# SINGLE SPACE SEGMENT

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# HRPT / LRPT DIRECT BROADCAST SERVICES SPECIFICATION

**DOCUMENT SIGNATURE TABLE**

| Name | Function | Signature | Date |
|---|---|---|---|
| Prepared by<br>A. Boissin | EUMETSAT EPS<br>Space Segment<br>Engineer | | |
| Prepared by<br>E. Neri | ESA METOP<br>Avionics<br>Engineer | | |
| Approved by<br>P.G.Edwards | ESA METOP<br>Project manager | | |
| Approved by<br>M. Langevin | EUMETSAT EPS<br>Programme<br>Manager | | |

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| **Issue 4** | **14/11/97** | MO-DS-ESA-SY0048<br>EPS/SYS/SPE/95413 | page 30: The HRPT EIRP has been decreased by 1 dB over the whole coverage.<br>page 37: The HRPT link budget has been modified to consider the variation in the HRPT EIRP. |
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## TABLE OF CONTENTS

# 1. INTRODUCTION

This document defines the specification of the HRPT and LRPT services provided by the METOP satellite.

The HRPT and LRPT direct broadcast services are characterised by the implementation of the CCSDS Recommendations (AD03 and AD04) and the encryption of selectable virtual channels. The on-board encryption mechanism, based on the DES algorithm, is described in [AD02]. The encryption is addressed in this document, only to specify the content of the Insert zone in the VCDU data structure in the Data Link Layer.

This document covers the implementation of the data communication model on METOP spacecrafts.

The structure of this document follows is as follows:

| | | |
|---|---|---|
| Chapter 1 | - | This chapter |
| Chapter 2 | - | Lists the applicable and reference documents |
| Chapter 3 | - | Details the Application Layer implementation specific to the EPS / METOP mission. |
| Chapter 4 | - | Deals with the Network Layer implementation details. |
| Chapter 5 | - | Deals with the Data Link Layer implementation details. |
| Chapter 6 | - | Describes the LRPT Physical Layer and the Ground Station main requirements. |
| Chapter 7 | - | Describes the HRPT Physical Layer and the Ground Station main requirements. |
| Annex 1 | - | Provides an overview of the link budget for HRPT and LRPT. |
| Annex 2 | - | Describe the algorithm used to compress the AVHRR High Rate and the packet format of the resulting AVHRR Low rate application. |
| Annex 3 | - | Lists the acronyms used in this document. |

# 2. DOCUMENTATION

## 2.1 Applicable Documents

AD01 Deleted

AD02 EPS/SYS/SPE/95424 EUMETSAT Polar System / METOP Programme:
MO/DS/ESA/SY/0049 Encryption System Specification

AD03 CCSDS 701.0-B-2 Advanced Orbiting Systems , Networks and Data, Blue Book, Issue 2.

AD04 CCSDS 101.0-B-3 Telemetry Channel Coding, Blue Book, Issue 3.

## 2.2 Reference Documents

RD01 Deleted

# 3. APPLICATION LAYER

The Application layer defines the information exchange between the METOP payload and the user specific applications.

The NOAA procured instruments (AVHRR, AMSU-A1, AMSU-A2, HIRS, SEM, DCS) will generate raw data which will be time tagged and formatted by the spacecraft NOAA Interface Unit (NIU). This NIU will also provide data compression of the AVHRR data for transmission on the LRPT link.

The IASI, MHS, GRAS, GOME and ASCAT instruments provide data in the form of CCSDS source packets.

The satellite provides housekeeping data, GRAS positioning and timing data and administrative messages in the form of CCSDS source packets.

The Application Process Identifiers relevant to each instrument are defined in 3.3.

## 3.1 Application Data

### 3.1.1 Application Data provided with LRPT

The application data provided by the Low Resolution Picture Transmission link are as follows:

- Compressed resolution imagery on selected channels of the AVHRR instrument (the data compression scheme is defined in the document "Instrument Data Packet Definition").
- Infrared and microwave sounding data from the Meteorological Payload: AMSU-A1, AMSU-A2, MHS, HIRS.
- SEM data.
- Spacecraft Housekeeping data.
- GRAS positioning and timing data.
- Administrative messages.

### 3.1.2 Application Data provided with HRPT

The application data provided by the High Resolution Picture Transmission link are as follows:

- Full resolution AVHRR imagery .
- Infrared and microwave sounding data from the Meteorological Payload: AMSU-A1, AMSU-A2, MHS, HIRS and IASI.
- SEM data.
- DCS data.
- Data provided by ASCAT, GOME.
- Spacecraft Housekeeping data.
- GRAS positioning and timing data.

- GRAS sounding data.
- Administrative messages.

## 3.2 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 (48 bits) | | | | | | | Secondary header<br>8 octets | User data<br>variable | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Packet identifier<br>2 octets | | | | Packet sequence control<br>2 octets | | Packet length<br>2 octets | | | | |
| Version No<br>3 bits<br>"000" | Type<br>1 bit<br>"0" | Secondary Header Flag<br>1 bit | APID<br>11 bits | Sequence flag<br>2 bits | Packet sequence Count<br>14 bits | 16 bits | Time stamp<br>64 bits | Ancillary data<br>var | Application data<br>var | PEC<br>16 bits |

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 APIDs are listed in 3.3.

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.

The Packet 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 CCSDS 301-B2 "level 1" Time Code.

The time stamp consists of

- 2 octets indicating the number of days with reference to 1/1/2000;
- 4 octets indicating the millisecond of the day;
- 2 octets indicating the microsecond of the day.

The time stamp will be synchronised to UTC with an accuracy of 4 milliseconds.

The User Data field contains the following fields:

– Ancillary data field: this field contains in the first six octets a secondary time stamp and, optionally, other 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 secondary time stamp consists of:

- one octet filled with "0";
- 3 octets of coarse time (second);
- 2 octets of fine time ($2^{-16}$ second). The 5 LSBs of this field are not used and set to “00000"

The reference time of the secondary time stamp (epoch) is known and defined by the Satellite Control Centre. A counter rollover happens every $2^{24}$ seconds (half a year). This is equivalent to a modification of the epoch. The secondary time stamp is synchronised with the time stamp in the Packet secondary header.

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

- 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.

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

## 3.3 Application data overview: APID and Source Packets size - data rates

The following table provides an overview of the METOP application data: It shows the reserved APIDs, the packetised data rate, the size of the whole packet, the Ancillary data and the Application data length and eventually the packet rate for each application.

***Note for the reader of the draft:***
***both the packet size and the data rate have been increased (8 octets) due to the additional time stamp;***
***the reference for the packet description is the ICD as the document "Instrument Data Packet Definition" has never been issued;***
***the Packet size of the "Satellite housekeeping packet" and the "GRAS positioning and timing data" must be multiple of 32 octets***

| Application | APID | packetised data rate (kbps) average/ (peak) | Packet size (octet) | Ancillary data length (octets) | Application data length (octet) | Rate (packet /s) |
|---|---|---|---|---|---|---|
| AVHRR/3 high resolution | 103, 104 | 622.272 | 12964 | 6 | 12944 | 6 |
| AVHRR/3 low resolution | 64..70 | 40 | var | 12 | var | 3 |
| MHS | 34 | 3.918 | 1306 | 6 | 1286 | 3/8 |
| DCS-2 | 35 | 2.580 | 2580 | 6 | 2560 | 1/8 |
| SEM (option) | 37 | 0.165 | 660 | 6 | 640 | 1/32 |
| HIRS/3 | 38 | 2.905 | 2324 | 6 | 2304 | 1/6.4 |
| AMSU-A1 | 39 | 2.100 | 2100 | 6 | 2080 | 1/8 |
| AMSU-A2 | 40 | 1.140 | 1140 | 6 | 1120 | 1/8 |
| IASI | 128..191 | 1500/ (2200) | detailed in the ICD | | | |
| ASCAT | 192..255 | 43 (60) | detailed in the ICD | | | |
| GOME | 384..447 | 400 | tbd | tbd | tbd | tbd |
| GRAS meteorological data | 448...511 | 20/(60) | detailed in the ICD | | | |
| Satellite housekeeping packet | 1 | 4.352 | 544 | 6 | 524 | 1 |
| GRAS positioning and timing data | 2, 3 | <0.100 | 192 or 42 (tbc) | 6 tbc | 172 or 22 (tbc) | 1/16 |
| Administrative messages | 6 | 2.005 | 8022 tbc | 8 | 8000 tbc | 1/32 |

### 3.4 Detailed Instrument source packet description

Although the instruments data follow the CCSDS recommendation together with the specific requirements listed in chapter 3.3, the packet data field structure is specific to the instrument itself.

***Note for the reader: The reference made in the previous specification to the document "Instrument Data Packet Definition" (RD01), cannot be longer made as the document has never been issued.***

# 4. 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 of 14 bits length, consisting of a spacecraft identifier (8 bits) and a virtual channel identifier (6 bits).

Spacecraft identifiers shall be assigned as follows:

| Spacecraft | Identifier |
|---|---|
| METOP1 | 00001011 |
| METOP2 | 00001100 |
| METOP3 | 00001101 |
| METOP SIMULATOR | 00001110 |

The virtual channel identifiers are given by the subsequent table:

LRPT:

| Instruments | Virtual Channel Identifier |
|---|---|
| Spacecraft Housekeeping | 34 |
| MHS | 12 |
| AMSU A1/2, SEM, HIRS | 3 |
| AVHRR low rate | 5 |
| GRAS positioning and timing data | 34 |
| Admin message | 34 |
| Fill VC | 63 |

HRPT:

| Instruments | Virtual Channel Identifier |
|---|---|
| Spacecraft Housekeeping | 34 |
| MHS | 12 |
| AMSU A1/2, SEM, HIRS | 3 |
| DCS | 27 |
| AVHRR High rate | 9 |
| IASI | 10 |
| ASCAT | 15 |
| GOME | 24 |
| GRAS positioning and timing data | 34 |
| GRAS  sounding data | 29 |
| Adm. messages | 34 |
| fill VC | 63 |

## 5. 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<br>2 octets</td><td colspan="3">VCDU Data Unit Zone</td><td rowspan="3">CVCDU Check symbols<br>128 octets</td></tr>
<tr><td rowspan="2">Version n°<br>"01"</td><td colspan="2">VCDU Id</td><td rowspan="2">VCDU counter<br>3 octets</td><td colspan="2">Signalling Field<br>1 octet</td><td colspan="2">M_PDU header<br>2 octets</td><td rowspan="2">M_PDU packet zone<br>882 octets</td></tr>
<tr><td>S/C id<br>8 bits</td><td>Type<br>6 bits</td><td>Replay flag<br>"0"</td><td>spare<br>"0000000"</td><td>M_PDU header spare</td><td>M_PDU first header pointer</td></tr>
</table>

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 |
| Reed-Solomon check symbols | contain Reed-Solomon code (255,223) encoded check symbols, calculated over the VCDU primary header and the VCDU data unit zone. |

### 5.1 VCDU primary header

The VCDU primary header consists of the following elements:

| | |
|---|---|
| version number | set to"0 1" specifying version-2 CCSDS structure |
| VCDU-ID | virtual channel data unit identifier as specified in Chapter 4, consisting of spacecraft identifier and virtual channel identifier. |
| VCDU counter | sequential count (modulo 16777216) of VCDUs on each virtual channel |
| signalling field | set to 0 specifying real-time VCDUs |

### 5.2 VCDU Insert Zone

The insert zone is always present and used for encryption control (AD02).

The structure of the IN_SDU used with LRPT or HRPT is as follows:

The insert service data unit (IN_SDU) is used for data encryption: this field is composed of:

- Encryption flag (1 octet): set to $00_{HEX}$ when encryption is off; set to $FF_{HEX}$ when encryption is on.

- Key number (1 octet): this octet indicates which message key is used to encrypt the VC. It is set to $00_{HEX}$ when encryption is off.

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

### 5.3 VCDU Data Unit 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.

## 5.4 Fill VCDU

In the event that there are no valid M_PDU available for transmission, a fill VCDU will be generated. The content of the VCDU Data Unit Zone will be all “0".

## 5.5 Reed Solomon Check Symbol Field

The Reed Solomon Check Symbol Field contains the check symbols which allow error correction. They are generated according to AD04 with an interleaving depth of I=4.

## 5.6 Randomisation

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

Randomization 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 reinitialized to an all-ones state. The resulting PN pattern begins with (hexadecimal) FF480EC09A.

## 5.7 Synchronisation marker

The synchronization 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.

## 5.8 CVCDUs commutation algorithm

Commutation of CVCDUs shall not be performed on basis of a priority system.

### 5.9 Data rate budget

The data rate budget for the LRPT and HRPT channels is given for information here below:

| Application | HRPT [kb/s] | LRPT [kb/s] |
|---|---|---|
| IASI | 1500.000 | 0.000 |
| AVHRR | 622.272 | 40.000 |
| HIRS | 2.905 | 2.905 |
| AMSU A1 | 2.100 | 2.100 |
| AMSU A2 | 1.140 | 1.140 |
| MHS | 3.918 | 3.918 |
| SEM | 0.165 | 0.165 |
| DCS | 2.580 | 0.000 |
| ASCAT | 60.000[1] | 0.000 |
| GRAS[2] | 60.000[1] (tbc) | 0.000 |
| GOME | 240.000 (tbc) | 0.000 |
| Satellite housekeeping packet | 4.352 | 4.352 |
| GRAS time and real time position | 0.100 | 0.100 |
| Admin messages | 2.005 | 2.005 |
| subtotal | 2,501.537 | 56.685 |
| Capacity reserved | 513.106 | 5.331 |
| sub-total | 3,014.643 | 62.016 |
| RS-coding (+16.1%) | 485.357 | 9.984 |
| total | 3500.000 | 72.000 |

1) Peak data rate
2) Meteorological data

## 6. LRPT PHYSICAL LAYER

The LRPT physical layer shall perform the following operations (see for reference the modulator block diagram in figure 6.1):

1) Convolutional encoding
2) Interleaving of the convolutionally coded signal
3) Insertion of a 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 antenna

### 6.1 Convolutional encoding

The input data stream shall be convolutional 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 |

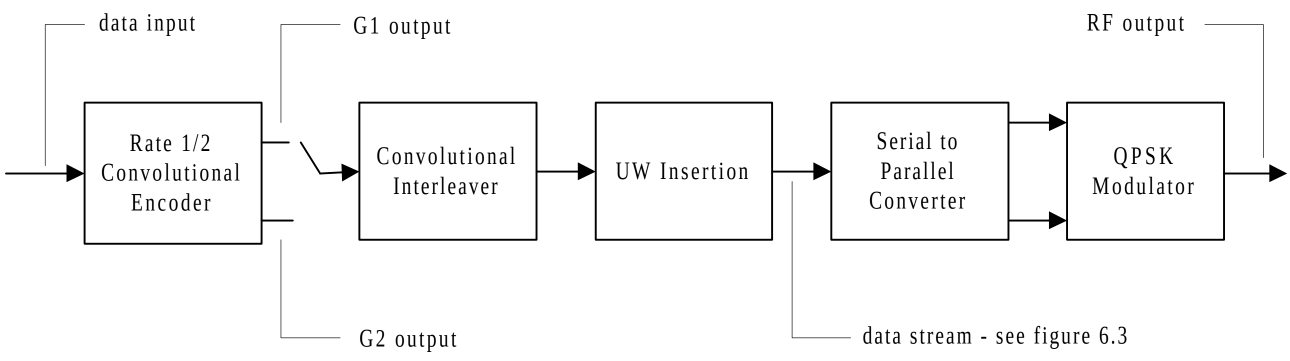



Figure 6.1 - Modulator block diagram

## 6.2 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 6.2).

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

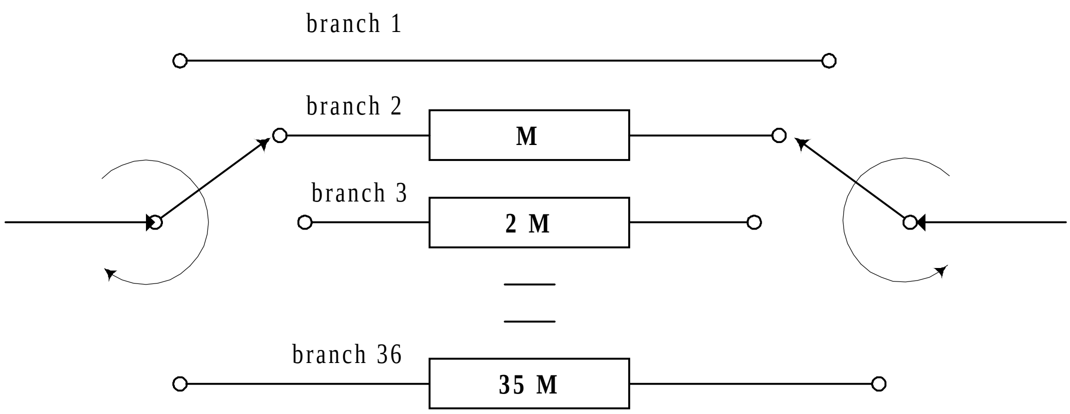



Figure 6.2 - Interleaver block diagram

### 6.3 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 defined as $tbd_{(HEX)}$.

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 6.3.

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

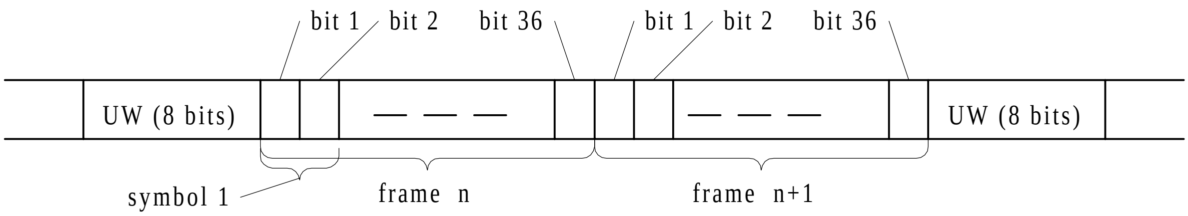



Figure 6.3 - Frame structure

### 6.4 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.

## 6.5 QPSK Modulation

### 6.5.1 Modulation mapping

The mapping onto the QPSK constellation shall be according the Gray encoding (see figure 6.4).

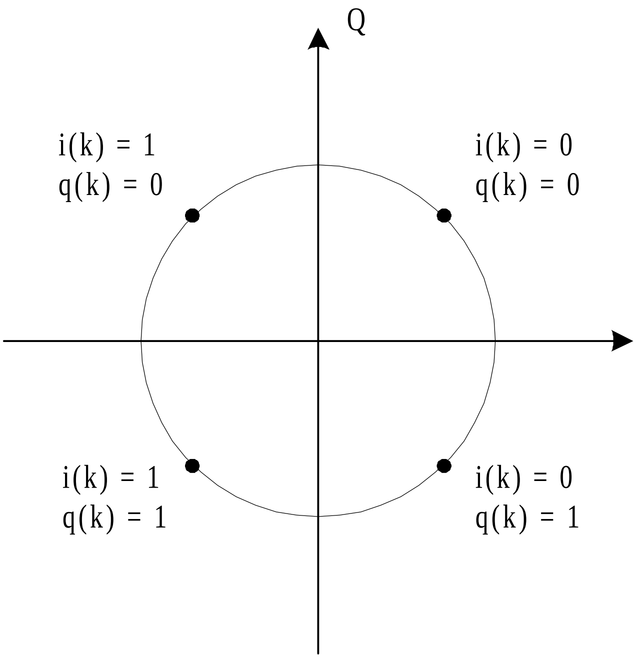



Figure 6.4 - QPSK constellation diagram

### 6.5.2 Modulation waveform

The data stream shall be modulated according to the QPSK format.
The QPSK format can be expressed in complex notation as:

$$\tilde{s}_T(t) = \sum_{i=-\infty}^{\infty} \sqrt{2P_T}\ [\cos(\phi_i)\, g_T(t - iT_s) + j\sin(\phi_i)\, g_T(t - iT_s)]$$

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

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

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

### 6.5.3 RF parameters

The QPSK ideal modulation is approximated by a two NRZ filtered data streams modulating the carrier on two orthogonal axis.
The two synchronous, NRZ rectangular pulses streams shall be filtered in baseband by a network approximating the square-root raised cosine Nyquist filter, defined as follows:

$$|H(j\omega)|=\begin{cases}\dfrac{\omega T_s/2}{\sin(\omega T_s/2)} & 0\le\omega\le\dfrac{\pi}{T_s}(1-\alpha)\\[2ex] \dfrac{\omega T_s/2}{\sin(\omega T_s/2)}\cos\left[\dfrac{T_s}{4\alpha}\left(\omega-\dfrac{\pi(1-\alpha)}{T_s}\right)\right] & \dfrac{\pi}{T_s}(1-\alpha)\le\omega\le\dfrac{\pi}{T_s}(1+\alpha)\\[2ex] 0 & \omega\ge\dfrac{\pi}{T_s}(1+\alpha)\end{cases}$$

The group delay caused by the filtering network shall be within the mask shown in figure 6.5 / Tables 6.1 and 6.2.

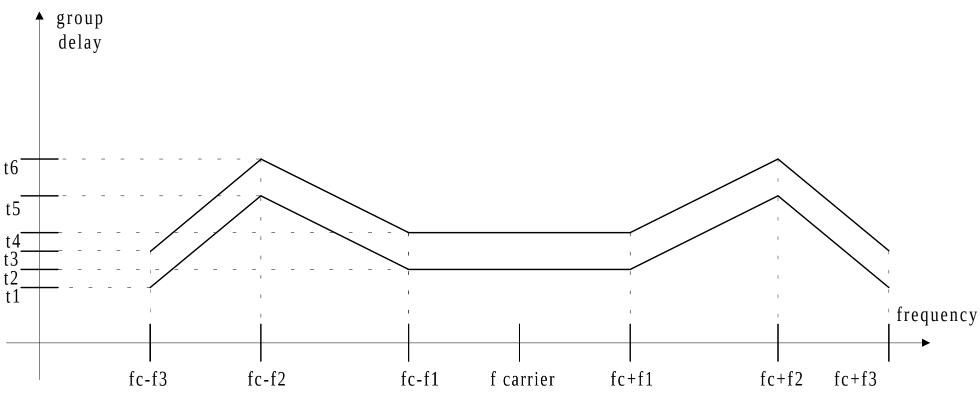



Figure 6.5 - Group delay of the transmitting channel

| Group delay (nsec) | |
|---|---|
| t1 | tbd |
| t2 | tbd |
| t3 | tbd |
| t4 | tbd |
| t5 | tbd |
| t6 | tbd |

Table 6.1

| Frequency | |
|---|---|
| f1 | tbd |
| f2 | tbd |
| f3 | tbd |
| f4 | tbd |

Table 6.2

This group delay distortion shall be compensated for at the receiving end to obtain the minimum channel degradation.

The roll-off factor shall be 0.6.

The LRPT physical layer shall generate a signal which requires an Eb/No of 4.5 dB to be coherently demodulated with a BER of 10-3 at the output of the Viterbi decoder.
The loss introduced by the demodulator (used for the test) shall be considered part of the requirement.

The loss associated to the synchronisation insertion - which is 10·log(80/72) dB; 0.5 dB - shall not be taken into account in this figure.

This requirement shall be met at the maximum allowed compression point of the amplifier and for a random data pattern.

The nominal carrier frequency shall be either: 137.1 MHz
or 137.9125 MHz

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

The carrier frequency deviation from the nominal or back-up frequency, including initial accuracy and drift due to aging and temperature, shall not exceed ±15·10-6.

## 6.6 Amplification

The QPSK modulated signal shall be amplified in order to achieve the EIRP defined in para 6.7.

The working point of the amplifier shall be selected in order to meet the requirements defined in para 6.5.3.

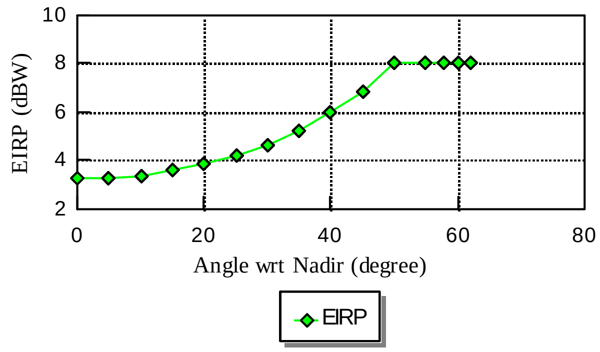
## 6.7 Transmission

The LRPT subsystem shall at least radiate at the S/C interface the EIRP defined in table 6.3.

| Angle w.r.t. Nadir | EIRP (dBW) |
|---|---|
| 0 | 3.21 |
| 5 | 3.24 |
| 10 | 3.36 |
| 15 | 3.55 |
| 20 | 3.82 |
| 25 | 4.19 |
| 30 | 4.65 |
| 35 | 5.23 |
| 40 | 5.95 |
| 45 | 6.85 |
| 50 | 8.00 |
| 55 | 8.00 |
| 60 | 8.00 |
| 62 | 8.00 |

Table 6.3

Figure 6.6- LRPT EIRP




The polarisation shall be RHCP.

The axial ratio shall be less than 4.5 dB.

### 6.8 LRPT ground stations

The LRPT link shall serve ground station equipments of two different types:

- Steerable antennas with a minimum elevation angle of 5°
- Omnidirectional antennas with a minimum elevation angle of 13°

The assumed ground station G/T and corresponding minimum elevation angles (used for link margin calculation provided in Annex 1) are as follows:

| Antenna type | System G/T | min. S/C Elevation |
|---|---|---|
| steerable YAGI antenna | -22.4 dB/K | 5° |
| omni-directional antenna | -30.4 dB/K | 13° |

Axial ratio: less than 3.5 dB.

Pointing losses: less than 0.2 dB (YAGI antenna).

The assumptions taken on ground stations modulation and receiver degradation for link budget calculation, are given in Annex 1.

# 7. HRPT PHYSICAL LAYER

The HRPT 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 HRPT antenna

## 7.1 Convolutional encoding

The input data stream shall be convolutional encoded.

The characteristics of the Viterbi encoder shall be 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 Viterbi coder (see figure 7.1 ).

- The output streams from the 3/4 rate Viterbi encoder - labelled i(k) and q(k) - consist of the output streams of the ½ rate Viterbi coder - 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 Viterbi encoder has a rate of 4666.667 kbit/s and is provided to the modulation section.

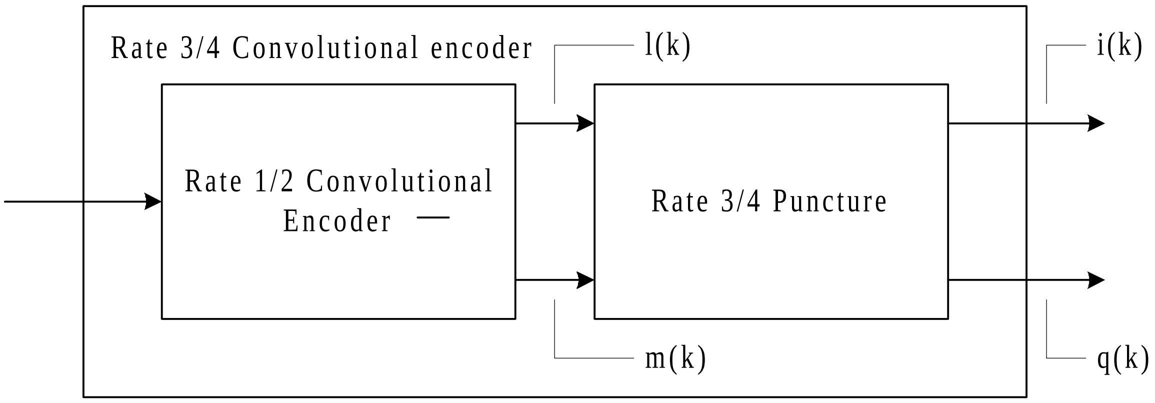



Figure 7.1 - Rate 3/4 convolutional encoder

## 7.2 QPSK Modulation

### 7.2.1 Modulation mapping

The mapping onto the QPSK constellation shall be according the Gray encoding (see figure 7.1).

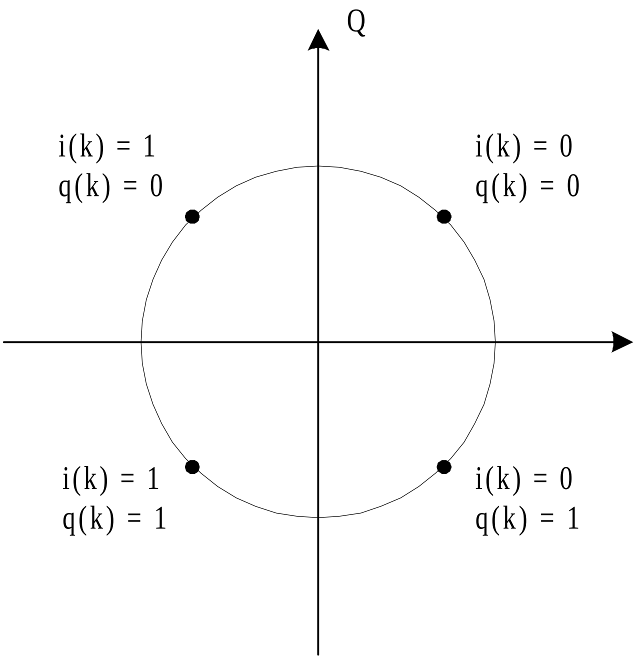



Figure 7.2 - QPSK constellation diagram

### 7.2.2 Modulation Waveform

The data stream shall be modulated according to the QPSK format.
The QPSK format can be expressed in complex notation as:

$$\tilde{s}_T(t) = \sum_{i=-\infty}^{\infty} \sqrt{2P_T}\ [\cos(\phi_i)\, g_T(t - iT_s) + j \sin(\phi_i)\, g_T(t - iT_s)]$$

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

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

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

### 7.2.3 RF parameters

The QPSK ideal modulation is approximated by a two NRZ filtered data streams modulating the carrier on two orthogonal axis.

The two synchronous, NRZ rectangular pulses streams shall be filtered in baseband by a network approximating the square-root raised cosine Nyquist filter, defined as follows:

$$|H(j\omega)| = \begin{cases} \dfrac{\omega T_s/2}{\sin(\omega T_s/2)} & 0 \le \omega \le \dfrac{\pi}{T_s}(1-\alpha) \\ \dfrac{\omega T_s/2}{\sin(\omega T_s/2)}\cos\left[\dfrac{T_s}{4\alpha}\left(\omega - \dfrac{\pi(1-\alpha)}{T_s}\right)\right] & \dfrac{\pi}{T_s}(1-\alpha) \le \omega \le \dfrac{\pi}{T_s}(1+\alpha) \\ 0 & \omega \ge \dfrac{\pi}{T_s}(1+\alpha) \end{cases}$$

The group delay caused by the filtering network shall be within the mask shown in figure 7.3 / Tables 7.1 and 7.2.

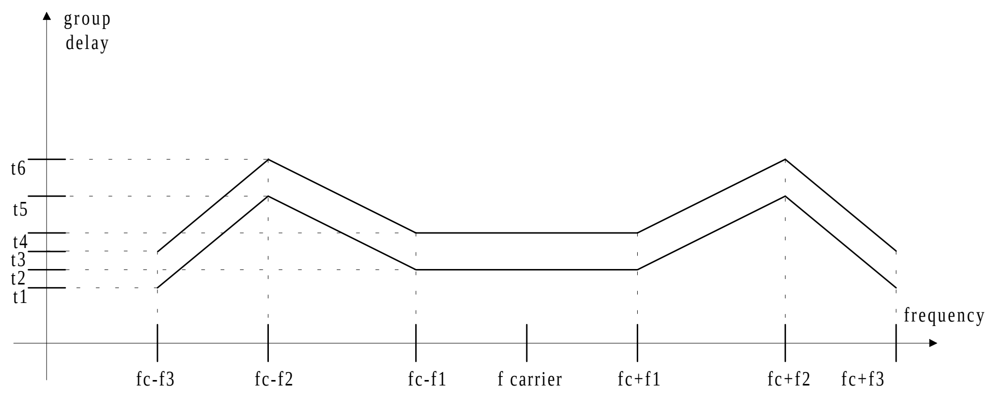



Figure 7.4 - Transmission channel group delay mask

| Group delay (nsec) | |
|---|---|
| t1 | tbd |
| t2 | tbd |
| t3 | tbd |
| t4 | tbd |
| t5 | tbd |
| t6 | tbd |

Table 7.1

| Frequency | |
|---|---|
| f1 | tbd |
| f2 | tbd |
| f3 | tbd |

Table 7.2

This group delay distortion shall be compensated for at the receiving end to obtain the minimum channel degradation.

The roll-off factor shall be 0.6.

The HRPT physical layer shall generate a signal which requires an Eb/No of 5.0 dB to be coherently demodulated with a BER of 10-3 at the output of the Viterbi decoder. The loss introduced by the demodulator (used for the test) shall be considered part of the requirement.

This requirement shall be met at the maximum allowed compression point of the amplifier and for a random data pattern.

The Nominal carrier frequency shall be:

either 1701.300 MHz, being the nominal bandwidth 1698.75 - 1703.25 MHz

or 1707.000 MHz; being the nominal bandwidth 1704.75 - 1709.25 MHz.

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

The carrier frequency deviation from the nominal or back-up frequency, including initial accuracy and drift due to aging and temperature, shall not exceed ±25·10-6.

### 7.3 Amplification

The QPSK modulated signal shall be amplified in order to achieve the EIRP defined in para 3.4. The working point of the amplifier shall be selected in order to meet the requirements defined in para 7.2.3.

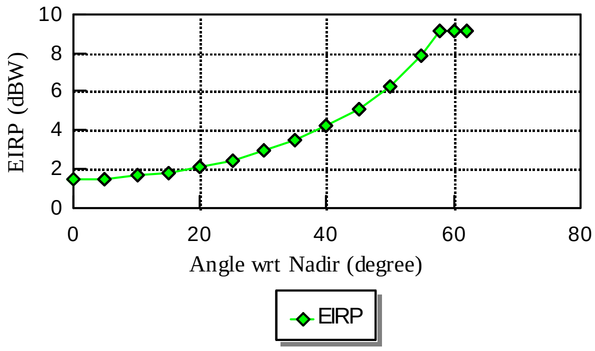
## 7.4 Transmission

The HRPT subsystem shall at least radiate at the S/C interface the EIRP defined in table 7.3.

| Angle w.r.t. nadir | EIRP (dBW) |
|---|---|
| 0 | 1.46 |
| 5 | 1.49 |
| 10 | 1.61 |
| 15 | 1.8 |
| 20 | 2.07 |
| 25 | 2.44 |
| 30 | 2.9 |
| 35 | 3.48 |
| 40 | 4.2 |
| 45 | 5.1 |
| 50 | 6.25 |
| 55 | 7.8 |
| 58 | 9.1 |
| 60 | 9.1 |
| 62 | 9.1 |

Table 7.3

Figure 7.4- HRPT EIRP




The gain of the antenna shall be such that the following PFD limitations are met:

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

The following assumptions shall be used in the PFD calculation:

- Peak of TX spectrum density including possible residual carrier.
- Typical values for TX power and antenna gain over elevation.
- Average values for antenna gain along azimuth.

The polarisation shall be RHCP. The axial ratio shall be less than 4.5 dB.

### 7.5 HRPT ground stations

The HRPT link shall serve ground stations, which may be located anywhere in the world, and which will have the following characteristics:

| | |
|---|---|
| G/T: | 6 dB/K |
| Pointing loss | 0.5 dB |
| Ground station axial ratio | less than 1 dB. |

The assumptions taken on ground stations modulation and receiver degradation for link budget calculation, are given in Annex 1.

## Annex 1. TYPICAL WORST CASE LRPT/HRPT LINK BUDGETS BASED ON SPECIFICATION VALUES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Link ID | METOP LRPT - High gain antenna receiver | | | | | | | | |
| Ground station | LRPT (G/T=-22.4) | | | | | | | | |
| | | | | | | | | | |
| Frequency | | (MHz) | 137.90 | 137.90 | 137.90 | 137.90 | 137.90 | 137.90 | 137.90 |
| S/C altitude | | (km) | 850.00 | 850.00 | 850.00 | 850.00 | 850.00 | 850.00 | 850.00 |
| Slant range | | (km) | 2,889 | 2,468 | 1,858 | 1,473 | 1,227 | 963 | 850 |
| S/C view angle | | (degree) | 61.51 | 60.33 | 56.00 | 49.82 | 42.52 | 26.18 | 0.00 |
| Data rate | | (kbit/s) | 72.00 | 72.00 | 72.00 | 72.00 | 72.00 | 72.00 | 72.00 |
| | | | | | | | | | |
| G/S view angle | | (degree) | 5.00 | 10.00 | 20.00 | 30.00 | 40.00 | 60.00 | 90.00 |
| | | | | | | | | | |
| S/C EIRP | note 1 | (dBW) | 8.00 | 8.00 | 8.00 | 7.96 | 6.40 | 4.28 | 3.21 |
| S/C antenna axial ratio | | (dB) | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 |
| Free space loss | | (dB) | 144.45 | 143.08 | 140.62 | 138.60 | 137.01 | 134.91 | 133.82 |
| Atmospheric loss | | (dB) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Polarisation loss | | (dB) | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| Reflection and multipath | note 7 | (dB) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total propagation loss | | (dB) | 145.90 | 144.53 | 142.07 | 140.05 | 138.46 | 136.36 | 135.27 |
| | | | | | | | | | |
| Ground station G/T (reference) | note 2 | (dB/K) | -22.40 | -22.40 | -22.40 | -22.40 | -22.40 | -22.40 | -22.40 |
| G/S axial ratio | | (dB) | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 |
| G/S pointing loss | | (dB) | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| | | | | | | | | | |
| C/KT at receiver input | | (dB/Hz) | 68.10 | 69.47 | 71.93 | 73.91 | 73.94 | 73.92 | 73.94 |
| Boltzmann's constant | | (dBW/k Hz | -228.60 | -228.60 | -228.60 | -228.60 | -228.60 | -228.60 | -228.60 |
| Bit rate | | (dBHz) | 48.57 | 48.57 | 48.57 | 48.57 | 48.57 | 48.57 | 48.57 |
| Eb/No at receiver input | | (dB) | 19.53 | 20.90 | 23.36 | 25.34 | 25.37 | 25.35 | 25.37 |
| Required Eb/No (BER=$10^{-3}$) | note 13 | (dB) | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 |
| Coding loss due to frame sync | note 11 | (dB) | 0.47 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 |
| Modulation degradation | note 8 | (dB) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Receiver degradation | note 3 | (dB) | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| System margin | note 4 | (dB) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Available link margin | | (dB) | 11.56 | 12.89 | 15.35 | 17.33 | 17.36 | 17.34 | 17.36 |
| | | | | | | | | | |
| note 1: minimum EIRP at S/C interface | | | | | | | | | |
| note 2: reference G/T of the ground station; the actual figure mainly depends on the receiver, the level of man-made noise in the receiver location and the pointing of the antenna | | | | | | | | | |
| note 3: allowed deviation from theoretical performance of the demodulator | | | | | | | | | |
| note 4: minimum system margin required by ESA | | | | | | | | | |

| |
|---|
| note 7: loss due to reflections from ground or from adjacent buildings |
| note 8: deviation from theoretical performance due to the modulation process, requirement by ESA |
| note 11: loss due the addition of synchronisation words in the interleaving protocol |
| note 13: theoretical Eb/No required to obtain a BER of $10^{-3}$ at the output of the Viterbi decoder. This BER requirement (due to the following R-S decoder) guarantees a virtually packet loss free link quality. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Link ID | METOP LRPT - Omnidirectional antenna receiver | | | | | | | |
| Ground station | LRPT (G/T=-30.4) | | | | | | | |
| | | | | | | | | |
| Frequency | | (MHz) | 137.90 | 137.90 | 137.90 | 137.90 | 137.90 | 137.90 |
| S/C altitude | | (km) | 850.00 | 850.00 | 850.00 | 850.00 | 850.00 | 850.00 |
| Slant range | | (km) | 2,256 | 1,858 | 1,473 | 1,227 | 963 | 850 |
| S/C view angle | | (deg.ree) | 59.28 | 56.00 | 49.82 | 42.52 | 26.18 | 0.00 |
| Data rate | | (kbit/s) | 72.00 | 72.00 | 72.00 | 72.00 | 72.00 | 72.00 |
| | | | | | | | | |
| G/S view angle | | (deg.ree) | 13.00 | 20.00 | 30.00 | 40.00 | 60.00 | 90.00 |
| | | | | | | | | |
| S/C EIRP | note 1 | (dBW) | 8.00 | 8.00 | 7.96 | 6.40 | 4.28 | 3.21 |
| S/C antenna axial ratio | | (dB) | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 |
| Free space loss | | (dB) | 142.30 | 140.62 | 138.60 | 137.01 | 134.91 | 133.82 |
| Atmospheric loss | | (dB) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Polarisation loss | | (dB) | 0.47 | 0.47 | 0.47 | 0.47 | 0.47 | 0.47 |
| Reflection and multipath | note 7 | (dB) | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Total propagation loss | | (dB) | 144.77 | 143.09 | 141.07 | 139.48 | 137.38 | 136.29 |
| | | | | | | | | |
| Ground station G/T (reference) | note 2 | (dB/K) | -30.40 | -30.40 | -30.40 | -30.40 | -30.40 | -30.40 |
| | | | | | | | | |
| G/S axial ratio | | (dB) | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 |
| G/S pointing loss | | (dB) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | | | |
| C/KT at receiver input | | (dB/Hz) | 61.43 | 63.11 | 65.09 | 65.12 | 65.10 | 65.12 |
| Boltzmann’s constant | | (dBW/kHz) | -228.60 | -228.60 | -228.60 | -228.60 | -228.60 | -228.60 |
| Bit rate | | (dBHz) | 48.57 | 48.57 | 48.57 | 48.57 | 48.57 | 48.57 |
| Eb/No at receiver input | | (dB) | 12.86 | 14.54 | 16.52 | 16.55 | 16.53 | 16.55 |
| Required Eb/No (BER=$10^{-3}$) | note 13 | (dB) | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 |
| Coding loss due to frame sync | note 11 | (dB) | 0.47 | 0.47 | 0.47 | 0.47 | 0.47 | 0.47 |
| Modulation degradation | note 8 | (dB) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Receiver degradation | note 3 | (dB) | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| System margin | note 4 | (dB) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Available link margin | | (dB) | 4.89 | 6.57 | 8.55 | 8.58 | 8.56 | 8.58 |
| | | | | | | | | |
| note 1: minimum EIRP at S/C interface | | | | | | | | |
| note 2: reference G/T of the ground station; the actual figure mainly depends on the receiver and the level of man-made noise in the receiver location | | | | | | | | |
| note 3: allowed deviation from theoretical performance of the demodulator | | | | | | | | |
| note 4: minimum system margin required by ESA | | | | | | | | |
| note 7: loss due to reflections from ground or from adjacent buildings | | | | | | | | |
| note 8: deviation from theoretical performance due to the modulation process, requirement by ESA | | | | | | | | |
| note 11: loss due the addition of synchronisation words in the interleaving protocol | | | | | | | | |

note 13: theoretical Eb/No required to obtain a BER of $10^{-3}$ at the output of the Viterbi decoder. This BER requirement (due to the following R-S decoder) guarantees a virtually packet loss free link quality.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Link ID | METOP HRPT | | | | | | | | |
| Ground Station | HRPT (G/T=6.0) | | | | | | | | |
| | | | | | | | | | |
| Frequency | | (MHz) | 1707.00 | 1707.00 | 1707.00 | 1707.00 | 1707.00 | 1707.00 | 1707.00 |
| S/C altitude | | (km) | 850.00 | 850.00 | 850.00 | 850.00 | 850.00 | 850.00 | 850.00 |
| Slant range | | (km) | 2889 | 2468 | 1858 | 1473 | 1227 | 963 | 850 |
| S/C view angle | | (degree.) | 61.51 | 60.33 | 56.00 | 49.82 | 42.52 | 26.18 | 0.00 |
| Data rate | | (kbit/s) | 3500.00 | 3500.00 | 3500.00 | 3500.00 | 3500.00 | 3500.00 | 3500.00 |
| | | | | | | | | | |
| G/S view angle | | (degree.) | 5.00 | 10.00 | 20.00 | 30.00 | 40.00 | 60.00 | 90.00 |
| | | | | | | | | | |
| S/C EIRP | note 1 | (dBW) | 9.10 | 9.10 | 8.23 | 6.21 | 4.65 | 2.55 | 1.46 |
| S/C antenna axial ratio | | (dB) | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 |
| | | | | | | | | | |
| Free space loss | | (dB) | 166.30 | 164.93 | 162.47 | 160.45 | 158.86 | 156.76 | 155.67 |
| Rain loss | | (dB) | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| Polarisation Loss | | (dB) | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| Reflection and multipath | note 7 | (dB) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total propagation loss | | (dB) | 166.73 | 165.36 | 162.90 | 160.88 | 159.29 | 157.19 | 156.10 |
| | | | | | | | | | |
| Ground station G/T (reference) | note 2 | (dB/K) | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| G/S axial ratio | | (dB) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| G/S pointing loss | | (dB) | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| | | | | | | | | | |
| C/KT at receiver input | | (dB/Hz) | 76.47 | 77.84 | 79.43 | 79.43 | 79.46 | 79.46 | 79.46 |
| Boltzmann’s constant | | (dBW/kHz) | -228.60 | -228.60 | -228.60 | -228.60 | -228.60 | -228.60 | -228.60 |
| Bit rate | | (dBHz) | 65.44 | 65.44 | 65.44 | 65.44 | 65.44 | 65.44 | 65.44 |
| Available Eb/No | | (dB) | 11.03 | 12.40 | 13.99 | 13.99 | 14.02 | 14.02 | 14.02 |
| Required Eb/No (BER=$10^{-3}$) | note 9 | (dB) | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 |
| Modulation degradation | note 3 | (dB) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Receiver degradation | note 8 | (dB) | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| System margin | note 4 | (dB) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Available link margin | | (dB) | 3.03 | 4.40 | 5.99 | 5.99 | 6.02 | 6.02 | 6.02 |

note 1: minimum EIRP at S/C interface

note 2: reference G/T of the ground station

note 3: deviation from theoretical performance due to the modulation process; requirement by ESA

note 4: minimum system margin required by ESA

note 7: loss due to reflections from ground or from adjacent buildings

note 8: allowed deviation from theoretical performance of the demodulator note 9: theoretical Eb/No required to obtain a BER of $10^{-3}$ at the output of the Viterbi decoder. This BER requirement (due to the following R-S decoder) guarantees a virtually packet loss free link quality.

# Annex 2. AVHRR/LRPT Data Compression system

## A2.1 General

The AVHRR is a multi-spectral imager able to scan the earth in six spectral bands covered by five channels. The AVHRR scanning rate is 360 rpm producing one line per channel of earth view samples and calibration data every 1/6th of second.

The AVHRR samples are 10 bits wide and each earth view line contains 2048 pixels corresponding to a data rate of 2048(samples) x 5 (channels) x 6 (lines per second) x 10 (bits per sample), thus yielding an overall data rate of about 600 kbit/s.

The compression will operate on 10 bit input data. The output data will have the same resolution than the input data, i.e. the JPEG extended DCT-based process using 12 bit samples will be used. The AVHRR/LRPT compression system will deliver to the ground user 3 compressed channel out of the 5 channel provided by the AVHRR. The compression will operate on the 10 bit samples. The three compressed channels may be any combination of the channels available on board.

The data compression algorithm used for the AVHRR/LRPT is a modified version of the standard JPEG to adapt to a fixed compression ratio option and a continuous instrument operation mode (neither header nor trailer in the compressed stream)

The fixed compression ratio option is used to reduce the on board smoothing buffer size and to cope with a fixed average output data rate and to avoid risks of overflow.
The baseline of the JPEG algorithm is maintained, including the 8*8 sub-block extraction, quantization, zigzag reordering and Huffman coding [see for reference: Digital Compression and Coding of Continuous-tone Still Images, ISO/IEC CD10918-1, part 1, Draft, June 1991]

A simple schematic of the algorithm is shown here below:

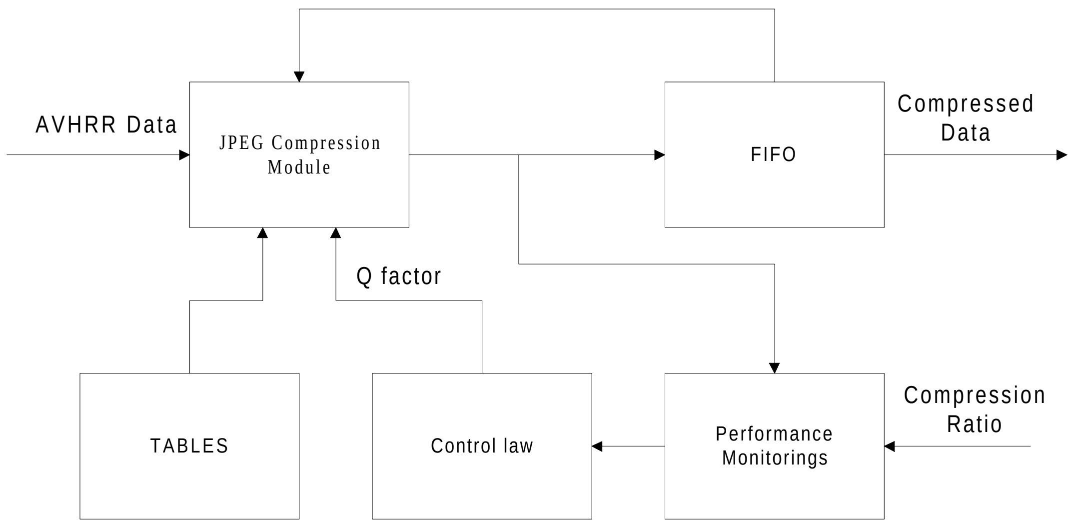



Figure A2.1.1 - Block diagram of the compression algorithm

The performance monitoring block computes of the actual compression ratio and compares it with the desired one. The result of the comparison is used to feed a nonlinear, empirical control-law that controls the Q factor.

The following drawing shows the control law; the saturation is used to avoid excessive oscillation in the quality factor.

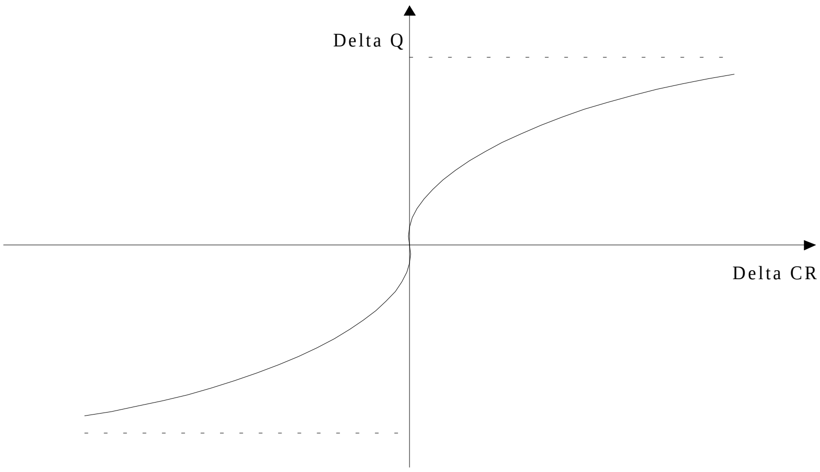



Figure A2.1.2 - Compression law

In order to achieve a fixed compression ratio, the compressed stream is divided into segments containing a number of MCUs. For every segment the difference between the actual compression ratio and the desired one is computed (Delta CR) and the new quality factor is computed according to the control law, thus having a constant Q factor within the segment.
The Q factor is communicated to the decoder by means of one of the spare JPEG markers, along with the compressed data stream just between two MCUs. To avoid overflows the FIFO signals the compressor whenever its occupancy has reached a critical value. To allow the restart after an error (re-synchronisation), the DC component of the first MCU of the first segment of every packet is transmitted not coded.

## A2.2 Data Format

### A2.2.1 CCSDS Packets

In the on board Compression Unit (CU), the earth view samples and calibration data are treated in two different ways: The earth view samples of each selected channel *i* are grouped into stripes of 8 lines * 2048 pixels; each stripe is then compressed and formatted in a CCSDS packet having an APID associated to the channel *i*; calibration data instead are sub-sampled once every stripe and formatted in a non compressed format in a specific CCSDS packet.
There are seven different APIDs:

APID 64) coded data channel 1;
APID 65) coded data channel 2;
APID 66) coded data channel 3a;
APID 67) coded data channel 3b;
APID 68) coded data channel 4;
APID 69) coded data channel 5;
APID 70) calibration data.

The packets' sequence follows this grammar:

{ [APID 64, APID 65,APID 66, APID 67, APID 68,APID 69]
[APID 65, APID 66, APID 67, APID 68,APID 69]
[APID 66, APID 67, APID 68,APID 69]
APID 70 }+

The first three packets of the sequence will be any combination of the packets with APID 64, APID 65, either APID 66 or APID 67 (day or night), APID 68, APID 69. The sequence is closed by the packet with APID 70 and then is repeated continuously.

### A2.2.1.1 Compressed image packets (APID 64-69)

The following drawing illustrates the packet structure.

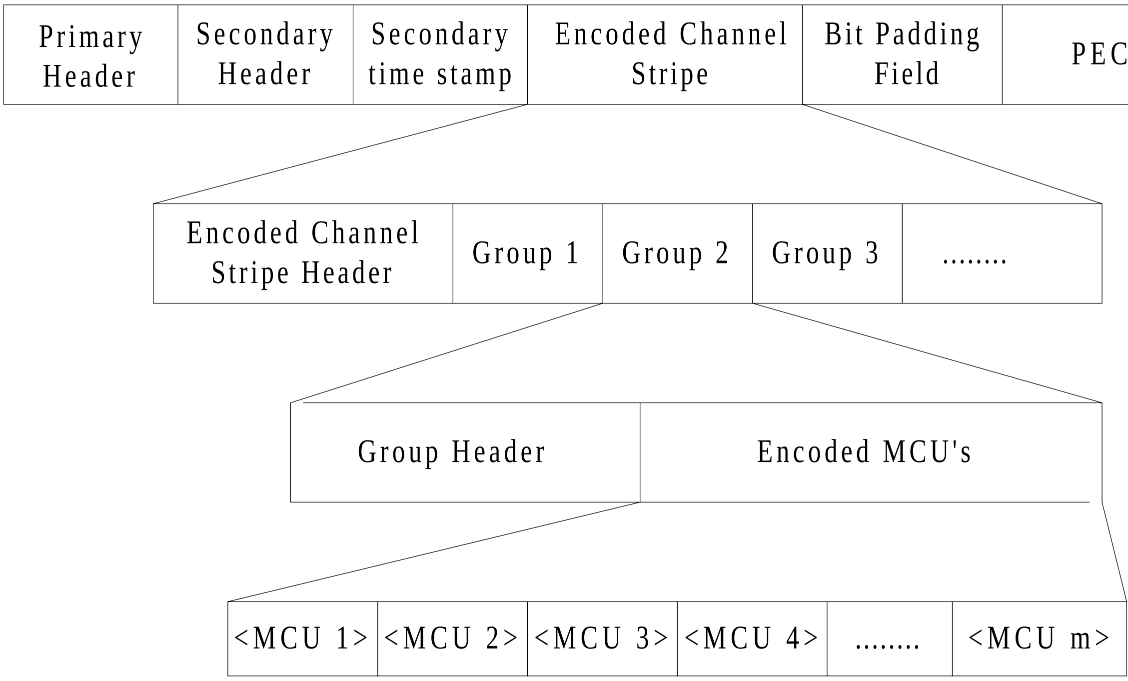



Figure A2.2.1.1.1 - Compressed packet structure

The Encoded Channel Stripe can contain any number (n) of Groups and each Group can contain any number (m) of MCUs (Minimum Coded Units) provided that the global number of MCUs per packet is 2048 / 8 = 256 MCUs.
The decoder can recognize the beginning of a new Group by means of its header and to decode the MCUs belonging to a Group the quality factor specified in the Group header must be used. The tables can change from one CCSDS compressed packet to the other but not inside a single Encoded Channel Stripe. Quantization and Huffman tables to be used within the Encoded Channel Stripe are specified in the Encoded Channel Stripe header.

To allow the restart (re-synchronization) after an error, the DC component of the first MCU of the first Group of every packet is not coded. This corresponds to setting the resynch interval to 256 (the number of MCUs per packet) in the JPEG standard.
The Bit Padding field is a variable length field and will allow the entire packet length to be an even number of bytes.

The secondary header will contain 8 bytes for the Time Tag. The secondary time stamp will contain 6 bytes for the additional time stamp.

**Encoded Channel Stripe Header**

At the beginning of each packet the Encoded Channel Stripe Header signals the decoder which tables are to be used in the decompression of the stripe. This field - see next figure - contains 3 fields of 4 bits each, thus allowing to use up to 16 different tables.

| | | |
|---|---|---|
| Qt (4 bits ) | DC Ht (4 bits) | AC Ht (4 bits) |

Encoded Channel Stripe Header

Qt: index of the quantization table to be used in the scan;

DC Ht: index of the DC Huffman table to be used in the scan;

AC Ht: index of the AC Huffman table to be used in the scan.

The Qt field corresponds to the Tq field in the frame header as described in JPEG standard. Analogously, DC Ht and AC Ht correspond to the Td and Ta fields in the scan header.

Group Header

The Group Header can be found anywhere in the Encoded Channel Stripe stream, between two successive MCUs, and it is used to communicate to the decoder that a new quality factor is used in the following MCUs, until a new Group Header is found.
As shown in the following drawing, the Group Header is a JPEG marker used to allow the detection of this field by the decoder.

| | |
|---|---|
| QFM (16 bits) | Q factor (8 bits) |

Group header

QFM: quality factor mark. Is one of the reserved JPEG markers, in this application it is set to xFFF0;

Q factor: it is the quality factor (or quantization factor) to be used within the Group.

#### A2.2.1.2 Calibration Packet (APID 70)

The following drawing illustrates the calibration packet structure.

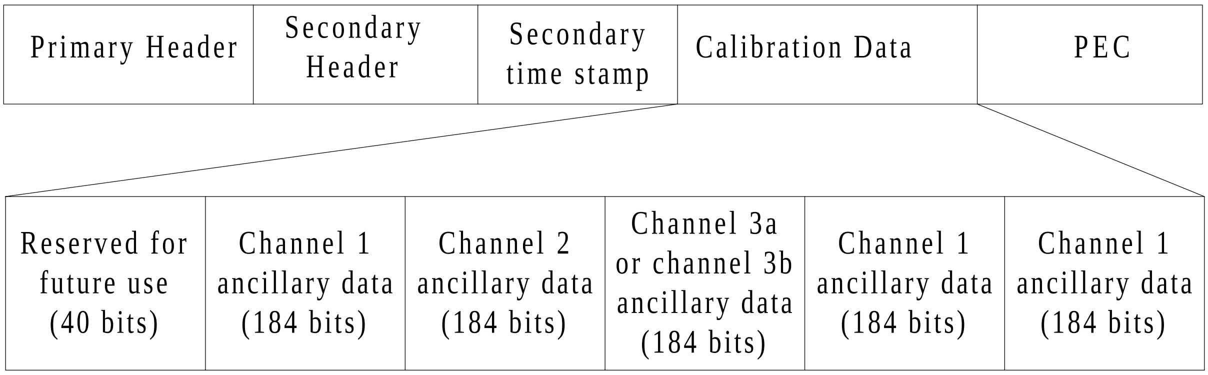



Figure A2.2.1.2.1 - Calibration packet structure

The secondary header contains a Time Stamp field of 6 octets.
The calibration data field is composed by a field reserved for future use (5 octets) and five fields of 184 octets for the ancillary data of each channel.

***Note for Stefano: Does not the requirement of even octets apply to each field? In such a case we should modify the ancillary data length to 190 bits and the segment reserved for future use to either 32 or 48 bits.***

**A2.3 System Architecture**

The ground system is mainly composed of two subsystems: the Signal Conditioning subsystem and the Digital Processing subsystem.

The Signal Conditioning subsystem, knowing the frame synchronisation pattern and the frame length can detect the CADUs and then can de-randomise the CVCDUs. The CVCDUs are then de-interleaved and R-S decoded to remove channel errors. The valid VCDUs are sent to the packet demultiplexer that sorts out the AVHRR packets that are stored in the host computer's hard disk either in DMA or under program control.

Administrative packets are first decoded to enable a correct setting of the decompression algorithm.
During the mission lifetime, it is possible that predefined quantization and Huffman tables (available to both space and ground systems) are updated or expanded. These new tables are broadcasted to the users by means of the Administrative messages.

Once the packets have been stored on the disk, the decompression process can take place off-line for visualisation purposes.

### A2.4 Software decoding

CCSDS Packets will be grouped and archived on hard disk or floppy disks in such a way to retrieve easily date and time of the scan acquisition. After the packets have been properly conditioned, visualisation can be performed by commercial or public domain tools.

The CCSDS packets conditioning process consists mainly in the decompression of several Encoded Channel Stripes belonging to packets having the same AP ID so that the raw data of a specific channel can be reconstructed. Then a conversion to a known image format can take place.

More in detail the conditioning consists of:

- stripping-off the header and trailer information of CCSDS packets related to a specific channel and observation time. For instance, to create a 2048*2048 pixel image of the AVHRR channel 1, a set of 256 consecutive packets with APID 64 must be considered

- reading the Administrative Messages to seek for new Quantization or Huffman tables

- for every new packet the Encoded Channel Stripe Header is read out to select the proper tables to be used within the Encoded Channel Stripe. If the specified tables are different from the ones predefined they must have been defined in the Administrative Messages

- detecting the Group Headers so that a new Group can be identified. The Group Header contains the Q factor value which must be used to re-scale the quantization table addressed by the Qt field in the Encoded Channel Stripe Header

- decompressing the MCUs according to JPEG compression standard

- saving the raw data to a known, inter-changeable format (GIF, TIFF, etc..).

The use of a lossy compressed format (such as JPEG) for the reconstructed images is not advisable because even with the highest quality set it would lead to some added loss beside the one due to the on-board compression algorithm.

## Annex 3. LIST OF ACRONYMS

| | |
|---|---|
| AM | Amplitude Modulation |
| AMSU | Advanced Microwave Sounding Unit |
| APid | Application Process identifier |
| ASCAT | Advanced Scatterometer |
| AVHRR | Advanced Very High Resolution Radiometer |
| BER | Bit Error Rate |
| CADU | Channel Access Data Unit |
| CCSDS | Consultative Committee for Space Data Systems |
| CRC | Cyclic Redundancy Checksum |
| CVCDU | Coded Virtual Channel Data Unit |
| DCS | Data Collection System |
| $E_b/N_0$ | Bit energy / noise density |
| EIRP | Equivalent Isotropic Radiated Power |
| FEC | Forward Error Correction |
| GRAS | GNSS Receiver for Atmospheric Sounding |
| G/S | Ground Station |
| G/T | Figure of merit (antenna gain ./. system noise temperature) |
| HIRS | High resolution InfraRed Sounder |
| HRPT | High Resolution Picture Transmission |
| IASI | Infrared Atmospheric Sounding Interferometer |
| IN_PDU | Insert service_ Protocol Data Unit |
| IN_SDU | Insert _Service Data Unit |
| LRPT | Low Resolution Picture Transmission |
| MHS | Microwave Humidity Sounder |
| M_PDU | Multiplex_ Protocol Data Unit |
| M_SDU | Multiplex _Service Data Unit |
| NRZ-L | Nonreturn-to-zero Type L |
| GOME | Global Ozone Monitoring Instrument |
| PCA_PDU | Physical Channel Access_Protocol Data Unit |

| | |
|---|---|
| PN | Pseudo Noise |
| QPSK | Quadrature Phase Shift Keying |
| RF | Radio Frequency |
| RHC | Right Hand Circular |
| SEM | Space Environment Monitor |
| S/C | Spacecraft |
| TBC | To Be Confirmed |
| TBUS | TIROS Bulletin United States |
| TBD | To Be Defined |
| UTC | Coordinated universal time |
| 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 |