Space-to-Ground Interface Control Documents of FY3E Meteorological Satellite

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1 CONTENTS

1 Scope....5
2 Reference Standards and Specifications....5
3 Terms and Definitions....5
4 Acronyms....6
5 Data Broadcasting....7
5.1 MPT: Direct Broadcast....7
5.1.1 Contents of MPT real-time data broadcasting....7
5.1.2 Process of MPT real-time data broadcasting....8
5.1.3 Multi-load Data Processing....8
5.1.4 Scrambling....9
5.1.5 Error Correction Coding....10
5.1.6 Modulation....13
5.1.7 Index of MPT real-time transmission downlink....13
5.1.8 MPT link control link-calculation....16
5.2 FY3-E data transmission format....18
5.2.1 Source package format....18
5.2.2 Low-rate load data stream....18
5.3 Orbital parameters....24

FIGURE 1 WORKING PROCESS OF MPT REAL-TIME DATA BROADCASTING 8
FIGURE 2 DATA SCRAMBLING FLOW 9
FIGURE 3 RS CODING WITH AN INTERLEAVING DEPTH OF I = 4 11
FIGURE 4 CONVOLUTIONAL CODING (7, 3/4) 11
FIGURE 5 CONVOLUTIONAL CODING (7, 1/2) 11
FIGURE 6 QPSK FLOW 13
FIGURE 7 MPT ANTENNA GAIN CURVE 15
FIGURE 8 – CADU DATA FORMAT 23

TABLE 1- FOUR-PHASE GRAY-CODE MODULATION 13
TABLE 2- MPT ANTENNA GAIN INDICATORS 15
TABLE 3 – MPT LINKS 16
TABLE 4 -INPUT INFORMATION FOR DATA PROCESSING 18
TABLE 5 – BASIC FORMAT OF 1553B DATA SOURCE PACKAGE 19
TABLE 6– THE IMPLICATION OF THE DOMINANT ELEMENT IN THE 1553B DATA SOURCE PACKAGE 19
TABLE 7 – INFORMATION PROCESSING VIRTUAL CHANNEL ASSIGNMENT 20
TABLE 8- FRAME FORMAT 21
TABLE 9 – ELEMENTS OF DATA FORMAT 22

Space-to-Ground Interface Control Documents of FY3E Meteorological Satellite

1 Scope

This document of standard illustrates technical requirements for the moderate resolution spectral image transmission (MPT) of FY-3E meteorological satellite.

The standard is applicable for data transmission and data receiving system between the satellite and ground station for FY-3E meteorological satellite.

2 Reference Standards and Specifications

The following documents are essential for the application of this document of standard. For the referred 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 referred 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

Followings are the terms and definitions applied in this document.

1) FENGYU 3E Meteorological Satellite; China's second generation polar orbiting meteorological satellites include FENGYUN 3A Meteorological Satellite (FY-3A), FENGYUN 3B Meteorological Satellite (FY-3B), FENGYUN 3C Meteorological Satellite (FY-3C),FENGYUN 3D meteorological Satellite (FY3-D) and FENGYUN 3E Meteorological Satellite (FY-3E). FY3-E carries 11 observation instruments in 9 categories. These observation instruments provide global scanning, all-weather

scanning, multi spectral scanning, three-dimensional remote sensing and quantitative observation data to Earth stations.

2) Moderate Resolution Picture Transmission; MPT

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

3) Primitive packet data

Observation data and auxiliary data ~~observed~~ from satellite payload.

4) Multiplexing Transmission Technology

Techniques for transmitting data from various detectors and application processes simultaneously using one actual physical channel.

5) Transmission Frame

Data structure for physical channel transmission.

4 Acronyms

Following are the acronyms applicable to this document.

HIRAS	Hyper infrared Atmosphere Sounder
SSIM	Solar Spectral Irradiance Monitor
SIM-II	Solar Irradiance Monitor -II
WindRAD	Wind Radar
TRI-IPM	Triple Ionospheric PhotoMeter
X-EUVI Solar	X-ray Extreme Ultraviolet Imager
GNOS-GPS	GNSS Radio Occultation Sounder-GPS
GNOSBDS	GNSS Radio Occultation Sounder-BDS
BDS MWTS-III	MicroWave Temperature Sounder
MWHS-II	MicroWave Humidity Sounder
MERSI-LL	Medium Resolution Spectral Imager
SEM	Space Environment Monitor
VASS	Vertical Atmospheric Sounding System
BPSK:	Binary Phase Shift Keying
CADU:	Channel Access Data Unit
Conv:	Convolutional Code
EIRP:	Equivalent Isotropically Radiated Power
G/T:	Gain/Temperature
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

FY3E 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 MPT link is shown as followings:

5.1 MPT: Direct Broadcast

5.1.1 Contents of MPT real-time data broadcasting

MPT broadcasts real-time data including:

MERS-LL: Medium Resolution Spectral Imager –LL
HIRAS:High-spectral Resolution Infrared Atomospheric Sounder
MWTS（III）: Microwave thermometer （III）
MWHS （II）: Microwave Humidity Sounder （II）

5.1.2 Process of MPT real-time data broadcasting

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

1) Format the MPT data based on the standards from CCSDS 102. Q-B-3;
2) Perform multiplexing, RS encoding and scrambling on the 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, which is Conv (7, 3/4);
5) Modulate the encoded data by QPSK mode, perform upward conversion, power amplifying and filtering on 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.

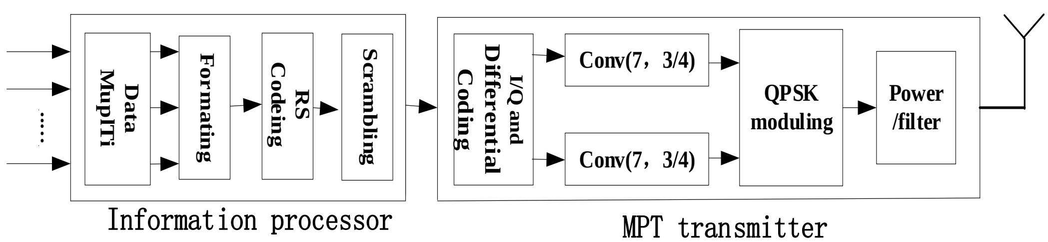

Figure 1 Working process of MPT real-time data broadcasting

5.1.3 Multi-load Data Processing

5.1.3.1 Low rate data payload source package

Create the low rate data payload source package based on format shown in 5.2.2.

5.1.3.2 Multiplexed data broadcasting technology

Multiplex the source package data and create virtual channels based on the parameters from 5.2.4.

5.1.3.3 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 12 and Figure 8.

5.1.4 Scrambling

With scrambling, Pseudo randomized sequence generates a polynomial equation:

$F(X)=X^8+X^7+X^5+X^3+1$ (1)

Where,
F(x) – Polynomial equation
X – Data bits.

Reduction of consecutive codes of “0” or “1” to ensure the timely recovery of data quality is quite essential in digital base-band signal transmission. To perform “randomization” on binary digital information into a pseudo randomized sequence could also limit the length of consecutive “0”s (or consecutive “1”s) , where this randomization is often called “code scrambling”.

Code scrambling brings better synchronization between clock and data. CCSDS suggests a polynomial of F(X)=X8+X7+X5+X3+1 for code scrambling process, where the sequence shall be repeated for every 255 bits and in each synchronous cycle the sequence generator will be reinitialized into “full 1” status.

The scrambling principle workflow is shown as below:

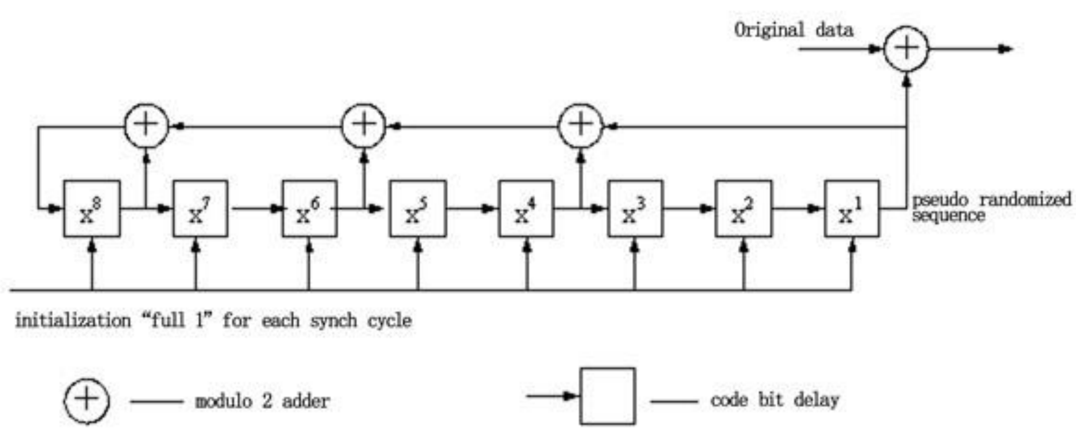

Figure 2 Data scrambling flow

5.1.5 Error Correction Coding

Based on characteristics of space communication efficiency (which is quite limited) and also considering construction costs of ground station, FY-3E satellite MPT data link adopts cascade coding scheme where RS(255,223) works as outer code and convolutional code works as inner code, which is suggested by CCSDS, meanwhile interleaving depth of RS code is I=4.

5.1.5.1. RS Coding

In accord 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 make RS(255,233) code meet the standards defined by CCSDS, the finite field GF(2^8) generates following polynomial in its character field GF(2):

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

Then the code generation polynomial is:

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

Where, α: generation cell for limited field GF(2^8)

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

G_i – coefficient

RS code derived from above polynomial is a system code which means the first 223 digits of generated codeword are primitive code cells, while the last 32 digits of the codeword are the verification code cells (generated by information code cells).

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

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

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

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

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

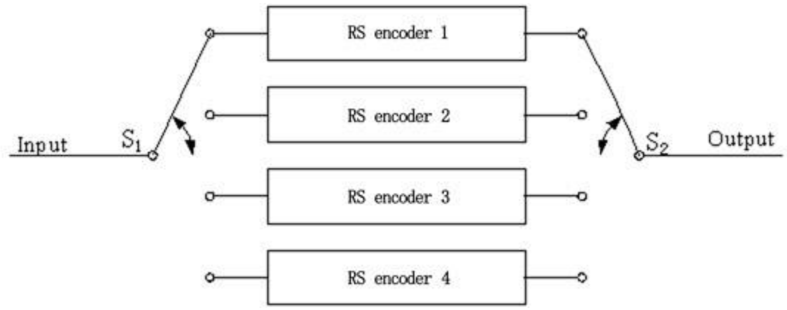

Figure 3 RS coding with an interleaving depth of I = 4

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

5.1.5.2. Convolutional Coding

Convolutional coding of Conv (7, 3/4) is applied based on the requirements from CCSDS 101.0-B-3.

To improve code rate while avoiding unnecessary demands of bandwidth and reducing the complicated calculation, MPT data link adopts Conv(7,3/4) convolutional coding.

3/4 code rate is derived from the output of 1/2 convolutional encoder. The coding flow is shown as in Figure 4.

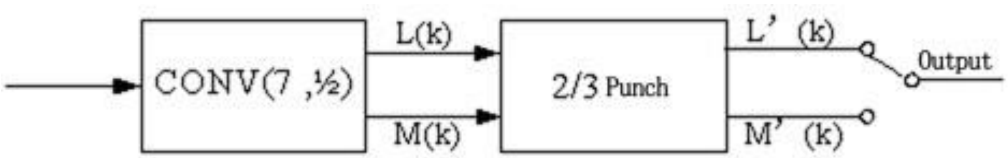

Figure 4 Convolutional coding (7, 3/4)

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

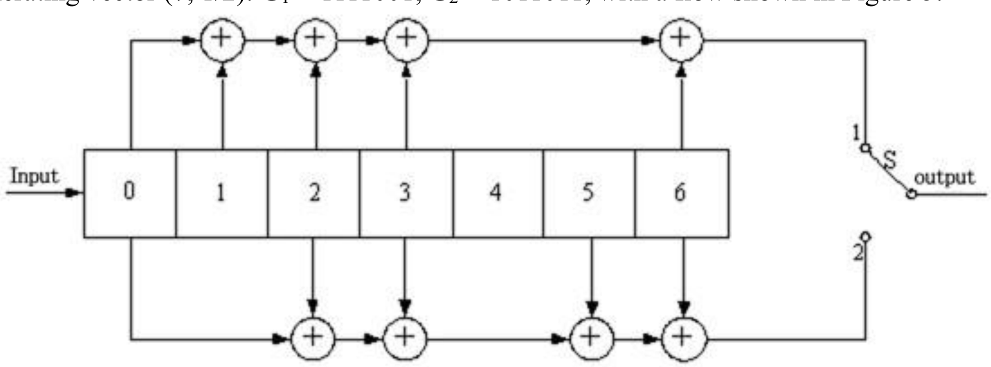

Figure 5 Convolutional coding (7, 1/2)

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 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 ...... 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 of previous output of the encoder;

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

FY3E is designed with a QPSK modulation system. The onboard QPSK is realized through two BPSKs which differentiates of π/2. The input data of Channel I and Channel Q are the two output values of gray-code logic.

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.

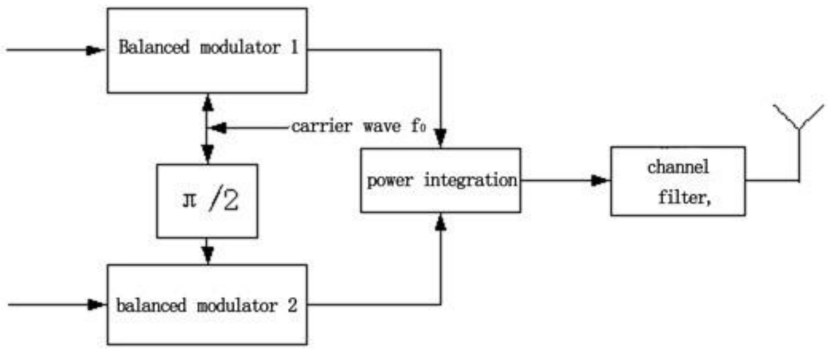

Figure 6 QPSK flow

By using gray-code logic, the modulator works in line with the following specifications:

Table 1- four-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 as below:

1) Data rate: 57.750 Mbps (after RS coding I = 4)
2) Data rate： 77 Mbps（after:CONV（7，3/4）
3) Frequency: X-band 7860MHz±78KHz
4) Modulation mode: QPSK
5) Bandwidth: 77MHz
6) EIRP: 46 dBm (EL=5°)
7) Polarization: RHCP
8) Axial ratio: not larger than 5dB for an area of ±62°

8） Direction pattern: multiple beams, and axis of symmetry

9） Real-time transmission covers the abroad area within international cooperation, and the domestic area with system of receiving capacity.

The antenna gain distribution is shown in Table 2:

Table 2- MPT ANTENNA GAIN INDICATORS

Antenna Elevation Angle θ (° degree)	**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:

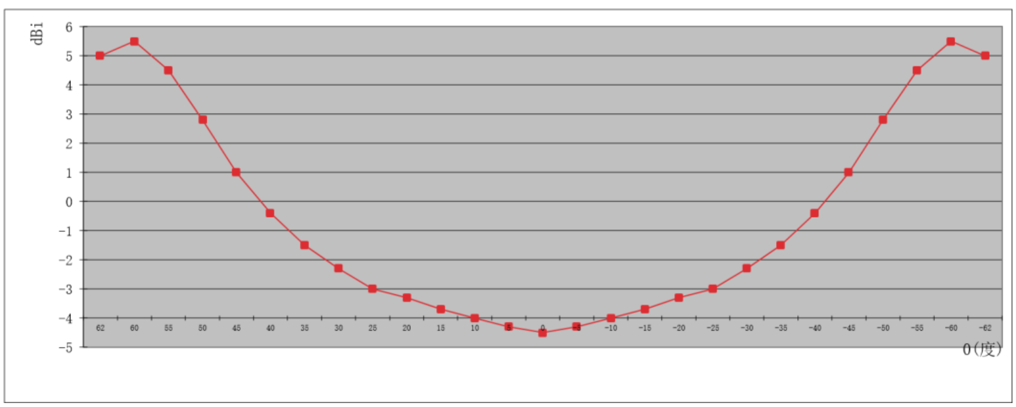

Figure 7 MPT Antenna gain curve

5.1.8 MPT link control link-calculation

Table 3 – MPT links

	PARAMETERS	LINK MARGIN FOR 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
	Satellite Track height (km)	830.00	830.00	830.00	830.00
	Satellite-ground distance (km)	2846.65	1307.43	904.60	830.00
	Working frequency (GHz)	7.86	7.86	7.86	7.86
	Ground antenna diameter (m)	4.2	4.2	4.2	4.2
Satellite	antenna efficiency	0.55	0.55	0.55	0.55
	Information bit rate (Mbps)	57.75	57.75	57.75	57.75
	Modulation symbol rate Rs (Mbps)	77.00	77.00	77.00	77.00
	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)	5.65	4.01	(0.17)	(0.91)
Channel	EIRP (dBW)	19.27	17.63	13.45	12.71
	Loss in space (dB)	179.44	172.68	169.48	168.73
	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 transmission loss[L](dB)	185.74	178.98	175.78	175.03
	Signal receiving power on the ground（dBW）	166.47	161.35	162.33	162.32
	[Gr/Tr]（dB）	25.678	25.678	25.678	25.678
	Boltzmann constant [k]（dBW/K/Hz）	228.60	228.60	228.60	228.60
	Receiver input C/N_0 (dBHz)	88.464	93.582	92.601	92.609
	Code rate（dBbps）	78.865	78.865	78.865	78.865
	[Eb/N0]（dB）	9.599	14.717	13.736	13.744
	Coding gain [Gc]（dB）	5.000	5.000	5.000	5.000
	Demodulation Loss（dB）	1.800	1.800	1.800	1.800
	The need for Eb/N0（dB） (error rate of 1e-7)	11.400	11.400	11.400	11.400
	Eb/N0 design margin [M]（dB）	1.399	6.517	5.536	5.544

5.2 FY3-E data transmission format

5.2.1 Source package format

The input information of multi-load data processing is shown in Table 4:

Table 4 -Input information for data processing

Remote sensing instrument	Code rate	Virtual channel	VC-ID	APID	Notes
MERSI-LL	8Mbps	VC1	00,0011		Broadcasts X-band data directly in real time
HIRAS (original)	22.5Mbps	VC6	00,0110		Broadcasts X-band data directly in real time
HIRAS (depressed data)	10Mbps	VC9	11,0110		Broadcasts X-band data directly in real time
Microwave Thermometer	packets	VC10	00,1100	000,0000,0111	Enter terminal processor through the number pipe 1553B , as X real-time data
Microwave Humidity Sounder	packets			000,0001,0000	Enter terminal processor through the number pipe 1553B , as X real-time data

5.2.2 Low-rate load data stream

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

Table 5 – Basic format of 1553B data source package

<table>
<tr><td colspan="7">Packet Primary header (6bit)</td><td rowspan="2">Package assistant head 6 bit</td><td colspan="2" rowspan="2">user data</td></tr>
<tr><td colspan="4">Packet marking
2bit</td><td colspan="2">Packet equence control
2bit</td><td>packet length 2bit</td></tr>
<tr><td>Packet Version number
3bits “000”</td><td>Packet Type symbol
1bits “0”</td><td>Packet header label
1bit</td><td>Appliction process label
11bits</td><td>Grouping flag
2bits</td><td>Packet sequence count
14bits</td><td>16bits</td><td>Time mark
48bits</td><td>secondary data
Can change</td><td>Application process data
Can change</td></tr>
</table>

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

Table 6– 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

Bit stream traffic from different SLS users cannot share the same virtual channel. FY3-E data transmission system processes information for each bit stream traffic service and it assigns one virtual channel for each user. The information data stream inputted by the 1553B bus shares one virtual channel. FY3-E number system information processing virtual channel assignment and virtual channel identifier (VC-ID) of each virtual channel are shown in Table 11.

Table 7 – Information processing virtual channel assignment

<table>
<tr><th>Remote sensing instrument</th><th>Virtual channel</th><th>VC-ID</th></tr>
<tr><td>Medium Resolution Spectral Imager -LL</td><td>VC1</td><td>00,0011</td></tr>
<tr><td>Hyper infrared Atmosphere Sounder (Original)</td><td>VC6</td><td>00,0110</td></tr>
<tr><td>Hyper infrared Atmosphere Sounder (Depressed)</td><td>VC9</td><td>11,0110</td></tr>
<tr><td>Microwave Thermometer （III）</td><td rowspan="2">VC10</td><td rowspan="2">00,1100</td></tr>
<tr><td>Microwave Humidity Sounder （II）</td></tr>
</table>

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. FY3-E uses frame format shown in Table 11.

Table 8- frame format

Attached Sync Marker(ASM)	Version（01）	Aerocraft（00110100）	VC identification		count	playback	patcharea	pointer（2Bytes）	Data area data（882Bytes）	RS（128Bytes）
1A CF FC 1D	01	001110 00	Medium Resolution Spectral Imager -LL	03		Real-time：00 Delayed：80	Encryption：FF+key number code：00 00	MPT：3F FF DPT：3F FF		
			Hyper infrared Atmosphere Sounder (Original)	06						
			Hyper infrared Atmosphere Sounder (Depressed)	36						

28

Table 9 – Elements of data format

Element	Definition	
Attached Sync Marker(ASM)	32bits， “1ACFFC1D”，mean the head of CADU frame	
Version number	2bits ,Set to “01”B, representing CCSDS version 2.	
Aerocraft	8bits ,Form VCDU-ID，“00111000”B , with VC identifier.	
VC-ID	6bits ,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.

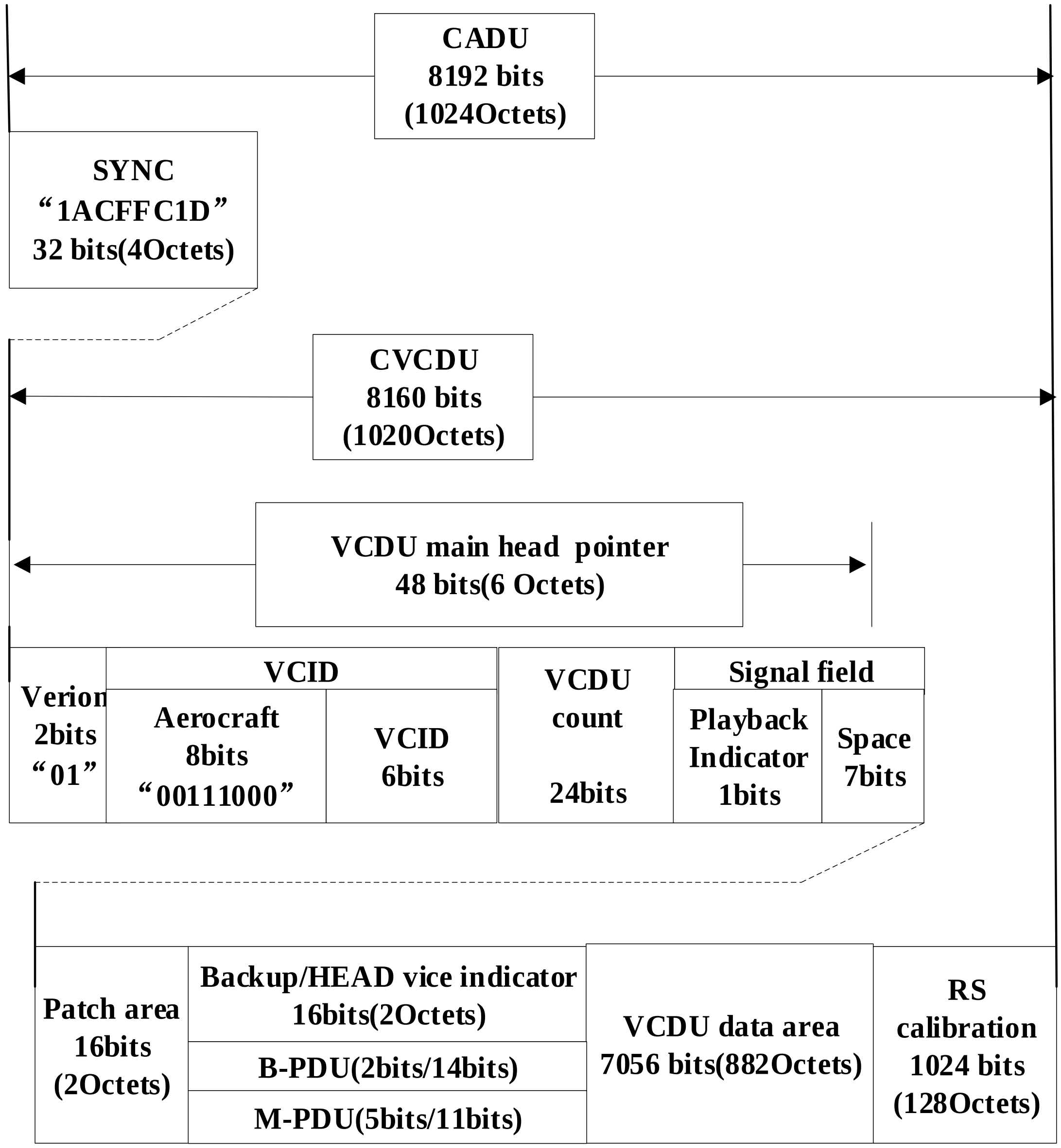

Figure 8 – CADU data format

5.3 Orbital parameters

1) Orbit type: polar orbiting, sun-synchronous
2) Theoretical orbit altitude: 830km
3) Theoretical inclination angle: 98.75°
4) Orbit precision: semi major axis deviation: $|\Delta a| \leq 5$km
5) Inclination angle deviation: $|\Delta i| \leq 0.08°$
6) Deviation of eccentricity: ≤0.003
7) Sub-satellite point return cycle: D = 4 – 10 days
8) Orbit maintenance eccentricity: ≤0.0025
9) Satellite launch window: symmetrical window for launches in early morning, when the descending node local time at 5:30～5:50.
10) Descending (ascending) node local time shift: less than 20 minutes in 8 years (reference to orbit descending node local time)

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