently selected as prime or redundant, including cross strapping. In principle any combination of transmitter connection to antenna shall be possible.

The two hot redundant receivers shall be able to be connected to any two of the antennas, nominally to the same antennas to which their respective transmitters are connected. There shall also be receiver cross strapping such to ensure reception of telecommands through the transmitting antenna, even when either one of the receivers has failed.

A pictorial view of the above specified switching scheme is given in figure 3.1 below.

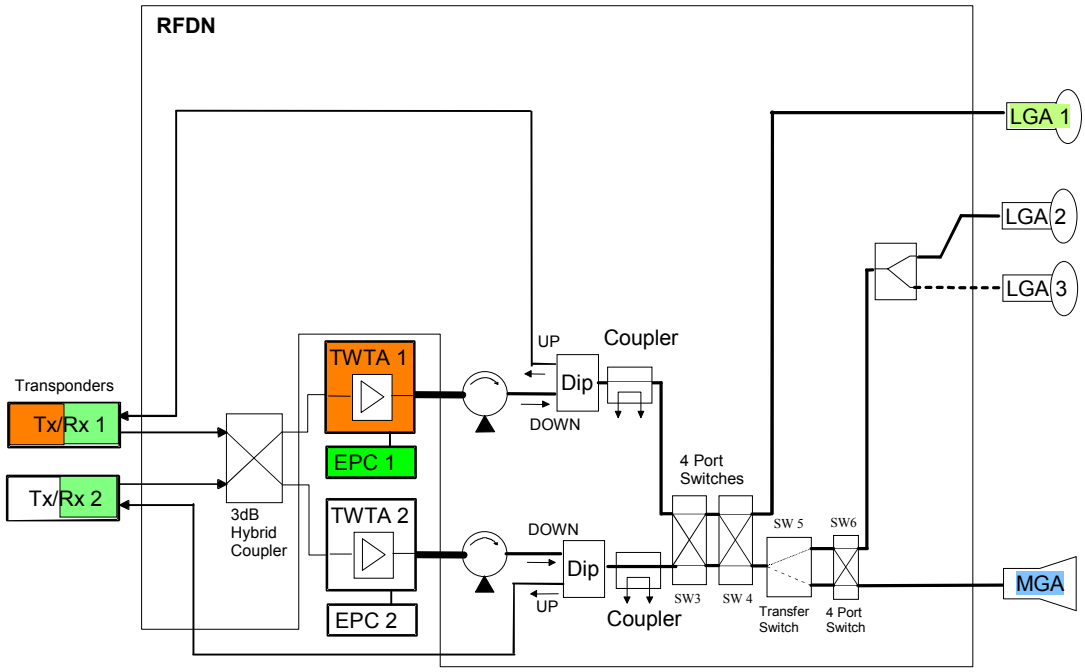

FIG. 3.1 – ON-BOARD TTC SYSTEM SCHEMATICS.

3.2 Command Operations Procedure (COP-1)

Reference **HP-SGICD-COM-OPS-020**

The Command Operations Procedure COP-1 shall be supported. Within COP-1, the packet telecommand services AD and BD shall be supported in parallel.

*

4. PERFORMANCE

4.1 Spacecraft

4.1.1 Up Link Parameters (On-Board Reception)

Reference **HP-SGICD-COM-PER-005**

The up link parameters for Herschel shall be as summarised in Table 4-1:

*

Table 4-1: Herschel Uplink Spacecraft Parameters

		NOM	ADV	FAV
Antenna gain[dBi]	LGA	-3 dBi TBC	-3 dBi TBC	-2.8 dBi TBC
	MGA (10°)	16 dBi TBC	15.6 dBi TBC	16 dBi TBC
Polarisation		RHC		
Axial ratio[dB]	LGA	<4 dB	<4 dB	<4 dB
	MGA	<1.5 dB	<1.5 dB	<1.5 dB
Pointing losses	LGA	NA	NA	NA
	MGA	NA	NA	NA
Circuit losses [dB]	LGA	TBC	TBC	TBC
	MGA	TBC	TBC	TBC
Antenna noise temperature[°K]	LGA	100 TBC	100 TBC	100 TBC
	MGA	120 TBC	120 TBC	120 TBC
Receiver noise figure [dB]		2 TBC	2 TBC	1.8 TBC
Ranging on-board Channel bandwidth (double-sided) [MHz]		1.4 TBC	1.4 TBC	1.4 TBC
Loop bandwidth at threshold (double-sided) [Hz]		100 TBC	120 TBC	80 TBC
Input signal range [dBm]		-141 to -60	-141 to -60	-141 to -60
Receiver telecommand threshold at 300 °K [dBm]		-135 dBm TBC	-135 dBm TBC	-135 dBm TBC
Implementation losses [dB]	Carrier	1 dB TBC	1 dB TBC	1 dB TBC
	Telecommand	1.3 dB TBC	1.3 dB TBC	1.3 dB TBC

	Ranging	1.3 dB TBC	1.3 dB TBC	1.3 dB TBC
Modulation index [rad]	Telecommand	1	(*) ±5%	(*) ±5%
	Ranging	> 0.65	(*) ±5%	(*) ±5%

(*) plus or minus to be taken favourable or adverse as required by the computed parameters, e.g. +5% is favourable to the telecommand recovery but adverse for the carrier and ranging recovery.

Reference **HP-SGICD-COM-PER-010**

The up link parameters for Planck shall be as summarised in Table 4-2:

*

Table 4-2: Planck Uplink Spacecraft Parameters

		NOM	ADV	FAV
Antenna gain[dBi]	LGA	-3 dBi TBC	-3 dBi TBC	-2.8 dBi TBC
	MGA (10°)	16 dBi TBC	15.6 dBi TBC	16 dBi TBC
	MGA (15°)	13 dBi TBC	12.8 dBi TBC	13 dBi TBC
Polarisation		RHC		
Axial ratio[dB]	LGA	<4 dB	<4 dB	<4 dB
	MGA	<1.5 dB	<1.5 dB	<1.5 dB
Pointing losses	LGA	NA	NA	NA
	MGA	NA	NA	NA
Circuit losses [dB]	LGA	TBC	TBC	TBC
	MGA	TBC	TBC	TBC
Antenna noise temperature[°K]	LGA	100 TBC	100 TBC	100 TBC
	MGA	120 TBC	120 TBC	120 TBC
Receiver noise figure [dB]		2 TBC	2 TBC	1.8 TBC
Ranging bandwidth (double-sided) [MHz]		1.4 TBC	1.4 TBC	1.4 TBC
Loop bandwidth at threshold (double-sided) [Hz]		100 TBC	120 TBC	80 TBC
Input signal range [dBm]		-141 to -60	-141 to -60	-141 to -60
Receiver telecommand threshold at 300 °K [dBm]		-135 dBm TBC	-135 dBm TBC	-135 dBm TBC
Implementation losses [dB]	Carrier	1 dB TBC	1 dB TBC	1 dB TBC
	Telecommand	1.3 dB TBC	1.3 dB TBC	1.3 dB TBC
	Ranging	1.3 dB TBC	1.3 dB TBC	1.3 dB TBC
Modulation index [rad]	Telecommand	1	(*) ±5%	(*) ±5%
	Ranging	> 0.65	(*) ±5%	(*) ±5%

(*) plus or minus to be taken favourable or adverse as required by the computed parameters, e.g. +5% is favourable to the telecommand recovery but adverse for the carrier and ranging recovery.

4.1.2 Down Link Parameters

Reference **HP-SGICD-COM-PER-015**

The down link parameters for Herschel shall be as summarised in Table 4-3:

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Table 4-3: Herschel Downlink Spacecraft Parameters

		NOM	ADV	FAV
TT&C S/S output power [dBW]		14.77	14.77	14.77
Circuit losses [dB]	LGA	TBC	TBC	TBC
	MGA	TBC	TBC	TBC
Antenna gain[dBi]	LGA	-3 dBi TBC	-3 dBi TBC	-2.8 dBi TBC
	MGA	16 dBi TBC	15.6 dBi TBC	16 dBi TBC
Pointing losses [dB]	LGA	NA	NA	NA
	MGA	NA	NA	NA
Polarisation		RHC		
Axial ratio[dB]	LGA	<4 dB	<4 dB	<4 dB
	MGA	<1.5 dB	<1.5 dB	<1.5 dB
Modulation index [rad]	Telemetry	1.2 TBC	(*) ±10%	(*) ±10%
	Ranging	0.7 TBC	(*) ±10%	(*) ±10%

(*) plus or minus to be taken favourable or adverse as required by the computed parameters, e.g. +10% is favourable to the telemetry recovery but adverse for the carrier and ranging recovery.

The combined telemetry and ranging modulation index shall in any case result in carrier suppressions of more than or equal to 15 dB.

The telemetry modulation index is not applicable for high rate telemetry.

Reference HP-SGICD-COM-PER-020

The down link parameters for Planck shall be as summarised in Table 4-4:

*

Table 4-4: Planck Downlink Spacecraft Parameters

		NOM	ADV	FAV
Transmitter output power [dBW]		14.77	14.77	14.77
Circuit losses [dB]	LGA	TBC	TBC	TBC
	MGA	TBC	TBC	TBC
Antenna gain[dBi]	LGA	-3 dBi TBC	-3 dBi TBC	-2.8 dBi TBC
	MGA (10°)	16 dBi TBC	15.6 dBi TBC	16 dBi TBC
	MGA (15°)	13 dBi TBC	12.8 dBi TBC	13 dBi TBC
Pointing losses [dB]	LGA	NA	NA	NA
	MGA	NA	NA	NA
Polarisation		RHC		
Axial ratio[dB]	LGA	<4 dB	<4 dB	<4 dB
	MGA	<1.5 dB	<1.5 dB	<1.5 dB
Modulation index[rad]	Telemetry	1.2 TBC	(*) ±10%	(*) ±10%
	Ranging	0.7 TBC	(*) ±10%	(*) ±10%

(*) plus or minus to be taken favourable or adverse as required by the computed parameters, e.g. +10% is favourable to the telemetry recovery but adverse for the carrier and ranging recovery.

The combined telemetry and ranging modulation index shall in any case result in carrier suppressions of more than or equal to 15 dB.

The telemetry modulation index is not applicable for high rate telemetry.

4.1.3 Transponder Requirements

The requirements to be satisfied by the transponder are comprised in the Radio Frequency and Modulation Standard **[AD-5]** and the Ranging Standard **[AD-4]**. The detailed requirements to be applied to the transponder and agreed with the ESA project office are comprised in **[RD-6]**.

4.2 Ground Stations

The performance characteristics together with the foreseen equipment configurations for the ESA ground stations are depicted in paragraph 4.2.1 to 4.2.3.

4.2.1 Kourou 15m, French Guyana

Reference **HP-SGICD-COM-PER-025**

The Kourou ground station parameters shall be as summarised in the table below:

*

Kourou 15m, French Guyana				
Geographical Co-ordinates: Longitude East [deg]		-52.80		
Latitude North [deg]		5.25		
UPLINK Antenna polarisation		LHC or RHC		
Antenna gain [dB]		$56.7_{X\text{-Band}}$		
DOWNLINK Antenna polarisation		any		
Antenna gain [dB]		$60.0_{X\text{-Band}}$		
TIMING system synchronisation to UTC [microsec]		5.0		
		NOM	ADV	FAV
Atmospheric loss* [dB]		1.00	1.00	0.50
Ionospheric loss [dB]		0.00	0.00	0.00
UPLINK				
EIRP (300-W HPA X-Band [dBW]		81.00	80.00	81.00
Pointing Loss [dB]		0.05	0.12	0.00
Axial Ratio [dB]		0.50	1.00	0.00
DOWNLINK				
Effective G/T at 10° elevation X-Band [dB/K]		38.00	37.50	38.00
Pointing Loss X-Band [dB]		0.30	0.40	0.00
Axial Ratio [dB]		0.50	1.25	0.00
Carrier loop bandwidth $2B_L$: continuous 0.3 - 3000 [Hz]		NOM	+20%	-20%
TM demodulation technological losses [dB]		0.40	0.50	0.30
Ranging Tone Loop Bandwidth [rad/sec]		10^{-3} to 1.5		
Required Ranging Loop S/N [dB]		19.00	19.00	19.00
Required C/N in $2B_L$ for no data degradation [dB]		RESIDUAL CARRIER: 17		
[dB]		SUPPRESSED CARRIER: 25		
Required TM E_b/N_0 [dB]		see **[AD-3]**		
STATION EQUIPMENT (for information): Low Noise Amplifier		100-K $FET_{X\text{-Band}}$		
Receiver		IFMS		
Demodulators		IFMS		
Telemetry		TMTCS		
Decoders		TCDS		
Telecommand		TMTCS		
Tracking		IFMS		
Data Communications		TCP/IP based equipment		
Timing System		CESIUM + GPS		
Station Control		STC2, FEC, MCM3		

* 95% probability at 10^0 elevation, for 99% probability the losses are [dB]: 2.6 / 3.1 / 2.1

4.2.2 Vilspa 15m, Spain

Reference **HP-SGICD-COM-PER-030**

The Vilspa ground station parameters shall be as summarised in the table below:

*

Vilspa 15m, Spain				
Geographical Co-ordinates: Longitude East [deg]		3^0 57' 4.6026" W		
Latitude North [deg]		40 26' 48.3941" N		
UPLINK Antenna polarisation		LHC or RHC		
Antenna gain [dB]		$56.3_{X\text{-Band}}$		
DOWNLINK Antenna polarisation		any		
Antenna gain [dB]		$58.6_{X\text{-Band}}$		
TIMING system synchronisation to UTC [microsec]		5.0		
		NOM	ADV	FAV
Atmospheric loss* [dB]		1.00	1.00	0.50
Ionospheric loss [dB]		0.00	0.00	0.00
UPLINK				
EIRP (300-W HPA X-Band [dBW]		81.00	80.00	81.00
Pointing Loss [dB]		0.05	0.12	0.00
Axial Ratio [dB]		0.50	1.00	0.00
DOWNLINK				
Effective G/T at 10° elevation X-Band [dB/K]		35.70	35.20	36.70
Pointing Loss X-Band [dB]		0.30	0.40	0.00
Axial Ratio [dB]		0.50	1.25	0.00
Carrier loop bandwidth $2B_L$: continuous 0.3 - 3000 [Hz]		NOM	+20%	-20%
TM demodulation technological losses [dB]		0.40	0.50	0.30
Ranging Tone Loop Bandwidth [rad/sec]		10^{-3} to 1.5		
Required Ranging Loop S/N [dB]		19.00	19.00	19.00
Required C/N in $2B_L$ for no data degradation [dB]		RESIDUAL CARRIER: 17		
[dB]		SUPPRESSED CARRIER: 25		
Required TM E_b/N_0 [dB]		see **[AD-3]**		
STATION EQUIPMENT (for information): Low Noise Amplifier		$100\text{-K FET}_{X\text{-Band}}$		
Receiver		IFMS		
Demodulators		IFMS		
Telemetry		TMTCS		
Decoders		TCDS		
Telecommand		TMTCS		
Tracking		IFMS		
Data Communications		TCP/IP based equipment		
Timing System		CESIUM + GPS		
Station Control		STC2, FEC, MCM3		

* 95% probability at 10^0 elevation, for 99% probability the losses are [dB]: 2.6 / 3.1 / 2.1

4.2.3 New Norcia 35m, Australia

Reference **HP-SGICD-COM-PER-035**

The New Norcia ground station parameters shall be as summarised in the table below:

*

New Norcia 35m, Australia				
Geographical Co-ordinates:	Longitude East [deg]	116.21		
	Latitude North [deg]	-30.97		
UPLINK	Antenna polarisation	LHC or RHC		
	Antenna gain [dB]	$64.3_{X\text{-}Band}$		
DOWNLINK	Antenna polarisation	Any		
	Antenna gain [dB]	$68.0_{X\text{-}Band}$		
TIMING system synchronisation to UTC [microsec]		5.0		
		NOM	ADV	FAV
	Atmospheric loss* [dB]	0.50	0.60	0.40
	Ionospheric loss [dB]	0.00	0.00	0.00
UPLINK				
EIRP (2 kW HPA) at 10° elevation	X-Band [dBW]	97.0	96.0	97.6
EIRP (20 kW HPA*) at 10° elevation *In emergency or for Deep Space missions	X-Band [dBW]	107.0	106.0	107.6
Pointing Loss	[dB]	0.10	0.20	0.00
Axial Ratio	[dB]	0.50	1.00	0.00
DOWNLINK				
Effective G/T at 10° elevation	X-Band [dB/K]	50.1	49.6	50.1
Pointing Loss	X-Band [dB]	0.30	0.40	0.00
Axial Ratio	[dB]	0.50	1.00	0.00
Carrier loop bandwidth $2B_L$: continuous 0.3 - 3000	[Hz]	NOM	+20%	-20%
TM demodulation technological losses	[dB]	0.40	0.50	0.30
Ranging Tone Loop Bandwidth	[rad/sec]	10^{-3} to 1.5		
Required Ranging Loop S/N	[dB]	19.00	19.00	19.00
Required C/N in $2B_L$ for no data degradation	[dB]	RESIDUAL CARRIER: 17		
	[dB]	SUPPRESSED CARRIER: 25		
Required TM E_b/N_0	[dB]	see **[AD-3]**		
STATION EQUIPMENT (for information):	Low Noise Amplifier	20-K HEMT		
	Receiver	IFMS		
	Demodulators	IFMS		
	Telemetry	TMTCS		
	Decoders	TCDS		
	Telecommand	TMTCS		
	Tracking	IFMS		
	Data Communications	TCP/IP based equipment		
	Timing System	H-Maser + GPS		
	Station Control	STC2, FEC, MCM3		

* 95% probability at 10^0 elevation, for 99% probability the losses are [dB]: 1.0 / 1.2 / 0.8

4.3 Required Links

4.3.1 Required Link Performance

Reference HP-SGICD-COM-PER-040

The link budgets shall be computed as defined in ESA PSS-04-105 **[AD-5]**, that means including nominal, adverse, favourable, mean - 3 sigma and worst case RSS (Root Sum Square). The minimum values of those margins shall be:

- nominal: $\geq$ 3 dB
- RSS worst case: $\geq$ 0 dB
- mean - 3 sigma: $\geq$ 0 dB

*

The link budget margins shall be computed under the following assumptions:

- Telemetry :

  telemetry bit error rate associated with 99.999% of transfer frame delivery for concatenated coding (probability of frame loss = 10^{-5});The required Eb/No for obtaining the above specified probability of frame loss is 2.7 dB for concatenated encoding (I=5) compliant with **[AD-3].**
- Telecommand : The requirements of ESA PSS-04-105 **[AD-2]**, chapter 5 are applicable.
- Ranging : see ESA PSS-04-104, Volume I **[AD-4]** .

4.3.2 Ground Station Network

The ground station network to support the required telemetry, telecommand and tracking links will be as follows:

Station	LEOP	L2 Transfer	Commissioning	Performance Verification	Science
Kourou 15m	**Yes**	**Yes**	**Yes**	**TBD**	**No**
Vilspa 15m	**Yes**	**No**	**No**	**No**	**No**
New Norcia 35m	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

4.3.3 Link Budget Formats and Definitions

Reference **HP-SGICD-COM-PER-010**

Any link budget calculations shall be presented in a standard format as specified in Appendix 3, and shall further include summary tables and graphical presentations for both uplink and downlink.

*

Reference **HP-SGICD-COM-PER-015**

The link budgets for maximum distances shall be verified for both ranging on (with exception of high rate telemetry) and off for the following information rates:

Herschel/Planck

Uplink	**X-Band**		
	LGA	**LGA**	**MGA**(*)
Kourou 15m	125 bps	4 kbps(***)	4 kbps
New Norcia 35m	4 kbps		4 kbps
Downlink	**X-Band**		
	LGA	**LGA**	**MGA**(*)
Kourou 15m	500 bps	5 kbps(****)	150 kbps(**)
New Norcia 35m	5 kbps		1.5 Mbps

(*) The MGA operational range shall be:
- Herschel +z- axis – earth angle <= 15 deg
- Planck spin axis – earth angle <= 15 deg

(**) For TM to Kourou the MGA operational range may be restricted to
- Herschel +z- axis – earth angle <= 10 deg
- Planck spin axis – earth angle <= 10 deg

(***) Maximum distance shall be at least 350000 km.

(****) Maximum distance shall be at least 750000 km.

*

Note: The nominal acquisition/closing sequence at New Norcia will be:

1. Signal acquisition at medium rate
2. Ranging for some minutes
3. Switch to high rate

.

.

4. Return to medium rate
5. Ranging for some minutes

6. LOS

4.4 RF Compatibility Test

A spacecraft/ground station pre-RF compatibility test will be performed according to the test procedures and results as documented in the Herschel/Planck RF Test Procedure and Report **[RD-10]**.

To confirm RF compatibility between the spacecraft and the ground segment, an RF suitcase model shall be provided by the contractor according to the requirements in section 6.8.5 of **[RD-14]**. The suitcase shall comprise flight representative hardware (EM units) sufficient to test all up- and down-links for both functional and performance characteristics. This shall include verification of all telemetry, telecommand and ranging functions, and combination thereof, as well as spectral analyses and link budget verification.

Reference **HP-SGICD-COM-PER-025**

The RF suitcase shall be delivered to ESOC at the latest *L-24 months*, and shall be available for at least 1 month. Together with the RF suitcase model, a RF suitcase description and operations manual shall be delivered, such that operation of the suitcase by ESOC technical personnel is possible without the need for assistance from Industry.

*

The RF detailed suitcase requirements and interfaces are described in **[RD-3]**. The suitcase will include at least the following:

- a TTC subsystem including the RF switch(es);
- those data handling subsystem units required for the generation of telemetry. The telemetry shall contain transfer frames in the same layout as during flight with representative packets;
- those data handling subsystem units required for the reception of commands, including the support of lower level protocols, e.g. COP-1.

5. TELEMETRY STRUCTURE

5.1 Telemetry Source Packet

Reference HP-SGICD-STR-TM-005

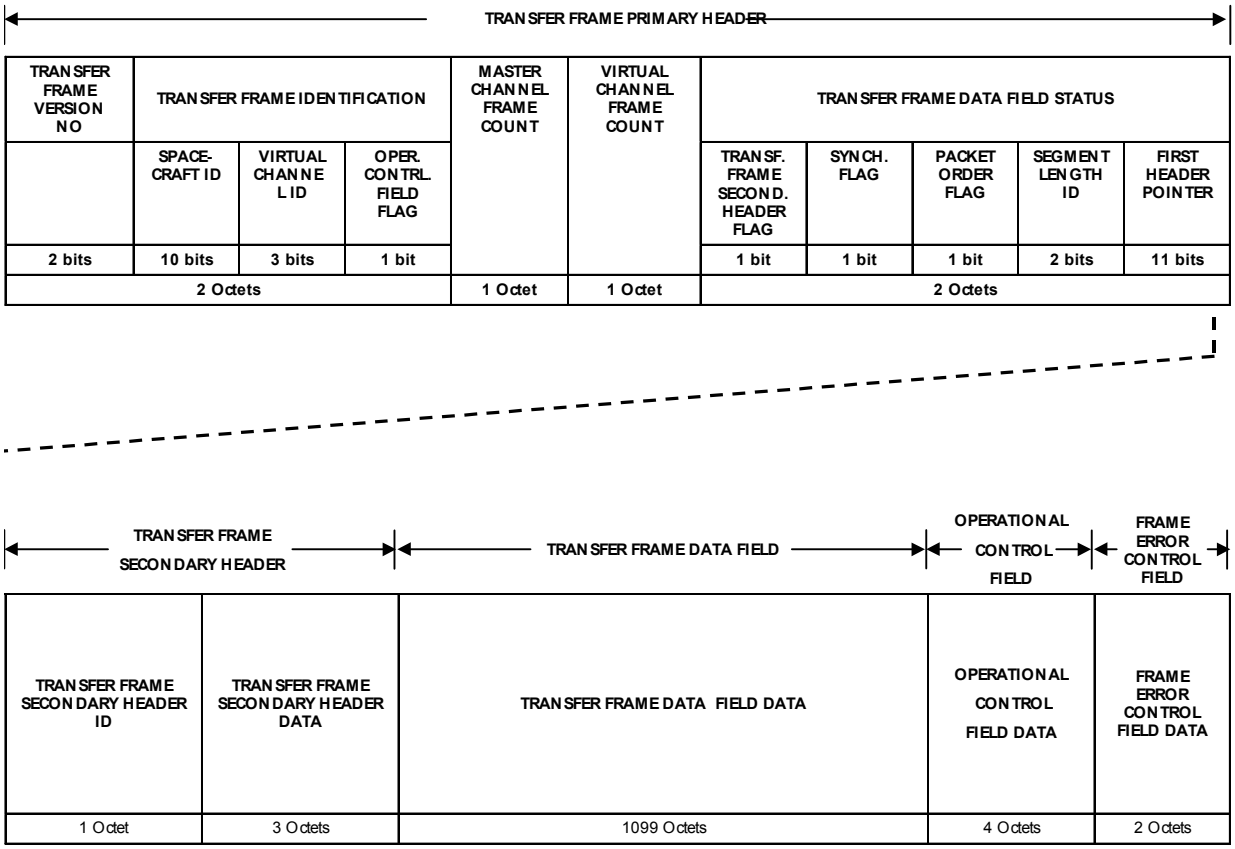
All telemetry Source Packets must conform to the structure defined in **[AD-1]** and detailed in **[RD-9].**

*

5.2 Telemetry Transfer Frame

Reference HP-SGICD-STR-TM-010

All telemetry Transfer Frames must conform to the structure defined in **[AD-1]** with the remarks listed here below.



*

5.2.1.1 Transfer Frame Length

Reference **HP-SGICD-STR-TM-015**

The only allowed frame length (before encoding) shall be 1115 octets (i.e. 8920 bits).

*

5.2.1.2 Version Number

Reference **HP-SGICD-STR-TM-020**

The Version Number shall be set to 00_{BIN}.

*

5.2.1.3 Spacecraft ID

Reference **HP-SGICD-STR-TM-025**

The following Telemetry Spacecraft Identification (TM S/C ID) has been assigned:

	HEX	DEC
Herschel Flight Model	**1E6**	**486**
Planck Flight Model	**1E9**	**489**
Avionics Model	**1EA**	**490**

*

5.2.1.4 Virtual Channel ID

Reference **HP-SGICD-STR-TM-030**

Data sources on board will be allocated a virtual channel number to identify them to the ground processing facilities as follows:

VC0 Real Time essential spacecraft HK and critical instruments HK

VC1 Real Time Science data

VC2 Stored spacecraft HK and instruments HK (periodic and non-periodic)

VC3 Stored science data

VC4 Real Time routine spacecraft HK and routine instruments HK (periodic and non-periodic)

VC5 Not Required

VC6 Not Required

VC7 Idle Frames (A full frame where the data field is filled with random data)

*

Reference HP-SGICD-STR-TM-035

Virtual Channel ID 7 shall contain only Idle Frames, the term «Idle Frame» meaning a Transfer Frame containing (only) Idle Data in its Transfer Frame Data Field. In fact, a Transfer Frame containing (only) Idle Data in its Transfer Frame Data Field, can still carry non-idle information outside the Transfer Frame Data Field and then be used for «active» purposes (e.g. extraction of the CLCW in the OCF for the Telecommand protocol; reference Time for time calibration procedures, etc.) Other Virtual Channels may contain Idle Packets if no data is available when they have to be transmitted.

*

Reference HP-SGICD-STR-TM-040

It shall be possible to downlink any combination of VC's independent of the selected bit rate.

*

Reference HP-SGICD-STR-TM-045

It shall be possible to downlink partially filled frames by completing the frame with an idle packet.

*

Reference HP-SGICD-STR-TM-050

The priority scheme for downlinking of VCs will be:

1. VC0 when ready or when a time packet should be sent
2. VC4 when ready and no VC0 available
3. VC2 when ready and no VC0 or VC4 available
4. VC1 when ready and no VC0 or VC4 or VC2 available
5. VC3 when ready and no VC0 or VC4 or VC2 or VC1 available
6. VC7 Idle Frames - when no other data is available

Note: If a VC frame is not completely filled with real data, the VC frame shall be filled up with one (or more) idle packet(s) and sent before VC7 begins to send idle frames.

*

5.2.1.5 Operational Control Field Flag

Reference HP-SGICD-STR-TM-055

The Operational Control Field Flag shall be set to 1 and a Command Link Control Word (CLCW) shall be inserted in the Operational Control Field (OCF) for all frames.

*

5.2.1.6 Master Channel Frame Count Field

Reference **HP-SGICD-STR-TM-060**

The Master Channel Frame Count field shall contain a sequential binary count (modulo 256) of each Transfer Frame transmitted within the Herschel/Planck specific Master Channel. A re-setting of the MASTER CHANNEL FRAME COUNT before reaching 255 shall not take place unless it is unavoidable. Any case when it is unavoidable shall be documented in the Spacecraft User Manual.

*

5.2.1.7 Virtual Channel Frame Count Field

Reference **HP-SGICD-STR-TM-065**

The Virtual Channel Frame Count field shall contain a sequential binary count (modulo 256) of each Transfer Frame transmitted through a specific Virtual Channel of a Master Channel. A re-setting of the Virtual Channel Frame Count before reaching 255 shall not take place unless it is unavoidable. Any case when it is unavoidable shall be documented in the Spacecraft User Manual.

*

5.2.1.8 Secondary Header Flag

Reference **HP-SGICD-STR-TM-070**

The Secondary Header shall always be set to one indicating a secondary header shall be inserted in the frame.

*

5.2.1.9 Data Field Synchronisation Flag

Reference **HP-SGICD-STR-TM-080**

The Data Field Synchronisation Flag shall be set to zero; i.e. octet-synchronised and forward-ordered Telemetry Source Packet or Idle Data (only for VC7) shall be inserted in the Transfer Frame Data Field.

*

5.2.1.10 Packet Order Flag

Reference **HP-SGICD-STR-TM-085**

The Packet Order Flag shall be set to zero. The Packet sequence count order shall be **forward**.

*

5.2.1.11 Segment Length Identifier

Reference **HP-SGICD-STR-TM-090**

Since the Data Field Synchronisation Flag is set to zero, the Segment Length Identifier shall be set to 11_{BIN}.

*

5.2.1.12 First Header Pointer

Reference **HP-SGICD-STR-TM-095**

Since the Synchronisation Flag is set to zero, the First Header Pointer shall contain information on the position of the first Telemetry Source Packet within the Transfer Frame Data Field; i.e. the binary representation of the location of the first octet of the first Packet Primary Header. *The locations of any subsequent headers within the same Transfer Frame Data Field will be determined by calculating these locations using the Packet Data Length Field.*

*

Reference **HP-SGICD-STR-TM-100**

If no Packet Primary Header starts in the Transfer Frame Data Field, the First Header Pointer shall be set to «11111111111» $_{BIN}$.

*

Reference **HP-SGICD-STR-TM-105**

For Idle Frames (VC7) the First Header Pointer shall be set to «11111111110» $_{BIN}$.

*

5.2.1.13 Secondary Header

Reference **HP-SGICD-STR-TM-110**

A Transfer Frame Secondary Header shall be inserted in all frames. This shall contain a header and an expansion of the virtual channel frame counter.

*

Secondary Header ID

Reference **HP-SGICD-STR-TM-115**

The secondary header ID shall be 8 bits in length and shall indicate the version number and the header length for Herschel/Planck, this shall be set to $00000011_{BIN.}$

*

Secondary Header Data

Reference HP-SGICD-STR-TM-120

The secondary header data shall be a 3 Octet field containing an additional 24 bits of the virtual channel frame count as defined in **[AD-1]**.

*

5.2.1.14 Operational Control Field

Reference HP-SGICD-STR-TM-125

The Operational Control Field shall be inserted in each frame and it shall contain the CLCW (i.e. the Type-Flag shall be set to zero) with the format defined in **[AD-2]**.

Control Word Type	CLCW Version	Status Field	COP in Effect	Virtual Channel Identification	Spare
1	2	3	2	6	2
"0"	"00"	"000"	"01"		"00"

Flags					Farm B Counter	Report Type	Report Value
No RF Available	No Bit Lock	Lock-out	Wait	Retransmit			
1	1	1	1	1	2	1	8
						"0"	

*

Reference HP-SGICD-STR-TM-130

The values of the (Telecommand) VC Identifiers inserted in the CLCWs shall be consistent with those used for the Telecommand Frames.

*

Reference HP-SGICD-STR-TM-135

The CLCW Standard Insertion Scheme No. 2 defined in **[AD-2]** is applied as follows:

CLCWs with a VC ID belonging to the nominal Command Decoder are transmitted in the Transfer Frames with an even Master Channel Frame Count and CLCWs with a VC ID belonging to the redundant Command Decoder are transmitted in the Transfer Frames with an odd Master Channel Frame Count.

*

5.2.1.15 Frame Error Control Word

Reference **HP-SGICD-STR-TM-140**

The Frame Error Control Word shall be inserted in each frame.

*

6. TELECOMMAND STRUCTURE

6.1 Telecommand Source Packets

Reference HP-SGICD-STR-TC-005

All telecommand source packets (except those for distribution by the CPDU) must conform to the structure defined in **[AD-2]** and are detailed in **[RD-9]**

*

6.2 Telecommand Segments

Reference HP-SGICD-STR-TC-010

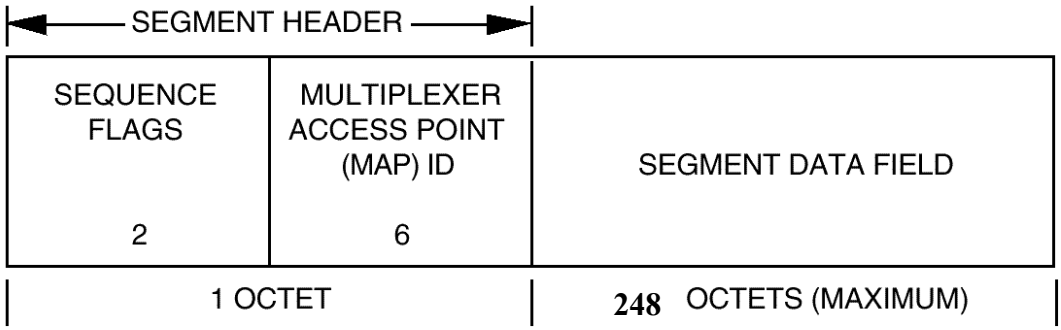
The Telecommand Segment defined in **[AD-2],** and shown in the figure below, shall be used as TC Frame Data Unit (i.e. the data unit transferred from the Segmentation Layer to the Transfer layer to be inserted in the Frame Data Field of the Telecommand Frame).

*

Reference HP-SGICD-STR-TC-015

The Segment Header shall contain the following two fields:

- Sequence Flags (Bits 0,1), and
- Multiplexer Access Point (MAP) Identifier (Bits 2 through 7)



*

6.2.1 Sequence Flags

Reference HP-SGICD-STR-TC-020

There shall be no command packet segmentation for Herschel/Planck, so the sequence flags shall be set to 11_{BIN}

*

6.2.2 Multiplexer Access Point (MAP) Identifier

Reference **HP-SGICD-STR-TC-025**

MAP ID's shall be used to route the telecommands from the decoder depending on the type of handling required for the command. The following MAP ID's are defined:

MAP ID	Destination
0	The CPDU connected to the current decoder
1	The active processor
2	The non-active processor
5	CROME reinitialise
6	Set TC only mode in the reconfiguration module connected to the current decoder

*

6.2.3 Packet Aggregation

Reference **HP-SGICD-STR-TC-030**

The Segment Data Field contains all or a portion of the higher layer TC User Data Unit, i.e. a TC Packet or an aggregation of TC Packets.

*

Reference **HP-SGICD-STR-TC-035**

In order to maximise the throughput of commands on the uplink, packet aggregation will be used where possible **[RD-8].** Aggregation is a CCSDS concept where several complete packets can be put into a single segment. Therefore at the start of a segment there will always be the start of a packet, the length of the first packet will define the start position of the next packet.

Segment Data Field		
Packet #1	Packet #2	Packet #3

(« Packet Length » of packet #1)+7octets = Start address Octet of Packet #2

Start address Octet of Packet #2+(« Packet Length » of packet #2)+7octets = Start address Octet of Packet #3

*

6.3 Telecommand Frame

Reference **HP-SGICD-STR-TC-040**

The Telecommand Frame must conform to the structure defined in **[AD-2]**.

Frame Header: 5 octets									Max 251 octets	
Version Number	Bypass Flag	Control Cmnd Flag	Spare	S/C ID	Virtual Channel ID	Reserved Field	Frame Length	Frame Sequence Number	Frame Data Filed	Frame Error Control
2	1	1	2	10	6	2	8	8		16
"00"			"00"			"00"				

*

6.3.1 Spacecraft ID

Reference **HP-SGICD-STR-TC-045**

The following Telecommand Spacecraft Identifications (TC S/C IDs) have been assigned:

	HEX	**DEC**
Herschel Flight Model	**1E6**	**486**
Planck Flight Model	**1E9**	**489**
Avionics Model	**1EA**	**490**

*

6.3.2 Virtual Channel ID

Reference **HP-SGICD-STR-TC-050**

The following two Virtual Channels Identifiers shall be used addressing the two on-board decoders:

VC ID	Decoder
0	A
1	B

These two values shall be used consistently in the CLCWs.

*

6.3.3 Frame Length

Reference **HP-SGICD-STR-TC-055**

This 10-bit field contains a length count «C» which equals one fewer than the total octets in the TC Transfer Frame. The count is measured from the first bit of the FRAME HEADER to the last bit of the FRAME ERROR CONTROL FIELD (if present), or the last bit of the FRAME DATA FIELD if the error control is omitted. The size of this field limits the maximum length of a TC Transfer Frame to 1024 octets. The length count «C» is expressed as:

«C» = (Total Number of Octets) - 1

*

Reference **HP-SGICD-STR-TC-060**

The maximum frame length allowed by **[AD-2]** and applicable to Herschel/Planck is 256 octets. Therefore the first two bits of the Frame Length field (Reserved Field B in **[AD-2]**) must always be set to 00_{BIN}, leaving an effective "ESA Frame Length Field" of 8 bits.

*

6.4 Telecommand Lower Layers

Reference **HP-SGICD-STR-TC-065**

All the telecommand lower layers data structures and procedures must conform to the structure defined in **[AD-2]**.

*

7. APPENDIX 1 CONVENTIONS

7.1 Bit Numbering Conventions

The following convention shall be used to identify each bit in an N-bit field :

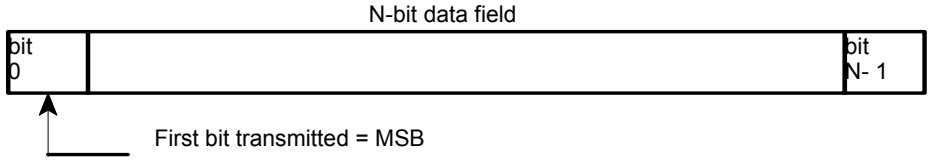


Figure A1.1 Bit numbering

Note about the first bit transmitted:

In all case except on the link IEEE1355, the first bit transmitted = MSB

In the particular case of the link IEEE1355, the first bit transmitted = LSB

However this is transparent to the space-ground link.

- The first bit in the field (starting from the left) is defined to be "Bit 0" and will be represented as the left most justified bit in a figure. The next bit is called "Bit 1", and so on, up to "Bit N-1", the bits being represented in this order from left to right in a figure.
- If the N-Bit field is to be interpreted as "Unsigned Integer" value, Bit 0 is the MSB and Bit N-1 is the LSB.
- If the N-Bit field is to be interpreted as "Signed Integer" value, Bit 0 indicates the sign with Bit 0 = 0 corresponding to a positive number and Bit 0 = 1 corresponding to a negative number.
- Adjacent groups of bits are described in terms of octets and words.
- Octet = 1 byte = 8 bits (1 word = 2 octets = 16 bits).

7.2 Field Alignment Conventions

The following convention shall be used to construct packet parameter fields:

- Parameters with a length longer or equal 16 bits shall be word aligned, i.e. the LSB shall coincide with the word boundary.
- Parameters with a length shorter than 16 bits shall not be allowed to span over word boundaries.
- Parameters with a length shorter than 16 bits shall be right-adjusted within the occupied 16-bit word, leaving any required padding-bits in the most significant bits of the 16-bit word.
- If more than one parameter is held in a single word the parameters shall be right adjusted.

8. APPENDIX 2 ACRONYMS AND GLOSSARY OF TERMS

8.1 Acronyms

Acronym	Description
ACK	Acknowledgement
AD	(short name) for Sequence-Controlled Service
AD	Applicable Document
ADV	Adverse
AOCMS	Attitude & Orbit Control and Measurement Subsystem
AOCS	Attitude & Orbit Control Subsystem
APID	Application Process Identifier
BD	(short name) for Expedited Service
BTb	Bandwidth Time bit (duration)
CCSDS	Consultative Committee for Space Data Systems
CDMU	Central Data Management Unit
CDS2A	CCSDS Day Segmented A
CLCW	Command Link Control Word
CLTU	Command Link Transfer Unit
C/N	Carrier-to-Noise ratio
COP1	Command Operation Procedure number 1
CPDU	Command Pulse Distribution Unit
CRC	Cyclic Redundancy Code
DEC	Decimal
DMS	Data Management System
Eb/NO	Energy per bit / Noise power density
EIRP	Equivalent Isotropic Radiated Power
EM	Engineering Model
ESA	European Space Agency
ESOC	European Space Operations Centre
FAV	Favourable
FEC	Front End Controller
GMSK	Gaussian Minimum Shift Keying
HEX	Hexadecimal
HGA	High Power Amplifier

Acronym	Description
HK	Housekeeping
HPA	High Power Amplifier
ICD	Interface Control Document
ID	Identifier
IFMS	Intermediate Frequency Mass System
ISO	International Standards Organisation
ISS	Integrated Switching System
LGA	Low Gain Antenna
LHC	Left Hand Circular
LNA	Low Noise Amplifier
LSB	Least Significant Bit
MAP	Multiplexed Access Point
MCM	Monitor and Control Module
MGA	Medium Gain Antenna
MOC	Mission Operations Centre
MPTS	MultiPurpose Tracking System
MSB	Most Significant Bit
N/A	Not Applicable
NOM	Nominal
NRZ-L	Non-Return to Zero-Level
OBCP	On Board Control Procedure
OCF	Operational Control Field
PCM	Pulse Code Modulation
PM	Phase Modulation
PSS	Procedures, Specifications and Standards
PSK	Phase Shift Keying
PUS	Packet Utilisation Standard
RF	Radio Frequency
RFDU	Radio Frequency Distribution Unit
RHC	Right Hand Circular
ROM	Read Only Memory
RT	Real Time
RTU	Remote Terminal Unit
Rx	Receiver
S/C	Spacecraft

Acronym	Description
SCET	Spacecraft Elapsed Time
SFCG	Space Frequency Coordination Group
S/N	Signal to Noise
SOC	Science Operations Centre
SP-L	Split Phase-Level
SRRC	Spare-Root Raised Cosine
STC	Station Computer
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
TC	Telecommand
TCE	Tele Command Equipment
TM	Telemetry
TTC	Telemetry and Telecommand
Tx	Transmitter
UTC	Universal Time Coordinated
VC	Virtual Channel

9. APPENDIX 3 LINK BUDGET FORMAT

LINK ID : P30SH1k
DATE : 01-08-97 09:18
ORBIT : MOP
STATION : New Norcia 35-m

ALTITUDE (1000km): 120000 (0.80 AU)
ELEVATION (deg): 10

TELECOMMAND BIT RATE (kb/sec) : 1.00
TELEMETRY BIT RATE (kb/sec) : 1.00
RS (1) or CONCAT. CODING (2) : 2

RANGING : No

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BASIC UPLINK (1/2)

	NOM	ADV	FAV	MEAN	VAR	PDF
G/S TX POWER.....dBW	33.00	33.00	33.00	33.00	0.00	TRI
CIRCUIT LOSS.....dB	0.20	0.60	0.00	0.30	0.03	UNI
TX ANT GAIN.....dBi	54.30	53.70	54.60	54.15	0.07	UNI
G/S ANT TX AXIAL RAT..dB	0.50	1.00	0.00			
POINTING LOSS.....dB	0.10	0.12	0.00	0.06	0.00	UNI
EIRP G/S.....dBW	87.00	85.98	87.60	86.79	0.10	
FREQUENCY.....GHz	2.11	2.11	2.11	2.11		
SLANT RANGE.....1000*km	120005	120005	120005	120005		
PATH LOSS.....dB	260.51	260.51	260.51	260.51		
ATMOSPHERIC LOSS.....dB	0.20	0.25	0.10	0.18	0.00	GAU
IONOSPHERIC LOSS.....dB	0.00	0.00	0.00	0.00	0.00	GAU
COPOLAR ANT-GAINS(Y=1/N=0)?	1					
POLARISATION MISMATCH.dB	0.01	0.03	0.00	0.01	0.00	UNI
TOTAL PROPAG. LOSS....dB	260.72	260.78	260.61	260.70	0.00	
POW.-FLUX at S/C.dBm/m^2	-115.58	-116.60	-114.98	-115.79		
RX ANT GAIN.....dBi	29.00	29.00	29.00	29.00	0.00	TRI
POINTING LOSS (*)..dB	0.00	0.00	0.00	0.00	0.00	TRI
S/C ANT RX AXIAL RAT..dB	1.00	1.00	1.00			
ANTENNA NOISE TEMP.....K	60.00	60.00	60.00			
ANTENNA/FEED VSWR.....:1	1.00	1.00	1.00			
VSWR LOSS.....dB	0.00	0.00	0.00	0.00	0.00	TRI
CABLE PHYSICAL TEMP....K	290.00	330.00	240.00			
CABLE LOSS.....dB	0.00	0.00	0.00	0.00	0.00	UNI
CIRCUITS TEMPERATURE...K	290.00	330.00	240.00			
RFDU CIRCUIT LOSS.....dB	3.00	3.00	3.00	3.00	0.00	UNI
TOTAL CIRCUIT & CABLE LOSS.....dB	3.00	3.00	3.00			
DIPL. CIRCUIT LOSS....dB	0.00	0.00	0.00	0.00	0.00	UNI
RECEIVER NOISE FIGURE.dB	2.50	2.50	2.00			
REF SYSTEM TEMP (**).K	515.70	515.70	459.62			
RX SYSTEM TEMP (***)..K	400.43	420.38	319.41			
RX SYSTEM TEMP (***)dBK	26.03	26.24	25.04	25.64	0.04	GAU
S/C RX G/T.....dB/K	-0.03	-0.24	0.96			
RX POWER (***).....dBm	-117.72	-118.80	-117.01	-117.91	0.10	
THEOR CAR THRSH(**)dBm	-148.47					
CAR ACQ THRSH (**).dBm	-150.00	-150.00	-150.00			
THEOR TC THRSH(**).dBm	-126.26					
TC RX THRSH (**).dBm	-147.00	-147.00	-147.00			
REQ RX POWER (***).dBm	-147.00	-147.00	-147.00	-147.00		
RX POWER MARGIN.....dB	29.28	28.20	29.99	29.09	0.10	
MEAN-3*SIGMA.....dB	28.15					
MARGIN - w.c. RSS..dB	28.56					
RX S/No.....dBHz	54.85	53.56	56.55	55.05	0.14	

*) POINTING LOSS may be included in RX ANTENNA GAIN.

**) Reference at Diplexer/RFDU Interface, 290 K input noise temperature.

***) Reference at Diplexer/RFDU Interface.

P30SH1k **PAGE 2/4**

LINK ID :
DATE : 01-08-97 09:18
ORBIT : MOP ALTITUDE (1000km): 120000
STATION : New Norcia 35-m ELEVATION (deg): 10

TELECOMMAND BIT RATE (kb/sec) : 1.000 RANGING : No
TELEMETRY BIT RATE (kb/sec) : 1.00 with CONCAT. CODING : Yes

UPLINK (2/2)

	NOM	ADV	FAV	MEAN	VAR	PDF
RX S/No.....dBHz	54.85	53.56	56.55	55.05	*0.14*	
MODULATION INDICES (*)						
TELECOMMAND.....rad pk	*1.00*	1.05	0.95	(sine)		
RANGING (RNG).....rad pk	*0.00*	0.00	0.00			
RNG, sine(1) or sqre(2):	*1*					
CARRIER RECOVERY						
CARRIER SUPPRESSION...dB	2.32	2.58	2.08	2.33	0.01	TRI
BPL (1), non-coh AGC (2)						
or coherent AGC (3) ?	*3*					
AGC INPUT BNDWDTH..kHz	*3.00*	3.30	2.70			
PLL-BDW 2*Blo (**)...Hz	*20.00*	24.00	16.00			
THRSHD C/N in 2*Blo...dB	*10.00*	(common Definition)				
PLL DAMPING (**).....	*0.71*	0.78	0.64			
Effect PLL DAMPING.....	0.71	0.78	0.64			
Effect PLL-BDW 2*Bl...Hz	20.00	24.00	16.00			
Max ACQ SWEEP RATE.kHz/s	0.03	0.02	0.04	0.03		
Effect PLL-BDW 2*Bl.dBHz	13.01	13.80	12.04	12.95	0.13	TRI
BP-LIMT SYSTEM LOSS...dB	0.00	0.00	0.00	0.00	0.00	TRI
IMPLEMENTATION LOSS...dB	*1.50*	*2.00*	*1.00*	1.50	0.04	TRI
REQ C/N in PLL-BDW....dB	*10.00*	10.00	10.00	10.00		
CARRIER MARGIN.....dB	28.02	25.17	31.43	28.27	0.32	
MEAN-3*SIGMA.....dB	26.57					
MARGIN - w.c. RSS..dB	26.79					
TELECOMMAND RECOVERY						
MODULATION LOSS.....dB	4.12	4.45	3.81	4.13	0.02	TRI
IMPLMENT LOSS (***)..dB	*1.50*	*2.00*	*1.00*	1.50	0.04	TRI
BIT RATE.....kb/s	1.000	1.000	1.000			
BIT RATE.....dBHz	30.00	30.00	30.00	30.00		
REQ Eb/No (****)..dB	*9.60*	9.60	9.60	9.60		
TELECOMMAND MARGIN....dB	9.63	7.50	12.14	9.83	0.20	
MEAN-3*SIGMA.....dB	8.49					
MARGIN - w.c. RSS..dB	8.67					
TRANSPD RANGING-CHANNEL						
TC in RNG-Vdbd ? Y=1/N=0	*0*					
TONE MODULATION LOSS..dB	No RG	No RG	No RG			
RNG NOISE BNDWIDTH...kHz	*3000.00*	3300.00	2700.00			
RNG NOISE BNDWIDTH..dBHz	64.77	65.19	64.31			
IMPLEMENTATION LOSS...dB	*1.46*	*1.60*	*1.20*			
S(Tone)/N in Videobd..dB	No RG	No RG	No RG			
S(TC)/N in RG-Videobd.dB	N.A.	N.A.	N.A.			

*) ADV and FAV Cases refer HERE to the Carrier Recovery !
Variation of the Preset Indices is +/- 5 % .
**) Reference at Carrier Acquisition Threshold.
***) Demod Loss until TC Video Output; TC Decoder Loss not included.
****) Includes TC Decoder Implementation Losses.

LINK ID : P30SH1k **PAGE 3/4**
DATE : 01-08-97 09:18
ORBIT : MOP ALTITUDE (1000km): 120000
STATION : New Norcia 35-m ELEVATION (deg): 10

TELECOMMAND BIT RATE (kb/sec) : 1.00 RANGING : No
TELEMETRY BIT RATE (kb/sec) : 1.00 with CONCAT. CODING : Yes

BASIC DOWNLINK (1/2)

	NOM	ADV	FAV	MEAN	VAR	PDF
S/C TX POWER.....dBW	*6.90*	*6.90*	*6.90*	6.90	0.00	TRI
DIPL. CIRCUIT LOSS....dB	*0.00*	*0.00*	*0.00*			
RFDU CIRCUIT LOSS.....dB	*3.00*	*3.00*	*3.00*			
CABLE LOSS.....dB	*0.00*	*0.00*	*0.00*			
VSWR, overall.....:1	*1.00*	*1.00*	*1.00*			
VSWR LOSSES.....dB	0.00	0.00	0.00			
TOTAL LOSS.....dB	3.00	3.00	3.00	3.00	0.00	UNI
S/C TX ANT GAIN.....dBi	*29.00*	*28.50*	*29.50*	29.00	0.04	TRI
S/C ANT TX AXIAL RAT..dB	*1.00*	*1.00*	*1.00*			
POINTING LOSS (*)..dB	*0.00*	*0.00*	*0.00*	0.00	0.00	TRI
EIRP S/C.....dBW	32.90	32.40	33.40	32.90	*0.04*	
FREQUENCY.....GHz	2.29	2.29	2.29	2.29		
SLANT RANGE.....1000*km	120005	120005	120005	120005		
PATH LOSS.....dB	261.22	261.22	261.22	261.22		
ATMOSPHERIC LOSS.....dB	0.20	0.25	0.20	0.23	0.00	GAU
IONOSPHERIC LOSS.....dB	*0.00*	*0.00*	*0.00*	0.00	0.00	GAU
COPOLAR ANT-GAINS(Y=1/N=0)?	*1*					
POLARISATION MISMATCH.dB	0.01	0.03	0.00	0.01	0.00	UNI
TOTAL PROPAG. LOSS....dB	261.44	261.50	261.42	261.46	*0.00*	
FLUX at G/S.....dBm/m^2	-169.68	-170.18	-169.18	-169.68	*0.04*	
POWER FLUX DENS..dBW/m^2	-201.78	-200.78	-202.90	(in 4 kHz)		
MAXIM FLUX DENS..dBW/m^2	-151.50	-151.50	-151.50	(S- or X-Bnd)		

FLUX MARGIN.....dB	50.28	49.28	51.40			
G/S RX ANT GAIN.....dBi	56.00	55.50	56.00	55.75	0.02	UNI
POINTING LOSS.....dB	*0.10*	*0.20*	*0.00*	0.10	0.00	UNI
G/S ANT RX AXIAL RAT..dB	*0.50*	*1.00*	*0.00*			
SYSTEM NOISE TEMP....dBK	18.50	18.50	18.00	18.25	0.01	GAU
RX G/T.....dB/K	37.50	37.00	38.00	37.50	*0.03*	
RX S/No.....dBHz	37.46	36.30	38.58	37.44	*0.07*	
S/N in RANGING BANDWIDTH						
S(Tone)/N in Videobd..dB	No RG	No RG	No RG			
S(TC)/N in RG-Videobd.dB	N.A.	N.A.	N.A.			
MODULATION INDICES (**)						
TELEMETRY (TM)....rad pk	*1.00*	1.10	0.90			
TM, sine(1) or sqre(2) :	*2*					
RANGING (sine)....rad pk	*0.00*	0.00	0.00			
RANG. TONE effec..rad pk	0.00	0.00	0.00			
TC in RG-Videobd..rad pk	0.00	0.00	0.00			
NOISE INDEX.....	0.00	0.00	0.00			

*) POINTING LOSS may be included in TX ANTENNA GAIN.

**) ADV and FAV Cases refer HERE to the Carrier Recovery !
Variation of the Preset Indices is +/- 10 % .

LINK ID : P30SH1k **PAGE 4/4**
DATE : 01-08-97 09:18
ORBIT : MOP ALTITUDE (1000km): 120000
STATION : New Norcia 35-m ELEVATION (deg): 10

TELECOMMAND BIT RATE (kb/sec) : 1.00 RANGING : No
TELEMETRY BIT RATE (kb/sec) : 1.00 with CONCAT. CODING : Yes

DOWNLINK (2/2)

	NOM	ADV	FAV	MEAN	VAR	PDF
RX S/No.....dBHz	37.46	36.30	38.58	37.44	*0.07*	
CARRIER RECOVERY						
CARRIER SUPPRESSION...dB	5.35	6.87	4.13	5.45	0.31	TRI
PLL BANDWIDTH 2*Bl...Hz	*10.00*	12.00	8.00			
PLL BANDWIDTH.....dBHz	10.00	10.79	9.03	9.94	0.13	TRI
REQ LOOP S/N.....dB	*17.00*	17.00	17.00	17.00		
CARRIER MARGIN.....dB	5.12	1.64	8.42	5.05	0.52	
MEAN-3*SIGMA.....dB	2.89					
MARGIN - w.c. RSS..dB	3.26					
TELEMETRY RECOVERY						
TLM MODULATION LOSS...dB	1.50	2.12	1.00	1.54	0.05	TRI
DEMODULATOR TECH LOSS.dB	*0.40*	*0.50*	*0.30*	0.40	0.00	TRI
BIT RATE.....kb/s	1.00	1.00	1.00			
BIT RATE.....dBHz	30.00	30.00	30.00	30.00		
CONCAT CODING GAIN(*).dB	*9.70*	9.70	9.70			
CODING RATE 1/R.....	2.29					
REQ Eb/No (PFL=1.E-5).dB	*2.80*	2.80	2.80	2.80		
TELEMETRY MARGIN.....dB	2.76	0.88	4.48	2.70	0.13	
MEAN-3*SIGMA.....dB	1.63					
MARGIN - w.c. RSS..dB	1.81					
TONE RECOVERY						
TONE MODULATION LOSS..dB	No RG	No RG	No RG	No RG		
IMPLEMENTATION LOSS...dB	0.00	0.00	0.00	0.00		
REQ S(Tone)/N.....dB	*19.00*	19.00	19.00	19.00		
MAX REQ LOOP-BDW(**).mHz	No RG	No RG	No RG	No RG		
COMB. CARR. JITTER (***)						
RX TRSPD-PLL JITT...deg	0.51	0.71	0.34	0.49		
TRANSMT CARR. JITT...deg	*2.00*	*3.00*	*1.00*	2.00		
JITT BDW 2*B (****)...Hz	*5.00*	*10.00*	*3.00*	6.50		
RX COMBD CARR JITT...deg	3.31	5.04	2.21	3.53		

*) PFL=Probability of Frame Loss. Transfer Frame Length is FS=1275 Octets, and Interleaving Depth is I=5.

**) The required MINIMUM Loop-Bandwith supported by MPTS is 1.25 mHz; the MAXIMUM Loop-Bandwidth (two-sided) is 1880 mHz.

***) Coherent transponder mode assumed for RX COMBD CARR JITTer at G/S.

****) 2*B is the bandwidth of the jitter from the TX chain or a HPA.

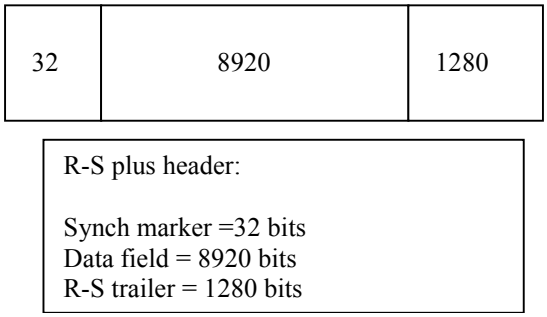
END of *P30SH1k*

10. APPENDIX 4 TELEMETRY BIT/SYMBOL RATE DEFINITION

The on-board functions that concur to the generation of the transmitted telemetry frame are pictorially depicted in fig. A4.1 below.

10.1 Concatenated encoding

Frame structure before convolutional encoding:



Defining: fs = data rate at convolutional encoder input

fb = information bit rate

yields:

$$\frac{fs}{fb} = \frac{32+8920+1280}{8920} = \frac{10232}{8920} \approx 1.147085$$

Example: fs=32.768 kb/s corresponds to an information rate fb=28.56632 kb/s

Frame structure after convolutional encoding:

The structure is the same as before. However, the rate ½ convolutional encoder doubles every bit. Therefore, the frame length will be twice as long or 20464 symbols.

Moreover, what counts is the symbol rate at the modulator input or at the convolutional encoder output. For the standard rate ½ code, this is given by:

$$\frac{fs'}{fb} = 2\frac{fs}{fb} = 2\frac{10232}{8920} \approx 2.29417$$

where fs' is the transmitted symbol rate.

Example: the information rate fb=28.56632 kb/s above given corresponds to a transmitted symbol rate fs'=65.536 ks/s.

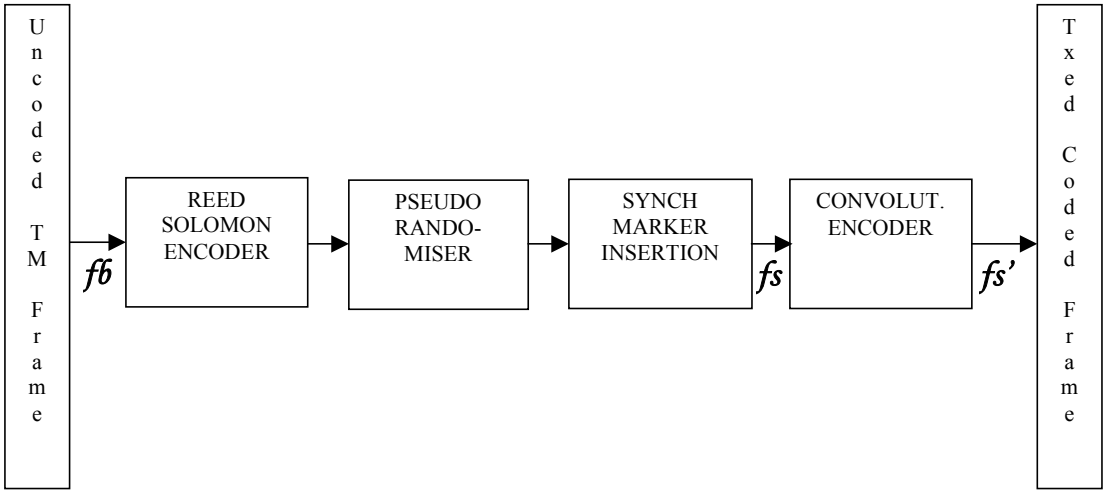


Fig. A4.1 – On-board Coded Frame Generation Scheme

APPENDIX 5 SPECTRAL EMISSION MASKS

The spectral emission of Herschel/Planck medium and high rate telemetry shall comply with the emission masks (SFCG REC 17-2R1) of figure A5.1.

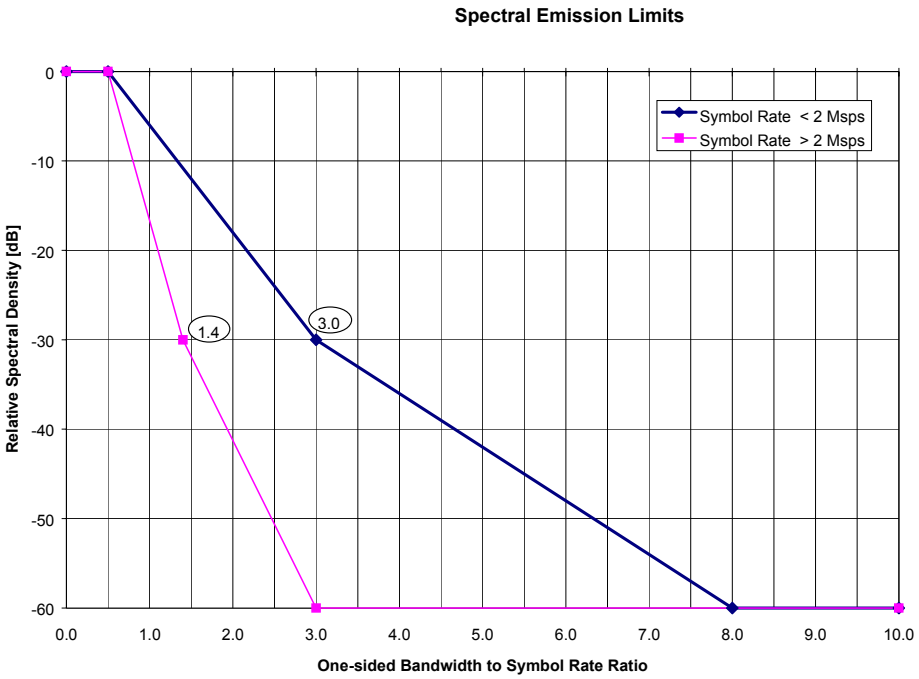


FIG. A5.1 – Applicable Spectral Emission Masks

In figure A5.1, the word symbol rate has to be taken as the transmitted symbol rate fs' as defined in section 2.1.5 and Appendix 4. In case of PCM(SP-L)/PM modulation, the symbol rate in the mask as to be taken as 2*fs'.

For medium rate telemetry where a residual carrier is employed, the emission mask is referred to the peak of the modulating signal.

No emission mask is required to be met by low rate telemetry for which the constraints on the ratio subcarrier frequency/transmitted symbol rate of section 2.1.5 apply.

– END OF DOCUMENT –