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Sentinel-1

Space to Ground Interface Control Document ICD

(IF-1)

VOLUME 4

SAR and Auxiliary data handling (X-Band)

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CHANGE RECORDS

ISSUE	DATE	§ CHANGE RECORDS	AUTHOR
1	26-02-08	First Issue	
2	16-04-08	Par. 2.1 : encryption descoped Par. 2.1.2: note added to clarify association of packet stores with virtual channels Par. 2.1.2: note deleted (Costant TM bitrate is mantained) Par. 2.3, par. 2.4: further clarification.	
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		Section 1.4.1 Applicable document updated, reference to current applicable SRD aligned	Cossu
		Section 1.4.2 S1-IF-ASD-PL-0007 Issue added as reference document	Cossu
		Section 2.1 Pseudo random generator. Note added	Cossu
		Section 2.1.2. IDLE Packet description updated	Cossu
		Section 2.1.2. Virtual Channel ID description updated	Cossu
		Figure 2-2 CADU structure updated	Cossu
		Section 2.1.2 Frame Header Error Control section reworded	Cossu
		Section 2.2.1 Figure 2-3 and 2-4 aligned wrt S1-IF-ASD-PL-0007 Issue 3	Cossu
		Section 2.2.1 APID definition added	Cossu
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		Figure 2-2 updated	
		Table 2-8 updated with the correct SAR Data Packet format	Cossu
		Section 2.1.2 updated in accordance to RID OP-120	Cossu
		Section 2.1.3. updated for IDLE Frame/IDLE Packet description	Cossu

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1. INTRODUCTION

1.1. Overview.

This document defines the formats of the X-Band SAR data, S/C Telemetry data and Auxiliary (GPS) data that are transmitted from Spacecraft to Ground Stations in the frame of Sentinel-1 mission. Data types, format structure and content will be herein specified in relation with compatibility with mission objectives and recommendations included in ECSS and CCSDS reference documents.

Moreover the document “SAR Space Packets Protocol Data Unit”, in charge to *Eads Astrium,* gives a comprehensive description of the Sentinel-1 Space Packet on packet layer level. It describes the structure of the packets, provides the data formats and decoding algorithms for user data decoding and gives a detailed description of the annotated SAR ancillary header data (RD.13 “SAR Space Packets Protocol Data Unit”, S1-IF-ASD-PL-0007).

1.2. Scope

The document is issued in the framework of Sentinel-1A Program.

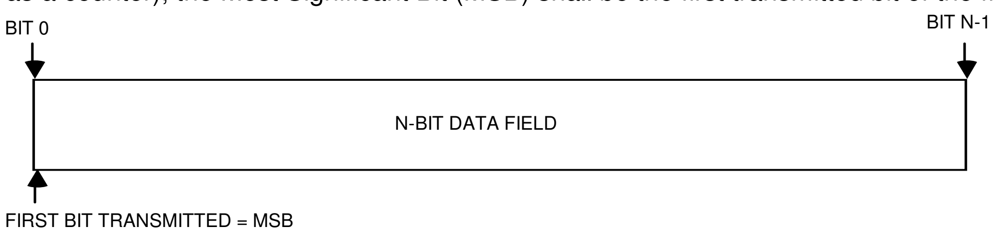
1.3. Definition

1.3.1. Language

(a) “SHALL “ is used to indicate a mandatory requirement.
(b) “SHOULD” indicates a preferred alternative but is not mandatory.
(c) “MAY” indicates an option.
(d) “WILL” indicates a statement of fact or intention.

1.3.2. Bit Numbering and Bit Ordering Convention

In this document, unless otherwise stated, the following CCSDS convention is used to identify each bit in an N-bit field. The first bit in the field to be transmitted (i.e., the most left justified when drawing a figure) is defined to be “Bit 0”; the following bit is defined to be “Bit 1” and so on up to “Bit N-1”. When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., “Bit 0”.



Data fields are often grouped into 8-bits called an “octet” in CCSDS / ESA standard terminology. The 8-bits are also referred to a byte in digital design terminology whereas 16-bits or two bytes are referred to as a word.

The above-defined numbering convention for identifying a bit is also used for identifying each octet in a forward-ordered N-octet field.

When successive fields are shown in diagrams, the fields are shown in order of transmission, with the most left justified field being the first field to be transmitted.

Hence, Octet / Byte is the aggregate of 8 bits:

Bit	0	1	2	3	4	5	6	7
	MSB							LSB

Word is the aggregate of 16 bits or 2 bytes:

Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	MSB															LSB
Byte	High Byte								Low Byte							

1.4. Applicable & Reference Documents

1.4.1. Applicable Documents

[A.D.01] S1-RS-ESA-SY-0001, issue 3, revision 2, System Requirements Document

[A.D.02] S1-LI-TASI-0006, SENTINEL-1 Acronyms List

[A.D.03] S1-RS-ESA-SY-0003, issue 2, revision 1, Management Requirements

[A.D.04] S1-IF-TASI-SC-0005, S1 Specific Packet Utilisation Standard

[A.D.05] S1-IF-AAE-SC-0001, S1 GPSR Command and Housekeeping Data Interface Specification

[A.D.06] S1-IF-AAE-SC-0002, S1 GPSR Measurement Data Interface Specification

1.4.2. Reference Documents

[R.D.01] S1-TN-TASI-SC-0001, PDHT Technical Description

[R.D.02] Deleted

[R.D.03] Deleted

[R.D.04] Deleted

[R.D.05] Deleted

[R.D.06] S1-IF-TASI-SC-0003, ICD

[R.D.07] Deleted

[R.D.08] Deleted

[R.D.09] Deleted

[R.D.10] EGOS-MCS-S2K-ICD-0001, SCOS 2000 Database Import ICD

[R.D.11] S2K-MCS-ICD-0014-TOS-GCI, SCOS 2000 OBSM External ICD

[R.D.12] S1-PL-TASI-PM-0010, CADM PLAN

[R.D.13] S1-IF-ASD-PL-0007 SAR Space Packet Protocol Data unit

[R.D.14] S1-IF-TASI-SY-0004 Space to Ground ICD Vol. 3 TC/TM Data Handling (S-Band)

1.4.3. Standards

[SD-01] ECSS-E-50-05A Radio frequency and modulation
[SD-02] CCSDS 133.0-B-1 - SPACE PACKET PROTOCOL
[SD-03] CCSDS 732.0-B-1 - AOS SPACE DATA LINK PROTOCOL
[SD-04] CCSDS 131.0-B-1 – TM Synchronization and CHANNEL CODING

2. X-BAND DATA FORMATS

2.1. Transfer frame formats

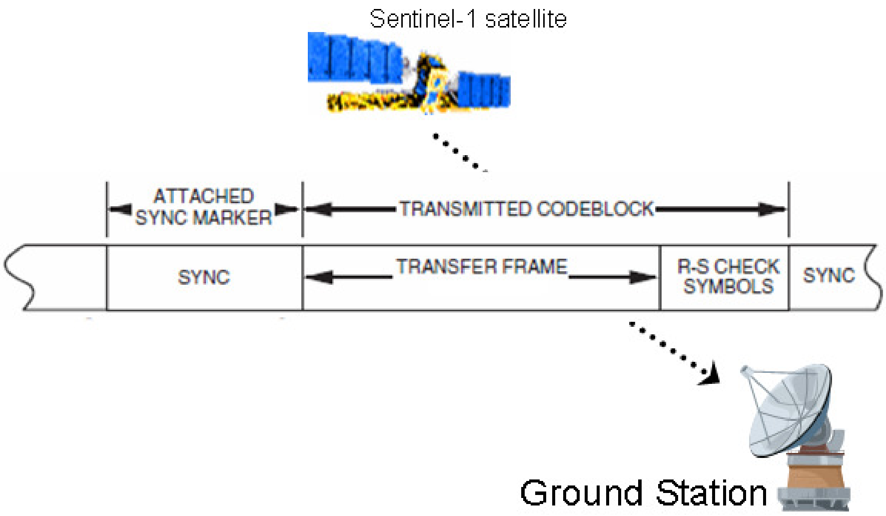


Figure 2-1 Channel Access Data Unit (CADU)

Sentinel-1 Transfer Frame format will be provided with the following key characteristics:

- The downlink format complies with the Consultative Committee for Space Data Systems (CCSDS) Recommendations for Advanced Orbiting Systems.
- The entire Transfer Frame is Reed-Solomon forward error correction coding protected.
- The Reed-Solomon code applied is the RS(255,239), compliant with CCSDS 131.0-B-1.

Transfer Frame shall carry payload data (SAR Data, Auxiliary Data or S/C Telemetry Data); its length will be:

$$L = (255 - 2E)I$$

Where :

- E = 8 symbols. Reed-Solomon error correction capability within an R-S codeword
- I = 8 is the depth of interleaving.

With an interleaving factor of 8, the Reed-Solomon Codeword is fixed length, 1912 bytes long, the Reed-Solomon Check Symbols is 128 Bytes length.

SAR data, auxiliary data and S/C Telemetry data will be downlinked by Sentinel-1 satellite through the Physical Channel as a serial string of coded Transfer Frames; the boundaries between them are delimited by an Attached Synchronization Marker (ASM) at each coded Transfer Frame.

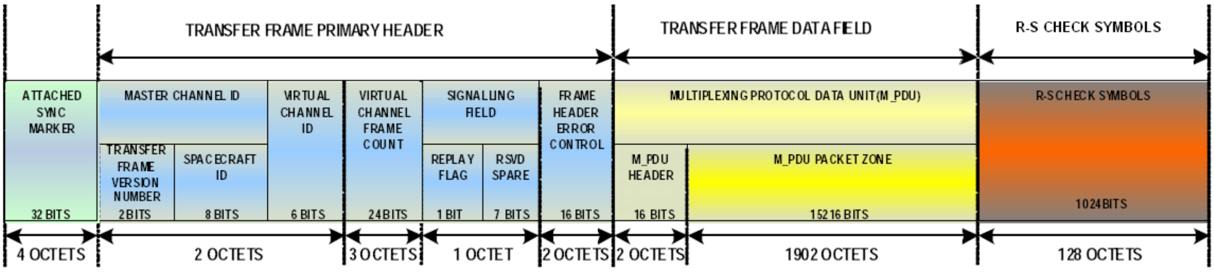


Figure 2-2 Channel Access Data Unit (CADU) Structure

One individual Transfer Frame with Reed-Solomon check symbols, prefixed by its Synchronization Marker, is a CCSDS Channel Access Data Unit (CADU).

CADU is 2044 Bytes long and is provided for an interleaving factor of 8.

At Ground Station facility the acquired data will result in a sequence of CADU.

A serial stream of bits, representing a continuous and contiguous string of CADUs, forms the Channel Symbols which is used to access the Physical Channel layer.

To ensure adequate bit transition density when the Channel Symbols are modulated directly onto the space channel a random sequence is exclusively ORed with each bit of the transfer frame. The pseudo-random sequence is NOT exclusive-ORed with the ASM, as reported in following figure.

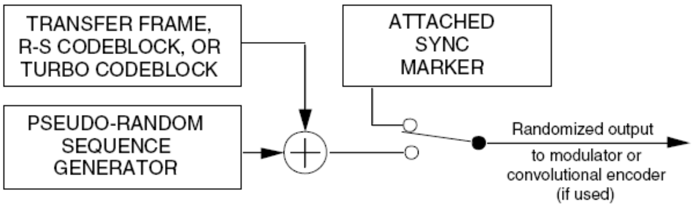


Figure 2-3 Pseudo-Randomizer Configuration

Such a random sequence is generated using the following polynomial:

$h(x) = x^8 + x^7 + x^5 + x^3 + 1$, it repeats after 255 bits and the sequence generator is re-initialised to an all-ones state during each Synchronisation Marker period.

2.1.1. Attached Synchronization Marker

Fixed 4 byte value: 0x1ACFFC1D.

2.1.2. Transfer Frame Primary Header

The Transfer Frame Primary Header contains the following fields:

Field		Length (bits)
MASTER CHANNEL ID		10
	Transfer Frame Version Number	(2)
	Spacecraft ID	(8)
VIRTUAL CHANNEL ID		6
VIRTUAL CHANNEL FRAME COUNT		24
SIGNALLING FIELD		8
	Replay Flag	(1)
	Reserved Spares	(7)
FRAME HEADER ERROR CONTROL		16

Table 2-1 Transfer Frame Primary Header structure

The total length of the Transfer Frame Primary Header is 64 bits.
Each field is implemented as specified in CCSDS 732.0-B-1.
The CCSDS 732.0-B-1 recommendation, fully applicable to S-1 as per SRD, provides the description of Virtual Channel Frame Count usage.
The purpose of this field is to provide individual accountability for each Virtual Channel. A resetting of the Virtual Channel Frame Count before reaching 16,777,215 shall not take place unless it is unavoidable (e.g. in case of PDHT re-initialization for recovery action); in that case the completeness of a sequence of Transfer Frames in the related Virtual Channel cannot be determined.

Master Channel ID (Bits 0-9)

The Master Channel Identifier shall consist of:

a) Transfer Frame Version Number (Bits 0-1)

   The two Version Number bits occupies the two most significant bits of the Transfer Frame Primary Header, reserved for identification of the Transfer Frame structure.
   A value of “01” identifies the frame as a CCSDS Transfer Frame.

b) Spacecraft Identifier (Bits 2-9)

   The Spacecraft Identifier (SCID) is assigned by CCSDS and shall provide the identification of the spacecraft which is associated with the data contained in the Transfer Frame. The Spacecraft Identifier shall be static throughout all Mission Phases.
   The value of these bits is (TBD).

Virtual Channel ID (Bits 10-15)

The six-bit VCID field enables up to 64 Virtual Channels (VCs) to be run concurrently in association with each SCID that is authorised in a particular Physical Channel Access Protocol Data Unit (PCA-PDU).
Data Flows are organized in different VCs, nominally one for each packet store to be downlinked. It will be possible to modify the default association, through a dedicated PDHT telecommand. In particular will be possible also to associate different packet stores to the same virtual channel (*). The VC63 (all ones) is reserved to filler data (IDLE FRAME).

Type of Data	VC	VCID Value
Packet Store 0	VC0	000001
Packet Store 1	VC1	000010
Packet Store 2	VC2	000011
……	…	…
Packet Store 44	VC44	101100
Packet Store 45	VC45	101101
Packet Store 46	VC46	101110
Packet Store 47	VC47	101111
Packet Store 48	VC48	110000
Packet Store 49	VC49	110001
Filler Data	VC63	111111

Table 2-2 Example of VCID values

[0,44] identify the SAR Packet Stores
45] identifies the AUX Packet Store
[46 to 49] identify HK Packet Stores from Packet Stores A, B, C and D

*(*) **Note**: The on-board table is updatable by command and therefore the alignment of association PS&VCID between on-board table e ground table is ensured programming in the same manner the two tables.*
Usage of same VCID for different PS is provided as capability and depends on the table programming. Therefore it is ground that can decide if this features has to be used or not.
The relationship between packet store and VC as well as the fact that they should be different from those used for S-Band are under Ground responsibility.
When ever a PS is created it shall be also defined the Virtual Channel to be associated to it during downlink execution.
TM packets are DL in the same order as they are stored on board.
All the S/C telemetry acquisition is centralized by the SMU: there is a time delay between telemetry generation and telemetry delivery. Therefore chronological order can be guaranteed only for telemetry with the same application identifier.

Virtual Channel Frame Count (Bits 16-39)

The purpose of this field is to provide individual accountability for each of the sixty-four Virtual Channels, primarily to enable systematic Packet extraction from the Transfer Frame Data Field.
If the Virtual Channel Frame Count is reset because of an unavoidable re-initialization, the completeness of a sequence of Transfer Frames in the related Virtual Channel cannot be determined.

This 24-bit field shall contain a sequential binary count (modulo-16,777,216) of each Transfer Frame transmitted within a specific Virtual Channel.
A resetting of the Virtual Channel of the Virtual Channel Frame Count before reaching 16,777,215 shall not take place unless it is unavoidable.
A separate count is maintained and transmitted for Filler Transfer Frames; in this case, the 24 bit field represents a sequential count (modulo 16,777,216) of the total number of the total number of Filler Transfer Frames that have been transmitted.

In X-Band the filler Transfer Frames (IDLE Frames) start to be transmitted to ground as soon as the RF signal transmission is enabled: when in TX-ON condition, the DSHA will activate the FILLER Transfer Frames generation that will be transmitted on physical channel as soon as the TXA-CONF command will be issued by ground.
Filler transfer frames are transmitted until the packet store data downlink starts and after Data Downlink completion to keep the X-Band link connected with the earth station: filler Transfer Frames will be transmitted up to the receiving of DOWNLINK or PASSTHROUGH command when data from packet store will be transferred on the physical channel.
IDLE frames will be used also at the end of transmission when no other packet store data are available or to cope with the data rate difference in PT mode for lower input acquisition data rate than fixed downlink data rate.
Filler Transfer Frame are transmitted with a specific Virtual Channel and are not dependent on the data originator (SAR, TM or AUX). A further condition in which filler transfer frame are transmitted during a packet store downlink is related to the execution of a PASSTHROUGH task where the input data rate (from the SAR) is lower than the downlink data rate.

Signalling Field (Bits 40-47)

The Signalling field is defined in the standard to be used to alert the receiver of the Transfer Frame w.r.t. functions that:
(a) may change more rapidly than can be handled by management, or
(b) provide a significant cross check against manual or automated setups for fault detection and isolation purposes.

The Signalling field contains following two sub-fields:

- *Replay Flag (Bit 40)*
  The Replay Flag is not used for the Sentinel-1 mission and is always set to zero.

- *Reserved Spares (Bits 41-47)*

  The seven-bit field shall be programmable via DOWNLINK/MULTIPLE DOWNLINK, BITE and PASSTHROUGH TC. This field is reserved by CCSDS for potential future signalling applications and in the interim shall be set by convention to the value “all zeros”.

Frame Header Error Control (Bits 48-63)

The 10-bit Master Channel Identifier, the 6-bit Virtual Channel Identifier, and the 8-bit Signalling Field shall be protected by an error detecting and correcting code, whose check symbols are contained within this 16-bit field.
The mechanism for generating the Frame Header Error Control field shall be to use a shortened Reed-Solomon (10,6) code. The parameters of the selected code are as follows:

- “J=4” bits per Reed-Solomon (R-S) symbol.

- “E=2” symbol error correction capability within an R-S code word.

- The field generator polynomial shall be:
- $F(X) = x^4 + x + 1$ over GF(2)

- The code generator polynomial shall be:

- $g(x) = (x + \alpha^6)(x + \alpha^7)(x + \alpha^8)(x + \alpha^9)$ over GF(2^4)

where: $F(\alpha) = 0$, $\alpha^6 = 1100$, $\alpha^7 = 1011$, $\alpha^8 = 0101$, $\alpha^9 = 1010$

also: $g(x) = x^4 + \alpha^3 x^3 + \alpha x^2 + \alpha^3 x + 1$ over GF(2^4)

and: $\alpha^0 = 0001$, $\alpha^3 = 1000$, $\alpha = 0010$

- Within an R-S symbol, the transmission shall start from the bit on the left side; e.g., $\alpha^3 = 1000$ shall be transmitted as a 1 followed by three 0s.

- The bit to R-S symbol mapping shall be:

Bits in the Header	Symbol
0,1,2,3	0
4,5,6,7	1
8,9,10,11	2
12,13,14,15	3
40,41,42,43	4
44,45,46,47	5
48,49,50,51	6
52,53,54,55	7
56,57,58,59	8
60,61,62,63	9

Table 2-3 RS Symbol Mapping

2.1.3. *Transfer Frame Data Field*

The Transfer Frame Data Field shall include SAR Data, S/C Telemetry and auxiliary data, transmitted as bit-stream.
The Transfer Frame Data Field shall include Transfer Frame Data unit Zone of fixed length of 1904 Bytes and Reed-Solomon Check Symbols of fixed length of 128 Bytes.

Transfer Frame Data Unit Zone

The Transfer Frame Data Unit Zone will include Multiplexing Data Unit (**M_PDU**) of fixed length of 1904 bytes (considering the implementation of RS(255,239) coding with an interleaving factor of 8).
When no valid higher-layer data are available for transmission at Transfer Frame release time, the Virtual Channel ID shall be set to the value “all ones” and a specified “fill” pattern shall be inserted into the M_PDU packet zone.
When higher-layer valid data are available, the Transfer Frame Data Field contains the following fields:

Field	Length (octets)
M_PDU HEADER	2
M_PDU PACKET ZONE	1902

Table 2-4 Transfer Frame Data Unit Zone structure

- *M_PDU Header*

First 2 bytes represent the M_PDU Header.

M_PDU Header indicates the position of the first octet of the first Data Packet that starts in the M_PDU Packet Zone. The purpose of the M_PDU Header is to facilitate delimiting of variable-length Data Packets contained within the M_PDU Packet Zone (i.e., the boundary between user data).
The M_PDU HEADER is sub-divided as follows:

- ***Reserved Spare*** (5 bits):
  - Always set to zero.
- ***First Header Pointer*** (11 bits):
  - Contain the position of the first octet of the first Packet that starts in the M_PDU Packet Zone, numbered in ascending order. The first octet in this zone is assigned the number 0.
  - If no Packet starts in the M_PDU Packet Zone, the First Header Pointer will be set to '*all ones*'.
  - If the M_PDU Packet Zone contains only Idle Data, the First Header Pointer will be set to *'all ones minus one'*.

- *M_PDU Packet Zone*

The M_PDU Packet Zone will contain either Packets (SAR Space Packet Data or S/C Telemetry/Auxiliary Space Packet Data) or FILL data. The M_PDU Packet zone is 1902 bytes in length.
When higher-layer valid data are available, the M_PDU Packet Zone carries the Payload Data or S/C TM/Auxiliary Data (split into Transfer Frames).
Packets will be inserted contiguously and in forward order into the M_PDU packet Zone.

Two types of FILL data (IDLE Frames and IDLE Packets) are used:

IDLE Frames

IDLE frames will be used also at the end of transmission when no other packet store data are available or to cope with the data rate difference in PT mode for lower input acquisition data rate than fixed downlink data rate; when no valid higher-layer data are available for transmission at Transfer Frame release time, the Virtual Channel ID are set to the value "all ones" and a specified "fill" pattern will be inserted into the M_PDU Packet Zone. With the purpose to limit glitches' occurrence when transmitting a sequence of such defined IDLE Frames, the M_PDU Packet Zone is filled by a sequence generated through the polynomial $h(x) = x^{14} + x^{13} + x^{8} + x^{4} + 1$, and the sequence generator shall be re-initialized at each Transfer Frame with a seed of all ones.

IDLE Packets

IDLE Packets are reserved for the cases when it is necessary to complete a frame already containing a meaningful packet, and that otherwise would not be down-linked in an acceptable time (e.g. last packet of a dump in a dedicated virtual channel); the IDLE packet structure shall be defined according to CCSDS recommendation for Space Packet Protocol (133x0b1).
IDLE packet will not be multiple of 4 Bytes and will be as minimum 7 bytes in length. In case the last CADU to be transmitted is not completely filled by a SAR source packet, an IDLE packet will be inserted to complete the CADU (if the area to be fulfilled is lower than 7 bytes, the IDLE packet will be split in two CADUs).
The following indications are considered for IDLE packet implementation:

o the Secondary Header Flag shall be set to "0" for IDLE Packets;
o the APID shall be "11111111111", i.e., "all ones";
o IDLE Packets shall not be required to increment the Packet Sequence Count;
o the Packet Secondary Header is not allowed for IDLE Packets;
o the User Data Field shall contain Idle Data filled by a sequence generated through the following polynomial h(x) = x14 + x13 + x8 + x4 +1. The sequence generator is reinitialized at each IDLE packet with a seed of all ones.

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The packet structures included in the M_PDU Packet Zone are described in :

- Paragraph 2.2 for SAR data;
- Paragraph 2.3 for Auxiliary data;
- Paragraph 2.3.1 for S/C Telemetry data.

2.1.4. Reed-Solomon Check Symbols

The Transfer Frame Error Control field appended at the end of Transfer Frame contains the Reed-Solomon check symbols.
The parameters of the selected Reed-Solomon (R-S) code are as follows:

- J = 8 bits per R-S symbol.
- E = 8 symbols. Reed-Solomon error correction capability within an R-S codeword
- I = 8 the depth of interleaving
- N = 2^J-1 = 255 symbols per R-S codeword
- 2E is the number of R-S symbols among N symbols of an R-S codeword representing parity checks
- k =N-2E is the number of R-S symbols among N R-S symbols of an R-S codeword representing information.
- The field generator polynomial shall be:

$$F(x) = x^8 + x^7 + x^2 + x + 1$$

- The code generator polynomial shall be:

$$g(x) = \prod_{j=128-E}^{127+E} \left(x - \alpha^{11j}\right) = \sum_{i=0}^{2E} G_i x^i \quad ;$$

Over GF(2^8), where F(α)=0.

2.2. SAR Data packet format

SAR data are formatted into a Space Packet composed by a Packet Primary Header (6 Bytes) and the Packet Data Field (variable length up to 65534 Bytes).
SAR Data Packets format is shown in Table 2-5 and shall satisfy the following constraints:

- maximum packet length not greater than 65540 bytes;
- minimum packet length not less than 76 bytes;
- packet length multiple of 4 bytes.

Length Multiple of 4 Bytes								
PACKET PRIMARY HEADER							*PACKET DATA FIELD*	
Version number	Packet Identification			Packet Sequence Control		Packet Data Length	PACKET SECONDARY HEADER	*USER DATA FIELD*
	Type Indicator	Secondary Header Flag	Application Process ID	Grouping Flag	Source Sequence Number			
3 bits	1 bits	1 bits	11 bits	2 bits	14 bits	16 bits	62 Bytes	Variable, 8 to 65472 Bytes
6 Bytes							*70 to 65534 Bytes*	

Table 2-5 SAR Data packet format

2.2.1. Packet Primary Header

The Packet Primary Header consists of four contiguously fields, in the following sequence:

- Packet Version Number (3 bits)
- Packet Identification (13 bits)
- Packet Sequence Control (16 bits)
- Packet Data Length (16 bits)

Packet Primary Header						
Packet Version Number	**Packet Identification**			**Packet Sequence Control**		**Packet Data Length**
	Packet Type	Secondary Header Flag	Application Process Identifier	Sequence Flags	Packet Sequence Count	
3 bits	1 bit	1 bit	11bits	2 bits	14 bits	16 bits
6 bytes						

Figure 2-4 SAR Data Packet Primary Header

Packet Version Number

For Sentinel-1 mission this field shall be set to “000”.

Packet Identification

Packet Identification field contains following sub-fields:

- *Packet Type*

This 1-bit field reflects the type of data unit. For Sentinel-1 mission it shall be set to “0”.

- *Secondary Header Flag*

If set to “1”, this 1-bit field indicates the presence of secondary header within the space packet. Hence, for Sentinel-1 mission It shall be set to “1”.

- *Application Process Identifier*

Content of this 11-bits field is:

Process ID (PID): 1000001
Packet Category (PCAT): 1100

Packet Sequence Control

The 16-bits Packet Sequence Control field provides a sequential count of the packets generated. It is constituted by the following fields:

- *Sequence Flags*

This 2-bits field is a flag that indicates if the packet is the segment of a larger set of application data, i.e. if it is a continuation segment (“00”), a first segment (“01”), a last segment (“10”) or an unsegmented set of user data (“11”).

For Sentinel-1 mission, this flag is set to “11” to indicate that only unsegmented packets are used within the Network Layer.

- *Packet Sequence Count*

This 14-bits field provides the sequential binary continuous count (modulo 16384) of each source packet generated by an application process. Its purpose is to order this packet with other packets generated by the same Application process, even though their natural order may have been disturbed during transport to the user's processor on the ground. It shall be reset on entry a specific operational mode. The first packet transmitted shall have "0" in the Packet Sequence Count field.

Packet Data Length

This 16-bits field contains a binary number equal to the number of bytes in the Packet Data Field minus 1 including filling data if they have been added. The value contained in the Packet Data Length field may be variable and shall be in the range of 69 to 65533 corresponding to 70 to 65534 bytes.

2.2.2. Packet Data Field

See S1-IF-ASD-PL-0007 for the packet specification of SAR data.

2.3. S/C Telemetry and Auxiliary Data Packet Stores

2.3.1. S-Band Downlink Overview

The Avionics S/S (AVS) manages the S-Band telemetry.

Ground receives the following streams of VC TM Transfer Frames from the S-Band TT&C link:

- VC-0 TM Transfer Frames containing all real time S/C TM packets.
- VC-1 TM Transfer Frames containing HW generated High Priority TM packets.
- VC-2 TM Transfer Frames containing playback TM packets stored in the SMU Packet Store D.
- VC-3 TM Transfer Frames containing playback TM packets stored in the SMU Packet Store C.
- VC-5 TM Transfer Frames containing playback TM packets stored in the SMU Packet Store B.
- VC-6 TM Transfer Frames containing playback TM packets stored in the SMU. Packet Store A .
- VC-7 Idle TM Transfer Frames.

The SMU TM Store (also referred to as SMU Mass Memory) is managed as four Packet Stores where:

- Packet Store A contains all S/C TM packets except Service 6 TM packets.
- Packet Store B contains all Service 6 TM packets
- Packet Store C is Spare.
- Packet Store D functions as the System Log containing Service 1 Error TM packets and Service 5 TM packets..

Nominally Packet Store A contains 100 % of the S/C TM packets when no memory dumps have been requested..

The mapping between TM PID, Service Type and Service Subtype to specific Packet Store is managed by the ASW and is configurable in flight through PUS Service 15.

All S/C TM is also stored in the DSHA Packet Stores through the SpaceWire interface between the SMU and DSHA. An addition DSHA Packet Store is dedicated for the storage of Auxiliary Data also dispatched by the ASW through the SpaceWire interface.

Four DSHA packet stores are allocated for S/C TM and their contents are the same as the corresponding SMU Packet Stores A, B, C and System Log. It is possible through the SMU service TC(15,1) and TC(15,2) to enable and disable a specific Packet Store filling (SMU and/or DSHA). Hence for each corresponding pair of Packet Stores in the SMU and DSHA, it is possible to store in both Packet Stores (SMU and DSHA) or in only one Packet Store, either the SMU Packet Store or the DSHA Packet Store.

Through the SMU - DSHA SpaceWire link the DSHA receives Transfer Blocks containing multiple TM packets which are to be stored in the same Packet Store. A Transfer Block Header field provides the necessary information for routing and storage. While only the Transfer Block Data field is stored in a memory Sector which will be part of the specified Packet Store. Hence Ground does not receive the Transfer Block Header field which is only use for routing purposes inside the DSHA.

Auxiliary Data DSHA Packet Store has no equivalent in the SMU TM Store and contains all Packet Category 6 (PCAT 6) TM packets. The list of PCAT 6 TM packets are provided in section 2.3.3.
DSHA SW Service 15 provides Ground with the capability to request the retrieval and downlink of any DSHA Packet Store which include the S/C TM and Auxiliary Data Packet Stores.

2.3.2. S/C Telemetry Packet Formats

Sentinel-1 Specific PUS, S1-IF-TASI-SC-0005, [A.D.04], reports the full list of PUS TM packets supported by each packet terminal. It also reports the TM packet formats for the standard PUS Types.

The standard Sentinel-1 PUS Telemetry Packet format is also reported in Volume 3 of the Space to Ground ICD, [R.D.14].

2.3.3. Auxiliary Packet Store Content and Formats

The Packet Store reserved for the Auxiliary Data contains GPSR generated TM packets which are acquired by the SMU ASW through the 1553B Bus interface and dispatched to the DSHA through the SpaceWire interface .

The GPSR TM packet formats and their contents are specified in the following documents:

- Sentinel GPSR Command and Housekeeping Data Interface Specification
  S1-IF-AAE-SC-0001 – [A.D.05]

- Sentinel GPSR Measurement Data Interface Specification
  S1-IF-AAE-SC-0002 – [A.D.06]

The Sentinel-1 GPSR supplier is RUAG Austria.
The GPSR TM packets which can be part of the Auxiliary Data as they are classified as PCAT 6 are:

- TM(212,1) Carrier Phase: provides the carrier phase measurement suitable for computation of a navigation solution by the PDGS. This measurement is delivered for each single frequency channel being in a tracking state high enough to generate reliable data.
- TM(212,1) Code Phase: provides the code phase measurements suitable for computation of a navigation solution by the PDGS. This measurement is delivered for each single frequency channel being in a tracking state high enough to generate reliable data.
- TM(212,1) Satellites in View Status. Provides basic info of all GPS SVs currently in view (not only the ones being processed). All fields of a record form the basis for the current GNSS SV selection process.
- TM(212,1) Navigation Solution: provides the position and velocity of the receiver at a defined point in time. Additionally, quality measurents for the current navigation solution are supplied.
- TM(212,1) IMT/GPST Correlation. Provides all different time bases for a specific point in time. This specific point in time is the leading edge of the last PPS pulse.

The data records composing each of the above TM packets are defined in [A.D.06].
Note that the GPSR is a common item of Sentinel-1, 2 and 3. A PUS harmonisation activity was conducted by the three Sentinels resulting with some deviations with respect to the standard Sentinel-1 TC and TM packet formats. The harmonisation was largely conditioned to the minimisation of changes with respect to RUAG SWARM GPSR baseline.

2.4. OCP Downlink Data Format

The LIAU chooses two 8 bit wide data streams out of 4 incoming (2 nominal and 2 redundant) data streams. According to the LIAU design, the nominal data streams are handled preferred which means if valid data frames on the nominal and on the redundant channel are available at the same time the nominal data stream is selected for transmission. The LIAU perform correctly the data transfer also in case the S/C activates only the clock associated to LVDS interface where input data are sent.
The LIAU adapts the data rate of the incoming signal from 35MHz into a LCT transmission suitable data rate of 37.5MHz. The transfer data at the LIAU output is provided over a 16 bit wide bus to the LCT.
In a first step two consecutive incoming 8 bit data words will be combined into a 16 bit data word. A CADU frame consists of 1904x8bit data, 8x8bit Transfer Frame Header, 128x8 bit RS-Check symbols, 32 bit for ASM are added.
The data rate adaptation is achieved by inserting idle frames into the output data stream. After synchronisation the content of the data frames will be transferred transparently over the LIAU/LCT data link.
Incoming data from the two input channels are arranged by the LIAU according to following process:

LIAU input (from spacecraft):
At the LIAU input the data of one AOS frame is completely received and buffered with a clock rate of 35 MHz, individually for channel 1 (ch1) and channel 2 (ch2).
At the input, one AOS frame consists out of 2044 bytes, i.e. 2044 x 8 bit .

LIAU output (to LCT):
At LIAU output the AOS frames are transmitted transparently as 1022 x 16 bit, i.e. 1022 x 1 word with a clock rate of 37,5 MHz.
The buffered AOS frames of ch1 and ch2 are transmitted only when the complete frame is received and buffered.
The data transmission is accomplished in a frame-by-frame basis: the AOS frames of ch 1 and ch2 will be transmitted alternatively.
In case no complete AOS frame is available, an Idle Frame will be inserted by the LIAU for data rate adaption.

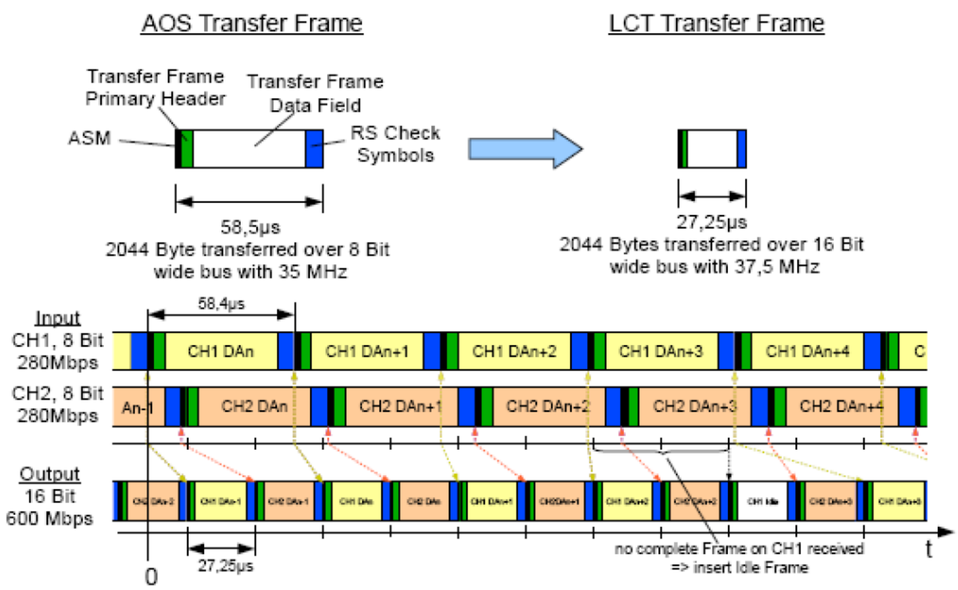

Figure 2-4 AOS Frame

The LIAU does not modify the content of the received AOS.
The LIAU separates the incoming ASM header and processes only the 2040 data byte transparently. At the end of the process a new 1ACFFC1DHEX ASM header is attached at the output frame provided to the LCT.
The finalization of the transfer frame at the LCT output is still under discussion within the Agency and TESAT.
Current LIAU IDLE FRAME definition is reported herebelow:

	Parameter	Length	Description	Content of LIAU Idle Frame
ASM	Attached Sync Marker	32 Bits	Frame Sync Marker	$1ACFFC1D_{HEX}$
Transfer Frame Primary Header	Transfer Frame Version Number	2 Bits	Identification of the unit as Transfer Frame Shall be set to Version 2 (01_{BIN}) (AOS Transfer Frame)	01_{BIN}
	Spacecraft ID	8 Bits	Spacecraft Identifier of Sentinel Satellite assigned by Space Operation Center	**01000011 IDLE Frame A** **01010011 IDLE Frame B**
	Virtual Channel ID	6 Bits	Used to identify the virtual channel. To be Defined	tbd.
	Virtual Channel Frame Count	24 Bits	contains a sequential binary count (modulo 16,777,216) of each Transfer Frame	000000_{HEX} set all to 0
	Replay Flag	1 Bit	Identifies Frame as Real time or Replay. Shall be set to real-time, no buffering required	0_{BIN}
	RSVD Spare	7 Bits	Reserved for future use. Shall be set to all 0 (VC Count not used).	0000000_{BIN}
	Frame Header Error Control	16 Bits	Header data encoded with a shortened R-S (10,6) code	R-S Check Sum of Header
Transfer Frame Data Field	M_PDU	16 Bits	According to the standard, this field contains the position of the first octet of the first Packet that starts in the M_PDU Packet Zone, numbered in ascending order. The first octet in this zone is assigned the number 0. The LIAU will only generate IDLE FRAMEs, the First Header pointer of 11 bits will be set to "all ones minus one"	$07FE_{HEX}$ Reserved Spare (5 Bits) set to 0 First Header pointer (11 Bits) set to "all ones minus one"
	M_PDU ata Zone	15216 Bits	Transfer data filled with idle data	Filled by a sequence generated through the following polynomial: $h(x) = x^{14} + x^{13} + x^{8} + x^{4} + 1$. The sequence generator is re-initialized at each Transfer Frame with a seed of all ones.
RS Check Symbols	Frame Error Control Field	1024 Bits	Encoded with R-S (255;239) I=8 (without Attached Sync Marker)	R-S Check Sum of Idle Frame

Table 2-6 IDLE Frame Structure

Distribution List

Name	Q.ty	Name	Q.ty
A. Pietropaolo		**ESTEC**	
P. Venditti		**ESOC:**	
		Pier Bargellini. I. Shurmer	
M. Masci		**ESRIN:**	
		Hermann Ludwig Moeller, Betlem Rosich,	
M. L'Abbate			
A. Panetti			
F. Ippoliti			
M. Cossu			
G. Olivieri			
E. Calio'			
A. Notarantonio			
S. Barrasso			
M. L'Abbate			
C. Bruno			
V. Iannucci			

END OF DOCUMENT