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Characteristics to be used for assessing interference to systems operating in the Earth exploration-satellite and meteorological-satellite services, and for conducting sharing studies

SA Series

Space applications and meteorology

International Telecommunication Union

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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Characteristics to be used for assessing interference to systems operating in the Earth exploration-satellite and meteorological-satellite services, and for conducting sharing studies

(2021)

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1 Introduction

This Report contains characteristics of systems, operating in the Earth exploration-satellite service (EESS)[1] and meteorological-satellite (MetSat) service, to be used to analyse potential interference from and to these systems, to achieve operational compatibility.

The different EESS and MetSat systems have been grouped into three categories according to functionalities of the links and the type of satellite orbits considered. The frequencies relevant to each category are listed below.

1 Space-to-Earth data transmission systems for non-GSO satellites (see § 3)

- 137-138 MHz
- 400.15-401 MHz
- 1 690-1 710 MHz
- 7 750-7 900 MHz
- 8 025-8 400 MHz
- 25.5-27 GHz

2 Raw data downlink and data dissemination systems for GSO satellites (see § 4)

- 1 670-1 698 MHz (space-to-Earth)
- 2 025-2 110 MHz (Earth-to-space)
- 7 450-7 550 MHz (space-to Earth) and 8 175-8 215 MHz (Earth-to-space)
- 25.5-27 GHz (space-to-Earth)

3 Data collection and platform interrogation systems (see § 5):

GSO satellites:

Data collection systems

- 401-403 MHz (Earth-to-space)
- 1 670-1 698 MHz (space-to-Earth)

Interrogation systems

- 460-470 MHz (space-to-Earth)
- 2 025-2 110 MHz (Earth-to-space)

Non-GSO satellites:

Data collection systems

- 401-403 MHz (Earth-to-space)
- 460-470 MHz (space-to-Earth)
- 1 697-1 699 MHz (space-to-Earth)

Interrogation systems

- 401-403 MHz (Earth-to-space)
- 460-470 MHz (space-to-Earth)

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1 This Report only addresses EESS transmission links. EESS (passive) and (active) sensors are described in different ITU-R RS-series documents under the purview of WP 7C.

1.1 Description of the fields in the system characteristics tables

The tables in this Report provide data for frequency coordination analyses and contain information about individual EESS and MetSat systems. Tables 1 and 2 provide information on non-GSO and GSO satellite orbits, and Table 3 gives the coordinates for earth station locations. Satellite names are identified by a letter, and ground station names by a number. These are cross-referenced among table entries in the rest of the Report.

Table 5 and higher contain specific information intended for use in interference analysis. For ease of reading, the row elements are described below, following definitions of the EESS and MetSat data links.

EESS-MetSat data links

The definitions for types of EESS-MetSat data links are provided below in consistency with the definitions included in the MetSat Handbook (Section 2.1).

Data links from geostationary MetSat satellites

The raw data gathered by the instruments on-board geostationary MetSat satellites are permanently transmitted to a primary ground station of the operating agency, processed, and distributed to various national meteorological centres, to official archives and other users. These links are usually referred to as **raw data downlink or mission data acquisition**.

The processed data are either sent back to the MetSat satellite for re-transmission directly to user stations, referred to as **data dissemination**, or distributed to users by using alternative means of data dissemination, not covered in this Report.

Data links from non-geostationary EESS and/or MetSat satellites

Different to geostationary MetSat satellites, where the satellite is permanently in visibility of its ground stations, the raw data acquired by the instruments on non-geostationary EESS or MetSat satellites have to be gathered and stored on-board the satellite until they can be transmitted to a primary ground station of the operating agency when the satellite passes over such a ground station. These links are referred to as **stored mission data**.

The raw instrument data are then processed by the operating agency and provided to the users by different/various data dissemination mechanisms. To improve the latency of the data, a subset of the data acquired by the instruments are 'broadcasted' directly from the satellite and can be received by user stations when the satellite is in the visibility of such a user station which can be located anywhere. Such a service is called **direct read-out**.

Row elements for EESS and MetSat

Function – Column header for the operational parameters required to characterize EESS and MetSat services (Recommendation ITU-R SA.1021).

Satellite – Name of sending or receiving space station for the data link.

Earth station – Name of sending or receiving ground station for a data or communications link.

Centre frequency – Either the centre frequency of the transmitted emissions or the centre frequency of a broadband receiver, which is receiving signals from multiple narrowband transmitters.

Information data rate – Actual rate of transmitted information before any coding; the information data rate should be applied to the performance criterion.

Necessary bandwidth – From the ITU Radio Regulations No. **1.152**: "For a given *class of emission*, the width of the frequency band, which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions." Formulas for necessary bandwidths are found in Recommendation ITU-R SM.1138 and Recommendation ITU-R SM.853.

Modulation – The format of the signal used to transmit the data.

Coding – Name of the method used to code the information.

Encoded data rate – Actual symbol rate of the modulated signal, which includes coding. If packetizing and or error correction are used, this is the final bit rate in bits per second (bit/s). If a pseudorandom code is used to create a spread spectrum signal, this is the coding chip rate (cps).

Minimum elevation angle – Elevation angle above which the performance parameters are applied.

Satellite antenna input power – Power from the transmitter less line losses.

Satellite antenna type – Often satellite antennas have special radiation patterns for their function, identifiable by the antenna type.

Satellite antenna radiation diagram/pattern – Identity of reference source to get the diagram, formulas or tables to describe the antenna pattern. Details are provided in **Annex A**.

Satellite antenna gain at nadir – Peak gain on low-Earth-orbiting satellites is often optimized for some off-nadir angle, so the nadir gain is provided here. In cases where the spacecraft antenna is steerable, this value is variable and not relevant.

Satellite antenna gain maximum gain – This is the maximum gain, which may not occur at nadir. For low earth orbiting stations this may occur at angles where the earth station antenna's elevation angle is low.

Satellite antenna polarization – The entries should specify whether the antenna polarization is linear or circular and whether dual polarization is used. In addition, the polarization direction should be included. For linearly polarized antennas, for example, it may be north to south (Linear N/S) or east to west (Linear E/W). For circularly polarized antennas it is either right hand circular (RHCP) or left hand circular (LHCP) or both.

Earth station antenna diameter – This assumes a parabolic dish antenna and can be used to calculate antenna gain.

Earth station antenna gain toward satellite – This is the maximum gain of the earth station antenna that is aimed toward the companion satellite.

Earth station antenna polarization – Does not necessarily match the satellite antenna.

Earth station antenna radiation diagram/pattern – Details are provided in Annex A.

Earth station receiver noise temperature – System noise includes the noise temperatures of the antenna, the receiver and the loss between the receiver and the feed expressed in degrees Kelvin (K).

1.2 Relevant ITU-R Recommendations SA-series

A complete description of EESS and MetSat systems can be found in the following ITU-R Handbooks:

– Handbook of Earth Exploration-Satellite Service (2011).

– Handbook on the Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction (2017).

The **interference criteria** to be used for studies involving different types of EESS and MetSat systems can be found in the following ITU-R Recommendations:

TABLE 1

ITU-R Recommendations providing interference criteria for EESS and MetSat services

Rec. ITU-R	Topics addressed in the Recommendation
SA.514	Interference criteria for command and data transmission systems
SA.1026	Aggregate interference criteria for space-to-Earth data transmission systems using low-Earth satellites
SA.1027	Sharing criteria for space-to-Earth data transmission systems using low-Earth satellites
SA.1160	Interference criteria for data dissemination and direct data readout systems using GSO satellites
SA.1161	Sharing and coordination criteria for data dissemination and direct data readout systems using GSO orbit
SA.1163	Interference criteria for service links in data collection systems
SA.1164	Sharing and coordination criteria for service links in data collection systems
Recommendations for specific bands	
SA.1258	Sharing of the frequency band 401-403 MHz between the MetSat, EESS and MetAid services
SA.1277	Sharing in the 8 025-8 400 MHz frequency band between the EESS, FS, FSS, MetSat and MS
SA.1745	Use of the band 1 668.4-1 710 MHz by the meteorological aids service and meteorological-satellite service (space-to-Earth)
SA.1807	System characteristics and interference criteria for MetSat systems operating around 18 GHz
SA.2044	Protection criteria for non-GSO data collection platforms in the band 401-403 MHz

The **performance objectives** of the EESS and MetSat systems are prerequisites for the establishment of the associated interference criteria, and are provided in the following ITU-R Recommendations:

TABLE 2

ITU-R Recommendations providing performance objectives for EESS and MetSat services

Rec. ITU-R	Topics addressed in the Recommendation
SA.1159	Performance criteria for data dissemination, data collection and direct data readout systems in EESS and MetSat services
SA.1627	Telecommunication requirements and characteristics of data collection and platform location systems

Finally, the **methodologies** for determining the above interference and performance criteria in the EESS and MetSat services can be found in the following ITU-R Recommendations:

TABLE 3

ITU-R Recommendations providing methodologies for determining the interference and performance criteria for EESS and MetSat services

Rec. ITU-R	Topics addressed in the Recommendation
SA.1020	Hypothetical reference system for the EESS and MetSat services
SA.1021	Methodology for determining performance objectives for systems in the EESS and MetSat services
SA.1022	Methodology for determining interference criteria for systems in the EESS and MetSat services
SA.1023	Methodology for determining sharing and coordination criteria for systems in the EESS and MetSat services

2 Satellite orbit parameters and earth station locations

Table 4 provides a typical range of orbit parameters for current and future MetSat/EESS non-GSO satellites that use the frequency bands given in § 3 and in a portion of § 5 of this Report. Most satellites in Table 4 are in sun-synchronous orbits. The purpose of the Table is to provide orbit information needed for conducting dynamic simulations.

TABLE 4

Typical Non-GSO satellite orbit parameters

Non-GSO satellite name	Orbit altitude (km)	Inclination (degrees)	Longitude ascending node (degrees) or local time of equatorial crossing (if in sun synchronous orbit)
Polar orbit (sun-synchronous)	About 400 to 870	Close to 97° / 98° (linked to orbit altitude)	Systems specific
Other types of circular orbits (e.g. $ISS, Jason, …)	400 to 1 336	System specific	Systems specific
Other types of orbits (e.g. Highly elliptical, …)	System specific	Systems specific	System specific

Detailed description of some of the corresponding non-GSO systems are given in Annex B.

Orbital parameters of current and future MetSat/EESS GSO satellites that use the frequency bands given in § 4 and in a portion of § 5 of this Report only relate to the longitudes of systems on the geostationary orbit.

Detailed description of some of the corresponding GSO systems are given in Annex B.

Finally, Annex B also provides a list of locations of representative specific earth stations and their locations that use the frequency bands given in §§ 3, 4 and 5.

It should be noted that all elements provided in Annex B (non-GSO, GSO systems and earth stations) are only a subset and cannot be taken as exhaustive.

3 Space-to-Earth data transmission systems for non-GSO satellites

This section provides the RF parameters needed to conduct interference assessments and sharing studies for space-to-Earth data transmission from typical non-GSO satellites. The information sent via these downlinks originate from instruments on the spacecraft.

3.1 137-138 MHz

The 137-138 MHz frequency band has a long history of providing data to private users using simple inexpensive receivers and data reading systems.

The Automatic Picture Transmission (APT) service continuously broadcasts low-resolution analogue data worldwide in this band from optical sensors. One sensor provides visible APT imagery during daylight, and another provides infrared imagery both day and night. The APT signal is transmitted continuously and can be received in real time by relatively unsophisticated, inexpensive ground station equipment while the satellite is within radio range. Thousands of APT receiving stations are in operation worldwide.

In contrast, the TIROS Information Processor (TIP) and the Low-Resolution Picture Transmission (LRPT) services using this band are digital. TIP provides low-resolution data from microwave sensors to users who do not intend to install the more complex equipment necessary to receive high-resolution data. TIP multiplexes this data with that from other services and transmits it as an 8.32 kbit/s split phase signal. The LRPT service is envisaged for gradually replacing the APT service.

The LRPT data is Nyquist-filtered to minimize inter-symbol interference and coded to reduce its vulnerability to interference and noise. Table 5 lists some typical characteristics for non-GSO MetSat data dissemination systems in the frequency band 137-138 MHz.

TABLE 5

Non-GSO MetSat space-to-Earth parameters for data dissemination systems in the frequency band 137-138 MHz

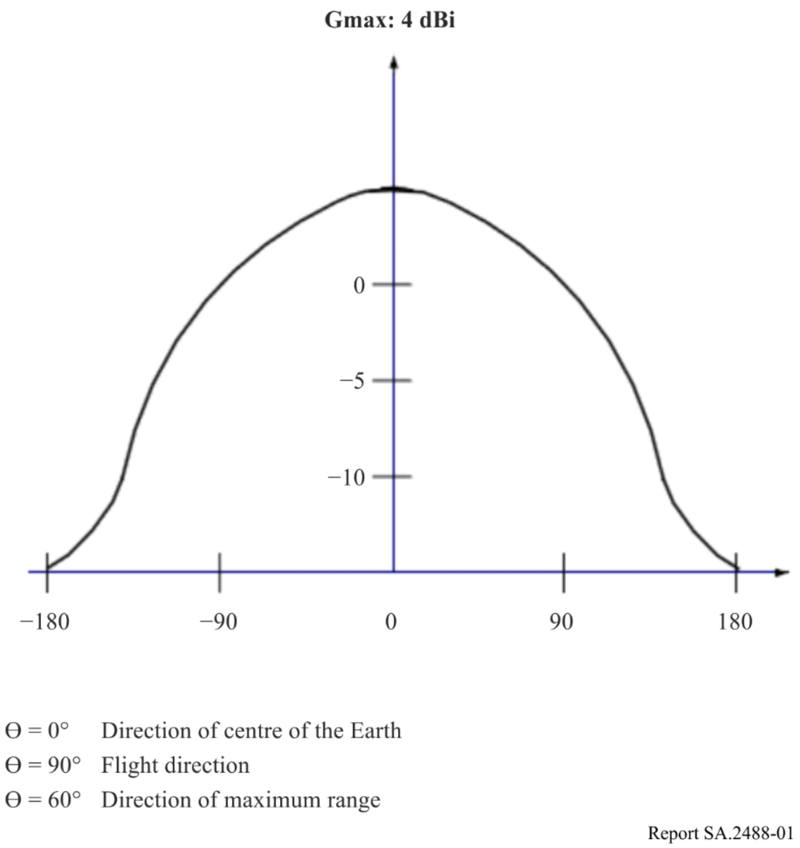
Function	APT		TIP	LRPT
Satellite	Satellites A and D	Satellite B	Satellite D	Satellite B
Earth station(s)	Worldwide		Stations 1 and 2	Stations 13, 14 and 15
Centre frequency (MHz)	A(137.5 and 137.62) D(137.1 and 137.9125	137.5	137.35 and 137.77	137.1 and 137.9125
Information data rate (Mbits/s)	0.038	0.0107	0.00832	0.144
Necessary bandwidth (MHz)	0.038	0.0568	0.046	0.144
Modulation	Analogue FM-carrier AM 2.4 kHz subcarrier	FM	PM ± 67 deg.	QPSK
Coding	None	None	None	None
Encoded data rate				
Minimum elevation angle (degree)	25	5	25	5
Satellite antenna input power (dBW)	4.9	4	−2.5	5
Satellite antenna type	Quadrifilar Helix	Whip	Dipole	Whip

TABLE 5 (*end*)

Function	APT		TIP	LRPT
Satellite antenna radiation diagram	3.7 dBi at nadir −0.25 dBi at horizon	see Fig. 1	5.8 dBi at nadir −6.0 dBi at horizon	see Fig. 1
Satellite antenna gain at nadir (dBi)	3.7	4	5.8	4
Satellite antenna maximum gain (dBi)	3.7	4	5.8	4
Satellite antenna polarization	RHCP	RHCP	Linear	RHCP
Satellite antenna diameter (m)		0.55		0.55
Earth station antenna gain (dBi)	2 (low-gain) 10 (high-gain)	2.5	49.6	0 (low–gain) 10 (high-gain)
Earth station antenna polarization	RHCP	RHCP	Linear	RHCP
Earth station antenna radiation diagram	Crossed dipole or high gain Yagi	Rec. ITU-R S.580-6	AP 7 Annex 3	Crossed dipole or high gain Yagi
Earth station receiver noise temperature (K)	1 000	450	300	300

FIGURE 1

Satellite antenna radiation diagram for Satellite B



3.2 400.15-401 MHz

The MetSat service has a primary allocation in the 400.15-401 MHz frequency band in the space-to-Earth direction and is currently used by non-geostationary satellites. Typical MetSat characteristics for this band are listed in Table 6. These characteristics are derived from Table 2 of Recommendation ITU-R SA.1026.

TABLE 6

Non-GSO MetSat space-to-Earth parameters for data dissemination systems in the band 400.15-401 MHz

Function	MetSat
Satellite	Satellite Y
Centre frequency (MHz)	400.15-401
Information data rate (dB/Hz)	49.5
Necessary bandwidth (kHz)	177.5
Minimum elevation angle (degree)	5 and 13
Satellite antenna input power (dBW)	11.1
Satellite antenna gain at nadir (dBi)	0.0
Satellite antenna maximum gain (dBi)	0.0
Earth station antenna gain (dBi)	0.0
Polarization mismatch loss (dB)	0.3
Earth station antenna radiation diagram	Omni-directional (non-tracking)
Earth station receiver noise temperature (K)	400

3.3 1 690-1 710 MHz

These services provide real time data and images directly to the user customer. The High Rate Picture Transmission (HRPT) service has been a major source of high quality data from polar-orbiting meteorological satellites at user stations throughout the world. HRPT transmitters operate continuously and data can be received by any user station. Hundreds of HRPT receiving stations worldwide are registered with the World Meteorological Organization (WMO). The data stream contains full resolution images in digital format from optical instruments as well as atmospheric information from a suite of sounding instruments. Through HRPT reception, the user site acquires data from three or more consecutive overpasses twice each day from each satellite, giving high-resolution data coverage of a region extending about 1 500 km radius from the user station. These are stored mission data systems when specific earth stations are indicated. Some typical characteristics for non-GSO MetSat direct readout systems in this band are found below in Tables 7 and 8 and typical characteristics for stored mission data in this band are found in Table 9.

TABLE 7

Non-GSO MetSat Space-to-Earth parameters for direct readout systems in the band 1 690-1 710 MHz

Function	CHRPT	AHRPT	HRPT
Satellite	Satellite E and G	Satellite F	Satellite B
Earth station(s)	Various locations		Russian territory
Carrier frequency (MHz)	1 704.5	1 701.3 & 1 707	1 700 and 1 705
Information Data rate (Mbits/s)	4.2	3.5	1.33
Necessary bandwidth (MHz)		4.5	3
Modulation	QPSK	QPSK	QPSK
Coding	Convolutional	Convolutional	Uncoded
Encoded data rate			
Minimum elevation angle (degree)	5	5	5
Satellite antenna input power (dBW)	10.5	6	9
Satellite antenna type		Quadrifilar helix	Spiral
Satellite antenna radiation pattern			see Fig. 2
Satellite antenna gain at nadir (dBi)			−7
Satellite antenna maximum gain (dBi)		−4.5	4
Satellite antenna polarization	RHCP	RHCP	RHCP
Earth station antenna diameter (m)		1.8	7 3.7 1.5
Earth station antenna gain toward satellite (dBi)	30	28	40.0 34.0 26.0
Earth station antenna polarization	RHCP	RHCP	RHCP
Earth station antenna radiation diagram	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	280	200	150/200

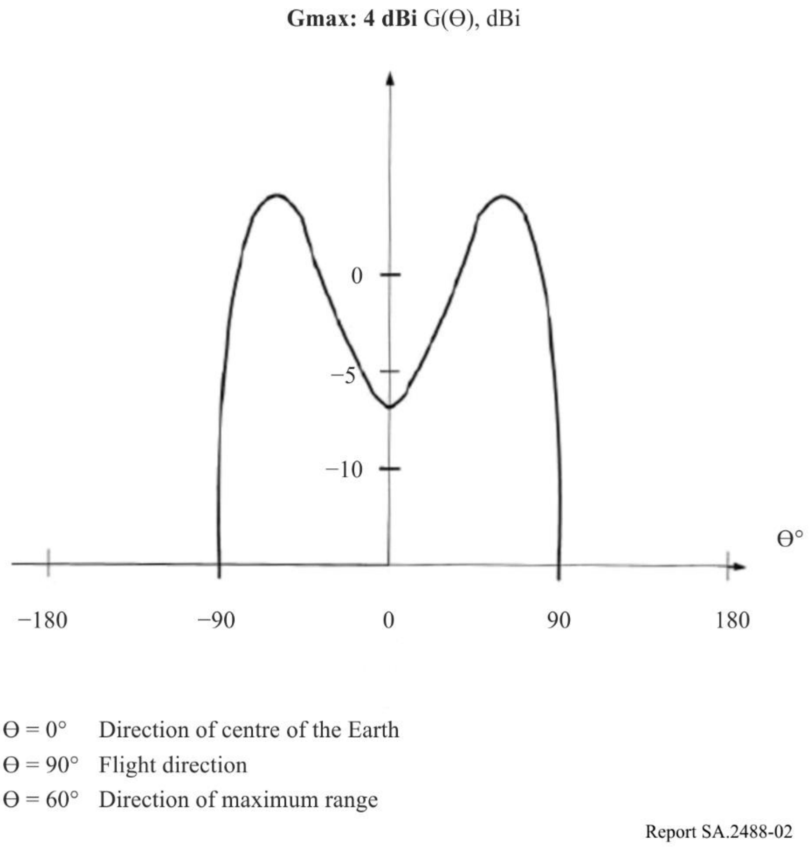
TABLE 8

Non-GSO MetSat Space-to-Earth parameters for direct readout systems in the band 1 690-1 710 MHz

Function	**LRPT**	**Direct Data Broadcast (DDB)**	**Direct Readout**
Satellite	Satellite BF	Satellite BG (Constellation of 8 to 16 satellites)	Satellites A and D
Earth station(s)	Stations 13, 14 and 15	Worldwide	Stations 1 & 2 User stations
Carrier frequency (MHz)	1703	1 701.3 or 1 707	1 698, 1 702.5 or 1 707
Information data rate (Mbits/s)	0.005	0.130	2.66 NRZ or 0.322 split phase
Necessary bandwidth (MHz)	0.02	0.127	5.34
Modulation	BPSK	QPSK	PM ±67 deg.
Coding	None	RS (255, 223)	None
Encoded data rate (Mbits/s)		0.149	
Minimum elevation angle (degree)	5	5	5
Satellite antenna input power (dBW)	−4	6	8
Satellite antenna type	Spiral		Quadrifilar helix
Satellite antenna radiation diagram/pattern	see Fig. 3	Isoflux	Isoflux
Satellite antenna gain at nadir (dBi)	16.2	0	−10
Satellite antenna maximum gain (dBi)	16.2	0	0 dBi at ±60 degrees
Satellite antenna polarization	RHCP	RHCP	RHCP
Earth station antenna diameter (m)	2.4	3	13 (stations 1 and 2) 1.2 (User stations)
Earth station antenna gain toward satellite (dBi)	30	32	46.8 dBi (13 m) 24 dBi (1.2 m)
Earth station antenna polarization	RHCP	RHCP	RHCP
Earth station antenna radiation diagram/pattern	Rec. ITU-R S.580-5	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	200	200	290

FIGURE 2

Satellite antenna radiation diagram for Satellite B



NOTE – Typical non-GSO simple antenna radiation diagram to meet PFD requirements.

FIGURE 3

Satellite antenna radiation diagram for Satellite BF

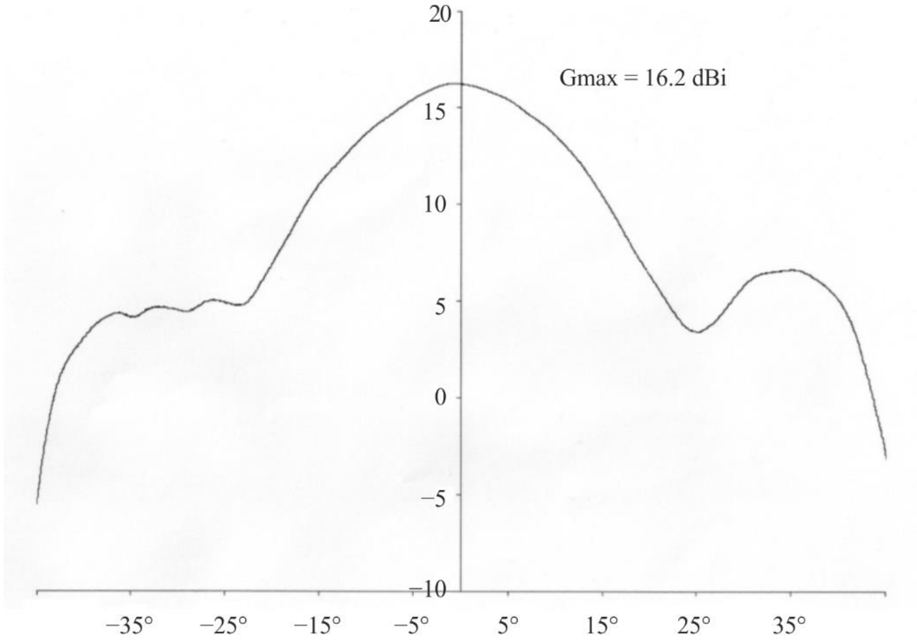


TABLE 9

Non-GSO MetSat space-to-Earth parameters for Stored Mission Data systems in the band 1 690-1 710 MHz

Function	Low rate data	Stored mission data
Satellite	Satellite Y	Satellite BG (Constellation of 8 to 16 satellites)
Earth station(s)	Worldwide	Station 5 and 18
Carrier frequency (MHz)	1 703	1 701.3 or 1 707
Information data rate (Mbits/s)	1.8 (max)	1.53
Necessary bandwidth (MHz)	1.80	5.1
Modulation	QPSK	QPSK
Coding	None	Concat.RS+Conv (1/2, 7)
Encoded data rate (Mbits/s)		3.5
Minimum elevation angle (degree)	5	5
Satellite antenna input power (dBW)	7.6	6
Satellite antenna type	Helix	
Satellite antenna radiation diagram/pattern	Isoflux	Isoflux
Satellite antenna gain at nadir (dBi)	7.3	0
Satellite antenna maximum gain (dBi)	7.3	0
Satellite antenna polarization	RHCP	RHCP

TABLE 9 (*end*)

Function	Low rate data	Stored mission data
Earth station antenna diameter (m)	13	Station 2: 1.8 Station 5: Digital Beamforming Network (DBFN) antenna
Earth station antenna gain toward satellite (dBi)	47	28
Earth station antenna polarization	RHCP	RHCP
Earth station antenna radiation diagram/pattern	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	290	290

3.4 7 750-7 900 MHz

Space-to-Earth parameters for systems in the frequency band 7 750-7 900 MHz are found in Table 10. Non-geostationary (usually polar orbiting) MetSat systems use this band for two modes of data distribution:

– Raw data transmissions to dedicated earth stations usually located at high latitudes, labelled in Table 10 as “Stored Mission Data”. Transmissions take place in bursts as each satellite overpasses its station, with the transmitters switched off at other times.

– Continuous transmission of real time data to any ground station within line-of-sight, labelled in Table 10 as “Direct Readout”.

TABLE 10

Non-GSO MetSat space-to-Earth parameters for systems in the band 7 750-7 900 MHz

Function	Stored mission data		Direct readout		
Satellite	Satellite F	Satellites E and G	Satellites C and S	Satellites AN	Satellite BF
Earth station(s)	Station 5		Worldwide	Worldwide	Stations 13, 14 and 15
Carrier frequency (MHz)	7 800	7 780 and 7820	7 812	7 825	7 865
Information data rate (Mbits/s)	70	60	13	80	30.7
Necessary bandwidth (MHz)	63	60	30	150	61.4
Modulation	QPSK	QPSK	QPSK	QPSK	BPSK
Coding	Concatenated	Convolutional	Concatenated	Concatenated	None
Encoded data rate (Mbits/s)		60	30	187	-
Minimum elevation angle (degree)	5	5	5	5	5
Satellite antenna input power (dBW)	6.5	14	9.6	19.4	10
Satellite antenna type	Quadrifilar	Quadrifilar	Isoflux	Isoflux	Dish
Satellite antenna	Isoflux	Isoflux	Isoflux	Isoflux	Rec. ITU-R

TABLE 10 (*end*)

Function	Stored mission data		Direct readout		
radiation diagram					S.672
Satellite antenna gain at nadir (dBi)			−2		
Satellite antenna maximum gain (dBi)	6	5	7	6.8	38
Satellite antenna polarization	RHCP		RHCP	RHCP	RHCP
Earth station antenna diameter (m)	10	12	3	3	5
Earth station antenna gain toward satellite (dBi)	55	57.2	44.9	44.3	50
Earth station antenna polarization	RHCP	LHCP and RHCP	RHCP	RHCP	RHCP
Earth station antenna radiation diagram	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.580
Earth station receiver noise temperature (K)	180	176	343	252	150

3.5 8 025-8 400 MHz

Functions in this band are similar to those of the 7 750-7 900 MHz band, i.e. transmission of direct readout data and of recorded data acquisition (stored mission data).

The band 8 025-8 400 MHz is very heavily used by EESS payload data downlink, with more than 130 systems in operation (many of them involving multiple satellites) and this number is still increasing. The higher bandwidth available (375 MHz total) makes this band attractive to download stored mission data that requires data rates around 100 megabits/second and higher and is used by most Earth observation missions involving high-resolution imaging or large instrument ensembles. Typically, the transmissions take place in bursts as each satellite overpasses its receiving station, with the transmitters switched off at other times.

Direct readout systems, typically requiring 15 to 20 Mbit/s, are also currently using this band. Direct readout systems typically maintain the transmitter on continuously.

Table 11 provides typical range of systems characteristics for both **stored mission data** and **direct read-out** applications.

Detailed description of some of the corresponding non-GSO systems are given in Annex C but cannot be taken as exhaustive.

TABLE 11

Typical system parameters for direct read-out and stored Mission Data services in the band 8 025-8 400 MHz

Typical range of non-GSO EESS space-to-Earth parameters for systems in the band 8 025-8 400 MHz	Direct readout	Direct readout and stored mission data	Stored mission data
Earth station(s)	Specific, country territory or worldwide	Specific, country territory or worldwide	Specific
Carrier frequency (MHz)	Single or multiple frequency within the 8 025-8 400 MHz band	Single or multiple frequency within the 8 025-8 400 MHz band	Single or multiple frequency within the 8 025-8 400 MHz band
Information data rate (Mbits/s)	3 to 320	60 to 300	4 to 800
Necessary bandwidth (MHz)	30 to 350	60 to 123	15 to 375
Modulation and coding information	System specific (see Annex C)	System specific (see Annex C)	System specific (see Annex C)
Minimum elevation angle (degree)	5	5	5
Satellite antenna input power (dBW)	3 to 24	3 to 11	3.5 to 17
Satellite antenna radiation diagram	Isoflux, Directional or specific	Isoflux, or steerable	Isoflux, Directional or horn
Satellite antenna gain at nadir (dBi)	−6 to 25	−3.5 to 4	−6 to 25
Satellite antenna maximum gain (dBi)	6 to 25	6.5 to 27.5	1 to 26
Satellite antenna polarization	RHCP, LHCP or both	RHCP, LHCP or both	RHCP, LHCP or both
Earth station antenna gain toward satellite (dBi)	41 to 57.6	48 to 53	54 to 60
Earth station antenna polarization	RHCP, LHCP or both	RHCP, LHCP or both	RHCP, LHCP or both
Earth station antenna radiation diagram	Rec. ITU-R S.465	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	90 to 280	120 to 150	100 to 470
Typical Orbital altitude (km)	700	700	700
Typical inclination angle (degree)	98.2	98.2	98.2

3.6 25.5-27 GHz

The frequency band 25.5-27 GHz is used by systems with bandwidth requirements for raw data transmission and stored mission data exceeding the spectrum capacities provided in the bands

7 750-7 900 MHz and/or 8 025-8 400 MHz or which would face incompatibility with existing systems in those bands due to congestion/saturation. The characteristics for these systems can be found below in TABLE 12.

TABLE 12

System parameters for Stored Mission Data services in the band 25.5-27 GHz

Function	**Stored Mission Data**			
Satellite	Satellite C and other LEO Earth Observing Satellites	Satellites AN	Satellite AP (Generic)	Satellite AZ and other commercial LEO (Generic)
Earth stations	Stations 2, 4, 5, 18 and 63	Stations 4 and 5	Stations 5 and 18 Earth Stations in Central Europe (Generic)	Station 5, 6 and 18 Earth Stations worldwide (Generic)
Carrier frequency (MHz)	26 703.4	26 295 and 26 700	26 000	25 875 and 26 625
Information data rate (Mbits/s)	130	390.5	1 700	Up to 1900 Mbit/s per channel (average VCM) one channel @ 500 Msps (total: Up to 4 channels with frequency and polarization reuse)
Necessary bandwidth (MHz)	300	2 × 366 MHz	680	2 × 750 MHz
Modulation	SOQPSK-TG Shaped offset Quadrature PSK	OQPSK	16/32-APSK	VCM (multiple modulations up to 64-APSK)
Coding	Concatenated	RS (255,223)	SCCC	SCCC
Encoded data rate (Mbits/s)	300		up to 2 000	Up to 2 000 (VCM dependant)
Minimum elevation angle (degree)	5	5	5	5
Satellite antenna input power (dBW)	6.0	14.8 per carrier	10.4	15
Satellite antenna type	Steerable Parabolic	Steerable Parabolic	Steerable Parabolic	Steerable Parabolic
Satellite antenna radiation pattern	Pencil Beam	Pencil Beam	Pencil Beam	Pencil Beam
Satellite antenna gain toward nadir (dBi)	Varies with antenna pointing	Varies with antenna pointing	Varies with antenna pointing	Varies with antenna pointing
Satellite antenna maximum antenna gain (dBi)	39.0	33.3	32	32
Satellite antenna polarization	RHCP	RHCP	Circular	RHCP/LHCP
Earth station antenna diameter (m)	Station 2: 4 and 11.3 Station 4: 4 Station 5: 4, 7.3 and 11.3 Station 18: 7.3 Station 63: 11.3	Station 4: 4 Station 5: 7.3	Station 5: 4 Station 18: 7.3 Generic Station: 6.4	Station 4: 4 Station 5: 6.4 Station 18: 7.3 Generic Station: 3

TABLE 12 (*end*)

Function	Stored Mission Data			
Earth station antenna gain toward satellite (dBi)	55.4 dBi (4 m) 64.5 dBi (7.3 m) 67 dBi (11.3 m)	55.4 dBi (4 m) 65 dBi (7.3m)	55.4 dBi (4 m) 64.5 dBi (7.3 m) 63.1 dBi (6.4 m)	55 dBi (3 m) 55.4 dBi (4 m) 63 dBi (6.4 m) 64.5 dBi (7.3 m)
Earth station antenna polarization	RHCP	RHCP	Circular	RHCP
Earth station antenna radiation diagram	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	363	395	363	395

4 Raw data downlink and data dissemination systems for GSO satellites

This section provides the RF parameters needed to conduct interference assessments and sharing studies for raw data downlink and data dissemination for GSO satellite systems. The low and high data rate processed information is up-linked to satellites in the 2 025-2 110 MHz band, and relayed, along with interfering signals entering the satellite in the same band, to the earth station receivers in the band 1 670-1 698 MHz via fixed-gain satellite transponders.

The ever-increasing bandwidth for raw data transmission requires gradual migration from the band 1 670-1 698 MHz to higher frequency bands (7 450-7 550 MHz, 8 025-8 400 MHz, 18.1-18.4 GHz (Regions 1 and 3), 18.0-18.3 GHz (Region 2) and 25.5-27 GHz). Recommendation ITU-R SA.1024-1 provides some guidance for band selection for the Earth exploration-satellite service indicating the use of higher bands for higher data rate applications.

4.1 1 670-1 698 MHz

The 1 670-1 698 MHz band is used for the downlinking of raw instrument data to specific ground stations of satellite operators. The sub-band 1 690-1 698 MHz is used for broadcasting data to the user. Data transmissions contain low- and high-resolution images including calibration and navigation information. Primary users are national meteorological centres, universities, private forecasters, and television broadcasters. Tables 13, 14, 15 and 16 lists some typical characteristics for systems in this band.

TABLE 13

GSO EESS space-to-Earth raw data downlink and data dissemination in the band 1 670-1 698 MHz

<table>
<tr><th>Function</th><th colspan="2">HRIT</th><th colspan="3">LRIT</th></tr>
<tr><td>Satellite</td><td>Satellite O</td><td>Satellite P</td><td>Satellite M</td><td>Satellite O</td><td>Satellite P</td></tr>
<tr><td>Earth station(s)</td><td>High rate user station</td><td>High rate user station</td><td>Low rate user station</td><td></td><td>Low rate user station</td></tr>
<tr><td>Carrier frequency (MHz)</td><td>1 687.1</td><td>1 681 and 1 679</td><td>1 691</td><td>1 691</td><td>1697</td></tr>
<tr><td>Information data rate (Mbits/s)</td><td></td><td>11.6 and 9.3</td><td>0.128</td><td></td><td>0.09</td></tr>
<tr><td>Necessary bandwidth (MHz)</td><td></td><td>12 and 8</td><td>0.586</td><td></td><td>1</td></tr>
<tr><td>Modulation</td><td>QPSK</td><td>QPSK</td><td>BPSK</td><td>BPSK</td><td>QPSK</td></tr>
<tr><td>Coding</td><td>Con-catenated</td><td>BCH+LDPC</td><td>Con-catenated</td><td>Con-catenated</td><td>BCH+LDPC</td></tr>
<tr><td>Encoded data rate (Mbits/s)</td><td></td><td>7 and 5.6</td><td></td><td></td><td>0.09</td></tr>
<tr><td>Minimum elevation angle (degree)</td><td></td><td>Fixed pointing</td><td>Fixed pointing</td><td></td><td>Fixed pointing</td></tr>
<tr><td>Satellite antenna input power (dBW)</td><td rowspan="4">e.i.r.p.
55 dBm</td><td>13</td><td>10.2</td><td rowspan="4">e.i.r.p.
55 dBm</td><td>10</td></tr>
<tr><td>Satellite antenna type</td><td></td><td>Planar Cup Dipole</td><td></td></tr>
<tr><td>Satellite antenna radiation pattern</td><td>Earth coverage</td><td>Earth coverage</td><td>Earth coverage</td></tr>
<tr><td>Satellite antenna gain at nadir (dBi)</td><td>15.5</td><td>15.6</td><td>15.5</td></tr>
<tr><td>Satellite antenna maximum gain (dBi)</td><td></td><td>15.5</td><td>15.6</td><td></td><td>15.5</td></tr>
<tr><td>Satellite antenna polarization</td><td></td><td>Linear V and H</td><td>Linear N/S</td><td></td><td>Linear V</td></tr>
<tr><td>Earth station antenna diameter (m)</td><td></td><td>7.3</td><td>1</td><td></td><td>0.8</td></tr>
<tr><td>Earth station antenna gain toward satellite (dBi)</td><td rowspan="4"></td><td>40</td><td>22.5</td><td></td><td>21</td></tr>
<tr><td>Earth station antenna polarization</td><td>RHCP and LHCP</td><td>Linear N/S</td><td></td><td>Linear V</td></tr>
<tr><td>Earth station antenna radiation diagram</td><td>AP7-Annex 3</td><td>AP7-Annex 3</td><td></td><td>AP7-Annex 3</td></tr>
<tr><td>Earth station receiver noise temperature (K)</td><td>239</td><td>200</td><td></td><td>280</td></tr>
</table>

TABLE 14

GSO EESS space-to-Earth raw data downlink and data dissemination in the band 1 670-1 698 MHz

Function	Processed data	GVAR	Raw data downlink	
Satellite	Satellite P	Satellite M	Satellite M	Satellite P
Earth station		Station 16	Station 1	Station 8
Carrier frequency (MHz)	1 687.5	1 685.7	1 676.0	1 681.6
Information data rate (Mbits/s)	0.66	2.11	2.6	14
Necessary bandwidth (MHz)		4.22	5.2	
Modulation	DPSK	BPSK	QPSK	QPSK
Coding		Uncoded	Uncoded	Uncoded
Encoded data rate				
Minimum elevation angle (degree)	2	5	5	2
Satellite antenna input power (dBW)	10	14.5	6.9	10
Satellite antenna gain at nadir (dBi)	18.5	15.6	15.6	18.5
Satellite antenna maximum gain (dBi)		15.6	15.6	
Satellite antenna type		Planar Cup Dipole	Planar Cup Dipole	
Satellite antenna polarization	Linear Vertical	Linear N/S	Linear N/S	Linear Vertical
Satellite antenna radiation diagram		1st sidelobe of −6 dBi at 60 degrees	1st sidelobe of −6 dBi at 60 degrees	
Earth station antenna diameter (m)		9.1	16.4	
Earth station antenna gain toward satellite (dBi)	31.5	40.5	48.4	48.8
Earth station antenna polarization	Linear Vertical	Linear	Linear	Linear Vertical
Earth station antenna radiation diagram		AP7-Annex 3	AP7-Annex 3	
Earth station receiver noise temperature (K)	80	199.5	156	96

TABLE 15

GSO EESS space-to-Earth raw data downlink and data dissemination in the band 1 670-1 698 MHz

Function	GOES Rebroadcast	HRIT/EMWIN	EMWIN
Satellite	Satellite R	Satellite R	Satellite M
Earth station(s)	Various	Various	Ubiquitous user stations
Carrier frequency (MHz)	1 686.6	1 694.1	1 692.7
Information data rate (Mbits/s)	15.5	0.400	0.0192
Necessary bandwidth (MHz)	9.79 or 10.90	1.21	0.027
Modulation	QPSK or 8-PSK	QPSK	QPSK
Coding	DVB-S2	Concatenated	Concatenated
Encoded data rate (Mbits/s)	23.48017 or 17.332	0.927	
Minimum elevation angle (degree)	5	5	5
Power supplied to the input of satellite antenna (dBW)	16	12.3	1.14
Satellite antenna type	Horn	Horn	15.6
Satellite antenna radiation diagram/pattern	First sidelobe −26.7 dB @ 115 deg.	First sidelobe −2.5 dB @ 52 deg.	15.6
Satellite antenna gain at nadir (dBi)	17.2	17.3	Planar Cup Dipole
Satellite antenna maximum gain (dBi)	17.2	17.3	Linear N/S
Satellite antenna polarization	Dual RHCP/LHCP	Dual Linear	1st sidelobe of −6 dBi at 60 degrees
Earth station antenna diameter (m)	4.8 to 9.1	1	1
Earth station antenna gain toward satellite (dBi)	36.5 to 40.5	22.7	22.7
Earth station antenna polarization	Dual RHCP/LHCP	V	Linear
Earth station antenna radiation diagram/pattern	First sidelobe 21.5 dBi @ 2.2 deg.	First sidelobe 10.5 dBi @ 20 deg.	AP7-Annex 3
Earth station receiver noise temperature (K)	150	160	160

TABLE 16

GSO EESS space-to-Earth Raw data downlink and data dissemination in the band 1 670-1 698 MHz

Function	Multi-use Data Link	LRIT	Raw data downlink	LRIT, HRIT, Raw data downlink
Satellite	Satellite M	Satellite N	Satellite N	Satellite Q
Earth station(s)	Stations 1, 21 and 22	Stations 7 and 12	Stations 7 & 12	Stations 13, 14 and 15
Carrier frequency (MHz)	1 681.478	1 691	1 686.833	1 691.0 and 1 693.0
Information data rate (Mbits/s)	0.400	0.128	3.27	0.0025 to 1.0 Bandwidth 5 to 1 970 kHz
Necessary bandwidth (MHz)	0.400	0.660	5.4	
Modulation	QPSK	BPSK	QPSK	BPSK and QPSK
Coding	Uncoded			Uncoded
Encoded data rate (Mbits/s)				
Minimum elevation angle (degree)	5			5
Power supplied to the input of satellite antenna (dBW)	8.2	8	0.9	9.7
Satellite antenna type	Planar Cup Dipole			
Satellite antenna radiation diagram/pattern	1st sidelobe of −6 dBi at 60 degrees			
Satellite antenna gain at nadir (dBi)	15.6	13	13	12
Satellite antenna maximum gain (dBi)	17.2			
Satellite antenna polarization	Linear N/S			RHCP
Earth station antenna diameter (m)	7.2	13 1.5	13	3.8 1.5
Earth station antenna gain toward satellite (dBi)	39	47.5 and 27.8	45.6	34.0 26.0
Earth station antenna polarization	Linear			RHCP
Earth station antenna radiation diagram/pattern	AP7-Annex 3			Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	160	135 and 140	135	150

4.2 2 025-2 110 MHz

The 2 025-2 110 MHz band is used for processed data uplinks for dissemination to the users. Performance of the composite circuit depends on the performance of each individual link. Characteristics of some typical systems can be found below in Tables 17 and 18.

TABLE 17

GSO MetSat Earth-to-space processed data in the band 2 025-2 110 MHz for data dissemination to the users

Function	LRIT	Processed data		EMWIN
Satellite	Satellite M	Satellite M	Satellite P	Satellite M
Earth station(s)	Station 1	Station 1	Station 8	User stations
Carrier frequency (MHz)	2 033.0	2 027.7	2 047.5	2 034.7
Information data rate (Mbits/s)	0.128	2.11	1	0.0192
Necessary bandwidth (MHz)	0.586	4.22	2	0.027
Modulation	BPSK	BPSK	QPSK	QPSK
Coding	Concatenated	Uncoded		Concatenated
Encoded data rate (Mbits/s)	0.293			0.03494
Minimum elevation angle (degree)	5		2	5
Earth station antenna input power (dBW)	10.4	21.2	20	3
Earth station antenna gain toward satellite (dBi)	49.5	49.5	50	49.5
Earth station antenna polarization	Linear	Linear	Linear Vertical	Linear
Earth station antenna radiation diagram	Recommendation ITU-R S.465-6	Recommendation ITU-R S.465-6		Recommendation ITU-R S.465-6
Satellite antenna gain (dBi)	17	17	18.5	17
Satellite antenna polarization	Linear (N/S)	Linear (N/S)	Linear Vertical	Linear (N/S)
Satellite antenna radiation diagram	1st sidelobe of −13 dBi at 40 deg.	1st sidelobe of −13 dBi at 40 deg.		1st sidelobe of −13 dBi at 40 deg.
Satellite receiver noise temperature (K)	588	588		588

TABLE 18

GSO MetSat Earth-to-space processed data in the band 2 025-2 110 MHz for data dissemination to the users

Function	HRIT/EMWIN	LRIT		
Satellite	Satellite R	Satellite N	Satellite P	Satellite P
Earth station	Stations 1 and 3	Stations 7 and 12	Stations 8 and 9	
Carrier frequency (MHz)	2 027.1	2 101.5	2 051	2 057
Data rate (Mbits/s)	0.400	0.128		0.256
Necessary bandwidth (MHz)	1.21	0.660		
Modulation	PSK	QPSK	QPSK	
Coding	Concatenated		FEC	
Encoded data rate (Mbits/s)	0.927			
Minimum elevation angle (degree)	5		2	
Earth station antenna input power (dBW)	18.8	20 and 17	20	21
Earth station antenna gain toward satellite (dBi)	49.6	47.5	50	46
Earth station antenna polarization	RHCP		Linear Vertical	CR
Earth station antenna radiation diagram	ITU-R S.465-6			AP7-Annex 3
Satellite antenna gain (dBi)	17.3	3	18.5	13
Satellite antenna polarization	RHCP		Linear Vertical	
Satellite antenna radiation diagram	1^{st} sidelobe of 0.5 dBi at 38 deg.			
Satellite receiver noise temperature (K)	1 007	700		

4.3 7 450-7 550 MHz and 8 175-8 215 MHz

The band 7 450-7 550 MHz is used for raw and processed data downlink (for dissemination to user stations) or specific ground stations of the satellite operator. The band 8 175-8 215 MHz is used for the uplink of processed data for dissemination to user stations. The characteristics for typical system in these bands are listed in Table 19.

TABLE 19

GSO MetSat for uplinking of processed data and data dissemination of to the users in the frequency bands 7 450-7 550 and 8 175-8 215 MHz

Function	**High rate data relay**		**APT**	**High rate data relay**	**HRIT**
Satellite	Satellite Q			Satellite P	
Earth station	Stations 13, 14 and 15			Stations 8 and 9	
Carrier frequency (MHz)	7 475 (transmit)	8 195 (receive)	7 500 (transmit)	7 500 (transmit)	8 185 and 8 205 (receive)
Transmit (receive) data rate (Mbits/s)	5.12; 30.72	0.331; 0.663; 1.31; 1.97; 5.12; 30.72	61.44		
Necessary bandwidth (MHz)					
Modulation	BPSK	PSK; QPSK	BPSK	GMSK	QPSK
Coding	None	None	None	LDPC	LDPC
Encoded data rate					
Satellite antenna input power (dBW)	9.5	-	9.5	17	13
Satellite antenna gain toward ES (dBi)	36	36	36	30	30
Satellite antenna polarization	Circular, CR	Circular, CL	Circular, CR	CL and CR	CR
Satellite antenna radiation diagram	Recommendation ITU-R S.672				
Earth station antenna gain toward satellite (dBi)	47 (3.8 m) 50 (5 m)	48 (3.8 m) 50 (5 m)	47 (3.8 m) 50 (5 m)	59 (13 m)	
Earth station antenna polarization	LHCP	LHCP	RHCP	LHCP & RHCP	RHCP
Earth station antenna radiation diagram	Recommendation ITU-R S.465-6			AP7-Annex 3	AP7-Annex 3
Earth station receiver noise temperature (K)	150			270	270
Minimum elevation angle (degree)	3				

4.4 8 025-8 400 MHz

The band 8 025-8 400 MHz is used for raw data downlink to specific ground stations of the satellite operator. The characteristics for typical system in these bands are listed in Table 20.

TABLE 20

GSO EESS space-to-Earth raw data in the frequency bands 8 025-8 400 MHz

Function	Raw Data Downlink: Continuous real-time data feed
Satellite	Satellite R
Earth station(s)	Stations 1 and 3
Carrier frequency (MHz)	8 220
Information data rate (Mbits/s)	105
Necessary bandwidth (MHz)	120
Modulation	QPSK
Coding	LDPC rate 7/8
Encoded data rate (Mbits/s)	120
Minimum elevation angle (degree)	Fixed Pointing
Satellite antenna input power (dBW)	10.4
Satellite antenna radiation diagram/pattern	First sidelobe 9.9 dBi @ 4.5 deg.
Satellite antenna gain at nadir (dBi)	0 dBi to −5 dBi
Satellite antenna maximum gain (dBi)	34.3
Satellite antenna polarization	Dual Linear
Earth station antenna diameter (m)	16.4
Earth station antenna gain toward satellite (dBi)	59.0
Earth station antenna polarization	Dual Linear
Earth station antenna radiation diagram/pattern	Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	150

4.5 25.5-27 GHz

The band 25.5-27 GHz is used by systems with bandwidth requirements for raw data transmission and stored mission data exceeding the spectrum capacities provided in the bands 7 750-7 900 MHz and/or 8 025-8 400 MHz or which would face incompatibility with existing systems in those bands due to congestion/saturation. Table 21 includes some typical characteristics for these systems. The mission data acquisition systems below are different from the non-GSO SMD 25.5-27.0 GHz systems in Section 3.6 because they do not require recorded data playback or recorded data acquisition where reception of data that has been collected and stored on the spacecraft and transmitted upon command. The systems in this section are in view of their associated ground stations almost all the time.

TABLE 21

GSO EESS space-to-Earth raw data downlink in the band 25.5-27 GHz

Function	**Mission Data Acquisition (MDA)**		
Satellite	Satellite AK	Satellite AL	Satellite P
Earth station(s)	Station 17	Stations 35 and 36	Stations 8 and 66
Carrier frequency (MHz)	26 500	26 360 and 26 760	26 600
Information data rate (Mbits/s)	150	164 (channel 1) 246 (channel 2)	1 Gbit/s
Necessary bandwidth (MHz)		287 MHz (Ch1) and 452 MHz (Ch 2)	600
Modulation	OQPSK	OQPSK	8PSK
Coding	Convolutional ½ Reed-Solomon	Convolutional ½ Reed-Solomon 255/253	LDPC rate 7/8
Encoded data rate		188 Msymbol/s (channel 1) 282 Msymbol/s (channel 2)	400 Mbits/s
Minimum elevation angle (degree)		10	
Satellite antenna input power (dBW)	−2.8	13	17
Satellite antenna gain at nadir (dBi)	43.5	Steerable reflector, ±8.7 degrees	43
Satellite antenna maximum gain (dBi)	43.5	42.5	43
Satellite antenna polarization	LHCP and RHCP	RHCP or LHCP	RHCP and LHCP
Satellite antenna radiation diagram	0.75 m reflector	1m single reflector	
Earth station antenna gain toward satellite (dBi)	70.4	60.6	58
Earth station antenna polarization	LHCP or RHCP	LHCP and RHCP	LHCP and RHCP
Earth station antenna radiation diagram		Rec. ITU-R S.580	Rec. ITU-R S.580
Earth station receiver noise temperature (K)	460.3	200	330

5 Data collection systems

Data collection systems (DCS) in use are the Advanced Data Collection System (A-DCS) which transmits to GSO, HEO or LEO satellites. The satellites from several administrations and international agencies support programs that use the satellite transponders for relaying data from terrestrial platforms, which can be fixed terrestrial, mobile, buoys, or animals.

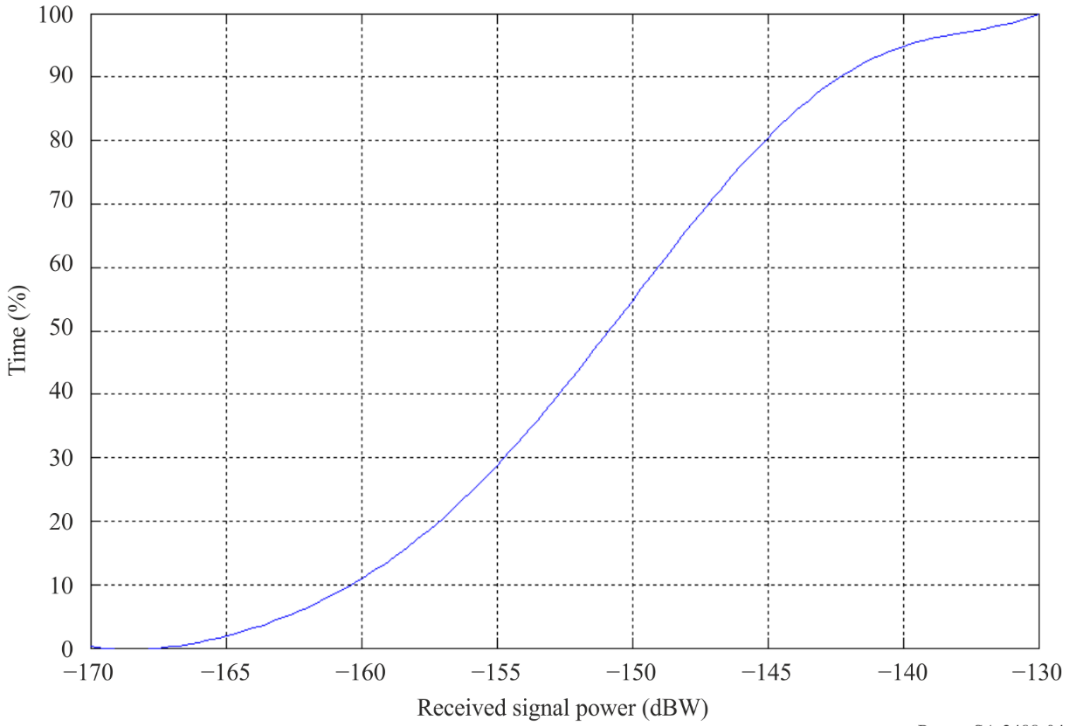
The programs are not always sponsored by the same agencies that provide the satellites and may not be the same administrations. The agencies who provide the satellite relay may assign time and frequency slots for data transmissions or the transmissions may be random. The technical characteristics for the terrestrial platforms are those of the various agencies that use the satellite relay and are not those of the satellite system directly. However, the transmitters on the platforms must conform to specifications of the satellite relay provider.

5.1 Non-GSO data collection systems

Non-GSO data collection system platform signals are uplinked in the band 401-403 MHz using signals through satellites in low-Earth or Highly elliptical orbits. The data rate ranges from 100 to 4 800 bit/s. The data collection platforms (DCP), operating with HEO satellites (ARCTICA-M) usually use a low-gain antenna (up to 6 dBi), maximum uplink e.i.r.p. would not exceed 16-18 dBW. Bent-pipe transponder is used to relay the DCS data to associated Earth stations. For LEO systems DCP typically uses a low-gain antenna (up to 3 dBi maximum at 40-degree elevation angle), and can be a mobile or fixed platform. The non-GSO satellite DCS processor demodulates the uplink DCS data, multiplexes the data with other telemetry, and transmits the corresponding digital data to the ground. The power received from one DCP will differ from that received from another. Figure 4 provides statistics of the ARGOS DCS uplink power measured at the satellite receiver.

FIGURE 4

Statistical distribution of uplink signal levels from measurements: received signal power vs. time (%)



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5.1.1 401-403 MHz

Tables 22 and 23 contain some of the DCP characteristics for the 401-403 MHz frequency band. Recommendation ITU-R SA.1627 has additional details.

TABLE 22

Non-GSO system parameters for platform uplinks in the band 401-403 MHz

Function	**ARGOS Low data rate**	**ARGOS (HD-A3) High Data Rate**	**Brazilian DCS**	**ICARUS**
Satellite	Satellites A, D, F and AM	Satellites A, F and AM	Satellite Z	Satellite AO
Earth station	DCS platform			
Carrier frequency (MHz)	Multiple channels	Multiple channels	401.62, 401.65	402.25
Information data rate (Mbits/s)	0.0004	0.0048	1.6	0.000521
Necessary bandwidth (MHz)	0.070	0.0096		1.2
Modulation	BPSK	GMSK	BPSK	8PSK/QPSK/BPSK
Coding	None	Convolutional 7, 3/4	None	LDPC
Encoded data rate		9 600 bit/s		900 kcps
Minimum elevation angle (degree)	5	5	5	40
Earth station antenna input power (dBW)	See Fig. 1 for measurements of uplink signal level statistics at the satellite receiver in Rec. ITU-R SA.1627	≤ 7	3	−25.76
Earth station antenna gain toward satellite (dBi)		Nominal 2 dBi Deployment dependent	−2	max. 1.76
Earth station antenna polarization		Linear	RHCP	Linear
Earth station antenna radiation diagram		Cardioid	Short dipole	Short dipole
Satellite antenna type		Helix	Helix	Phased array
Satellite antenna gain (dBi)		4	−6 (min) −1.5 (max)	>10 dBi in target pattern
Satellite antenna polarization		Circular	RHCP	RHCP
Satellite antenna radiation diagram		Cardioid		
Satellite receiver noise temperature (K)	600	600	924	500

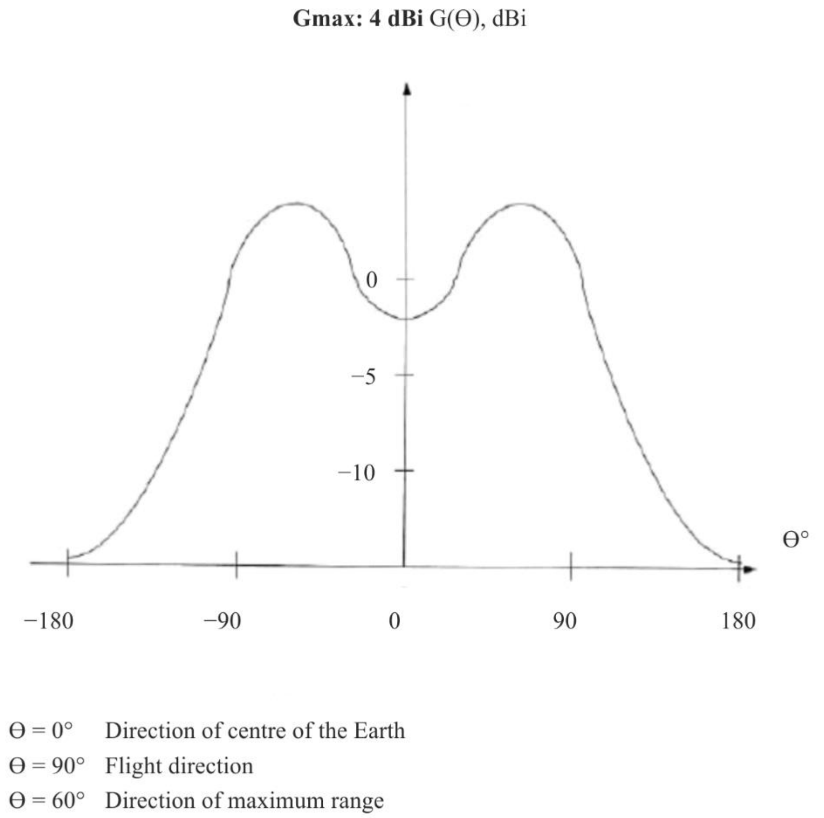
TABLE 23

Non-GSO system parameters for platform uplinks in the band 401-403 MHz

Function	**Low data rate**	
Satellite	Satellite B	Satellite BF
Earth station		
Carrier frequency (MHz)	Multiple Channels	401-403 MHz
Information data rate (bits/s)	400; 1200	100; 1200
Necessary bandwidth (kHz)	1.6; 2.4	0.4; 2.4
Modulation	PCM/PM; QPSK	BPSK/QPSK
Coding	None	None
Encoded data rate		
Minimum elevation angle (degree)	5	5
Earth station antenna input power (dBW)	10	12
Earth station antenna gain toward satellite (dBi)	2 Deployment dependent	6
Earth station antenna polarization	RHCP	RHCP
Earth station antenna radiation diagram	Non-Directional	Non-Directional
Satellite Antenna Type	Spiral	Spiral
Satellite antenna gain (dBi)	4	15.8
Satellite antenna polarization	RHCP	RHCP
Satellite antenna radiation diagram	See Fig. 4	See Fig. 5
Satellite receiver noise temperature (K)	600	500

FIGURE 5

Satellite antenna radiation diagram for Satellite B



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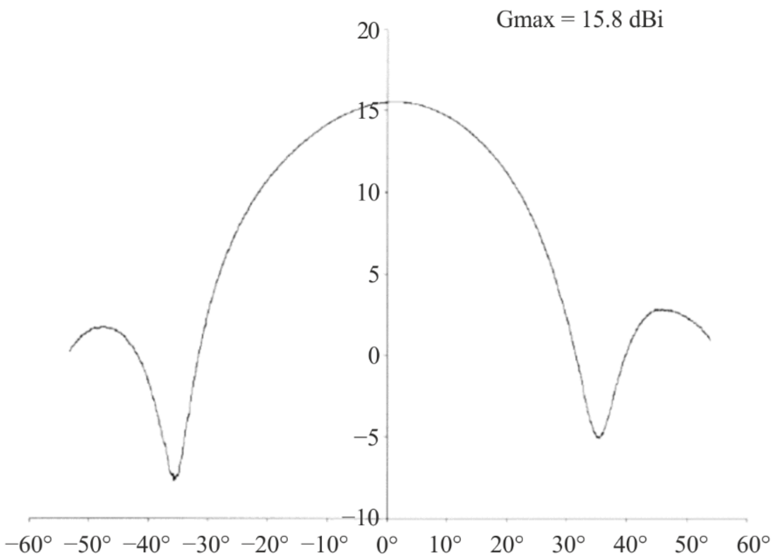
NOTE – Typical non-GSO simple antenna radiation diagram to meet PFD requirements.

FIGURE 6

Satellite antenna radiation diagram for Satellite BF



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5.1.2 460-470 MHz

The 460-470 MHz frequency band is used by the DCS to interrogate and command terrestrial platforms from GSO and non-GSO satellites. For operating DCS satellites that transmit a carrier frequency of 465.9875 MHz, Table 24 lists in-band technical characteristics of non-GSO DCS satellites.

In order to have reduced PFD levels on the ground, future satellites may implement spread spectrum multiple access (SSMA) transmission techniques.

Figure 7 graphically illustrates the maximum and minimum antenna gain patterns for the non-GSO DCPI system.

Similarly, for Icarus, which transmits a carrier frequency of 468.1 MHz, TABLE 25 lists in-band technical characteristics of non-GSO DCS satellites.

The Icarus antenna pattern is shown in Fig. 8.

TABLE 24

Non-GSO DCS technical characteristics (space-to-Earth)

Parameter	Value
Satellite	Satellites Y, AN and AJ
Earth station	worldwide
Carrier frequency (MHz)	465.9875 (±5 kHz)
Information data rate	
Necessary bandwidth (MHz)	1.00
Modulation	SSMA/OQPSK
Coding	NRZ-M
Encoded data rate	
Minimum elevation angle (degree)	5
Transmitter power (dBW)	10
Data bit rate (bit/s)	977.52
Chip rate (Msps)	1
Chip duration (seconds)	$1*10^{-6}$
Bandwidth (MHz)	2
Antenna gain (dBi) (1)	Maximum: −9.2 to 1.3 Minimum: −14 to -6.8 (90 to 5 degrees elevation angle)

TABLE 25

Non-GSO ICARUS technical characteristics (space-to-Earth)

Parameter	Value
Satellite	Satellite AO
Earth station(s)	Mobile; migratory animals tagged with transmitters
Carrier frequency (MHz)	468.1 (±5 kHz)
Information data rate	
Necessary bandwidth	
Modulation	8PSK/QPSK/BPSK
Coding	
Encoded data rate	
Minimum elevation angle (degree)	
Transmitter power (dBW)	5
Data bit rate (kbit/s)	
Symbol rate (Msps)	0.03375
Bandwidth (kHz)	50
Symbol duration (seconds)	0.03×10^{-3}
Antenna gain (see Fig. 3) (dBi)	Max. 5 dBi at 46 degrees; 2.3 dBi at boresight

FIGURE 7

Antenna gain patterns for non-GSO DCPI (DCS)

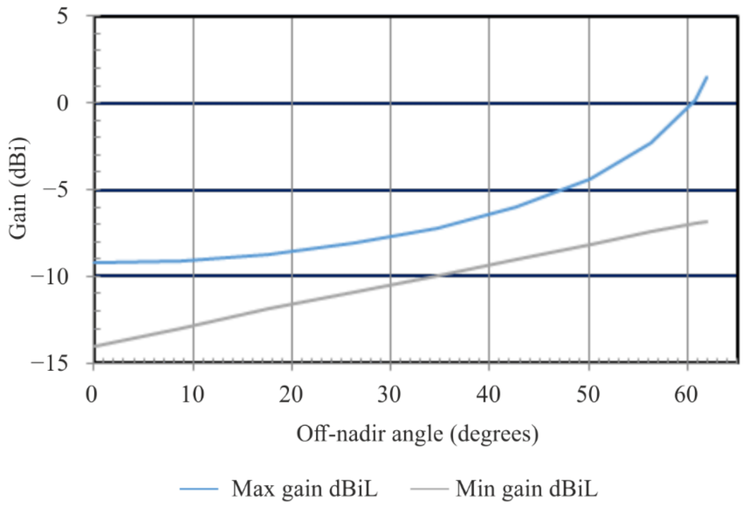

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FIGURE 8

ICARUS antenna gain pattern

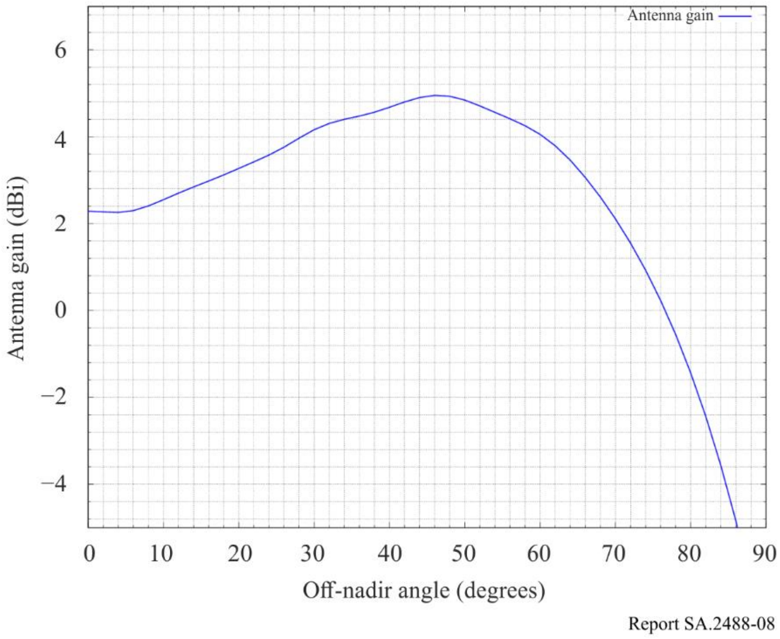


Table 26 presents an incumbent non-GSO EESS satellite BA characteristics, using the 460-470 MHz for a system not related to DCS.

TABLE 26

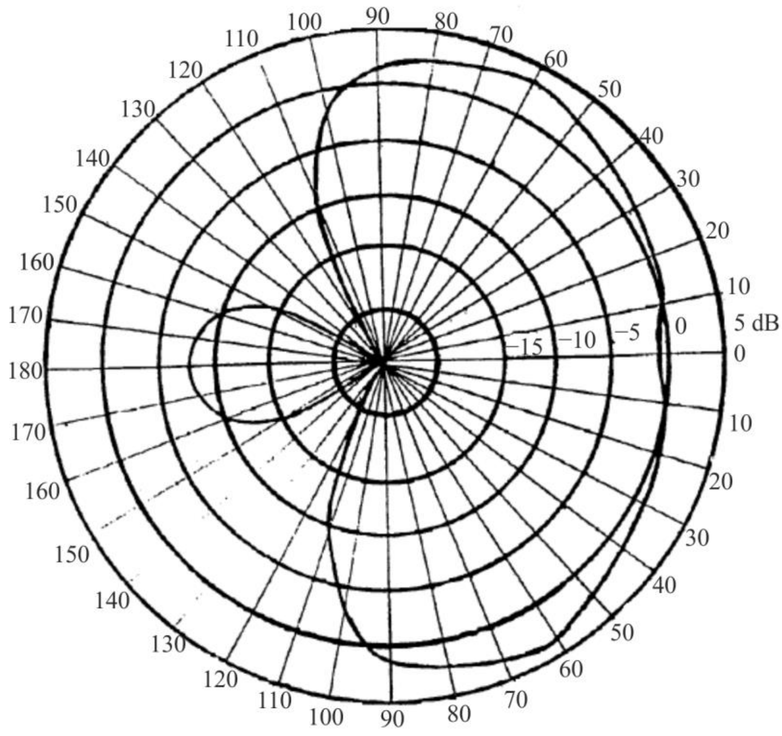
Non-GSO EESS Satellite BA technical characteristics

Parameter	Value
Satellite	Satellite BA
Orbit altitude (km)	1 000
Orbit inclination (degree)	99.4
Carrier frequency (MHz)	465
Emission class	4M00G1D
Antenna power (dBW)	10
Power spectral density (dBW/Hz)	−55
Maximum antenna gain (dBi)	3.3
Antenna pattern	See Fig. 4

Satellite BA antenna pattern in the specified frequency band is presented in Fig. 9.

FIGURE 9

Satellite BA antenna pattern



5.1.3 1 670-1 699 MHz

Data Collection Platforms (DCP) data include a number of environmental parameters that have an uplink in the 401-403 MHz band and a downlink in the 1 670-1 699 MHz band. Typical characteristics for downlink are listed in Table 27.

TABLE 27

System parameters for non-GSO DCS downlinks in the band 1 670-1 699 MHz

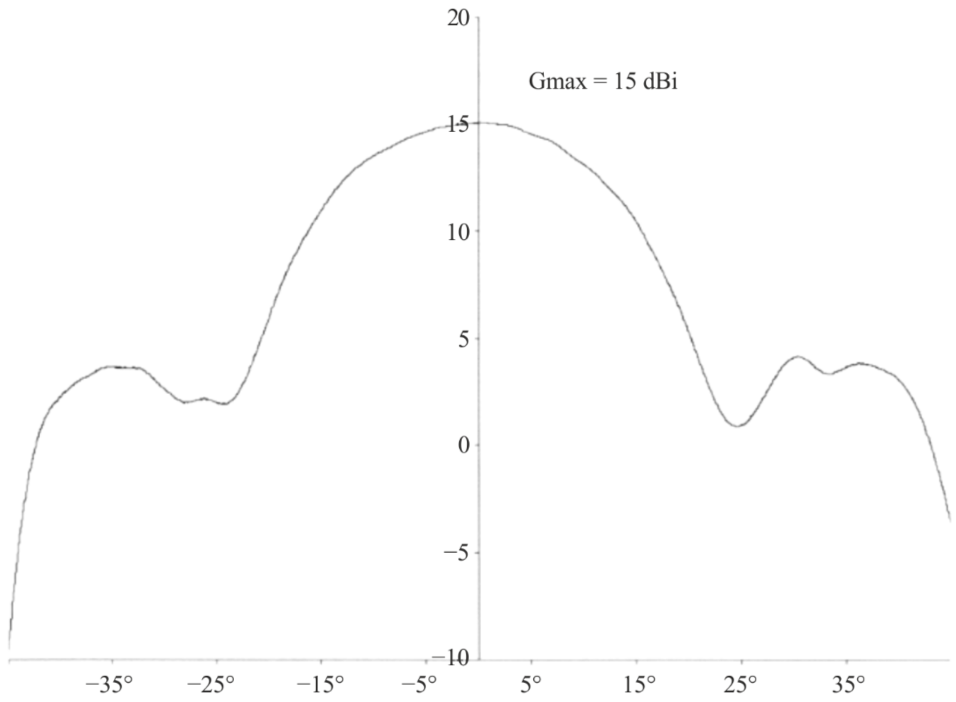
Function	**DCPR**
Satellite	Satellite BF
Earth station(s)	Stations 13, 14 and 15
Carrier frequency (MHz)	1 697-1 699
Information data rate (bits/s)	100-1 200
Necessary bandwidth (kHz)	0.4-2.4
Modulation	BPSK/QPSK
Coding	None
Encoded data rate	-
Minimum elevation angle (degree)	5
Satellite antenna input power (dBW)	9
Satellite antenna type	Spiral
Satellite antenna radiation pattern	See Fig. 6
Satellite antenna gain at nadir (dBi)	15

TABLE 27 (*end*)

Function	DCPR
Satellite antenna maximum gain (dBi)	15
Satellite antenna polarization	RHCP
Earth station antenna gain toward satellite (dBi)	41
Earth station antenna polarization	RHCP
Earth station antenna radiation diagram	Rec. ITU-R S.580
Earth station receiver noise temperature (K)	150

FIGURE 10

Satellite antenna radiation diagram for Satellite BF



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5.2 GSO Data Collection systems

Data Collection Platforms (DCPs) transmit Manchester-encoded PSK signals (DCP reports) in the 401-403 MHz band to GSO meteorological satellites at a data rate of 300 bit/s. High rate DCPs can operate up to 1 200 bit/s. The satellite relays these DCP reports (DCPR) to a specific station of the satellite operator as well as user terminals in the 1 670-1 698 MHz band. The satellite transponder, which is channelized to accommodate several hundred simultaneous DCPR transmissions, has an automatic gain control (AGC) that maintains the downlink DCPR e.i.r.p. constant regardless of the transponder input power.

Individual DCPs assigned to a given DCPR channel time-share that channel, the bandwidth of which is 750 Hz for 300 bit/s terminals and 2 250 Hz for 1 200 bit/s terminals for GOES NOP and the GOES-R series. For various reasons, the power radiated by one platform will differ from that radiated by another. Measurements of DCP e.i.r.p. in one GOES DCPR channel over a 24 h period have provided the statistics summarized in Table 21. In simulations, it can be assumed that all DCPs assigned to a given channel time-share the channel equally. To determine the total DCP e.i.r.p., the number of DCPR channels occupied simultaneously must be postulated. Assuming an average DCP e.i.r.p. of 15 dBW, and assuming that 100 DCPR channels are simultaneously active, the sum of the DCP e.i.r.p. values will be 35 dBW.

For the GOES-R series, the DCPR transponder has been designed to operate with 250 simultaneous channels with an average e.i.r.p. of 11 dBW. The maximum total uplink power would still be 35 dBW.

TABLE 28

GSO DCPR e.i.r.p. statistics

e.i.r.p. of a single DCP in the channel (dBW)	Number of DCPs having this e.i.r.p. in the channel	Number of DCPs having this e.i.r.p. or less
4	0	0
5	3	3
6	1	4
7	4	8
8	0	8
9	5	13
10	17	30
11	12	42
12	12	54
13	16	70
14	28	98
15	36	134
16	46	180
17	34	214
18	5	219
19	1	220
20	0	220

5.2.1 401-403 MHz

Data Collection Platforms (DCP) data include a number of environmental parameters that have an uplink in the 401-403 MHz band and a downlink in the 1 670-1 698 MHz band. Typical characteristics for both the uplink and downlink are listed in Table 29 and in Tables 30 and 31 respectively.

TABLE 29

System parameters for GSO DCS platform uplinks in the band 401-403 MHz

Function	**DCPR**			
Satellite	Satellite M and R	Satellite N	Satellite P	Satellites Q and AY
Earth station	DCS Platform	DCS platform	DCS platform	DCS platform
Carrier frequency (MHz)	401.7 to 402.1 Regional platforms operate between 401.7 and 402.0355	401.7-402.5	401.1-401.4 (100 channels) 402.0-402.1 (33 channels)	401.5-402.5
Information data rate (bit/s)	300 1 200 0 CW Beacon	300 (SRDCP) 1 200 (HRDCP) 0 CW Beacon		400; 1 200
Receiver bandwidth (kHz)	480	750		1 000
Modulation	8PSK	PCM/SP-L/PM	BPSK	BPSK/QPSK
Coding	Trellis rate 2/3	RS (255, 223) (for HRDCP)		None
Encoded data rate				
Minimum elevation angle (degree)	Fixed pointing			
Earth station antenna input power (dBW)	For GOES-NOP see Table 22 for measurements of platform uplink e.i.r.p. statistics. For GOES-R (GOES-16) the nominal e.i.r.p. is 11 dBW for 300 bit/s and e.i.r.p. of 17 dBW for 1 200 bit/s	up to 13	7	12
Earth station antenna gain toward satellite (dBi)		Omni: 5.7 Yagi: 11	10	6
Earth station antenna polarization	RHCP	RHCP	RHCP	RHCP
Earth station antenna radiation diagram	Yagi	Omni Yagi		
Satellite antenna type	Helix			
Satellite antenna gain (dBi)	14.0	3.9	10.6	12/15
Satellite antenna polarization	RHCP	RHCP	RHCP	RHCP
Satellite antenna radiation diagram	1st sidelobe of −2 dBi @50 degrees			
Satellite receiver noise temperature (K)	534	296	650	500/550

5.2.2 1 670-1 698 MHz

TABLE 30

System parameters for GSO DCS downlinks in the band 1 670-1 698 MHz

Function	**DCPR**		
Satellite	Satellite M	Satellite N	Satellite P
Earth station(s)	Station 1	Station 7 & 12	Station 8
Carrier frequency (MHz)	1 694.5 1 694.8	1 675.281	1 709.5 [(1)])
Information data rate (bits/s)	300 or 1 200 per channels	300 (SRDCP) 1 200 (HRDCP) per channel	100
Necessary bandwidth (kHz)	0.3 or 1.2	750 (for all channels)	
Modulation	8PSK	PCM/SP-L/PM	
Coding	Trellis		
Encoded data rate			
Minimum elevation angle (degree)	Fixed pointing		
Satellite antenna input power (dBW)	8	−34 (per channel)	
Satellite antenna type	Planar Cup Dipole		
Satellite antenna radiation pattern	1st sidelobe of −6 dBi at 60 degrees		
Satellite antenna gain at nadir (dBi)	15.6	11	
Satellite antenna maximum gain (dBi)	15.6	11	
Satellite antenna polarization	Linear N/S	Linear Horizontal	Linear Vertical
Earth station antenna gain toward satellite (dBi)	38	45.5	48.8
Earth station antenna polarization	Linear	Linear Horizontal	Linear Vertical
Earth station antenna radiation diagram	Rec. ITU-R S.465-6		
Earth station receiver noise temperature (K)	200	141	96

(1) The early FY-2 series satellite systems used this frequency outside of the 1 670-1 698 MHz band for the DCS downlink.

TABLE 31

System parameters for GSO DCS downlinks in the band 1 670-1 698 MHz

Function	**DCPR**		
Satellite	Satellite R	Satellite P	Satellites Q and AY
Earth station(s)	Stations 1 and 3	Stations 8 and 9	Stations 13, 14 and 15
Carrier frequency (MHz)	1 679.9 1 680.2	1 688	1 696-1 698
Information data rate (bit/s)	300/1 200 With coding 1 800	600	100-1 200
Necessary bandwidth (kHz)	400	4 000 (for all channels)	0.4-2.4 (1 000 kHz for all channels)
Modulation	8PSK	QPSK	BPSK/QPSK
Coding	Trellis	Convolutional	None
Encoded data rate			
Minimum elevation angle (degree)	Fixed pointing		5
Satellite antenna input power (dBW)	9	–0.4	9.7/5.9
Satellite antenna type	Horn		
Satellite antenna radiation pattern	1st sidelobe of −2.5 dBi at 52 deg.		
Satellite antenna gain at nadir (dBi)	16.2	15.5	12/15
Satellite antenna maximum gain (dBi)	16.2		
Satellite antenna polarization	Linear	Linear Vertical	LRHCP
Earth station antenna gain toward satellite (dBi)	47.5	44.3	44/39.6/35.7
Earth station antenna polarization	Linear	Linear Vertical	HRHCP
Earth station antenna radiation diagram	Rec. ITU-R S.465-6		Rec. ITU-R S.465-6 / S.580
Earth station receiver noise temperature (K)	200	200	150/200/250

5.3 GSO DCS interrogated systems

Geostationary satellites relay PSK-modulated DCP interrogations (DCPI) from a specific station of the satellite operator in the 2 025-2 110 MHz band to the DCPs in the 460-470 MHz band.

Though the satellite DCPI transponder is hard-limiting rather than linear, downlink power sharing is much the same as it is for the DCPR transponder. Tables 32 and Table 33 include some typical characteristics for these bands.

5.3.1 2 025-2 110 MHz

TABLE 32

GSO system parameters for DCS uplinks in the band 2 025-2 110 MHz

Function	DCPI	DCPI
Satellite	Satellite M	Satellite R
Earth station	Station 1	Stations 1 and 3
Carrier frequency (MHz)	2 034.8875 2 034.9000 2 034.9125	2 032.775 2 032.825
Receiver bandwidth (kHz)	11.0	44.5
Modulation	BPSK	QPSK
Coding	None	DSSS
Encoded data rate (kcps)		22.225
Minimum elevation angle (degree)	Fixed pointing	Fixed pointing
Earth station antenna input power (dBW)	4	3
Earth station antenna gain toward satellite (dBi)	47.6	49.6
Earth station antenna polarization	Linear	RHCP
Earth station antenna radiation diagram	AP7-Annex 3	AP7-Annex 3
Satellite antenna type	Planar Cup Dipole	Planar Cup Dipole
Satellite antenna gain (dBi)	12.9	16.5
Satellite antenna polarization	Linear	Linear
Satellite antenna radiation diagram	Earth coverage	Earth coverage
Satellite receiver noise temperature (K)	570	1 043

5.3.2 460-470 MHz

Systems in the 460-470 MHz band are used for transmitting commands and configuration data to Earth-based platforms. Using this service is optional for the platform owners. However, transmissions are continuous even without specific messages.

TABLE 33

GSO system parameters for DCS downlinks in the band 460-470 MHz

Function	Interrogate platforms (DCPI)	Interrogate platforms (DCPC)
Satellite	Satellite M	Satellite R
Earth station	DCS platform	DCS Platform
Carrier frequency (MHz)	468.8125 468.8250 468.8375	468.775 468.825
Information data rate (bit/s)	5 500	350
Necessary bandwidth (MHz)	0.011	0.0445
Modulation	BPSK	QPSK
Coding	None	DSSS
Encoded data rate (kcps)		22.225
Minimum elevation angle (degree)	5	5
Satellite antenna input power (dBW)	5.2	5
Satellite antenna type	Planar Cup Dipole	Planar Cup Dipole
Satellite antenna gain at nadir (dBi)	10.6	14.5
Satellite maximum antenna gain (dBi)	10.6	14.5
Satellite antenna polarization	RHCP	RHCP
Satellite antenna radiation diagram	Earth coverage	Earth coverage
Earth station antenna type	Yagi on land Monopole on buoy	Yagi on land Monopole on buoy
Earth station antenna radiation pattern	Yagi varies per installation Monopole-Cardioid	Yagi varies per installation Monopole-Cardioid
Earth station antenna gain toward satellite (dBi)	Land 13 Buoy 3	Land 13 Buoy 3
Earth station antenna polarization	RHCP	RHCP
Earth station receiver noise temperature (K)	1 338	1 338

Annex A

Antenna radiation diagrams/patterns

A.1 Introduction

Although measured patterns are preferable, representative patterns have been developed by the ITU and references to them are used in this Report. This Annex presents and discusses the referenced antenna gain patterns.

A.2 Earth station antennas

Pattern from ITU Radio Regulations Appendix 7, Annex 3 (see Note 1 below)

$$G(\varphi) = \begin{cases} G_{amax} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda} \varphi \right)^2 dBi & \text{for } 0 < \varphi < \varphi_m \\ G_1 \; dBi & \text{for } \varphi_m \leq \varphi < \varphi_r \\ 29 - 25 \log \varphi \; dBi & \text{for } \varphi_r \leq \varphi < 36° \\ -10 \; dBi & \text{for } 36° \leq \varphi \leq 180° \end{cases} \quad (1)$$

$$G_1 = \begin{cases} -1 + 15 \log (D/\lambda) \quad \text{dBi} & \text{for } D/\lambda \geq 100 \\ -21 + 25 \log (D/\lambda) \quad \text{dBi} & \text{for } 35 \leq D/\lambda < 100 \end{cases} \quad (2)$$

$$\varphi_m = \frac{20\,\lambda}{D} \sqrt{G_{amax} - G_1} \quad \text{degrees}$$

$$\varphi_r = \begin{cases} 15.85 (D/\lambda)^{-0.6} \quad \text{degrees} & \text{for } D/\lambda \geq 100 \\ 100 (\lambda / D) \quad \text{degrees} & \text{for } 35 \leq D/\lambda < 100 \end{cases} \quad (3)$$

NOTE 1 – In cases where $\frac{D}{\lambda}$ is not given, it may be estimated from the expression $20 \log \frac{D}{\lambda} \approx G_{max} - 7.7$, where G_{max} is the main lobe antenna gain (dBi).

Pattern from ITU Radio Regulations Appendix 8, Annex 3 (See Note 2 below)

a) for values of $\frac{D}{\lambda} \geq 100$ (maximum gain ≥ 48 dBi approximately) (See Note 3 below):

$G(\varphi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda} \varphi \right)^2$ for $0 < \varphi < \varphi_m$

$G(\varphi) = G_1$ for $\varphi_m \leq \varphi < \varphi_r$

$G(\varphi) = 32 - 25 \log \varphi$ for $\varphi_r \leq \varphi < 48°$

$G(\varphi) = -10$ for $48° \leq \varphi < 180°$

where:

D: antenna diameter } expressed in the same unit

λ: wavelength } expressed in the same unit

φ: off-axis angle of the antenna, in degrees, equal to θ_t or θ_g, as applicable

G_1: gain of the first sidelobe = $2 + 15 \log \frac{D}{\lambda}$.

$$\varphi_m = \frac{20\,\lambda}{D} \sqrt{G_{max} - G_1} \quad \text{degrees}$$

$$\varphi_r = 15.85 \left(\frac{D}{\lambda} \right)^{-0.6} \quad \text{degrees}$$

b) for values of $\frac{D}{\lambda} < 100$ (maximum gain < 48 dBi approximately) (see Note 3 below):

$G(\varphi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda}\varphi\right)^2$ for $0 < \varphi < \varphi_m$

$G(\varphi) = G_1$ for $\varphi_m \le \varphi < 100 \frac{\lambda}{D}$

$G(\varphi) = 52 - 10 \log \frac{D}{\lambda} - 25 \log \varphi$ for $100 \frac{\lambda}{D} \le \varphi < 48°$

$G(\varphi) = 10 - 10 \log \frac{D}{\lambda}$ for $48° \le \varphi \le 180°$

NOTE 2 – These patterns are also described in Recommendation ITU-R F.699-8 (*recommends* 2.1.1 and 2.1.2).

NOTE 3 – In cases where $\frac{D}{\lambda}$ is not given, it may be estimated from the expression $20 \log \frac{D}{\lambda} \approx G_{max} - 7.7$, where G_{max} is the main lobe antenna gain (dBi).

Pattern from Recommendation ITU-R S.465-6

$G = 32 - 25 \log \varphi$ dBi for $\varphi_{min} \le \varphi < 48°$ (4)

$G = -10$ dBi for $48° \le \varphi \le 180°$

where:

$\varphi_{min} = 1°$ or $100\ \lambda/D$ degrees, whichever is the greater, for $D/\lambda \ge 50$

$\varphi_{min} = 2°$ or $114\ (D/\lambda)^{-1.09}$ degrees, whichever is the greater, for $D/\lambda < 50$

This pattern does not contain representation of the main lobe. The mainlobe pattern from RR Appendix **7** Annex 3 can be considered.

Pattern from Recommendation ITU-R S.580-6

This Recommendation provides design objectives for antennas of earth stations operating with geostationary satellites:

1 That new antennas of an earth station operating with a geostationary satellite should have a design objective such that the gain, *G*, of at least 90% of the side-lobe peaks does not exceed:

$$G = 29 - 25 \log \varphi \quad \text{dBi} \quad (5)$$

(*G* being the gain relative to an isotropic antenna and φ being the off-axis angle in the direction of the GSO referred to the main-lobe axis).

This requirement should be met for φ between 1° or (100 λ/*D*) whichever is the greater and 20° for any off-axis direction that is within 3° of the GSO.

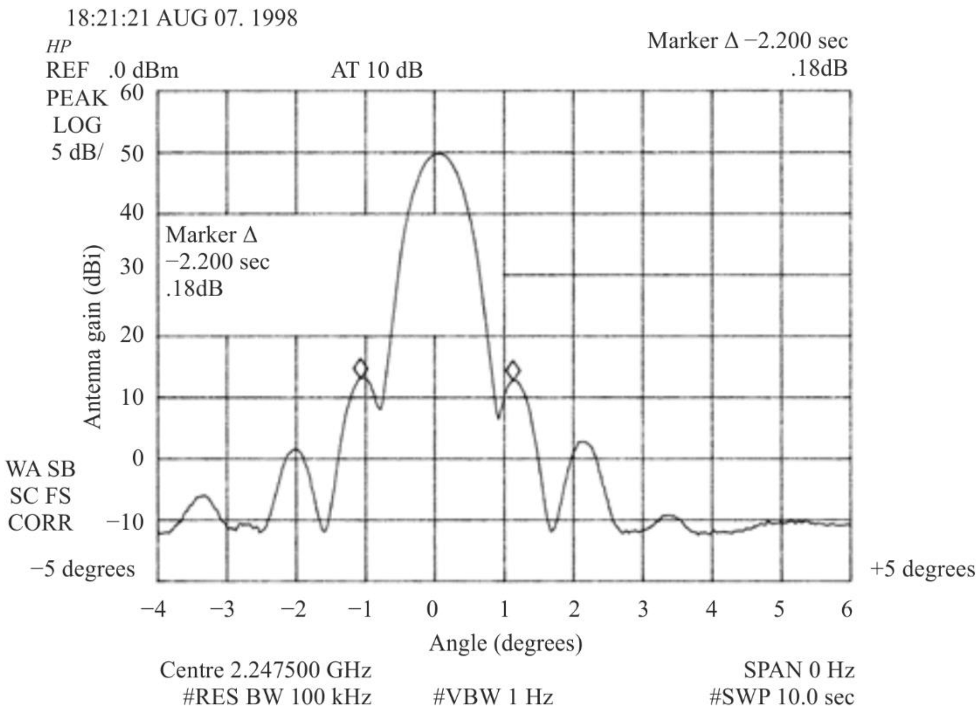
2 For an off-axis angle, φ, greater than the limits specified above, Recommendation ITU-R S.465 should be used as a reference.

Sidelobe level specification

Several of the entries provide the offset angle and absolute gain of the first antenna sidelobe (e.g. First sidelobe 9.9 dBi @ 0.26 deg). Figure A-1 below provides a sample pattern for large parabolic antennas. The first sidelobe is indicated by the diamonds. The sample antenna pattern is for a 13-metre antenna used in S-band.

FIGURE A-1

Antenna pattern at 2 247.5 MHz for a 13-metre antenna (50 dBi)



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A.3 Space station antennas

A.3.1 Geostationary satellites

A.3.1.1 Earth coverage

From the geostationary orbit the Earth subtends only 18 degrees. Antennas with beamwidth of 20 degrees or more will have a fairly constant gain across the Earth's visible surface.

A.3.1.2 Recommendation ITU-R S.672-4

This antenna pattern is a design objective of satellite antennas used in the fixed-satellite service employing geostationary satellites. For more details, see the Recommendation.

A.3.2 Low earth orbiting satellites

A.3.2.1 Isoflux pattern

The term Isoflux as used in this document refers to an antenna gain pattern used by low earth-orbiting satellites, which provides its maximum gain toward the horizon and attempts to provide a constant power flux density at all locations within the field of view of the spacecraft.

Antennas that approximate this pattern are sometimes referred to as Isoflux antennas but the actual antenna may be a quadrifiler or some other antenna.

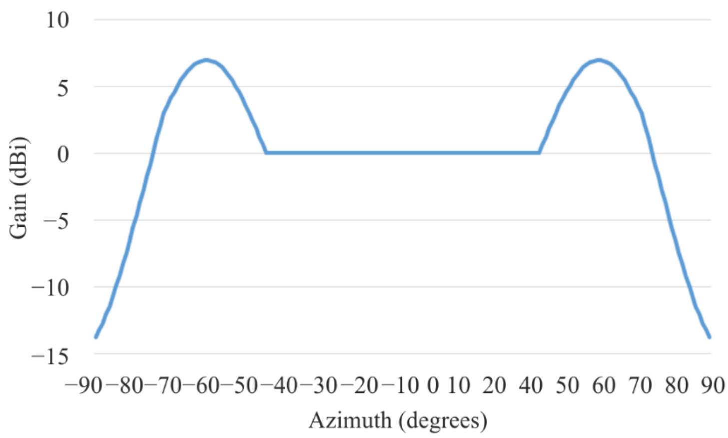
A generic isoflux radiation pattern that can be assumed is presented below:

$$G_{dB}(\theta) = \begin{cases} 0\ \text{dBi} & for\ \theta < 40° \\ k * \sin\left((\theta - 40) * \dfrac{180}{35}\right)\ \text{dBi} & for\ 40° < \theta < 70° \\ k * \sin\left((\theta - 40) * \dfrac{180}{35}\right) - 0.35 * (\theta - 70)\ \text{dBi} & for\ \theta > 70° \end{cases}$$

where k is the maximum gain in dBi and θ is the antenna boresight angle from nadir. Tables in this Report refer to this pattern as the 'Isoflux'. A sample Isoflux pattern (7 dBi max gain) is shown in Fig. A-2.

FIGURE A-2

Representative isoflux antenna pattern



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A.3.2.2 Pencil beam

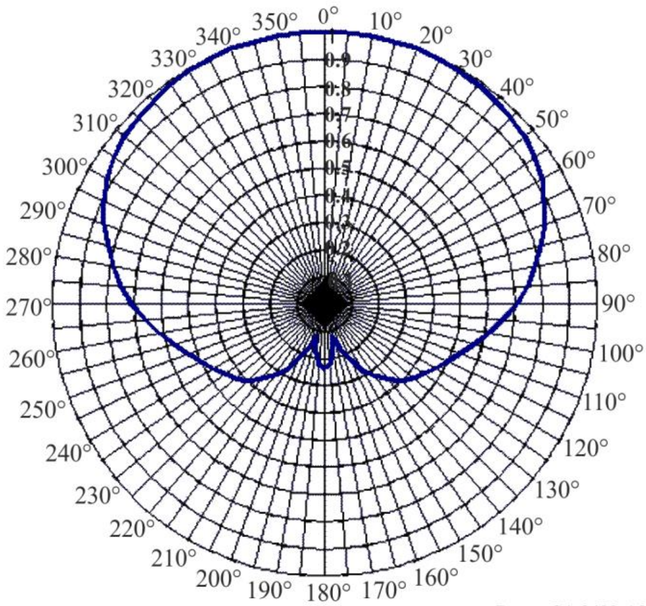
There is no specific pattern associated with this term. It might be assumed that the pattern is similar to Recommendation ITU-R S.672-4.

A.3.2.3 Cardioid

Satellite antennas that are not specifically designed for Isoflux type coverage will likely have their maximum gain at nadir and a cardioid rolloff pattern. A sample Cardioid pattern is shown in Fig. A-3.

FIGURE A-3

Representative cardioid antenna pattern



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A.3.2.4 ND

This term means non-directional. This is an ideal. The actual pattern is likely to be a cardioid but can be modelled as an Omni-directional antenna.

Annex B
(for information only)

Typical orbit parameters and earth station locations

This Annex provides reference information on typical orbit parameters for non-GSO and GSO systems as well as earth station locations. It should be noted that these elements are only a subset and cannot be taken as exhaustive (e.g. this is not an active database of all current and planned missions). It is not comprehensive lists but rather list of systems as added from several administrations over the course of development of this document. In addition, this annex is provided only for information and as a reference for any future updates to this Report containing representative characteristics.

Table B-1 lists typical orbit parameters for current and future MetSat/EESS non-GSO satellites that use the frequency bands given in § 3 and in a portion of § 5 of this Report. Most satellites in Table B-1 are in sun-synchronous orbits. The purpose of the Table is to provide orbit information needed for conducting dynamic simulations. Table B-2 lists typical longitudes of current and future MetSat/EESS GSO satellites that use the frequency bands given in § 4 and in a portion of § 5 of this Report. Table B-3 lists locations of representative specific earth stations and their locations that use the frequency bands given in §§ 3, 4 and 5, however, this is not an exhaustive list of locations.

TABLE B-1

Non-GSO satellite orbit parameters

Non-GSO satellite name	Orbit altitude (km)	Inclination (degrees)	Longitude ascending node (degrees) or local time of equatorial crossing (if in sun synchronous orbit)
Satellite A (NOAA KLM (NOAA-15 through -17))	812	98.5	140 deg.
Satellite B (Meteor-3M)	835	98.85	8:00 LTDN
Satellite C (JPSS (NOAA-20))	824	98.7	13:30 LTAN
Satellite D (NOAA N and N' (NOAA-18 and -19))	854 870	98.7	17:30 LTAN 14:30 LTAN
Satellite E (FY-3A)	824	98.73	306.24 deg.
Satellite F (Metop)	833	98.7	9:30 LTDN
Satellite G (FY-3B)	824	98.73	224.93 deg.
Satellite H (AQUA)	705	98.2	13:30 LTAN
Satellite I (Landsat-7)	705	98.2	22:00 LTAN
Satellite I1 (Landsat-8)	705	98.2	22:00 LTAN
Satellite J (TERRA)	705	98.2	22:30 LTAN
Satellite K (Resurs-P)	475	97.5	22:00 LTAN
Satellite L (AMAZONIA-1)	753	98.4	10 30 LTDN
Satellite S (Suomi-NPP)	824	98.74	10 30 LTDN
Satellite T (KANOPUS-V)	510	97.0	23:30 LTDN
Satellite U (Resurs-PM)	450-730	97-99	Not launched yet
Satellite V (BIOMASS)	661	98.07	06:00 LTAN
Satellite W (PROBA-V)	820	98.6	21:00 LTAN
Satellite X (Jason)	1 336	66	Jason-3 – Non sun-synchronous orbit Jason-CS (Sentinel-6), Non sun-synchronous orbit
Satellite Y (CDARS)	750	98.32	Sun-synchronous orbit 17:30 LTAN
Satellite Z (CBERS-04A)	628	97.9	10:30 LTDN
Satellite AA (ADM-AEOLUS)	300	97.0	18:00 LTAN
Satellite AB (ALOS-2)	628	97.9	24 00 local time
Satellite AC (CRYOSAT-2)	698	92.0	Non sun-synchronous orbit. Nodal regression of 0.25 deg per day.
Satellite AD (SMOS)	748	98.4	06:00 LTAN

TABLE B-1 (*cont.*)

Non-GSO satellite name	Orbit altitude (km)	Inclination (degrees)	Longitude ascending node (degrees) or local time of equatorial crossing (if in sun synchronous orbit)
Satellite AE (EARTHCARE)	398	97.0	02:00 LTAN
Satellite AF (EnMap)	675 × 660	97.96	Not yet launched
Satellite AG (AURA)	705	98.2	13:38 LTAN
Satellite AH (SENTINEL-5P)	819	98.6	13:35 LTAN
Satellite AI (Formosat-5)	718	98.28	10 00 LTDN
Satellite AJ (OCEANSAT-3)	720	98.25	12:00 LTAN
Satellite AM (SARAL)			
Satellite AN (Metop-SG)	830	98.7	09 30 LTDN
Satellite AO (International Space Station, ISS)	410 × 420	51.65	Non sun-synchronous orbit. Multiple payload
Satellite AP (TerraSAR-X)	514	97.4	18 00 LTAN
Satellite AQ (TanDEM-X)	514	97.4	18 00 LTAN
Satellite AR (HRWS)	514	97.4	Not yet launched (probably 18 00)
Satellite AS (TET-1)	550	97.5	
Satellite AT (BIROS)	505	97.4	09:30 LTDN
Satellite AU (High Resolution Radar Satellite) (generic)	750	98.4	
Satellite AV (Sentinel 1A/1B)	693	98.18	18:00 LTAN System with two satellite in same orbital plane (180º phasing)
Satellite AW (Sentinel 2A/2B)	786	98.5	22:30 LTAN System with two satellite in same orbital plane (180º phasing)
Satellite AX (Sentinel 3A/3B)	815	98.6	22:00 LTAN System with two satellite in same orbital plane (180º phasing)
Satellite AZ (Copernicus Evolution, and other commercial LEO, generic)	600 to 900	Typically polar orbits	
Satellite BA (GEO-IK)	1000	99.4	
Satellite BB (RADARSAT-2)	798	98.6	18:00 LTAN
Satellite BC (Radarsat Mission Constellation, RCM)	586 to 615	97.7	18:00 hours ±15 minutes LTAN System with three satellites in the same orbital plane.
Satellite BD (Obzor-R)	650-850	97-99	Non sun-synchronous orbit
Satellite BE (Kondor-FKA)	510-520	97.4-97.5	6:30 LTAN (initial, as has a temporal drift)

TABLE B-1 (*end*)

Non-GSO satellite name	Orbit altitude (km)	Inclination (degrees)	Longitude ascending node (degrees) or local time of equatorial crossing (if in sun synchronous orbit)
Satellite BF (ARCTICA-M)	40 000 (apogee) 3 000 (perigee)	62.8	Non sun-synchronous orbit
Satellite BG (AWS)	600	97.79	Constellation of 8 to 16 satellites Non sun-synchronous orbit

TABLE B-2

GSO Sub-satellite longitudes

GSO satellite	Longitude (degrees)
Satellite M (GOES-NOP)	60 W, 75 W, 89.5 W, 105 W and 135 W
Satellite N (Meteosat)	45.5 E, 41.5 E, 9.5 E, 3.5 E, 0 E, 3.4 W
Satellite O (MTSAT)	140 E and 145 E
Satellite P (FY-2 & FY-4)	133 E, 123.5 E, 112 E, 105 E, 99.5 E, 86.5 E and 79 E
Satellite Q (GOMS with Elektro-L)	76 E, 14.5 W and 165.8 E
Satellite R (GOES-R Series)	75.2 W, 89.5 W, 105 W and 137 W
Satellite AK (SDO)	102 W
Satellite AL (MTG)	0 E, 3.5 E, 9.5 E and 3.4 W
Satellite AY (Luch-5A, 5B, 5V)	16 W, 95 E and 167 E

TABLE B-3

Non-GSO and GSO specific earth station locations

Non-GSO and GSO earth stations	Longitude (degrees)	Latitude (degrees)
Station 1 (Wallops CDA, VA, USA)	75.5 W	37.9 N
Station 2 (Fairbanks, AK, USA)	147.5 W	65.0 N
Station 3 (Fairmont, WV, USA)	80.2 W	39.4 N
Station 4 (McMurdo Station, Antarctica)	166.7 E	77.8 S
Station 5 (Svalbard, Norway)	15.5 E	78.2 N
Station 6 (Kiruna, Sweden)	21.1 E	67.9 N
Station 7 (Cheia, Romania)	25.93 E	45.46 N
Station 8 (Beijing, CHN)	116.3 E	40.1 N
Station 9 (Guangzhou, CHN)	113.3 E	23.2 N
Station 10 (Prudhoe Bay, AK)	148.5 W	70.2 N
Station 11 (Usingen, Germany)	8.48 E	50.33 N
Station 12 (Fucino, Italy)	13.6 E	41.98 N
Station 13 (Moscow, Russia)	37.3 E	55.8 N

TABLE B-3 (*cont.*)

Non-GSO and GSO earth stations	Longitude (degrees)	Latitude (degrees)
Station 14 (Novosibirsk, Russia)	83.0 E	55.0 N
Station 15 (Khabarovsk, Russia)	135.2 E	48.5 N
Station 16 (Suitland, Maryland, USA)	76.9 W	38.9 N
Station 17 (White Sands, New Mexico, USA)	106.6 W	32.5 N
Station 18 (Troll, Antarctica)	2.5 E	72.0 S
Station 19 (Cachoeira Paulista, Brazil)	45.00 W	22.68 S
Station 20 (Cuiabá, Brazil)	56.04 W	15.33 S
Station 21 (Greenbelt, Maryland, USA)	76.84 W	39.00 N
Station 22 (Boulder, Colorado, USA)	105.26 W	39.99 N
Station 23 (Laurel, Maryland USA)	76.90 W	39.33 N
Station 24 (North Pole, Alaska, USA)	147.5 W	64.80 N
Station 25 (South Point, Hawaii, USA)	155.60 W	19.00 N
Station 26 (Goldstone, California, USA)	116.98 W	35.42 N
Station 27 (Xinjiang, CHN)	87.4 E	43.8 N
Station 28 (Jiamusi, CHN)	130.3 E	46.7 N
Station 29 (Perth, Australia)	115.86 E	31.93 S
Station 30 (T'ainai, Taiwan, CHN)	120.19 E	22.93 N
Station 31 (Chung-li,Taiwan, CHN)	121.19 E	24.97 N
Station 32 (Hsin-Chu, Taiwan, CHN)	120.98 E	24.81 N
Station 33 (Cheia, Romania)	25.93 E	45.46 N
Station 34 (Maspalomas, Spain)	15.63 W	27.76 N
Station 35 (Lario, Italy)	9.38 E	46.17 N
Station 36 (Leuk, Switzerland)	7.65 E	46.32 N
Station 37 (Katsuura, Japan)	140.30 E	35.21 N
Station 38 (Barrow, Alaska, USA)	159.6 W	71.3 N
Station 39 (Villafranca, Spain)	3.95 W	40.45 N
Station 40 (Neustrelitz, Germany)	13.07 E	53.33 N
Station 41 (Sagamihara, Japan)	139.49 E	35.71 N
Station 42 (Jeju, Rep. of Korea)	126.81 E	33.37 N
Station 43 (Sioux Falls, SD, USA)	96.62 E	43.73 N
Station 44 (Alice Springs, Australia)	133.87 E	23.70 S
Station 45 (Cordoba, Argentina)	64.46 W	31.52 S
Station 46 (Gatineau, Canada)	75.80 W	45.58 N
Station 47 (Prince Albert, Canada)	105.93 W	53.21 N
Station 48 (KaShi, CHN)	75.93 E	39.50 N
Station 49 (Parepare, Indonesia)	119.63 E	3.98 S
Station 50 (Rumpin, Indonesia)	106.60 E	6.37 S
Station 51 (Matera, Italy)	16.70 E	40.65 N
Station 52 (Kumamoto, Japan)	130.87 E	32.53 N

TABLE B-3 (*end*)

Non-GSO and GSO earth stations	**Longitude (degrees)**	**Latitude (degrees)**
Station 53 (Hartebeestoek, South Africa)	27.71 E	25.88 S
Station 54 (Bangkok, Thailand)	100.79 E	13.73 N
Station 55 (Si Racha, Thailand)	100.93 E	13.10 N
Station 56 (Hatayoma, Japan)	139.33 E	36.02 N
Station 57 (Weilheim, Germany)	11.08 E	47.88 N
Station 58 (Inuvik, Canada)	133.54 W	68.32 N
Station 59 (O´Higgins, Antarctica)	57.9 W	63.32 S
Station 60 (Libreville, Gabon)	9.60 E	0.39N
Station 61 (Riyadh, Saudi Arabia)	46.63 E	24.72 N
Station 62 (Shadagar, India)	78.19E	17.03N
Station 63 (Punta Arenas, Chile)	70.87 W	52.93 S
Station 64 (Sanya, CHN)	109.28 E	18.28 N
Station 65 (Sodankyla, FIN)	26.63 E	67.37 N
Station 66 (Neimeng, CHN)	111..65 E	41.55 N

Annex C

System characteristics of non-GSO systems in the 8 025-8 400 MHz band

TABLE C-1

Non-GSO EESS space-to-Earth parameters for systems in the band 8 025-8 400 MHz

Function	**Direct readout**				
Satellite	Satellite H	Satellite J	Satellite B	Satellite K	Satellites E and G
Earth station(s)	Worldwide		Russian territory	Worldwide	Station 8
Carrier frequency (MHz)	8 160	8 212.5	8 128 and 8 320	8 192 and 8 335	8 212.5
Information data rate (Mbits/s)	15	13.5	3 15.36, 122.88	76.8 153.6	225
Necessary bandwidth (MHz)			30.7 & 123	58 & 115	
Modulation					QPSK
Coding					RS(233,255)+CONV(3/4,7)
Encoded data rate					300

TABLE C-1 (*end*)

Function	**Direct readout**				
Minimum elevation angle (degree)	5	5	5		
Satellite antenna input power (dBW)	11.18	10.6	9	23.8	14
Satellite antenna radiation diagram	Isoflux	Isoflux	Isoflux	S.672/ Pointed	Isoflux
Satellite antenna gain at nadir (dBi)	−4.1	−6	24	25	5
Satellite antenna maximum gain (dBi)	6.8	6	8.5	25	5
Satellite antenna polarization	RHCP	RHCP	RHCP	RHCP and LHCP	RHCP
Earth station antenna gain toward satellite (dBi)	45.6	45.6	57 53 48 43	54.6 50 47 45	56
Earth station antenna polarization	RHCP	RHCP	RHCP	RHCP and LHCP	RHCP
Earth station antenna radiation diagram	Rec. ITU-R S.465-6		Rec. ITU-R S.465-6		Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	125	190	100/185	150	280

TABLE C-2

Non-GSO EESS space-to-Earth parameters for systems in the band 8 025-8 400 MHz

Function	Direct Readout	
Satellite system	Satellite AF	Satellite AP
Earth station(s)	Station 40	World-wide
Carrier frequency (MHz)	8 200	8 150
Information data rate (Mbits/s)	320	300
Necessary bandwidth (MHz)	350	225
Modulation		
Coding		
Encoded data rate		
Minimum elevation angle (degree)	5	5
Satellite antenna input power (dBW)	3.2	17.5
Satellite antenna radiation pattern	Directional	Isoflux
Satellite antenna gain toward nadir (dBi)	20.9	0
Satellite antenna maximum gain (dBi)	20.9	7
Satellite antenna polarization	LHCP	LHCP/ RHCP
Earth station antenna gain toward satellite (dBi)	41	57.6
Earth station antenna polarization	RHCP/LHCP	RHCP/ LHCP
Earth station antenna radiation diagram	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	226	92

TABLE C-3

Non-GSO EESS space-to-Earth parameters of systems in the band 8 025-8 400 MHz

Function	Direct Readout and Stored Mission Data				
Satellite	Satellite U	Satellite T	Satellite AO	Satellite BD	Satellite BE
Earth station(s)	Worldwide	Worldwide	Worldwide	Russian territory	Russian territory
Carrier frequency (MHz)	8077.5 8167.5 8257.5 8347.5	8 128.0; 8 320.0	8 225.0	8 192 and 8 335	8 128.0; 8 320.0
Information data rate (Mbits/s)	150; 300	123	1525	150; 300	61.44; 122.88
Necessary bandwidth (MHz)	62.9; 78.6; 94.4	123	270	62.9; 78.6; 105	123
Modulation					
Coding					
Encoded data rate					
Minimum elevation angle (degree)	5	5	5	5	5
Power supplied to the input of satellite antenna (dBW)	7-2	11.2	7	3.5	4.5
Satellite antenna radiation diagram/pattern	ITU-R S.672 (steerable)	isoflux	ITU-R S.672 (steerable)	ITU-R S.672 (steerable)	ITU-R S.672 (steerable)
Satellite antenna gain at nadir (dBi)	4	−3.5	0		
Satellite antenna maximum gain (dBi)	±27.5	±67 degrees from nadir +6.5	±15	25	23.3
Satellite antenna polarization	RHCP/ LHCP	Circular Right	RHCP/ LHCP	RHCP/ LHCP	Circular Right
Earth station antenna gain toward satellite (dBi)	48.0 (3.8 m) 53.0 (7 m)	48.0 (3.8 m) 53.0 (7 m)	48.0 (3.8 m) 53.0 (7 m)	50	49.4
Earth station antenna polarization	RHCP/ LHCP	Circular Right	RHCP and LHCP	RHCP/ LHCP	RHCP
Earth station antenna radiation diagram/pattern	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	120 (3.8 m) 130 (7 m)	120 (3.8 m) 130 (7 m)	120 (3.8 m) 130 (7 m)	150	150

TABLE C-4

Non-GSO EESS space-to-Earth parameters for systems in the band 8 025-8 400 MHz

Function	**Stored mission data**					
Satellite system	Satellite AA	Satellite AC	Satellite AE	Satellite V	Satellite W	Satellite AD
Earth station(s)	Stations 1, 5, 6 and 18	Stations 6 and 58	Stations 5, 6 and 18	Stations 5, 6, 10, 18, 58 and 65	Stations 2, 5 and 6	Stations 5 and 39
Carrier frequency (MHz)	8 040	8 100	8 100	8170	8090	8150
Information data rate (Mbits/s)	4.4	87.4	131	468	84.4	16.8
Necessary bandwidth (MHz)	15	75	120	270	100	18
Modulation	Filtered OQPSK	QPSK	Filtered OQPSK	Filtered 8PSK	Filtered OQPSK	8PSK
Coding	RS (255, 223) + Conv (1/2)	R-S (255,223) (I=5)	R-S (255,223)	RS (255,239)		RS (255,239)
Encoded data rate	10	100	150	500		18
Minimum elevation angle (degree)	5	5	5	5	5	5
Satellite antenna input power (dBW)	3.5	14	6.2	16.2	10	6.1
Satellite antenna radiation pattern	Isoflux	Isoflux	Isoflux	Isoflux	Isoflux	Isoflux
Satellite antenna gain toward nadir (dBi)	-3	1	2	2	2	−6.5
Satellite antenna maximum gain (dBi)	4	2	4.4	5	3.5	3.5
Satellite antenna polarization	RHCP	RHCP	RHCP	RHCP	RHCP	RHCP
Earth station antenna gain toward satellite (dBi)	57.7 - 61	60	57.8 - 58.7	53.6 - 58.7	56.3 - 58.6	47 - 58.9
Earth station antenna polarization	RHCP/LHCP	RHCP/ LHCP	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP	RHCP/LHCP
Earth station antenna radiation diagram	ITU App.8	ITU App.8	ITU App.8	ITU App.8	ITU App.8	ITU App.8
Earth station receiver noise temperature (K)	120-150	125	107/133	120-144.5	200-250	138-158

TABLE C-5

Non-GSO EESS space-to-Earth Parameters for systems in the band 8 025-8 400 MHz

Function	**Stored mission data**					
Satellite system	Satellite AH	Satellite AI	Satellite Z	Satellite L	Satellite S	Satellite X
Earth station(s)	Station 2	Stations 30, 31 and 32	Station 8, 19, 20, 48 and 64	Stations 19 and 20	Station 5	Stations 2 and 7
Carrier frequency (MHz)	8 225	8 190	8212	8 300	8 212.5	8 090
Information data rate (Mbits/s)	105	150	450	128	262	131
Necessary bandwidth (MHz)	105	150	375		300	120
Modulation						
Coding						
Encoded data rate						
Minimum elevation angle (degree)		5	5	5	5	5
Satellite antenna input power (dBW)	4.7	16	10	17	9.8	18
Satellite antenna radiation diagram		Isoflux	Directional			ND
Satellite antenna gain toward nadir (dBi)	Steerable antenna	0	25	−4	Gimballed	−1
Satellite antenna maximum gain (dBi)	23.3	8.81	25	6.5	9.4	4
Earth station antenna gain toward satellite (dBi)	56.5	58	Min 57.3	57.4	59.3	
Earth station antenna polarization			RHCP/LHCP	RHCP	RHCP	RHCP
Earth station antenna radiation diagram		Rec. ITU-R S.465-6			AP7-Annex 3	
Earth station receiver noise temperature (K)	190	470	100	155	282	

TABLE C-6

Non-GSO EESS space-to-Earth parameters for systems in the band 8 025-8 400 MHz

Function	**Stored Mission Data**					
Satellite system	Satellite AB	Satellite I	Satellite I1	Satellite H	Satellite AG	Satellite J
Earth station(s)	Stations 5, 37 and 56 Worldwide	Worldwide	Worldwide	Stations 1, 2 and 3		
Carrier frequency (MHz)	8 175	8 082.5 8 212.5 8 342.5	8 200.5	8 160	8 160	8 212.5
Information data rate (Mbit/s)	800		150	150	150	150
Necessary bandwidth (MHz)	275					
Modulation						
Coding						
Encoded data rate						
Minimum elevation angle (degree)	5	5	5	5	5	5
Satellite antenna input power (dBW)	5.6	−1.46	15.9	11.18	12.5	10.6
Satellite antenna radiation diagram	Horn	Directional	Isoflux	Isoflux	Isoflux	Isoflux
Satellite antenna gain toward nadir (dBi)	17.8	26.2	−3	−4.1	−4.1	−6
Satellite antenna maximum gain (dBi)	17.8	26.2	7	6.8	6.8	6
Satellite antenna polarization	RHCP	RHCP	LHCP	RHCP	RHCP	RHCP
Earth station antenna gain toward satellite (dBi)	59.2	55	55	56.1	56.1	56.1
Earth station antenna polarization	RHCP/ LHCP	RHCP	LHCP	RHCP	RHCP	RHCP
Earth station antenna radiation diagram	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6	Rec. ITU-R S.465-6
Earth station receiver noise temperature (K)	163	185	185	125	125	190

TABLE C-7

Non-GSO EESS space-to-Earth Parameters for systems in the band 8 025-8 400 MHz

Function	**Stored Mission Data**	
Satellite system	Satellite AV, AW and AX	Satellite AH
Earth station(s)	Stations 5, 6, 18, 34, 47, 51 and 58	Stations 5 and 58
Carrier frequency (MHz)	Two channels; F1: 8095 MHz and F2: 8260 MHz	8150
Information data rate (Mbit/s	262 per channel	271
Necessary bandwidth (MHz)	140 MHz per channel	233
Modulation	8PSK	Filtered OQPSK
Coding	R-S (255,239)	R-S (255,223)
Encoded data rate (Mbit/s)	280 per channel	310
Minimum elevation angle (degree)	5	5
Satellite antenna input power (dBW)	15.3	16
Satellite antenna radiation diagram	Isoflux	Isoflux
Satellite antenna gain toward nadir (dBi)	2	2
Satellite antenna maximum gain (dBi)	9	7
Satellite antenna polarization	RHCP	RHCP
Earth station antenna gain toward satellite (dBi)	54.8	54.6
Earth station antenna polarization	RHCP/ LHCP	RHCP/ LHCP
Earth station antenna radiation diagram	ITU App. 8	ITU App. 8
Earth station receiver noise temperature	120	120

Annex D

List of abbreviations and acronyms

8PSK Eight-level phase shift keying

A-DCS Advanced data collection system

AGC Automatic gain control

AHRPT Advanced high-resolution picture transmission

APT Automatic (or analogue) picture transmission

APSK Amplitude and phase shift keying, or asymmetric phase shift keying

ARGOS Name for satellite-based location and data collection system (Advanced Research and Global Observation Satellite)

BPSK Binary phase shift keying

CDA	Command and data acquisition
CDARS	Cooperative data and rescue service
CHRPT	Colour high-resolution picture transmission
DCP	Data collection platform
DCPC	Data collection platform command
DCPI	Data collection platform interrogate
DCPR	Data collection platform report
DCS	Data collection system
DPSK	Differential phase shift keying
DSSS	Direct sequence spread spectrum
EESS	Earth exploration-satellite service
e.i.r.p.	Effective isotropic radiated power
EMWIN	Emergency Managers Weather Information Network
FEC	Forward error correction
FY	Feng-Yun
GOES	Geostationary Operational Environmental Satellite (USA)
GMSK	Gaussian minimum shift keying
GSO	Geosynchronous orbit
GVAR	GOES variable data format
HRDCP	High-rate data collection platform
HRIT	High-rate information transmission
HRPT	High-resolution picture transmission
ICARUS	International Cooperation for Animal Research Using Space
LDPC	Low-Density Parity-Check code
LEO	Low Earth Orbit
LHCP	Left Hand Circular Polarization
LRIT	Low Rate Information Transmission
LRPT	Low-Resolution Picture Transmission
LTAN	Local Time Ascending Node
LTDN	Local Time Descending Node
MDA	Mission Data Acquisition
Metop	Meteorological Operational Polar Satellite (EUMETSAT)
MetSat	Meteorological Satellite (US)
MTG	Meteosat Third Generation (EUMETSAT)
MTSAT	Multifunctional Transport Satellite
NOAA	National Oceanic and Atmospheric Administration (USA)

NRZ	Non-Return to Zero (encoding)
OOBE	Out-Of-Band-Emissions
OQPSK	Offset Quadrature Phase Shift Keying
PCM	Pulse Code Modulation
PFD	Power Flux Density
PM	Phase Modulation
PSK	Phase Shift Keying
QPSK	Quadrature Phase Shift Keying
RHCP	Right Hand Circular Polarization
RS	Reed Solomon (error correction code)
SCCC	Serial Concatenated Convolutional Codes
SIDAR	Solar Irradiance, Data and Rescue
SOQPSK-TG	Shaped-Offset Quadrature Phase Keying
SSMA	Spread Spectrum Multiple Access
TIROS	Television Infrared Observation Satellite
TIP	TIROS Information Processor
VCM	Variable Coding Modulation
WMO	World Meteorological Organization