MANUAL / USER GUIDE / HANDBOOK

OPS-SAT UHF specifications

European Space Agency
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APPROVAL

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CHANGE RECORD

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DISTRIBUTION

Name/Organisational Unit

Table of contents:

1 REFERENCE DOCUMENTS AND SOURCES

- **GomSpace Nanocom AX100 datasheet**
  https://gomspace.com/UserFiles/Subsystems/datasheet/gs-ds-nanocom-ax100-33.pdf

- **AX.25 Link Access Protocolfor Amateur Packet Radio**
  https://www.tapr.org/pdf/AX25.2.2.pdf

- **High-Level Data Link Control**
  https://en.wikipedia.org/wiki/High-Level_Data_Link_Control

- **Cube Sat Protocol (CSP)**
  https://github.com/libcsp/libcsp

- **CCSDS Blue Book Telemetry Channel Encoding**
  https://public.ccsds.org/Pubs/101x0b6s.pdf

- **CCSDS Red Book Mission Operations – Common Services**
  https://public.ccsds.org/Lists/CCSDS%205220R1/522x0r1.pdf

- **GNU Radio Manual and C++ API Reference**
  https://www.gnuradio.org/doc/doxygen/

- **GPredict User Manual**
  http://www.w1npp.org/events/2010/2010-f~1/SATELL~1/GPREDI~1.PDF

2 INTRODUCTION

This document describes the UHF demodulation and decoding specifications for the ESA OPS-SAT mission. OPS-SAT is going to use the UHF radio for transmitting the UHF beacon as a heartbeat signal, nominal operations are done on a dedicated S-Band frequency.

3 UHF RADIO SPECIFICATIONS

Name	Specification
Space segment transceiver	GomSpace NanoCOM AX100
Frequency	UHF – 437.2 MHz
Modulation	GMSK
Occupied Bandwidth	25 kHz
Baudrate	9k6
Modulation Index	0.5

4 BEACON SPECIFICATIONS

The NanoCOM AX100 is configured in mode 6, which means that the data is encapsulated in a HDLC + AX.25 frame.

4.1 Frame encoding

The format is as follows, the number in the brackets represent the number of bytes being used:

	[110] NanoCOM AX100 frame			
[1] Flag	[16] AX.25 HDR	[94] Data Field	[2] CRC – 16 CCIT	[1] Flag

The whole frame is

- NRZI encoded,
- G3RUH/K9NG scrambled,
- LSB encoded (apart from the 16 bit CRC),
- and has a size of 110 bytes (without the flags).

The flag being used to separate frames is 0x7E (01111110). The NanoCom also sends 50 of those in the preamble for receiver synchronization.

After NRZI decoding and descrambling the AX.25 header becomes readable and does not require any further processing. The call signs are

- "**DLoESA**" for the ground station, and
- "**DPoOPS**" for the satellite.

4.2 Data field encoding

The data field ends with a 32 bit cyclic redundancy check (Castagnoli), followed by a Reed-Solomon (223,255) code block, and is finally being scrambled with the CCSDS polynomial

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

After descrambling, Reed-Solomon decoding, and the removal of the CRC, the data field becomes 58 bytes, as shown below.

[94] Data field		
[58] Payload data	[4] CRC-32C	[32] RS code block

The payload data itself is a Cube Sat Protocol (CSP) packet and starts with a four byte header with the following content :

- Priority: 3
- Source: 5
- Destination: 10
- Destination Port: 31
- Source Port: 0
- Flags: 0

The remaining 54 bytes contain the telemetry table #4 of the NanoCom AX100 as shown in the following table.

Offset	Description	Data type
0x00	Board temperature (near MCU)	Signed 16 bit integer
0x02	PA temperature (near PA)	Signed 16 bit integer
0x04	Last received RSSI	Signed 16 bit integer
0x06	Last received RF error	Signed 16 bit integer
0x08	Number of TX packets since reboot	Unsigned 32 bit integer
0x0C	Number of RX packets since reboot	Unsigned 32 bit integer
0x10	Number of TX bytes since reboot	Unsigned 32 bit integer
0x14	Number of RX bytes since reboot	Unsigned 32 bit integer
0x18	The currently active system configuration	Unsigned 8 bit integer
0x19	The number of reboots	Unsigned 16 bit integer
0x1B	The cause of the reboot (AVR32)	Unsigned 32 bit integer
0x1F	The timestamp of the last valid packet	Unsigned 32 bit integer
0x23	The current background RSSI level	Signed 16 bit integer
0x25	Total TX duty time since reboot	Unsigned 8 bit integer

0x26	Number of TX packets (total)	Unsigned 32 bit integer
0x2A	Number of RX packets (total)	Unsigned 32 bit integer
0x2E	Number of TX bytes (total)	Unsigned 32 bit integer
0x32	Number of RX bytes (total)	Unsigned 32 bit integer

5 NON-BEACON SPECIFICATIONS

OPS-SAT is not planning to downlink any housekeeping data on the UHF frequency, except the beacon signal. Nominal operations are done on a dedicated S-Band frequency. Only in case of a S-Band radio failure, the UHF link might be used. For decoding those packets the same instructions as before can be followed. The payload data will also be a CSP packet, but containing a Mission Operations (MO) Service Space Packet Protocol packet instead the beacon packet.

6 APPLICATION EXAMPLE

A clean UHF beacon recording and GnuRadio applications for receiving, demodulating, and decoding it can be found in the GitHub repository https://github.com/esa/gr-opssat.