



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

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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 apojoive 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 planets¹ 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.

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).

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.