International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R SM.2182-2

(06/2019)

Measurement facilities available for the measurement of emissions from both GSO and non-GSO space stations

SM Series

Spectrum management

International Telecommunication Union

Foreword

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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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REPORT ITU-R SM.2182-2

Measurement facilities available for the measurement of emissions from both GSO and non-GSO space stations

(Question ITU-R 232/1)

(2010-2017-2019)

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1 Introduction

The tasks of radio monitoring services related to emissions of both geostationary orbit (GSO) and non-geostationary orbit (non-GSO) space stations are in principle the same as for terrestrial radio services. The monitoring of emissions from terrestrial stations and space stations, however, is different in terms of technique and method. This Report provides information about space monitoring facilities operated by telecommunications regulatory authorities around the World.

2 Satellite orbital resources

The orbital slots for geostationary satellites are a valuable and scarce resource and therefore the knowledge of the operational status of geostationary satellites recorded in the ITU Master International Frequency Register (MIFR) is useful to administration's spectrum management departments.

Non-GSO satellite orbits present additional challenges, since the satellites are always moving in their orbital plane and therefore are not easily monitored.

It should be understood that the necessity to locate and eliminate the harmful interference to and from space stations may become important for administrations under whose jurisdiction no satellites have been notified to resolve terrestrial interference cases involving satellites.

3 Satellite facilities

Several monitoring earth stations operated by telecommunications regulatory authorities already exist in various parts of the World and are capable of collecting data relating to radiated emissions from space stations. Some of them are equipped with so called transmitter location systems enabling the geolocation of interference sources on the surface of the Earth that are affecting space satellites.

The technical challenges in the set-up and operation of such monitoring stations, the substantial amount of budget required and, last but not least, the necessity of having monitoring station operators with sufficient experience call for close cooperation between these stations.

4 Conclusion

The worldwide available space radio monitoring facilities operated by telecommunications regulatory authorities are presented in the Annexes in order to facilitate mutual cooperation of these stations. The locations of these facilities and contact information are provided, and these stations may be able to assist other administrations in cases involving satellite interference or monitoring. Each of the stations listed can cover a portion of the geostationary arc around its geographic location. The entire geostationary arc range is covered by the listed facilities.

NOTE 1 – Although a satellite is "in view" from a particular monitoring location, the GSO satellite downlink beam patterns (footprints) and the non-GSO orbit paths affect whether signals can be monitored.

Annex 1

Space Radio Monitoring Facilities in Germany

Station Leeheim of the German Bundesnetzagentur (Federal Network Agency)

1 Descriptive specifications of the space radio monitoring station

1.1 General description

The Space Radio Monitoring Station Leeheim belongs to the “Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen” (Federal Network Agency for Electricity, Gas, Telecommunications, Posts and Railways) or in short “Bundesnetzagentur”/“Federal Network Agency”.

The Agency’s responsibilities include spectrum management and spectrum monitoring. The Monitoring Station Leeheim is located on the river Rhine approximately 35 km south-west of Frankfurt/Main. Its full-motion antennas of up to 12 m in diameter are pointed towards satellites in space. These antennas do not serve commercial transmission purposes. They form the heart of an installation used to monitor the frequency spectrum allocated to space radio services and to detect interference on frequencies used for satellite communications.

1.2 Functions

As an aid for planning and coordination

General orbit observations reveal the actual use of the frequency spectrum for space services. This includes satellite transponder occupancy measurements and the determination of orbital positions in the geostationary orbit.

Specific frequency occupancy observations, for example in conjunction with radio-frequency coordination procedures, enable potential interference to be detected early during the planning stage of satellite systems.

Field experiments can support the optimization of theoretical models that facilitate the shared use of frequencies by space and terrestrial services.

As a tool for satellite positioning and operation

Pre-launch observations on telemetry and tracking frequencies guarantee the successful positioning of geostationary satellites.

Monitoring satellite emissions, transponder occupancy and satellite positions is an indispensable tool which enables the competent authorities to check whether a satellite is operated as advance published, coordinated and notified internationally.

Interference handling allows sources of harmful interference to be detected which otherwise would continue to hinder proper operation of satellite or terrestrial radio services.

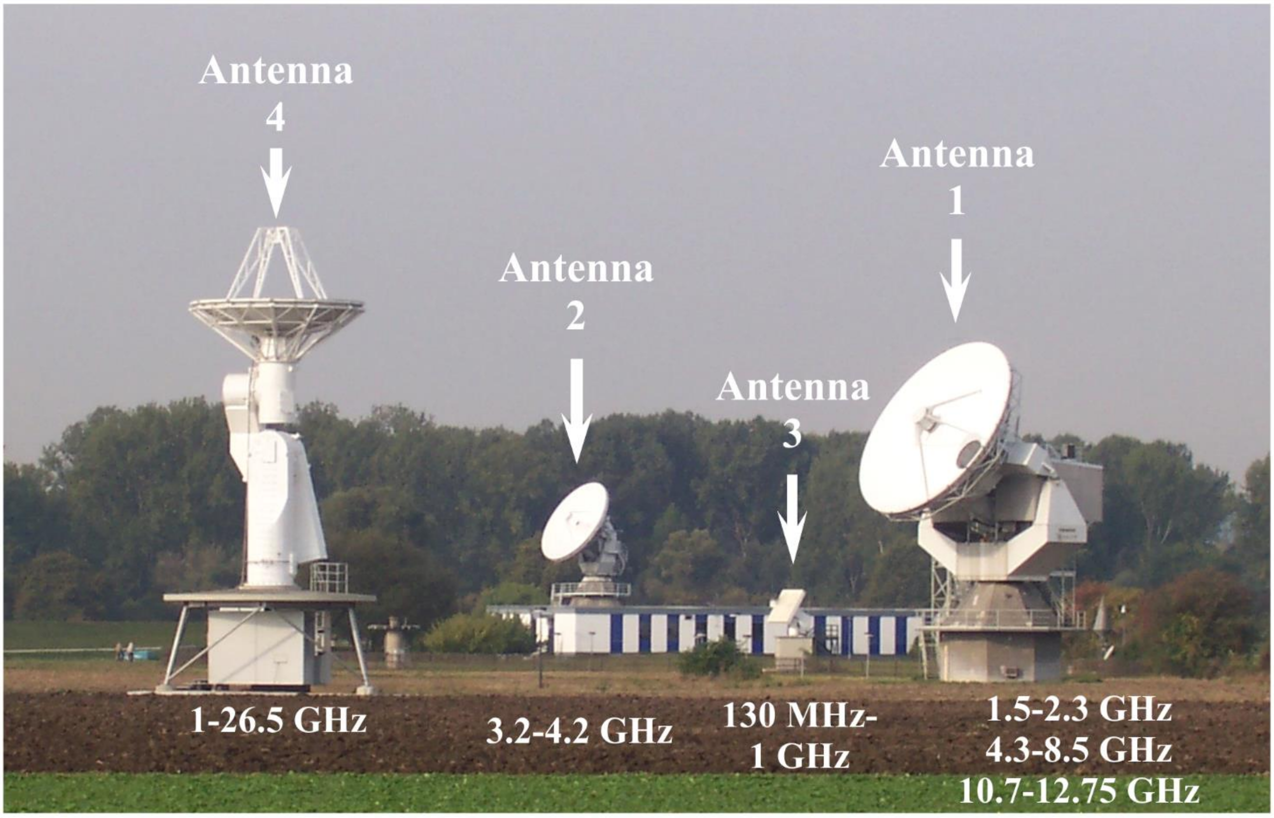
Detection of uplink interferers

Cases of uplink interference, i.e. when a satellite is not the source of interference but a satellite is the victim, appear more and more. Since users have obtained direct access to satellite capacities, the number of earth stations has risen rapidly. Earth stations are the major source of uplink interference. It can be caused by both technical and operational faults. Illicit uses of satellite transponders and cases of intentional interference to transponders have also been observed. Authorities, operators and users have to cope with this situation.

The monitoring system locates interferers by receiving their signals on two different paths, i.e. via the interfered satellite and a neighbouring satellite. The time difference and the frequency difference of the signals received at Leeheim are processed to obtain the geographical coordinates of the transmitter. As soon as the location of the interferer is known, the interference can normally be swiftly eliminated.

1.3 System characteristics

Location:	49°51'13" N	08°23'50" E
Visible geostationary arc:	67° W to 83° E	



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Antenna 1

Antenna 1, a 12 m Cassegrain-beam-waveguide antenna is a broadband antenna designed to cover the 1.0-13 GHz frequency range. Rather narrow feeds with optimized characteristics at 1.5-1.8 GHz and 2.1-2.3 GHz, as well as at 10.7-12.75 GHz, are a prerequisite for the so-called monopulse tracking for high precision antenna pointing. An adjustable rotary reflector and a slide-mounted feed allow switching between the frequency bands.

The rather wide 4.3-8.5 GHz frequency slot of Antenna 1 does not allow for monopulse tracking. However, it disposes of accurate computer controlled position tracking capability in all frequency bands.

Antenna 2

Antenna 2 is a Cassegrain antenna with a narrow-band feed in the frequency range 3.2-4.2 GHz with a diameter of 8.5 m. This antenna has a limited operational availability at the moment.

Antenna 3

Antenna 3, consisting of a square of 2.4 m × 2.4 m, is composed of three sectors of dipole arrays of different size covering in total the frequency band from 130-1 000 MHz.

Antenna 4

Antenna 4, a 7 m prime-focus antenna is a multiband antenna covering the range from 1-26.5 GHz. This range consists of eight sub-bands each of which overlaps slightly with the neighbouring sub-bands. The corresponding feed systems are partly of cross dipole and partly of horn type. The feed assembly is placed in the focus of the parabolic reflector. The assignment to a certain sub-band is accomplished by rotating the assembly.

This is an X-Y-mounted antenna, especially suitable for non-geostationary satellites travelling overhead.

Antenna 5

Antenna 5, a 3 m prime-focus antenna with a broadband logarithmic periodic feed 1-26.5 GHz, is mainly used in the Ka-band from 17.7-21.2 GHz. The antenna is mounted as a king-post antenna only for geostationary arc.

Omnidirectional antennas

The station disposes also of omnidirectional antennas to observe simultaneously all emissions from the sky in a certain frequency band, e.g. of a multi-satellite system. The frequency range is 100-2 500 MHz.

Computer-controlled antenna tracking

Computer-controlled antenna tracking of Antennas 1, 3 and 4 allows to follow geostationary or non-geostationary satellites by means of the so-called “two line elements” (TLE).

Antenna parameters

A summary of the parameters of Antennas 1-5 is shown in Table 1.

Transmitter location system

The transmitter location system is designed to identify the location of radio transmitters on Earth. The concept is to find the parameters of the triangle between the wanted transmitter and two satellites by means of time and frequency measurements. The system works via two monitoring antennas both operating in the same frequency bands.

Either the combination of Antenna 1 with Antenna 4 or of the combination of Antenna 2 with Antenna 4 or of the combination of Antenna 5 with Antenna 4 along with the interfered and an adjacent satellite form the measurement constellation.

An example for the results of such measurements is depicted in Fig. 1.

Reference transmitter for the transmitter location system

The four reference transmitter units transmit reference signals for the transmitter location system and can also be used as a calibrator for the correction for the satellite orbital elements. This permits the performance of self-contained measurements which do not have to rely on possibly insufficient orbital data and external reference emissions. The transmitters can also be operated mobile within Germany.

The uplink frequency ranges are:

C-Band: 5 850-6 850 MHz, Ku-Band: 12 750-14 500 MHz, Ka-Band: 17 300-18 400 MHz.

Frequency range

The frequency range of the station extends from 130 MHz to 26.5 GHz without any gap.

TLS operation is limited to frequencies available at the Antennas 1, 2 and 5. They cover all the bands of the fixed-satellite service (space-to-Earth) up to 21.2 GHz. In detail the frequency bands are: 1.5-1.8/2.1-2.3/3.2-4.2/4.3-8.5/10.7-12.75/17.7-21.2 GHz.

Frequency spectrum recorder

The frequency spectrum recorder can be connected to any antenna of the station. Six frequency bands of widths of up to 100 MHz each can be chosen freely. The spectra of these bands can be scanned quasi-simultaneously in a time-sharing mode and displayed in spectrograms.

Device for measurements below the noise floor

To measure emissions of low power flux-densities a monitoring method is available where the noise floor can be suppressed by typically 12 to 15 dB. This is achieved by multiple measurements of successive spectra, signal digitizing and processing. This device allows displaying spectra below the noise floor up to 100 MHz wide according to Recommendation ITU-R SM.1681.

1.4 Measurement parameters

The station can measure or determine emission characteristics such as:

– frequency;
– Doppler frequency shift;
– spectrum and bandwidth;
– class of emission and type of modulation;
– polarization;
– power flux-density in the reference bandwidth;
– total power flux-density;
– e.i.r.p.

In case of TV emissions:

– sound subcarrier frequencies;
– coding;
– programme sources, etc.

Due to sufficient angular velocities of the four antennas in azimuth and elevation, these parameters can be measured even in conjunction with non-geostationary satellites.

The station can measure and record orbital tracks in the frequency range 1.5-1.8 GHz; 2.1-2.3 GHz and 10.75-12.75 GHz with monopulse tracking.

2 Tasks

2.1 Spectrum occupancy monitoring

Monitoring the spectrum occupancy means to systematically observe the radio-frequency spectrum in order to achieve the following objectives:

– to identify the basic characteristics of all discoverable emissions from space stations;

– to determine whether limits are exceeded or whether there are deviations from the internationally published, coordinated and/or notified data;
– to derive the data of the actual occupancy of the frequency bands by space stations;
– to obtain the data of the actual occupancy of the geostationary orbit positions by space stations.

The results are stored in a database and complemented with spectrum prints for each monitored emission or for an assembly thereof. In this format (frequency atlas: Table 2) the results can be used for comparison with the internationally filed, coordinated and notified parameters. These measurements can be done for the geostationary and the non-geostationary orbit.

2.2 Position measurements

In cases where the inclination or ellipticity of a satellite orbit may cause interference to a neighbouring satellite, the trace of the occupied position has to be measured. This is done with monopulse-tracking over a 24 h period. The trace of the occupied position is given in geographical coordinates (the sub-satellite point) or in a celestial grid.

2.3 Interference measurements

When interference is reported a clear analysis of the reported data is required. Initial measurements may confirm the report or may require modification of the reported data. In principle, there are two possibilities. Either the source of interference is in space or it is on Earth.

In the case the source of interference is in space, there are two possibilities again. Either a known satellite emits a signal not complying with the publication, coordination and/or notification, or an unknown satellite is the source. For identification of the interfering source in space, similar measurements are necessary as for occupancy monitoring, although the goal is different.

In the case of an interferer on Earth that appears in the downlink of a satellite, transmitter location measurements are required.

2.4 Pre-launch monitoring

During the pre-phase of the launch of a satellite the frequencies used for telemetry, telecommand and tracking are monitored with respect to the planned orbit.

The measurement results facilitate a safer launch and a safer positioning of the satellite.

3 Working hours

The regular hours of service at Leeheim Monitoring Station are as follows:

Mondays to Thursdays	08:00 h – 16:00 h, local time
Fridays	08:00 h – 15:00 h, local time.

Due to flexi-time the station may also be manned outside these hours.

Leeheim Monitoring Station is not attended on public holidays.

4 Contact address

Bundesnetzagentur
Satelliten-Messstelle
D 64560 Riedstadt
Germany

During the regular working hours the station can be contacted through the following communication details:

Tel.: +49 6158 940-0
Fax: +49 6158 940-180
E-mail: Space.Monitoring@BNetzA.de

Outside the regular working hours, instructions on how to reach an operator are given on the answering machine.

TABLE 1

Antenna parameters
Space Radio Monitoring Station Leeheim

Parameter	Antenna 1				Antenna 2**	Antenna 3			Antenna 4								Antenna 5***
Frequency-band (GHz)	1.5-1.8	2.1-2.3	4.3-8.5	10.7-12.75	3.2-4.2	0.13-0.25	0.25-0.5	0.5-1.0	1.0-2.0	1.9-3.3	3.2-4.4	4.3-7.3	7.2-10.1	9.9-12.75	12.5-17.7	17.3-26.5	17.7-21.2
Antenna type	Full motion Az./El. Cassegrain beam waveguide				Full motion Az./El., Cassegrain	Full motion Az./El. Planar dipole array			Full motion, XY-mount, prime focus								King-post Az./El., prime focus
Antenna size	12 m Ø				8.5 m Ø	4 m^2	2 m^2	2 m^2	7 m Ø								3 m Ø
Polarization	LX LY	LX LY	LX, LY RHC LHC	LX, LY RHC LHC	RHC LHC	LX, LY	LX, LY	LX, LY	LX, LY RHC LHC	LX, LY RHC LHC	LX, LY RHC LHC	LX, LY RHC LHC	LX, LY RHC, LHC	LX, LY RHC LHC	LX, LY	LX, LY	LX, LY
Polarization adjustment	no	no	yes	yes	no	no			yes								yes
Antenna gain (dBi)	44	47	49-56	61-62	48-50	8-11	10-14	14-18	34-39	40-45	45-47	47–50	51-54	54–56	56-57	58-59	47-50
G/T (dB/K)	22	25	27-33	39-41	25-29	–			15-19	20-23	24-26	26-28	29-31	32-33	32-33	34-33	19-21
Angle velocity	Az. 16°/s El. 3.5°/s				Az. 5°/s El. 5°/s	Az. 10°/s El. 10°/s			X axle: 3.5°/s Y axle: 3.5°/s								Az. 0.5°/s El. 0.5°/s
Acceleration	$10°/s^2$				$5°/s^2$	$10°/s^2$			$3.5°/s^2$								
Antenna tracking	Mono-pulse-track		no	Mono-pulse-track	Manually	Manually, program track			Manually, program track								Manually
	Manually, program-track																
Level uncertainty rss* error	1.6 dB (95% confidence level)				N/A	1.6 dB (95% confidence level)			1.6 dB (95% confidence level)								N/A
Frequency uncertainty	$1*10^{-12}$ (rubidium standard)																

* rss = root sum square.
** Limited operational availability.
*** Operational in 2009.
N/A: Not applicable.

TABLE 2

Example frequency atlas

OBSERVATION AND MEASUREMENT RESULTS

Station identification		Position results				
<1> space station:	XYXYXYSAT-1R	<110> orbital position [°]	<190> elevation Leeheim [°]	remark	date of monitoring YYMMDD	<191> distance [km]
<2> responsible Administration:	XYZ					
<3> nominal position:	15,5E	15,5E	32,47			

signal	<115> frequency [MHz]	remarks	<116> bandwidth emission	remarks	<117> PFD [dBW]	remarks	<118> e.i.r.p. [dBW]	remarks	<119> polari-zation	remarks	<131> occu-pancy	spectra YYMMDD:HHMM	Annex	observation/ registration YYMMDD-MMDD	Annex
A	2210,000		1M00												
O	2210,000	4499	100M	599	−152,0	4699			L-X					040421-0422	
O	2210,000	4499	100M	599	−152,0	4699			L-Y					040420-0421	
A	2218,500		1M00												
O	2218,500	4499	100M	599	−152,0	4699			L-X					040421-0422	
O	2218,500	4499	100M	599	−152,0	4699			L-Y					040420-0421	
A	2281,000		1M00												
O	2281,000	4499	100M	599	−152,0	4699			L-X					040421-0422	
O	2281,000	4499	100M	599	−152,0	4699			L-Y					040420-0421	
A	2288,000		1M00												
O	2288,000	4499	100M	599	−152,0	4699			L-X					040421-0422	
O	2288,000	4499	100M	599	−152,0	4699			L-Y					040420-0421	

A=assigned, M=measured, O=observed, B=assigned beacon; N=no assignment

Extract of legend:

Generally applicable provisions

The term "assigned" is always used if details of the space station observed are recorded in ITU Publications and if the measured characteristics can be matched with the published characteristics. This term is used independently of the actual circumstances.

If the same position has been assigned to several space stations and ….

....

Meaning of the weighting code

Each of the rows comprising the measurement and observation results contains additional columns headed “Remarks" after the following columns:

<110> Position
<115> Frequency
<116> Bandwidth of emission and emission characteristics
<117> PFD in reference bandwidth
<118> e.i.r.p.
<119> Polarization
<1> Name of space station

The name indicated is that specified under <1>. Any unknown space stations are allocated the designation “UNKNOWN” supplemented with a fictitious nominal position.

<2> Responsible Administration

<8> Nominal geographical longitude of the geostationary satellite orbit, in degrees. Negative and positive values denote positions to the west and to the east of the Greenwich meridian respectively…………..

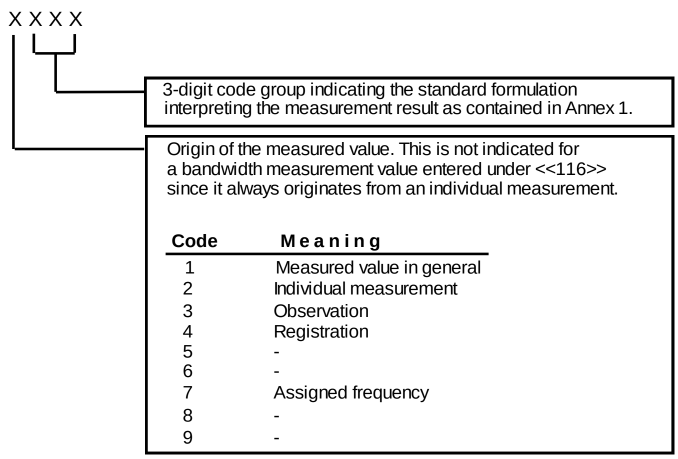
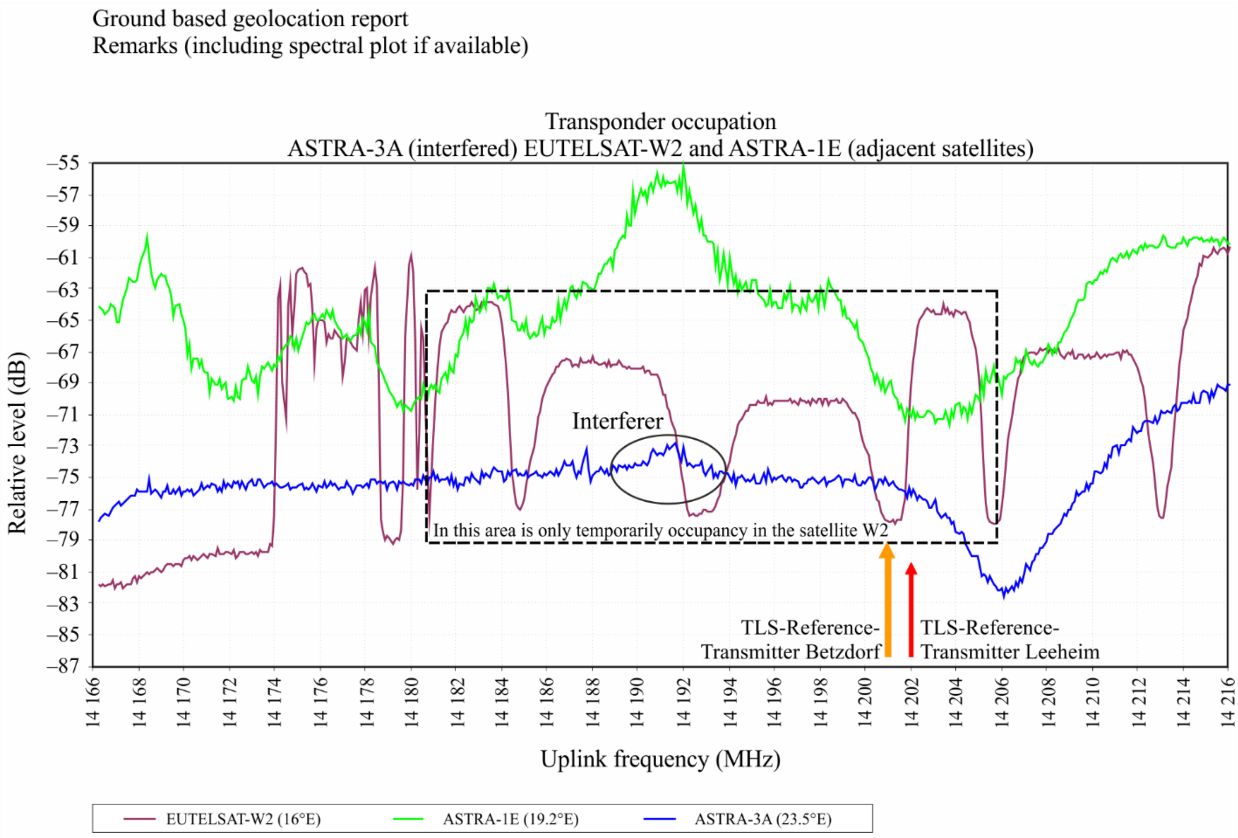


Fig. 1

End of extract! The legend may extend over several pages as required.

FIGURE 1

Example result of a transmitter location measurement



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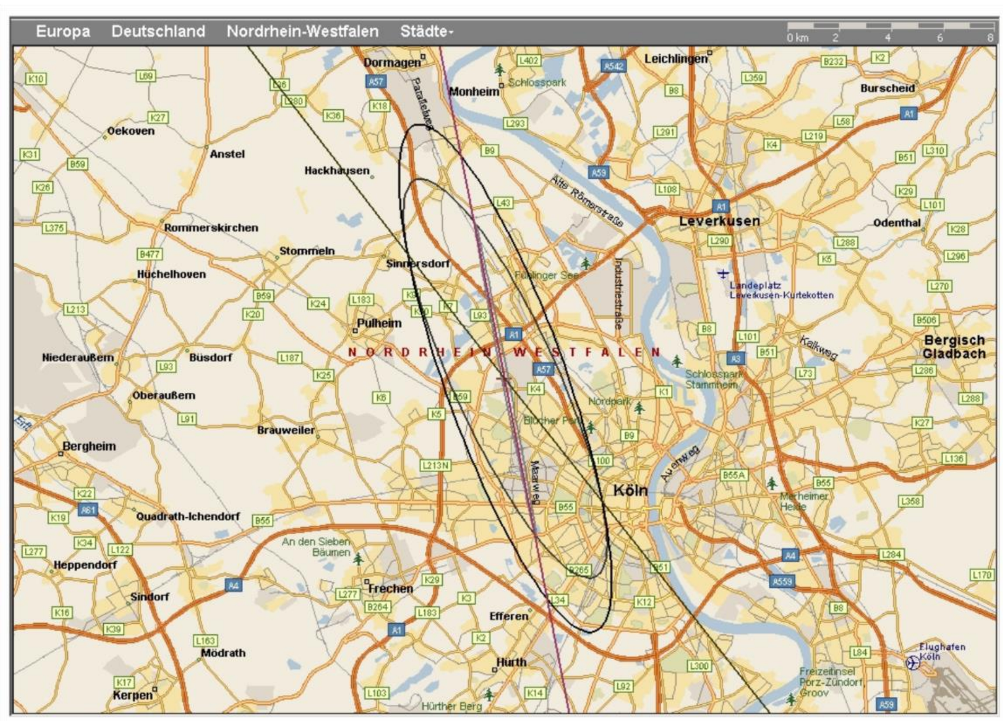

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Annex 2

Space Radio Monitoring Facilities in China

1 General introduction

The Beijing Monitoring Station, directly under the State Radio Monitoring Center (SRMC), Ministry of Industry and Information Technology (MIIT) is a complex which has functionalities such as monitoring of the HF, VHF, UHF bands, EMC testing and space monitoring. For space radio monitoring, the station is capable of monitoring non-GSO satellites and GSO satellites with a visible arc of 50° East longitude to 180° East longitude. The facility is located in Daxing District, some 20 km South of Beijing, and it is registered with ITU as a monitoring facility.

2 Space radio monitoring facilities in Beijing Monitoring Station

Beijing Monitoring Station was established in 2003, and it plays an important role in China's radio management and ensures an efficient usage of spectrum and safe operation of satellites. These include addressing over 30 satellite interference cases (by 2008), ensuring the satellite broadcasting of the 2008 Beijing Olympic Games, and supporting the satellite coordination negotiations.

2.1 Monitoring systems

Beijing Monitoring Station maintains seven satellite monitoring systems dedicated to GSO and non-GSO satellites. These seven systems are described in the following paragraphs.

2.1.1 System No. 1

This system consists of a 13 m C-band antenna and a 13 m Ku-band antenna for GSO satellites with their receiving and measuring equipment (there are also two 7.3 m backup antennas). The four antennas in this system are the earliest antennas in the station. The two 13 m Cassegrain antennas and the measuring equipment allow the measurement of the following parameters:

– frequency;

– bandwidth;

– modulation type;

– pfd;

– polarization;

– satellite orbit (GSO).

Two measuring systems can be routed to any of the band-polarization configurations so that high flexibility can be achieved. There are also two 7.3 m antennas (with lower speed) which can serve as backups for the 13 m ones (see Figs 2 and 3).

FIGURE 2

Antennas belonging to Systems 1, 3 and 4

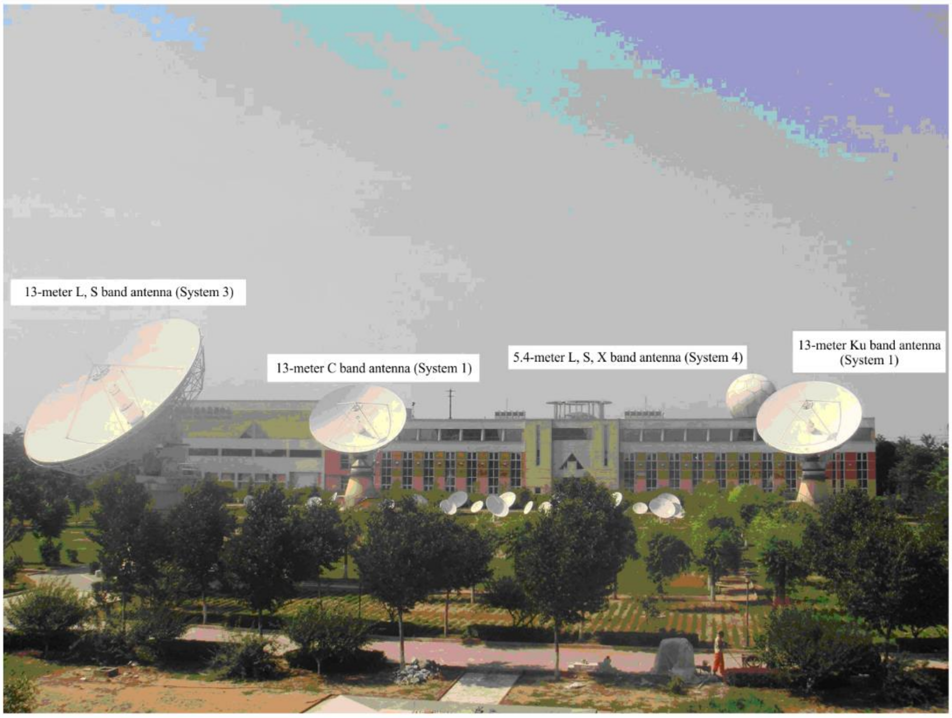


FIGURE 3

Two backup 7.3 m antennas

2.1.2 System No. 2

This system consists of four 7.3-metre C and Ku dual-band antennas (see Fig. 4) for GSO satellites with their receiving and measuring equipment. Two geolocation systems are also available with this system. The four high-speed C and Ku dual-band antennas are identical to one another in antenna parameters. Because interference investigation is the primary task of this system, it is equipped with high performance surveillance receivers and two geolocation systems. Interference emitters can be detected, measured and located with high precision, typically within about tens of kilometres (major axis). Then the final search stage can be triggered with the help of monitoring vehicles.

FIGURE 4

Four 7.3 m antennas belonging to System No. 2 and the reference transmitters (on rooftop)

SM.2182-04

2.1.3 System No. 3

This system consists of a 13-metre L- and S-band antenna (see Fig. 2) for GSO satellites with its receiving and measuring equipment. It has roughly the same structure as the System No. 1 except that it covers different bands.

2.1.4 System No. 4

This system comprises a 5.4-metre L-, S- and X-band antenna for non-GSO satellites with its receiving and measuring equipment. The system is capable of tracking the non-GSO satellite based on the calculation of known ephemeris and recording the parameters of its emissions.

2.1.5 System No. 5

This system is able to control 12 reference transmitters (C- and Ku-band) for geolocation purposes. These reference transmitters are located in different regions of the country. Reference signals with good geographic distribution are important for a geolocation operation. While at the same time, they are not always available for a satellite pair. Having recognized this, SRMC established 12 dedicated reference transmitters at six different monitoring stations, including Beijing Monitoring Station. A controlling software application is installed at each station so that it is possible to control these antennas within the SRMC local network.

2.1.6 System No. 6

This system is a monitoring vehicle (see Fig. 5) which is used for measurement of satellite uplinks and downlinks, with portable equipment. The vehicle is also used for monitoring terrestrial signals. The vehicle carries receiving systems which cover the frequency range from 1 GHz to 18 GHz. The antennas and the feeds of the receiving system can be shifted manually. The system is able to measure basic parameters of signals and decode TV signals. The monitoring coverage can be improved with the help of a 6-metre telescopic mast.

FIGURE 5

The monitoring vehicle

SM.2182-05

2.1.7 System No. 7

This system is dedicated to satellite broadcast monitoring. Twenty-four small antennas (TVRO antennas, see Fig. 6) with diameters ranging from 1.8 m to 3.2 m are available for measuring the satellite broadcast transmissions. This system also comprises a number of satellite TV receivers for different TV channels. Since broadcast is an important space service, it is found necessary and economical for space monitoring to use small antennas to measure TV parameters of transmission quality.

FIGURE 6

TVRO antennas for broadcast monitoring

SM.2182-06

All the above-mentioned systems can be displayed on 12 computer screens. By connecting the GUI computers to a KVM system, the user can easily access any one of the GUI of the six systems from these screens, except for the monitoring vehicle.

2.2 Basic parameter of some most-frequently used equipment

These parameters can be found in Table 3.

2.3 Working hours and contact

Working hours: 08:00-16:00 h (Beijing time) on weekdays.

Contact: Official contact is advised through fax at +86 10 6800 9299 (headquarter, SRMC).

TABLE 3

Antenna basic parameters
Beijing Monitoring Station, SRMC

Basic parameters of System Nos 1 to 4 can be found in Table 3:

Parameter	**System No. 1**				**System No. 2**		**System No. 3**		**System No. 4**		
Frequency-band (GHz)	3.4-4.2, 4.5-4.8	10.7-12.75	3.4-4.2	10.7-12.75	3.4-4.2	10.7-12.75	1.45-1.75	2.1-2.8	1.45-1.75	2.1-2.8	7.5-9.0
Antenna type	Full motion Az./El. Cassegrain		King-post Az./El.		Full motion Az./El., Cassegrain		Full motion Az./El., Cassegrain		Full motion, XY-mount, prime focus		
Antenna size	13 m Ø		7.3 m Ø		7.3 m Ø		13 m Ø		5.4 m Ø		
Polarization	LX, LY, RHC, LHC				LX, LY, RHC, LHC		LX, LY, RHC, LHC		RHC, LHC		
Polarization adjustment	yes				yes		yes		no		
Antenna gain (dBi)*	53(4)	62(12.5)	48(4)	58(12.5)	47(4)	57(12.5)	45(1.6)	48(2.45)	35(1.6)	39(2.45)	49(8)
G/T (dB/K)	32	39	29	37	27	36	24	28	12	16	27
Angle velocity	Az. El. 3°/s		Az. El. 0.1°/s		Az. El. 1°/s		Az. El. 1°/s		X axle: 5°/s Y axle: 5°/s		
Antenna tracking	Mono-pulse-track		Step-track		Step-track		Step-track		Mono-pulse-track, program track		

* 53(4) shows 53 dBi at 4 GHz.

Annex 3

Space Radio Monitoring Facilities in the United States of America

Federal Communications Commission (FCC)

1 Specifications of space radio monitoring station

1.1 Introduction

The Columbia Satellite Monitoring Facility is a function of the Enforcement Bureau (EB) of the U.S. Federal Communications Commission. The Enforcement Bureau is responsible for rule enforcement and interference investigations across many radio services, including satellite services. Satellite coordination and licensing is a function of the International Bureau of the FCC.

1.2 General description

The Enforcement Bureau of the Federal Communications Commission has maintained a satellite receiving system to accomplish the Bureau mission related to space communications services at the Columbia Office since 1979. The Satellite Monitoring Facility is located in Columbia, Maryland, about 22 miles (35 km) North of Washington, DC. This facility is the only satellite monitoring capability that the FCC maintains.

SM.2182-Annex3-01

1.3 Functions

1.3.1 General responsibilities of the EB in the satellite services include:

– fulfilling obligations under Title 47, Code of Federal Regulations, Section 25.274 of FCC Rules to assist satellite operators in interference resolution;

– meeting international obligations to investigate satellite interference reported through the International Telecommunications Union (ITU) and other civil satellite communications regulators. The Columbia Satellite Facility is registered with the ITU as a space radio monitoring facility;

– conducting spectrum utilization studies as needed by EB and other FCC Bureaus;

– investigating and resolving complaints of rule violations as needed;

– conducting investigations on behalf of, or in cooperation with, other FCC Bureaus;
– conducting technical portions of investigations of intentional interference to satellite (Title 18, USC, Section 1367) in cooperation with Department of Justice;
– gathering and disseminating information on satellite related matters.

1.3.2 Interference resolution is the primary work that is conducted in current operations. For interference investigations, the role of the facility and the staff includes:
– analyzing some satellite-related interference complaints coming directly to the FCC to determine the category and appropriate handling;
– providing self-help information for complaints that are determined to be unrelated to interference to space satellites, and/or referring the complaint to the appropriate FCC Office or Bureau for further handling;
– working with complainants to identify interference, through signal analysis, demodulation or other means;
– reviewing of FCC records (licenses, construction permits and special temporary authority grants) to determine possible sources for the interference;
– making observations or measurements that may be necessary to document a violation of FCC rules;
– performing inspections or making other contacts with FCC licensees to require "on-off" or other testing in order to verify interference sources;
– conducting follow-up investigations and production of violation notices or other official documents;
– conducting or coordinating on-scene measurements or ground-based direction-finding when the general location of the interference source has been identified by the satellite operator, ground station operator, other parties or is otherwise known;
– contacting and coordinating with other civil regulatory authorities and the ITU regarding interference matters requiring international coordination (i.e. sources in the U.S. affecting satellites of other countries, or sources in other countries affecting U.S. registered satellites).

1.4 Equipment

The main antenna is a 5-metre Scientific-Atlanta azimuth-over-elevation mount full motion antenna. It covers the spectrum from approximately 1 to 12.2 GHz in four bands, via manually-installable feed horns and amplifier sets. The instrumentation for this antenna permits spectrum analysis directly on the RF signal. Further details can be found in § 1.5.

SM.2182-Annex3-02

A 3-metre “polar mount” antenna using standard “C” and “Ku”-band low noise block converters (LNB) is also available for observations on geostationary satellites in the U.S. domestic portion of the geostationary arc (approximately 72° West longitude to 137° West longitude).

SM.2182-Annex3-03

1.5 System characteristics

1. Name of the station:

   Columbia, Maryland (United States of America)

2. Geographical coordinates:

   76°49’ West longitude 39°10’ North latitude

3. Hours of service:

   Variable as required

4. Information on main antenna in use:

   5 m Cassegrain feed parabolic for frequency range 1 GHz to 12 GHz slew rate 17°/s

5. Range of azimuth and elevation angles:

0-360°, 0-90°.

6. Maximum attainable accuracy in determining orbital positions of space stations:

$$\frac{0.3°}{f[\text{GHz}]}$$

7. Information on system polarization:

Dual orthogonal linear, mechanically adjusted

(with electronically-derived circular polarization in some bands)

8. System noise temperature:

3.7 GHz – 4.2 GHz: 250 K

11.7 GHz – 12.2 GHz: 600 K

9. Ranges of frequencies with the maximum attainable accuracy of frequency measurement for each frequency range:

a) 1 GHz – 12 GHz: 1×10^{-9}

b) 3.7 GHz – 4.2 GHz: 1×10^{-9}

c) 11.7 GHz – 12.2 GHz: 1×10^{-9}

10. Ranges of frequencies in which field strength or power flux-density measurements can be performed:

3.7 GHz – 4.2 GHz

11.7 GHz – 12.2 GHz

11. Minimum value of measurable field strength or power flux-density, with indication of attainable accuracy of measurement:

–175 dBW/m^2 ± 1 dB (3.7 GHz – 4.2 GHz)

–165 dBW/m^2 ± 2 dB (11.7 GHz – 12.2 GHz)

12. Information available for bandwidth measurements:

Bandwidth measurements made in accordance with the methods described in Chapter 4.5 of the ITU Handbook on Spectrum Monitoring

13. Information available for spectrum occupancy measurements:

Spectrum trace information can be collected upon request

14. Information available for orbit occupancy measurements:

Orbit occupancy measurements can be carried out on request

The geostationary arc-in-view for the 5-metre antenna is approximately 5° West longitude to 148° West longitude.

2 Working hours and contact information

Normal operating hours are 8 AM to 4:30 PM, Eastern Time, Monday – Friday.

The facility is located at:

Columbia Operations Center
9200 Farm House Lane,
Columbia, MD 21046

Voice: 301-725-0555
Fax: 301-206-2896

Interference-related work is the main priority for current operations.

Outside of normal operating hours, contact is possible through the FCC's Centralizing Office located in Washington, DC. The FCC Operations Center (FCCOC) is staffed 24 h/day, 365 days/year and can be reached at 202-418-1122 (voice) or 202-418-2812 (Fax).

Annex 4

Space Monitoring Facilities in the Republic of Korea

1 The details of SRMC

1.1 General description

Satellite Radio Monitoring Center (SRMC) is a government agency of the Central Radio Management Service (CRMS) under the auspices of the Ministry of Science and ICT (MSIT). SRMC is located in Seolseong-myeon, Icheon-si, Gyeonggi-do South Korea where is away from Seoul 80 km and it has started monitoring satellite radio waves since August, 2002. Major facilities include a main building of 2.198 m^2, two buildings for antenna, and a security building on the ground of 49.587 m^2. Also, over 150 people can meet at a conference room which has advanced equipment.

1.2 Function

- Tracking and receiving satellite radio waves (1.45~21.2 GHz, L/S/C /X/Ku/Ka) downward linked on the 55° East longitude to 160° West longitude.
- Measuring the orbit information and transmission features of a geostationary orbit satellite.
- Checking whether radio waves are in accordance with ITU Radio Regulations (RR).
- Quick searching of the interference source when harmful interference radio waves are generated.

FIGURE 7

Antenna 1, 2 in SRMC

SM.2182-07

1.3 System characteristics

– The geostationary orbit is monitored: 55° East longitude to 160° West longitude.

– Antenna 1 and 2

Parameter		Antenna 1, 2
Frequency Bands (GHz)	L-Band	1.450-1.800
	S-Band	2.170-2.655
	C-Band	3.400-4.800
	X-Band	6.700-7.750
	Ku-Band	10.700-12.750
	Ka-Band	17.700-21.200
Type of antenna		Beam wave guide Cassegrain
Antenna diameter (m)		13
Antenna gain (dBi)		44.2-64.6
Half-power beamwidth (degrees)		1.0-0.1
Figure of merit G/T (dB/K)		22.6-40.0

Parameter	Antenna 1, 2
Max. speed of antennas − Azimuth (degrees/s) − Elevation (degrees/s) − Polarization (degrees/s)	 5 2.5 1.5
Travel range − Azimuth (degrees) − Elevation (degrees)	 ±270 0-90
Antenna steering	Computer-controlled automatic chase
Polarization	Circular polarization Linear polarization
Doppler shift elimination (kHz)	–
Measurement accuracies − Power flux density (dB) − Frequency	 ±1.5 $2*10^{-14}$

Two antennas are beam wave guide (BWG) Cassegrain antennas which are 13 m in diameter. They have the same functions and performance each other and consist of a feed system, a reflector, a pedestal, an antenna control unit (ACU) and a LAN subsystem. The feed system follows the order: Horn->Mode coupler->Diplexer. The feed system has a polarization control (Circular or Linear) function. Also, six feed horns are mounted on a circular rotation device so that L, S, C, X, Ku, Ka-band frequency may be selected. The antenna system is designed to be a multi-band receiving antenna to receive six bands. The satellite radio wave is conveyed from a main reflector, to/from a sub-reflector, to/from a mirror, to/from a feed horn, to/from a polarization control unit, to a measurement room orderly. The feed horn structure adapts a feeding method by a corrugate horn, so that it is possible to chase a satellite orbit precisely and to correct Doppler because of the mounted RF Plate which does monopulse tracking functions for each band.

An antenna control system can choose to drive antenna, to control speed, and to select polarization. In this case an antenna operator can control them by himself. Also, it is possible to measure radio waves and to chase a satellite automatically at the reservation time of the satellite radio wave-monitoring program.

The two antennas which have the same performance has an important role in examining into the reason for harmful radio wave interference and will increase trust in the results of monitoring the satellite radio waves.

1.4 Measuring parameter

− Measuring the orbit position of a space station.

− Measuring the transmission features of a satellite radio waves:

  – Discerning polarization.
  – Mean frequency.
  – Occupied frequency bandwidth.
  – The intensity of spurious emission.
  – Power flux density (pfd).
  – e.i.r.p.

  – Frequency and modulation type.
  – The demodulation of broadcast signals (Image/voice).
- The ratio of frequency usage.

1.5 Mobile satellite radio monitoring system

- Purpose:
  – To perform satellite radio monitoring beyond the limitation of the fixed monitoring system.
  – Taking measurement anytime, anywhere for the satellite user's interests.
- Specifications:
  – Monitor frequency: L, S, C, X, Ku, Ka (satellite), 200 MHz ~ 40 GHz (terrestrial).
  – Height: 3.62 m.
  – Weight: 5 tons.
- Configuration:
  – Satellite radio monitoring system.
  – Terrestrial interference investigation system (including SW).
  – Data base, Navigation, Power system, etc.
- Mission:
  – Satellite radio monitoring.
  – Interference Investigation.
  – Monitoring Satellite TV reception conditions.
  – Investigation of satellite radio environment.

FIGURE 8

Mobile satellite radio monitoring system

SM.2182-08

2 Tasks

2.1 The measurement of geostationary satellite orbit and transmission characteristics

− Measuring a satellite orbit and transmission features within target range in a regular method:
  – Discerning whether the satellite radio waves emitted from the space station are the same as the orbit information and transmission features as ITU-R Registration specification.
  – Retrieving satellite registration, measuring orbit position, and retrieving location information.
  – Protecting the satellite network service from harmful interference by finding out the interference source after analysing measurement route and examining into harmful interference radio waves.
  – Reporting the measured monitoring data with the form of database to Central Radio Management Service (CRMS) and ITU.

2.2 The close examination of reasons for harmful interference radio waves

− Protecting a satellite network by seeking the interference of radio waves emitted between the ground station and satellite network or other satellite networks, examining into its reason and getting rid of it.

− Playing a decisive role in solving the jamming of the satellite network by calculating the frequency difference of arrival (FDOA) and presuming the location of the emitting source of harmful propagation with Doppler shift and the time difference of arrival (TDOA) which shows the arrival of radio waves according to the distance of a signal which is inputted into two antennas through other different routes respectively when interference occurs at the satellite network.

2.3 Offering of satellite radio measurement data

– The data on satellite radio waves are utilized in the registration of the country's satellite communications networks, research on basic satellite technologies, observation of the conditions of the satellites in operation, etc.

3 Work hours and contact information

3.1 The work time

Office and Operation room

Monday ~ Friday 09:00 ~ 18:00

Sunday, Saturday, and holidays are off duties.

3.2 Contact information

100 Sinam-ro, Seolseong-myeon, Icheon-si
Gyeonggi-do 17413, Republic of Korea
Satellite Radio Monitoring Center Office

Tel.: +82 31 644 5921
Fax: +82 31 644 5829

Oh Hwa Seok
Tel.: +82 31 644 5942
Fax: +82 31 644 5829
E-mail: ohs0301@korea.kr
Seong Ji EonTel.: +82 31 644 5991
Fax: +82 31 644 5829
E-mail: srmc@korea.kr

Annex 5

Space Radio Monitoring Facilities in Japan

1 Overview

1.1 History

Space radio monitoring in Japan commenced in 1998 with the establishment of the first space radio monitoring facilities. During 2008 to 2010, the Ministry of Internal Affairs and Communication (MIC), the governing agency in charge of radio administration in Japan, renewed these first-generation facilities as they had grown old. Operation of the renewed facilities has started since April 2010.

Space radio monitoring facilities are located in Miura City, Kanagawa Prefecture at latitude 35° North and longitude 139° East, approximately 60 km South of central Tokyo. The facilities are situated on a hill overlooking the Pacific ocean. Main components of the facilities include 2 units of 13 m parabola antenna capable of monitoring 5 bands (L/S/C/Ku/Ka).

1.2 Role

1.2.1 Monitoring of domestic and foreign satellites

Visible arc (range of visible geostationary satellite orbits) is between 67° East longitude and 147° West longitude. Currently, there are approximately 300 satellites within this range, and all of these satellites within visible range are subject to monitoring. We measure the orbital location of the satellites and various radio wave parameters to promote appropriate satellite radio utilization as well as investigate and analyze frequency utilization and radio emission to contribute to effective allocation of satellite frequency bands.

1.2.2 Elimination of interference

The new space radio monitoring facilities which have come into operation since April 2010 are equipped with a unique system for uplink interference source identification. This system was not an existing package, but was uniquely developed by Japan. Uplink interference source identification allows us to proactively monitor and eliminate harmful interferences.

1.2.3 Data collection to utilize for international coordination of the satellite communication network

Various data collected through daily monitoring operations are recorded and accumulated in appropriate formats that can be reproduced and analyzed as necessary. These data are utilized as basic information for international coordination of the satellite communication network. Moreover, the new space radio monitoring facilities are provided with features for data format conversion, allowing preparation of data files compatible with the data formats used for international data transfer.

1.3 System configuration

Japan's space radio monitoring facilities mainly consist of outdoor antennas (2 units of 13 m multi-band parabola antenna capable of operating at L/S/C/Ku/Ka bands and 7 units of fixed antenna for providing backup in each of the bands) and an indoor operation center which is connected to the antennas by high-speed communication circuits.

The outdoor antenna units are remotely controlled from the operation center to measure the orbital location and radio emission of geostationary satellites. Spectrum information and images are also monitored and recorded. Measurement data are transferred to the operation center and displayed for archiving and analysis. The operation center also assumes the function of managing operation of the space radio monitoring facilities as a whole.

Figures 9 and 10 respectively shows the configuration and system layout of the space radio monitoring facilities, while Fig. 11 describes the configuration of the 13 m antenna.

1.4 Main attributes

Table 4 shows main attributes of 13 m antenna for the space radio monitoring facilities.

FIGURE 9

Configuration of the space radio monitoring facilities

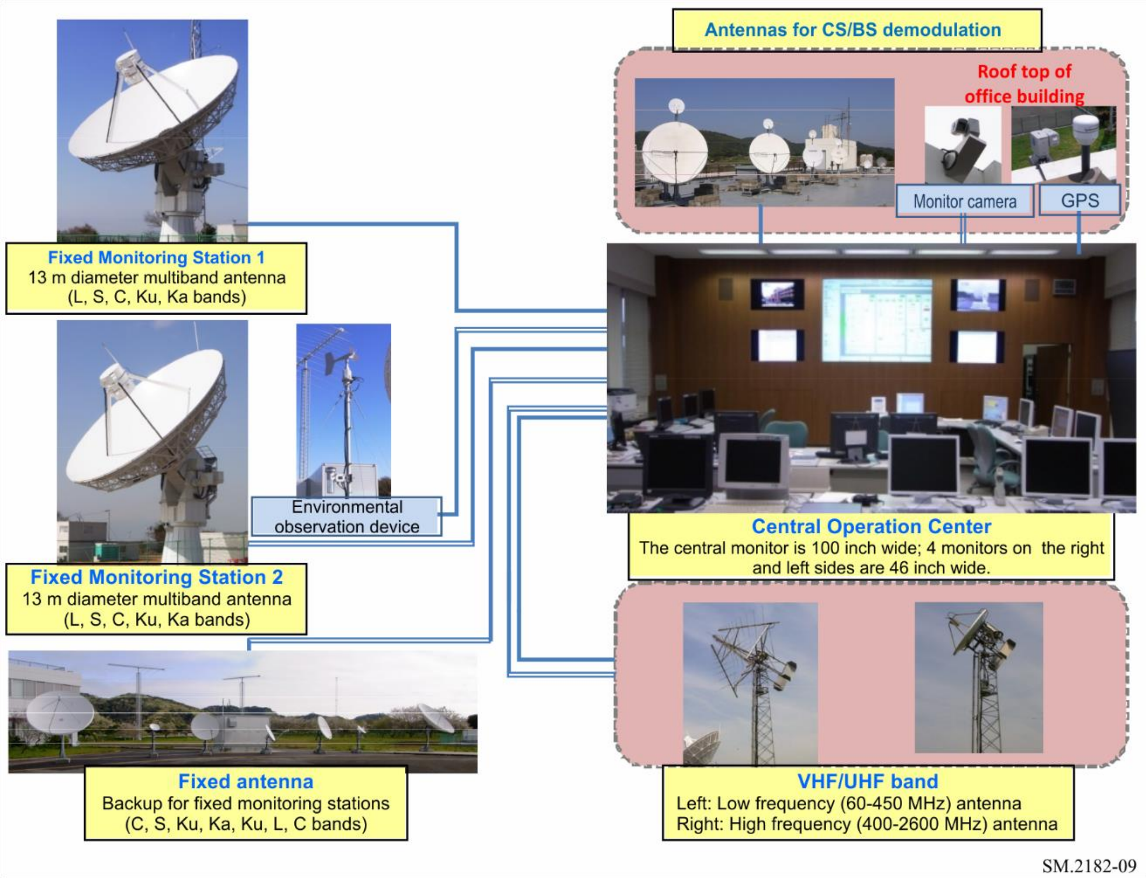
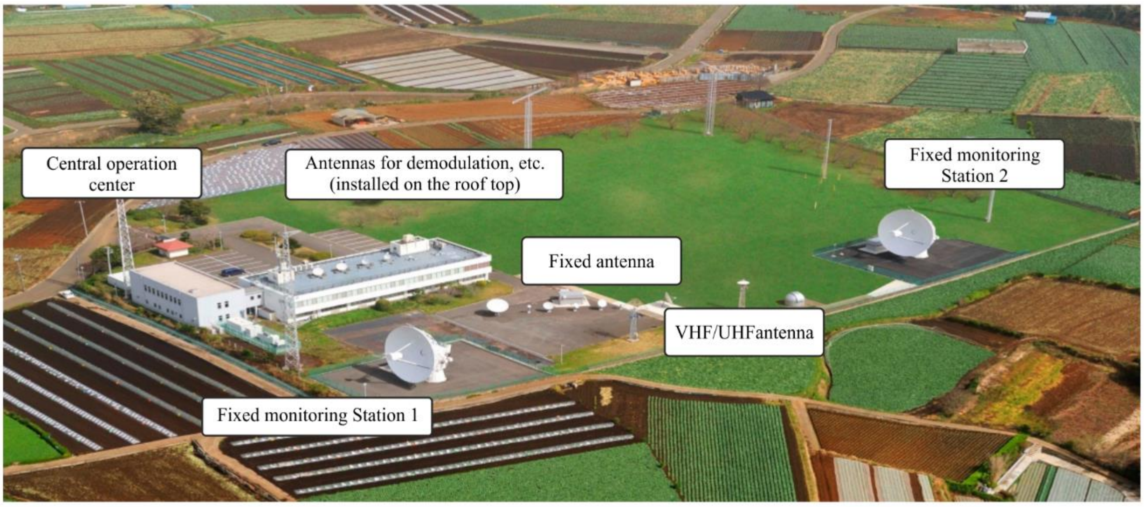


FIGURE 10

System layout of the space radio monitoring facilities



- Fixed Monitoring Station (L, S, C, Ku, Ka multiband antenna)
Receives downlink signals from geostationary satellites within visible range from the Miura Monitoring Station (visible arc: between longitudes 67 east and 147 west).

- Fixed antenna (L, S, C, Ku, Ka band antennas)
7 units of fixed antennas have been installed to provide backup in each of the frequency bands and polarizations in case of failure or maintenance of the Fixed Monitoring Stations.

- VHF/UHF antenna (60~2 600 MHz)
Receives signals from mainly non geostationary satellites by tracking antennas for lower (60-450 MHz) and higher (400-2 600 MHz) frequency ranges.

- Central Operation Center
Equiped with devices for data processing recording and reproduction. Through remote conrol with control terminals, the center analyzes data received by the fixed monitoring stations, fixed antennas, VHF/UHF facilities as well as manage and monitor operation of the entire system.

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FIGURE 11

Configuration of the 13 m antenna

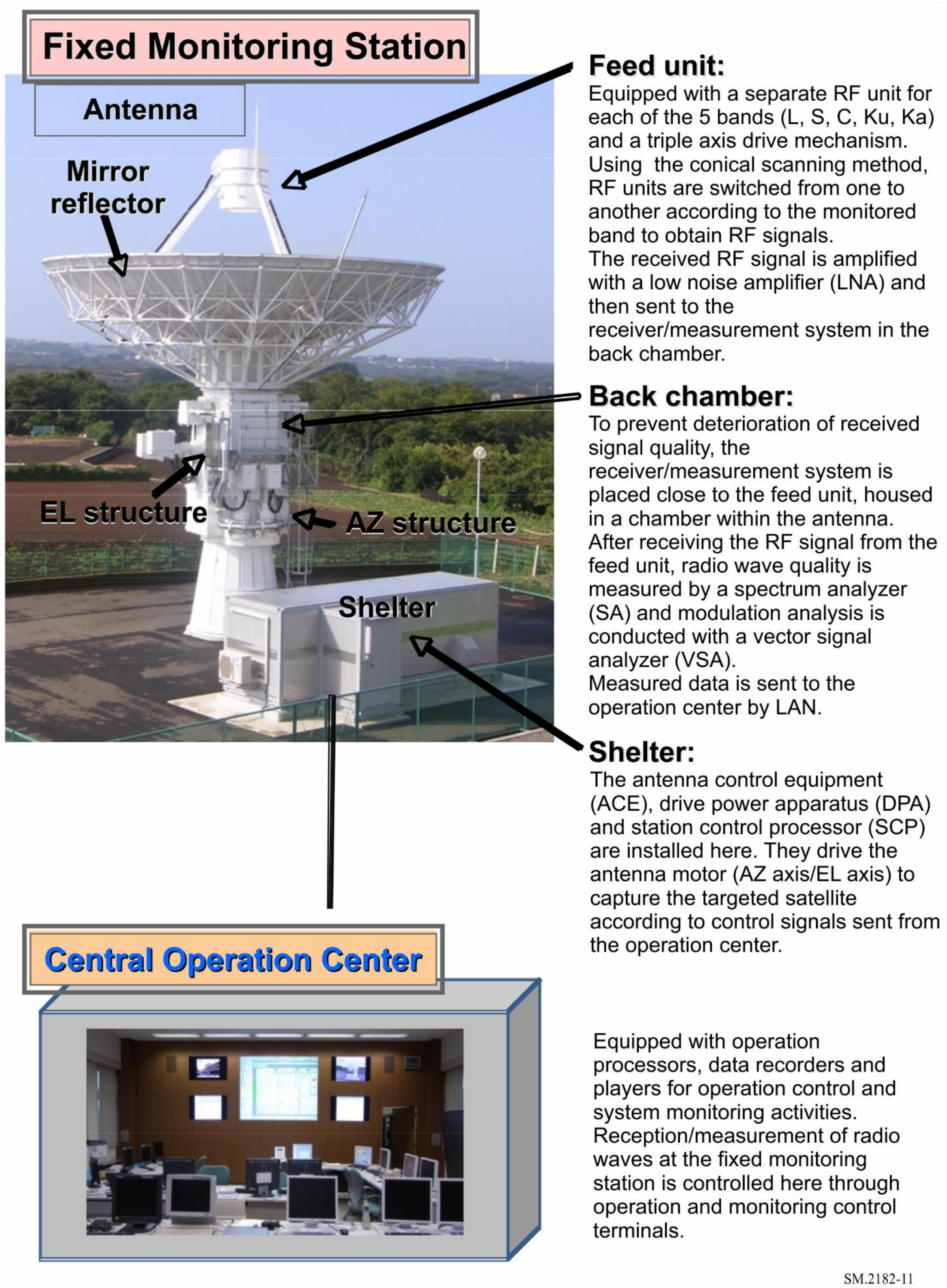


TABLE 4

Main attributes of 13 m antenna for the space radio monitoring facilities

Item	Specifications				
	L-band	**S-band**	**C-band**	**Ku-band**	**Ka-band**
Reception frequency range	1.525 MHz 1.710 MHz	2.120 MHz 2.690 MHz	3.400 MHz 4.800 MHz	10.700 MHz 12.750 MHz	17.700 MHz 22.000 MHz
Polarization	Linear polarization (vertical, horizontal) Circular polarization (right-hand, left-hand)				
Antenna drive range	AZ: –90°～+90° EL: 0°～90°				
Antenna drive speed	AZ: 0.9°/s or above EL: 0.25°/s or above				

1.5 Main measurement parameters

Main parameters measured at the space radio monitoring facilities are listed below:

- Frequency.
- Spectrum.
- Occupied bandwidth.
- Polarization.
- Power flux-density.
- e.i.r.p.
- Intensity of spurious emission.
- Demodulation of TV broadcast signals.

2 Main operations

2.1 Measurement and analysis of orbital location

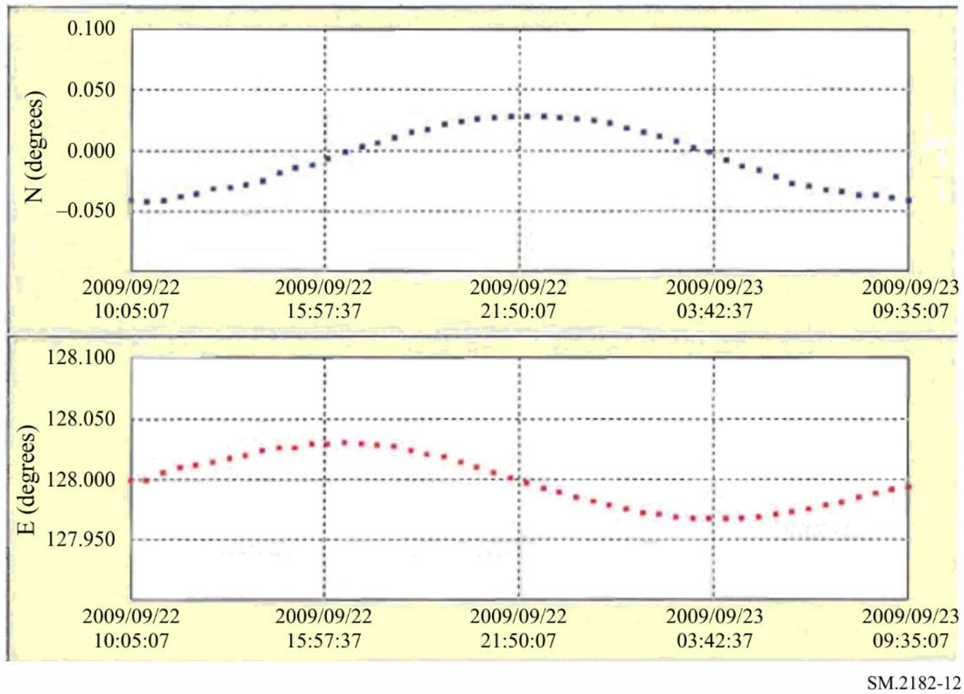
The orbital location of satellites within visible range is measured to determine whether each satellite is being operated within the allowable range from its nominal orbital location.

In measuring the orbital location of satellites, antenna direction values (AZ/EL) are obtained from an automatic tracking system, then these values are used to analyze the orbital location (latitude/longitude). Automated measurements are conducted for longer time periods to monitor the orbital location of rotating satellites.

In analyzing the orbital location, measurement results are displayed in a graph to judge whether the satellite is staying within its allowable range. There are several graph options available for display, and a screenshot of the time-trend graph option is shown in Fig. 12 as an example.

FIGURE 12

Analysis of orbital location (sample screenshot of the time-trend graph option)



2.2 Measurement and analysis of various radio parameters

Various parameters of radio emission from satellites subject to monitoring are measured to determine whether the quality of the radio wave meets the values specified by the Japanese Radio Act and ITU RR and their Appendixes.

Parameters measured as indicators of radio quality are center frequency, occupied bandwidth, electric power, e.i.r.p. and pfd. Our system is capable of simultaneous measurement of two differently polarized waves (combination of either vertically/horizontally-polarized waves or left/right-handed circularly polarized waves) as well as broad/narrow-band measurements.

These radio parameters are analyzed by extracting the parameters of a specific carrier wave based on markers indicating the analysis frequency range and thresholds defined for each parameter, and then outputted as a graph. Spectrums exceeding the threshold value will be detected and notified automatically. When measurements took place for a prolonged period, the measurement results of a certain time point can be selected and analyzed using the fast-forward, rewind or frame-step functions.

Figure 13 shows a sample screenshot displaying radio parameter analysis results.

2.3 Measurement and analysis of frequency utilization

Time occupancy during the measurement period and frequency occupancy in certain frequency bands are analyzed based on radio emissions from satellites. Frequency utilization trends (whether and when radio waves have been actually emitted) can be monitored by analyzing the above mentioned parameters.

Frequency utilization trends within analysis frequency range can be displayed in waterfall mode, color-coded according to reception levels. Time occupancy and frequency occupancy are displayed in numerical values.

Figure 14 shows a sample screenshot displaying frequency utilization analysis results.

FIGURE 13

Sample screenshot displaying radio parameter analysis results

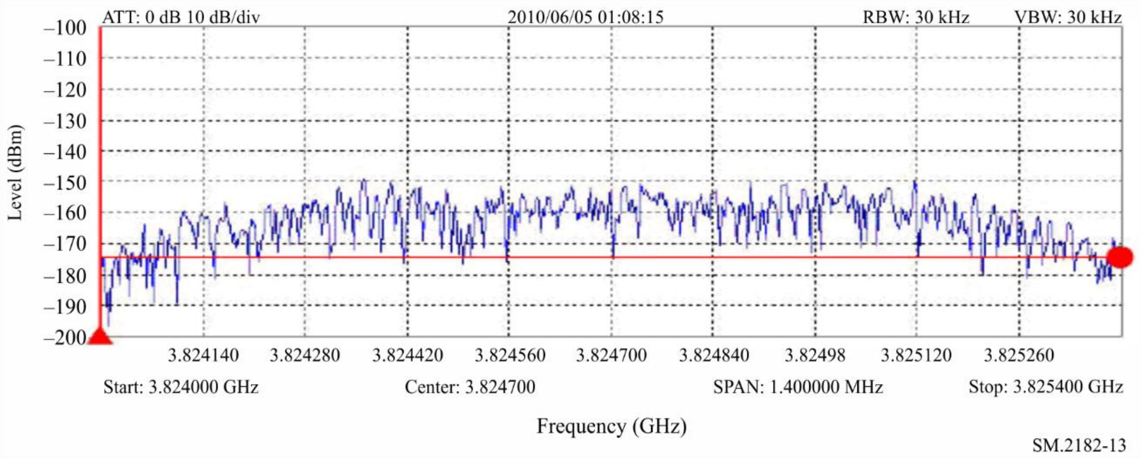
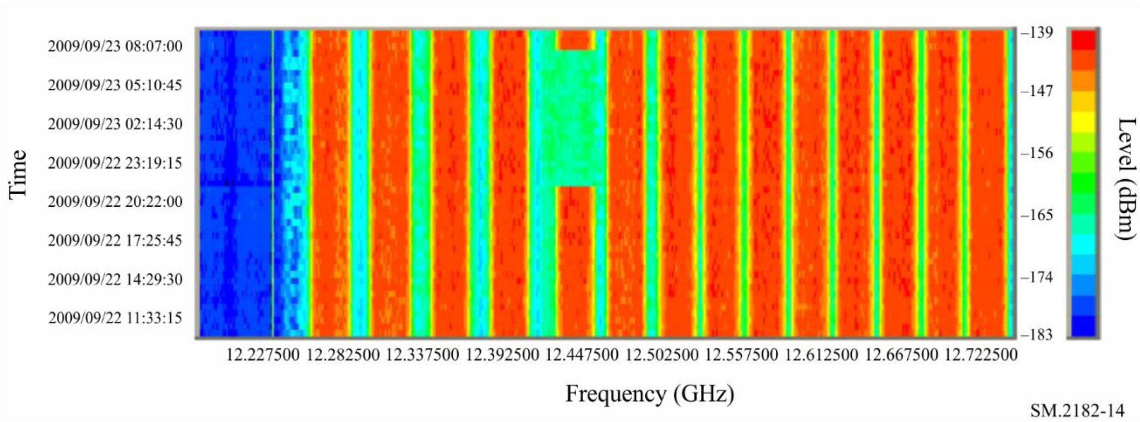


FIGURE 14

Sample screenshot displaying frequency utilization analysis results



2.4 Measurement and analysis of radio emissions

The spectrum of radio waves transmitted from satellites are measured and analyzed in reference to registered orbital locations for the purpose of monitoring satellite activities.

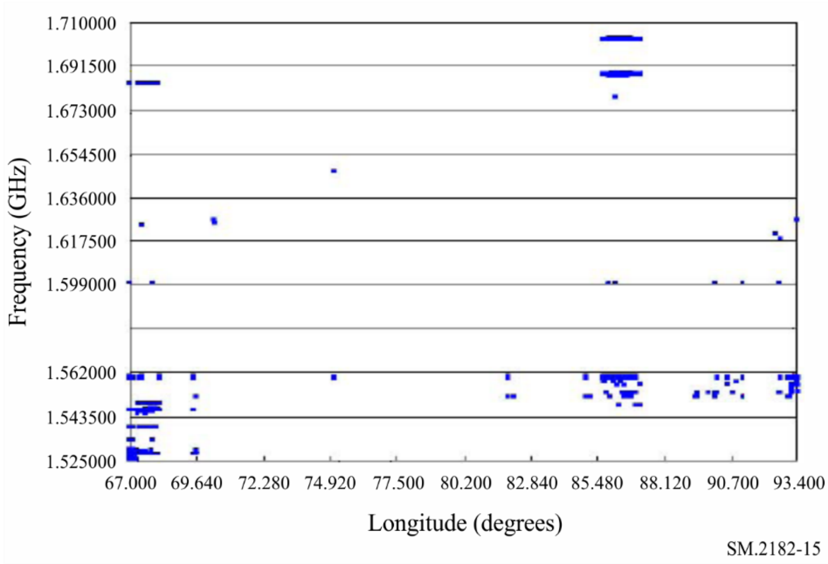
These spectra are measured by driving the antenna along geostationary satellite orbits using arc trace or spiral trace functions.

The measurement results are checked against the registration information database of orbital locations. The satellite's name and orbital location will be displayed in a list for those measurement values that match the database. Those that do not match any of the registered information in the database can be identified on the screen with a mark to indicate that it as an unregistered satellite.

Figure 15 shows a sample screenshot displaying radio emission analysis results.

FIGURE 15

Sample screenshot displaying radio emission analysis results



2.5 Uplink interference source identification

The uplink interference source identification system is a system for identifying the location of the interference source when interference with the uplink circuit occurs.

In operating this system, radio waves from two adjacent satellites are received. Usually, fixed monitoring station Nos 1 and 2 are used as measurement stations (i.e. antennas) to receive these radio waves.

Signals from the satellite experiencing interference are called the "main signal", while signals from the adjacent satellite chosen for uplink measurement are called "sidelobe signals". Two types of signals, that is, target signal which is the interference signal and reference signal for ensuring accuracy of source identification are received from each of the main and sidelobe satellites respectively. In other words, location of the interfering earth station (or the target) is estimated by uplink measurement of a total of four different signals: target signals (of main and sidelobe signals) and reference signals (of main and sidelobe signals).

If the interference wave is a continuous wave (CW), it is difficult to accurately detect the time difference of arrival (TDOA), so measurements are repeated multiple times to plot the frequency difference of arrival (FDOA) in a time-cumulative manner. In addition, when the satellite movement is very small, Doppler frequency is less likely to occur. This makes it difficult to accurately detect the FDOA. In such cases, TDOA alone will be displayed on the map to assist source identification.

Figure 16 shows the mechanism of the uplink interference source identification system, and Fig. 17 shows a sample screenshot displaying source identification results.

FIGURE 16

Mechanism of the uplink interference source identification system

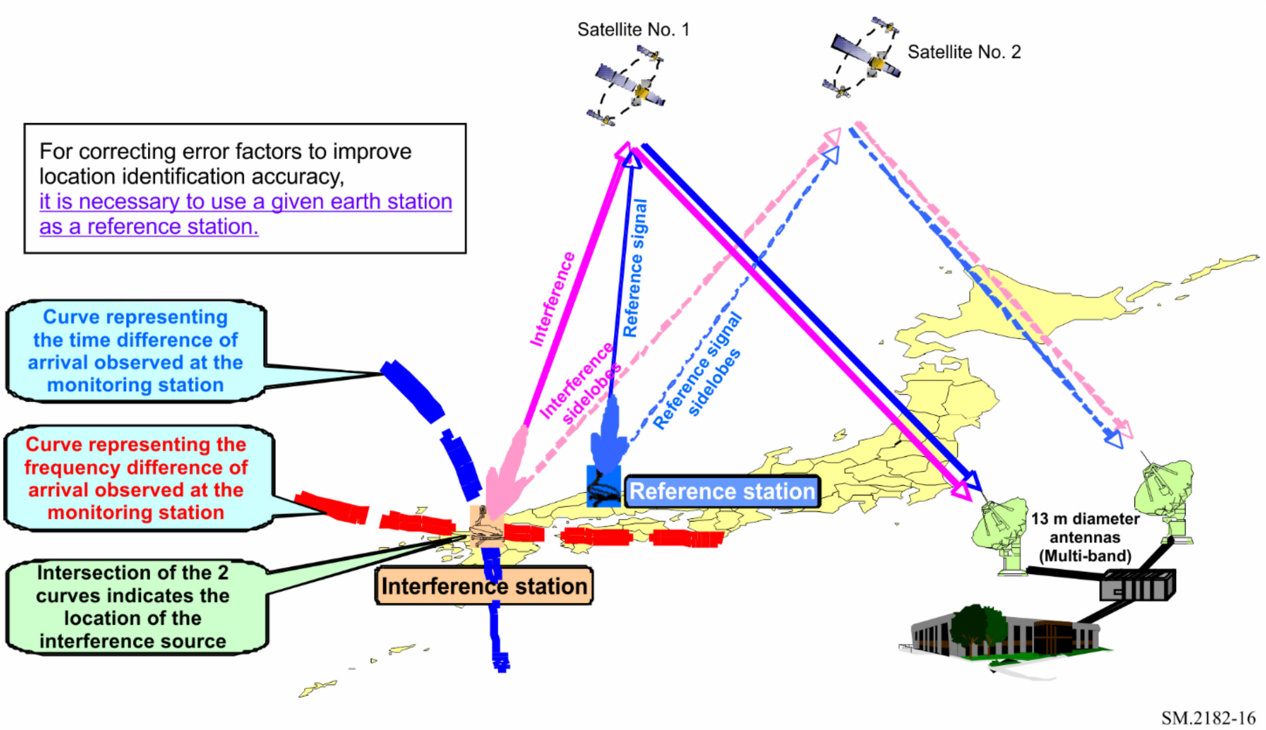


FIGURE 17

Sample screenshot displaying source identification results

3 Working hours

Normal working hours are from 8:30 AM to 5:15 PM on weekdays (by Japan time).

4 Contact address

Radio Monitoring Office
Electromagnetic Environment Division, Radio Department
Telecommunications Bureau
Ministry of Internal Affairs and Communication (MIC)
1-2 Kasumigaseki 2-chome
Chiyoda-ku
Tokyo 100-8926
Japan

E-mail: kanshikokusai@ml.soumu.go.jp

Annex 6

Space Radio Monitoring Facilities in Ukraine

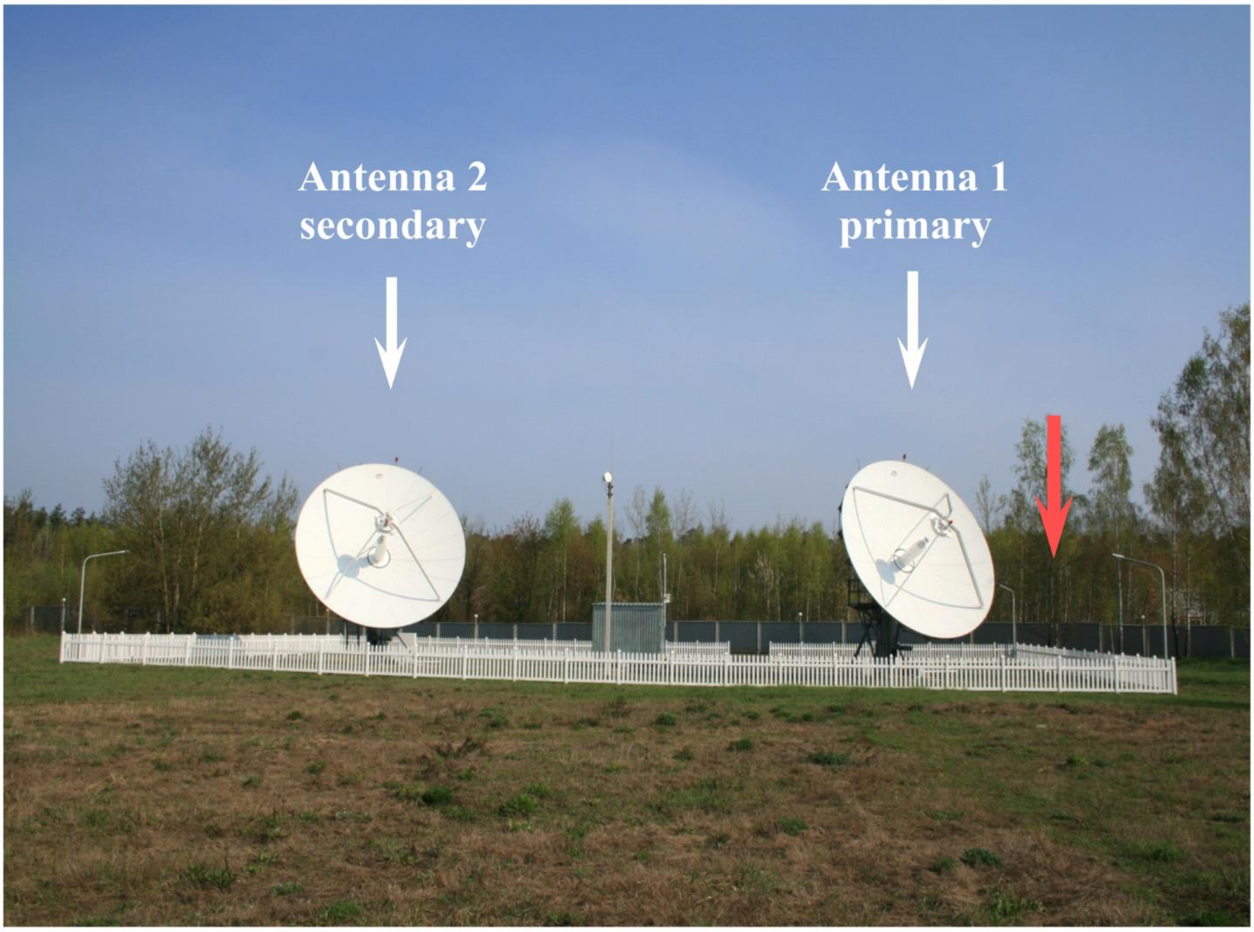
1 General introduction

The Kyiv space radio monitoring station is a part of Radio Monitoring System of the Ukrainian State Centre of Radio Frequencies (the UCRF). The UCRF is responsible for spectrum management and spectrum monitoring in the civil frequency bands.

The Kyiv space radio monitoring station is designed for measuring parameters of emissions of earth stations and satellite stations on carrier frequencies and performing earth stations location (geolocation) in frequency bands C (3.4-5.25 and 5.725-7.025 GHz) and Ku (10.7-14.8 GHz). The station is able to observe retransmitted emissions of earth stations from satellites, located on GSO at orbital positions from 20° West longitude (Azimuth 237° and Elevation 15°) to 80° East longitude (Azimuth 123° and Elevation 15°).

The Kyiv space radio monitoring station was established in 2009 and its development is going on.

Geographical coordinates of the station are 50°26'54" N; 30°17'30".



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2 The main tasks of the Kyiv space radio monitoring station

The main tasks of the Kyiv space radio monitoring station are:

– checking the conformance of emissions parameters to the ones indicated in permissions for operation or in technical regulations;
– frequency bands occupancy observations;
– detection of harmful interference in accordance with complains of spectrum users, legal and physical persons;
– detection of cases of frequency usage violation and determination of location of unlawfully operating transmitting devices with the aim of taking lawful measures for eliminating violations and switching off unlawfully operating devices;
– radio monitoring activity in the framework of international cooperation on the radio frequency resource usage issues.

3 Kyiv space radio monitoring station structure

Functionally, Kyiv space radio monitoring station combines four subsystems:

– 2 receiving satellite antennas with a diameter of 7.3 m;
– subsystem for diagnostics and control for terrestrial equipment of space radio monitoring station and for antennas pointing to given satellites;

– subsystem for measuring of satellite emission parameters, satellite station carrier frequencies and for database maintenance;

– subsystem for earth stations location finding (geolocation) and calculation of satellites ephemerides.

3.1 Antennas

The parameters of antennas are given in Table 5.

TABLE 5

Parameter	Antenna 1	Antenna 2
Antenna type	Cassegrain	Cassegrain
Antenna size, m ∅	7.3	7.3
Frequency band	C/Ku	C/Ku
Antenna gain, dBi	49.73/58.41	49.50/58.84
Polarization	Circular/Linear	Circular/Linear
Azimuth travel	120°	120°
Elevation travel	0-90°	0-90°
Rotation angle on polarization	±90°	±90°

3.2 Subsystem for diagnostics and control for terrestrial equipment

This subsystem allows checking operability of antenna system components and equipment failure. As well it is designed for antennas pointing to given satellites (both in manual and automatic modes) using integrated database with satellites parameters.

3.3 Subsystem for measuring of satellite emission parameters

Many measurements of uplink earth station parameters can also be made through the satellite.

The software of this subsystem allows to measure parameters of radio electronic facilities, mentioned below:

– modulation type (BPSK, QPSK, 8-PSK, OQPSK, 16-QAM, 16-APSK, 32-APSK, CW, MSK);

– symbol rate;

– central frequency;

– effective isotropic radiated power (e.i.r.p.);

– bandwidth;

– carrier-to-noise ratio (C/N_0);

– data rate;

– bit error rate (BER);

– carrier standard (DVB-S, DVB-S2, IESS-308, IESS-309, IESS-310, IESS-315);

– forward error correction (1/2, 2/3, 2/5, 3/4, 3/5, 4/5, 5/6, 7/8, 8/9, 9/10).

System allows storing measured data and comparing it with the ones existed in the database of frequency assignments or with the parameters measured earlier. Moreover there is a possibility to scan satellite transponders with the aim of determination of all carrier frequencies and identification of them by comparing with the ones in existed database.

3.4 Subsystem for earth stations location finding (geolocation) and calculation of satellite's ephemerides

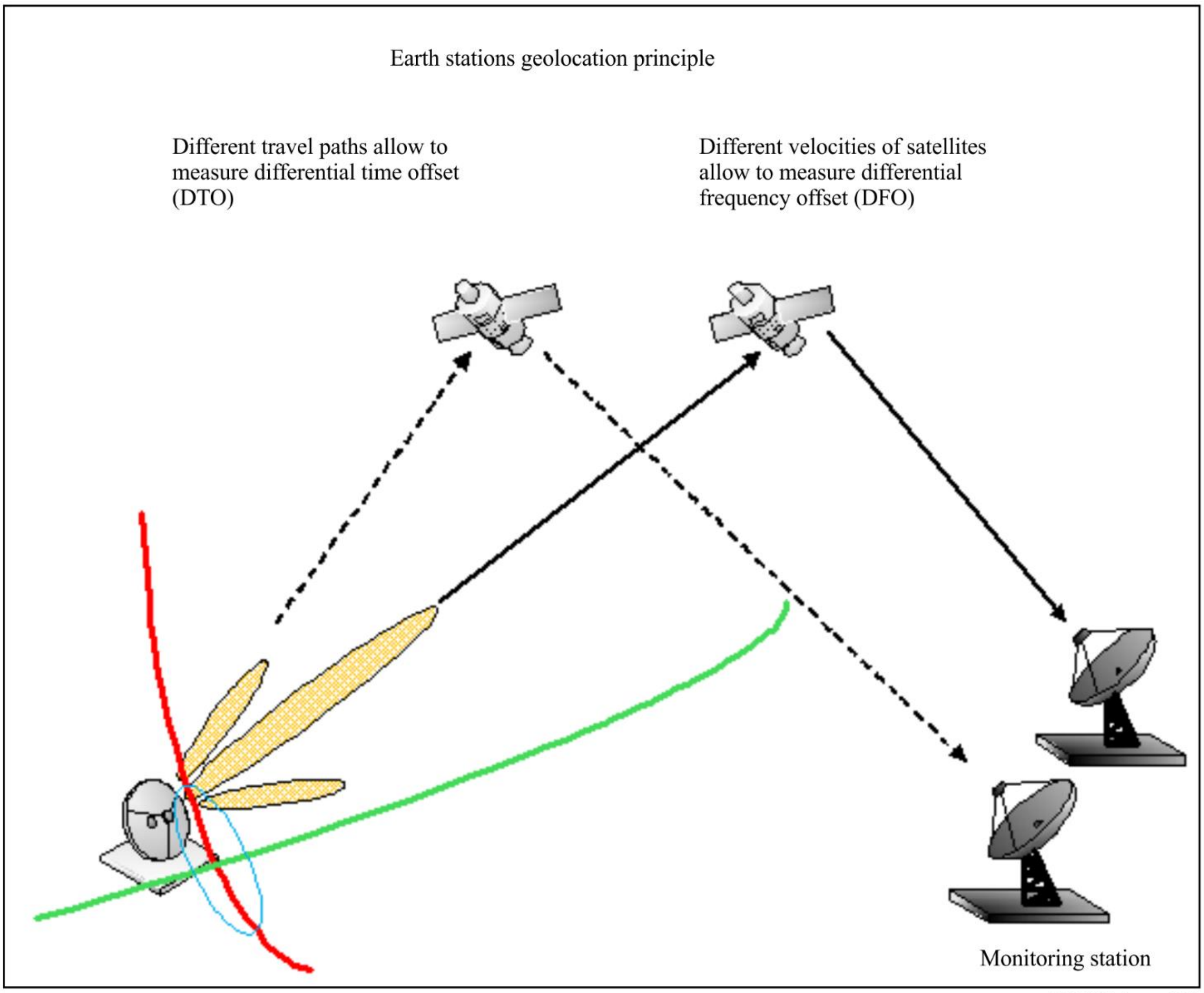
Earth stations location finding principles (geolocation) is based on analysis of signals, which are transmitted by earth station and retransmitted by satellite. While the targeted signal (main lobe) is transmitted to the particular satellite, the part of the side-lobe of this signal is transmitted to adjacent satellite (operating on the same frequency, with the same polarization and having the similar service area). The signal from two paths is received, converted and digitized by space radio monitoring station.

The different location of satellites on the geostationary orbit and signal travelling along different paths through two or more satellites allow to obtain the differential time offset (DTO) and to draw the time line of position on the Earth surface (red line on the figure below).

Taking into account the movement of satellites during the given time, offset and frequency oscillation on satellite generators, it is possible to calculate differential frequency offset (DFO) and to draw the frequency line of position on the Earth surface (green line on the figure below).

Using obtained data the space radio monitoring station calculates ellipse, inside of which the targeted earth station is located.

From the difference between signals time delay the bearing in the direction of South-North is derived with inaccuracy 0.5-10 km. The bearing in the direction of east-west is derived from the difference of frequencies and phase shift (50-80 km inaccuracy). In order to increase the accuracy of the earth station geolocation, it is necessary to make several measurements with ephemeris error compensation. In such case potential inaccuracy of earth station geolocation of 0.5-1 km could be achieved.



4 Contact address

Ukrainian State Centre of Radio Frequencies
15 km, pr. Peremogy
03179 Kyiv
Ukraine

Fax: +38 044 422 81 81
E-mail: centre@ucrf.gov.ua

Annex 7

Space Radio Monitoring Facilities in Kazakhstan

In 2005 the Republic of Kazakhstan Space Vehicles Ground Control Center (GCC "Akkol") has been built and placed into operation. In 2008-2009 Center «Akkol" was modernized under the "KazSat-2" program.

GCC “Akkol” consists of Mission Control Centre (MCC “Akkol”) and Communication Monitoring System (CMS “Akkol”).

GCC “Akkol” is located in Akkol town, Akmolinskaya region with the following geographical co-ordinates: North latitude 52°0'11", East longitude 70°54'3", height above sea level is 410 m. Figures 18 and 19 show the general view of the “Akkol” center.

FIGURE 18

General view of the “Akkol” center

SM.2182-18

FIGURE 19

7.3 m Antenna system

SM.2182-19

“Akkol” Communication monitoring system consists of:

– monitoring stations with antenna d = 9 m;

– two receiving antennas d = 7.3 m;

– two receiving antennas d = 2.4 m for TVRO;

– hardware-software control and measuring equipment;
– server and client equipment with corresponding software.

"Akkol" Communication monitoring system carries out the following regular monitoring activities in orbital positions from 15° East longitude to 130° East longitude:

– interference handling;
– transponders orbital measurement in Ku-band with linear polarization;
– continuous automated monitoring the transponder's real frequency and power parameters in Ku-band;
– measurement of the declared Earth station's characteristics for their access to a space segment;
– monitoring and measurements of the carrier's frequency-power characteristics;
– continuous monitoring of the carriers and the digital signal parameters;
– storage of the measured data;
– monitoring of the broadcasting channels.

"Akkol" Communication monitoring system parameters:

downlink frequency range:	10 700 MHz – 12 750 MHz,
uplink frequency range:	13 750 MHz – 14 500 MHz,
polarization:	linear.

GCC "Akkol" Communication system monitoring allows to carry out its functions for two satellites simultaneously and independently.

FIGURE 20

General view of the measurement equipment

SM.2182-20

Figure 21 shows the general view of the antenna Systems Nos 1, 2 and 3 and Table 6 contains the parameters of these systems.

FIGURE 21

General view of the antenna Systems Nos 1, 2 and 3

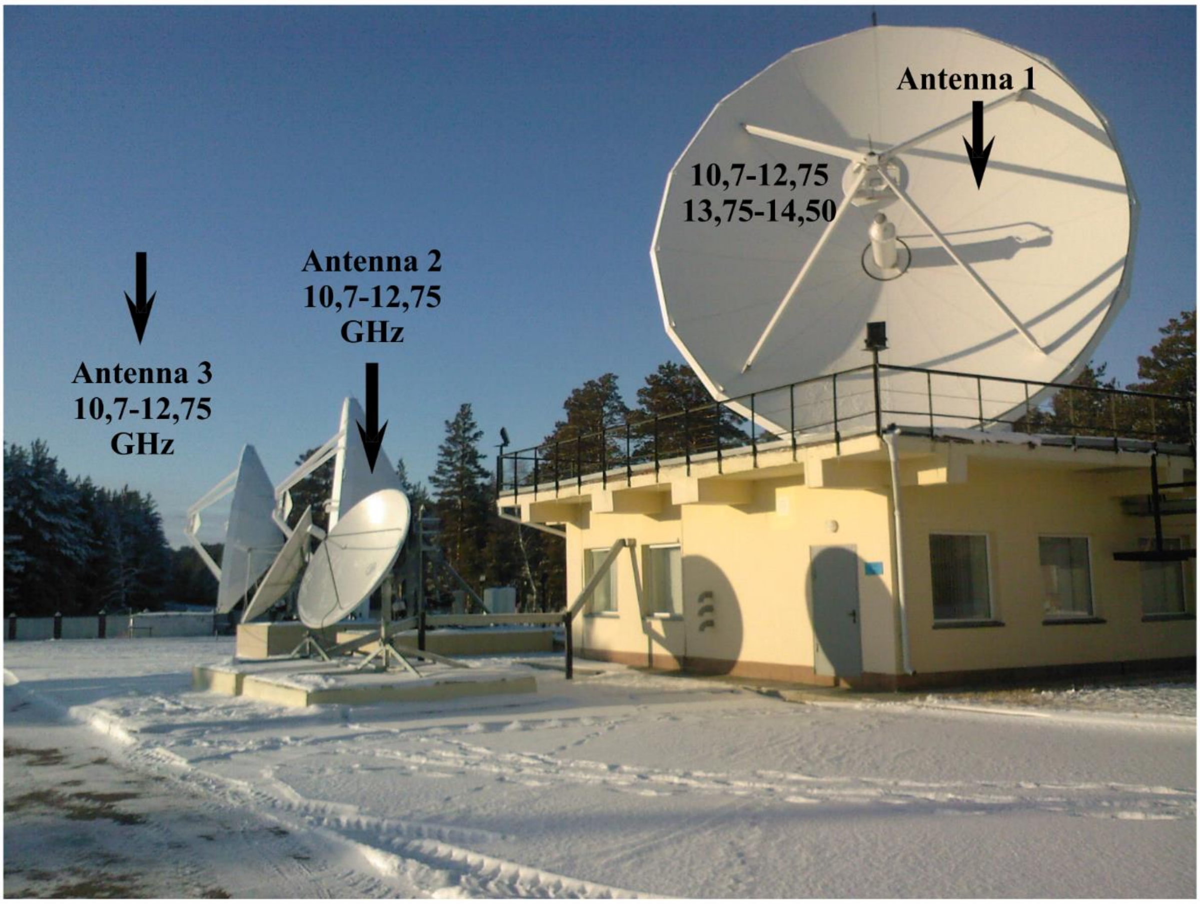


TABLE 6

Parameters of the antenna Systems Nos 1, 2 and 3

Parameter	Antenna 1	Antenna 2	Antenna 3
Antenna type	Cassegrain 2 ports RX + 2 ports TX	Cassegrain 2 ports RX	Cassegrain 2 ports RX
Receiving frequency (GHz)	10.7-12.75	10.7-12.75	10.7-12.75
Transmission frequency (GHz)	13.75-14.50	–	–
Antenna size	9.0 m Ø	7.3 m Ø	7.3 m Ø
Polarization	Linear	Linear	Linear
Antenna gain (dBi)	RX 57.6-59.0 TX 59.7-60.1	RX 55.8-57.1	RX 55.8-57.1
G/T (dB/K)	36.2-36.8	34.6-35.2	34.6-35.2
Available GEO positions	25º-107º E	11.5º-112º E	11.5º-107º E
Tracking type	Steptrak, OPT, Manually	Steptrak, OPT, Manually	Steptrak, OPT, Manually

Contact address:

Republican Center of Space Communication and
Electromagnetic Compatibility of Radio-Electronic Units JSC
Address: Republic of Kazakhstan,
34, Dzhangildin Street, Astana City

Tel/Fax: +7 (7172) 326478
E-mail: info@rcsc.kz

Annex 8

Space Radio monitoring Station in Brazil

National Telecommunication Agency (Anatel)

1 Specifications of space radio monitoring station

1.1 Introduction

In the year of 2014, Anatel (National Telecommunication Agency), the telecom regulatory body in Brazil, deployed its first Satellite Radio monitoring Station (EMSAT). This was part of an extensive spectrum monitoring expansion programme developed by the Brazilian regulator in support to international major events such as 2014 FIFA World Cup and Rio2016 Olympic and Paralympic games. After the events, the facility remains as a spectrum and orbit management support tool, being operated by Anatel Enforcement Bureau.

1.2 General Description and functions

The station is located in the city of Rio de Janeiro. It has only receiving capabilities, and is prepared for measurements in C, Ku and Ka bands on GSO satellites.

The main functions are:

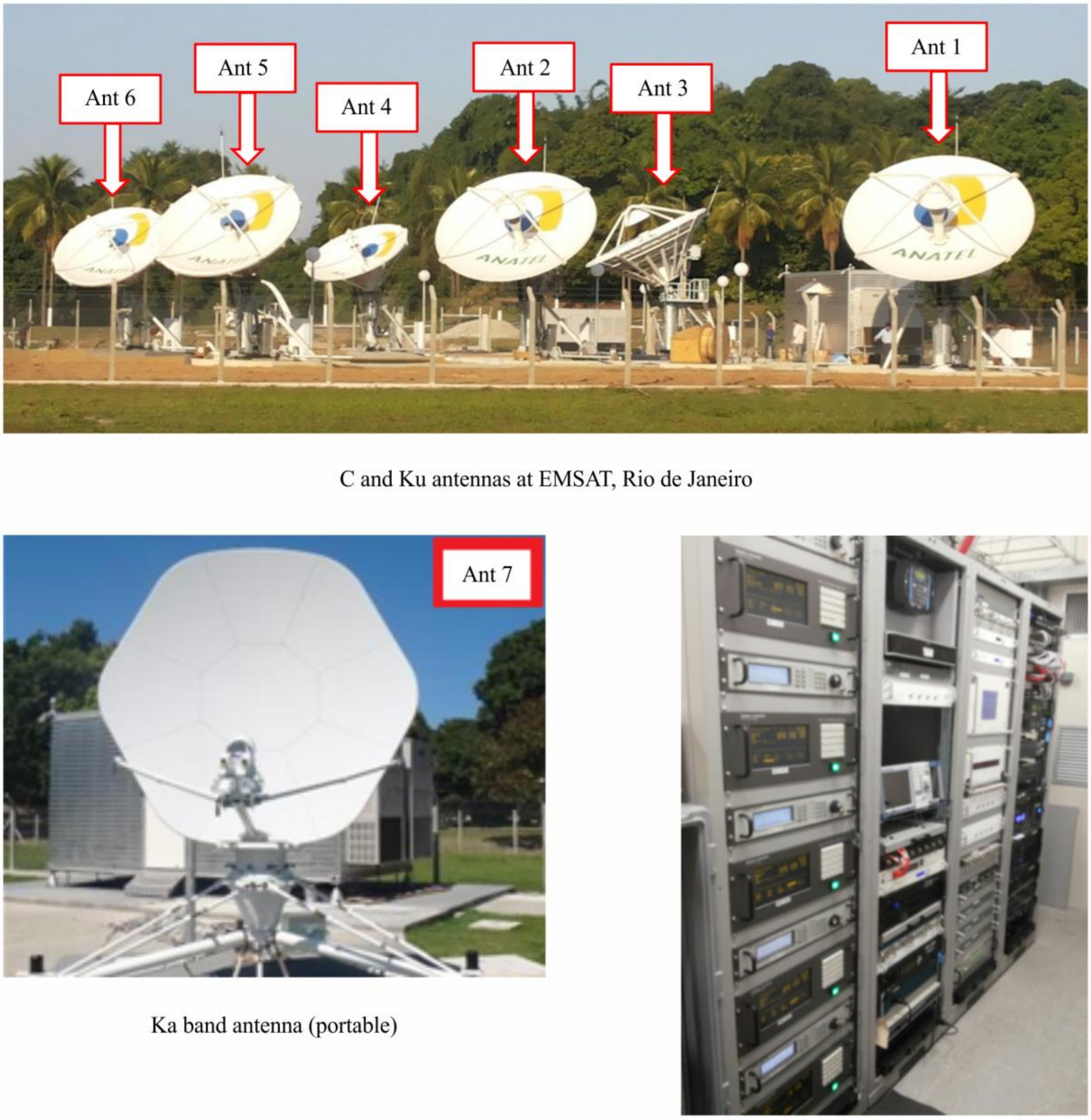
– Detection of unauthorized emissions;
– Evaluation of authorized parameters;
– Satellite and orbital position occupancy measurements;
– Automated spectrum monitoring;
– Geolocation;
– Signal characterization;
– Data base with spectrum monitoring historical information and trend analysis functionalities;
– Signal under carrier detection.

1.3 System characteristics

The monitoring system comprises a set of seven antennas (C, Ku and Ka bands) described as follows.

FIGURE 22

C and Ku antennas at EMSAT, Rio de Janeiro; Ka band antenna (portable); Measurement equipment



C and Ku antennas at EMSAT, Rio de Janeiro

Ka band antenna (portable)

Measurement equipment

SM.2182-22

C-Band antennas

Parameter	Antennas 1 and 2	Antenna 3	Antenna 4
Antenna type	Gregorian	Gregorian	Displaced-axis-ellipse
Frequency range	C Band 3 625 MHz – 4 200 MHz	C Band 3 625 MHz – 4 200 MHz	C Band (**AP30B**) 4 500 MHz – 4 800 MHz
Antenna diameter	6 m	6 m	4.5 m
Polarization	Linear	Circular	Linear
Tasks	Monitoring and Geolocation	Monitoring and Geolocation* *used as a pair with another C Band antenna (Ants 1 or 2)	Monitoring
Antenna gain (dBi)	46.7	46.7	45
Orbital Positions	110ºW to 10ºW	96ºW to 1ºW	80ºW to 17ºW

Ku and Ka Bands antennas

Parameter	Antenna 5 and 6	Antenna 7*
Antenna type	Displaced-axis-ellipse	Offset
Frequency range	Ku Band 10.7 GHz – 12.75 GHz	Ka Band 17.7 GHz – 21.2 GHz
Antenna diameter	4.5 m	2.4 m
Polarization	Linear	Circular
Tasks	Monitoring and Geolocation	Monitoring
Antenna gain (dBi)	53.2	51.4
Orbital Positions	110ºW to 29ºW	110ºW to 40ºW* *portable facility, it can be repositioned to reach further orbital positions as needed.

The station is enabled to perform spectrum monitoring measurements with all antennas working individually. However, geolocation operations can only be performed by using (simultaneously) antenna pairs, as bellow:

– C-Band signals with linear polarization → antennas 1 and 2

– C-Band signals with circular polarization → antennas 1 and 3 or 2 and 3

– Ku-Band signals with linear polarization → antennas 5 and 6.

1.4 RF Front End and Infrastructure

The Figure of Merit (G/T) is used as a parameter for the overall performance of the reception chain. The specifications of the minimum Figures of Merit in the centre of the band, for different frequencies are:

– C-band, linear polarization, 3 625 MHz to 4 200 MHz: 27.8 dB/K

– C-band (AP **30B**), linear polarization, 4 500 MHz to 4 800 MHz: 26.8 dB/K

– C-band, circular polarization, 3 625 MHz to 4 200 MHz: 27 dB/K

– Ku-band, linear polarization, 10 700 MHz to 12 750 MHz: 30.9 dB/K

– Ka-band, circular polarization, 17 700 MHz to 21 200 MHz: 27.2 dB/K

All the measurement equipment are connected to a single reference time base of 10 MHz, with 2×10^{-11} accuracy.

2 Tasks

2.1 Measurements and analysis of technical parameters

The EMSAT was designed to perform measurements according to the recommendations of the ITU and the Spectrum Monitoring Handbook.

The main parameters monitored are: e.i.r.p. (dBW), frequency (MHz) and bandwidth (MHz) of the transmitted signals from the satellite to the earth station. Derived measurement values, such as power flux-density (pfd), can also be provided.

Maximum attainable accuracy:

– Downlink e.i.r.p.: tolerable error of ±1.0 dB, for a minimum signal-to-noise ratio of 12 dB. Variation of up to ±0.3 dB in successive measures.

– Frequency measurement: tolerable error of ±1% of the signal bandwidth for a carrier with minimum signal-to-noise ratio of 15 dB.

– Bandwidth measurement: tolerable error of ±1% of the signal bandwidth for a carrier with minimum signal-to-noise ratio of 12 dB.

– Frequency response: maximum variation of ±1 dB to each 36 MHz and ±2.5 dB in the whole band

The system also has the capacity to perform the following measurements: Eb/N_0, symbol rate, C/N and C/N_0. It also has the functionality of detection and characterization of digital signals, graphically displaying the constellation diagram, the type of modulation used and the error correction code.

Regarding modulation and error correction, the station can recognize the following modulations and error correction codes:

– Modulation schemes: BPSK, QPSK, 8-PSK, 16QAM, 16APSK

– Error correction codes: RS (Reed-Solomon), CV (ConvolutionalCodes), LDPC (LowDensityParityCodes).

The EMSAT can automatically identify interfering signals, including a function of signal-under-carrier detection and measurement. This function allows the system to filter out specific interfering signals within a carrier or under the spectrum analyser noise floor.

Ultimately, the system has a feature of spectrogram and also the function of spectrum analyser with a 10 Hz minimum resolution.

2.2 Geolocation operations

In order to perform geolocation operations, which are essential for cases related to uplink interference or non-authorized earth stations operations, TDOA (Time Difference of Arrival) and FDOA (Frequency Difference of Arrival) are the techniques used by Anatel EMSAT.

The geolocation results can be achieved in different ways. Depending on the characteristics of the target signal, the geolocation results can be reached by using both FDOA and TDOA techniques, or only one technique (TDOA or FDOA). As an example, for the geolocation of CW signal sources FDOA is the only technique applied during the geolocation processing by EMSAT.

As mentioned in § 1.3, geolocation operations performed with EMSAT requires simultaneous downlink measurements of the target signal, acquiring the signals from two adjacent satellites, meaning the "affected" satellite (named as primary), and the adjacent satellite (named as secondary). In general, the georeferenced ellipsis produced by EMSAT geolocation platform indicates the probable search area of the transmitting earth station.

After the successful geolocation processing, results are presented in digital maps, and may also be exported in .KMZ file format, allowing further geoprocessing studies. One kind of relevant analysis that can be made is the overlay of the geolocation ellipsis with the potentially interfering earth stations inner the search area, which can be exported from Anatel licensing database.

One example of the geolocation ellipse is presented in the following Figures.

FIGURE 23

Geolocation output results (TDOA and FDOA lines and target indication)

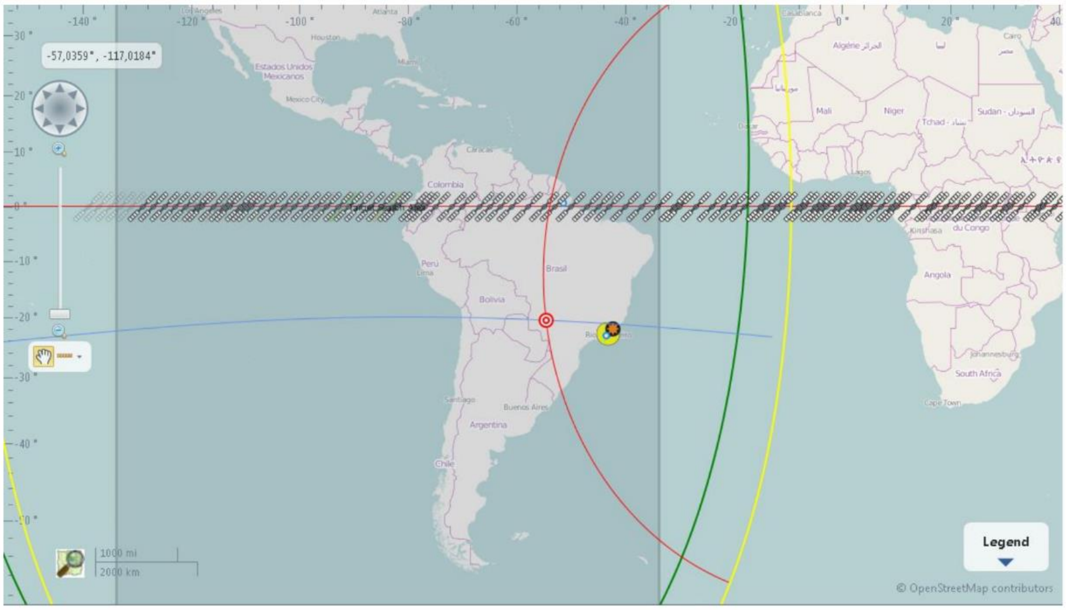


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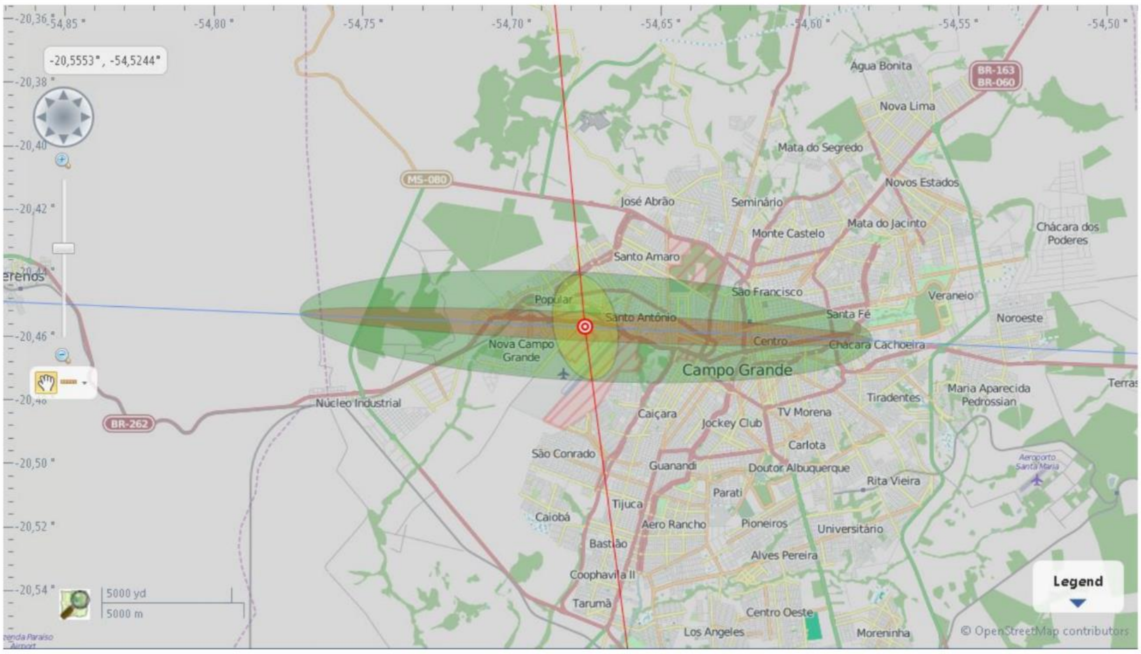
FIGURE 24

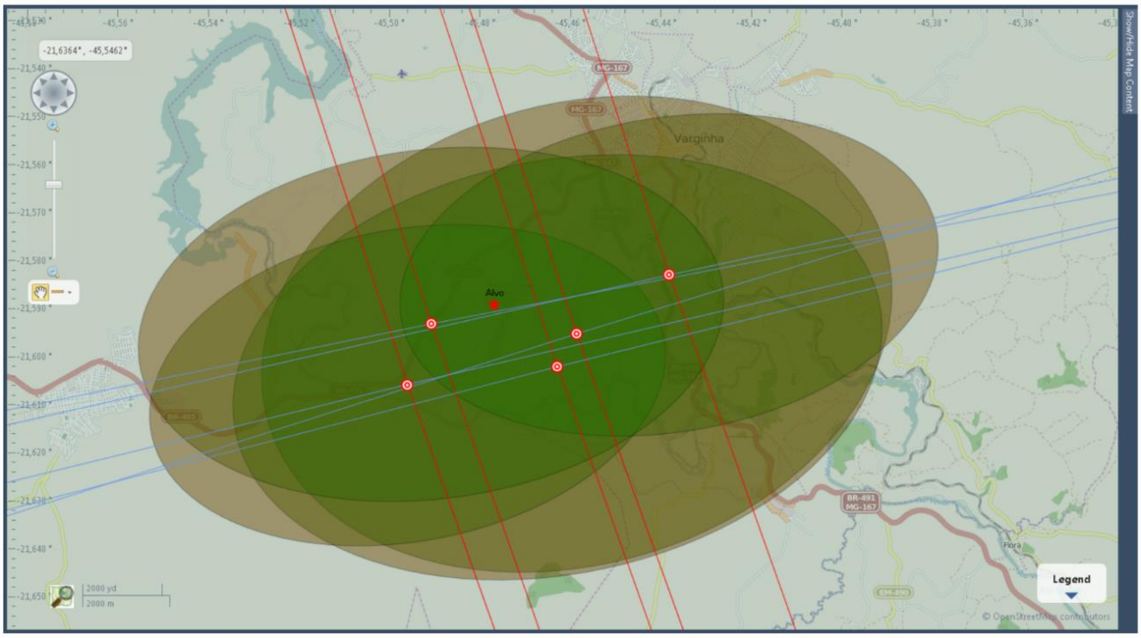
Geolocation output results (Geolocation ellipsis)



SM.2182-24

FIGURE 25

Geolocation output results (Geolocation ellipsis repeated five times and converging to same region)



SM.2182-25

3 Working hours and contact information

Service hours: 12h00 to 20h00 UTC from Monday to Friday (9h00 to 17h00 Brasília Local Time, UTC -03:00).

Electronic-mail: msat@anatel.gov.br and er-2@anatel.gov.br.

Faxes: +55 61 2312-2244 (Anatel International Advisory) and +55 61 2312-2670 (Anatel Spectrum, Orbit and Broadcasting division).

Annex 9

Space Radio Monitoring Facilities in Sultanate of Oman

Telecommunication Regulatory Authority (TRA)

1 General description

The Space Radio Monitoring Station (SRMS) belongs to the Telecommunication Regulatory Authority (TRA), which is responsible for spectrum management and spectrum monitoring in the Sultanate of Oman. The SRMS is located in Muscat about 7 km from TRA main Headquarters and about the same distance as well from Muscat International Airport. The station was officially inaugurated on 17th January 2018.

Major facilities of the station include a main building and an antenna farm, which is placed at the highest part of the site that provide the station with best orbital arc visibility. The station is capable of monitoring GSO satellites and non-GSO satellites, and performs measurement in C, Ku, X, Ka, L and S frequency bands.

FIGURE 26

SRMS Site

SM.2182-26

2 Functions

The main functions of SRMS are as follows:

– Control the use of frequency spectrum and space resources by verifying that existing users are compatible with the licenses granted by TRA.

– Monitoring and measurement of radio signals in space services.

– Detection of any unlawful usage.

– Resolution and elimination of harmful interference.

– Support national activities related to Space Services.

– International coordination with International Telecommunication Union (ITU) and other regulators on interference related matters.

3 System characteristics

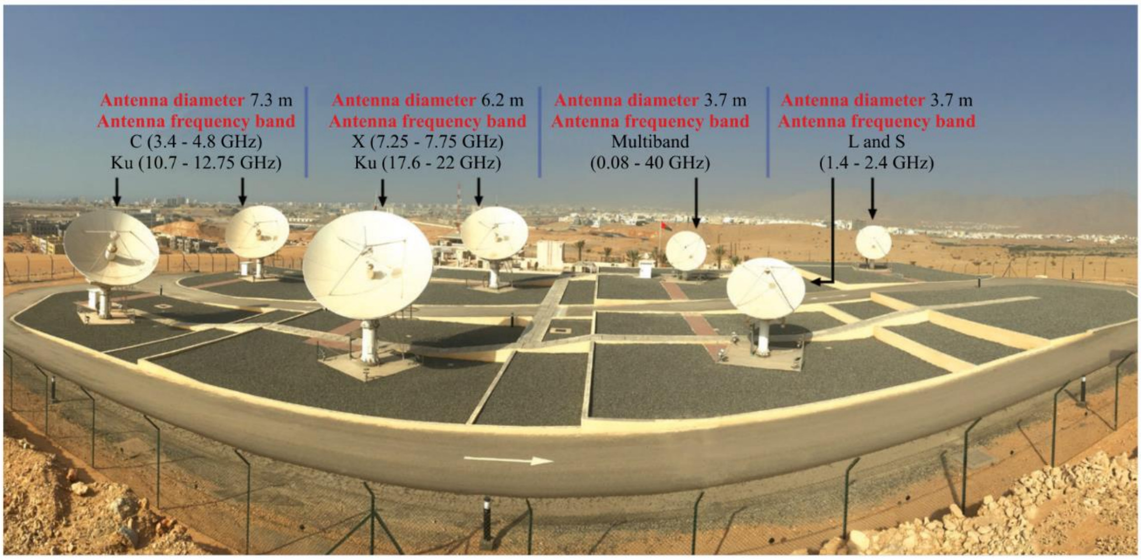
Geographical Coordinates of the station: 23°33'09.37"N58°19'59.76"E

Visible geostationary arc: 16° W to 133° E

The station includes seven antennas with the following technical details:

FIGURE 27

SRMS Antenna Farm



Antenna				Frequency band	Polarization		Range of Azimuth & Elevation Angles
Name	**Size**	**Type**	**Tracking Type**				
Antenna_1 (**Secondary**)	7.3m	Turning Head	Step-track, IESS & Norad	**C:** 3.4 – 4.8 GHz	Linear	Circular	AZI = 94º – 266º ELE = 5º – 88º
				Ku: 10.7 – 12.75 GHz	Linear	-	
Antenna_2 (**Primary**)	7.3m	Turning Head	Step-track, IESS & Norad	**C:** 3.4 – 4.8 GHz	Linear	Circular	AZI = 94º – 266º ELE = 5º – 88º
				Ku: 10.7 – 12.75 GHz	Linear	-	
Antenna_3 (**Secondary**)	6.2m	Turning Head	Step-track, IESS & Norad	**X:** 7.25 – 7.75 GHz	-	Circular	AZI = 94º – 266º ELE = 5º – 88º
				Ka: 17.6 – 22 GHz	Linear	Circular	
Antenna_4 (**Primary**)	6.2m	Turning Head	Step-track, IESS & Norad	**X:** 7.25 – 7.75 GHz	-	Circular	AZI = 94º – 266º ELE = 5º – 88º
				Ka: 17.6 – 22 GHz	Linear	Circular	
Antenna_5 (**Multiband**)	3.7m	Full Motion	Step-track, IESS & Norad	**Band-1:** 0.08 – 1.3 GHz	Linear	-	AZI = 5º – 355º ELE = 5º – 85º
				Band-2: 1 – 18 GHz	Linear	Circular	
				Band-3: 18 – 40 GHz	Linear	-	
Antenna_6 (**Secondary**)	3.7m	Full Motion	Step-track, IESS & Norad	**L:** 1.4 – 2.15 GHz	-	Circular	AZI = 5º – 355º ELE = 5º – 85º
				S: 2.1 – 2.4 GHz	-	Circular	
Antenna_7 (**Primary**)	3.7m	Full Motion	Step-track, IESS & Norad	**L:** 1.4 – 2.15 GHz	-	Circular	AZI = 5º – 355º ELE = 5º – 85º
				S: 2.1 – 2.4 GHz	-	Circular	

The station can perform spectrum monitoring measurements using any of the seven antennas mentioned above. However, a simultaneous use of antenna pairs is required to perform geolocation measurement as follows:

– Antenna 1 & 2 can be used for C, Ku frequency bands.

– Antenna 3 & 4 can be used for X, Ka frequency bands.

– Antenna 6 & 7 can be used for L, S frequency bands.

4 Structure of the Space Radio Monitoring Station

The TRA Oman space radio monitoring station comprises of ten functional subsystems.

4.1 Antennas

Seven receiving satellite antennas with different diameters and technical specifications as indicated in § 3.

4.2 Subsystem for diagnostics and controlling devices in the station and for pointing antennas to satellite orbital positions

This subsystem is in charge of monitoring all SRMS components and controlling them remotely. It has two key elements, the first is responsible for the monitoring and control of ground station equipment like Antenna Control Unit (ACU), Low Noise Amplifier (LNA), switches and Block Down Converters (BDC) and the second is responsible for the Monitoring of network equipment (Network Switch, Firewall, Server, Workstation). In case of any problem or malfunction occurrence in SRMS, this subsystem issues warnings/notifications to the operator. Moreover, this subsystem enables pointing the antenna either manually or automatically to any orbital positions within the visible Arc.

4.3 Subsystem for monitoring, detecting and characterizing satellite signals

This subsystem monitors and analyses radio signals received from satellites and identifies its technical specifications. The following technical parameters can be measured using the software of this subsystem:

– Centre Frequency (MHz)

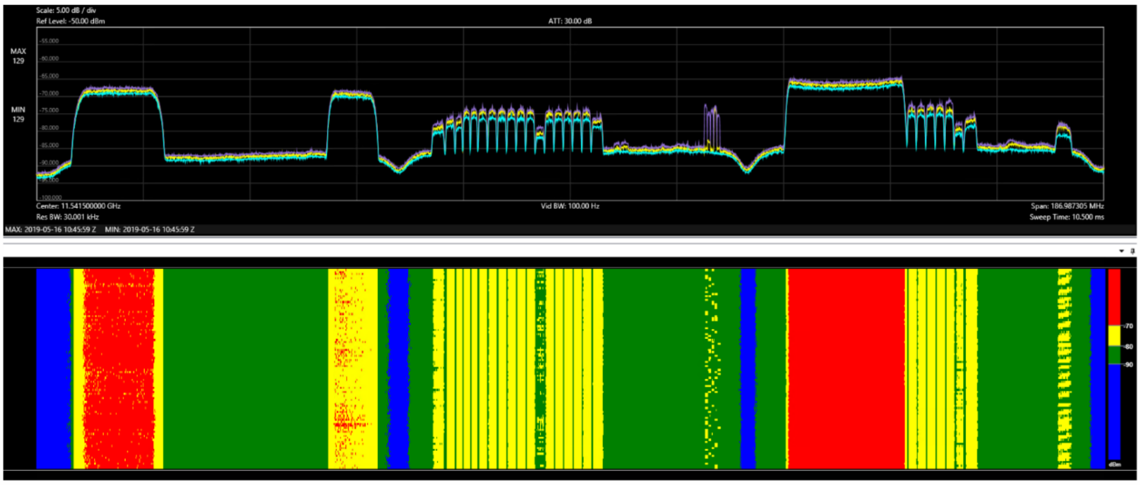
– Bandwidth (kHz)
– Symbol Rate (kBS)
– Data Rate (kBS)
– Effective Isotropic Radiated Power - E.I.R.P. (dBW)
– Carrier to Noise ratio – C/N (dB)
– Carrier to Noise density – C/N_o (dB)
– Carrier to Interference ratio – C/I (dB)
– Energy per bit to Noise power spectral density – E_bN_o (dB)
– Energy per symbol to Noise power spectral density – E_sN_o (dB)
– Modulation Type
– Carrier Standard
– Inner & outer Coding
– Bit Error Rate – BER.

The power flux-density (pfd) can also be calculated.

To determine frequency carriers, the software is capable of scanning the satellite transponders and presents the results using spectrogram. The results can be then compared with the existing database to identify the found carriers.

FIGURE 28

Spectrogram of received transponders



SM.2182-28

The system allows the simultaneous reception of satellite signals with different polarizations.

FIGURE 29

Reception of two different polarizations
(Note: Main Pol = Yellow Trace, Cross Pol = Purple Trace)

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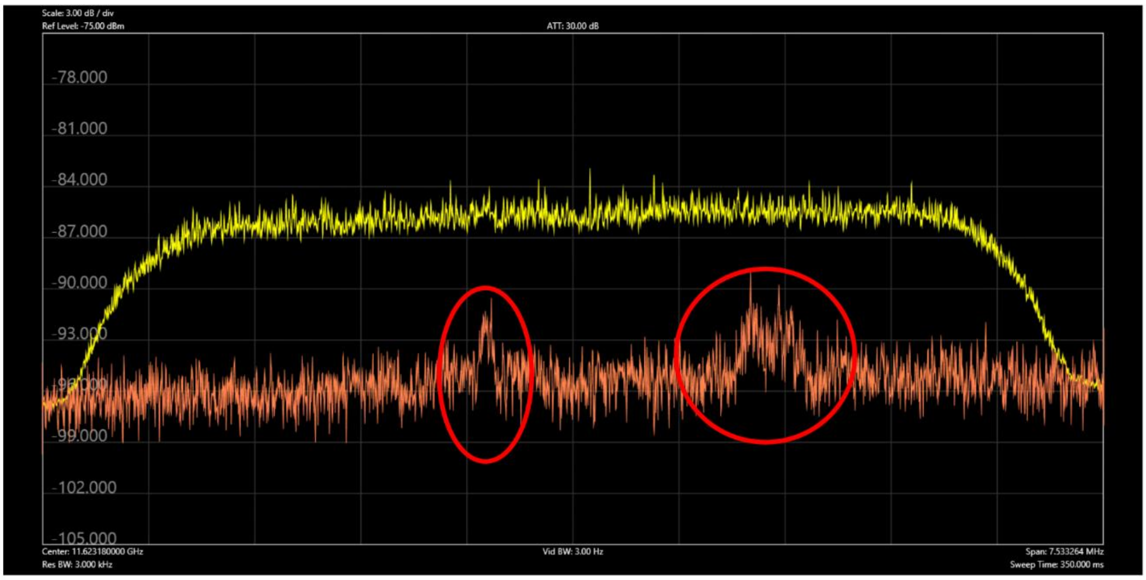
The system has the capacity to identify hidden interfering signals under the main carrier using Carrier Under Carrier analysis.

FIGURE 30

Carrier under carrier analysis



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The subsystem also enables the following:

– Creating a satellite database with its technical parameters, which makes the measurement setup an easy and quick task.

– Storage of measurements results and comparing them with earlier measurements or with data of licensed users available in the database.

– Manual or automated Satellite transponder scans and spectrum occupancy measurements.

– Calibration of antennas RF paths using Noise Injection Calibration Hub that is capable to control multiple noise injection sources in many antennas.

4.4 Transmitter Location System (geolocation)

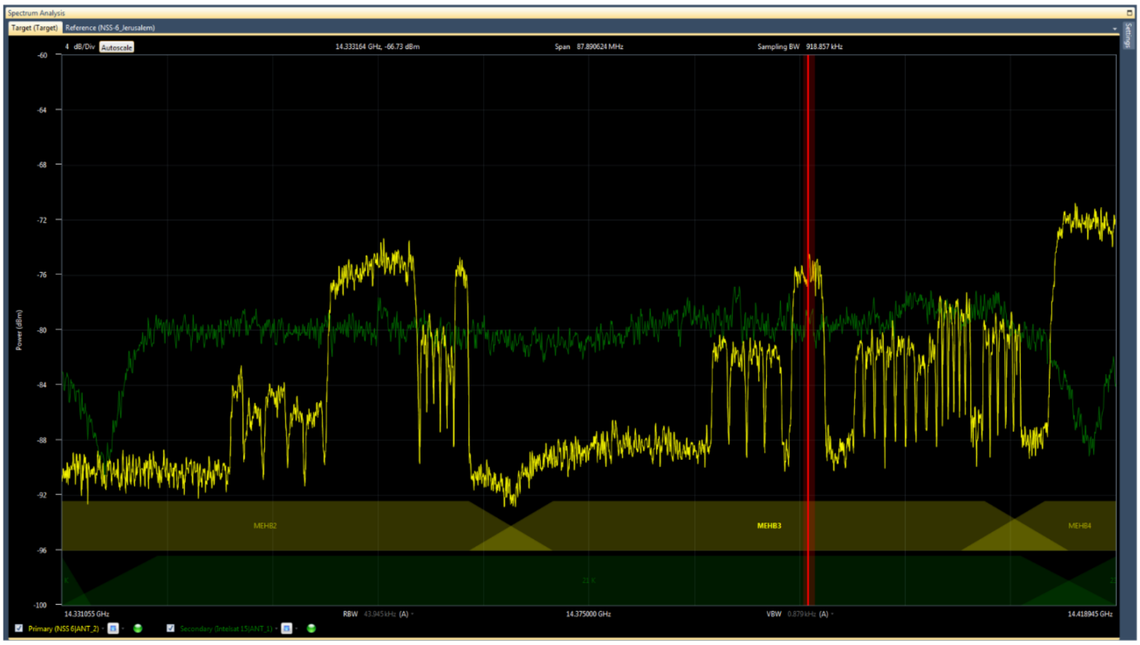
The transmitter location system is a subsystem for determining the geographical location of the earth station causing uplink interference to satellite or transmit without legal authorization (i.e. unlawful usage). To estimate the location of the originating signal, it uses the techniques of TDOA (Time Difference of Arrival) and FDOA (Frequency Difference of Arrival). This entails monitoring the downlink of target signal from two adjacent satellites known as primary (i.e. interfered satellite) and secondary satellite, which is adjacent to the primary satellite. As mentioned in § 3, two antennas operating in the same frequency bands are used for geolocation operations.

The subsystem is capable of making correction for satellite's ephemeris to improve the accuracy of geolocation results and allows creation of its satellites database for geolocation operations.

An example of geolocation results is shown in Figs 31 and 32 below.

FIGURE 31

Shows received spectrum from primary Satellite (yellow trace) and secondary satellite (green trace)
<u>(Note: Red line indicates target signal)</u>



SM.2182-31

FIGURE 32

Shows Geolocation Result on Map

SM.2182-32

4.5 Mobile Monitoring Unit

This subsystem allows monitoring the satellite signals in the uplink (Earth-to-Space) and the downlink (Space-to-Earth) as well.

For the uplink measurement, the subsystem uses both omni and directional antennas that cover the frequency range 0.8-40 GHz. The monitoring coverage can be enhanced with the help of an 8.5 m mast by raising the directional horn antennas to make measurements at a higher position. It will also be possible to point these antennas in any direction to perform the measurement. After successful geolocation operation, this subsystem allows determining the location of unlawful usage transmission or the source of radio interference on earth.

For the downlink measurement, the subsystem can perform measurement using one receiving antenna in C, X, Ku, and Ka frequency bands. Such measurements can be useful in case of satellite spot beams not covering the SRMS main antennas. The subsystem mentioned in § 4.2 and § 4.3 are used as well in the mobile unit for controlling the devices and also to characterize and analyse the received signals. Automatic pointing to satellite orbital position is possible as well.

FIGURE 33

Mobile Monitoring Unit

4.6 Unmanned Arial System (UAS)

The UAS or Drone subsystem is used to determine the location of unlawful usage and the radio interference of signals in the Uplink (Earth to Space) in L, C, X, Ku & Ka bands, when it is not possible to use the mobile unit due to terrain constraints or the high elevation of the transmission angle of earth station antennas.

4.7 Reference Emitter

Typically, the geolocation system operates with opportunistic reference emitters, which are commercial satellite uplinks whose locations and uplink frequencies are publicly published. However, due to uncertainties in the locations of opportunistic reference emitters besides, they are subject to changes like being moved, retuned, reassigned to different satellites, or taken off the air. This results in additional ephemeris and bias errors making such emitters not ideal for accurate geolocation measurement. To address this shortfall, a dedicated reference emitter is used.

The reference emitter (RE) is a transmit-only device that provides a low-power signal for use as a reference signal. Its usage has to be in conjunction with the geolocation system in order to assist in improving the accuracy of the geolocation results of the received signals in C, X, Ku and Ka bands. This subsystem allows satellite auto acquisition and auto-pointing of the transmit antenna to the desired orbital position. The reference emitter is moveable whenever needed by the Mobile Monitoring Unit to any location in Oman.

4.8 DVB Monitoring

This subsystem enables the display, identification and tracing the source of unscrambled satellite TV channels.

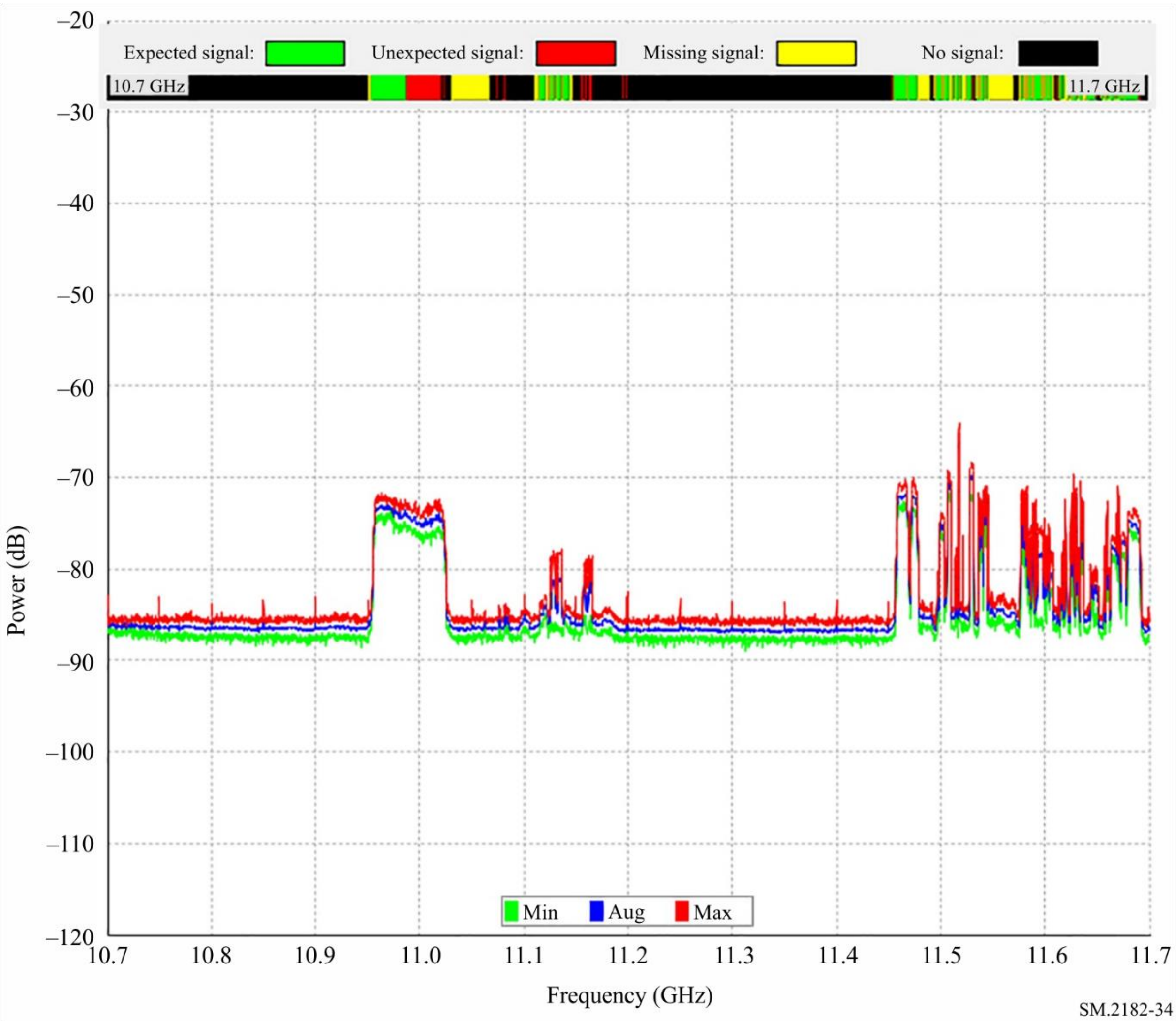
4.9 Subsystem for license verification and checking orbit occupancy

This is a centralized subsystem that gathers information from various subsystems explained in §§ 4.2, 4.3 and 4.4. It allows operators to plan, schedule, execute and automate missions as well as create different reports.

This subsystem facilitates the verification of the actual usages with the radio licenses granted by TRA OMAN and the measurement of how busy the geostationary satellite orbits. Licenses are verified by automatically checking expected e.i.r.p., centre frequency, and bandwidth based on an RF downlink measurement. Satellite orbital slots could be scanned and comparing the spectrum measurement with known satellites in a specific orbital position. Figure 34 shows an example of the results of an orbital slot measurement.

FIGURE 34

Shows an example of result for orbital slot measurement



Both tasks can be scheduled over a time to run automatically. The subsystem further allows booking the antenna resources to perform a geolocation mission.

4.10 L-Band recorder

This is a real-time recording and playback system that stores the spectrum of the wanted signal and its technical characteristics.

5 Tasks

The main tasks of the space radio monitoring station are as follows:

– Verification of the actual spectrum usage with radio licenses granted by the Authority.

– Measurement of satellite signals to identify the technical parameters of received emissions.

– Checking the received satellite signal to ensure conformance with the Radio Regulations (RR).

– Geolocation measurements to identify the source of uplink interference or to locate an unknown signal, which can be an unlawful transmission.

– Spectrum occupancy measurements to identify the actual usage of the spectrum and orbits by satellite stations and whether they are in conformance with coordinated, notified and registered data in the ITU.

– Supporting the coordination process for national satellite launches by making spectrum occupancy measurement with the aim to identify suitable frequencies and orbital options.

6 Working hours

Normal working hours (Sunday ~ Thursday) are from 07:30 to 15:00 (Oman Time).

7 Contact information

Telecommunication Regulatory Authority
P.O. Box: 3555
P.C.: 111, Seeb
Sultanate of Oman

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Fax: +968 24 2222 35
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