第 19 卷第 5 期
2000 年 10 月

红 外 与 毫 米 波 学 报
J. Infrared Millim. Waves

Vol. 19, No. 5
October, 2000

10-BAND VISIBLE-IR SCANNING RADIOMETER ON CHINESE FY-1C METEOROLOGICAL SATELLITE

GONG Hui-Xing ZHENG Qin-Bo WENG Cui-Jun ZHANG E

(Shanghai Institute of Technical Physics, Chinese Academy of Sciences, Shanghai 200083, China)

Abstract The 10-band visible-IR scanning radiometer is the main payload of the Chinese polar-orbit FY-1C meteorological satellite. Its instrument configuration, detecting bands, detectors, orbital signal processor and behavior in orbit were described in this paper.

Key words meteorological satellite, radiometer.

FY-1C 气象卫星上的 10 波段可见-红外扫描辐射计

龚惠兴 郑亲波 翁垂骏 张 镓

(中国科学院上海技术物理研究所，上海，200083)

摘要：10 波段可见-红外扫描辐射计是我国极轨 FY-1C 气象卫星上的主要有效荷载，本文介绍了该仪器的构成、探测波段、探测器、在轨信号处理器和运行表现。

关键词：气象卫星，辐射计

INTRODUCTION

The Chinese FY-1C meteorological satellite was launched successfully in China by a CZ-4B carrier rocket in Taiyuan Satellite Launch Center on May 10th, 1999. The satellite accurately entered the sun-synchronous orbit at a height of 862.8km with an inclination of 98.8° and a period of 102.23 min, and descending time of 08：34. The main payload of FY-1C is a 10-band visible-IR scanning radiometer with 1.26mrad instantaneous-field-of-view (I-FOV) and 1.1km resolution at the nadir.

1 Composition of the Radiometer

The radiometer (shown as Fig. 1) is composed of a scanner system, an optical system, visible and infrared detectors, image information processor, reference blackbody, radiant cooler and electrical system. The 45° scan mirror rotating at 360rpm is used. By means of the IFOV cross-track scanning and forward flight of the satellite, the two-dimension image of the earth is formed. Figure 2 is the block diagram of the radiometer.

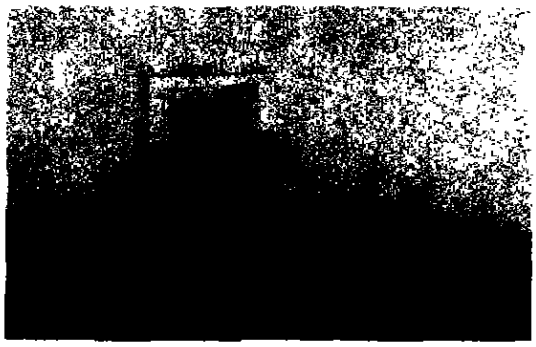

Fig. 1 The scanning radiometer
图 1 扫描辐射计

Received 2000-06-28

稿件收到日期 2000-06-28

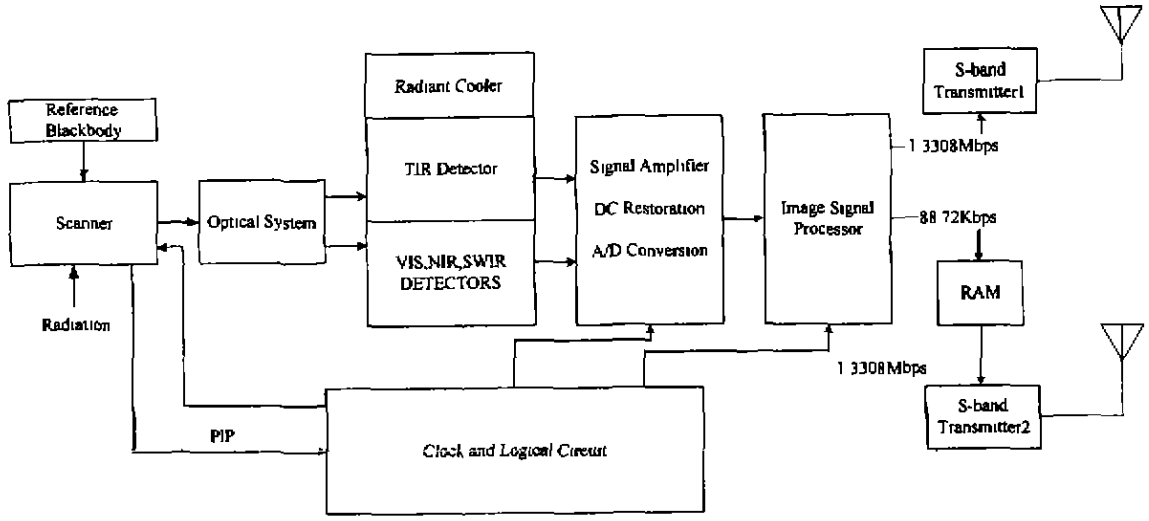

Fig. 2 Block diagram of the 10-band scanning radiometer
图 2 10 波段扫描辐射计流程图

Table 1 The detecting bands of 10-band scanning radiometer
表 1 10 通道扫描辐射计的探测波段

Serial number	Detecting band(μm)	Objects
1	0.58～0.68	Cloud, Vegetation
2	0.84～0.89	Vegetation, Atmospheric correction
3	3.55～3.93	Fire and Night temperature
4	10.3～11.3	Ocean and land surface temperature
5	11.5～12.5	Ocean and land surface temperature
6	1.58～1.64	Crop water content and soil moisture
7	0.43～0.48	Ocean water color
8	0.48～0.53	Ocean water color
9	0.53～0.58	Ocean water color
10	0.900～0.965	Vapor content

2 Detecting Bands

The radiometer has 10 detecting bands, among which the bands 1～6 are the same as in AVHRR on NOAA satellite. The bands 7～9 are used for observing ocean water color. The band 10 is located in the vapor-absorbing spectrum area and it is combined with band 2, which is located in no vapor-absorbing spectrum area to estimate the content of vapor in atmosphere. Because the band 1, band 9 and band 7 are located at R, G, B of the spectrum, respectively, the FY-1C can get real color image of the earth once a day.

The detecting bands of the radiometer are listed in Table 1.

3 Optical System

Figure 3 shows the optical configuration of the 10-band scanning radiometer. The incoming scene radiation is reflected and collected by a folded telescope. The collected radiation is then relayed through dichroic beam splitters to separate the radiation into four parts—each part encompassing four, two, one and three bands of the FY-1C individually. The radiation in the four separate wavelength intervals is directed by four corresponding

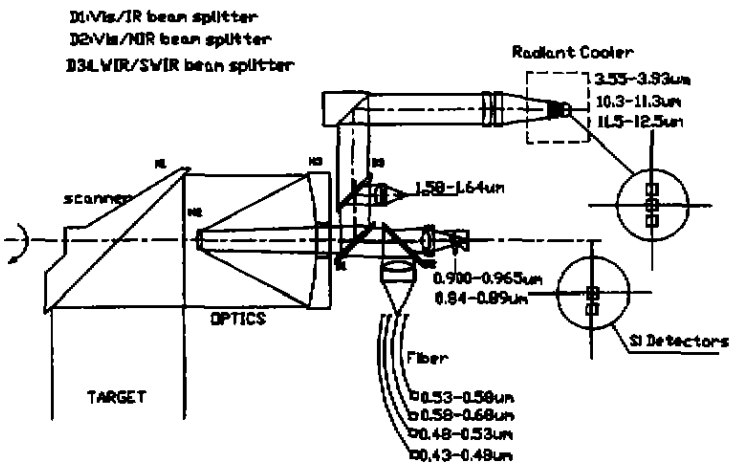

Fig. 3 The optical system of the scanning radiometer
图 3　扫描辐射计的光学系统

aft-optics assemblies, respectively. Four fibers are used in bands 1, 7, 8 and 9 and the radiation is sent via the fiber to the silicon detectors. Silicon detectors are also used in band 2 and band 10. The PC-HgCdTe detectors cooled by the radiant cooler working at 105K are used in bands 3, 4 and 5. The PV-HgCdTe detector working at room temperature is used in band 6. Bandpass filters set before the detectors form the required ten spectral bands. The error between measured and designed values of central wavelength is less than 1%. The IFOVs of each detecting band are all 1.26mrad.

In order to simplify the optical system, the common IFOV of the optical system is not used. IFOVs of 4 bands are located at the optical axis and registered, IFOVs of other 6 bands are arranged on both sides of the optical axis along the scanning direction. Bands 5, 9, 10 have a lead of two sampling periods, band 7 has a lead of four sampling periods and bands 3, 8 have a lag of two sampling periods from the axis (shown as Fig. 4). The images of different bands can be registered basically after processing on the ground.

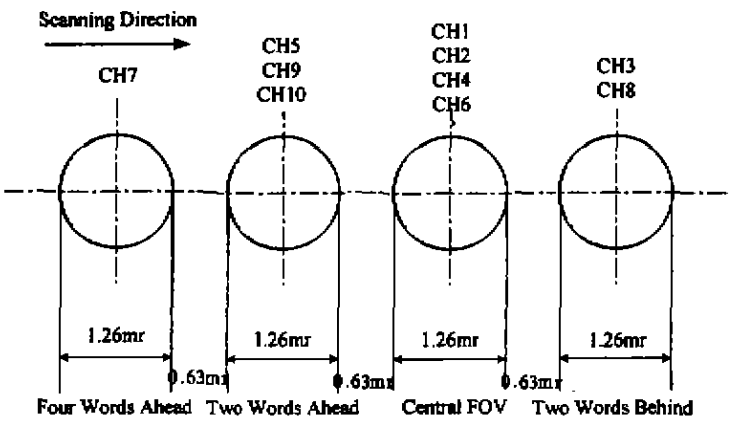

Fig. 4 The arrangement of 10 bands' IFOV
图 4　10 个波段瞬时视场的排列

4 Detectors

Single-element Si detectors are used in the four visible detecting bands with an effective sensitive area 0.7mm×0.7mm. The peak response at 0.9μm is better than 0.5 A/W and the response at 0.43μm is better than 0.15A/W after using violet-enhancement technology. This helps the radiometer to improve the ability to observe ocean chlorophyll content.

The band 6 uses PV-HgCdTe detector working at room temperature with the sensitive area of 0.4mm×0.4mm and $D^* \geq 3\times10^{11}\text{cmHz}^{1/2}\text{W}^{-1}$.

The three-element LW-IR PC-HgCdTe detectors with micro-filters are operated at 105K cooled by a radiant cooler. The D^* is better than 1×10^{11} $\text{cmHz}^{1/2}\,\text{W}^{-1}$ at 3.55～3.93μm and $2\times10^{10}\text{cmHz}^{1/2}$ W^{-1} at 10.5～12.5μm. The sensitive area of each element is all 0.25mm×0.27mm. The power consumption of three detectors is less than 10mW.

5 Radiant Cooler

The radiant cooler adopts two-stage adiabatic supporting structure and the radiators are open to deep space. By the relay optics, the IR radiation is coupled to the detectors set on the second stage cold patch. The cooling power is more than 20mW at 105K and exceeds the heating power produced by bias current of three IR detectors working.

The radiant cooler has an anti-contaminant cover. In the early period of satellite in the orbit, the anti-contaminant cover was closed and the radiant cooler was heated to disperse the vapor preventing the decrease of IR band signal caused by vapor deposit on the cool lens surface. The heating power

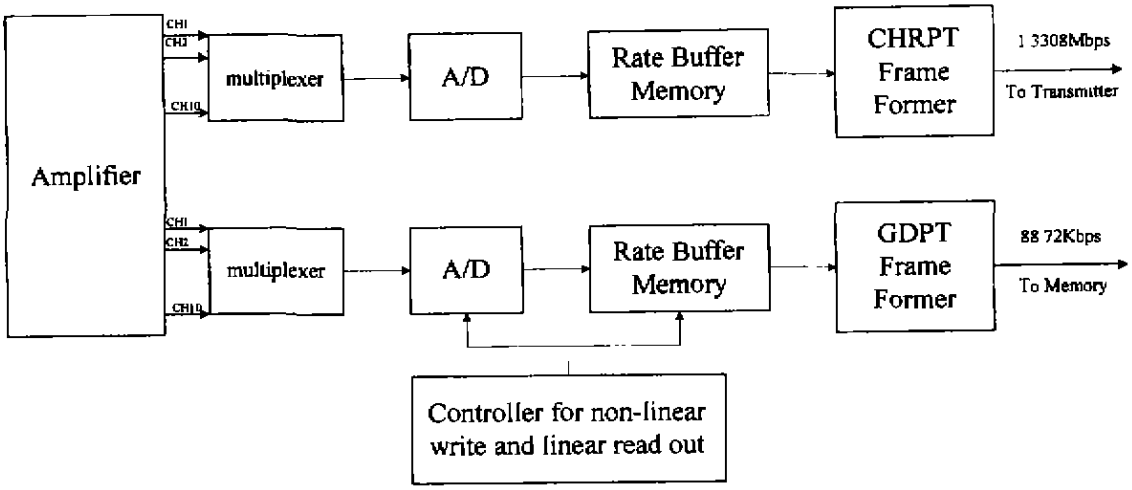

Fig. 5 Image signal processor configuration
图 5 图像信号处理器的构成

was 40W. After 30 days, the anti-contaminant cover was opened according to the command, heating stopped and radiant cooler began to work. When the radiator reaches 105K, three IR bands started to work, then the radiometer was in normal working state.

6 Image Signal Processing

For each detecting band the signal bandwidth of the 10-band radiometer is 0.04 Hz～15.7KHz, the sampling period is 25μs, and data are digitized in 10bit. The image signal processor with its configuration shown as Fig. 5 has two functions:

- Rate buffer and form CHRPT information frame
- Depressing the resolution of image, correcting the geometrical distortion from scanning and forming GDPT information frame.

At the orbit altitude of 870km, the angle subtended by the earth is 123.25°. Considering that the ground resolution of image drops notably while viewing the earth edge, only the part of scene information of ± 55.4° is digitized. The data are stored in the RAM in the way of quickly storing and slowly reading. The data read from the RAM are expanded to 332.4° on the time axis to make information rate compressed by three times. The synchronous code, time code, attitude code and reference blackbody signal for radiation correction will be inserted in the remaining 27.6°, and the information format of CHRPT with a rate of 1.3308 Mbps is formed finally. Each frame of image signal consists of 22180 words and its format is shown in Fig. 6.

Although the CHRPT image signal is still transmitted in the S-band, the rate of CHRPT image signal is double of that of the HRPT signal of NOAA satellite. The current ground stations for NOAA satellite should be improved so as to receive the real-time image data sent from the Chinese FY-1C Meteorological Satellite.

In order to get world cloud image and let the record volume not be too large, we process the image signals of bands 1,2,4,6 in the way of picking up one from each three scan line data. Then the scan line data of both sides between ± 55.4° of nadir are divided into 11 sections, written in RAM

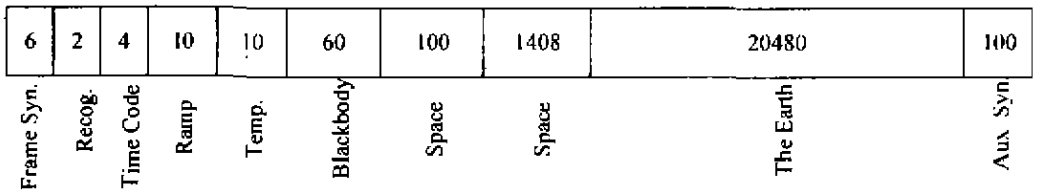

Fig. 6 The format of image signal
图 6 图像信号格式

at different speed and read out at the same speed to correct the geometrical distortion from scan. The average resolution is 3. 1km and signal output speed is 88. 72Kbps.

7 Performance of the Radiometer in Orbit

The FY-1C satellite was launched into the predetermined orbit at 09 : 33 a. m., Beijing Time, on May 10th, 1999. The scanning radiometer began to work at 11 : 16 a. m., the ground station received the real-time image signal of four visible bands, two N-IR bands and one SW-IR band from the satellite at once. The radiant cooler began to work on June 9th after the heating for outgassing for about one month. On June 10th, the temperature of the cooler's patch reached 105K, three infrared bands were switched on and image signals of ten bands of the scanning radiometer were transmitted. The image data of FY-1C satellite are being applied in weather forecast, flood monitoring, forest fire monitoring, vegetation index estimation, observation of ocean chlorophyll, monitoring of the global weather and ocean temperature, etc. It has worked normally for more than one year. The main specifications of the 10-band scanning radiometer are shown in Table 2.

Fig. 7 The first cloud image taken from FY-1C meteorological satellite
图 7　FY-1C 气象卫星第一张云图

Figure 7 is the first cloud image of FY-1C meteorological satellite and Fig. 8 is the first IR cloud image of FY-1C meteorological satellite. We hope that the FY-1C meteorological satellite can work normally and reach its expected lifetime of two years.

Fig. 8 The first IR cloud image taken from FY-1C meteorological satellite
图 8　FY-1C 气象卫星第一张红外云图

Table 2 The main specifications of the 10-band scanning radiometer
表 2　10 通道扫描辐射计的主要特性

Parameter	Measured Specification
Number of detecting bands	10
IFOV	1. 26mr
Ground resolution of image	1. 1km
Detector	Si, PV-HgCdTe, PC-HgCdTe
Cooler	Radiant cooler, 105K
Detection sensitivity	$NE\Delta\rho \leq 3 \times 10^{-4}$ (Bands1, 2, 7, 8, 9, 10) $NE\Delta\rho \leq 1 \times 10^{-3}$ (Band 6) $NE\Delta T \leq 0.27K$ (Bands 3, 4, 5)
Optical aperture	φ200mm
Scanning rate	360rpm
Data quantization	10bit
Data rate	1. 3308Mbps
Weight	53kg
Power consumption	44W

REFERENCES

[1]KUANG Din-Bo, GONG Hui-Xing, ZHENG Qin-Bo. Very high resolution scanning radiometer on FY-1 meteorological satellite and its operation performance in orbit, *Proc. of the 11th Asian Conference on Remote Sensing*., 1990, Vol. 1, p. E-8-1

[2]GONG Hui-Xing, ZHENG Qin-Bo, WANG Wei-Yang. The improvement of the detecting property and the performance of the very high resolution scanning radiometer on "FY-1B" meteorological satellite, *Advances in the Astronautical Sciences*, 1991, **77**: 493—503

[3]GONG Hui-Xing, WEI Jun, ZHENG Qin-Bo, *et al*. 10-channel scanning radiometer of meteorological satellite, *Proc. of the First Conference on Space Technology and Developing Countries*., 1995, p. 174

[4]Larry Owens, Donald Ceckowski, Alan J Ames. Characteristics of the AVHRR/3 and HIRS/3 for NOAA-K, L, M. *Proc. Fourth Conference on Satellite Meteorology and Oceanography*, 1989, p. 183～186