International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R RS.2106-0
(07/2017)

Detection and resolution of radio frequency interference to Earth exploration-satellite service (passive) sensors

RS Series
Remote sensing systems

International Telecommunication Union

Foreword

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SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

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

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RECOMMENDATION ITU-R RS 2106-0

Detection and resolution of radio frequency interference to Earth exploration-satellite service (passive) sensors

(Question ITU-R 255/7)

(2017)

Scope

Administrations operating EESS passive sensors which encounter instances of harmful radio frequency interference (RFI) should use the information in this Recommendation and its RFI reporting form in recording and reporting the RFI instance to the administration with jurisdiction over the transmitting stations which are causing the interference. The attached RFI reporting form should be provided in addition to the form in Appendix **10** of the Radio Regulations and is intended for use by administrations to report additional detailed information on interference to EESS passive sensors.

Keywords

Harmful interference, RFI, passive sensors, reporting form

The ITU Radiocommunication Assembly,

considering

a) that Resolution **673 (Rev.WRC-12**) – The importance of Earth observation radiocommunication applications, urges administrations to take into account Earth observation radio-frequency requirements and in particular protection of the Earth observation systems in the related frequency bands;

b) that recent microwave images derived from the operation of EESS (passive) sensors have shown an increasing number of events where the retrieved data are corrupted by interference;

c) that, in particular, harmful interference is experienced in frequency bands identified under RR No. **5.340** which prohibits all emissions in the bands identified in that footnote;

d) that the interference experienced by EESS (passive) sensors typically originates from terrestrially based emitters;

e) that the number of individual interference sources encountered by EESS (passive) sensors is typically greater than 100 and dispersed over the surface of the Earth;

f) that passive sensor operators have experienced difficulties in resolving these interference cases, and in particular, the need to address numerous interference instances occurring globally imposes costly efforts on passive sensor operators in interacting with all relevant Administrations;

g) that the duration of this interference resolution process typically spans many years,

recognizing

a) that, according to the Constitution and Convention of the ITU, one purpose of the ITU is to coordinate efforts to eliminate harmful interference;

b) that RR Article **15** and in particular its provisions No. **15.21** (section on Reports on Infringements) and Nos. **15.22-15.46** (section on Procedure in case of harmful interference) are applicable in cases of harmful interference;

c) that full particulars relating to harmful interference shall, whenever possible, be given in the form indicated in Appendix **10** of the Radio Regulations;

d) that RR Appendix **10** states that sufficient information shall be provided to the administration receiving the report of interference so that an appropriate investigation can be conducted;

e) that Appendix **10** was designed for the reporting of harmful interference involving terrestrial services and that its applicability related to radio frequency interference (RFI) events detected by EESS (passive) sensors is limited;

f) that Report ITU-R SM.2181 provides information on how, in addition to the particulars indicated in RR Appendix **10**, other data fields and information can be documented in the Report of harmful interference originating from space stations;

g) that the provisions of the ITU-R Radio Regulations cited under *recognizing b)* and *c)*, were formulated to address instances of interference between communication services that occur on a single entry basis,

recommends

that, in addition to the information contained in the RR Appendix **10** form, the form provided in the Annex to this Recommendation should be used to report cases of harmful interference received by EESS (passive) sensors to the Administrations having jurisdiction over the interfering stations.

Annex

Form for the Reporting of interference to EESS (passive) sensor

1 Particulars concerning the general reporting information

The following Table 1 defines the General Reporting Information fields that should be completed by the administration reporting an RFI event.

TABLE 1

General Reporting Information

<table>
<tr><td>Administration or Entity Submitting Report:</td><td colspan="3">[Name of the Administration (or other entity) submitting Interference Report]</td></tr>
<tr><td rowspan="2">Contact person:</td><td rowspan="2">[POC within the Administration submitting the report of interference]
Name & title
Address, phone, fax
email</td><td>Date:</td><td>DD-MM-YYYY</td></tr>
<tr><td>Report or Case #</td><td>[Report # or Case # used by Administration submitting the report of interference]</td></tr>
<tr><td>Subject:</td><td colspan="3">[EXAMPLE: Reporting of harmful RF Interference (RFI) observed by the satellite XXX over the {country name} on {date} in the frequency band {FFFF-FFFF MHz}]</td></tr>
</table>

TABLE 1 (*end*)

Action requested:	[EXAMPLE: Identification of reported interference source(s) and to take the necessary remedial actions to ensure elimination of the interference thereof.]		
Administration Interference Enforcement Agency:	[Name of the Administration and the Frequency Management Authority within the Administration (if applicable)receiving the report of interference]		
Contact person:	[POC within the Administration receiving the report of interference] Name & title Address, phone, fax email	Ref #:	[Reserved for use by the Administration receiving the report of interference]
Basis for Identification of Responsible Administration	[Basis for identification of location of interference source – EXAMPLE: 'X' (number) of satellite passes with lost or corrupted data when located over territory of (country name)...]		
Affected Frequency or Frequency Band	[EXAMPLE: 1 400-1 427 MHz EESS(passive) sensing band]		
Relevant ITU-R Regulations	[EXAMPLE: RR No. **5.340** (All emissions prohibited in band); Resolution **750 (WRC-15)** on the Compatibility between the EESS (passive) and relevant active services]		
Report cc: to	[Copies of Report provided to ITU-BR, sensor operating entity, etc. depending on sender and recipient]		

2 Particulars concerning the impacted EESS (passive) system

The following Table 2 defines the fields for reporting the system characteristics of the affected EESS (passive) system.

TABLE 2

Impacted EESS (passive) system characteristics

Satellite	[Example: name of the space mission]
Mission web site	http://XXX.YYY
Launch date	DD-MM-YYYY
Payload	[Description of payload instrument affected]
Payload Sensor Characteristics	[Sensor freq. response/bandwidth/RF selectivity, etc.]
Main objective	[Top level function of the payload instrument affected.]
Swath width (km)	[Linear ground distance covered in the cross-track direction.]
Spatial resolution (km)	[Ability to distinguish between two closely spaced objects on an image.]
Polarization	[vertical/horizontal/circular, etc.]

TABLE 2 (*end*)

Type of orbit	[Such as: circular or elliptical, sun-synchronous (SSO) or non-sun-synchronous (NSS)]
Altitude (km)	[The height above the mean sea level]
Inclination (degrees)	[Angle between the equator and the plane of the orbit]
Ascending Node LST	[The local solar time (LST) of the ascending node is that local solar time for which the ascending orbit of the spacecraft crosses the equator]
Eccentricity	[The ratio of the distance between the foci of the (elliptical) orbit to the length of the major axis]
Revisit Time (days)	[The time for the footprint of the antenna beam to return to (approximately) the same geographic location. This is somewhat different than the "Repeat Period" in which a satellite returns to the same geographic location at the same local time.

3 Particulars concerning the interferenc

3.1 Summary of the RF Interference sources

The following Table 3 defines the fields in the Summary of RFI Sources form that should be completed by the administration reporting an RFI event.

TABLE 3

Summary of RFI Sources

Date of this RFI status update	[Date(s) of the sensor observations used for the RFI identification to be provided here]
TOTAL number of RFI cases detected	[Total number of RFI cases detected, including RFI ON and OFF. To be noted that typically each RFI case is associated to a single RFI source or interferer, however in some cases the interference is due to the aggregate effect of multiple sources]
Active RFI sources	[Number of reported RFI sources which are unresolved]
**** Old RFI active sources**	[Number of un-resolved RFI sources] RFIs [Listing of resolved RFI sources with unique ID number starting at "ID 001" and relevant notes] [EXAMPLE ENTRY: ID 035 (15,000 K). Very strong. Pulsed emission. Consistent with radar emission.]
**** New RFI active sources**	[Number of new RFI sources detected since previous reporting] RFIs [EXAMPLE ENTRY: ID 036 (1,000 K) in [location], only descending passes. Consistent with radiolink emission.]
RFI sources OFF	[Number of resolved RFI instances since initiation of this report] RFIs

3.2 Geo-location and other detailed RFI information

This section contains detailed information about the RFI instances detected in the territory of the administration where RFI has been detected. These particulars are provided in the "Interference Source Detail Log" presented in Table 4.

The accuracy of RFI location is an important parameter that the administration providing the report of RFI must provide in this section.

Investigations are typically iterative where the reporting administration provides updates to previously submitted reports. It is useful to the administration receiving the report to be informed of changes to previously reported information. For this purpose, it is recommended that new reports of RFI be highlighted in yellow.

The different fields considered in Table 4 are described here below:

Field 1: Source Id

Unique identification number of the RFI source: [XXX-01], [XXX-02], etc. For easier reference it is recommended that the ITU letter **codes** be used in place of XXX identifying the country where the RFI source has been detected.

Field 2: Observed geo-location

Geographic location of the RFI source, given as longitude and latitude in decimal degrees. The number of decimal points provided will be consistent with the accuracy of RFI location. For example, 10 km accuracy is equivalent to about 0.008 degrees of the circumference of the Earth.

Field 3: Centre frequency

Generally, the strongest part of the emission, or where a distinct carrier can be observed, provides the best starting search frequency for investigative agents. The frequency of the strongest part of the interfering emission, (or centre frequency if no part of the emission is clearly the strongest) should be listed under the column "Centre Frequency".

Field 4: Source detection characteristics

– Point or extended RFI source: The emission causing the interference may be detected by the radiometer as a point or an extended RFI source A point source is when there is only one interfering emitter within the sensor spatial resolution on the ground. When this type of RFI sources are due to single emissions, these RFIs can be more accurately detected, characterised, and geo-located when surrounded by interference free areas. When there are multiple emitters within the sensor footprint, the source is referred to as extended. Extended sources, when caused by tens or hundreds of RFI interferers, are usually linked to a deployed system (for example, a network of transmitters) on the ground. The sensor is not able to distinguish the geo-location of each individual source contributing to the extended interference, therefore just a reference location can be provided. This type of interference imposes an increase in the background noise detected by the sensor. The resolution of extended RFI cases is typically more complex than the point RFI cases.

– Directivity of the RFI source: Directive sources may be suspected when the interference is detected stronger in a sensor pass in one direction (e.g. North-South versus South-North).

– Pulsed or continuous emission: Pulsed emissions may indicate that the RFI source is due to a radar system.

Field 5: Level of interference detected by the sensor

This field is an indication of the strength of the interference, and it is provided as Brightness Temperature (T_B in degrees Kelvin) or other sensor metric.

Field 6: Estimated received power level

Administration spectrum enforcement agencies are familiar with reporting RFI received power (P_R) into receivers as measured in watts and prefer receiving reports of RFI in those units.

Generally, to approximate T_B to a single RFI source EIRP, the Friis formula can be used when substituting for P_R as a function of e.i.r.p. as described in Attachment 2. However, for some sensors with many antennas (e.g. interferometric radiometers such as SMOS) this approach may not be very accurate. In these cases the remote sensing systems may use another metric, such as brightness temperature (T_B, in degrees Kelvin).

Field 7: City/State/Region where the RFI source has been located

Field 8: Other Observations

This column is used to provide additional RFI characteristics that may be useful to facilitate the work of the enforcement agencies in the identification of the interference sources. The factors to be reported here will depend on the type of RFI, and can include comments such as:

– estimated accuracy radius around the identified coordinates, other factors can be reported here, such as whether the interference:
  – is pulsed or continuous;
  – has an observable bandwidth;
  – is observed in horizontal, vertical and/or circular polarization;
  – is intermittent in nature, etc. In some cases, the interference may not be observed in all passes and this is also relevant to investigators.

Field 9: Date/time log

This column may contain the following information:

– Date when the RFI was first detected.
– Date when the RFI has been reported for the 1st time.
– Date/time of last sensor observation, Monitoring and processing the sensor data to detect any interference can take several days. Therefore, this date, if a few weeks old, should not be considered an indication that the interference is not present anymore.

Field 10: Present Status of the RFI source: ON, OFF

TABLE 4

Interference Source Detail Log

Number of ACTIVE sources listed: [##]

Interference Source Detail Log										
1. Source ID.	**2. Observed geolocation**		**3. Centre frequency (MHz)**	**4. Source detection characteristics**	**5. Level of interference detected by sensor**	**6. Received power or (dBm or watts)**	**7. City/ State/ Region**	**8. Other observations (including accuracy)**	**9. Date/ time log**	**10. Present status**
	Longitude (degrees)	**Latitude (degrees)**								
Identification number of source used for tracking	Longitude in decimal degrees	Latitude in decimal degrees	Centre frequency or strongest part of emission, if known	Directive source, Point source or extended source	Brightness Temp.(T_B in Kelvins) or other sensor metric	Received power in dBm or power density as estimated from sensor metric	Description of geographic area, e.g. region, town, city, etc.	Comments regarding interference observations, incl estimated accuracy radius around lat/long if known	Date/time of First detection, first reporting, last sensor observation	Interference ‘ON’ ‘OFF’

3.3 Supporting information

This section will contain the supporting information intended to facilitate the investigations of the administration to locate the interference emissions. The type of material which may be included in this section could be as follows:

– RFI probability maps (global, regional or with detail over specific locations),

– Brightness temperature maps and snapshots over relevant areas,

– RFI categorisation with indication of RFI strength,

– RFI categorisation per regional location,

– Remarks about specific RFI observations,

– RFI log showing the cases resolved and type of RFI emission found out after investigation by the authorities.

Some examples are presented in Attachment 1.

Attachments to Annex:

Attachement 1 – Example of RFI reporting for § 3.2 (Table A1-1) and § 3.3.

Attachement 2 – Use of the FRIIS Equation to approximate interfering emitter power levels from T_B for a single source interferer

Attachement 3 – Blank RFI reporting forms (Tables A3-1 to A3-4)

Attachment 1

to Annex

Part 1: RF Interference Source Detail Log (Table 4, § 3.2)

Interference Source Detail Log										
1. Source ID.	**2. Observed geolocation**		**3. Centre frequency (MHz)**	**4. Source detection characteristics**	**5. Level of interference detected by sensor (Kelvin)**	**6. Received power or (dBm or watts)**	**7. City/State/ Region**	**8. Other observations (including accuracy)**	**9. Date/time log**	**10. Present status**
	Longitude (degrees)	**Latitude (degrees)**								
ADM-01	xx.xxx	yy.yyy	1 413.5 MHz (RFI observed over the full passive band)	– Point source – Pulsed emission – Observed in all passes with same strength	400	Not provided for this type of sensor	Region x	Compatible with radar emissions. Geolocation accuracy: 5 km	– First detected: 15 May 2012 – Last observation: 20 Nov 2016	ON
ADM-03	xx.xxx	yy.yyy	1 413.5 MHz (RFI observed over the full passive band)	– Extended source – Continuous emission – Observed in all passes with same strength	1 500	Not provided	City x	Interference over extensive area, compatible with aggregate of multiple sources		ON
ADM-04	xx.xxx	yy.yyy	1 413.5 MHz (RFI observed over the full passive band)	– Point source – Continuous emission – Directivity: detected in ascending passes with higher strength	5 000	Not provided	Rural area x	Compatible with radiolink or other directive emitter	No	ON

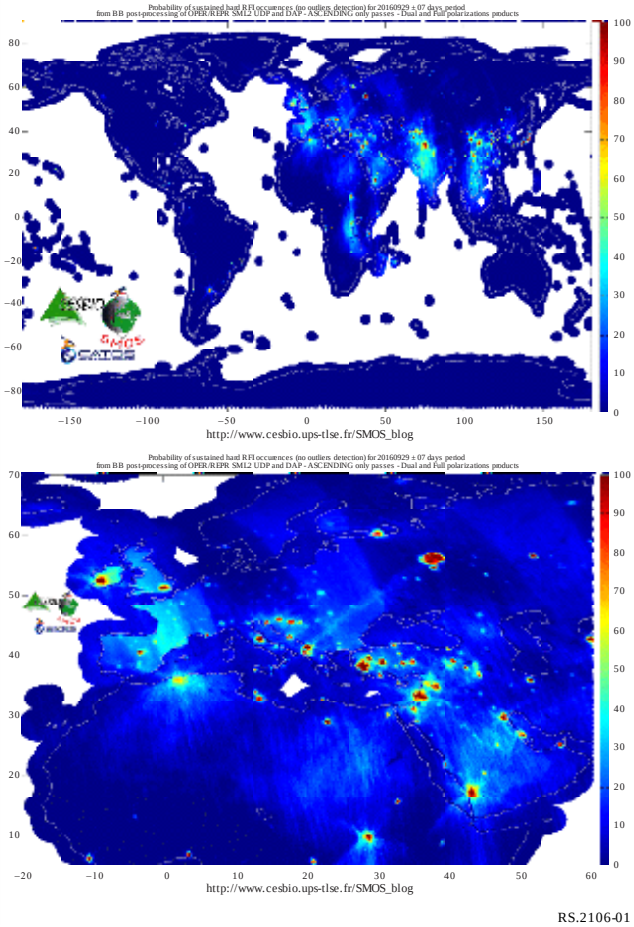
Interference Source Detail Log										
1. Source ID.	**2. Observed geolocation**		**3. Centre frequency (MHz)**	**4. Source detection characteristics**	**5. Level of interference detected by sensor (Kelvin)**	**6. Received power or (dBm or watts)**	**7. City/State/ Region**	**8. Other observations (including accuracy)**	**9. Date/time log**	**10. Present status**
ADM-05	xx.xxx	yy.yyy	1 413.5 MHz (RFI observed over the full passive band)	Directive emission	2 000	Not provided	Region x	Local surveillance transmitter located by authorities and switched off (11 Nov. 26)	RFI has not been observed after 13 Nov. 2016	OFF
ADM-08	xx.xxx	yy.yyy		– point source – continuous emission – observed in all passes	12 000	Not provided	Region x	Very strong interference causing important disturbance to sensor meas	NEW RFI. Detected 20 Nov 2016	ON

Part 2: Examples of supporting information (as identified in § 3.3)

a) Global RFI probability maps

FIGURE 1

SMOS RFI probability maps worldwide and Europe (Oct 2016). Source: CESBIO



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b) Regional RFI probability maps

FIGURE 2

SMOS RFI probability maps in North America (May 2010). Source: CESBIO

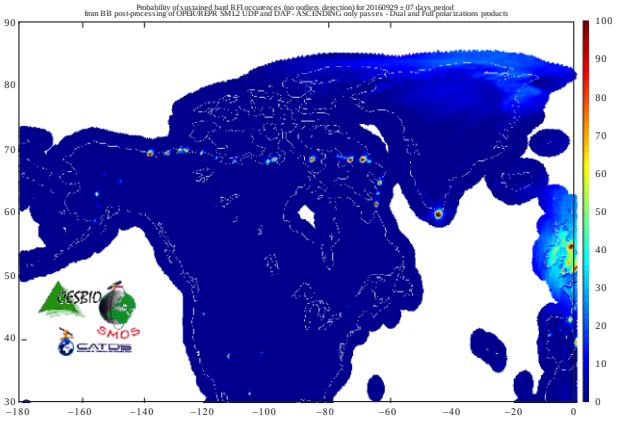

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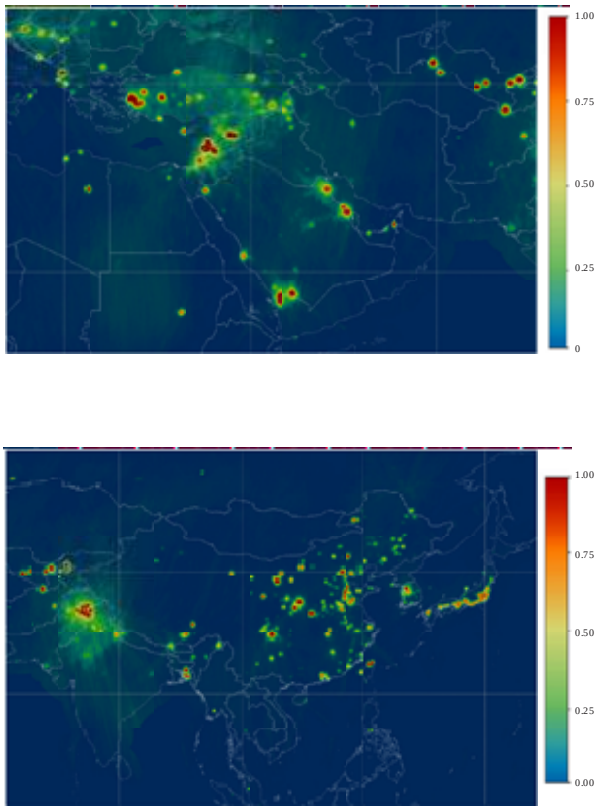
FIGURE 3

SMOS Regional RFI probability maps (16 to 31 May 2016). Source: ESA/ESAC



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c) Local images and snapshots

FIGURE 4

Snapshots showing BT measurements over Spain (left) and Hawaii (right). Source: ESA/ESAC

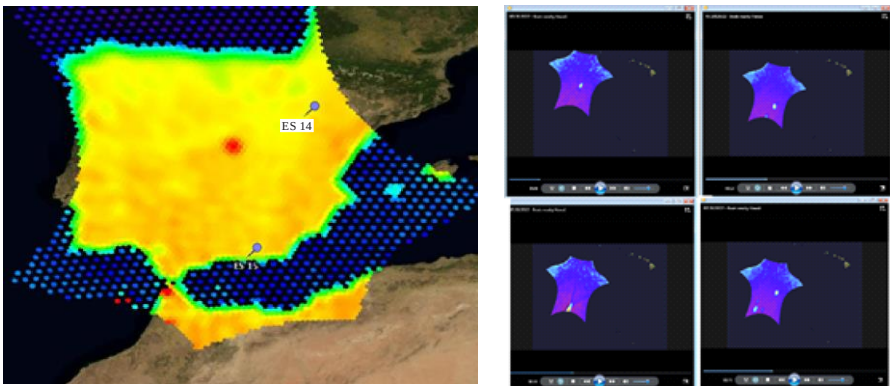

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FIGURE 5

Snapshot of UK23 and UK9, captured on 1 April 2015

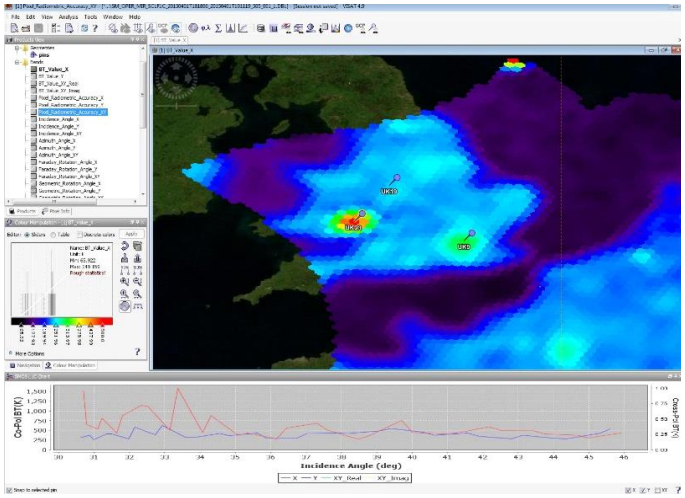

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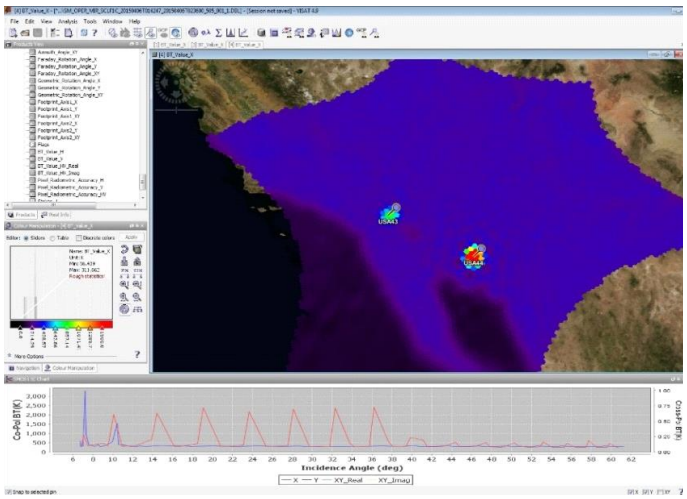
FIGURE 6

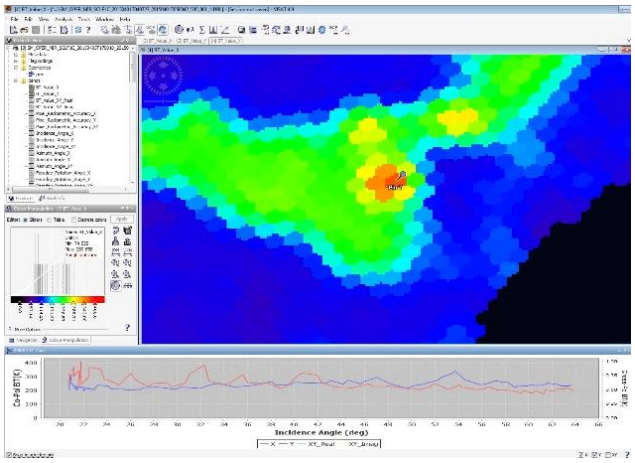
Snapshot of USA 43/Arizona and USA 44/California, taken on 6 April 2015



RS.2106-06

FIGURE 7

Snapshot of IT45/ Catania, Sicily, taken on 1 April 2015



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d) Classification of RFIs per intensity (Status as per dd.mm.yyyy)

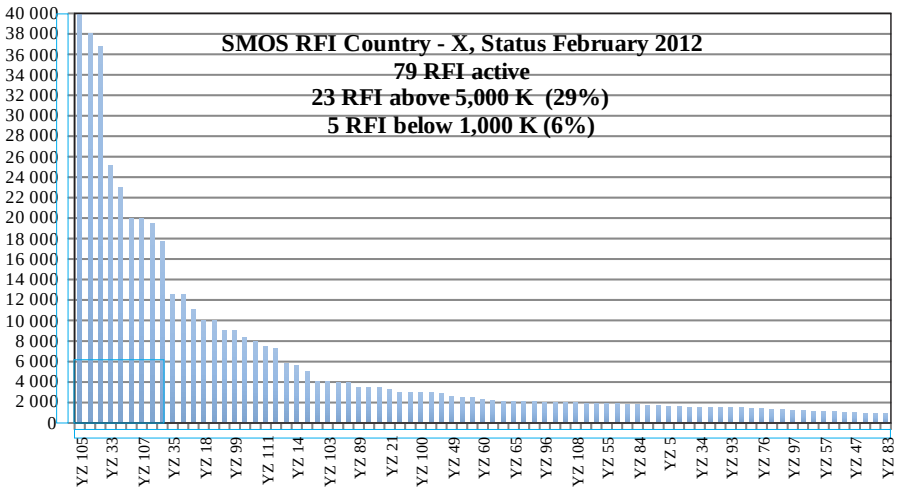
– Very strong RFIs (T_B > 5000 K) 20 RFI sources

– Strong RFIs (5000 K > T_B > 1000 K) 39 RFI sources

– Moderate RFI (T_B < 1000 K) 17 RFI sources

FIGURE 8

Classification of RFIs per intensity



RS.2106-08

TABLE A1-1

Summary table including the RFI cases that have been re-solved in {administration name}

ID.	Observed geo-location		Level of interference detected by sensor (Kelvin)	City/State/ Region		Status
	Longitude (degrees)	Latitude (degrees)				
ADM-02	xx.xxx	yy.yyy	400	Region x	Type of source: Radar Accuracy in geo-location (considering real position): 4.7 km	OFF. Solved after actions taken by Admin
ADM-06	xx.xxx	yy.yyy	1 500	City x	Type of source: Unknown	OFF. RFI has disappeared without any action
ADM-07	xx.xxx	yy.yyy	5 000	Rural area x	Type of source: In-band malfunctioning radiolink Accuracy in geo-location (considering real position): 6.2 km	OFF. Solved after actions taken by Admin

– – – End of example – – –

Attachment 2

to Annex

Use of the FRIIS Equation to approximate interfering emitter power levels from T_B for a single source interferer

Signal power levels of interferers are generally not directly measured by passive sensing satellite instruments such as radiometers, due to the objectives of what is being sensed by the satellite instruments. In some cases (for example, the SMOS satellite operated by the European Space Agency) the radiometer measures "Brightness temperature" (T_B).

An estimate of the magnitude of emission source power of a single source interferer is helpful for regulators to determine what measurement instrumentation, antennas and/or preamplifiers might be necessary to acquire the signal in the search area of an interference source. However, it should be noted that the interference source power cannot be precisely determined, due to a number of factors that are not readily known, including:

– interfering source antenna direction and gain;

– precise satellite antenna orientation and gain (since T_B may be an aggregate level resulting from a number of detections at different ranges, such as from a synthetic aperture antenna whose main lobe direction may be varying);

– the orientation of the emission source antenna and the satellite sensor antenna;

– other effects such as multipath waves.

These and other factors make it difficult to accurately calculate the power of a detected interferer. However, the Friis Transmission equation, which defines the relationship between received power, antenna gains and transmitted power, can be used to calculate a rough estimate of emitter power, based on T_B measured by a radiometer. It must be noted that assumptions must be made for unknown parameters and that will affect the accuracy of the estimated single source interferer power.

Ideally, the entity operating the satellite and reporting the interference will provide some rough order-of-magnitude estimate of emission power, using the best information available at the time of reporting. Regulatory agencies which are resolving incidents of reported interference should consider the above issues in their investigations. The following example of using the Friis Transmission Formula to determine the estimated e.i.r.p. of the offending transmitter is for the SMOS sensor encountering a single source interferer with a received T_B of 5000°K.

FRIIS Transmission Formula

$$P_t G_t(\theta_r, \varphi_r) = kB\left(\frac{4\pi}{\lambda}\right)^2 \frac{T_B R^2}{G_{smos}(\theta_T, \varphi_T)} \quad (1)$$

where:

k = Boltzmann's constant (1.38×10^{-23} W/H/K)

T_B = Brightness Temperature (K)

B = 3 dB bandwidth of the receiver experiencing interference (Hz, specified as 20 MHz [2.0×10^7 Hz])

R = distance to the sensor satellite (m)

λ = wavelength at the sensor centre frequency (0.21 m @ 1413 MHz).

The product, $P_t G_t(\theta_r,\varphi_r)$, is also referred to as the *Equivalent Isotropic Radiated Power* (e.i.r.p.) of the interfering source in the direction of the receiver experiencing interference (in this example, the SMOS radiometer).

$G_{smos}(\theta_T,\varphi_T)$ is the gain of the receiving antenna (dBi) in the direction of the interferer. (In the case of the SMOS satellite, the gain in the main lobe of the radiometer antenna is approximately 24 dBi, though the calculation with this value assumes an alignment of the main lobe to the source, which may not always be true.)

Equation (1) can be simplified by combining the constant values of k, B, π, $G_{smos}(\theta_T,\varphi_T)$ and the value of 1 000 m/km:

$$e.i.r.p. = 3.9345 \times 10^{-9} T_B R^2 \tag{2}$$

or in log form:

$$e.i.r.p._{(dBW)} = -84.05 + 10\log(T_B) + 20\log(R) \tag{3}$$

where R is the range of the satellite to the estimated area of the emitter, in kilometres.

Calculating the estimated power level for T_B = 5 000°K and R = 1 000 km:

$$e.i.r.p._{(dBW)} = -84.05 + 10\log(5000) + 20\log(1000) = -84.05 + 36.9897 + 60.0 = 12.9 \text{ dBW}$$

It should be noted that SMOS payload is a passive microwave 2-D interferometric radiometer comprising 69 antenna elements. The Friis transmission formula gives an approximation of the power received by a narrow beam radiometer pointing towards an extended source. In that case, T_B is the brightness temperature of the location where the radiometer is pointing. The Friis formula may be also used for an interferometric system considering all spatial directions. In that case, the power received by the interferometric system can be interpreted as the power that a conventional radiometer pointing to the same ground location would receive if the antenna diagram pattern would be the same as the pattern synthesized by the interferometric system in the same direction.

Attachment 3

to Annex

Blank RFI Reporting Form (Tables A3-1 to A3-4)

In addition to the form, consisting of the following four Tables, in this Attachment 3 which should be completed by the reporting administration, supporting information intended to facilitate the investigations of the administration to locate the interference emissions should also be provided. The type of supporting material may be as follows:

– RFI probability maps (global, regional or with detail over specific locations).

– Brightness temperature maps and snapshots over relevant areas.

– RFI categorisation with indication of RFI strength.

– RFI categorisation per regional location.

– Remarks about specific RFI observations.

– RFI log showing the cases resolved and type of RFI emission found out after investigation by the authorities.

Some examples are presented in Attachment 1 of this Recommendation.

TABLE A3-1

General Reporting Information

Administration or Entity Submitting Report:			
Contact person:		Date:	
		Report or Case #	
Subject:			
Action requested:			
Administration Interference Enforcement Agency:			
Contact person:		Ref #:	
Basis for Identification of Responsible Administration			
Affected Frequency or Frequency Band			
Relevant ITU-R Regulations			
Report cc: to			

TABLE A3- 2

Impacted EESS (passive) system characteristics

Satellite	
Mission web site	
Launch date	
Payload	
Payload Sensor Characteristics	
Main objective	
Swath width (km)	
Spatial resolution (km)	
Polarization	
Type of orbit	
Altitude (km)	
Inclination (degrees)	
Ascending Node LST	
Eccentricity	
Revisit Time (days)	

TABLE A3-3

Summary of RFI Sources

Date of this RFI status update	
TOTAL number of RFI cases detected	
Active RFI sources	
**** Old RFI active sources**	
**** New RFI active sources**	
RFI sources OFF	

TABLE A3-4

Interference Source Detail Log

Number of ACTIVE sources listed: [##]

1. Source ID.	2. Observed geolocation		3. Centre Frequency (MHz)	4. Source detection characteristics	5. Level of interference detected by sensor (Kelvin)	6. Received power or (dBm or watts)	7. City/State/ Region	8. Other Observations (including accuracy)	9. Date/time log	10. Present Status
	Longitude (degrees)	Latitude (degrees)								