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PREFLIGHT CALIBRATION OF HY-1 SATELLITE 4-BAND CCD CAMERA

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ABSTRACT: HY-1 satellite is China's first ocean observation satellite. HY-1 is equipped with a 10-band IR ocean color scanner and a 4-band CCD camera, which will be launched in late 2001. CCD camera is an important payload on board HY-1. CCD camera has four bands from 420nm to 890nm. Its ground pixel resolution is 250m and scan swath is 500Km. This paper presents the preflight radiometric calibration of HY-1 satellite 4-band CCD camera. The preflight calibration using an integrating sphere and its instruments and the radiometric calibration using the spaceborne calibration unit in the laboratory are described. The results of the calibration are presented and discussed.

1. INTRODUCTION

HY-1 satellite, developed by Chinese Academy of Space Technology (CAST), is China's first ocean observation satellite and the second small satellite based on CAST968 bus (the first one is SJ-5). HY-1 is mainly used for exploiting oceanic resources and mitigating oceanic disasters. HY-1 satellite has the weight of about 365kg and will be operated for the lifetime over 2 years on the 798-km sun-synchronous orbit with inclination 988, and orbit revisit time of 7 days. The NOAA and SeaWiFS satellite have provided a lot of remote sensing information of the coastal area and nearby seas. Later HY-1 Satellite will also provide similar information with higher resolution.

2. INSTRUMENT DESCRIPTION

CCD camera is an important payload on board HY-1. CCD camera has four bands from 420nm to 890nm. Each band has 2048 detectors and 12-bit AD conversion. Its ground pixel resolution is 250m and scan swath is 500Km. Table 1 shows the performance specifications of the center wavelength, bandwidth and maximum radiance of CCD camera. Figure 1 shows the 4-band CCD camera of HY-1 satellite. Figure 2 shows the actual spectral response of band1-band4.

Table 1. The Performance Specifications of the Center Wavelength, Band width and Maximum Radiance

Band	Central Wavelength (nm)	Band Width (nm)	Maximum Radiance ($W/m^2 \cdot \mu m \cdot sr$)
1	460	80	132.4
2	560	80	234.5
3	650	80	145.0
4	825	130	133.5

3. PREFLIGHT CALIBRATION

The radiometric calibration plays an important role in the quantitative interpretation. Generally, remote sensor should be calibrated before launch on the ground, and after launch in orbit. The comparison of radiometric calibration of several typical remote sensors is shown in Table 2.

3.1 Integrating Sphere

We developed a high accuracy integrating sphere for the preflight calibration of HY-1 CCD camera. The integrating sphere is a large internally illuminated integrating sphere with an inner diameter of 1.6m and an aperture of 300mm, which supplies radiance necessary for preflight calibration of the CCD camera in the spectral range from 400nm to 2500nm. The integrating sphere has 24 halogen lamps of 150W operated at stabilizing DC power supply. Generally,

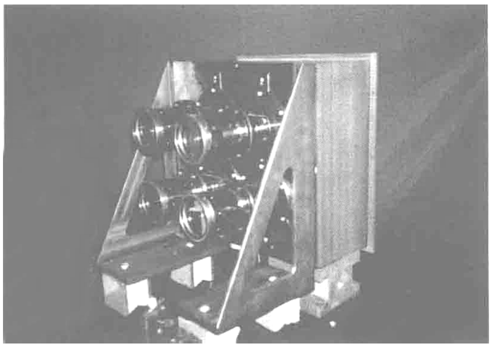


Figure 1. 4-Band CCD Camera of HY-1 Satellite

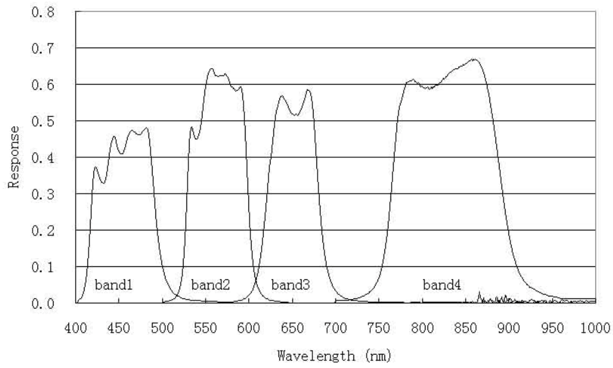


Figure 2. Actual Spectral Response of Band1-Band4

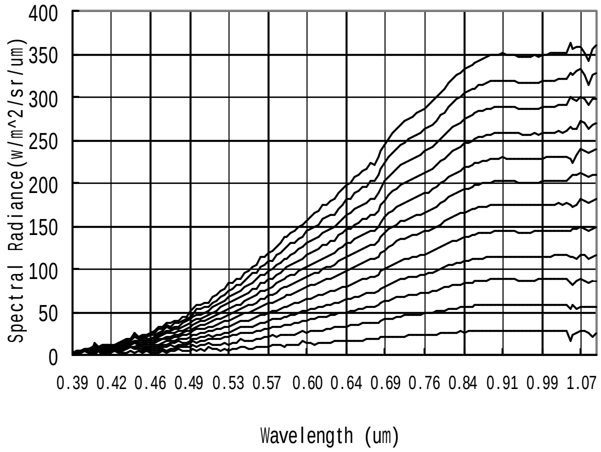


Figure 3. 12 Levels of Spectral Radiance Of Integrating Sphere

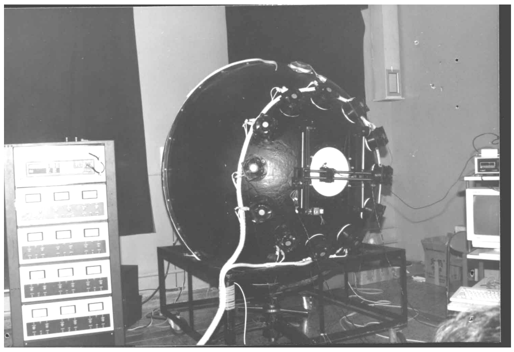


Figure 4. Photograph of the Large Integrating Sphere

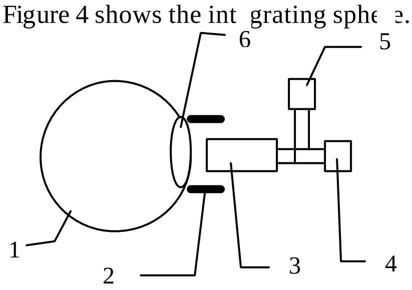
Table 2 Comparison of Radiometric Calibration of Several Typical Remote Sensors (Zhang Yufeng, 1999)

Remote sensor	Spaceborne relative calibration	Preflight calibration	In-flight ground field calibration
CBERS-CCD	halogen lamp	integrating sphere	Gobi
CBERS-IRMSS	halogen lamp	integrating sphere, blackbody	Gobi
ZY-2	halogen lamp	integrating sphere	Gobi
HY-1 CCD	light bar	integrating sphere	Gobi
SPOT1-4-HRV	halogen lamp	integrating sphere	La Crau? White Sands
Landsat 4-6-TM	halogen lamp	integrating sphere, blackbody	La Crau? White Sands

the color temperature is 2800K, and it is adjustable. The 24 lamps are divided into 12 groups (2 symmetrical lamps per group) to give 12 levels of radiance. Each group of lamps can be switched on/off individually. The non-uniformity of the spectral radiance over the aperture is very small, less than 2 percent. This enables to calibrate all the detectors of each band at the same time.

The primacy standard is the spectral radiance standard lamp of the National Institute of Metrology (NIM). The radiance is transferred to a small integrating sphere, then to a laboratory Spectroradiometer, and at last to the large integrating sphere (Fumihiro SAKUMA, 1991).

Figure 3 shows the 12 levels of spectral radiance. It is illustrated that the linearity of the 12 levels of spectral radiance is good. Figure 4 shows the int grating sphe e.



1. integrating sphere 2. diaphragm
3. CCD camera
4. driver and special device
5. oscillograph 6. aperture

Figure.5 Experimental Apparatus of Preflight Calibration Using An Integrating Sphere

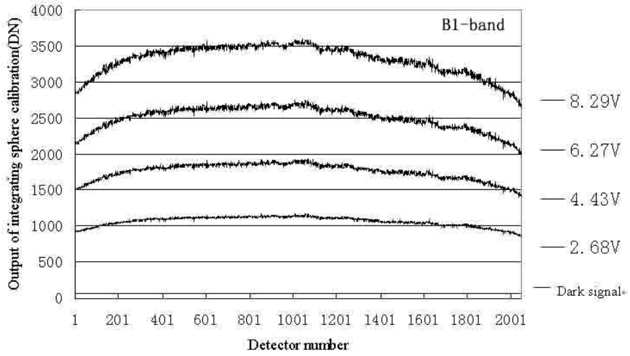


Figure.6 B1-band Output of Integrating Sphere Calibration

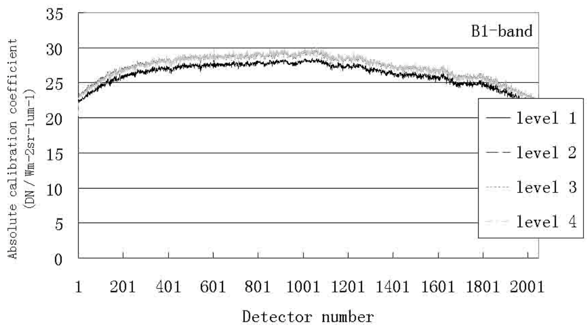


Figure.7 B1-band Absolute Calibration Coefficient of 4-level Radiance

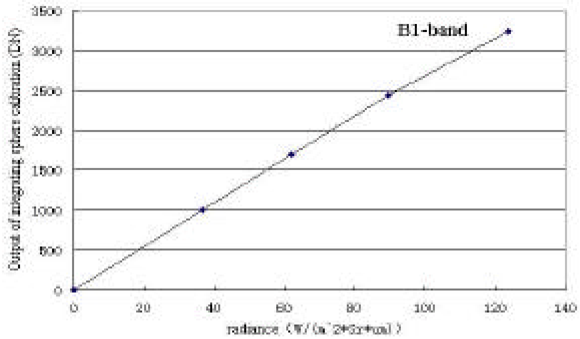


Figure.8 Linearity of Sensitivity of B1-band

Table 3 B1-band Data of Integrating Sphere Calibration

Output Voltage (V)	Spectral Radiance (W/(M^2*STR*μm))
8.29	123.73
6.27	89.49
4.43	62.08
2.68	36.69

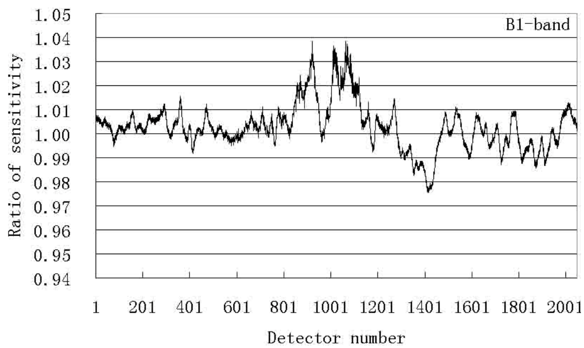
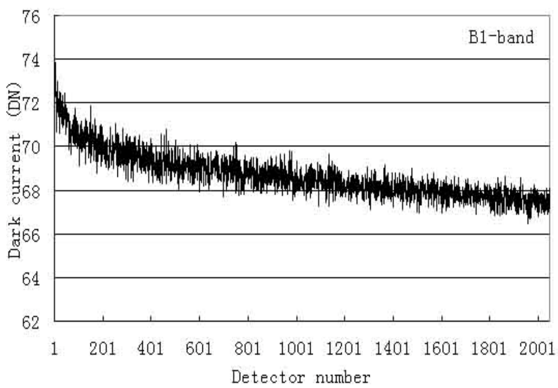


Figure.9 Ratio of Sensitivity (Calibration Data Set Date 29.5.01/20.12.00)



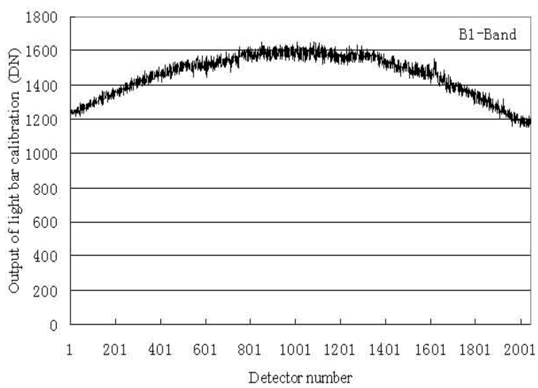


Figure.10 B1-band Dark Current

Figure.11 B1-band Output of internal calibration using a light bar

3.2 Preflight Calibration Using Integrating Sphere

Experimental apparatus of preflight calibration of the CCD camera using an integrating sphere is shown in Figure 5. The CCD camera was calibrated against the large integrating sphere before launch on the ground. The radiance of the integrating sphere in the spectral bandpass of the CCD camera is given by

$$L_k = \frac{\int_0^{\infty} L(l) \cdot S_k(l) \cdot dl}{\int_0^{\infty} S_k(l) \cdot dl} \tag{1}$$

Where:

L_k: average spectral radiance (μW/cm^2·str·nm) across the CCD camera bandpass for particular integrating sphere level

$L(\lambda)$: spectral radiance (μW/cm^2·str·nm) of integrating sphere at λ

$S_k(\lambda)$: relative spectral response at λ for CCD camera

Define the absolute calibration coefficient as equation (2).

$$A_k = X_k/(G_m L_k) \tag{2}$$

Where:

X_k: average DN after excluding the dark signal

A_k: absolute calibration coefficient (DN/μW/cm^2·str·nm)

G_m: gain

L_k: average spectral radiance (μW/cm^2·str·nm)

k: band serial number (1,2,3,4 for HY-1 CCD camera)

It is shown from equation (2) that the absolute calibration coefficient A_k and the X_k are relative to average spectral radiance L_k.

Figure 6 – Figure 10 show the results of the calibration of B1-band of CCD camera in the preflight calibration. It is illustrated that the sensitivity linearity of B1-band is good. Table 3 shows the spectral radiances of B1-band corresponding to every output voltage. Table 4 shows the spectral radiances of B2, B3, B4-band corresponding to every output voltage. Table 5 shows the absolute calibration coefficient of 4-band camera.

Table 4 Spectral Radiances of B2, B3, B4-band Corresponding to Every Output Voltage

B2-band		B3-band		B4-band	
Output Voltage(V)	Spectral Radiance (W/(M^2*STR*μm))	Output Voltage(V)	Spectral Radiance (W/(M^2*STR*μm))	Output Voltage(V)	Spectral Radiance (W/(M^2*STR*μm))
8.46	260.92	8.43	152.23	8.46	134.01
6.59	212.20	6.63	118.06	6.48	100.84
4.57	150.27	4.54	80.47	4.47	68.82
2.58	90.72	2.48	42.95	2.40	35.49

Table 5 Absolute Calibration Coefficient of 4-band Camera

Band	B1	B2	B3	B4
Absolute calibration coefficient A_k (DN/ Wm^{-2}sr^{-1}μm^{-1})	26.3742	12.8864	22.0562	24.9567

3.3 Preflight Calibration Using the Spaceborne Calibration Unit

The 4-band CCD camera has also in-flight calibration using the spaceborne calibration unit. A new spaceborne calibration unit that uses light bar (LED arrays) as radiometric calibration source is designed after a lot of calculation and experiments. The characters of this kind of radiometric calibration source have been measured. The results indicate that the light bar can be used as spaceborne radiometric calibration source in small satellite's remote sensor. Four kinds of light bars have been selected to match with the four bands of the 4-band CCD camera. Two light bars are used as calibration sources for each band(as shown in Figure 12). The dimension of light bar is 20×5×6mm. The total weight of eight light bars is 100 grams, and the power consumption is less than 4.48W. The calibration unit has the characters of small volume, light weight, low power consumption. Figure.11 shows the output signal of B1- band of CCD camera in the internal calibration using the spaceborne calibration unit in the laboratory.

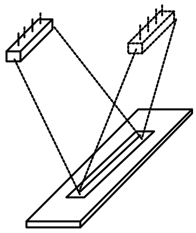


Figure.12 Schematic drawing of the spaceborne radiometric calibration unit

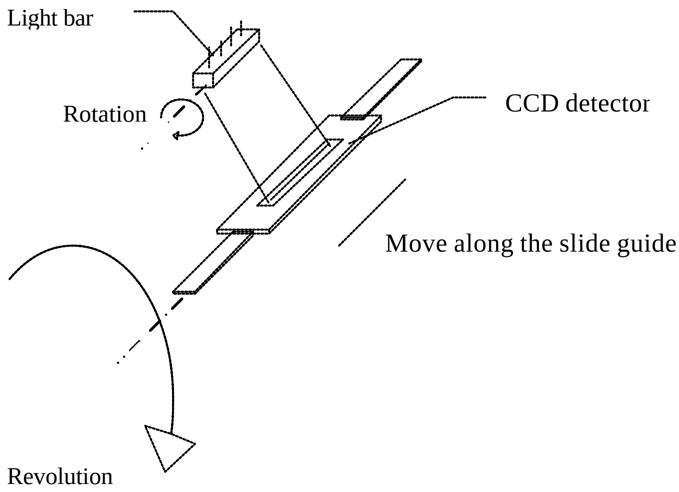


Figure 13 Experimental method of the uniformity test of irradiance in the focal plane

It is essential to accurate calibration that the uniformity of irradiance in the focal plane of the spaceborne optical remote sensor is exactly measured during the calibration. In the measurement of the laboratory, the spaceborne conditions should be simulated, and the instrument and method should be selected according to the objects under test. The measuring method is shown as Figure 13. The relative position between light bar and CCD detector may be adjusted as Figure 13 shown. Thus, the uniformity of irradiance in the focal plane may be accurately measured according to the relative position between spaceborne calibration system and focal plane.

4. SUMMARY

The results of the preflight calibration of HY-1 satellite 4-band CCD camera have initially been applied in quantitative analysis of the data. The spaceborne calibration unit using semiconductor light bar meets the requirement of preflight calibration in the laboratory. Other performance of the spaceborne calibration unit will be tested in-flight calibration.

The further research on radiometric calibration of HY-1 satellite 4-band CCD camera, such as in-flight, radiometric field calibration, calibration precision, will be continued.

5. ACKNOWLEDGMENT

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