

RECOMMENDATION ITU-R RS.1804*

Technical and operational characteristics of Earth exploration-satellite service (EESS) systems operating above 3 000 GHz

(Question ITU-R 235/7)

(2007)

Scope

Instruments have been operating on EESS systems at frequencies above 3 000 GHz for many years. The instruments are comprised of both active and passive devices, are deployed on geostationary orbit (GSO) and non-GSO systems, and utilize narrow-spectral lines as well as widebands. This recommendation summarizes the instruments, spacecraft, spectrum of interest and type of data collected using spectrum above 3 000 GHz.

The ITU Radiocommunication Assembly,

considering

- a) that observations at frequencies above 3 000 GHz provide data critical to the study of the characteristics of the Earth and its natural phenomena, including data relating to the state of the environment;
- b) that the technology for Earth exploration-satellite service (EESS) sensors operating above 3 000 GHz is continuously evolving to provide better accuracy and resolution of measurement data;
- c) that the spectrum above 3 000 GHz is used for active and passive sensor systems as well as for many telecommunication applications;
- d) that, as these systems are rapidly expanding and increasing in number, the likelihood of harmful interference between sensors in the EESS and other services operating above 3 000 GHz may increase;
- e) that the Earth-to-space laser radiation used by some optical ground stations to conduct precise satellite and lunar ranging and to measure atmospheric parameters represents a possible source of interference to, and may potentially damage, sensitive satellite passive sensors;
- f) that while there are significant differences between the technologies used in this part of the spectrum compared with lower frequencies (e.g. counting photons versus integrating power over time), there are also many similarities;
- g) that protective measures and sharing considerations have to be considered to ensure that EESS sensors can continue to operate at frequencies above 3 000 GHz without harmful interference,

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 1, 3, 4, 8 and 9.

recommends

- 1 that operators of EESS systems operating above 3 000 GHz should take into account the possibility of interference from transmitters of the science services (including those of EESS) in their selection of mission requirements and choices of sensor design;
- 2 that studies of interference to and from EESS systems operating above 3 000 GHz should take into account the technical and operational parameters provided in Annex 1.

Annex 1

1 Introduction

Instruments have been operating on EESS systems at frequencies above 3 000 GHz for many years. These instruments operate in several modes and provide a variety of types of data. The instruments are comprised of both active and passive devices, are deployed on GSO and non-GSO systems, and utilize narrow-spectral lines as well as widebands. The information contained in the following sections summarizes the instruments, spacecraft, spectrum of interest and type of data collected using spectrum above 3 000 GHz.

2 Instruments

The instruments to be described are categorized as the following: imagers, radiometers/spectrometers, or LIDAR altimeters. Imagers are instruments whose prime objective is to present two-dimensional representations of physical phenomena such as clouds or the Earth's surface. Radiometers/spectrometers are instruments which measure electromagnetic radiative flux. LIDAR altimeters are instruments which measure the height from the spacecraft to the surface directly underneath via pulses of light emissions.

2.1 Imaging technical characteristics

One of the earliest uses of the spectrum above 3 000 GHz for EESS applications is imaging the Earth's surface and cloud cover. More recently imaging systems have been used to gather data on the distribution and frequency of lightning. The three types of imaging systems described below are representative of the general capabilities of EESS systems performing imaging at frequencies above 3 000 GHz. A fourth system described below optically senses weather phenomena.

2.1.1 Multispectral cloud imaging

Systems A1 through A3 operate as a single instrument which collects imagery at 14 different wavelengths ranging from 0.5 to 12 μm . It is used for long-term cloud monitoring at spatial resolutions of 15 to 90 m depending on the wavelength measured. The instrument is divided into three separate systems each with its own telescope monitoring a different set of wavelengths. The systems' bands are:

- Visible/near infrared (VNIR) 0.50 to 0.90 μm (600 to 333 THz¹).
- Short-wave infrared (SWIR) 1.6 to 2.43 μm (187.5 to 123 THz).
- Thermal infrared (TIR) 8 to 12 μm (37.5 to 25 THz).

With its high-spatial resolution, broad spectral coverage, and stereo imaging capability, this instrument provides essential measurements of cloud amount, type, spatial distribution, morphology, and radiative properties. While many cloud imagery instruments measure similar parameter sets, the ability to observe with this high-spatial resolution provides data that can be directly related to detailed physical properties. Furthermore, in areas where no cloud cover is present, this instrument provides long-term monitoring of local and regional changes to the Earth's surface which either lead to, or are in response to, global climatic changes (e.g. land use, deforestation, desertification, lake and playa water-level changes and other changes in vegetation communities, glacial movement and volcanic processes). A summary of the technical parameters of this instrument is provided in Table 1.

TABLE 1
Technical parameters of multispectral cloud imaging systems

System	A1	A2	A3
Field of view (degrees)	6.09	4.9	4.9
Instantaneous field of view (μrad)	21.5	42.6	128
Wavelengths measured (μm)	0.52-0.60 0.63-0.69 0.76-0.86	1.60-1.70 2.145-2.185 2.185-2.225 2.235-2.285 2.295-2.365 2.360-2.430	8.125-8.475 8.475-8.825 8.925-9.275 10.25-10.95 10.95-11.65
Spatial resolution (m)	15	30	90
Data rate (Mbit/s)	62	23	4.2
Cross-track pointing (degrees)	± 24	± 8.55	± 8.55
Cross-track pointing (km)	± 318	± 116	± 116
Swath width (km)	60	60	60
Detector type	Silicon (Si)	Platinum Silicide-Silicon (PtSi-Si)	Mercury Cadmium Telluride (HgCdTe)
Quantization (bits)	8	8	12

¹ 1 THz = 1 000 GHz.

2.1.2 Multispectral imaging of the Earth's surface

Systems B1 through B5 operate together as a single instrument to collect imagery at seven narrow wavelengths ranging from 0.45 to 12.5 μm and one panchromatic range from 0.5 to 0.9 μm . It is used to characterize and monitor change in land-cover and land-surface processes. The high-spatial resolutions (15 to 60 m depending on wavelength range) and seasonal global coverage of this instrument will allow assessment of both the rates of land-cover change and the local processes responsible for those changes. Deforestation, ecosystem fragmentation, agricultural productivity, glacier dynamics, coastal hazards, and volcano monitoring are representative science targets for this instrument.

The instrument conducts its measurements through a single aperture in four bands:

- Visible (VIS) 0.45 to 0.69 μm (667 to 435 THz).
- Near infrared (NIR) 0.76 to 0.90 μm (395 to 333 THz).
- SWIR 1.55 to 2.35 μm (194 to 128 THz).
- TIR 10.42 to 12.5 μm (28.8 to 24 THz).

System B6 is a visible and near-infrared radiometer for observing land and coastal zones. It is used to provide land coverage maps and land-use classification maps for monitoring regional environment. The instrument has a cross-track pointing capability for disaster monitoring.

System B7 is a panchromatic radiometer with 2.5 m spatial resolution. In order to obtain terrain data including elevation, this instrument has three optical systems for forward, nadir, and backward views. The instrument provides precise geographical information suitable to create 1/25 000 scale global maps.

A summary of the technical parameters of these systems is provided in Table 2.

TABLE 2
Technical parameters of multispectral imaging of the Earth's surface

System	B1	B2	B3	B4	B5	B6	B7
Instantaneous field of view (μrad)	42.5	42.5	42.5 × 39.4	42.5 × 85.0	21.25 × 18.5	14.28	3.57
Wavelengths measured (μm)	0.45-0.52 0.52-0.60 0.63-0.69	0.76-0.90	1.55-1.75 2.08-2.35	10.42-12.50	0.50-0.90	0.45-0.50 0.52-0.60 0.61-0.69 0.76-0.89	0.52-0.77
Spatial resolution (m)	30	30	30	60	15	10	2.5
Data rate	Data merged into 150 Mbit/s data stream					160 Mbit/s (after data compression: 120 Mbit/s)	320 Mbit/s × 3 telescopes = 960 Mbit/s (after data compression: 240 Mbit/s, 120 Mbit/s)
Swath width	185 km (±7.5°). Each image frame represents a 170 km increment along the satellite track					70 km	Up to 70 km
Detectors per band	16	16	16	8	32	7 000	40 000

2.1.3 Hyperspectral imaging

This instrument works in a similar manner as multispectral imagers; however, hyperspectral analysis utilizes contiguous spectral channels, allowing the use of derivatives and sophisticated analysis techniques. A much larger number of bands allows more complex systems to be addressed without the under-sampling inherent in multispectral systems. Hyperspectral imaging has wide ranging applications in mining, geology, forestry, agriculture, and environmental management.

The System C hyperspectral imager utilizes 220 bands over a spectral range, 0.4 to 2.5 μm (from 750 to 120 THz). Detailed classification of land assets through System C will enable more accurate remote mineral exploration, better predictions of crop yield, and assessments, and better containment mapping.

A summary of the technical parameters of this system is provided in Table 3.

TABLE 3

Technical parameters of a hyperspectral imaging system

System	C
Instantaneous field of view (μrad)	43
Wavelengths measured (μm)	0.4 to 2.5 (contiguous across 220 bands)
Spatial resolution (m)	30
Data rate	250-500 MB over 8-12 second collection periods
Image size (km^2)	7.6×100
Detectors per band	1 (220 individual detectors)

2.1.4 Lightning sensing

System D investigates the global incidence of lightning, its correlation with convective rainfall, and its relationship with the global electric circuit. This instrument consists of a staring imager that is optimized to locate and detect lightning with storm-scale resolution (from 4 to 7 km) over a large region ($600 \times 600 \text{ km}$) of the Earth's surface. The system can monitor individual storms in its field of view for 80 s, long enough to estimate the lightning flash rate. A combination of four methods is used to extract lightning data from the surrounding image. These methods require the ability to separate spatial, temporal and spectral details from consecutive image frames in order to identify lightning signatures from other emissions. Temporal filtering is required to confirm the duration of the emission is approximately that of a lightning flash (typically $\sim 400 \mu\text{s}$). Spectral filtering is required to confirm the presence of energy at the strong OI(1) emission multiplet in the lightning spectrum $0.7774 \mu\text{m}$ (385.9 THz). Spatial filtering is then required to identify the location of the lightning flash.