FY-3A Satellite to Ground Interface Control Document(HRPT)

Content

1. Executive Summary

The FY-3 system is the second-generation polar-orbiting meteorological satellite developed by China, aboard with an array of sophisticated instruments, including VIRR (Visible-Infrared Radiometer), IRAS(Infrared Atmospheric Sounder), MWTS (Microwave Temperature Sounder), MWHS(Microwave Humidity Sounder), MERSI (Medium Resolution Spectral Imager), MWRI(Microwave Radiation Imager), Solar Backscatter Ultraviolet and Total Ozone Sounder (SBUV/TOS), ERM(Earth Radiation Measurement), SIM (Solar Irradiation Monitor), and SEM (Space Environment Monitor). The system is able to collect diverse global data, in an all-weather, three dimensional, and quantitative manner.

A FY-3 meteorological satellite transmits its payload data and telemetry parameters via three downlinks as follows:

Table 1-1 Instrument channels and corresponding downlinks

Sounders	HRPT
MERSI	×
VIRR	√
MWRI	√
IRAS	√
Ultraviolet Ozone Vertical Sounder	√
Ultraviolet Ozone Total Sounder	√
ERM	√
SIM	√
MWTS	√
MWHS	√
SEM	√
Telemetry parameters (including GPS signals）	√

- High Resolution Picture Transmission（HRPT）real-time data are broadcasted globally via L-Band downlinks (HRPT）;

2. Transmission formats

Formats for transmitting scientific instrument data are given in Fig. 2-1, and pad frame in Fig. 2-2. FY-3 frame formats are listed in Table 2-1, and associated definitions in Table 2-2.

TABLE 2-1 FY-3 FRAME FORMATS

<table>
<tr><td>4Bytes</td><td>2Bits</td><td>8Bits</td><td colspan="2">6Bits</td><td>3Bytes</td><td>1Byte</td><td>2Bytes</td><td colspan="3">1012 Bytes</td></tr>
<tr><td rowspan="2">Synchronization</td><td rowspan="2">Version</td><td rowspan="2">Aircraft</td><td colspan="2" rowspan="2">VC identifier</td><td rowspan="2">Counts</td><td rowspan="2">Playback</td><td rowspan="2">Insert</td><td colspan="3">Data field</td></tr>
<tr><td>Pointer（2Bytes）</td><td>Data（882Bytes）</td><td>RS（128Bytes）</td></tr>
<tr><td rowspan="5">1A CF FC 1D</td><td colspan="2" rowspan="5">4C</td><td>MERSI VC1</td><td>43</td><td></td><td rowspan="5">Realtime：00
Delay：80</td><td rowspan="5">Encryption：FF+code
Open code：00 00</td><td rowspan="4">MPT/HRPT：3F FF
DPT：3F FF</td><td></td><td></td></tr>
<tr><td>VIRR（Day）VC2</td><td>45</td><td></td><td></td><td></td></tr>
<tr><td>VIRR（Night）VC3</td><td>49</td><td></td><td></td><td></td></tr>
<tr><td>MWRI VC4</td><td>4A</td><td></td><td></td><td></td></tr>
<tr><td>1553B VC5</td><td>4C</td><td></td><td>5bits“0”+11bits</td><td></td><td></td></tr>
</table>

TABLE 2-2 DEFINITIONS OF DATA ELEMENTS

Elements	Definition
Version	“01”B, meaning a structure defined by V. 2 CCSDS.
Spacecraft	“00110001”B , along with VC identifier, makes a VCDU-ID
VC-ID	A virtual channel identifier, a full “1”B for pad CADU
VCDU count	Sequential count (modulo 16777216) of VCDUs for each virtual channel. The VCDU count of a pad CADU is a sequential count（modulo 16777216）。
Signal field	According to CCSDS, playback is marked as “0”B, representing the real-time L/X-band VCDU; when marked

	as "1"B, meaning a delayed X-band VCDU; backup is marked as a full "0"B.	
Insert	Encrypted	
Backup/Header pointer	B-PDU	Backup 2bits, full "0"B，flow data pointer 14bits, full"1"B。
	M-PDU	Backup 5bits, full"0"B，11bits identifier, M-PDU header pointer。

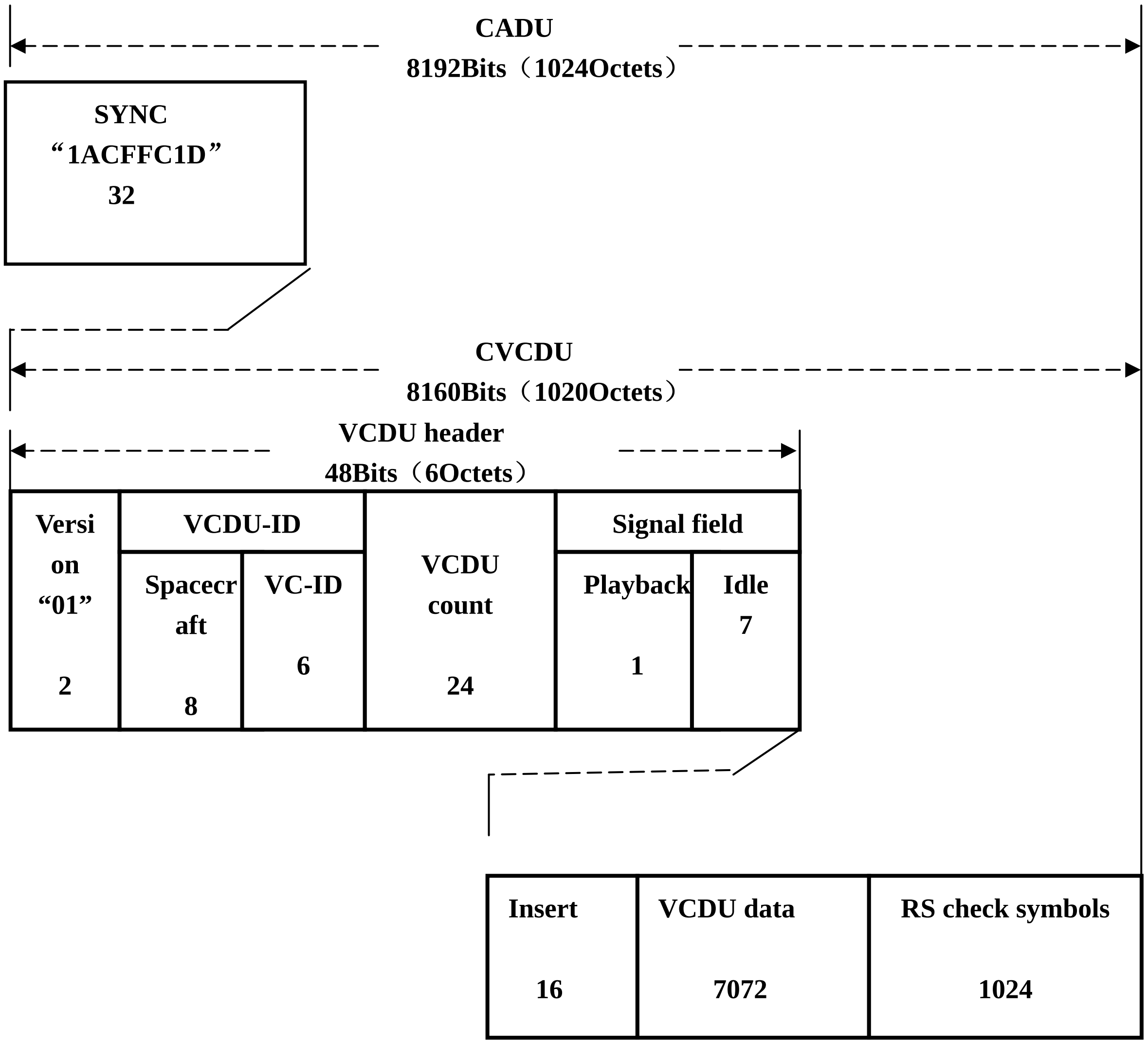


Fig. 2-1 Format CADU

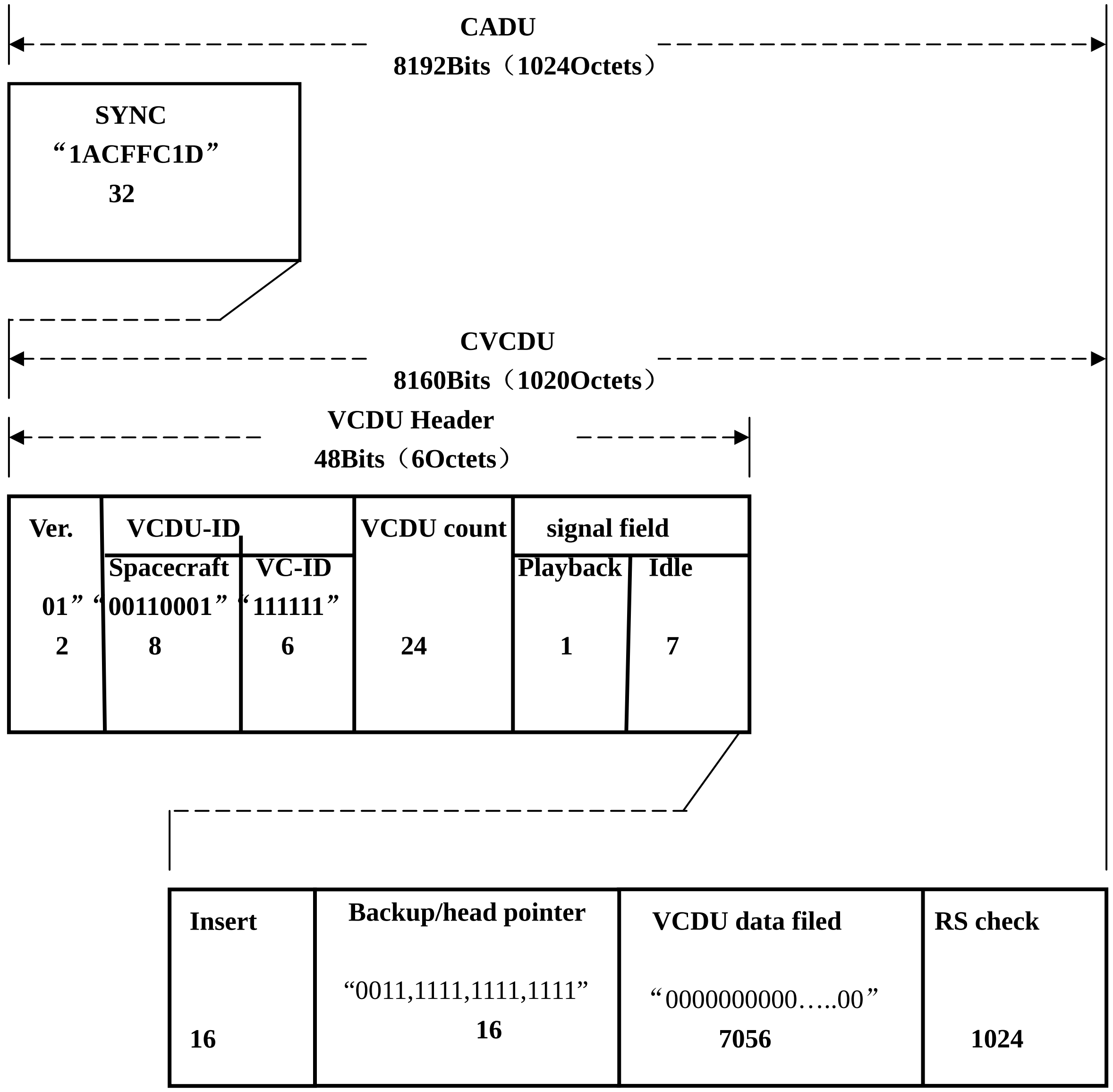


Fig 2-2 Pad CADU format

2.1 Baseband processing

2.1.1 Scrambling

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 255bit. 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.

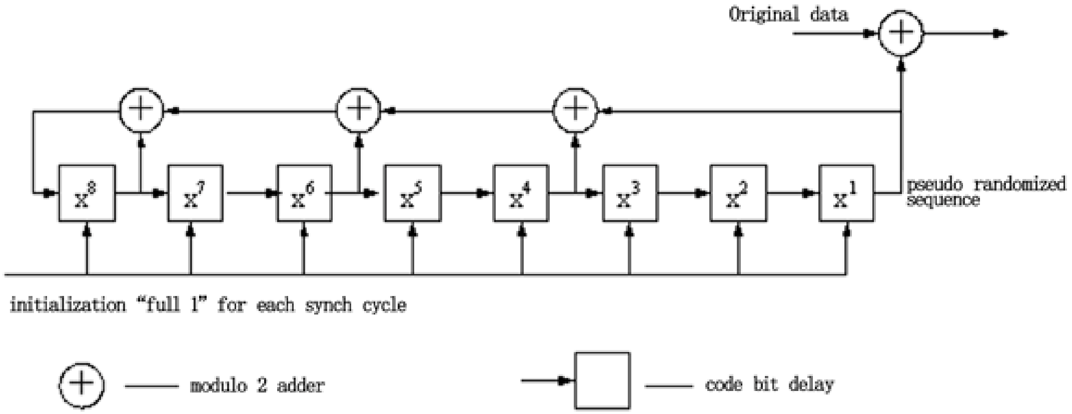


Fig. 2-3 Data scrambling flow

3. Error correction coding

RS code (255,223), recommended by CCSDS, is used as an outer code, and convolutional code an inner code. Meanwhile, RS codes are generated with an interleaving depth of I=4.

HRPT downlink works on concatenated codes, or RS (255,223) + CONV (7,3/4), with its flow shown in Fig. 3-1.

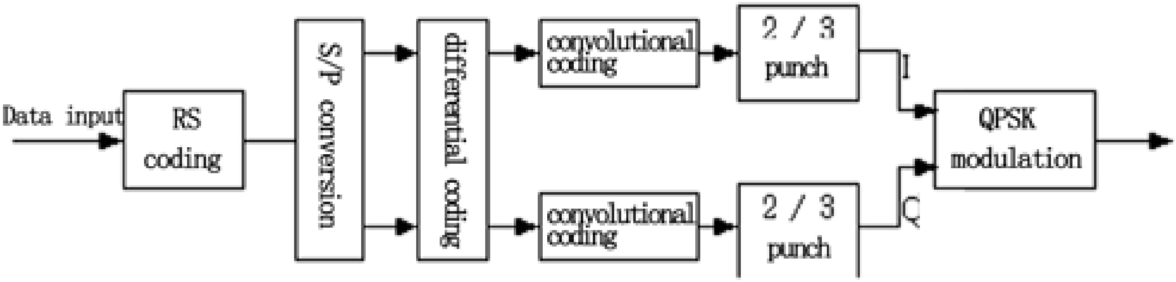


Fig. 3-1 Concatenated coding using HRPT RS (255,223)+ CONV(7,3/4)

3.1 RS（255,223）coding

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 Fig. 3-4.

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：$c_1c_2c_3c_4$……c_{223}, output：$c_1c_2c_3c_4$……$c_{223}C_1C_2$……C_{32};
RS encoder 4 input：$d_1d_2d_3d_4$……d_{223}, output：$d_1d_2d_3d_4$……$d_{223}D_1D_2$……D_{32}；
Output：$a_1b_1c_1d_1a_2b_2c_2d_2a_3b_3c_3d_3$……$a_{223}b_{223}c_{223}d_{223}$, $A_1B_1C_1D_1A_2B_2$
$C_2\,D_2$……$A_{32}B_{32}C_{32}D_{32}$。

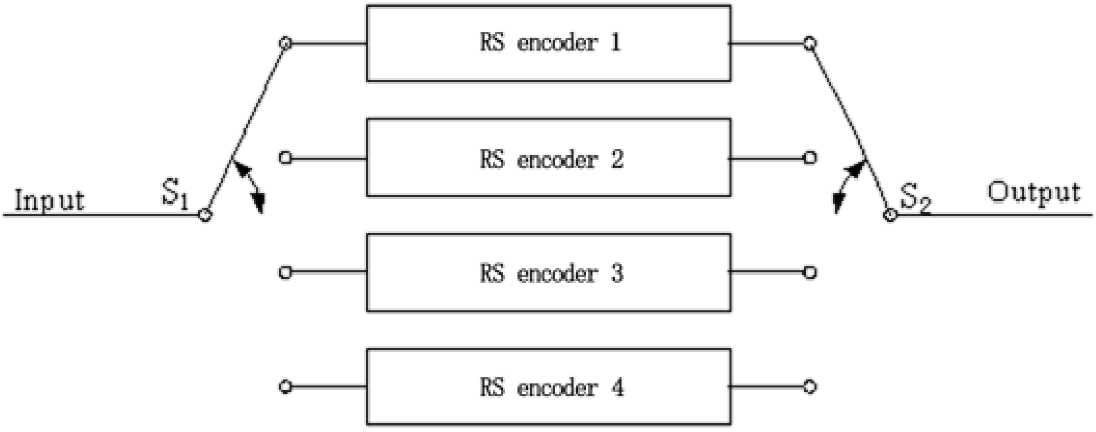


Fig. 3-4 RS coding with an interleaving depth of I=4

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

3.2 Conversion

3.2.1 Serial-to-Parallel conversion

In HRPT links, what an information processor sends to an HRPT transmitter is one-channel data. The HRPT transmitter will divide serial data flows received into two- channel parallel data flows in odd and even manner. One of the channels will be given 1-bit delay, so as to match the first code cells into a pair.

Assuming input is $m_1m_2m_3m_4m_5m_6m_7m_8$……
Then the output will be：I：m_1,m_3,m_5,m_7
Q: m_2,m_4,m_6,m_8

3.2.2 Data 8/2 conversion

In DPT links, the solid-state recorder sends eight-channel data to the DPT transmitter. The latter consolidates the parallel data from eight channels into two channels (No. 0, 2, 4, and 6 into one, and No. 1, 3, 5, and 7 into another). One of the channels will be given 1-bit delay, so as to match the first code cells into a pair.

If the input is：flow 0 $A_1A_2A_3A_4A_5A_6A_7A_8$……
Flow 1 $B_1B_2B_3B_4B_5B_6B_7B_8$……
Flow 2 $C_1C_2C_3C_4C_5C_6C_7C_8$……
Flow 3 $D_1D_2D_3D_4D_5D_6D_7D_8$……
Flow 4 $E_1E_2E_3E_4E_5E_6E_7E_8$……
Flow 5 $F_1F_2F_3F_4F_5F_6F_7F_8$……
Flow 6 $G_1G_2G_3G_4G_5G_6G_7G_8$……
Flow 7 $H_1H_2H_3H_4H_5H_6H_7H_8$……
Then the output will be： Flow 1 $A_1C_1E_1G_1A_2C_2E_2G_2A_3C_3E_3G_3A_4C_4E_4G_4$……
Flow 2 $B_1D_1F_1H_1B_2D_2F_2H_2B_3D_3F_3H_3B_4D_4F_4H_4$……

3.3 Differential coding

When the previous pair of output code cells is same, then $X_{out(i-1)}+Y_{out(i-1)}=0$, here:

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

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

When the previous pair of output code cells is not same, then $X_{out(i-1)}+Y_{out(i-1)}=1$, here:

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

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

Where：

$X_{\text{out }i}$ ，$Y_{\text{out }I}$ means the current output of the encoder

$X_{\text{in }i}$ ，$Y_{\text{in }i}$ is the current input of the encoder

$X_{\text{out}(i-1)}$，$Y_{\text{out}(i-1)}$ is the previous output of the encoder

3.4 Convolutional coding and punctured codes

3.4.1 CONV（7,1/2）

Convolutional coding (7,1/2), with code generating vectors of G_1=1111001, and G_2=1011011 (G_2 is the inverse output). The coding flow is shown in the following diagram:

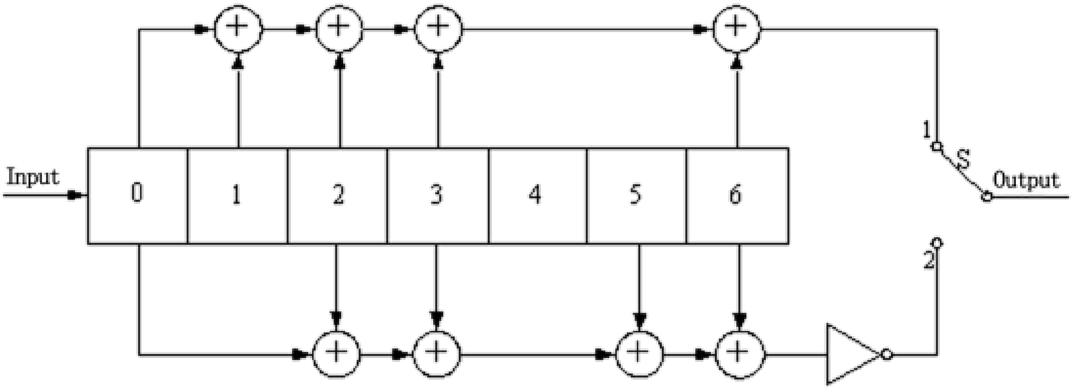


Fig. 3-5 Convolutional coding (7,1/2）

Flow 1：$X_1X_2X_3X_4X_5X_6X_7X_8$……

Flow 2：$Y_1Y_2Y_3Y_4Y_5Y_6Y_7Y_8$……

Output：$X_1Y_1X_2Y_2X_3Y_3X_4Y_4X_5Y_5X_6Y_6X_7Y_7X_8Y_8$……

3.4.2 CONV（7,3/4）

In an attempt to raise the code rate, avoid excessive width demands, and accommodate heavy assignments for convolutional encoding and decoding, both HRPT and DPT links are 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 Fig. 3.6.

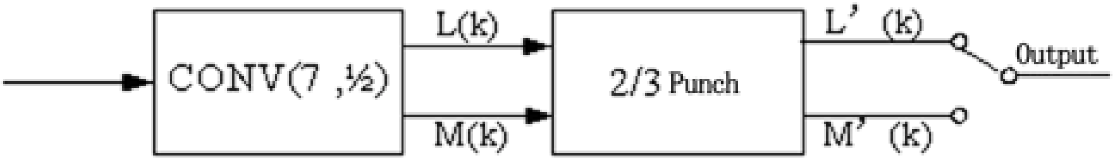
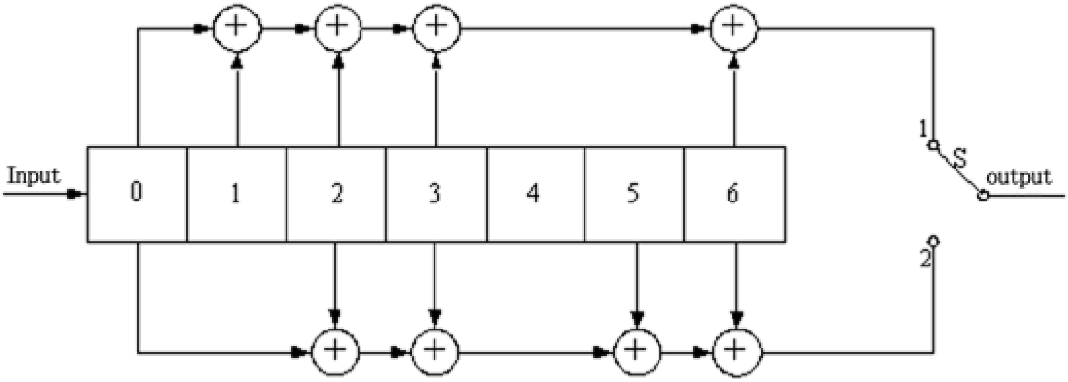


Fig. 3-6 Convolutional coding (7,3/4）

Code generating vector (7,1/2)：G_1=1111001, and G_2=1011011, with a flow shown as follows:



Input, output

Fig. 3-7 （7,1/2）coding flow for punctured coding（7,3/4）

The following are the details of 2/3 punching process:

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),……

4. Modulation

Modulation models shall be selected in line with the bandwidth limit allowed for a satellite, and other requirements, including interference resistance, and feasibility. FY-3 is designed with a QPSK modulation system, as the result of a balanced consideration.

The onboard QPSK is a $\pi/2$ system. Channel I and Channel Q are the convolutional coding outputs as shown in Fig. 3-1, Fig. 3-2 and Fig. 3-3.

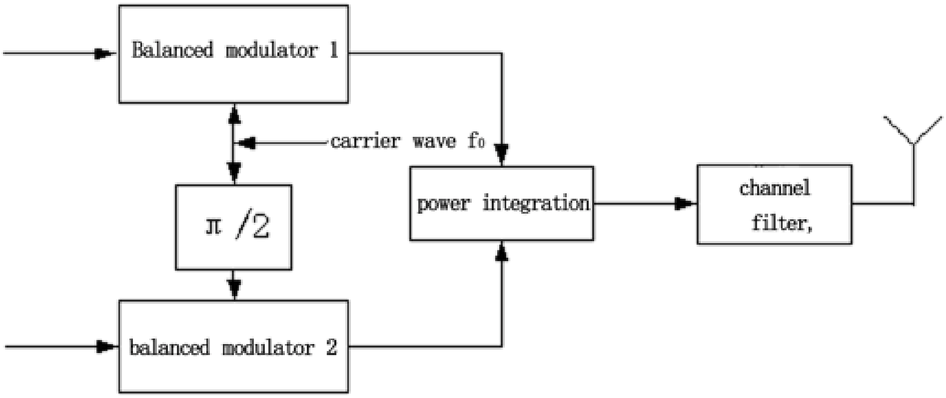


Fig. 4-1 QPSK flow

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

TABLE 4-1 4-PHASE GRAY-CODE MODULATION

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

5. Satellite-ground data processing

5.1 HRPT links

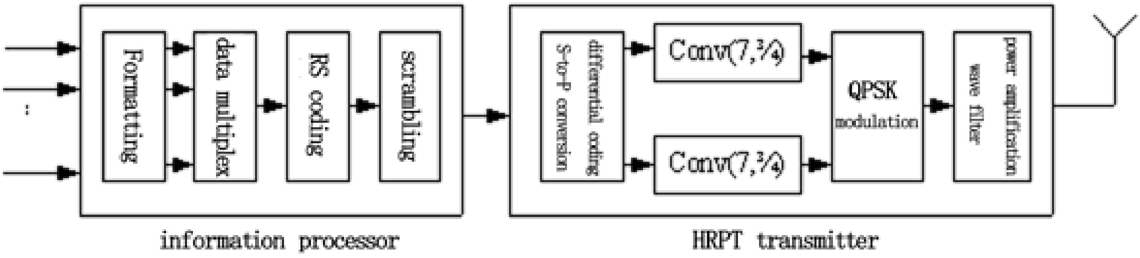


Fig. 5-1 HRPT links

HRPT flow diagram is given in Fig. 5-1. A range of functionalities, including data receiving, formatting, multiplex, scrambling, and RS coding, are realized in the information processor, while others, such as serial-to-parallel conversion, differential coding, convolutional coding, modulation, power amplification, and wave filter, are worked out by the HRPT transmitter. All payload data transmitted via HRPT links have to be processed by the HRPT module in the information processor, before going through modulation for transmitting.

5.1.1 Date type

TABLE 5-1 DATE TYPES FOR HRPT DOWNLINKS

Sounder	Receiving mode	Data rate	Length（bytes）
VIRR (day)	Direct	1.3308Mbps	--
MWRI	Direct	100Kbps	--
IRAS	Via 1553B	4 packets/6.4s	1024
SBUV	Via 1553B	1 packet/64s	512
		10 packets /120s（once a day）	
		10*4 packets /month	
TOS	Via 1553B	1 packet/8.16s	832
ERM	Via 1553B	1 packets/4s	1024
SIM	Via 1553B	2~6 packets /30s	512
MWTS	Via 1553B	1 packet /16s	256
MWHS	Via 1553B	2 packets /2.667s	1024
SEM	Via 1553B	1 packet /42s	512
Satellite telemetry parameters	Via 1553B	2 packets /s	256

5.1.2 Data multiplex

Multiplexed data units, transmitted from VIRR, MWRI, and 1553B, have their respective virtual channels at the HRPT module of the information processor. Meanwhile, the payload data from the same sources are buffer stored in a 4K×8bit FIFO. When the memory reaches 882 bytes, a logic dispatch unit concerning status and virtual channels will be sent out. The unit will take care of VCDU compiling and conversion, in line with sequencing algorithms of releasing speed, priorities, and synchronization. In an attempt to secure the required consistency and fixed code rate for the code flows destined to the real-time physical channels, a virtual data fill-in process will be staged to produce needed data, in case the payload data has not reached the required volume of 882 bytes. The said process is shown in Fig. 5-2.

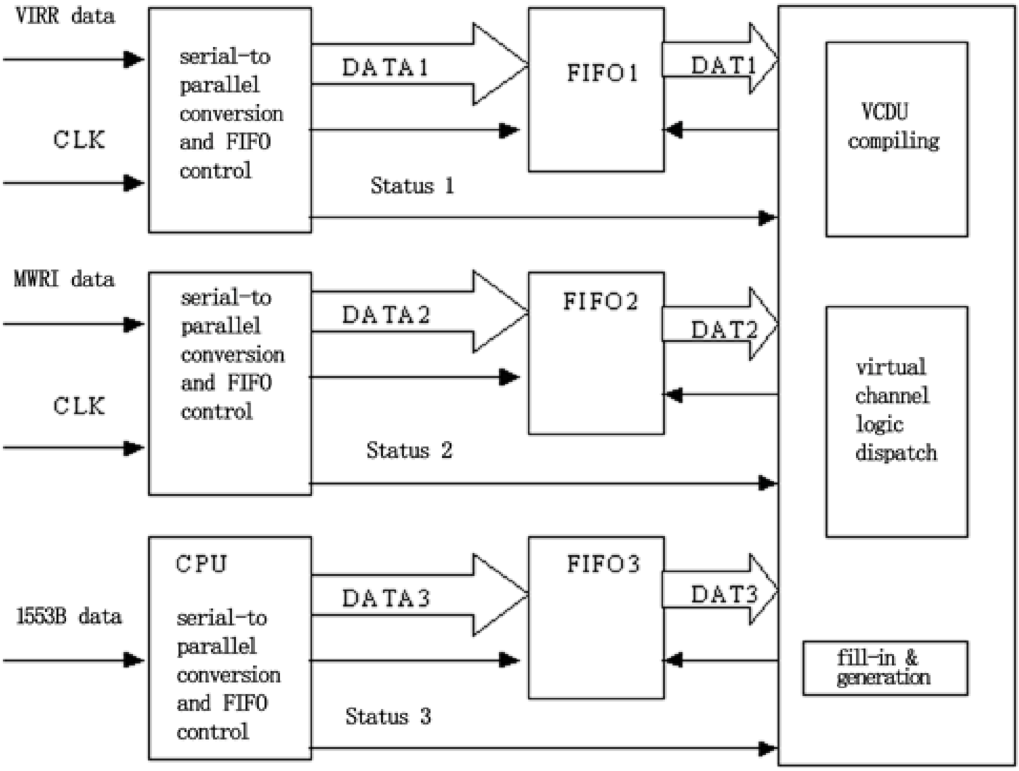


Fig.5-2 data multiplex

5.1.3 Data formatting

When above-mentioned three data flows reach the volume of 882 bytes in FIFO, they shall be framed in line with CADU formats defined by CCSDS AOS.

5.1.4 RS coding

A volume of 892Byte is allowed for the data frames fed into RS coding modules, though header (1ACFFC1D) is not included. The data will be divided into four groups. The four groups, having been turned into interleaved codes, will have 128Byte correction bits at the rear of the data field.

5.1.5 Data scrambling

The data frames will then be processed by the scrambling module, allowing all the data except the synchronous header to go with a 255bit scrambling sequence that is repeated in cycle.

5.1.6 Serial-to-parallel conversion and differential coding

After the above-mentioned processing, L-band real-time information processing module will produce a code rate of 4.2Mbps, in non-return to zero code, for HRPT transmitter. The data, after serial-to-parallel conversion and differential coding, will be divided into two channels of data.

5.1.7 Convolutional coding

The two channels of data will be convolutionally coded（7,3/4）.

5.1.8 Modulation model

A QPSK model will be used to modulate two channels of convolutional codes.
Carrier frequency: 1704.50MHz±34KHz
Width (zero): 5.6MHz

5.1.9 Power amplification and wave filter

A narrow wave filter will be added before power amplification. A solid-state linear power amplifier will be used for the purpose.
Transmitting power: not less than 11W.

5.1.10 Antenna

Signals have to be amplified and filtered, before sending to HRPT links for transmission. The antenna shall meet the following technical specifications:

Frequency and bandwidth: 1698～1710MHz
Polarization: RHCP
Gain (including RF cable loss): when antenna beam is ±61.71°, not less than 2.5dBi; when antenna beam is 0°, not less than -4.0dBi.
Axial ratio: not larger than 5dB, for an area of ±62°
Direction pattern: multiple beams, and axis of symmetry

TABLE 5-2 HRPT ANTENNA GAIN INDICATORS

Elevation angle θ（°)	Antenna gain (dBi)
±62°	≥2.5
±60°	≥2.5
±55°	≥2.5
±50°	≥2.0
±45°	≥1.3
±40°	≥0.7
±35°	≥0.1

±30°	≥-0.8
±25°	≥-1.7
±20°	≥-2.5
±15°	≥-3.3
±10°	≥-3.6
±5°	≥-3.8
0°	≥-4.0

Gain curves smooth out between ±62°~0° as follows:

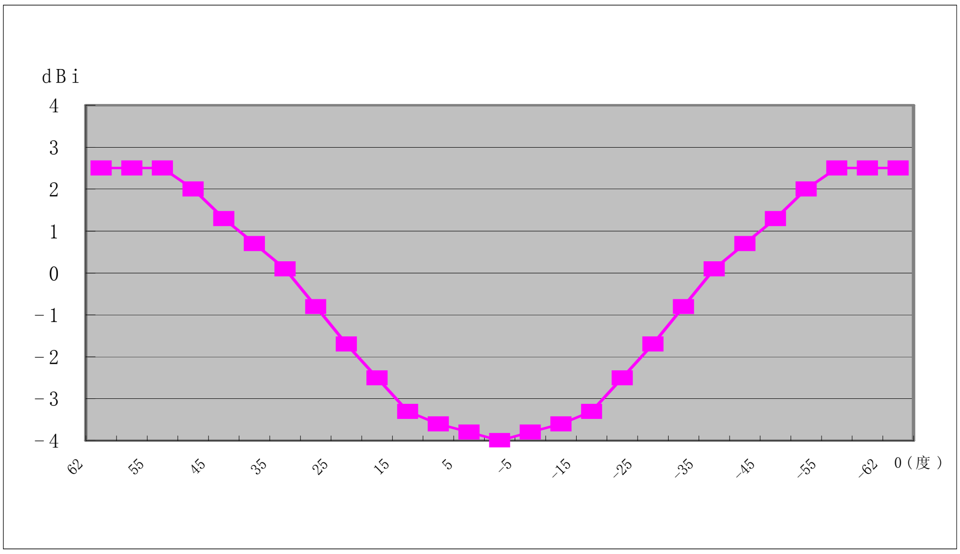


Fig. 5-3 HRPT antenna beam pattern

5.1.11 Key parameters of HRPT link

TABLE 5-3 HRPT RF LINK

Elevation angle	o	5	40	63	90
Carrier frequency	MHz	1704.5	1704.5	1704.5	1704.5
Orbit altitude	Km	836.4	836.4	836.4	836.4
Ground station G/T	dB/K	5.3	7.3	7.7	8.0
EIRP	dBw	11.0	3.5	1.2	0.3
Code rate	dB-bps	66.2	66.2	66.2	66.2
System link margin	dB	4.2	5.2	6.5	6.8

5.1.12 HRPT link control

HRPT link control steps are given in Table 5-4

TABLE 5-4 PROGRAMED HRPT LINK CONTROL

Step	Action	Note
Action		

1	HRPT information processing reset	10 seconds prior to the start of HRPT transmitter
2	HRPT transmitter switches on	
3	HRPT transmitter switches off	

6. Satellite orbit and programmed control

6.1 Orbital parameters

1) Orbit type: polar orbiting, sun-synchronous
2) Nominal orbit altitude: 836.4km
3) Inclination: 98.753°
4) Launch windows: morning and afternoon as symmetrical windows, local time for descending node: 10:00~10:20, and local time for ascending node: 13:40~14:00. The first satellite is designed for morning window launch.
5) Drifting of descending/ascending node: less than 15 minutes in two years (calculated on the benchmark of descending node).

6.2 Data transmission

L-Band HRPT downlink
Data rate：4.2Mbps （after RS coded）
Frequency：L-band（1704.5MHZ）
Modulation model：QPSK
EIRP：41dBm（EL=5°）
Real-time global transmission, with programmed control function