Space-to-Ground Interface Control Documents of FY3D Meteorological Satellite

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1. Scope

   This standard states technical requirements for the moderate resolution spectral image transmission (MPT) and global delay data (DPT) of FY3D meteorological satellite.

   This standard is applicable for the data transmission and data receiving system between the satellite and ground station for the FY3D meteorological satellite.

2. Normative References

   The following documents are essential for the application of this standard. For the referencing documents with specific dates noted, only the versions with those specific dates are applicable for this standard. For those without specific dates, the latest versions of the referencing documents (including all the amendments) are applicable for this standard.

   GB 50174 Requirements for design of computer room

   GB 13615 Requirements for Earth station electromagnetic environment protection

   CCSDS 101.0-B-3 Telemetry channel coding

   CCSDS 102.0-B-3 Packet telemetry

   CCSDS 202.1-B-1 Command operation procedures

   CCSDS 202.0-B-2 Data routing service

3. Terms and Definitions

   Following are the terms and definitions applied in this document.

   1). FENGYU No. 3 D Meteorological Satellite; FY-3D

   China's second generation polar orbit meteorological satellites include FENGYU No. 3 A meteorological Satellite (FY-3A), FENGYU No. 3 B meteorological Satellite (FY-3B), FENGYU No. 3 C meteorological Satellite (FY-3C) and FENGYU No. 3 D meteorological Satellite (FY-3D). All the four satellites use the three-axis stabilized attitude control mode, which FY-3A/B carrying 11 kinds of observation instruments in 9 categories, FY-3C carrying 12 kinds of observation instruments in 9 categories, and FY-3D carrying 11 kinds of observation instruments in 9 categories. These observation instruments can provide global, all-weather, multi spectral, three-dimensional, and quantitative observation to Earth.

   2). Moderate Resolution Picture Transmission; MPT

   Broadcast image data from moderate resolution spectrum imaging instrument on polar orbit satellite in real time through satellite X band data transmission link.

   3). Global Delay Picture Data Transmission; DPT

   Transmit the global remote sensing and telemetry data stored on the satellite to the ground through the X band when the satellite passes through a specified ground station.

   4). Primitive packet data

   Data and auxiliary data observed from satellite payload.

5). Multiplexing Transmission Technology
Techniques for transmitting data from various detectors and application processes simultaneous using an actual physical channel.

6). Transmission Frame
Data structure for physical channel transmission.

4. Acronyms

Following are the acronyms applicable to this document.
BPSK: Binary Phase Shift Keying
CADU: Channel Access Data Unit
Conv: Convolutional Code
EIRP: Equivalent Isotropically Radiated Power
ERM: Earth Radiation Measurement
GNOS: Gnss Occultation
G/T: Gain/Temperature
IRAS: Infrared Atmospheric Sounder
MERSI((2): Medium Resolution Spectral Imager
MWRI: Microwave Radiation Imager
MWHS(2): Microwave Humidity Sounder
GNOS:GNSS Occultation Sounder
WAI:Wide Angle Aurora Imager
HIRAS:High-spectral Resolution Infrared Atomospheric Sounder
MWTS(2): Microwave Temperature Sounder
GAS:Greenhouse gases Absorption Spectrometer
SEM: Space Environment Monitor
IPM:Ionospheric spectromer
PCI: Peripheral Component Interconnect
QPSK: 4-Phase Shift Keying
RHCP: Right Hand Circular Polarized
LHCP: Left Hand Circular Polarized
RS: Reed-Solomon codes
SBUS: Solar Backscatter Ultraviolet Sounder
SIM: Solar Irradiance Monitor
TOU: Total Ozone Unit
USB: Universal Serial Bus
VC: Virtual Channel
VC-ID: Virtual Channel-Identity
VCDU: Virtual Channel Data Unit
VCDU-ID: Virtual Channel Data Unit-Identity

VIRR: Visible and Infrared Radiometer

5. Data Broadcasting

FY-3D transmits data to the ground station through two satellite links. These data include real-time data MPT and global delay data DPT. Detailed technical specifications of each link are shown as followings:

5.1. MPT: Direct Broadcast

5.1.1. Contents of MPT real-time data broadcasting

MPT broadcasts real-time data include:

MERSI((2): Medium Resolution Spectral Imager

MWRI: Microwave Radiation Imager

MWHS(2): Microwave Humidity Sounder

GNOS:GNSS Occultation Sounder

WAI:Wide Angle Aurora Imager

HIRAS:High-spectral Resolution Infrared Atomospheric Sounder

MWTS(2): Microwave Temperature Sounder

GAS:Greenhouse gases Absorption Spectrometer

SEM: Space Environment Monitor

IPM:Ionospheric spectromerMedium and Satellite telemetry data.

5.1.2. Process of MPT real-time data broadcasting

The working process of MPT real-time data broadcasting is shown in Figure 1, which includes channel coding, modulation, transition, etc. The working process of MPT data broadcasting in FY-3D meteorological satellite is:

1) Format the MPT data based on the standards from CCSDS 102. Q-B-3;
2) Provide multiplexing, RS encoding and scrambling to these data to form a transmission frame data stream, using multiplexing technology to carry out the transmission of the load data frame operation;
3) Apply serial-to-parallel conversion and differential coding to transmission frame stream;
4) After the serial-to-parallel conversion, apply convolutional coding with constrained length of 7 and rate of 3/4 to the data, that is, Conv (7, 3/4);
5) Modulate the encoded data by QPSK, provide up conversion, power amplifier and filter to these data, and finally transmit these data through antenna;
6) MPT downlink works on concatenated codes, or RS (255,223) + CONV (7,3/4), with its flow shown in Figure 1.

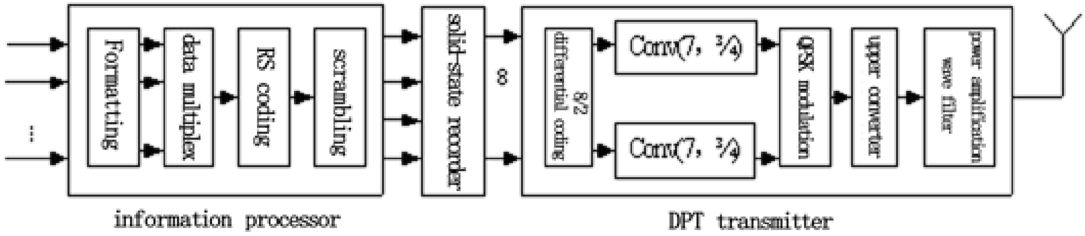

Figure 1. Working process of MPT real-time data broadcasting

5.1.3. Multi-load Information Processing

5.1.3.1. High rate data payload source package

Create the High rate data payload source package based on the format in 5.3.1 and 5.3.3.

5.1.3.2. Low rate data payload source package

Create the low rate data payload source package based on the format in 5.3.2.

5.1.3.3. Multiplexed data broadcasting technology

Multiplex the source package data and create virtual channels based on the parameters from 5.3.4

5.1.3.4. Data transmission frame

Create data transmission frames using data from the virtual channels based on the data format standards specified in CCSDS 102.0-B-3. Format of the transmission frame is shown in Table 16 and Figure 12.

5.1.4. Scrambling

With scrambling, Pseudo randomized sequence generates a multinomial equation:

$$F(x) = x^8 + x^7 + x^5 + x^3 + 1 \quad (1)$$

Where,

F(x) – Multinomial equation

X – Data bits.

The practice is designed to ensure the timely recovery of data quality, through reducing consecutive codes of 0 or 1. The binary information shall be randomized into a pseudo randomized sequence, in an attempt to limit the length of consecutive 0 or 1. The randomization is often termed as code scrambling.

Code scrambling makes a better synchronization between clock and data. CCSDS suggests a multinomial: $F(X)=X^8+X^7+X^5+X^3+1$ for code scrambling. The sequence shall be repeated every 255 bits. Re-initialization of the sequence generator shall be a full '1' status for each synchronous cycle.

The scrambling flow is given in the following diagram:

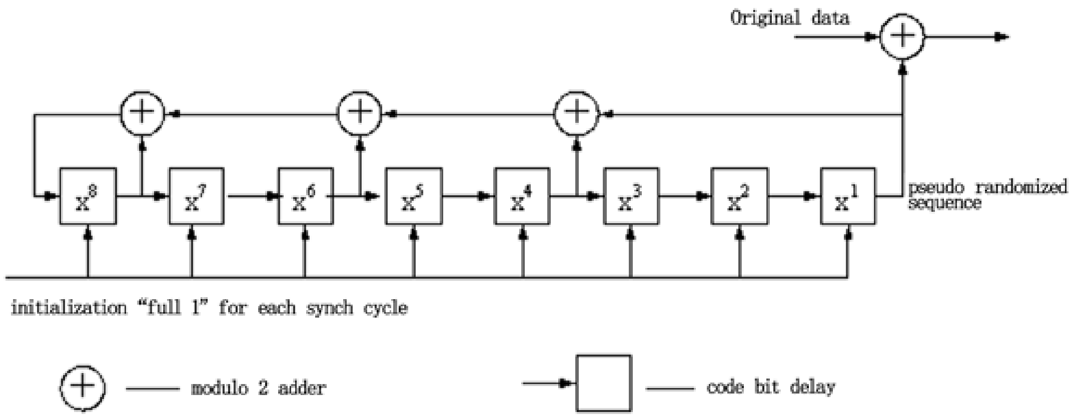

Figure 2. Data scrambling flow

5.1.5. Error Correction Coding

RS code (255, 223), recommended by CCSDS, is used as an outer code, and convolutional code as an inner code, according to the characteristics of space communication power limit and the construction cost of land station. Meanwhile, RS codes are generated with an interleaving depth of I=4 for FY-3D satellite.

5.1.5.1. RS Coding

In accordance with the requirements of the CCSDS 101.0-B-3, encode with the number of symbols of 255, message length of 223, and the symbol for 8 of RS (255,223, 8). The interleaver depth is 4.

To meet the standards defined by CCSDS, RS(255,223) shall have a multinomial that is built on GF(2), or GF(2^8) as follows:

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

Then, code generating multinomial is:

$$g_{(x)} = \prod_{j=112}^{143}(x-\alpha^{11j}) = \sum_{i=0}^{32} G_i x^i$$

Where, α - generating cell for limited GF(2^8)

α ^{11} – primitive cell for limited GF(2^8)

G_i – coefficient

RS code, derived from the above-mentioned multinomial, is a system code, which means the first 223 digits of codeword are primitive code cells, while 32 digits in the rear are the check code cells generated by information code cells.

To raise the burst error correcting capability of data transmission sub-systems, an RS code with an interleaving depth of I = 4 is applied. Its flow diagram is shown in Figure 3.

Input: $a_1b_1c_1d_1a_2b_2c_2d_2a_3b_3c_3d_3......a_{223}b_{223}c_{223}d_{223}$;

RS encoder 1 input: $a_1a_2a_3a_4......a_{223}$, output: $a_1a_2a_3a_4......a_{223}A_1A_2......A_{32}$;

RS encoder 2 input: $b_1b_2b_3b_4......b_{223}$, output: $b_1b_2b_3b_4......b_{223}B_1B_2......B_{32}$;

RS encoder 3 input：$c_1c_2c_3c_4\ldots\ldots c_{223}$, output：$c_1c_2c_3c_4\ldots\ldots c_{223}C_1C_2\ldots\ldots C_{32}$;

RS encoder 4 input：$d_1d_2d_3d_4\ldots\ldots d_{223}$, output：$d_1d_2d_3d_4\ldots\ldots d_{223}D_1D_2\ldots\ldots D_{32}$；

Output ： $a_1b_1c_1d_1a_2b_2c_2d_2a_3b_3c_3d_3\ldots\ldots a_{223}b_{223}c_{223}d_{223}$, $A_1B_1C_1D_1A_2B_2C_2D_2\ldots\ldots A_{32}B_{32}C_{32}D_{32}$

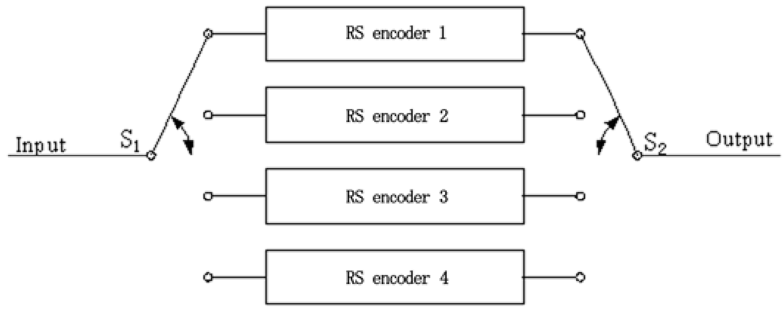

Figure 3. RS coding with an interleaving depth of I = 4

On-board RS codes are generated using the Berlekamp Approach.

5.1.5.2. Convolutional Coding

Convolutional codes with Conv (7, 3/4) are applied based on the requirements from CCSDS 101.0-B-3.

In an attempt to raise the code rate, avoid excessive width demands, and accommodate heavy assignments for convolutional encoding and decoding, MPT links re applied with punctured codes (7, 3/4) of (7, 1/2). 3/4 code rate is derived from the output of 1/2 convolutional encoder. The coding flow is given in Figure 4.

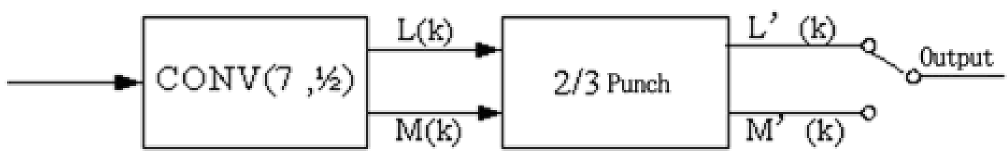

Figure 4. Convolutional coding (7, 3/4)

Code generating vector (7, 1/2): G_1 = 1111001, G_2 = 1011011, with a flow shown in Figure 5.

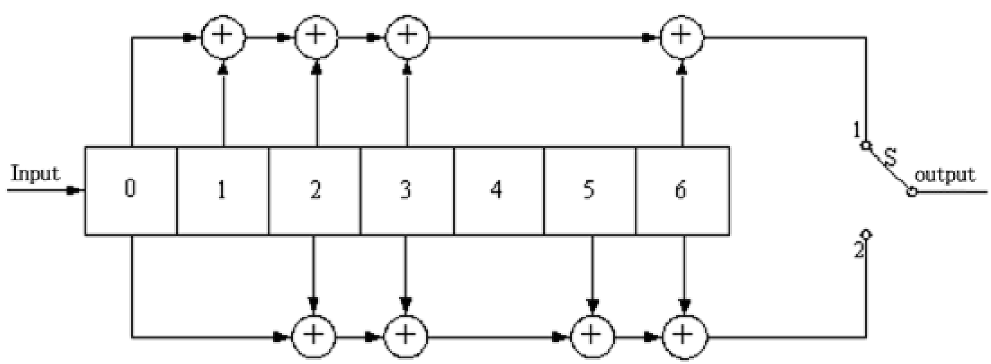

Figure 5. Convolutional coding (7, 1/2)

Flow 1: $X_1X_2X_3X_4X_5X_6X_7X_8$……

Flow 2: $Y_1Y_2Y_3Y_4Y_5Y_6Y_7Y_8$……

Output: $X_1Y_1X_2Y_2X_3Y_3X_4Y_4X_5Y_5X_6Y_6X_7Y_7X_8Y_8$……

2/3 punch module input:：

L(k)=…l(k)，$\boxed{\text{l(k+1)}}$，l(k+2)，l(k+3)，$\boxed{\text{l(k+4)}}$，l(k+5)，l(k+6)，……

M(k)=…m(k)，m(k+1)，$\boxed{\text{m(k+2)}}$，m(k+3)，m(k+4)，$\boxed{\text{m(k+5)}}$，m(k+6)，……

2/3 punch module output:

L'(k)=…l(k)，l(k+2)，l(k+3)，l(k+5)，l(k+6)，……

M'(k)=…m(k)，m(k+1)，m(k+3)，m(k+4)，m(k+6)，……

CONV(7,3/4) serial output:：

…l(k),m(k),m(k+1),l(k+2),l(k+3),m(k+3),m(k+4),l(k+5),l(k+6),……

5.1.5.3. Data transfer bit conversion

1) Serial-Parallel Converter

Serial data streams will be separated into odd and even parallel data streams. In one of the flows, there will be a 1 bit delay, making two consecutive symbols to form a pair of symbols. After the data processing, x-band real-time information processing module will produce a code rate of 4.5Mbps in non-return to zero code, for MPT transmission.

If input: m1, m2, m3, m4, m5, m6, m7, m8 ……

Then, the output will be:

I: m1, m3, m5, m7 ……

Q: m2, m4, m6, m8 ……

2) Differential Coding

There are two kinds of differential coding based on the previous pair of output code cells.

When the previous pair of output code cells is the same, then, the current output of the encoder is:

$X_{out\ i}=X_{in\ i}+X_{out(i-1)}$

$Y_{out\ i}=Y_{in\ i}+Y_{out(i-1)}$

Where,

$X_{out\ i}$ means the 1st flow current output of the encoder;

$Y_{out\ i}$ means the 2nd flow current output of the encoder;

$X_{in\ i}$ means the 1st flow current input of the encoder;

$Y_{in\ i}$ means the 2nd flow current input of the encoder;

$X_{out(i-1)}$ means the 1st flow previous output of the encoder;

$Y_{out(i-1)}$ means the 2nd flow previous output of the encoder.

When the previous pair of output code cells is not the same, then,

$X_{out\ i}=Y_{in\ i}+X_{out(i-1)}$

$Y_{out\ i}=X_{in\ i}+Y_{out(i-1)}$

5.1.6. Modulation

FY-3D is designed with a QPSK modulation system. The onboard QPSK is a π/2 system. Channel I and Channel Q are the input data, using gray-code logics.

Specifications for the 4-phase gray-code modulation: dual-bit coding pair AB are 00, 01, 11, and 10, and the corresponding carrier phases are: 0°, 90°, 180°, and 270°, respectively.

The onboard QPSK is a π/2 system. Channel I and Channel Q are the convolutional coding outputs.

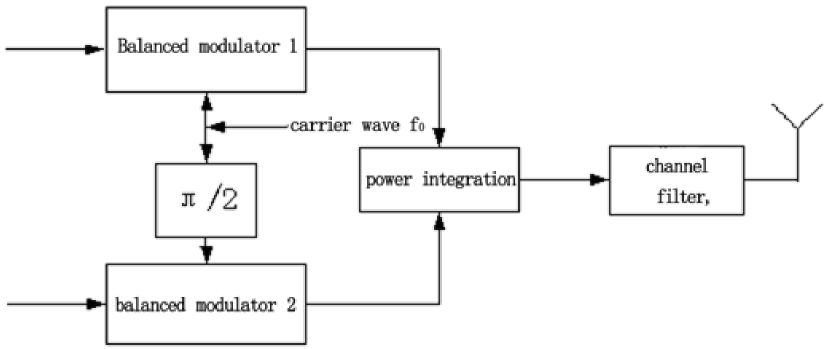

Figure 6. QPSK flow

Using gray-code logics, the modulator works in line with the following specifications:

TABLE 1 4-PHASE GRAY-CODE MODULATION

Dual-bit coding pair AB	Carrier phase φ
00	0°
01	90°
11	180°
10	270°

5.1.7. Index of MPT real-time transmission downlink

MPT real-time transmission downlink parameters are shown below:

1) Data rate: 45Mbps (after RS coding I = 4)
2) Frequency: x-band 7820MHz±78KHz
3) Modulation model: QPSK
4) Bandwidth: 60MHz
5) EIRP: 46 dBm (EL=5°)
6) Polarization: RHCP
7) Axial ratio: not larger than 5dB for an area of ±62°
8) Direction pattern: multiple beams, and axis of symmetry
9) Real-time transmission for the areas enjoying international cooperation, and for the

domestic areas having a receiving capability.

The antenna gain distribution is shown in Table 2:

TABLE 2 - MPT ANTENNA GAIN INDICATORS

Elevation angle θ (°)	Antenna gain (dBi)
±62 °	≥5.0
±60 °	≥5.5
±55 °	≥4.5
±50 °	≥2.8
±45 °	≥1.0
±40 °	≥-0.4
±35 °	≥-1.5
±30 °	≥-2.3
±25 °	≥-3.0
±20 °	≥-3.3
±15 °	≥-3.7
±10 °	≥-4.0
±5 °	≥-4.3
0 °	≥-4.5

Gain curves smooth out between ±60° ~ 0° as follows:

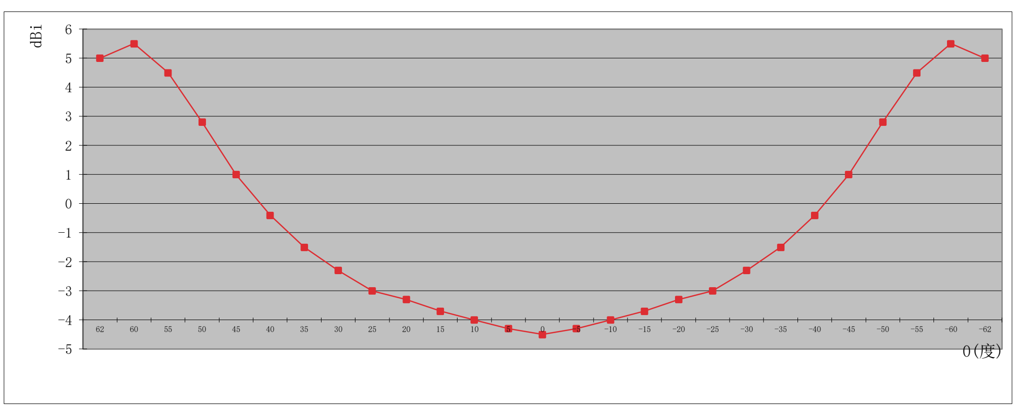

Figure 7: MPT Antenna gain curve

5.1.8. MPT link control steps calculation (Parameters associated with the device is variable according to different equipment)

Table 3 – MPT links

PARAMETERS		LINK MARGIN UNDER DIFFERENT ANGLES			
System	Link	MPT LINK	MPT LINK	MPT LINK	MPT LINK

Parameters	Elevation angle（°）	5.00	35.00	65.00	90.00
	Earth radius（km）	6371.00	6371.00	6371.00	6371.00
	Track height（km）	836.40	836.40	836.40	836.40
	Star-earth distance（km）	2860.18	1316.72	911.50	836.40
	Working frequency（GHz）	7.82	7.82	7.82	7.82
	Land antenna diameter（m）	10.00	10.00	10.00	10.00
Satellite	antenna efficiency	0.55	0.55	0.55	0.55
	Information bit rate（Mbps）	45.00	45.00	45.00	45.00
	Modulation symbol rate Rs（Mbps）	60.00	60.00	60.00	60.00
	FEC coding	RS(223,255)+ CONV(7,3,4)	RS(223,255)+ CONV(7,3,4)	RS(223,255)+ CONV(7,3,4)	RS(223,255)+ CONV(7,3,4)
	Transmitting power（W）	23.00	23.00	23.00	23.00
	Antenna gain (dBi)	5.00	1.00	-3.00	-4.50
Channel	EIRP (dBW）	18.62	14.62	10.62	9.12
	Loss in space (dB)	179.43	172.69	169.50	168.75
	Absorption loss in atmosphere（dB）	0.30	0.30	0.30	0.30
	Rainfall loss (dB)	4.50	4.50	4.50	4.50
	Antenna pointing loss（dB）	0.50	0.50	0.50	0.50
	Polarization loss（dB）	1.00	1.00	1.00	1.00
Ground Receiver	Total propaganda loss[L](dB)	185.73	178.99	175.80	175.05
	Receiving power on ground（dBW）	-161.11	-158.38	-159.18	-159.94
	Antenna gain Gr(dBi)	55.67	55.67	55.67	55.67
	[Gr/Tr]（dB）	30.00	30.00	30.00	30.00
	Boltzmann constant [k]（dBW/K/Hz）	-228.60	-228.60	-228.60	-228.60
	Receiver input C/N_0 (dBHz)	91.49	94.22	93.42	92.66
	Code rate（dBbps）	77.78	77.78	77.78	77.78
	[Eb/N0]（dB）	13.70	16.44	15.64	14.88
	Coding gain [Gc]（dB）	6.00	6.00	6.00	6.00
	Demodulation Loss（dB）	1.80	1.80	1.80	1.80
	The need for Eb/N0（dB） (error rate of 1e-7)	11.40	11.40	11.40	11.40
	Eb/N0 design margin [M]（dB）	6.50	9.24	8.44	7.68
Link margin above 3dB		3.50	6.24	5.44	4.68

5.2. DPT

5.2.1. DPT content

The DPT link onboard the FY-3D satellite mainly works on global sounding data processing, storing, and transmission. All payload data, including telemetry data, can be transmitted to the ground receiving station, through its solid-state recorder and DPT links. payload data types, recording time, and other parameters are given in Table 4.

Table 4. Types of DPT data

Remote sensing instrument	（ RS422 interface）	Data rate	Package length（byte）	Remarks
Medium resolution spectral imager (day)	direct	20Mbps	--	Day/Night Data Programmable
Medium resolution spectral imager (night)	direct	20Mbps		
Microwave imaging instrument	direct	100Kbps	--	Global Recording
GPS-MET Occultation sounder	direct	200Kbps	--	Global Recording
Wide Angle Aurora Imager (WAAI)	direct	1.6Mbps	--	Global Recording
Hyperspectral infrared atmospheric sounder	direct	10Mbps	--	Global Recording
High light spectrum greenhouse gas monitor	direct	5Mbps	--	Global Recording
Satellite telemetry parameters（including GPS signals）	1553B Bus	--	2 packets/s， 288bytes per packet	Global Recording
Microwave thermometer	1553B Bus	--	4 packets/2.667s 1024bytes per packet	Global Recording
Space environment monitor	1553B Bus	--	1 packet/42s 512 bytes per packet	Global Recording
Microwave moisture meter	1553B Bus	--	4 packets/2.667s 1024bytes per packet	Global Recording
Small ionospheric spectrometer	1553B Bus	--	1 packet/10s，256bytes per packet	Global Recording
Micro vibration detection box	1553B Bus	--	Initial stage on orbit: 1 packet/s； 1024bytes per packet After low rate payload powered on: 1 packet/10s（lower priority）， 1024 bytes per packet	Command control after on orbit
Original data packet for control of satellite position and orbit	1553B Bus	--	1 packet/5s（lower priority）， 512 bytes per packet	Global Recording

DPT data broadcast process

Figure 10 shows the process of DPT data broadcast, including information processing and DPT emission. DPT data broadcast in FY-3D satellite follows the following procedures:

1) Format the DPT data according to the requirements of the CCSDS102.0-B-3
2) In accordance with multiplexing technology to carry on the transmission of the load data frame operation, the data are multiplexed, RS encoded and scrambled to form a transmission frame data stream
3) String and differential coding of transmission frame data stream
4) After the serial coding, apply convolutional coding to the data with constrained length of 7 and the rate of 3/4, that is, Conv (7, 3/4)
5) The encoded data is modulated by QPSK, up conversion, power amplifier and filter, and finally transmitted through the antenna
6) DPT downlink uses concatenated encoding with RS (255,233)+CONV(7,3/4). The flow diagram is shown in Figure 8:

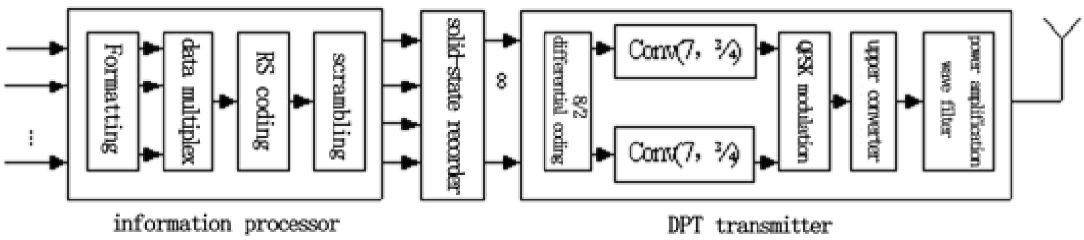

Figure 8 – DPT data broadcast process

All DPT data link transmission are processed through the information processing module of DPT processor and the solid-state recorder storage. When satellite flies to the designated station, DPT transmitter transmits the data through DPT antenna to the ground.

5.2.2. Multiload information processing

This process includes：

MERSI(⑵: Medium Resolution Spectral Imager

MWRI: Microwave Radiation Imager

MWHS⑵: Microwave Humidity Sounder

GNOS:GNSS Occultation Sounder

WAI:Wide Angle Aurora Imager

HIRAS:High-spectral Resolution Infrared Atomospheric Sounder

MWTS⑵: Microwave Temperature Sounder

GAS:Greenhouse gases Absorption Spectrometer

SEM: Space Environment Monitor

IPM:Ionospheric spectromerMedium and Satellite telemetry data.

5.2.2.1. High rate data load source package

The High rate data load source package is created in the format of 5.3.1 and 5.3.3.

5.2.2.2. Low rate data load source package

The low rate data load source package is created in the format of 5.3.2.

5.2.2.3. Multiplex transmission technology

The source package data is multiplexed to form a virtual channel according to the parameters in 5.3.4.

5.2.2.4. Transmission frame data generation

Transmission frame data is generated based on the requirements to the allignment flow in CCSDS 102.0-B-3, and it is formatted according to Table 16 and Figure 12 in 5.3.4.

5.2.3. Scrambling

Scrambling is performed based on the provisions of 5.1.4.

5.2.4. Data error correction coding

According to the characteristics of space communication power limited, FY-3D uses a concatenated coding scheme. In this scheme, the RS (255,223) works as the outer code and the convolutional code works as the inner code, as recommended in CCSDS.

5.2.4.1. RS coding

RS coding is performed based on the requirements in 5.1.5.1.

5.2.4.2. Convolutional coding

The constraint length is 7, and the rate of convolutional coding is 3/4, which is named, Conv (7, 3/4). Convolutional coding is performed based on the requirements in 5.1.5.2.

5.2.4.3. Data transfer bit conversion

Including: string and differential coding

Performed based on the requirements in 5.1.5.3.

5.2.5. Modulation

Performed based on the requirements in 5.1.6.

5.2.6. DPT data transmission channel

The parameters of DPT transmission channels are shown as followed:

1) Code rate: 225Mbps (after RS I=4 coding)
2) Carrier frequency: 8250MHz
3) Modulation: QPSK
4) Signal bandwidth: 300MHz
5) The minimum EIRP of the satellite receiving antenna elevation above 6 degrees: 46 dBm

(EL=6°)

6) Polarization mode of satellite antenna: RHCP (Right-hand circular polarization)
7) Satellite antenna pattern: Shaped beam, axial rotation symmetry
8) Working scheme: Record the global sounding data. In the replay region, transmit the time-delayed data to ground station, and the repeated data should be no less than 5 seconds in two consecutive downloads.

Gain distribution of satellite data transmission antenna is shown in Table 7.

Gain (including RF cable loss): In antenna beam ±62.0°: not less than 5.0 dBi;

In antenna beam ±60.0°: not less than 5.5 dBi;

In antenna beam 0°: not less than -4.5 dBi.

Axial ratio: within the range of ±62°, not greater than 8dB

Direction map: Shaped beam, Axial rotational symmetry.

Table 5 – DPT data transmission antenna gain index assignment

Antenna elevation angle θ	Antenna gain index(dBi)
±62°	⩾5.0
±60°	⩾5.5
±55°	⩾4.5
±50°	⩾2.8
±45°	⩾1.0
±40°	⩾-0.4
±35°	⩾-1.5
±30°	⩾-2.3
±25°	⩾-3.0
±20°	⩾-3.3
±15°	⩾-3.7
±10°	⩾-4.0
±5°	⩾-4.3
0°	⩾-4.5

The gain curve is smoothly connected within ±60° ~ 0°, and the index curve is shown in Figure 9:

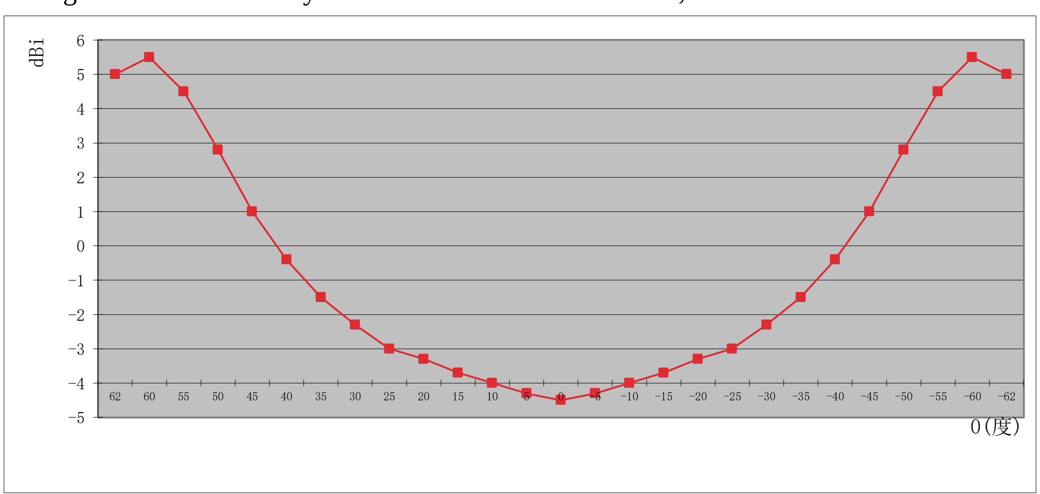

Figure 9 – DPT gain curve

5.2.7. Calculation and main parameters of DPT data transmission link

Table 6 – DPT link radio frequency link

PARAMETERS		LINK MARGIN UNDER DIFFERENT ANGLES			
System Parameters	Link	DPT LINK	DPT LINK	DPT LINK	DPT LINK
	Elevation（°）	6.00	35.00	65.00	90.00
	Earth radius（km）	6371.00	6371.00	6371.00	6371.00
	Track height（km）	836.40	836.40	836.40	836.40
	Star-earth distance（km）	2769.23	1316.72	911.50	836.40
	Work frequency（GHz）	8.25	8.25	8.25	8.25
	Ground antenna diameter（m）	12.00	12.00	12.00	12.00
Satellite	Ground antenna efficiency	0.55	0.55	0.55	0.55
	Information rate（Mbps）	225.00	225.00	225.00	225.00
	Modulation symbol rate Rs（Mbps）	300.00	300.00	300.00	300.00
	FEC Coding method	RS(223,255)+ CONV(7,3,4)	RS(223,255)+ CONV(7,3,4)	RS(223,255)+ CONV(7,3,4)	RS(223,255)+ CONV(7,3,4)
	Emission power（W）	23.00	23.00	23.00	23.00
	Antenna gain (dBi)	5.00	1.00	-3.00	-4.50
Channel	EIRP (dBW）	18.62	14.62	10.62	9.12
	Free space attenuation loss (dB)	179.62	173.16	169.96	169.22
	Atmosphere absorption loss（dB）	0.30	0.30	0.30	0.30
	Rainfall loss (dB)	4.50	4.50	4.50	4.50
	Antenna pointing loss（dB）	0.50	0.50	0.50	0.50
	Polarization loss（dB）	1.00	1.00	1.00	1.00
Ground Receiver	Total propaganda los [L](dB)	185.92	179.46	176.26	175.52
	Receiving power on ground（dBW）	-161.30	-158.84	-159.65	-160.40
	Antenna gain Gr(dBi)	57.72	57.72	57.72	57.72
	[Gr/Tr]（dB）	34.00	34.00	34.00	34.00

	Boltzmann constant [k]（dBW/K/Hz）	-228.60	-228.60	-228.60	-228.60
	Receiver input C/N_0 (dBHz)	95.30	97.76	96.95	96.20
	Code rate（dBbps）	84.77	84.77	84.77	84.77
	[Eb/N0]（dB）	10.53	12.99	12.18	11.43
	Coding gain [Gc]（dB）	6.00	6.00	6.00	6.00
	Demodulation Loss（dB）	1.80	1.80	1.80	1.80
	The need for Eb/N0（dB）(error rate of 1e-7)	11.40	11.40	11.40	11.40
	Eb/N0 design margin [M]（dB）	3.33	5.79	4.98	4.23
Link margin above 3dB		0.33	2.79	1.98	1.23

The link margin between satellite data transmission and the ground receiver is 3.33dB, which is greater than 3dB. This margin satisfies the requirement for the ground data receiving from the satellite.

5.3. FY-3D data transmission format

5.3.1. Source package format

The input information of multi-load information processing is shown in Table 7:

Table 7 – Input information for information processor

Remote sensing instrument	Code rate	Virtual channel	VC-ID	APID	Remarks	Unit（byte）
MERIS（day）	20Mbps	VC1	00,0011		Send X directly in real time, control command to send X delay module	
MERIS（night）	20Mbps	VC2	00,0001		Control command to send x delay module	
MERIS（partial way）	3.2Mbps	VC0	00,0010		Send L directly in real time	
Microwave imaging instrument	100Kbps	VC3	00,1010		Direct access to information processor， X Real time /delay module	
GNOS occultation sounder	200Kbps	VC4	00,1011		Send X directly in real time, control command to send X delay module	
Wide Angle	1.6Mbps	VC5	00,010		Send X directly in real time,	

Aurora Imager (WAAI)			1		control command to send X delay module	
Hyperspectral infrared atmospheric sounder	10Mbps	VC6	00,0110		Send X directly in real time, control command to send X delay module	
High light spectrum greenhouse gas monitor	5Mbps	VC7	00,1001		Send X directly in real time, control command to send X delay module	
Satellite telemetry parameters	2 packet/s	VC8	00,1100	000,0000,0001	Through the number of pipe 1553B into the general processor, X real-time /X delay module	288
Microwave thermometer	4 packet/2.667s			000,0000,0111	Through the number of pipe 1553B into the general processor, X real-time /X delay module	1024
Space environment monitor	1 packet/42s			000,0000,1111	Through the number of pipe 1553B into the general processor, X real-time /X delay module	512
Microwave moisture meter	4 packet/2.667s			000,0001,0000	Through the number of pipe 1553B into the general processor, X real-time /X delay module	1024
Small ionospheric spectrometer	1 packet/10s			000,0001,0001	Through the number of pipe 1553B into the general processor, X real-time /X delay module	256
Micro vibration detection box	1 packet/s（Initial stage on orbit）；10 packets/s（after low rate payload powered on）			000,0000,1000	Through the number of pipe 1553B into the general processor, X real-time /X delay module	1024

Original data packet for control of satellite position and orbit	1 packet/5s			000,0000,0011	Through the number of pipe 1553B into the general processor, X real-time /X delay module	512

5.3.2. Low-rate load data stream

7 kinds of low rate load data streams transmitted through 1553B are in accordance with the basic format shown as followed.

Table 8 – Basic format of 1553B data source package

Packet header (6bit)							Package assistant head 6 bit	user data Can change	
Packet marking 2bit				Packet sequence control 2bit		packet length 2bit			
version number 3b "000"	type symbol 1b "0"	Packet header label 1b	Application process label 11b	Grouping flag 2b	Packet sequence count 14b	16b	Time mark 48b	secondary data Can change	Application process data Can change

The main elements of the package lead are shown in the following table:

Table 9 – the implication of the dominant element in the 1553B data source package

Elements	Means
Version number	Set to 000, version of a CCSDS package
Type indicator	Set to 0, not used in ASO
Header flag	Set to 1, indicating the existence of deputy head; set to 0, said no deputy head, or idle packets, or encryption source package
Application process identifier	Set to 0-2015, indicating the logical path of the message；
Grouping flag	"01"：Package group of the first source； "00"：Package group connected source package； "10"：The last source of Package group ； "11"：Source package does not belong to the package group。

Packet sequence count	An application process for the binary count of each source package, module 16384；
Packet data length	The number of bytes in the packet header and user data fields is reduced by 1

The load data source package specific format is shown in Table 10.

Table 10 – Load data source package specific format

	Packet main header（6Bytes）						Package assistant header	User dat
	Packet marking（2Bytes）				Package sequence control	Packet length	Time mark	
Remote sensing instrument	Version number	Type indicator	Packet assistant header label	Application process identifier	2Bytes	2Bytes	6Bytes	**Bytes
Small ionospheric spectrometer	08 11					00F9		
Microwave thermometer	08 07					03F9		
Microwave moisture meter	08 10					03F9		
Space environment monitor	08 0F					01F9		
Satellite telemetry parameters	08 01					0119		
Micro vibration detection box	08 08					03F9		
Original data packet for control of satellite position and orbit	08 03					01F9		

Note: ** means lengths of the user data in different load data source packages are different.

5.3.3. High-rate load data stream

7 kinds of high-rate load data streams, including data from MERIS(day), MERIS(night), Microwave imaging instrument, GNOS occultation sounder, Wide angle laser imager，Hyperspectral infrared atmospheric sounder，High spectrum greenhouse gas monitor, have a format shown in Table 11.

Table 11 – Main format information of High rate load data source

<table>
<tr><td></td><td colspan="3">Package main header（6Bytes）</td></tr>
<tr><td>Remote sensing instrument</td><td>Application process identifier（2Bytes）</td><td>Packet count</td><td>Packet length (2Byte)</td></tr>
<tr><td>Partial channel</td><td>Frame header：aa55aa55aa55aa55aa55</td><td>24bits</td><td>Frame length：4178544bits</td></tr>
<tr><td>MERIS（day）</td><td>Frame Header：aa55aa55aa55aa55aa55</td><td>24bits</td><td>Frame length ：29829024bits</td></tr>
<tr><td>MERIS（night）</td><td>Frame header：aa55aa55aa55aa55aa55</td><td>24bits</td><td>Frame length ：10996704bits</td></tr>
<tr><td>Wide Angle Aurora Imager (WAAI)</td><td>080CH</td><td rowspan="7">2Byte</td><td>ABH</td></tr>
<tr><td rowspan="3">Hyperspectral infrared atmospheric sounder</td><td>High spectral Hyperspectral data packet：0804</td><td>0075H</td></tr>
<tr><td>High spectral picture data：0804</td><td>62C9H</td></tr>
<tr><td>Interferometer telemetry data：0804</td><td>1DDBH</td></tr>
<tr><td>Microwave imaging instrument</td><td>0950</td><td>1D6BH</td></tr>
<tr><td>High light spectrum greenhouse gas monitor</td><td>080EH</td><td>A3AADH（32bits）</td></tr>
<tr><td>GNOS occultation sounder</td><td>0802C0(3BYTES)</td><td>Packet length varies for different user data types，see details in load data information format</td></tr>
</table>

5.3.4. Application of AOS service and virtual channel assignment

The core of the CCSDS standard grid is space link subnet (SLS), which supports six different types of business: packaging, multiplexing, flow, virtual channel access, virtual channel data unit and insert operations. Based on the analysis of the information data stream, the FY-3D data transmission subsystem uses multiplexing and bit stream two services to complete the real-time dynamic processing of 14 different code rate source, as shown in Table 12.

Table 12 – Information processing input information application service classification

Remote Sensing Instrument	Application business
MERIS (partial channel)	Bit stream service
MERIS (day)	Bit stream service
MERIS (night)	Bit stream service
Wide Angle Aurora Imager (WAAI)	Bit stream service
Microwave imaging instrument	Bit stream service
Hyperspectral infrared atmospheric sounder	Bit stream service
High light spectrum greenhouse gas monitor	Bit stream service
Small ionospheric spectrometer	Multiplexing service
Microwave thermometer	Multiplexing service
Microwave moisture meter	Multiplexing service
Space environment monitor	Multiplexing service
Satellite telemetry parameters	Multiplexing service
Micro vibration detection box	Multiplexing service
Original data packet for control of satellite position and orbit	Multiplexing service
GNOs occultation sounder	Bit stream service

APID, lengths, and content of Satellite telemetry parameter source packet identifier (APID) and 6 kinds of load data source package entered into the information processor through 1553B, are shown in Table 13.

Table 13 – APID and length of 1553Bdata source package

Remote sensing instrument	APID	Source packet length（byte）
Satellite telemetry parameter	000,0000,0001	288
Microwave thermometer	000,0000,0111	1024
Small ionospheric	000,0001,0001	256

spectrometer		
Space environment monitor	000,0000,1111	512
Microwave moisture meter	000,0001,0000	1024
Micro vibration detection box	000,0000,1000	1024
Original data packet for control of satellite position and orbit	000,0000,0011	512

Bit stream traffic from different SLS users cannot share a virtual channel. FY-3D data transmission system processes information for each bit stream traffic service, and it assigns each user a virtual channel. The information data stream inputted by the 1553B bus shares a virtual channel. FY-3D number system information processing virtual channel assignment and virtual channel identifier (VC-ID) of each virtual channel are shown in Table 14.

Table 14 – Information processing virtual channel assignment

Remote sensing instrument	Virtual channel	VC-ID
MERIS	VC0（partial channel）	00,0010
	VC1（day）	00,0011
	VC2（night）	00,0001
Microwave imaging instrument	VC3	00,1010
GNOS occultation sounder	VC4	00,1011
Wide Angle Aurora Imager (WAAI)	VC5	00,0101
Hyperspectral infrared atmospheric sounder	VC6	00,0110
High light spectrum greenhouse gas monitor	VC7	00,1001
Microwave thermometer	VC8	00,1100
Microwave moisture meter		
Space environment monitor		
Small ionospheric spectrometer		
Satellite telemetry parameter		
Micro vibration detection box		
Original data packet for		

control of satellite position and orbit		

Output data from two channels to the MPT transmitter and solid state recorder. The data output to the MPT transmitter must be continuous, and if necessary, fill the idle data to ensure continuous physical channel. FY-3D uses frame format shown in Table 15.

Synchronization	Version(01)	Aerocraft (00110100)	VC identification		count	playback	patcharea	Data area		
								pointer (2Bytes)	data (882Bytes)	RS (128Bytes)
1A CF FC 1D			MERIS（partial） VC0	02		Real-time：00 Delayed：80	Encryption：FF+key number code：00 00	MPT：3F FF DPT：3F FF		
			MERIS（day） VC1	03						
			MERIS（night） VC2	01						
			Microwave imaging instrument VC3	0A						
			GNOS occultation sounder VC4	0B						
			Wide Angle Aurora Imager (WAAI) VC5	05						
			Hyperspectral infrared atmospheric sounder VC6	06						
			High light spectrum greenhouse gas monitor VC7	09						
			filled CADU format	3F				MPT：3F FF	All 0	
			1553B	0C				5bits“0”+11bits		

Table 16 – Elements of data format

Element	Definition	
Version number	Set to “o1”B, representing CCSDS version 2.	
Aerocraft	Form VCDU-ID，“00110100”B , with VC identifier.	
VC-ID	Virtual channel identifier. Filled CADU set for all “1”B。	
VCDU count	The order of the number of the total number of VCDU transmitted on each VC (16777216), together with the VCID domain is used to maintain a separate count for each VC, the VCDU count of the filled CADU is counted for the order (mode 16777216).。	
Signal field	In the proposed CCSDS interpretation, playback flag is set to "0" on behalf of B, representing L band /X band real-time VCDU; playback flag is set to “1”, representing X band delayed VCDU; spare flag is set to all “0”.	
Patch area	Encryption control	
Spare/guide head pointer	B-PDU	Spare 2bits are set to all “0” B, bit stream data pointer 14bits are set to all “1” B.
	M-PDU	Spare 5bits are set to all “0” B, 11bits indicate M-PDU head pointer.

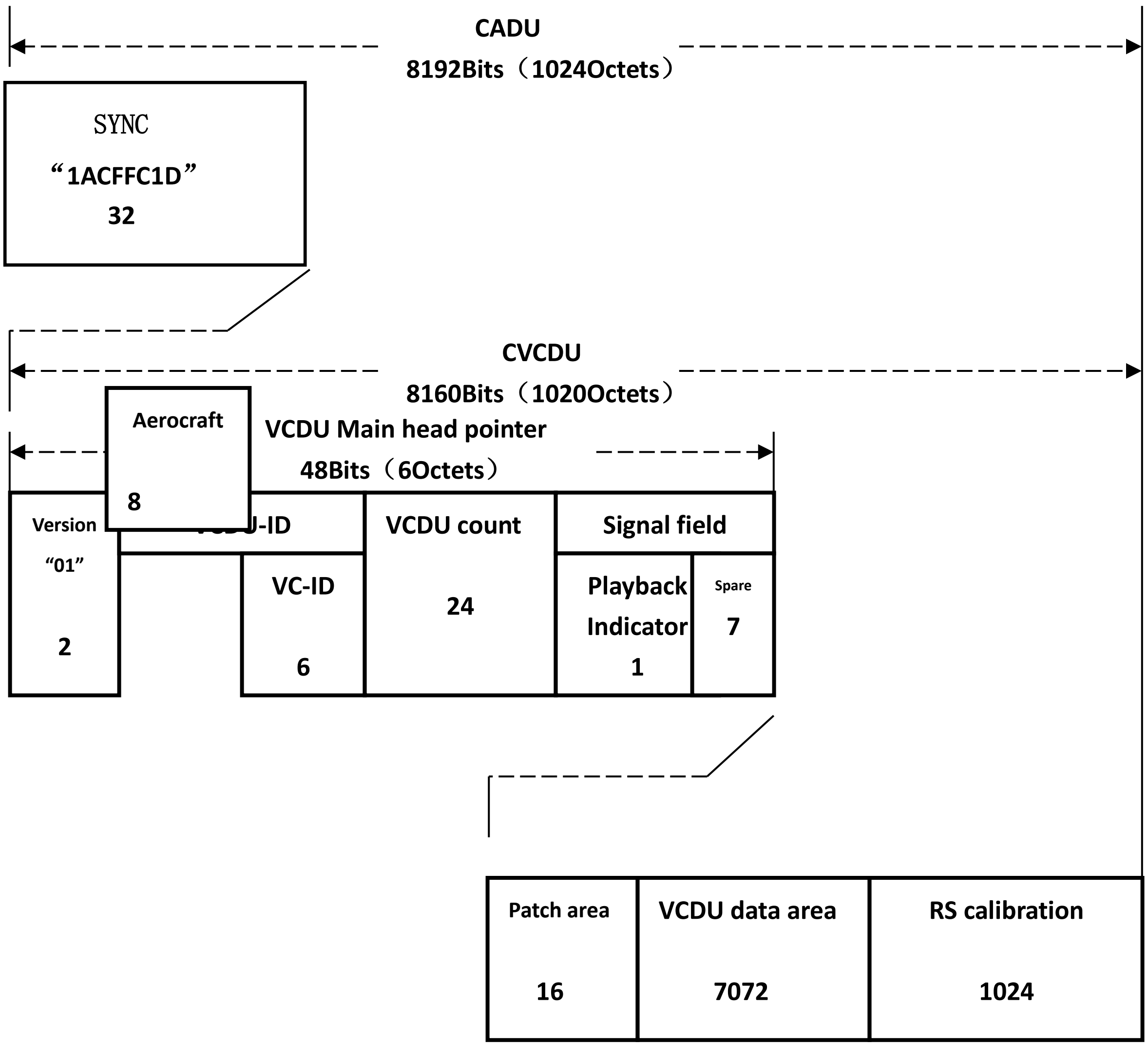

Figure 10 – CADU data format

5.4. Orbital parameters

1) Orbit type: polar orbiting, sun-synchronous
2) Nominal orbit altitude: 836.4km
3) Nominal inclination: 98.73°
4) Orbit precision: semi major axis deviation: |Δa|≤5km
5) Inclination angle deviation: |Δi|≤0.08°
6) Deviation of eccentricity: ≤0.0025
7) Sub-astral point return cycle: D = 4 – 10 days
8) Orbit keeping eccentricity: ≤0.0025
9) Satellite launch window: symmetrical window for launches in morning and afternoon, when the descending node local time at 10:00-10:20 or the ascending node local time at 13:40-14:00, 04 star window design based on the afternoon window design.
10) Descending (ascending) node local time shift: less than 15 minutes in 4 years (reference to orbit descending node local time)

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