DEVELOPMENT OF A FIELD RADIOMETER
AS A GROUND TRUTH EQUIPMENT FOR THE JAPANESE ERS-1

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ABSTRACT

A new field radiometer has been developed to provide ground truth data for the optical sensor of the Japanese ERS-1 (Earth Resources Satellite), which is scheduled to be launched in 1992. This radiometer has two motor-driven filter wheels, each of which can contain up to eight filters and corresponds to the silicon and lead-sulphide detectors respectively. The same field of view exactly is guaranteed to all the spectral bands, because only one aperture is used to observe a target. It takes approximately twenty seconds to perform one continuons measurement for the seven spectral bands equivalent to the ERS-1 sensor. A portable lap-top computer controls the radiometer and records measured results on a floppy disc. An officially-calibrated lamp and a standard reflection plate mounted on an optical bench were also prepared for the purpose of absolute energy calibration of the radiometer. Preliminary investigation has shown that this newly developed radiometer can provide reliable spectral data.

1. INTPODUCTION

The Japanese ERS-1 (Earth Resources Satellite) is scheduled to be launched in 1992 and will be equipped with both an eight-band optical sensor and an L-band SAR (Technology Research Association of Resources Remote Sensing System, 1986). The optical sensor has four bands in the visible to near-infrared (VNIR; 0.4-1.1 um) region and four bands in the short-wavelength-infrared (SWIR; 1.1-2.5 um) region respectively (Teble 1). The VNIR bands have the similar bandpasses to those of the Landsat TM. The bands 3 and 4 are selected for stereoscopic imaging along the nadir track of the satellite. The SWIR bands are particularly of interest to geologists because of their expected capability to discriminate among some lithologic units.

Yamaguchi (1987, 1988) has already discussed possible data processing techniques for lithologic and vegetation discrimination using the optical sensor data of the ERS-1. His discussions based upon reflectance data obtained by the

718

high-resolution spectroradiometer prior to actual measurements by the satellite sensor, because the sensor is currently being manufactured. The reflectance spectra with spectral resolution of 2 nm in the 0.35-1.0 um region and 4 nm in the 1.0-2.5 um region were convolved into hypothetical sensor responses. However, spectral measurements by such a spectroradiomter as well as the subsequent convolution process are somewhat time consuming and are not an efficient way to get enough sensor responses for statistical investigation. Instead, a field radiometer with the same bandpasses as the ERS-1 sensor should greatly help evaluate capability of the satellite sensor prior to its operation.

After the satellite becomes operational, the field radiometer will be able to provide ground truth data in various applications. In some data processing concepts, ground reflectance measurements are indispensable for "reflectance calibration" of images (e.g., Elvidge and Lyon, 1985; Roberts et al., 1987). If we can assume a linear nature between the recorded digital numbers in a magnetic tape and ground reflectance, it is easy to convert the digital numbers into reflectance using field targets with enough spatial distribution (Marsh and Lyon, 1980). Kepper et al. (1986) reported that the reflectance calibrated image was composed of fewer image units than an uncalibrated image and these units corresponded more closely to the mapped geologic formations. Some field radiometers have already been developed as ground truth tools for the Landsat sensors, but some modifications have been desired in their specifications. For these reasons, we have developed a new field radiometer for the ERS-1 optical sensor.

2. SPECIFICATION OF THE NEW RADIOMETER

There are some user requirements for a field radiometer. First of all, it has to be portable, i.e., it has to be operated in field by batteries and its weight should not be too great. The newly developed radiometer consists of the optical head and the battery unit as shown in Fig. 1. The radiometer can be operated by the DC 12V battery, which is rechargable from AC 100V or 200V power supply and lasts about 3.5 hours in case of continuous measurements. Voltage of the battery can be checked by the analog-meter on the battery unit. A lap-top personal computer (NEC PC-98LT) is used for control of the radiometer and can work about 4 hours in field with its internal battery. As the total weight of the radiometer including the battery unit and the computer is about 15 kilograms, two persons are needed to carry and operate it in field.

This radiometer has two filter wheels in the optical head as shown in Fig. 2. Each wheel can contain up to eight interference filters and corresponds to the silicon and lead-sulphide detectors respectively. Therefore, up to eight spectral bands in the VNIR region and another eight bands in the SWIR region are available. At present , three filters in the VNIR region and four filters in the SWIR region whose bandpasses are similar to those of the ERS-1 optical sensor

(Fig. 3) have been installed. The filter wheels are automatically rotated by pulse motors in order to accomplish shorter measurement time. During field operations, illumination conditions are always changing. Thus, the shorter the time necessary for a measurement, the less influence from fluctuations of illumination conditions. It takes about twenty seconds to perform one continuous measurement for the seven spectral bands.

Other requirements for a field equipment are easy operation and a reliable recording medium. It is also desired that a measured result can be checked immediately in field. Otherwise, we can not recognize a failure of measurements until returning to a laboratory from a field survey. For these reasons, it was decided to use a lap-top personal computer for control of the radiometer. The optical head is connected to the computer through the battery unit by RS232C interface (Fig. 1). We can easily operate the radiometer using the computer keyboard and can check the result immediately on the liquid-crystal display. Measured data can be recorded on a 3.5-inch floppy disc.

An important advantage of this radiometer is that there is only one observation aperture in the optical head. Generally speaking, geologic targets such as surface rocks or soils are quite inhomogeneous even within a field of view of a radiometer. Thus, it is important to carry out a spectral measurement in the same filed of view exactly for the different spectral bands when we discuss a spectral response pattern of a particular target. Many of the previously developed radiometers measure a target with different fields of view using multiple apertures. If there is significant inhomogeneity in the target, such systems might cause a problem that each spectral band measures different areas with different spectral properties. In order to avoid it, the optical head of the newly developed radiometer has only one objective aperture (Fig. 2) as to guarantee the same field of view to all the spectral bands. The field of view can be checked through the sighting telescope. When we start a measurement, the light path to the telescope is closed automatically and the incident ray is directed to the filters. The radiometer also has four different types of irises as shown in Table 2. The most appropriate iris for the measurement is chosen by rotating the iris wheel.

3. CALIBRATION USING A STANDARD LAMP ON AN OPTICAL BENCH

An optical bench (Fig. 4) has been prepared for the purpose of performing absolute energy calibration of the radiometer. An officially-calibrated illumination lamp is mounted on the optical bench, a distance of fifty centimeters from a standard reflection plate (Fig. 5). This is the same material as the reference plate being used in field measurements, i.e., an aluminum plate with thin coating of barium-sulphate on the surface.

Using this optical bench, we can easily get calibration factors to convert readings obtained by the radiometer into absolute energy values. Calibration factors are stored on a

floppy disc as a data file and are called when energy conversion is required. An integrating sphere with barium-sulphate coating on its internal surface is also prepared. It will be possible to monitor irradiance from the sun using the calibration factors and the integrating sphere equipped at the objective aperture of the radiometer. This capability will allow us to evaluate the satellite data and correct atmospheric effects after the satellite sensor becomes operational.

4. RELIABILITY OF THE RADIOMETER IN SPECTRAL MEASUREMENTS

Some measurements have been carried out as a test of the radiometer. Firstly, the repeatability of measurements and the effect of temperature were examined by changing the temperature at 0, 25, and 40 degrees celcius. The dark current did not exceed 0 ± 1 percent of readings in any cases. It was also shown that the fluctuation of the measurements was not more than two percent of the readings when measured over the white reference plate in any cases of the three temperatures tested.

Next, reliability of the radiometer was tested by comparing the measurement results to the spectra obtained by the high-resolution spectroradiometer over the same targets. Fig. 6 shows the typical reflectance spectrum of kaolinite; an important clay mineral in hydrothermally-altered areas. This spectrum was then convolved into the hypothetical response pattern through the filters installed in the radiometer by multiplying the filter transmittance curves (Fig.3). The same target was also measured by the radiometer. As shown in Table 3, these two response patterns coincided sufficiently well. Namely, kaolinite shows high response except the bands 7 and 8 in the SWIR region because of the characteristic absorption at 2.2 um due to the existence of hydroxyl. Many other measurements have also shown good coincidence between the response patterns obtained by these two methods. Consequently, it can be concluded that the newly developed radiometer would provide reliable spectral data as the ground truth to the ERS-1 optical sensor.

5. CONCLUSION

A new field radiometer has been developed as a ground truth equipment for the optical sensor of the Japanese ERS-1. As a result of the preliminary investigation, it has been shown that the radiometer worked sufficiently well with enough reliability in spectral measurements. It will be possible to get enough sensor response patterns for statistical investigation of the ERS-1 sensor prior to its launching. After the satellite becomes operational, this radiometer will be used to collect ground truth data in various applications.

The filter wheels in the radiometer can contain up to sixteen filters, more than the seven spectral bands of the ERS-1 sensor. So, such usage as identification of clay minerals using filters with the specific bandpasses in the SWIR region might be possible in future. This is another possible

application of the radiometer as a field tool for exploration geology (e.g., Gladwell at al., 1983).

6. REFERENCES

Elvidge, C.D. and Lyon, R.J.P., 1985, Influenece of rock-soil spectral variation on the assessment of green biomass. Remote Sensing of Environment, v.17, p.265-279.

Gladwell, D.R., Lett, R.E. and Lawrence, P., 1983, Application of reflectance spectrometry to mineral exploration using portable radiometers. Economic Geology, v.78, p.699-710.

Kepper, J.C., Lugaski, T.P. and MacDonald, J.S., 1986, Discrimination of lithologic units, alteration patterns and major structural blocks in the Tonopah, Nevada area using Thematic Mapper data. In Proc. Fifth Thematic Conf. on Remote Sensing for Exploration Geology, Environmental Research Institute of Michigan, Ann Arbor, MI, p.97-115.

Marsh, S.E. and Lyon, R.J.P., 1980, Quantitative relationships of near-surface spectra to Landsat radiometric data. Remote Sensing of Environment, v.10, p.241-261.

Roberts, D.A., Yamaguchi, Y. and Lyon, R.J.P., 1987, Comparison of various techniques for calibration of AIS data. In Proc. of the Second Airborne Imaging Spectrometer Data Analysis Workshop, Jet Propulsion Laboratory, Pasadena, CA, p.21-30.

Technology Research Association of Resources Remote Sensing system, 1986, RRSS News, n.2, p.1 (in Japanese).

Yamaguchi, Y., 1987, Possible techniques for lithologic discrimination using the short-wavelength-infrared bands of the Japanese ERS-1. Remote Sensing of Environment, v.23, p.117-129.

Yamaguchi, Y., 1988, Spectral indices for vegetation and rock type discrimination using the optical sensor of the Japanese ERS-1. In Proc. Sixth Thematic Conf. on Remote Sensing for Exploration Geology, Environmental Research Institute of Michigan, Ann Arbor, MI, in press.

TABLE 1   Bandpasses of the optical sensor of the ERS-1

Band	Bandcenter (nm)	Bandwidth (nm)	
1	560	80	
2	660	60	
3	810	100	stereo
4	810	100	stereo
5	1650	110	
6	2060	110	
7	2190	120	
8	2340	130	

TABLE 2   Shape and size of the irises in the radiometer

Iris no.	shape	size(mm)	FOV
1	square	8 x 8	$4.6°$
2	square	4 x 4	$2.3°$
3	square	2 x 2	$1.15°$
4	circle	ϕ 1.5	$0.86°$
5	rectangle	1.5 x 8	$0.86 \times 4.6°$
6	(closed)	–	–

TABLE 3   Comparison of the responses to kaolinite powder whose reflectance spectrum is shown in Fig. 6. Notice that these measurement results coincide well each other.
(a) Measurement results by the new field radiometer. An average of ten measurements.
(b) Hypothetical responses convolved from the reflectance data obtained by the high-resolution spectroradiometer. An average of four spectra.

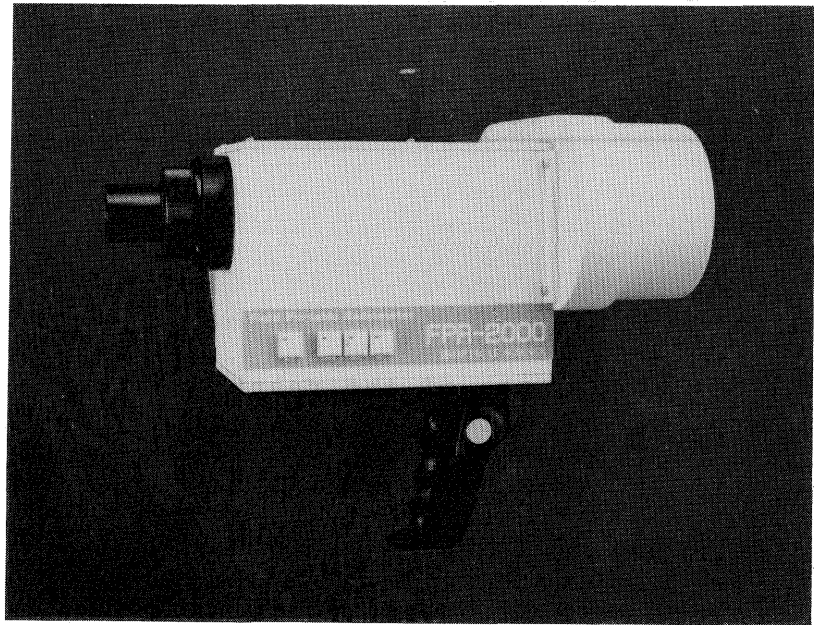|	Band 1	Band 2	Band 3	Band 5	Band 6	Band 7	Band 8
(a)	79.99	86.00	86.78	89.39	79.92	54.34	54.59
(b)	82.27	88.02	91.60	95.03	83.00	54.04	56.10

Figure 1 (1) A field unit of the radiometer. An optical head
on the tripod, a battery unit (left) and a lap-top
computer (bottom right) with a printer (bottom
left).
(2) The optical head of the radiometer. The
observation aperture on the left and a viewer of
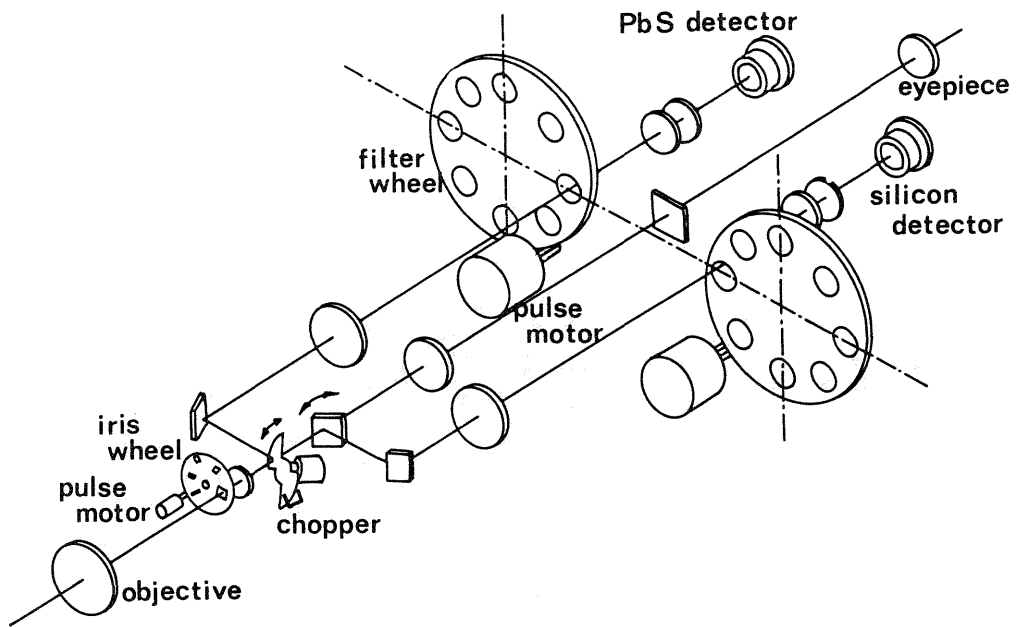the sighting telescope on the right.

Figure 2 The optical system in the optical head of the radiometer. Notice two filter wheels and the only one aperture for observation.
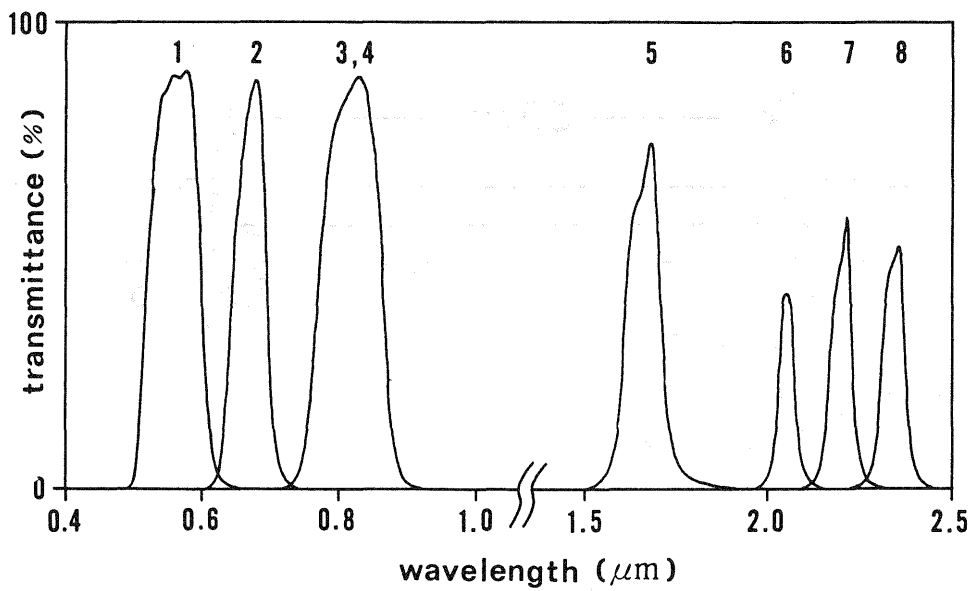
Figure 3 Transmittance curves of the filters installed.
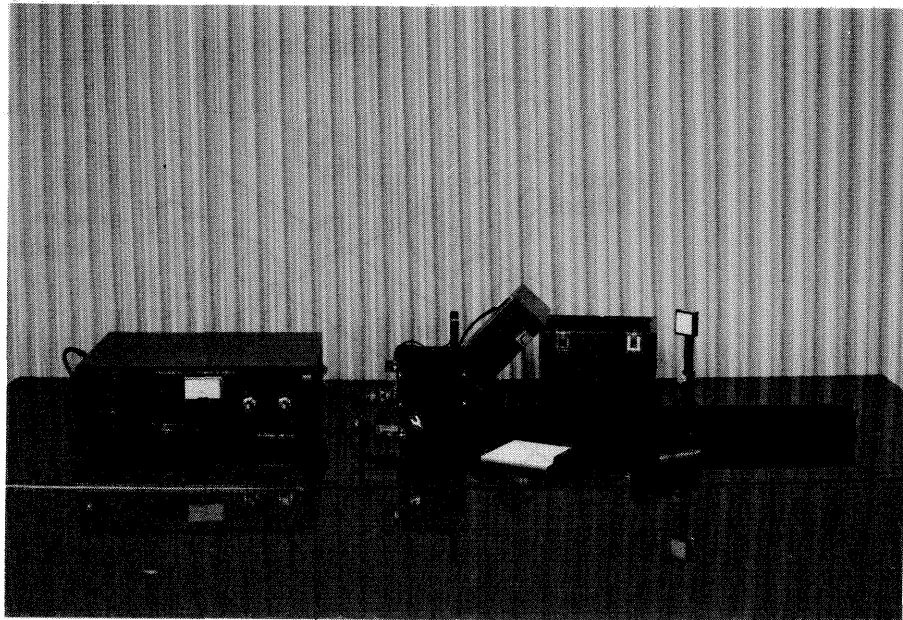
Figure 4   The optical bench for calibration of the radiometer.
            The stabilizing system of the power supply (left),
            the officially-calibrated illumination lamp
            (center), and the standard reflection plate (right).
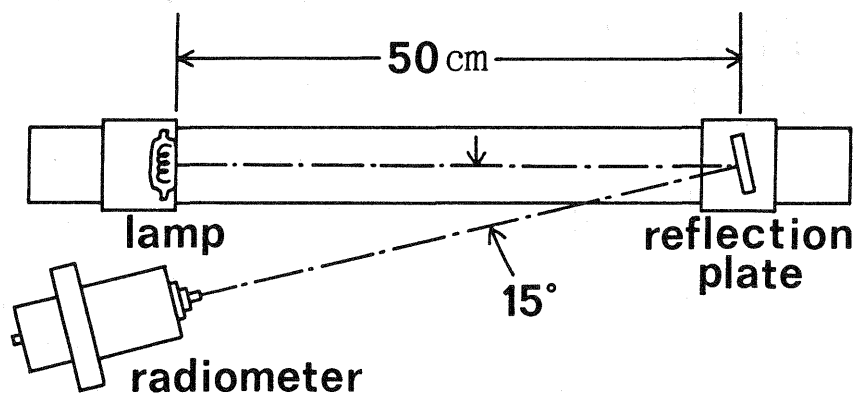

Figure 5   The arrangement for calibration of the radiometer
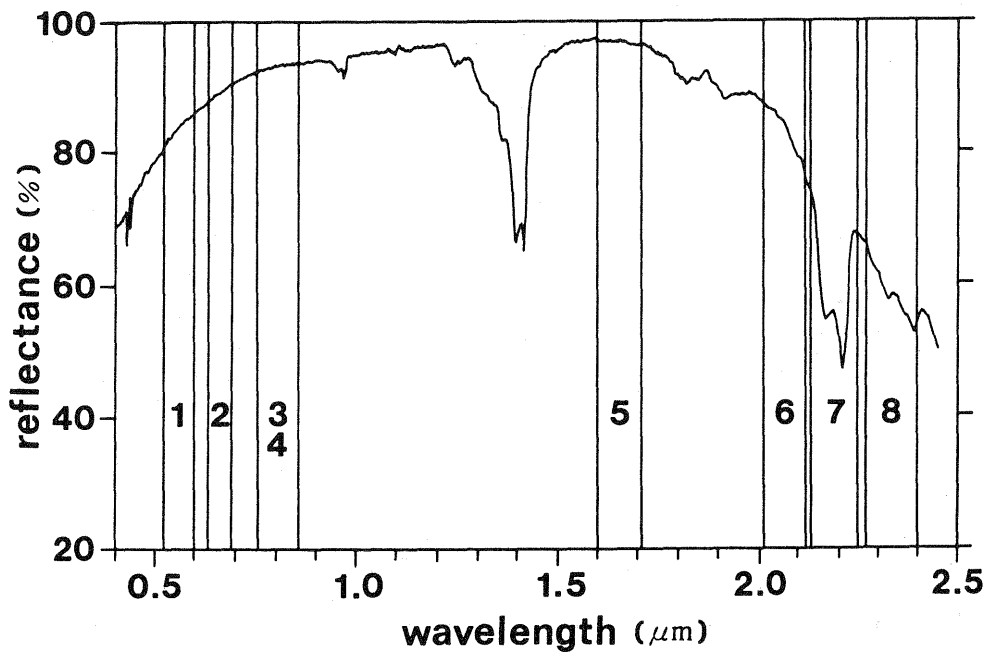   using the optical bench.

Figure 6   A reflectance spectrum of kaolinite powder obtained
by a high-resolution spectroradiometer and the
bandpasses of the ERS-1 shown in Table 1.