Coordination Group for Meteorological Satellites

Direct Broadcast Services

LRPT/AHRPT Global Specification

CGMS Secretariat

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1. INTRODUCTION

1.1 Purpose and Scope

This document defines the Global Specification of the LRPT and AHRPT Direct Broadcast Services.

1.2 Structure of the Document

The structure of this document follows is as follows:

Section 1	-	this section
Section 2	-	details the Application Layer.
Section 3	-	deals with the Network Layer implementation details.
Section 4	-	deals with the Data Link Layer implementation details.
Section 5	-	describes the LRPT Physical Layer.
Section 6	-	describes the AHRPT Physical Layer.
Appendix A	-	lists the acronyms used in this document.
Appendix B	-	lists the mission specific items.
Appendix C	-	lists all TBCs and TBDs.

1.3 Reference Documents

[RD.1] CCSDS: "Advanced Orbiting Systems, Networks and Data Links: Architectural Specification", CCSDS recommendation 701.0-B-2, November 1992

[RD.2] CCSDS: "Telemetry Channel Coding", CCSDS recommendation 101.0-B-3, May 1992

[RD.3] CCSDS: "Time Code Formats", CCSDS recommendation 301.0-B-2, April 1990

1.4 Assumptions and Open Issues

1.4.1 Assumptions

This document follows closely the terminology and the recommendations of [RD.1]. It is assumed that the reader is familiar with the CCSDS AOS concepts.

1.4.2 Open Issues

For a complete list of open issues the reader should refer to Appendix C of this document.

2. APPLICATION LAYER

The application layer defines source packets. At least one of the source packets will contain ephemeris information.

2.1 Source Packet Structure

The source packet, in addition to the source data carries information needed for the acquisition, storage, distribution and exploitation of the source data by the end user.

The source packet structure is as follows:

Packet Primary Header							Secondary Header	User Data		
Packet Identifier 2 octets				Packet Sequence Control 2 octets		Packet Length 2 octets	8 octets	variable		
Version No 3 bits "000"	Type 1 bit "0"	Secondary Header Flag 1 bit	APID 11 bits	Sequence Flag 2 bits	Packet Sequence Count 14 bits	16 bits	Time Stamp 64 bits	Ancillary Data variable	Application Data variable	PEC 16 bits

Figure 2-1 Source Packet Structure

The utilisation of the fields within the primary header is as follows:

Packet Identifier

- Version Number — 000 (CCSDS packet Version number 1)
- Type — 0 (This bit is not used within AOS)
- Secondary Header Flag — This bit shall be always set to 1 to indicate the presence of a secondary header.
- Application Process Identifier — This field defines the data route between two users application endpoints. The definition of the APIDs is **mission specific.**

Packet Sequence Control

- Sequence Flag — This flag is set to ‘11’ indicating that the packet contains unsegmented user data. The maximum length of the packet is 65542 octets.
- Packet Name/Sequence Count — This field is a modulo 16384 counter, which numbers the packets.
- Packet Length — This field contains a sequential binary count "C" that expresses the length of the Secondary Header and the User Data. The value of "C" is the length (in octets) minus 1.

Secondary Header

The Secondary Header contains the time stamp. The time stamp is associated to a known time preceding the event measured. The time stamp is compliant with the "level 1" Time Code as described in [RD.3].

The time stamp consists of

- 2 octets indicating the number of days with reference to 1/1/2001;
- 4 octets indicating the millisecond of the day;
- 2 octets indicating the microsecond of the day.

The time stamp will be synchronised to UTC. The definition of its accuracy is **mission specific**.

User Data

The User Data field contains the following fields:

- Ancillary Data: This field contains all the information required for the processing of the application data, i.e. instrument mode, instrument telemetry and calibration data, redundancy. Its size - an even number of octets - depends on the instrument requirement.

  The definition of the Ancillary Data field contents is **mission specific.**

- Application Data: This field contains information provided by the source; its length shall be an even number of octets.

  The use of data compression and the compression method are **mission specific.**

- Packet Error Control: This field is optional. If required by the user it shall contain one of the following checksum:

  a) a Cyclic Redundancy Checksum (CRC) computed over all other octets that constitute the packet. The polynomial generator shall be:

     $G(x) = x^{16}+x^{12} +x^5 +1$.

     Both encoder and decoder shall be initialised with all ones state for each packet.

  or

  b) a vertical parity checksum calculated by performing an exclusive-OR on all the other octets pairs that constitute the packet

  The use and the method of the packer error control field are **mission specific.**

3. NETWORK LAYER

The network layer is represented by the path layer in the CCSDS standard. In this case, the only function of the path layer shall be to generate the VCDU-ID and to forward CP_PDUs to the multiplexing service.

The VCDU-ID is a data structure which has a length of 14 bits. It consists of a spacecraft identifier (SCID) of 8 bits and a virtual channel identifier (VCID) of 6 bits.

The definition of VCIDs and SCIDs is **mission specific**.

4. DATA LINK LAYER

The Data Link Layer is organised into two sublayers: a Virtual Channel Link Control sublayer (VCLC) and a Virtual Channel Access sublayer (VCA). The VCLC sublayer receives CCSDS packets from the Network layer, while the VCA sublayer forwards the physical channel access protocol data unit (PCA_PDU) to the physical layer.

The virtual channel procedures are functions required to generate virtual channel data units (VCDUs) from VCA_SDUs and vice versa. One of the channel access procedures is to handle Reed-Solomon check symbols. A VCDU with attached check symbols is called coded virtual channel data unit (CVCDU). The PCA_PDU consists of a succession of CVCDU prefixed by a Synchronisation Marker.

The structure of one CVCDU is shown in the following figure:

<table>
<tr><td colspan="6">VCDU Primary Header
6 octets</td><td rowspan="3">VCDU
Insert
zone</td><td colspan="3">VCDU Data Unit Zone
884 octets</td><td rowspan="3">CVCDU
Check
Symbols</td></tr>
<tr><td>Version
N°</td><td colspan="2">VCDU-ID</td><td rowspan="2">VCDU
Counter</td><td colspan="2">Signalling Field</td><td colspan="2">M_PDU Header</td><td rowspan="2">M_PDU
Packet Zone</td></tr>
<tr><td>"01"</td><td>SCID</td><td>VCID</td><td>Replay
Flag
"0"</td><td>Spare

"0000000"</td><td>Spare

5 bits</td><td>First Header
Pointer
11 bits</td></tr>
<tr><td>2 bits</td><td>8 bits</td><td>6 bits</td><td>3 octets</td><td colspan="2">1 octet</td><td>2 octets</td><td colspan="2">2 octets</td><td>882 octets</td><td>128 octets</td></tr>
</table>

Figure 4-1 CVCDU Structure

The elements of the CVCDU are as follows:

VCDU Primary Header	contains a six octets header structure.
VCDU Insert Zone	contains one IN_SDU having a length of 2 octets.
VCDU Data Unit Zone	contains one VCA_SDU in case of a valid VCDU or all zeros in case of a fill VCDU, the size of this field is 884 octets.
CVCDU Check Symbols	contain Reed-Solomon code (255,223) encoded check symbols, calculated over the VCDU Primary Header and the VCDU Data Unit Zone as defined in [RD.2].

Table 4-1 CVCDU Fields

4.1 VCDU Primary Header

The VCDU Primary Header consists of the following elements:

Version Number	is set to"01" specifying version-2 CCSDS structure.
VCDU-ID	represents the Virtual Channel Data Unit Identifier as specified in section 3, consisting of SCID and VCID.
VCDU Counter	contains a sequential count (modulo 16777216) of VCDUs on each virtual channel.
Signalling Field	is set to “0” specifying real-time VCDUs.

Table 4-2 VCDU Primary Header Fields

4.2 VCDU Insert Zone

The insert zone is always present and used for encryption control.

The structure of the IN_SDU is **mission specific**.

In case of failure of the encryption mechanism, the system shall not prevent data transmission to the ground; data shall then be transmitted in the clear.

4.3 VCDU Data Zone

The CVCDU data unit zone contains the multiplexing protocol data unit; this field consists of:

- M_PDU Header Spare bits (5 bits) : all set to "0"
- M_PDU Header First Pointer (11 bits): it contains a binary count P, which, when incremented by one, points directly to the number of the octet that contains the first octet of the first CCSDS packet header. If the VCDU data zone does not contain any packet header at all , the bits shall be set to "1".
- M_PDU Packet Zone (882 octets): it contains part, parts or complete CCSDS packets.

4.4 Fill VCDU

In the event that there are no valid M_PDU available for transmission, a fill VCDU will be generated.

The fill VCDU contents is **mission specific**.

4.5 Reed Solomon Check Symbol Field

The Reed Solomon Check Symbol field contains the check symbols which allow error correction. They are generated according to [RD.2] with an interleaving depth of I = 4.

4.6 Randomisation

Each commutated sequence of CVCDUs is converted into a sequence of channel access data units (CADUs). For this purpose each CVCDU is randomised first and preceded by a synchronisation marker then.

Randomisation is performed by multiplying all 8160 bits of the CVCDU with a pseudo noise pattern. The pseudo noise sequence is generated by means of the following polynomial:

$$h(x) = x^8 + x^7 + x^5 + x^3 + 1$$

This sequence repeats after 255 bits with the sequence generator being reinitialised to an all-ones state. The resulting PN pattern begins with (hexadecimal) FF480EC09A.

For further information, the reader shall refer to [RD.2].

4.7 Synchronisation Marker

The synchronisation marker is defined to be (hexadecimal)

1ACFFC1D

which describes a 32 bits pattern to precede each CVCDU.

Each CADU has a length of 8192 bits.

4.8 Data rate

The data rate for LRPT in the 137 MHz band is 72 kbit/s.

The data rate for LRPT in frequency bands other than the 137 MHz band and for AHRPT channels is **mission specific**.

5. LRPT PHYSICAL LAYER

5.1 Physical Layer Definition for the 137 - 138 MHz Frequency Band

Note: For the convenience of the reader, in the following the '137 – 138 MHz frequency band' will be called '137 MHz band' only.

The 137 MHz band LRPT physical layer shall perform the following operations (see for reference the modulator block diagram in):

1) Convolutional encoding
2) Interleaving of the convolutionally coded signal
3) Insertion of a unique word (UW) for interleaving synchronisation and delimitation
4) Serial to parallel conversion
5) Modulation according to the QPSK format
6) Amplification of the modulated signal
7) Transmission from the LRPT S/C antenna

5.1.1 Convolutional Encoding

The input data stream shall be convolutionally encoded.

The characteristics of the encoder are the following

Code rate:	½
Constraint length:	7 bits
Connection vectors:	G1= 1111001 / G2=1011011
Symbol inversion:	No
Puncturing:	No

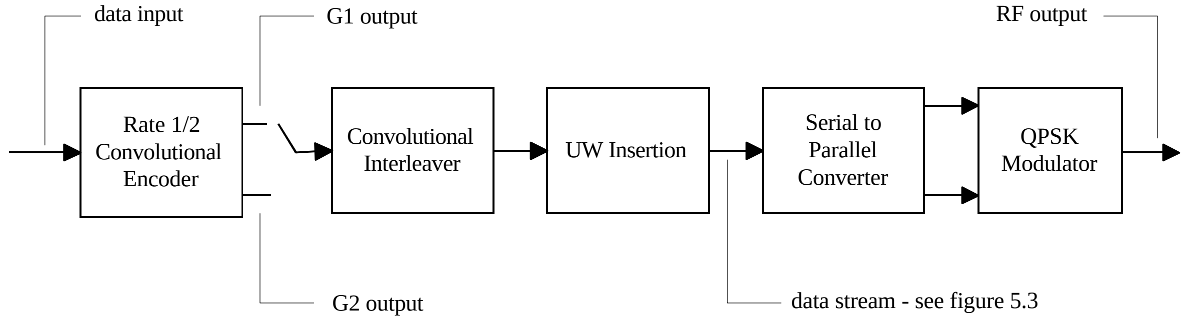

Figure 5-1 Modulator Block Diagram

5.1.2 Interleaving

In this section coded data units will be called bits.

The bits delivered by the convolutional encoder are shifted sequentially into a bank of registers. With each new coded bit, the commutator switches to a new register, and the new bit is shifted in while the old coded bit in that register is shifted out to the following stage (see Figure 5-2).

The output G1 of the convolutional encoder shall feed the odd numbered branches, whereas the output G2 shall feed the even numbered branches.

The number of the interleaver branches (B) shall be 36.

The number of the elementary delay (M) in each branch shall be 2048 bits.

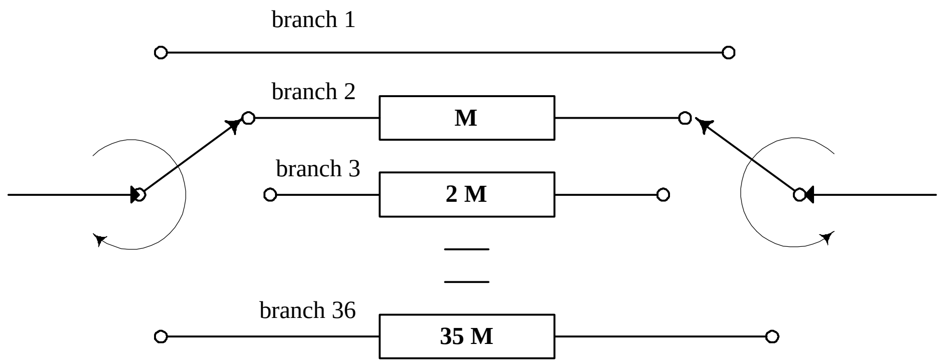

Figure 5-2 Interleaver Block Diagram

5.1.3 Synchronisation Marker Insertion

A synchronisation marker shall be inserted every 72 bits of the data stream delivered by each interleaving process. The synchronisation marker is 8 bit long and is **[TBD]**.

A synchronisation marker is inserted at the output of the convolutional interleaver after the bit supplied by the last (36th) branch every two frames. The frame is structured as shown in Figure 5-3.

The bit rate after the synchronisation marker insertion is 160 kbit/s.

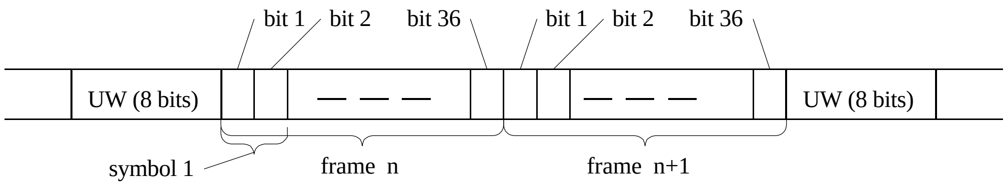

Figure 5-3 Frame Structure

5.1.4 Serial-to-Parallel Conversion

The grouping of pairs of bits for the QPSK modulator shall be obtained from the 1st and 2nd, the 3rd and 4th etc. branches of the convolutional interleaver output.

5.1.5 QPSK Modulation

5.1.5.1 Modulation Mapping

The mapping onto the QPSK constellation shall be according the Gray encoding (see Figure 5-4).

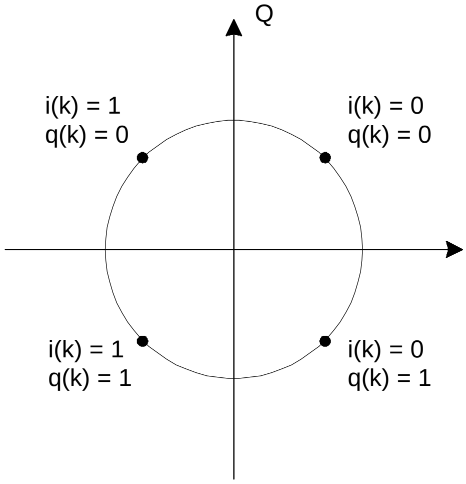

Figure 5-4 QPSK Constellation Diagram

5.1.5.2 Modulation Waveform

The data stream shall be modulated according to the QPSK format.

$$\tilde{s}(t) = \sum_{i=-\infty}^{\infty} \sqrt{2P_T}\left[\cos(f_i) g_T(t - iT_S) + j\sin(f_i) g_T(t - iT_S)\right]$$

The QPSK format can be expressed in complex notation as:

The baseband square-root raised-cosine filter impulse response is given by:

$$g_T(t) = \frac{1}{p}\left\{\left[\frac{16\sqrt{T_S}a^2 t}{(4\ a\ t + T_S)(4\ a\ t - T_S)} - \frac{\sqrt{T_S}}{t}\right]\sin\left(\frac{(a-1)\ p\ t}{T_S}\right) - \frac{4a\ \sqrt{T_s^3}\cos\left(\frac{(a+1)\ p\ t}{T_S}\right)}{(4\ a\ t + T_S)(4\ a\ t - T_S)}\right\}$$

where T_s is the symbol duration, ϕ_i is the information bearing phase (ϕ_i belongs to the 4-ary alphabet {±π/4; ±3π4}), α is the roll-off factor, P_T is the transmitter power.

The roll-off factor α shall be 0.6 .

The nominal carrier frequency shall be either: 137.1000 MHz
or 137.9125 MHz

The bandwidth of the signal (99% of total power) shall not exceed 150 kHz.

The specification of the carrier frequency uncertainties is **mission specific**.

5.1.6 Transmission

The 137 MHz LRPT subsystem shall radiate at the S/C interface a RHCP signal.

The 137 MHz LRPT S/C antenna pattern and EIRP are **mission specific**.

5.2 LRPT Physical Layer Definition for other Frequency Bands

The LRPT physical layer definition for frequency bands other than the 137 MHz band is **mission specific**.

6. AHRPT PHYSICAL LAYER

6.1 Physical Layer Definition for the 1698 – 1710 MHz Frequency Band

Note: For the convenience of the reader, in the following the '1698 – 1710 MHz frequency band' will be called '1.7 GHz band' only.

The 1.7 GHz band AHRPT physical layer shall perform the following operations:

1) Convolutional encoding
2) Modulation according to the QPSK format
3) Amplification of the modulated signal
4) Transmission from the AHRPT S/C antenna

6.1.1 Convolutional Encoding

The input data stream shall be convolutionally encoded.

The characteristics of the encoder are the following:

Code rate: 3/4

Constraint length: 7 bits

Connection vectors: G1= 1111001 / G2=1011011

Phase relationship: G1 is associated with the first symbol

Symbol inversion: No

Puncturing: Yes

Puncturing scheme:

- The 3/4 rate code is realised by puncturing the output of a ½ rate convolutional coder (see Figure 6-1).
- The output streams from the 3/4 rate convolutional encoder (labelled i(k) and q(k)) consist of the output streams of the ½ rate convolutional encoder (labelled l(k) and m(k) and associated with the G1 and G2 vectors) with the exception of two out of six bits, which are deleted in a repeating pattern.
- The bits to be deleted are shown struck out:

  i(k) = ..., l(k), ~~l(k+1)~~, l(k+2), l(k+3), ~~l(k+4)~~, l(k+5), l(k+6), …

  q(k) = ..., m(k), m(k+1), ~~m(k+2)~~, m(k+3), m(k+4), ~~m(k+5)~~, m(k+6), …
- Therefore the two streams i(k) and q(k) are composed by the following bits:

  i(k) = ..., l(k), l(k+2), l(k+3), l(k+5), l(k+6), …

  q(k) = ..., m(k), m(k+1), m(k+3), m(k+4), m(k+6), …

The output of the convolutional encoder is then provided to the modulation section.

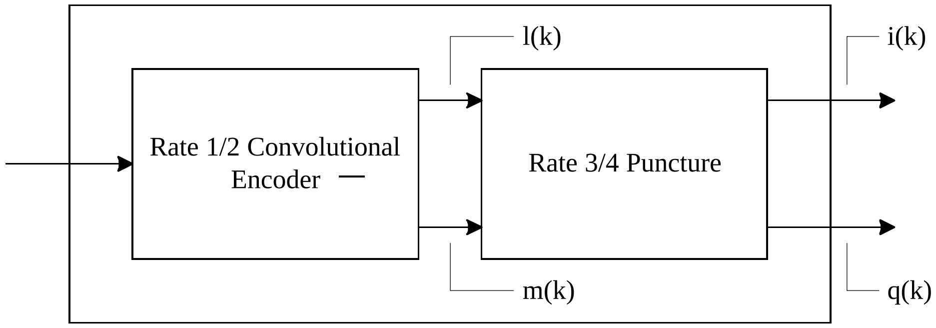

Figure 6-1 Rate 3/4 Convolutional Encoder

6.1.2 QPSK Modulation

6.1.2.1 Modulation Mapping

The mapping onto the QPSK constellation shall be according the Gray encoding (see Figure 6-2).

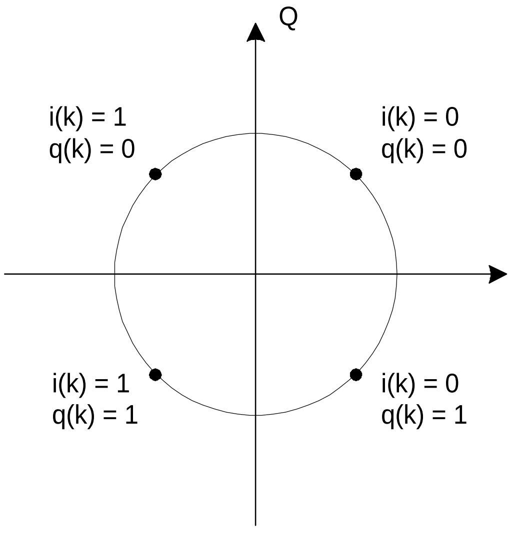

Figure 6-2 QPSK Constellation Diagram

6.1.2.2 Modulation Waveform

The data stream shall be modulated according to the QPSK format.

The QPSK format can be expressed in complex notation as:

$$\tilde{s}(t) = \sum_{i=-\infty}^{\infty} \sqrt{2P_T}\left[\cos(f_i)g_T(t-iT_S) + j\sin(f_i)g_T(t-iT_S)\right]$$

The baseband square-root raised-cosine filter impulse response is given by:

$$g_T(t) = \frac{1}{p}\left\{\left[\frac{16\sqrt{T_S}a^2 t}{(4\ a\ t+T_S)(4\ a\ t-T_S)} - \frac{\sqrt{T_S}}{t}\right]\sin\left(\frac{(a-1)\ p\ t}{T_S}\right) - \frac{4a\ \sqrt{T_s^3}\cos\left(\frac{(a+1)\ p\ t}{T_S}\right)}{(4\ a\ t+T_S)(4\ a\ t-T_S)}\right\}$$

where T_s is the symbol duration, ϕ_i is the information bearing phase (ϕ_i belongs to the 4-ary alphabet {±π/4; ±3π4}), α is the roll-off factor, P_T is the transmitter power.

The roll-off factor α shall be 0.6 .

The nominal bandwidth shall not exceed	either	1698.75 - 1703.25 MHz
	or	1704.75 - 1709.25 MHz.

The nominal bandwidth shall contain 99% of the total signal power.

The specification of the carrier frequency uncertainties is **mission specific**.

6.1.3 Transmission

The 1.7 GHz band AHRPT subsystem shall radiate at the S/C interface an RHCP signal.

The 1.7 GHz band AHRPT S/C antenna pattern and EIRP are **mission specific**.

Nevertheless, the 1.7 GHz band AHRPT transmission shall be conform to the following PFD limitations which derive from the ITU-R radio regulations:

-154	$dBW/(m^2 \cdot 4\ kHz)$	for elevation angle (δ) lower than 5°
-154 + 0.5 · (δ-5)	$dBW/(m^2 \cdot 4\ kHz)$	for elevation angle (δ) between 5° and 25°
-144	$dBW/(m^2 \cdot 4\ kHz)$	for elevation angle (δ) greater than 25°
-133	$dBW/(m^2 \cdot 1.5\ MHz)$	at any elevation angle (from 1670 to 1700 MHz).

6.2 AHPRT Physical Layer Definition for other Frequency Bands

The physical layer definition for frequency bands other than the 1.7 GHz band is **mission specific**.

APPENDIX A - LIST OF ACRONYMS

AHRPT	Advanced High Rate Picture Transmission
APID	Application Process identifier
AOS	Advanced Orbiting Systems
CADU	Channel Access Data Unit
CCSDS	Consultative Committee for Space Data Systems
CP_PDU	CCSDS Path Protocol Data Unit
CRC	Cyclic Redundancy Code
CVCDU	Coded Virtual Channel Data Unit
EIRP	Equivalent Isotropic Radiated Power
GHz	Gigahertz
IN_SDU	Insert Service Data Unit
ITU-R	Radiocommunication Sector of the International Telecommunication Union
kHz	Kilohertz
LRPT	Low Rate Picture Transmission
M_PDU	Multiplex Protocol Data Unit
MHz	Megahertz
PCA_PDU	Physical Channel Access Protocol Data Unit
PN	Pseudo Noise
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RHCP	Right Hand Circular Polarised
S/C	Spacecraft
TBC	To Be Confirmed
TBD	To Be Defined
UW	Unique Word
UTC	Universal Time Co-ordinated
VC	Virtual Channel
VCA	Virtual Channel Access
VCA_SDU	Virtual Channel Access Service Data Unit
VCLC	Virtual Channel Link Control
VCDU	Virtual Channel Data Unit
VCDU-ID	Virtual Channel Data Unit Identifier

APPENDIX B - LIST OF MISSION SPECIFIC ITEMS

Section	Item
2.1	APID definition
2.1	Definition of time stamp accuracy
2.1	Ancillary Data field contents
2.1	Use and method of compression applied to the Application Data field
2.1	Use and method for Packet Error Control
3	Definition of VCIDs and SCIDs
4.2	IN_SDU structure
4.4	Fill VCDU contents
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6.2	AHRPT physical layer definitions for frequency bands other than the 1.7 GHz band

APPENDIX C - LIST OF OPEN ISSUES

Section	Item
5.1.3	The synchronisation marker is 8 bit long and is **[TBD]**.