|  |
| --- |
| **Recommendation ITU-R RS.2064-0**  **(12/2014)** |
| **Typical technical and operating characteristics and frequency bands used  by space research service (passive) planetary observation systems** |
| **RS Series**  **Remote sensing systems** |

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

# Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU‑T/ITU‑R/ISO/IEC and the ITU-R patent information database can also be found.

|  |  |
| --- | --- |
| Series of ITU-R Recommendations  (Also available online at <http://www.itu.int/publ/R-REC/en>) | |
| **Series** | Title |
| **BO** | Satellite delivery |
| **BR** | Recording for production, archival and play-out; film for television |
| **BS** | Broadcasting service (sound) |
| **BT** | Broadcasting service (television) |
| **F** | Fixed service |
| **M** | Mobile, radiodetermination, amateur and related satellite services |
| **P** | Radiowave propagation |
| **RA** | Radio astronomy |
| RS | Remote sensing systems |
| **S** | Fixed-satellite service |
| **SA** | Space applications and meteorology |
| **SF** | Frequency sharing and coordination between fixed-satellite and fixed service systems |
| **SM** | Spectrum management |
| **SNG** | Satellite news gathering |
| **TF** | Time signals and frequency standards emissions |
| **V** | Vocabulary and related subjects |

|  |
| --- |
|  |

|  |
| --- |
| ***Note***: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.* |

*Electronic Publication*

Geneva, 2015

© ITU 2015

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

RECOMMENDATION ITU-R RS.2064-0

Typical technical and operating characteristics and frequency bands used   
by space research service (passive) planetary observation systems

(Question ITU-R 221/7)

(2014)

Scope

This Recommendation provides typical technical and operational characteristics of space research service (passive) systems and frequency bands used by space research service (passive) planetary observation systems.

The ITU Radiocommunication Assembly,

considering

*a)* that one application of the space research service (SRS) (passive) is for spacecraft to measure physical phenomena of extraterrestrial bodies;

*b)* that SRS (passive) observation systems may receive emissions from transmitters operating in active radiocommunication services;

*c)* that there are exclusive SRS (passive) allocations in which all emissions are prohibited by RR No. **5.340**;

*d)* that certain frequency bands are allocated to the SRS (passive) on a co-primary basis with active services;

*e)* that studies considering protection for SRS (passive) systems may take place within ITU‑R;

*f)* that in order to perform compatibility and sharing studies concerning SRS (passive) systems, the technical and operational characteristics of these systems must be known;

*g)* that the sensing of different physical properties requires the use of different frequencies;

*h)* that simultaneous measurements at a number of frequencies are often needed to distinguish between the various physical properties being measured,

recommends

**1** that the technical and operational parameters presented in Annex 1 of this Recommendation should be taken into account in studies considering SRS (passive) systems operating in bands allocated to the SRS (passive);

**2** that the frequency bands used for SRS (passive) sensing should be in accordance with Annex 2.

Annex 1  
  
Typical technical and operating characteristics used by space   
research service (passive) observation systems

# 1 Introduction

The purpose of this Recommendation is to present typical technical and operating characteristics and preferred frequency bands of space research service (SRS) (passive) observation systems.

The “*decides*” of Question ITU-R 221/7 – Preferred frequency bands and protection criteria for space research service observations (passive), includes the studying of: 1) typical technical and operating characteristics of SRS (passive) observation systems; 2) preferred frequency bands for SRS (passive) observations; and 3) protection criteria for SRS (passive) observations.

This Recommendation focuses on the first two study objectives mentioned above. Annex 1 presents typical technical and operating characteristics of the spaceborne passive sensors in the SRS (passive) which have been flown or are planned to be used, and Annex 2 lists the preferred frequency bands along with missions associated with those frequency bands.

# 2 Specific missions with SRS (passive) systems

The following sections describe various space research missions that have used or are using passive sensors (i.e., microwave radiometers).

## 2.1 Mariner 2 microwave radiometer at Venus

Mariner 2 was a Venus flyby mission in December 1962 where a microwave radiometer was used to determine the absolute temperature of the Venus surface and atmosphere. Mariner 2 approached Venus from 30 degrees above the dark side of the planet, and passed below the planet at its closest distance of 34 773 km on 14 December 1962. Simultaneous measurements were made in two frequency bands at 15.8 GHz and 22.2 GHz with predetection bandwidths of 1.6 GHz and 1.5 GHz (Table 1). The microwave radiometer used a 48.5 cm diameter parabolic antenna with two reference horns looking 60 degrees away at space. The 3 dB beamwidths were 2.64 degrees and 2.2 degrees for the two frequencies, respectively. The microwave radiometer was of the crystal video type operating in the standard Dicke mode of chopping between the main antenna pointed at the target and a reference horn pointed at cold space. The planetary emissions were characterized by limb‑darkening and confirmed the high temperature of Venus. The dual‑channel microwave radiometer obtained three scans across the planet Venus. The peak temperature values supported a hot-surface model for the planet. The model best to match the limb‑darkening ratios and temperature values measured at both frequencies pointed to a specular surface and an isothermal cloud-type layer at a temperature near 350 K. The magnitude of the relative dielectric coefficient of the surface varied between 3 and 4. Scientific discoveries made by Mariner 2 included a slow retrograde rotation rate for Venus, hot surface temperatures and high surface pressures, a predominantly carbon dioxide atmosphere, continuous cloud cover with a top altitude of about 60 km, and no detectable magnetic field.

TABLE 1

Mariner 2 microwave radiometer characteristics

|  |  |  |
| --- | --- | --- |
| Parameters | Values | |
| RF centre frequency | 15.8 GHz | 22.2 GHz |
| Altitude | Min 34 773 km | Min 34 773 km |
| RF predetection bandwidth | 1.6 GHz | 1.5 GHz |
| Receiver noise figure | 4 dB | 4 dB |
| Detectable delta temperature | 4 K | 7 K |
| Number of scans | 3 | 3 |
| Duration/scan | 220 s | 220 s |
| Antenna type | Parabolic reflector | Parabolic reflector |
| Antenna diameter | 48.5 cm | 48.5 cm |
| Antenna beamwidth | 2.64 degrees | 2.2 degrees |
| Receiver noise figure | 4 dB | 4 dB |

## 2.2 Cassini microwave radiometer at Titan

The Cassini radar instrument was used in a passive microwave radiometer mode to map the microwave emission from Titan. These were the first resolved microwave emission measurements of an icy satellite. The measurement data provide crude composition maps of Titan’s surface, confirm equator-to-pole temperature gradients without the influence of the atmospheric effects, and provide some bistatic reflection measurements using the sun as a source to constrain roughness of ethane seas. The Cassini spacecraft was launched in October, 1997, and arrived at Saturn in July 2004. Ninety-seven flybys of Titan occurred between July 2004 and January 2014. Flybys are planned monthly for the duration of the mission. The Cassini radar instrument uses a 4 m diameter antenna and operates at 13.78 GHz as shown in Table 2. In the microwave radiometer mode, the incident microwave radiation is measured between echo pulses, hence the microwave brightness of targets in the beam. Microwave radiometry takes place throughout the Titan encounter and is the only mode for distant observations at 25 000-100 000 km. Internal calibrations are made with a noise diode and a resistive load of known characteristics. The microwave radiometer is linearly polarized either horizontally or vertically, depending on how the spacecraft antenna is oriented.

TABLE 2

Cassini microwave radiometer mode characteristics

|  |  |
| --- | --- |
| Parameters | Values |
| RF centre frequency | 13.78 GHz |
| Altitude | 1 000-100 000 km |
| RF bandwidth | 135 MHz |
| Antenna type | Parabolic reflector |
| Antenna diameter | 4 m |
| Antenna beamwidth | 0.35 degrees |
| Antenna orientation | Nadir |
| Antenna polarization | Linear H, V |
| Receiver noise temperature | 574 K |

## 2.3 Magellan microwave radiometer at Venus

The Magellan radar had a microwave radiometer mode which operated at 2.38 GHz and observed the radio emissivity of more than 91% of the Venus surface. The Magellan spacecraft was launched in May 1989 and arrived at Venus in August 1990. With an extended mission of two further mapping cycles, Magellan mapped Venus until September 1992. The microwave radiometer uses the 3.7 m diameter antenna which has a 2.1 degree beamwidth and uses horizontal linear polarization as shown in Table 3. This yields surface resolutions varying between 15 km and 85 km as the altitude varied from 280 km to 2 100 km. The microwave radiometer mode is enabled for 50 milliseconds at the end of each radar “burst” sequence, following either the altimeter or SAR observations. In the radiometer mode, the receiver is switched alternately from burst to burst between the high gain antenna and a dummy load as a reference. The microwave radiometer measurements show a global mean value of emissivity of 0.845 corresponding to a dielectric permittivity of 4.0 to 4.5, depending on the surface roughness, and is consistent with dry basaltic minerals composing the bulk of the Venus surface.

TABLE 3

Magellan microwave radiometer mode characteristics

|  |  |
| --- | --- |
| Parameters | Values |
| RF centre frequency | 2.38 GHz |
| Altitude | 280-2 100 km |
| RF bandwidth | 10 MHz |
| Horizontal resolution | 15-85 km |
| Antenna type | Parabolic reflector |
| Antenna diameter | 3.7 m |
| Antenna orientation | Nadir |
| Antenna polarization | Linear H |
| Antenna beamwidth | 2.1 degrees |

## 2.4 Juno MWR at Jupiter

The Juno microwave radiometer on the Juno spacecraft, launched on 5 August 2011, is scheduled to arrive at Jupiter in 2016. This will be the second microwave instrument to explore the planets since the first observations from Mariner 2 of Venus in 1962. The microwave radiometer will operate in direct detection mode to quantify the distributions and abundances of water and ammonia in Jupiter’s atmosphere. After Jupiter orbit insertion, the 11 day orbit will have a perijove at 1.06 Jupiter radii and an apojove at about 39 Jupiter radii, providing 32 orbits over the nominal one year mission. This polar orbiting (inclination 90 degrees) instrument will probe deep into the atmosphere of Jupiter at six frequencies 0.6 GHz, 1.25 GHz, 2.6 GHz, 5.2 GHz, 10 GHz, and 22 GHz (Table 4). The six radiometers are to measure the planet’s thermal emissions of ammonia and water in Jupiter’s atmosphere. Measurements at frequencies of 9.6 GHz and 23.1 GHz are for the ammonia NH3 clouds at 200 K at 1 bar pressure, and measurements at frequency of 1.2 GHz are for the water H2O clouds at 300 K and 8 bars pressure. The microwave radiometer has a 12 degree beamwidth antenna. The six radiometers use direct-detect Dicke-style receivers with about 4% bandwidth. The six receivers are fed by a combination of patch array antennas at 0.6 GHz and 1.25 MHz; slot array antennas at 2.6 GHz, 5.2 GHz, and 10 GHz; and a horn antenna at 22 GHz. The primary acquisition of data occurs at ±3 hours around perijove when the altitude varies between 4 200 km and 5 200 km. During the radiometer science passes, the microwave radiometer measurements are taken with the solar array plane of the spinning spacecraft passing through the centre of Jupiter and the radiometer antennas aligned with nadir.

TABLE 4

Juno microwave radiometer characteristics

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameters | Values | | | | | |
| RF centre frequency | 0.6 GHz | 1.25 GHz | 2.6 GHz | 5.2 GHz | 10 GHz | 22 GHz |
| Altitude | 4 200-5 200 km | | | | | |
| RF bandwidth | 24 MHz | 50 MHz | 100 MHz | 200 MHz | 400 MHz | 900 MHz |
| Antenna type | Patch array | Patch array | Slot array | Slot array | Slot array | Horn |
| Antenna beamwidth | 12 degrees | | | | | |
| Receiver noise temperature | 350 K | | | | | |

## 2.5 Chang’e-1 microwave radiometer at the moon

The Chang’e-1 microwave radiometer was launched on the Chang’e-1 spacecraft in October 2007. The microwave radiometer measures the natural radiation emanating from the lunar surface at four microwave frequencies 3 GHz, 7.8 GHz, 19.35 GHz, and 37 GHz (as shown in Table 5). The objective is to profile the lunar regolith thickness and to measure the radiation brightness temperature with a resolution of 0.5 K. The instrument is expected to measure depths up to 30 m, 20 m, 10 m, and 1 m at the four frequencies. The circular orbit is at a low 200 km altitude with an inclination of 90 ± 5 degrees and a period of 127 minutes. There are four horn antennas pointed at nadir, each diameter of which is scaled to the wavelength so that the four footprints are co-aligned and overlapping.

TABLE 5

Chang’e-1 microwave radiometer characteristics

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameters | Values | | | |
| RF centre frequency | 3 GHz | 7.8 GHz | 19.35 GHz | 37 GHz |
| Altitude | 200 km | | | |
| RF bandwidth | 100 | 200 | 500 | 500 |
| Ground resolution | 56 | 30 | 30 | 30 |
| Antenna type | Horn | Horn | Horn | Horn |
| Penetration thickness | 30 m | 20 m | 10 m | 1 m |

## 2.6 Summary of SRS (passive) system characteristics

The characteristics of the SRS (passive) systems in the previous sections are summarized in Table 6 below.

TABLE 6

Summary of SRS (passive) microwave radiometer characteristics

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameters | Mission | | | | | | | | | | | |
| Juno | Juno | Magellan | Juno | Chang’e-1 | Juno | Chang’e-1 | Juno | Cassini | Chang’e-1 | Juno | Chang’e-1 |
| Planet/Moon | Jupiter | Jupiter | Venus | Jupiter | Earth’s Moon | Jupiter | Earth’s Moon | Jupiter | Titan | Earth’s Moon | Jupiter | Earth’s Moon |
| RF centre frequency | 0.6 GHz | 1.25 GHz | 2.38 GHz | 2.6 GHz | 3 GHz | 5.2 GHz | 7.8 GHz | 10 GHz | 13.78 GHz | 19.35 GHz | 22 GHz | 37 GHz |
| Altitude | 4 200-5 200 km | 4 200-5 200 km | 280-2 100 km | 4 200-5 200 km | 200 km | 4 200-5 200 km | 200 km | 4 200-5 200 km | 1 000- 100 000 km | 200 km | 4 200-5 200 km | 200 km |
| RF bandwidth | 24 MHz | 50 MHz | 10 MHz | 100 MHz | 100 | 200 MHz | 200 | 400 MHz | 135 MHz | 500 | 900 MHz | 500 |
| Antenna type | Patch array | Patch array | Parabolic reflector | Slot array | Horn | Slot array | Horn | Slot array | Parabolic reflector | Horn | Horn | Horn |
| Antenna diameter (reflector) |  |  | 3.7 m |  |  |  |  |  | 4 m |  |  |  |
| Antenna beamwidth | 12 degrees | 12 degrees | 2.1 degrees | 12 degrees |  | 12 degrees |  | 12 degrees | 0.35 degrees |  | 12 degrees |  |
| Antenna orientation | Nadir | Nadir | Nadir | Nadir | Nadir | Nadir | Nadir | Nadir | Nadir | Nadir | Nadir | Nadir |
| Receiver noise temperature | 350 K | 350 K |  | 350 K |  | 350 K |  | 350 K | 574 K |  | 350 K |  |
| Ground resolution |  |  | 15-85 km |  | 56 |  | 30 |  |  | 30 |  | 30 |

# 3 Additional passive sensing by SRS systems

In addition to the “classic” passive sensing by microwave radiometers, SRS missions often exploit the presence of their Telemetry, Tracking and Control (TT&C) transponders to perform additional passive measurements of some solar system planets[[1]](#footnote-1) characteristics.

The most common of these passive measurement is what is normally called radio science. It consists in measuring from the Earth station the distortion introduced by the planet atmosphere and its gravity field on the spacecraft telemetry carrier signal when it is moving at the limb of the planet. As the spacecraft moves behind the planet, its radio signals cuts through successively deeper layers of the planetary atmosphere. Measurements of signal strength and polarization vs. time can yield data on the composition and temperature of the atmosphere at different altitudes. Variation in the Doppler shift can provide information on the gravity field.

This kind of measurements are typically performed in the following SRS (s-to-E) bands:

2 290-2 300 MHz,

8 400-8 500 MHz,

31.8-32.3 GHz, and

37-38 GHz.

Examples of the many SRS missions that performed radio science are: Cassini/Huygens, Venus Express, Messenger, Voyager 1 and 2.

Another more recent way of performing passive space science by exploiting the presence of the spacecraft transponder is to use its telecommand receiving part as a microwave radiometer and measure the variation of the transponder RF noise levels when the transponder is looking at the planet body versus when looking away from the planet.

For this kind of measurements the SRS (E-to-s) frequencies that can be used are:

7 145-7 235 MHz,

34.2-34.7 GHz, and

40-40.5 GHz.

# 4 Preferred frequency bands for SRS (passive)

There are many preferred frequency bands of the SRS (passive) as currently allocated. Several planetary and lunar missions have used microwave radiometers at frequencies which are not allocated. Table 7 of Annex 2 summarizes the SRS (passive) preferred frequency bands and allocation status.

# 5 Summary

This Annex presents typical technical and operating characteristics of the spaceborne passive sensors in the SRS (passive) which have been flown or are planned to be used.

Annex 2  
  
Frequency bands used by space research service (passive)   
observation systems

TABLE 7

SRS (passive) sensing by frequency band and mission

| Frequency  bands(1) (GHz) | Missions | Allocation status | Comments |
| --- | --- | --- | --- |
| 0.588-0.612 | Juno | None(2) | Juno MWR BW of 24 MHz |
| 1.225-1.275 | Juno | None(2) | Juno MWR BW of 50 MHz |
| 1.37-1.4s |  | SRS (passive) secondary |  |
| 1.4-1.427P |  | SRS (passive) primary |  |
| 2.55-2.64 | Juno | None(2) | Juno MWR BW of 100 MHz |
| 2.64-2.655s |  | SRS (passive) secondary |  |
| 2.655-2.69s |  | SRS (passive) secondary |  |
| 2.69-2.7P |  | SRS (passive) primary |  |
| 2.95-3.05 | Chang’e-1 | None(2) | Chang’e-1 MWR BW of 100 MHz |
| 4.2-4.4s |  | SRS (passive) secondary |  |
| 4.95-4.99s |  | SRS (passive) secondary |  |
| 4.99-5.00s |  | SRS (passive) secondary |  |
| 5.1-5.3 | Juno | None(2) | Juno MWR BW of 200 MHz |
| 7.7-7.9 | Chang’e-1 | None(2) | Chang’e-1 MWR BW of 200 MHz |
| 10.6-10.7P |  | SRS (passive) primary |  |
| 13.71-13.85 | Cassini | None(2) | Cassini MWR BW of 135 MHz |
| 15.2-15.35s | Mariner 2 | SRS (passive) secondary | Mariner 2 MWR BW of 1.6 GHz |
| 15.35-15.4P | Mariner 2 | SRS (passive) primary | (15.8 ± 0.8 GHz) |
| 15.4-16.6 | Mariner 2 | None(2) |  |
| 18.6-18.8p |  | SRS (passive) secondary |  |
| 19.1-19.6 | Chang’e-1 | None(2) | Chang’e-1 MWR BW of 500 MHz |
| 21.2-21.4 |  | SRS (passive) primary |  |
| 21.4-22.21 | Mariner 2, Juno | None(2) | Mariner 2 MWR BW of 1.5 GHz |
| 22.21-22.5p | Mariner 2, Juno | SRS (passive) primary | Juno MWR BW of 900 MHz |
| 22.5-22.9 | Mariner 2 | None(2) |  |
| 23.6-24P |  | SRS (passive) primary |  |
| 31.3-31.5P |  | SRS (passive) primary |  |
| 31.5-31.8p |  | SRS (passive) primary |  |
| 36-37p | Chang’e-1 | SRS (passive) primary | Chang’e-1 MWR BW of 500 MHz |
| 37-37.25 | Chang’e-1 | None(2) | (37.0 ± 0.25 GHz) |
| 50.2-50.4P |  | SRS (passive) primary |  |

TABLE 7 (*end*)

| Frequency  bands (1) (GHz) | Missions | Allocation status | Comments |
| --- | --- | --- | --- |
| 52.6-54.25P |  | SRS (passive) primary |  |
| 54.25-59.3p |  | SRS (passive) primary |  |
| 86-92P |  | SRS (passive) primary |  |
| 100-102P |  | SRS (passive) primary |  |
| 109.5-111.8P |  | SRS (passive) primary |  |
| 114.25-116.P |  | SRS (passive) primary |  |
| 115.25-116P |  | SRS (passive) primary |  |
| 116.0-122.25p |  | SRS (passive) primary |  |
| 148.5-151.5P |  | SRS (passive) primary |  |
| 155.5-158.5p |  | SRS (passive) primary |  |
| 164-167P |  | SRS (passive) primary |  |
| 174.8-182p |  | SRS (passive) primary |  |
| 182-185P |  | SRS (passive) primary |  |
| 185-190p |  | SRS (passive) primary |  |
| 190-191.8P |  | SRS (passive) primary |  |
| 200-209P |  | SRS (passive) primary |  |
| 226-231.5P |  | SRS (passive) primary |  |
| 235-238p |  | SRS (passive) primary |  |
| 250-252P |  | SRS (passive) primary |  |
| 275-277 |  | None(2) |  |
| 294-306 |  | None(2) |  |
| (1) P: Primary allocation, shared only with passive services (No. **5.340** of the Radio Regulations); p: primary allocation, shared with active services; s: secondary allocation.  (2) This frequency band is not allocated to the space research service (passive) and is used under No. **4.4** of the Radio Regulations. | | | |

1. The term planets here is meant to cover the solar system planets (except the Earth) as well as any of their satellites (Moon or others). [↑](#footnote-ref-1)