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Protection of the 406-406.1 MHz band

M Series

Mobile, radiodetermination, amateur
and related satellite services

Foreword

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

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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 M.2359-0

Protection of the 406-406.1 MHz band

(2015)

TABLE OF CONTENTS

Page

1 Introduction

1.1 Resolution 205 (Rev.WRC-12)

This Report addresses WRC-15 agenda item 9.1, issue 9.1.1, Resolution **205 (Rev.WRC-12)** – Protection of the systems operating in the mobile-satellite service in the band 406-406.1 MHz.

Resolution **205 (Rev.WRC-12)** indicates the following:

"*resolves to invite ITU-R*

1 to conduct, and complete in time for WRC-15, the appropriate regulatory, technical and operational studies with a view to ensuring the adequate protection of MSS systems in the frequency band 406-406.1 MHz from any emissions that could cause harmful interference (see RR No. **5.267**), taking into account the current and future deployment of services in adjacent bands as noted in *considering f)*;

2 to consider whether there is a need for regulatory action, based on the studies carried out under *resolves* 1, to facilitate the protection of MSS systems in the frequency band 406-406.1 MHz, or whether it is sufficient to include the results of the above studies in appropriate ITU-R Recommendations and/or Reports,

instructs the Director of the Radiocommunication Bureau

1 to include the results of these studies in his Report to WRC-15 for the purposes of considering adequate actions in response to *resolves to invite ITU-R* above;

2 to organize monitoring programmes in the frequency band 406-406.1 MHz in order to identify the source of any unauthorized emission in that band,"

Considering f) reads as follows:

"f) that Nos. **5.267** and **4.22** and Appendix **15** (Table 15-2) require the protection of the mobile-satellite service (MSS) within the frequency band 406-406.1 MHz from all emissions of systems, including systems operating in the lower adjacent bands (390-406 MHz) and in the upper adjacent bands (406.1-420 MHz);"

Recommendation ITU-R M.1478-3 provides the latest protection requirements for the various types of instruments mounted on board operational satellites receiving EPIRB signals in the frequency band 406-406.1 MHz against both wide-band out-of-band emissions and narrow-band spurious emissions. This Recommendation should be the technical basis of all further calculation concerning the protection of the frequency band 406-406.1 MHz. However, technical studies are needed to adequately address the consequence of aggregate emissions from a large number of transmitters operating in adjacent bands and the consequent risk to space receivers intended to detect low-power distress-beacon transmissions. Subsequent regulatory proposals may follow.

1.2 Report objective

This Report follows the stated objectives from Resolution **205 (Rev.WRC-12)** by studying the emission levels of all present systems in the 390 to 406 MHz and 406.1 to 420 MHz ranges and determining their relative contributions to the interference noise into the search and rescue (SAR) receiver. These interference noise sources will be assessed in terms of the maximum amount of interference noise that the SAR receivers on LEO, MEO and GSO satellites can receive.

Once these sources are characterized, they can be applied to an aggregate interference analysis that may be dynamic, which will study limits on their deployment parameters that will eliminate harmful interference, which is the exceedance of the maximum aggregate interference level. The set of deployment parameters that achieves compatibility may be considered for regulatory proposals.

1.3 Overview of Cospas-Sarsat system, various types of satellites and related payloads

The 406-406.1 MHz frequency band is exclusively allocated to mobile-satellite service, which is currently used by the Cospas-Sarsat system. The International Cospas-Sarsat Programme implements, maintains, co-ordinates and operates satellite systems designed to provide distress alert and location data to assist SAR operations, using spacecraft and ground facilities to detect and locate the signals of distress beacons operating on 406 MHz.

The international Cospas-Sarsat system provides accurate, timely, and reliable distress alert and location data to help search and rescue (SAR) authorities assist persons in distress and its objective is to reduce, as far as possible, delays in the provision of distress alerts. The time required to detect and locate a distress signal and to provide adequate assistance, has a direct impact on the probability of survival of the person in distress at sea or on land.

The detection and location of distress signals is facilitated by global monitoring based on low-altitude spacecraft in near-polar orbits. Complete coverage of the Earth, including the polar regions, can be achieved using simple emergency beacons operating on 406 MHz to signal a distress. Significant enhancements to the initial low Earth orbit (LEO) component is provided by a geostationary complement to the Cospas-Sarsat polar-orbiting system in terms of alerting time advantage, and the benefits to SAR services of this rapid alerting capability.

In addition to the LEO and geostationary Earth orbit (GEO) components, the Cospas-Sarsat system is currently deploying new SAR repeaters on MEO global navigation satellites (e.g. Glonass, GPS and Galileo). The medium Earth orbit (MEO) space segment will provide a significant enhanced global coverage. When the MEO system reaches full operational capability, it will offer a number of advantages over the current combined LEO/GEO system, such as real-time message delivery and a worldwide first-burst (e.g. less than one minute) localization of distress beacons and allow for an enhanced tracking of moving distress signals (such as beacons drifting at sea).

As a summary, the Cospas-Sarsat system encompasses three space segment components:

1) a LEO component with satellites embarking SARP (Search and Rescue Processor) and SARR (Search and Rescue Repeater) instruments on polar sun-synchronized orbit;
2) a GEO component with different satellites (MSG, GOES, Insat-3A, Electro and Luch) embarking a SAR repeater;
3) a MEO component with three main radionavigation systems (GPS, Galileo, Glonass) embarking on their satellites a SAR repeater.

The SARP or SARR payloads are developed by several countries and present different characteristics and performance. Since the introduction of the first elements of the Cospas-Sarsat system in 1982, more than 35 000 persons (end of 2012 data) have been rescued worldwide with the assistance of the information provided by the Cospas-Sarsat system. The information provided by the Cospas-Sarsat system has also allowed to significantly reduce the time needed for numerous rescue operations therefore reducing the cost and risks associated with such operations.

2 Existing situation concerning the MSS band 406-406.1 MHz

In order to effectively convey the 406 MHz beacon distress signal to the Cospas-Sarsat ground segment, the frequencies used for the uplink and downlink communications between the different elements of the Cospas-Sarsat system needs to be protected from harmful interference. In the past years, Cospas-Sarsat space segment providers have developed protection criteria for the Cospas-Sarsat search and rescue instruments and local user terminals, respectively in the 406-406.1 MHz and 1 544-1 545 MHz bands, in order to protect them against wide-band out-of-band emissions and against narrow-band spurious emissions.

These protection criteria have been recognized at ITU level through two specific Recommendations: Recommendation ITU-R M.1478-3 for the protection of the 406.0-406.1 MHz band and Recommendation ITU-R M.1731-2 for the protection of the 1 544-1 545 MHz band.

The protection criteria developed in Recommendations ITU-R M.1478-3 and ITU-R M.1731-2 provide allowable power flux-density requirements against wide-band out-of-band and narrow-band spurious emissions for the frequency bands used by the Cospas-Sarsat systems. Emissions in adjacent bands, if not adequately controlled, could raise the level of noise captured by the Cospas-Sarsat systems and hinder their abilities to detect and/or relay signal from beacons and/or degrade the accuracy of the positions reported for the distress signals. The systems operating in adjacent bands shall ensure compliance with RR No. **5.267**, “Any emissions capable of causing harmful interference to the authorized uses of the band 406-406.1 MHz is prohibited”.

Some administrations have deployed land mobile systems operating in the vicinity of the MSS 406.0-406.1 MHz band, which has significantly enhanced concerns regarding possible harmful interference caused by adjacent band emissions. It is expected that other terrestrial operators worldwide will ask for extended spectrum capacities in UHF band in the future. An example of industrial forecast in North America is found in the following reference.

Doe, L 2015, ‘Predicted growth in TETRA by IHS ahead of IWCE 2015’, *Tetra Today* 16 March. Available from: <http://www.tetratoday.com/news/predicted-growth-in-tetra-by-ihs-ahead-of-iwce-2015>.

3 Protection of the frequency band 406-406.1 MHz: Maximum permissible level of interference

The compatibility analyses contained in this Report are based upon the characteristics of the following systems for both narrow-band and wide-band emissions.

3.1 Narrow-band spurious emissions

3.1.1 Protection for narrow-band spurious emissions for the low Earth orbit space segment

Recommendation ITU-R M.1478-3, Annex 2 provides the protection requirement from narrow-band spurious emissions. It is recalled that in order to satisfy SAR performance requirements in respect of low power distress beacons, the Sarsat SARP instrument has been designed to detect and process extremely weak signals. Its performance is such that any signal, C_{min}, which exceeds the local noise density level by 21 dB (Hz) ($C_{min}/N_0 > 21$ dB (Hz)) would be assigned to a DRU (on-board Data Recovery Unit) for additional processing. Consequently, narrow-band interfering signals meeting these criteria would cause a DRU to be assigned to it. The consequence would be that the performance of the SARP, in terms of capacity (e.g. the number of simultaneous distress messages that are able to be processed), would be seriously degraded. Following computations lead to a maximum level of interference of –177.6 dBW (or –147.6 dBm). In accordance with Recommendation ITU-R M.1478-3, the basic current resolution of the SARP instrument is 19 Hz (see Recommendation ITU-R M.1478-3, Annex 3). In addition, as explained in § 3.2, the corresponding resolution applicable to this receiver sensitivity can be extended up to 2 kHz.

Another way to compute the protection criteria (or the maximum level of the interfering signal) is to define a minimum acceptable C/I. It is generally considered that a C/I of 10 dB is the minimum level that can be accepted without disturbing too much a radio communication link. For the case of the LEO instrument, the minimum distress signal that can be properly detected is –137 dBm. Applying 10 dB at C/I level gives a maximum level of I (the interfering signal) = –147 dBm, which is in accordance with the level computed in Recommendation ITU-R M.1478-3. The LEO instrument maximum permissible level of interference is provided below. It confirms the level of –147 dBm as the maximum interfering signal permissible in the 406.0-406.1 MHz band, through direct measures performed by the instrument manufacturer, by injecting out-of-band signals at the RF input connector of the SARP. The level for each band is given for the noise signal providing a degradation of the detection/demodulation process on a “useful” distress message.

The levels of interference measured by the LEO instrument can be found in Table 3-1. The interference levels that are shown in the table have taken into account the performance of the on board demodulation process as well as the filtering capability.

TABLE 3-1

Maximum permissible level of interference of the SARP for narrow-band emissions at the receiver level

Frequency (MHz)	Maximum permissible level of interference (dBm)
390-401	–70
401-405	–80
405-405.9	–110
405.9-406.0	–145
406.0-406.1	–147
406.1-406.2	–145
406.2-407	–110
407-411	–80
411-420	–70

For instance, in the frequency ranges 401-405 MHz and 407-411 MHz, the SARP instrument can tolerate narrow-band levels below –80 dBm at its input.

3.1.2 Protection for narrow-band spurious emissions for the geostationary Earth orbit space segment

According to Recommendation ITU-R M.1478-3, Annex 7 concerning MSG GEOSAR, no requirements concerning narrow-band spurious emissions are available. However, it is to be noted that the level of –147 dBm (or –177 dBW), which is the sensitivity within the 406-406.1 MHz band, is also the maximum level of interference that can be withstood by the GEO MSG SAR repeater.

The maximum permissible level of interference valid for the GEO space segment (MSG satellite) is as shown in Table 3-2 which gives the maximum permissible level of interference for narrow-band emissions.

TABLE 3-2

Maximum permissible level of interference of the GEO space segment for narrow-band emissions (MSG satellite)

Frequency (MHz)	Maximum permissible level of interference (dBm)
390-401	–102
401-405	–107
405-405.9	–112
405.9-406.0	–141
406.0-406.1	–147
406.1-406.2	–141
406.2-407	–112
407-411	–107
411-420	–102

The mask of the maximum permissible interference level for electro satellite is given in Table 3-3.

TABLE 3-3

Maximum permissible level of interference of the GEO (electro satellite) space segment for narrow-band emissions

Frequency (MHz)	Maximum permissible level of interference (dBm)
390-405.96	–109.8
405.96-406.0	–136.8
406.0-406.1	–139.8
406.1-406.14	–136.8
406.14-420	–109.8

3.1.3 Protection for narrow-band spurious emissions for the medium Earth orbit space segment

Recommendation ITU-R M.1478-3 Annex 10 proposes protection criteria concerning the medium Earth orbit (MEO) space segment, in particular GALILEO MEOSAR satellites. Table 3-4 provides the corresponding maximum permissible level of narrow-band interference valid for the MEO space segment (GALILEO).

TABLE 3-4

Maximum permissible level of interference of the MEO space segment (GALILEO satellite) for narrow-band emissions

Frequency (MHz)	Maximum permissible level of interference (dBm)
390-405.05	–56.1
405.05-406.0	–79.6
406.0-406.1	–136.8
406.1-407.05	–80.6
407.05-420	–56.1

Table 3-5 provides the corresponding maximum permissible level of narrow-band interference valid for the MEO space segment (GLONASS satellite).

TABLE 3-5

Maximum permissible level of interference of the MEO space segment (GLONASS satellite) for narrow-band emissions

Frequency (MHz)	Maximum permissible level of interference (dBm)
390-402.05	–87.1
402.05-405.05	–117.1
405.05-406.0	–144.1
406.0-406.1	–147.1
406.1-407.05	–144.1
407.05-410.05	–117.1
410.05-420	–87.1

3.2 Wide-band emissions

3.2.1 Protection for wide-band emissions for the low Earth orbit space segment

According to Recommendation ITU-R M.1478-3, the maximum acceptable spfd at the antenna of the Sarsat SARP instrument (aggregate sources within the band 406-406.1 MHz), is equivalent to a broadband noise density of –198.6 dBW/m^2/Hz or –210.1 dBW/Hz. The relation between spfd and the noise density is:

spfd = –210.1 (broad band noise density) + 1.6 (losses) – 10 $\log_{10} S$ = –198.6 dB (W/(m^2 · Hz)), with

S being the equivalent surface area of the antenna ($S = G \frac{\lambda^2}{4\pi}$, with G = 3.85 dBi).

The maximum permissible level of interference measured on the SARP instrument (LEO space component) is as shown in Table 3-6, which gives the maximum wide-band permissible level.

TABLE 3-6

Maximum permissible interference level of the SARP for wide-band emissions

Frequency (MHz)	Power spectral flux density (dBW/m^2/Hz)	Maximum permissible level of interference (dBW/Hz)
390-401	–121.6	–133.1
401-405	–131.6	–143.1
405-405.9	–161.6	–173.1
405.9-406.0	–196.6	–208.1
406.0-406.1	–198.6	–210.1
406.1-406.2	–196.6	–208.1
406.2-407	–161.6	–173.1
407-411	–131.6	–143.1
411-420	–121.6	–133.1

This maximum permissible level of interference is applicable for any bandwidth within the corresponding frequency range. In order to make a link with § 3.1, which computes the narrow-band receiver sensitivity, if the bandwidth equals 1 600 Hz (typical bandwidth of an EPIRB), the corresponding minimum level within the band 406-406.1 MHz equals –210.1 + 10*log10(1 600) = –178 dBW or –148 dBm, which is very close to the sensitivity of –147 dBm applicable for narrow-band emissions. It means that the receiver sensitivity for narrow-band emissions (see § 3.1) is not applicable for resolutions greater than 2 kHz.

3.2.2 Protection for wide-band emissions for the GEO space segment

According to Recommendation ITU-R M.1478-3, Annex 7 concerning MSG GEOSAR, the requirement concerning wide-band emissions is –217 dBW/Hz or –206.4 dB (W/(m^2 · Hz)) within the band 406-406.1 MHz at the receiver level. The relation between spfd and the noise density is:

spfd = –217 (broad band noise density) – 10 $\log_{10} S$ = –206.4 dB (W/(m^2 · Hz)), with S being the equivalent surface area of the antenna ($S = G \frac{\lambda^2}{4\pi}$ = 0.087 m^2 with G = 3 dBi).

The maximum wide-band permissible level of interference valid for the GEO space segment (MSG satellite) is shown in Table 3-7.

TABLE 3-7

Maximum permissible level of interference of the GEO space segment (MSG satellite) for wide-band emissions

Frequency (MHz)	Power spectral flux density (dBW/m^2/Hz)	Maximum permissible level of interference (dBW/Hz)
390-401	–161.4	–172
401-405	–166.4	–177
405-405.9	–171.4	–182
405.9-406.0	–200.4	–211
406.0-406.1	–206.4	–217
406.1-406.2	–200.4	–211
406.2-407	–171.4	–182
407-411	–166.4	–177
411-420	–161.4	–172

This maximum permissible level of interference is applicable for any bandwidth within the corresponding frequency range.

It is necessary to consider the GOES satellites as well as the MSG GEOSAR satellite because the footprint covers different areas of the globe and thus different populations of potential interferes. The GOES SAR repeater (SARR) has a noise temperature of 359 K and an antenna gain of 12 dBi; therefore, the value of I_0 is –207.62 dB (W/Hz) and the spfd is –164.10 dB (W/m^2/Hz). The GOES-R system noise temperature is 531 K and the antenna gain is 14.3 dBi. The resultant Io is –205.92 dB (W/Hz) and the power spectral density is –164.70 dB (W/m^2/Hz). The MSG GEOSAR satellite is almost 10 dB more sensitive to interference than the other systems in terms of noise power in the receiver and about 5 dB more sensitive in terms of the power spectral flux density.

Since the satellites view different parts of the world and different potentially interfering populations, the appropriate interference threshold should be applied to the location of the satellites field-of-view. The extension of Table 3-7 for the GOES satellites is presented below, in Table 3-8. The values in this table assume that the same filter is being used for each system.

TABLE 3-8

Maximum permissible interference level of the GOES space segment for wide-band emissions

GOES SARR	psfd dB (W/Hz/m^2)	I_0 dB (W/Hz)	GOES-R	psfd dB (W/Hz/m^2)	I_0 dB (W/Hz)
390-401	–159.18	–162.62	390-401	–159.67	–160.92
401-405	–164.18	–167.62	401-405	–164. 67	–165.92
405-405.9	–169.18	–172.62	405-405.9	–169. 67	–170.92
405.9-406.0	–198.18	–201.62	405.9-406.0	–198. 67	–199.92
406.0-406.1	–204.18	–207.62	406.0-406.1	–204. 67	–205.92
406.1-406.2	–198.18	–201.62	406.1-406.2	–198. 67	–199.92
406.2-407	–169.18	–172.62	406.2-407	–169. 67	–170.92

TABLE 3-8 (*end*)

GOES SARR	**psfd dB (W/Hz/m^2)**	**I$_0$ dB (W/Hz)**	**GOES-R**	**psfd dB (W/Hz/m^2)**	**I$_0$ dB (W/Hz)**
407-411	–124.18	–167.62	407-411	–124. 67	–165.92
411-420	–119.10	–162.62	411-420	–119. 67	–160.92

In accordance with Annex 8 of Recommendation ITU-R M.1478-3 and in relation with the Electro satellite, the required broad band emission level is –200.3 dBW/Hz or –198.7 dBW/m^2 /Hz in the frequency band 406.0-406.1 MHz at the receiver input. The relationship between spfd and noise density is given as follows:

spfd = –200.3 (broad band noise density) – 10 log$_{10}$ S = –198.7 dB (W/(m^2×Hz)),

where S is the equivalent surface area of the antenna ($S = G\,\frac{\lambda^2}{4\pi}$, = 0.69 m^2 with G = 12.0 dBi).

The maximum broadband permissible level of interference for the GEO space segment (Electro satellite) is shown in Table 3-9.

TABLE 3-9

Maximum permissible level of interference of the GEO space segment (Electro satellite) for wide-band emissions

Frequency (MHz)	**Power spectral flux density (dBW/m^2/Hz)**	**Maximum permissible level of interference (dBW/Hz)**
390-405.96	–168.7	–170.3
405.96-406.0	–195.7	–197.3
406.0-406.1	–198.7	–200.3
406.1-406.14	–195.7	–197.3
406.14-420	–168.7	–170.3

This maximum permissible level of interference is applied for any bandwidth in the corresponding frequency range. In relation to § 3.1, where the receiver sensitivity is calculated for the bandwidth of 1 600 Hz (typical value of the bandwidth of an EPIRB), the corresponding minimum level within the band 406-406.1 MHz equals –200.3 + 10*log10(1 600) = –168.3 dBW or –138.3 dBm, which is very close to the sensitivity of –139.8 dBm, applicable for narrow-band emissions. It means that the receiver sensitivity for narrow-band emissions (see § 3.1) is not applicable for resolutions greater than 2 kHz.

3.2.3 Protection for wide-band emissions for the Medium Earth Orbit (MEO) space segment

Recommendation ITU-R M.1478-3 proposes protection criteria concerning the MEO space segment, in particular GALILEO MEOSAR satellites. The relation between spfd and the noise density is:

spfd = –207.28 (broad band noise density) + 0.51(losses) – 10 log$_{10}$ S = –206.1 dB (W/(m^2 · Hz)),

with S being the equivalent surface area of the antenna ($S = G\,\frac{\lambda^2}{4\pi}$ = 0.87 m^2 with G = 13 dBi).

Table 3-10 provides the corresponding maximum permissible level of wide-band interference valid for the MEO space segment (GALILEO).

It is to be noted that the permissible levels of interference in Table 3-10 are computed using the spectral separation coefficient (SSC) method between interference signal and a reference signal. This method describes the spectral coupling between an interfering signal i(t) (having unit power normalized spectral density *Gi(f)*) and a reference signal s(t) also having a normalized spectral density *Gs(f)*, which is a typical signal as transmitted by a 406 MHz distress beacon. Both spectra are normalized over an infinite bandwidth. The SSC coefficient *Kis* is computed as follows, with *H(f)* being the receiver transfer function.

$$Kis = \int_{-\infty}^{+\infty} |H(f)|^2 Gi(f) Gs(f) df$$

The computation of *Kis* allows deriving the maximum interference power I, that, according to Recommendation ITU-R M.1478-3, will not degrade the bit error rate performance of 5×10^{-5}. I(dBW) equals –207.28 (dBW/Hz) – *Kis*(dB/Hz). It is to be noted that –207.28 dBW/Hz is the acceptable level of noise density as calculated in Recommendation ITU-R M.1478-3.

TABLE 3-10

Maximum permissible level of interference of the MEO space segment (GALILEO satellite) for wide-band emissions

Frequency (MHz)	**Power spectral flux density (dBW/m^{2}Hz)**	**Maximum permissible level of interference (dBW/Hz)**
390-405.05	–157.5	–157.52
405.05-406.0	–163	–163.02
406.0-406.1	–206.1	–207.28
406.1-407.05	–165.5	–165.52
407.05-420	–157.5	–157.528

In accordance with Recommendation ITU-R M.1478-3 in relation to GLONASS satellite, the required broad band emission level is –207.3 dB (W/Hz) or –205.2 dB (W/m^2/Hz) in the frequency band 406.0-406.1 MHz at the receiver input. The relationship between spfd and noise density is given in the following way:

$$\text{spfd} = -207.3 \text{ (broad band noise density)} - 10 \log_{10} S = -205.2 \text{ dB } (\text{W}/(\text{m}^2 \times \text{Hz})),$$

where S is the equivalent surface area of the antenna ($S = G \frac{\lambda^2}{4\pi}$, = 0.61 m^2 with G = 11.5 dBi).

The maximum broadband permissible level of interference valid for the MEO space segment (GLONASS satellite) is shown in Table 3-11.

TABLE 3-11

Maximum permissible level of interference of the MEO space segment (GLONASS satellite) for broadband emissions

Frequency (MHz)	Power spectral flux density (dBW/m^2/Hz)	Maximum permissible level of interference (dBW/Hz)
390-402.05	–145.2	–147.3
402.05-405.05	–175.2	–177.3
405.05-406.0	–202.2	–204.3
406.0-406.1	–205.2	–207.3
406.1-407.05	–202.2	–204.3
407.05-410.05	–175.2	–177.3
410.05-420	–145.2	–147.3

This maximum permissible level of interference is applied for any bandwidth in the corresponding frequency range. In relation to § 3.1, where the receiver sensitivity is calculated for the bandwidth of 1 600 Hz (typical value of the bandwidth of an EPIRB), the corresponding minimum level within the band 406-406.1 MHz equals –207.3 + 10*log10(1 600) = –175.3 dBW or –145.3 dBm, which is very close to the sensitivity of –147.1 dBm applicable for narrow-band emissions. It means that the receiver sensitivity for narrow-band emissions (see § 3.1) is not applicable for resolutions greater than 2 kHz.

4 Monitoring of the MSS band 406-406.1 MHz and in adjacent frequencies

According to Resolution **205 (Rev.WRC-12)**, the frequency band 406-406.1 MHz is constantly monitored. Reports on the presence of in-band interferers are provided to the ITU by various administrations on a monthly basis. It is to be noted that a new generation of LEO instruments already flying on board various satellites makes noise measurements: each time the LEO receiver demodulates a signal within the 406-406.1 MHz band, the receiver provides an estimate of the strength of the signal power as well as the corresponding noise density. Those data (signal and noise density) are useful for statistics as well for monitoring purposes.

Figure 4-1 plots the noise density as detected by the LEO NOAA N’ instrument. This figure clearly indicates that the level of the noise is highly dependent on the location of the measurement. This figure shows the total amount of noise: system beacons, real distress beacons and additional noise (mainly derived from radio stations operated in the adjacent band). The level of noise roughly equals –190 dB (W/Hz) which is 20 dB above the interference level of –210 dB (W/Hz) (see Table 3-4 in § 3.2.1).

For most of the locations on the Earth (mainly over oceans), a distress beacon can be correctly received and processed by the LEO space segment even for low signal levels received by the instrument. In other areas such as Europe or Asia, Fig. 2-1 shows an important level of radio noise present within the satellite footprint. This map reflects the situation in terms of noise density as seen by the LEO satellite: each point in this map corresponds to a demodulated signal. These signals can be either derived from real distress beacons, reference and orbitography beacons and also out of band noise or spurious emissions from adjacent bands. In Europe, the level of noise is quite high. In fact, in Europe, there are many orbitography/reference beacons compared to some other parts of the world:

France (Toulouse), Russia (Moscow), UK, and Norway. There is also one beacon in Thule (Denmark).

Taking into account these orbitography beacon transmissions and the real distress that may occur in Europe, this area experiences a significant number of beacons transmissions, which increase the noise floor within the 406-406.1 MHz band, but also allows opportunities for system monitoring.

In Antarctica (McMurdo Station) and in France (Kerguelen), there are orbitography and reference beacons which explain the significant number of plots on the figure in the southern Indian Ocean and in the South Pole region. Concerning America, only one reference beacon is operational in Canada (Edmonton), and no system beacon is operational in Asia.

Figure 4-2 plots the noise density as measured by LEO instruments in the vicinity of the 406-406.1 MHz band, i.e. the 401-402 MHz frequency band (using the Advanced Data Collection System or ADCS instrument embarked on the SARAL satellite orbiting at an altitude of 814 km). This figure indicates a noise activity of similar magnitude (around 15 to 20 dB) above the same European and Asians areas. This noise issue in UHF band encompasses the frequency range between 390 MHz and 420 MHz and is suspected to be the result of operational terrestrial systems deployed in many countries.

All these measurements provide a rationale as to why the protection of the 406-406.1 MHz band has to be carefully examined, with a specific concern within Europe and Asia, in order to ensure that distress signals from all 406 MHz beacons (including weaker signals which are sometimes generated in challenging environments) could continue to be detected and successfully processed by the each of Cospas-Sarsat space components.

FIGURE 4-1

Noise density detected by the LEO NOAA N' instrument

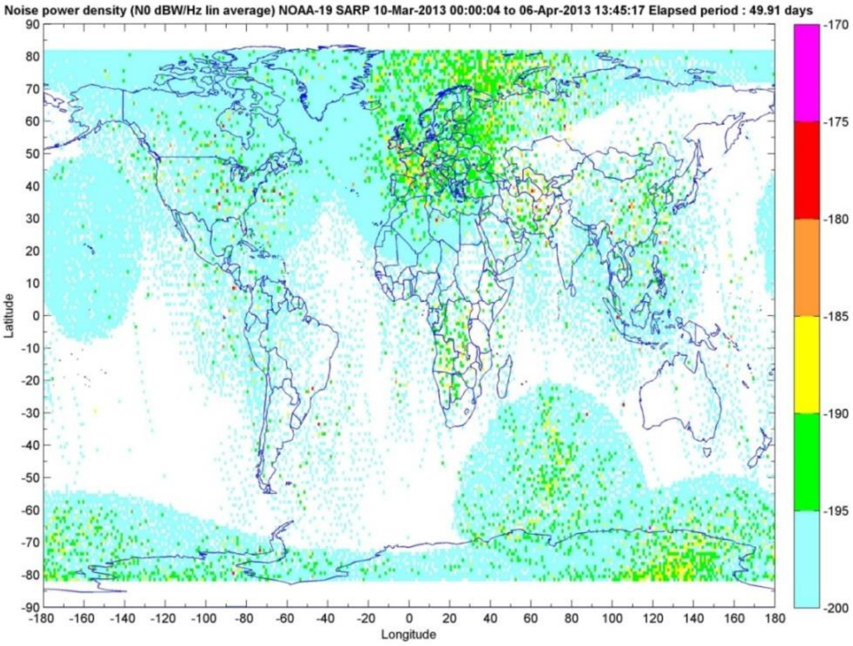
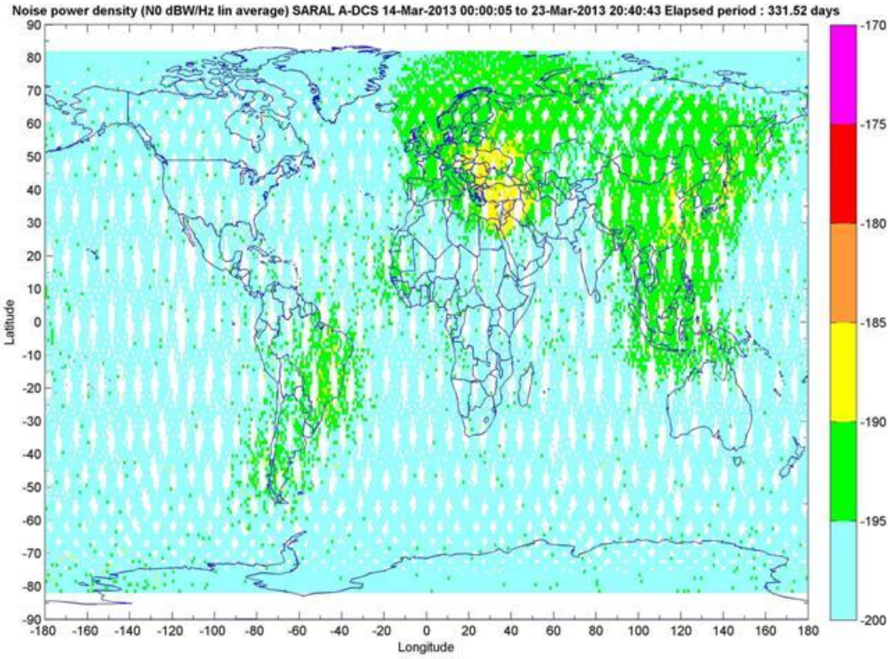


FIGURE 4-2

Noise level in the band 401-402 MHz measured by the SARAL satellite



Annex 1 of this Report provides detailed spectrum-monitoring data collected using GEO and MEO space components providing additional evidence of potentially harmful emissions near the 406-406.1 MHz band.

The MEO data was gathered from both experimental S-band and operational L-band transponders. Observations include (i) visible impact on transponder gain control and (ii) increased noise levels within the 406.0-406.1 MHz band that could significantly impact transmissions from distress radio beacons.

Observations performed with GPS, GLONASS and GALILEO confirm the presence of noise providing additional evidence of emissions near the 406-406.1 MHz band potentially causing harmful interference in the 406-406.1 MHz band, further justifying the need for technical and regulatory studies.

These observations show that above 406.1 MHz, especially within CEPT countries, there is a significant amount of emissions that may cause interference to 406-406.1 MHz space receivers.

In addition, observations have shown that strong interferers are very close to 406 MHz, the lower part of the MSS band. These adjacent-channel emissions, although having lower amplitude than at frequencies higher than 406.1 MHz, have a harmful impact on the reception of effective distress beacons in the 406 MHz band.

This data further justifies the need for technical and regulatory studies related to interference near this frequency band. It is also essential to continue to organize monitoring programmes in the frequency band 406-406.1 MHz in order to identify the source of any unauthorized emission in that frequency band, and to organize monitoring programmes on the impact of the unwanted emissions from systems operating in the frequency bands 405.9-406 MHz and 406.1-406.2 MHz on the MSS reception in the frequency band 406-406.1 MHz.

5 Technical characteristics of the systems being deployed in adjacent bands

5.1 Technical characteristics of EESS (Earth-to-space) service (data collection platforms) operating in the 401 to 403 MHz range

Data on these systems can be found in Recommendation ITU-R SA.1627, Telecommunication requirements and characteristics of EESS and MetSat service systems for data collection and platform location. These characteristics are presented in Table 5-1.

TABLE 5-1

RF characteristics of data collection platforms

System	Power	Bit rate	# channels on receiver
Low Earth orbiting systems			
PCM/FM	3 watts	400 b/s	Not channelized
Mixed QPSK	3 watts	800 b/s (coded)	Not channelized
GMSK	5 watts	6400 b/s (coded)	Not channelized
Geostationary systems			
International DCS	40 watts e.i.r.p.	100 b/s	33 of 3 kHz each
GOES	15 dBW	100, 300 b/s	933 separated by 750 Hz the 1 200 bit/s stations occupy 3-kHz channels
	19 dBW	1200 b/s	

Platforms transmitting to low earth orbiting satellites on the same frequency but are separated by the Doppler frequency shift in the receiver. A single receiver channel of about 70 or 80 kHz can discriminate between as many as eight signals simultaneously. Future plans for a U.S. satellite would have 8 channels and thus a total capacity of 64 signals.

Platforms transmitting to geostationary satellites have individual fixed channels. Thirty three channels in the 402.0 to 402.1 MHz range are available for international stations which are mobile and drift between satellite systems. The number of international channels in use is only eleven because of low demand. The worldwide regional channel plan alternates between the 401.7 to 402.0 MHz and 402.1 to 402.4 MHz in adjacent regions to avoid interference between them. This is shown in Table 5-1A below.

TABLE 5-1A

GSO spacecraft containing DCS receivers

Satellite	Organization	Location	Frequency Range for Regional Platforms
GOES East	U.S.	75° West	401.7 to 402.0 MHz
GOES West	U.S.	135° West	401.7 to 402.0 MHz
METEOSAT	EUMETSAT	0° East	402.1 to 402.4 MHz
Elektro-L	Russian Federation	76° East	401.7 to 402.0 MHz
MTSAT	Japan	140° East	402.1 to 402.4 MHz

Four hundred channels between 401.7 and 402.0 MHz are used for GOES regional platforms, 200 interleaved channels each for the GOES-East and GOES-West satellites to avoid self-interference in the GOES system.

The platforms transmit to low earth orbiting satellites at random with a low duty cycle. Platforms transmitting to geostationary satellites are scheduled.

The transmitting characteristics are presented in Table 5-2.

TABLE 5-2

Transmit timing of data collection platforms

System	Duration of transmission	Time between transmissions	Duty Cycle (calculated)
Low Earth orbiting systems			
PSK/PM	200 to 760 ms	60, 100 and 200 seconds	0.001 to 0.01267
Mixed QPSK	200 to 760 ms	60, 100 and 200 seconds	0.001 to 0.01267
GMSK	120 ms to 1.1 seconds	200 seconds	0.0006 to 0.055
Geostationary systems			
International	55.19 seconds maximum	33 Interrogated channels	N/A
GOES	10 second time slots	933 Interrogated channels	N/A

The frequencies at which the current systems operate are shown in Table 5-3.

TABLE 5-3

Operating frequencies of data collection platforms

System	Centre frequency	Offset/Channeling	Source
MOS PCM/FM	401.5 MHz		Rec. ITU-R SA.1627
Argos PCM/FM and Mixed QPSK	401.65 MHz	± 30 kHz	Rec. ITU-R SA.1627
Brazilian DCS	401.635	± 30 kHz	Rec. ITU-R SA.1627
Argos GMSK	401.595 MHz	± 3 kHz	Rec. ITU-R SA.1627
Argos-4 A-DCS	399.94 MHz 401.05 MHz 401.145 MHz 401.34 MHz 401.455 MHz 401.57 MHz 401.65 MHz	± 40 kHz ± 40 kHz ± 40 kHz ± 40 kHz ± 75 kHz ± 40 kHz ± 40 kHz	CNES, France NASA and NOAA, U.S.
International DCS	402.05 MHz	–49 kHz and +50 kHz	Rec. ITU-R SA.1627
GOES Regional	401.7 to and 402.0 MHz	400 channels with a separation of 750 Hz	U.S. NOAA

TABLE 5-3 (*end*)

System	**Centre frequency**	**Offset/Channeling**	**Source**
Meteosat Regional	402.1 to 402.435 MHz	44 3-kHz channels from 401.2 to 402.2 MHz plus 144 1.5-kHz channels from 402.2 to 402.4 MHz and 8 3-kHz channels from 402.2 to 402.435 MHz	Meteosat Data Collection and Distribution Service – Technical Description EUMETSAT
MTSAT Regional	402.1 to 402.4 MHz	1.8 kHz and 4-kHz channels	DCS (Data Collection System)
Electro-L Regional	401.7 to 402.0 MHz	300 channels	WMO ET-SUP-6_Doc_09-02_ROSH

Currently, for low Earth orbiting satellites, there are roughly 18 000 platforms in operation (8 800 actively transmitting platforms every day) within a bandwidth of 80 kHz.

This number is expected to grow significantly taking into account the requests for the data collection applications using satellites, which are mostly for environmental applications. One hundred and eighty of these 18 000 platforms are active at any one time worldwide.

In the future 21 000 platforms are planned worldwide for low data rates, and 7 000 platforms worldwide for high data rates. It is also useful to note that for a typical LEO satellite within the band 401 to 403 MHz (at an altitude of around 800 km), the expected capacity will be 18.5 transmitting platforms for low data rates and 6 transmitting platforms for high data rates, operating at the same time within the satellite footprint.

For U.S. geostationary satellites there are presently 35 000 users transmitting over 750 000 messages per day The number of messages far exceeds the channel capacity and the channel loading is influenced by reporting requirements of the data collecting organizations. It was assumed for the sake of this analysis that the channels are fully loaded all the time.

5.2 Technical characteristics of the mobile services

5.2.1 ITU-R Documentation

The technical characteristics of mobile systems can be found in the following Recommendations and Reports ITU-R:

Recommendation ITU-R M.1808 – Technical and operational characteristics of conventional and trunked land mobile systems operating in the mobile service allocations below 869 MHz to be used in sharing studies

Recommendation ITU-R M.1823 – Technical and operational characteristics of digital cellular land mobile systems for use in sharing studies

Report ITU-R M.2014 – Digital land mobile systems for dispatch traffic

NOTE – This Report is currently under discussion in WP 5A for review and revision in relation to the work in response to WRC-15 agenda item 1.3.

Recommendation ITU-R F.758 – System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference

Report ITU-R M.319 – Characteristics of equipment and principles governing the assignment of frequency channels between 25 and 1 000 MHz for land mobile services

Recommendation ITU-R M.478 – Technical characteristics of equipment and principles governing the allocation of frequency channels between 25 and 3 000 MHz for the FM land mobile service

5.2.2 Deployment of mobile services within CEPT Administrations

Table 5-4 provides an overview of the various documents addressing the issue of the frequency bands around 400 MHz.

TABLE 5-4

Overview of CEPT documentation regarding the deployment of mobile systems around 400 MHz

Frequency plan under Recommendation TR 25-08 CEPT	29.9 MHz duplex – 380 to 389.9 MHz band (uplink) and 390 to 399.9 MHz (downlink); – Bands 410-420 MHz (uplink) and 420-430 MHz (downlink); – Bands 450-460 MHz (uplink) and 460-470 MHz (downlink). 14 MHz simplex: band 389.9 to 390 MHz, 406.1-410 MHz and 440-450 MHz.
Other provisions	The 400 MHz band is identified by Decision (08) 05 ECC dated June 27 2008 for the harmonized implementation of digital systems for PPDR applications. This decision provides that Member States must make available the necessary frequencies: – For the implementation of digital narrow-band (less than 25 kHz channel) for PPDR applications in the band 380-385 MHz duplex / 390-395 MHz; – The implementation of broadband digital systems (channel equal or greater than 25 kHz) for applications in the PPDR band 380-470 MHz. The bands 406.1-430 MHz and 440-470 MHz are identified by Decision (06) 06 ECC dated 7 July 2006, in which CEPT Member States are encouraged to make available, according to market demand, the amount of spectrum required for digital PMR systems to narrow-band (channels equal or less than 25 kHz).

To be more specific for frequencies between 390 and 420 MHz (scope of WRC-15 agenda item 9.1.1), the following picture, which is valid for CEPT since this frequency arrangement is based upon CEPT reports/decisions/recommendations. Annex 2 provides detailed information about the usage of frequency bands between 390 and 420 MHz within CEPT countries.

5.2.3 Deployment of mobile services within Canada

To support the technical and strategic planning functions for spectrum in Canada, a study of current spectrum assignments was undertaken in 2010. In essence, the study was a snapshot of the frequencies assigned in Canada as of August 2010. With respect to land mobile systems, Chapter 3 of the inventory provides some notes on the use of the 406.1-430 MHz and 450-470 MHz range (referred to as the UHF band). Figures 5-1 and 5-2 are extracted from the study. They indicate the number of licenses and frequency assignments across Canada as of 2010. The study also suggests that there have been a relatively stable number of land mobile frequency assignments and licenses in the UHF band in Canada over a 12-year period. For the full study, please see: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10023.html.

FIGURE 5-1

UHF Regional distribution

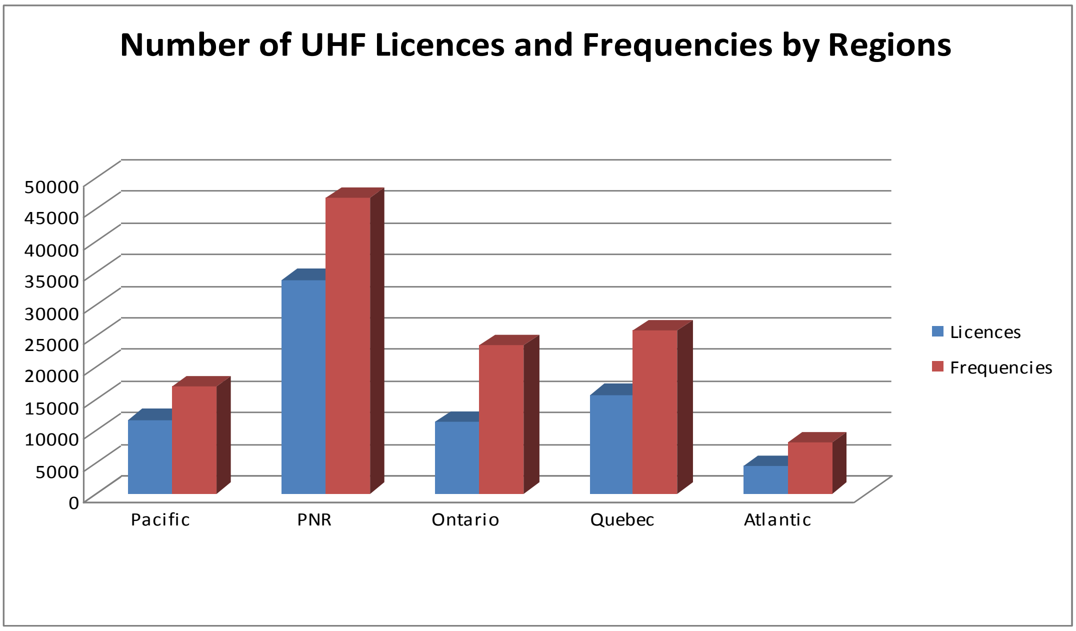
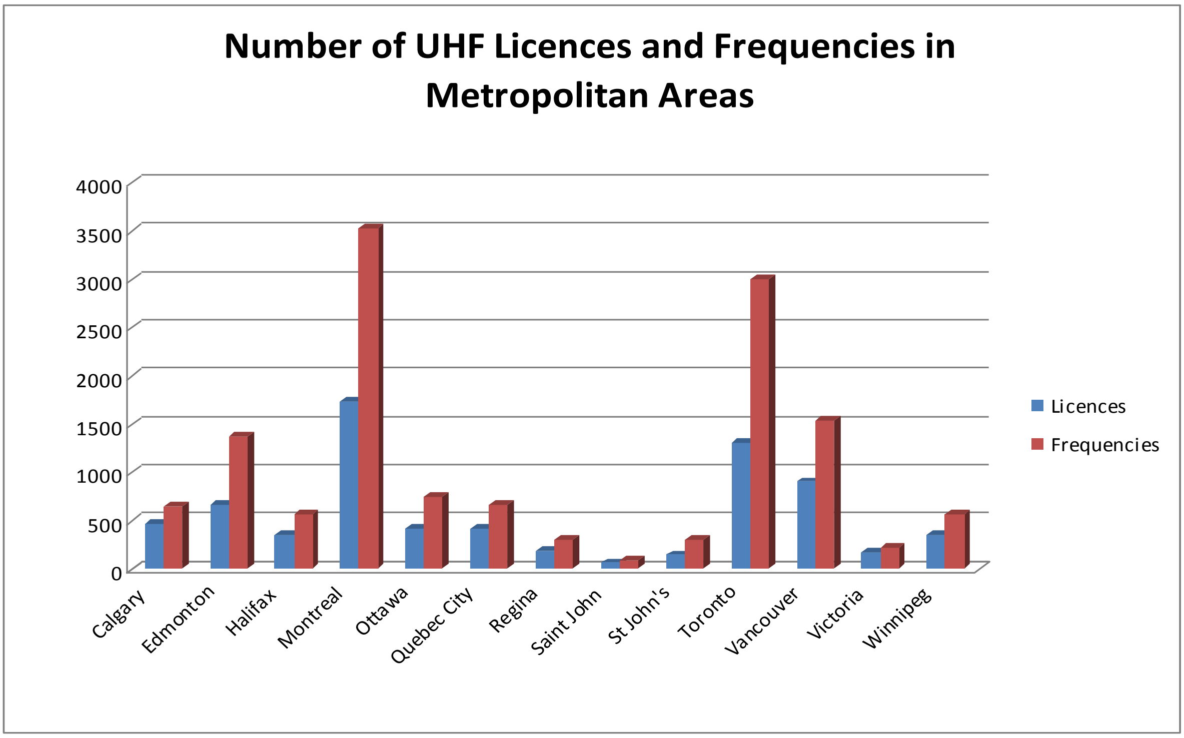


FIGURE 5-2

UHF Major metropolitan distribution



As indicated in the spectrum inventory, in Canada, land mobile systems deployed in the UHF band are used to provide push-to-talk voice communications and low-speed data. Conventional, trunked systems as well as one-way and two-way paging systems are deployed in the UHF band. These systems are licensed on a first-come, first-served basis.

In the 406.1-420 MHz band, land mobile systems are used for public protection at all government levels (federal, provincial and municipal), commercial entities (e.g. taxi and delivery companies, industrial users) and commercial communications providers (e.g. trunking services). However, the major licensees in the 406.1-420 MHz band are assigned to commercial entities.

Eighty percent (80%) of Canada's population is within 120 km of the Canada – United States border. Deployment of stations within the 406.1-420 MHz band also follows this trend (i.e. there is dense deployment of stations within 120 km of the border). However, since this is spread-out longitudinally and Canada's population in large population centres is much less than those in some of the CEPT countries, deployment density for land mobile systems in Canada is less than the density for land mobile networks in CEPT countries.

In Canada, this band is also popular for natural resource users (e.g. forestry, oil and gas) since the band has favourable propagation characteristics, equipment is cost effective and suitable for a variety of applications such as dispatching and diverting personnel or work vehicles, coordinating the activities of workers and machines on location, or remotely monitoring and controlling equipment. Consequently, there is also a dense deployment of stations in areas that draw upon Canada's natural resources. (These areas, with dense deployment of stations to support natural resource users are generally in the provinces of British Columbia, Alberta, Ontario, Quebec, and New Brunswick).

Tables 5-5 and 5-6 provide information on the range of technical characteristics of Canadian land mobile systems operating in the band 406.1-420 MHz. Typical values are shown in parenthesis. Systems in this band are predominately analogue, using channels that are 12.5 kHz or 25 kHz wide. In spectrum congested areas, newer systems being deployed tend to be trending towards digital technologies.

TABLE 5-5

Base station characteristics of systems in Canada in the band 406.1-420 MHz

Output power (W)	1 to 30 (7)
Antenna gain (dBd)	0 to 15 (10)
ERP (dBW)	0 to 28 (16)
Necessary bandwidth (kHz)	11/16

NOTE – Typical values are shown in parenthesis.

TABLE 5-6

Mobile station characteristics of systems in Canada in the band 406.1-420 MHz

Output power (W)	1 to 30 (H: 5, V: 30)
Antenna gain (dBd)	0
ERP (dBW)	0 to 15 (H: 7, V: 15)
Necessary bandwidth (kHz)	11 / 16

NOTE – Typical values are shown in parenthesis. "H" represents the value for handheld mobile stations and "V" represents the value for vehicular mobile stations.

5.2.4 Unwanted levels according to ITU-R Recommendations and ETSI Standards for land mobile systems

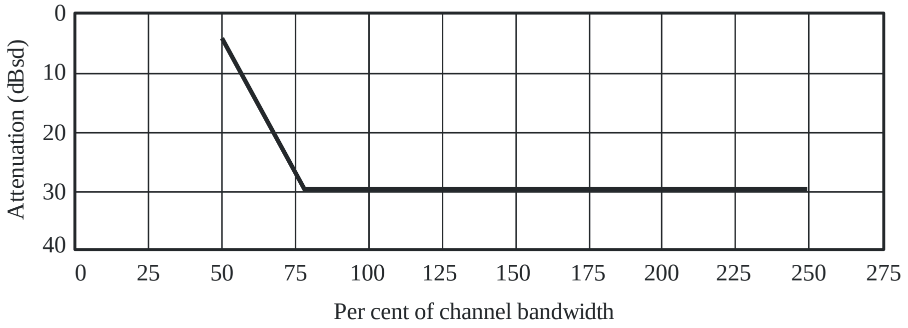
In addition to the filtering pattern provided by the various space segments, it is necessary to check that the unwanted emission limits of the mobile service do not provide excessive levels within the MSS band.

According to Recommendation ITU-R SM.1541-4, the out-of-band (OoB) domain emission limits are as follows for land mobile systems. It is indicated that the generic mask, as shown in Fig. 5-3, which addresses all of the systems in the land mobile service, needs to be further studied. This service has indicated its preference to use adjacent band (or channel) power ratio limits rather than limit curves as it facilitates frequency coordination and system planning.

It is recalled that the normal separation between the centre frequency and the spurious domain boundary is 250% of the necessary bandwidth. According to Recommendation ITU-R SM.1539-1, this boundary may vary depending on various parameters.

FIGURE 5-3

OoB mask for 12.5 kHz channel bandwidth land mobile systems as in SM.1541-1 for land mobile



SM.1541-36

The following shows that current digital systems have much better performance in terms of OoB than the recommended levels as mentioned in Recommendation ITU-R SM.1541.

1) According to Recommendation ITU-R SM.329-12, the spurious emission limits equals –36 dBm for 30 MHz ≤ f < 1 GHz (category B adopted in Europe, table 3) for land mobile systems. This is an absolute value which is widely adopted in Europe and usually, the real value is lower.

2) For category A systems, the attenuation (dB) supplied to the antenna transmission line is: 43 + 10 log P, or 70 dBc, whichever is less stringent, with P = mean power (W) at the antenna transmission line, in accordance with RR No. **1.158**.

Therefore, taking into account that typical power values for base stations and hand held terminals (TETRA and TETRAPOL systems) respectively vary between 30 W and 1 W, the corresponding spurious levels are –13 dBm, which is obviously less stringent than the limit of –36 dBm valid for category B.

5.2.4.1 dBc and dBsd Considerations

In Recommendation ITU-R SM.1541, dBsd refers to decibels relative to the maximum value of power spectral density (psd) within the necessary bandwidth. The maximum value of psd of a random signal is found by determining the mean power in the reference bandwidth when that reference bandwidth is positioned in frequency such that the result is maximized.

In Recommendation ITU-R SM.1541, dBc refers to decibels relative to the unmodulated carrier power of the emission. In the cases of systems which do not have a carrier (which is now the case of almost all digital modulation waveforms); the carrier is not accessible for measurement. For those systems, which have suppressed carrier modulated waveforms, the reference level equivalent to dBc is dB relative to the mean power *P*.

In the following, as the systems considered have all suppressed carriers in their waveforms, the dBc increment is a measure of relative signal strength level below carrier: it shall refer to the level measured at the nominal centre frequency. For instance, 0 dBc refers to the transmit power during normal operation measured at the nominal centre frequency.

Therefore, for these specific systems, we may consider that the dBsd and dBc units are equivalent.

5.2.4.2 TETRA Characteristics in the unwanted domain

Concerning the TETRA devices, according to ETSI standards EN 300 392-2 or EN 300 394-1, we have the following requirements for different classes (the emission bandwidth equals 25 kHz).

The maximum allowed power for each spurious emission shall be less than –36 dBm measured in a 100 kHz bandwidth in the frequency range 9 kHz to 1 GHz.

Wide-band noise levels are shown in Table 5-7 and are valid for a filter of 25 kHz bandwidth.

TABLE 5-7

TETRA noise levels in the unwanted domain

Frequency offset	Maximum level for power levels below 1 W	Maximum level for power levels between 1.8 and 3 W	Maximum level for power levels above 5.6 W
25 kHz	–55 dBc	–60 dBc	–60 dBc
50 kHz	–55 dBc	–60 dBc	–60 dBc
75 kHz	–70 dBc	–70 dBc	–70 dBc
100 to 250 kHz	–75 dBc	–78 dBc	–80 dBc
250 to 500 kHz	–80 dBc	–83 dBc	–85 dBc
500 kHz to 5 MHz	–80 dBc	–85 dBc	–90 dBc

All these relative levels in the table before are expressed in dBc (see previous definitions) and are obviously more stringent than the attenuations as mentioned in Recommendation ITU-R SM.1541-4.

It is to be noted that the frequency offsets above 75 kHz are outside the OoB domain and are within the spurious domain. Therefore, starting at a frequency offset of 75 kHz, we can note that all the attenuations in dBc correspond to spurious emissions in relative, not in an absolute way as mentioned before. Table 5-8 makes the conversion into absolute spurious limits for specific values of output powers and frequency offsets.

TABLE 5-8

TETRA spurious absolute levels for a 25 KHz bandwidth

Frequency offset	**Maximum spurious levels for power levels of 1 W**	**Maximum spurious levels for power levels of 3 W**	**Maximum spurious levels for power levels of 5.6 W**
75 kHz	–40 dBm	–35.2 dBm	–32.5 dBm
100 to 250 kHz	–45 dBm	–43.2 dBm	–42.5 dBm
250 to 500 kHz	–50 dBm	–48.2 dBm	–47.5 dBm
500 kHz to 5 MHz	–50 dBm	–50.2 dBm	–52.5 dBm

We can see that, in some cases, the spurious absolute value can be higher than the –36 dBm for a filter of 100 kHz (which is equivalent to –42 dBm for 25 kHz) when close to the lower boundary of the spurious domain. However, for the rest of the spurious domain, the levels are lower than the already specified –36 dBm/100 kHz.

5.2.4.3 TETRAPOL characteristics in the unwanted domain

TETRA is an acknowledged European standard, whereas TETRAPOL has not yet been accepted as an ETSI standard, but it offers compliance with European ETSI standard ETS 300 113.

The channel spacing is 12.5 kHz and the modulation method used is GMSK (Gaussian Minimum Shift Keying), which provides good co-existence with existing terrestrial systems and low out-of-band emissions. This modulation method is also used for GSM and has the advantage that simple and relatively cheap transmitters can be used and out-of-band emissions can also be greatly reduced.

In terms of spurious emissions, the maximum allowed power for each spurious emission shall be less than –36 dBm measured in a 100 kHz bandwidth in the frequency range 9 kHz to 1 GHz. The unwanted limits in the spurious domain are the same for both, ETSI standard and Recommendation ITU-R SM.329-12.

Concerning the wide-band noise levels, it appears that ETSI standard EN 300 113-1 addresses only unwanted limits in the spurious domain. However, as shown in Table 5-9, measurements provided by the TETRAPOL forum have provided additional information regarding OoB noise levels in the unwanted domain.

TABLE 5-9

TETRAPOL noise levels in the unwanted domain

Frequency offset	**Maximum level**
12.5 kHz	–60 dBc
25 kHz	–70 dBc

Concerning the out of band domain, TETRAPOL transmitters also provide limits that are more stringent than those contained within Recommendation ITU-R SM.1541-4. For TETRAPOL, no characteristics are available far from the carrier, but it is expected to get lower spurious levels than –36 dBm/100 kHz.

5.3 Technical characteristics of the meteorological-aids service

Radiosondes are meteorological aids devices which are borne aloft by balloons or propelled by rockets. They are also dropped from aircraft. Their operating frequency range extends from 400.15 to 406.00 MHz. The general characteristics of these systems can be found in Recommendation ITU-R RS.1165-2. For some digitally synthesized systems, the frequency is tuned by a switch starting with lowest centre frequency at 400.250 MHz and there are 16 centre frequencies in increments of 0.375 MHz ending at 405.875 MHz.

The radiosondes are available in analogue and digital version. Specifications are shown in Table 5-10.

TABLE 5-10

Radiocommunication characteristics of 403 MHz band radiosonde transmitters

Parameter	Analogue	Digital
Tuning range	400.15 to 406 MHz	400.15 to 406 MHz
Transmitter power	–6 dBW	–6 dBW
Maximum antenna gain	2 dBi	2 dBi
Bandwidth	20 kHz (manufacturer's specification)	16.8 kHz
Emission	F9D	16K8F1D
Bit rate	1.2 or 2.4 kbps	4.8 kbps
Coding	None	Convolutional
Modulation	FM/FSK	GFSK
Modulating signal	7-10 kHz	NA
Deviation	45 ± 15 kHz	NA
Bandwidth (Carson's Rule)	140 kHz	NA
Occupied bandwidth (–40 dBc)	200 kHz	200 kHz
Spurious emissions	< –43 dB	< –48 dB
Frequency drift	± 800 kHz	± 20 kHz

Due to technology advances, the use of analogue radiosondes is expected to decrease and eventually cease as stocks are depleted.

Flights of radiosondes are synoptic and non-synoptic. Per agreement with the World Meteorological Organization, synoptic flights are launched simultaneously worldwide starting at approximately 1115 and 2315 UTC and lasting 90 to 120 minutes or at alternate times spaced 6 hours apart. Non-synoptic flights are unscheduled and uncoordinated with each other.

5.4 Technical characteristics of the mobile satellite service

Recommendation ITU-R M.2046 provides the Characteristics and protection criteria for non-geostationary mobile-satellite service systems operating in the 399.9-400.05 MHz frequency band (Earth-to-space). It can be noted that the characteristics of the MSS terminals in this band are similar to the PCM/FM data collection platforms as in Table 5-1.

6 Computation of simulations, results and assessment analysis

Interference to the satellite receiver will be assessed by comparison of the aggregate power density of the potential interference sources to the maximum permissible level of interference.

The received interference level from a single source varies with the SARP antenna gain and propagation distance. For this analysis a mean value of the received signal is determined by integration over several satellite antenna angles. This provides a mean received level of an interference source.

The mean level of interference power for a single transmitter is multiplied by the estimated number of transmitters and divided by the operational bandwidth of the potential interfering system. This provides an aggregate power density to be compared with the maximum permissible level of interference power density. The margin between these values is used to evaluate the percentage of the maximum interference level of the interference to which the sources contribute. However, each power density is applied across an operational frequency range. The total impact of interference should consider the full applied range of the maximum power density level.

6.1 Assessment of interference from EESS (Earth-to-space) service (Data Collection Platforms DCP) operating in the 401 to 403 MHz range

A wide-band and a narrow-band criterion are specified for the search and rescue receivers. The wide-band criteria will be addressed first.

Data collection platforms are located worldwide and each measures some parameter of the environment or the location of an animal under study and transmits that data to a satellite. The ARGOS system uses low Earth orbiting satellites and transmits data at random with a small transmitter which could be attached to an animal. The GSO systems use larger stationary platforms often with a high gain antenna and transmits data on a schedule to the geostationary satellite. Table 6-1A shows the worldwide deployment of GSO satellites and the approximate regions covered by each. Additionally it shows the number of simultaneous transmitters estimated for each system.

TABLE 6-1A

Service areas and platform populations for each GSO spacecraft

Satellite	Range latitude	Range longitude	Number of platforms transmitting simultaneously*
GOES East	56 N to 56 S	131 W to 5 E	196
GOES West	56 N to 56 S	191 W to 79 W	196
METEOSAT 1.5 kHz channels	56 N to 56 S	56 W to 56 E	144
METEOSAT 3 kHz channels	56 N to 56 S	56 W to 56 E	49
Elektro-L	56 N to 56 S	20 E to 132 E	300
MTSAT	56 N to 56 S	130 E to 180 E	160

* The number channels shown in this column are the numbers used in a simulation. They must fit evenly in a rectangle so for example the population of 200 channels for GOES is 14 by 14 platforms.

Mobile international platforms transmit to geostationary satellites, but may move into the footprint of different satellites.

6.1.1 Low Earth orbit satellites

6.1.1.1 Interference criteria

The two protection criteria are presented in § 3 above. The first referred to as the narrow-band criterion is based upon spurious emissions of transmitters falling into the 406.0 to 406.1 MHz band where it could potentially capture the receiver processor reducing the processing capacity of the receiver system. The second criterion, which is referred to as wide-band noise interference increases the noise floor of the receiver and thus, reduces the C/N. In this case weaker signals cannot be detected and processed.

It is the wide-band noise interference that should be applied to out-of-band emissions. These levels are provided in § 3.2. The value comes from the susceptibility mask measured on the SARP instrument, which has been identified as the most vulnerable SAR instrument.

Table 3-6 provides spectral power flux density (spfd) levels in specific bands for the SARP in the wide-band emission mode. For the 401 to 403 MHz range, where the data collection systems operate, the receiver sensitivity is −131.6 dB (W/m^2 ·Hz). This is identified as the "maximum broadband level." This level is based upon *recommends* 1 of Recommendation ITU-R M.1478-3, which states, "that analysis to determine the effect upon Sarsat SARP instruments by systems using adjacent frequency bands should be based upon a maximum acceptable spfd at the Sarsat antenna of –198.6 dB (W/m^2 ·Hz). Comparison of the in-band level and out-of-band level indicated that the SARP instrument had a sensitivity level in the 401 to 405 MHz band that is 67 dB above the in-band sensitivity.

6.1.1.2 Assessment of EESS (Earth-to-space) service (data collection platform) interference to low Earth orbit satellite

Platforms for low Earth orbit (LEO) systems have linear polarization while the space stations and GOES data collection platforms have circular polarization. The search and rescue satellite receivers also have circular polarization. When interference from the data collection platform used with LEO satellites is the being analysed, an additional 3 dB polarization loss is considered in the interference calculations.

The received interference power for each angle is calculated as the antenna gain and the range from the satellite to the platform changes. Table 6-1B presents the results for various off-nadir angles from the satellite. The gains are provided in Recommendation ITU-R M.1478-3, and are valid for the EESS missions controlled by the European Meteorological Satellite agency EUMETSAT and the U.S. National Oceanic and Atmospheric Administration (NOAA).

The initial step to assess the amount of interference power is to determine a mean value of received interference accounting for antenna gain and range from Earth to space. An integration was performed for the area in view of the satellite antenna. Across the circular area the antenna gain and range from the satellite to the earth is different. To determine a mean value of interference power, the circular area is divided into concentric rings. Each ring has a different antenna gain, range from satellite to earth, and area. The received interference power is multiplied by the portion of the area of the ring to the total area of the circle. The proportional powers are added to determine the mean interference power. The calculation is shown in Table 6-1B where each line provides the calculation for one of the concentric rings. The summation provides the mean received power at the SARP receiver from DCS platforms.

TABLE 6-1B

Calculated average received interference power for satellite off-nadir angles for low data rate platforms

Off-Nadir angle	Range	Receiver gain	Polarization Loss (dB)	e.i.r.p. (dBW)	Received signal (dBW)	Portion of area	Proportional power (Watts)	Mean interference power (Watts)
0.01	850	–3.96	–3	4.77	–146.90	1.19E-13	2.04E-15	2.43E-28
5	854	–3.8	–3	4.77	–146.78	1.50E-05	2.10E-15	3.16E-20
13	875	–3.08	–3	4.77	–146.28	2.64E-04	2.36E-15	6.22E-19
22	927	–2.24	–3	4.77	–145.94	1.25E-03	2.55E-15	3.19E-18
31	1017	–1.33	–3	4.77	–145.83	3.72E-03	2.61E-15	9.73E-18
39	1146	–0.17	–3	4.77	–145.71	8.50E-03	2.68E-15	2.28E-17
47	1361	–1.24	–3	4.77	–148.27	2.25E-02	1.49E-15	3.35E-17
54	1702	2.62	–3	4.77	–146.35	6.02E-02	2.32E-15	1.39E-16
59	2208	3.54	–3	4.77	–147.70	1.57E-01	1.70E-15	2.67E-16
61.93	3350	3.85	–3	4.77	–151.01	7.47E-01	7.93E-16	5.92E-16
							Mean power	1.07E-15 W

The mean interference power received from a single low data rate platform power is –149.71 dBW (1.07E-15 W)(. Similar calculations for other platforms provide the following results. For high data rate, the value is –157.88 dBW. For the GOES Regional platforms, which do not have a polarization mismatch, the value is –138.28 dBW, and for GOES International platforms the value is –143.06 dBW. These values will be used in later calculations.

The second consideration is the interference threshold value. From Table 3-6 the maximum permissible level of interference for the 401 to 405 MHz range is –143.1 dB (W/Hz). The third consideration is the number of stations that will be contributing to the interference at the same time. From § 5.1 the highest mean number of low data rate platforms is 18.5 and for the high data rate platforms, it is 6. The number of international platforms was chosen at 2. The worldwide deployment of regional platforms was represented in a scenario and evaluated with a dynamic simulation.

The results of combining these parameters and calculating the percentage of interference power are shown in Table 6-2. The purpose of the calculations in this table is to determine the percentage of the interference power threshold that is contributed by the data collection platforms. The aggregate interference power from multiple platforms is calculated and the power density determined by the bandwidth of the receiver channel. The interference power density is derived from the following equation.

Density dB(W/Hz) = Mean interference power dBW – 10*log(bandwidth) +10*log(number for interferers)

$$-147.71 \text{ dBW} - 10*\log(80\,000 \text{ Hz}) + 10*\log(18.5) = -186.07 \text{ dB(W/Hz)}$$

The margin is the difference between the calculated power density and threshold power density.

The percentage is determined from the margin as follows:

$$\text{Percent total} = 100 * 10^{(\text{margin}/10)} = 10^{(-42.97/10)} = 0.005\%$$

This calculation applies to all interference margin tables.

For the regional DCS platforms, where a dynamic simulation was used, the value in the column labelled "Mean interference power" is the maximum aggregate power from the platforms within view of the satellite as determined by the dynamic simulation. For these calculations the number of simultaneous transmitters in view of the satellite is variable and determined by the simulation, so the word "scenario" is placed in this column. This applies to all tables where the word "scenario" appears.

TABLE 6-2

Calculation of percentage of interference to the LEO SAR receiver from Data Collection platforms

System	Mean interference power (dBW)	Bandwidth (Hz)	Number of simultaneous transmitters in view	Density dB (W/Hz)	Threshold dB (W/Hz)	Margin (dB)	Percent total
Low Rate Data	–149.71	80 000	18.5	–186.07	–143.10	–42.97	0.005%
High Rate Data	–145.89	80 000	6.0	–187.14	–143.10	–44.04	0.004%
Regional	119	300 000	scenario	–173.39	–143.10	–30.29	0. 0935%
International	–133.86	100 000	2.0	–180.85	–143.10	–37.75	0.017%
Total							0.1195%

6.1.1.3 Results of EESS (Earth-to-space) service (data collection platform) interference to low Earth orbiting satellites

From the above calculations it can be seen that the interference contribution to low Earth orbiting search and rescue receivers is only a fractional percentage. The total percentage is the summation of the individual percentages which implies simultaneous operation. The total bandwidth covered by these systems is 560 kHz while the range over which the interference threshold density is applied is 4 MHz. If the total power in the full 4 MHz range was considered, the contribution of power from the data collection system would be 0.1117% *(0.560/4) = 0.01564% of the threshold power in the 4-MHz segment.

6.1.2 Geostationary orbiting satellites (GEO)

Interference was assessed for various geostationary satellite systems. GOES SARR represents the current U.S. operational systems. GOES-R represents the future U.S. operational systems. Meteosat Second Generation (MSG) GEOSAR represents the current European systems. The GOES and MSG not only have different characteristics but their fields-of-view are unchanging and cover different parts of the globe with different populations of potential interferers. In § 3.3 the MSG was identified as having the worst case sensitivity mask and thus will be used in the following analysis.

6.1.2.1 Interference criteria

One of the primary characteristic of the satellite is the system noise temperature, which determines the maximum acceptable interference power. MSG GEOSAR has a noise temperature of 600 K and an interference threshold of –217.15 dB (W/Hz). In the band from 401 to 405 MHz the sensitivity values is –177.15 dB (W/Hz) for the MSG GEOSAR.

6.1.2.2 Assessment of EESS (Earth-to-space) service (data collection platform) interference to geostationary orbit satellites (GEO)

Additional considerations in the calculation of the average interference level from a single platform are the satellite antenna gain and the coupling loss between the antenna and the receiver.

The geostationary satellites have a wider field-of-view than the LEO satellites. The ARGOS low and high data rate platforms transmit at random and not necessarily when the LEO satellite is in view. The estimated population of transmitting platforms used for the GSO systems is presented in Table 6-1B above.

The calculation results are contained in Table 6-3.

TABLE 6-3

Calculation of percentage of interference contributed to the MSG GEOSAR receiver from Data Collection platforms

System	Mean Interference Power (dBW)	Bandwidth (Hz)	Number of simultaneous transmitters in view	Density dB (W/Hz)	Threshold dB (W/Hz)	Margin (dB)	Percent total
Low Rate Data	–168.31	80000	291	–192.70	–177.15	–15.55	2.786%
High Rate Data	–166.09	80000	22	–201.70	–177.15	–24.55	0.351%
Meteosat	–149.0	300000	Scenario in Table 6-1A above	–199.77	–177.15	–22.62	0.547%
International	–157.06	100000	11	–196.65	–177.15	–19.50	1.123%
Total							4.807%

6.1.2.3 Results of EESS (Earth-to-space) service (data collection platform) interference to geostationary orbiting satellites (GEO)

The total interference exceeds 4.807% of the interference threshold based upon power density and is dominated by the GOES domestic data platforms. For GOES SAR the maximum load at the beginning of the hour could last up to 12.5 minutes, considering 30,000 platforms sending messages in 10 second slots over 400 channels. This is approximately 20% of the time.

The total bandwidth covered by these systems is 560 kHz while the range over which the interference threshold density is applied is 4 MHz. If the total power in the full 4 MHz range were considered the contribution of power from the data collection system would only be 4.807% *(0.560/4) = 0.673% of the threshold power in the 4 MHz segment for the worst case of the MSG GEOSAR system.

It should be noted that the assessment for the MSG GEOSAR is based upon the load of the GOES system traffic. The results would be different if a different traffic load model is used.

6.1.3 Medium altitude orbiting satellites (MEO)

6.1.3.1 Galileo

6.1.3.1.1 Interference criteria

The Medium Earth Orbiting (MEO) satellites have a different interference threshold value from the LEO satellite. From Table 3-10 (as revised), the maximum permissible level of interference in the 390 to 405.05 MHz band is –157.52 dB (W/Hz).

6.1.3.1.2 Assessment of EESS (Earth-to-space) service (data collection platform) interference

The values in the mean interference power column were derived from integrations similar to Table 6-1. The spacecraft antenna gain is 13 dBi. Polarization mismatch loss was applied for the cases of the low data-rate and high data-rate.

The number of simultaneous interferers was calculated by accounting for the field-of-view of the MEO to the field-of-view of the LEO satellite in the case of the low and high data-rate platforms. The number of simultaneous regional platforms in view was determined automatically by the simulation. The results of the calculation of the percentage of interference to the MEO SAR receiver from data collection platforms are listed in Table 6-4.

TABLE 6-4

Assessment of percentage of interference contributed to the MEO SAR receiver (Galileo) from data collection platforms

System	Mean Interference Power dBW	Bandwidth (Hz)	Number of simultaneous transmitters	Spectral power density of interference dB(W/Hz)	Interference threshold dB(W/Hz)	Margin dB	Percent total
Low Data Rate	–155.09	80 000	214	–180.82	–157.5	–23.32	0.466%
High Data Rate	–157.88	80 000	69	–188.52	–157.5	–31.02	0.079%
Regional	–122.38	300 000	Scenario	–177.15	–157.5	–19.68	1.084%
International	–143.06	100 000	8	–184.03	–157.5	–26.53	0.222%
Total							1.85%

6.1.3.1.3 Analysis of results

The results show that the MEO satellite receiver on Galileo spacecraft receives less of a percentage of interference power than the LEO SARP receiver. The total bandwidth covered by these systems is 560 kHz while the range over which the interference threshold density is applied is 15.05 MHz. If the total power in the full 15.05 MHz range were considered the contribution of power from the data collection system would only be 1.84% *(0.560/15.05) = 0.068% of the threshold power in the 15.05 MHz segment for the worst case of the MSG GEOSAR system.

The sum of the percentages in the Table 6-4 implies that all the number of data collection platforms are operating at the same time within the satellite footprint. This is an unlikely, worst case assumption.

6.1.3.2 GLONASS

6.1.3.2.1 Interference criteria

Interference threshold values for the Cospas-Sarsat receivers on GLONASS spacecraft for interference level analysis are presented in Table 3-11.

6.1.3.2.2 Assessment of EESS (Earth-to-space) service (data collection platform) interference

Unlike the mask of the maximum interference level for Galileo, the mask of the maximum interference level for GLONASS has two different values in the frequency band 401-403 MHz. These values are –147.3 dBW/Hz in the band 401-402.05 MHz and –177.3 dBW/Hz in the band 402.05-403 MHz. Thus, it is reasonable to consider the impact of the data collection platforms on Cospas-Sarsat receivers in these two frequency bands separately.

The results of the calculation of interference to the MEO SAR receiver on GLONASS spacecraft in 401-402.05 MHz frequency band from data collection platforms are presented in Table 6-5. Antenna gain for this receiver is 12 dBi. According to Table 5-3, only LEO data collection platforms operate in this frequency band.

TABLE 6-5

Assessment of percentage of interference contributed to the MEO SAR receiver (GLONASS) from data collection platforms operating in the frequency band 401-402.05 MHz

System	Mean Interference Power dBW	Bandwidth (Hz)	Number of simultaneous transmitters	Spectral power density of interference dB(W/Hz)	Interference threshold dB(W/Hz)	Margin dB	Percent total
Low Data Rate	–158.144	80 000	180	–184,62	–147,3	–37,32	0,018%
High Data Rate	–155.925	80 000	58	–187,32	–147,3	–40,02	0,010%
Total							0,028%

The results of the calculation of interference in 402.05-403 MHz frequency band are presented in Table 6-6. In this frequency band only GSO data collection platforms operate. The number of simultaneous interferers was determined by the simulation.

The GLONASS receiver has two sensitivity values applied over the range that the data collection platforms operate. These are shown in Table 6-5A below.

TABLE 6-5A

Interference Threshold values for GLONASS and DCS systems in frequency range

Range	Threshold Power Density	Threshold Power in 300 kHz	DCS satellites in frequency range
401.7 to 402.05 MHz	–147.3 dBW/Hz	–92.5 dBW	GOES East GOES West Elektro-L
402.05 to 402.4 MHz	–177.3 dBW/Hz	–122.5 dBW	Meteosat MTSAT

TABLE 6-6

Assessment of percentage of interference contributed to the MEO SAR receiver (GLONASS) from data collection platforms operating in the frequency band 402.05-403 MHz

System	Mean Interference Power (dBW)	Bandwidth (Hz)	Number of simultaneous transmitters	Spectral power density of interference dB(W/Hz)	Interference threshold dB(W/Hz)	Margin (dB)	Percent total
401.7 to 402.05 MHz							
Regional	–122.15	300 000	Scenario	–176.92	–147.3	–29.62	0.109%
International	–143.785	50 000	4	–184.754	–147.3	–37.453	0.018
Total							0.127%
402.05 to 402.4 MHz							
Regional	–122.83	300 000	Scenario	–177.60	–177.3	–0.30	93.30%
International	–143.785	50 000	4	–184.75	–177.3	–7.454	0.180%
Total							93.48%

The results in Table 6-6 apply over a 350 000 Hz bandwidth. The sensitivity of –147.3 dBW/Hz applies over the 390 to 402.5 frequency range. Adjusting the percentage for the entire applicable range of 12.5 MHz results in the following 0.127*(0.35/12.5) = 0.00356%. Similarly the sensitivity of –177.3 dBW/Hz is applied over the range from 402.05 to 405.05 MHz or 3 MHz so adjusting the interference percentage 93.48*(0.35/3) = 10.91%.

Observation of the computerized scenario shows that the interference periods within 3 dB of the interference threshold occur when the MEO satellite is within 25 degrees of the GSO satellite location. These periods last from 1.5 to 2.25 hours per occurrence.

6.1.3.2.3 Analysis of results of EESS (Earth-to-space) service (data collection platform) interference to medium Earth orbiting satellites (GLONASS)

The results show that the MEO satellite receiver on GLONASS spacecraft received a higher percentage of interference than the Galileo receiver. The percent of total interference is 0.127% in the frequency band 401-402.05 MHz and 93.48% in the frequency band 402.05-403 MHz. This is caused by a more strict maximum interference level mask in the frequency band 402.05-405.05 MHz for GLONASS receiver as compared with Galileo receiver.

The results in Table 6-6 apply over a 350 000 Hz bandwidth. The sensitivity of –147.3 dBW/Hz applies over the 390 to 402.05 frequency range. Adjusting the percentage for the entire applicable range of 12.05 MHz results in the following 0.127*(0.35/12.05) = 0.00368%. Similarly the sensitivity of –177.3 dBW/Hz is applied over the range from 402.05 to 405.05 MHz or 3 MHz so adjusting the interference percentage 93.48*(0.35/3) = 10.91%.

The sum of the percentages in the table implies that all of data collection platforms (High rate, Low Rate, Regional and International) are operating at the same time within the satellite footprint. This is a worst case assumption.

6.1.4 Application of the narrow-band criterion

The narrow-band criteria for each satellite system are presented in Tables 3-1, 3-2, 3-3, 3-4 and 3-5. It is presented as a power level in dBm. It represents the maximum level for a single interfering transmitter. The specified spurious emissions level for data collection platform is significantly lower than the interference threshold.

Table 6-7 shows the comparison of the sensitivity levels for four cases, one each for the LEO and GEO orbits and two for MEO orbits, compared to the direct emission levels from the data collection platforms.

TABLE 6-7

Narrow-band margins

System	Maximum permissible level of in-band interference from tables	Maximum permissible level of in-band interference	Calculated mean interference power	Margin between received power and narrow-band threshold
SARP on LEO satellite	–147 dBm (Table 3-1)	–177 dBW		
Low Data Rate			–149.71 dBW	27.29 dB
High Data Rate			–145.89 dBW	31.11 dB
Regional			–129.12 dBW	47.88 dB
International			–133.86 dBW	43.14 dB
SARR on MSG GEOSAR	–147 dBm (Table 3-2)	–177 dBW		
Low Data Rate			–168.31 dBW	8.69 dB
High Data Rate			–166.09 dBW	10.91 dB
Regional			–152.32 dBW	24.68 dB
International			–147.06 dBW	29.94 dB
SARR on MEO satellite (Galileo)	–136.8 dBm (Table 3-4)	–166.8 dBW		
Low Data Rate			–155.09 dBW	11.71 dB
High Data Rate			–157.88 dBW	8.92 dB
Regional			–138.28 dBW	28.52 dB
International			–143.06 dBW	23.74 dB
SARR on MEO satellite (GLONASS)	–147.1 dBm (Table 3-5)	–177.1 dBW		
Low Data Rate			–158.14 dBW	18.96 dB
High Data Rate			–155.92 dBW	21.18 dB
Regional			–144.80 dBW	32.3 dB
International			–143.78 dBW	33.32 dB

The margin values in the right hand column show the minimum spurious rejection that a transmitter would need to not exceed the narrow-band interference threshold. If that spurious rejection were at least 50 dB then there would not be any interference from spurious emissions into the SAR receivers. From NESDIS specifications, "At any frequency removed from the channel centre frequency by more than 300% of the NB, at least 43 + 10 log (P) dB attenuation, where P is the total mean power in Watts in the necessary bandwidth. This includes harmonics and any spurious radiation.) "For a total mean power of 10 Watts, spurious emissions must be 53 dB down from the main carrier. From EUMETSAT – "Any out of band spurious HRDCP transmitter emission, for any carrier modulation mode, is required to be lower than the unmodulated carrier level by 60.0 dB (referred to a measurement bandwidth of 500 Hz, corresponding to −62 dB at 300 Hz).

6.1.5 Results

1) For the non-GSO satellite data collection the aggregated power flux density of these systems will not exceed the interference threshold. For the worst case there is a 15.55 dB margin below the interference threshold, according to the wide-band protection criterion in the 401 to 403 MHz band.

2) For the GSO data collection platforms no single platform will violate the power flux density interference criterion For all systems except GLONASS the potential interference power is less than 1% of the interference threshold value.

3) GLONASS has two interference thresholds that are 30 dB different, each applied to 350 kHz portions of the 700 kHz DCS platform transmission range. For the lower frequency range the potential interference power is below 1% of the interference threshold. For the upper frequency range with an interference threshold 30 dB lower the interference power is calculated to be over 10% of the interference power threshold for the range over which the value is applied. The interference power is within 3 dB of its maximum value for periods on the order of 2 hours.

4) Specified spurious emission levels are below the narrow-band interference threshold.

6.1.6 Conclusion

Operation of the EESS (Earth-to-space) service (data collection platforms) will not cause sufficient interference power to exceed the measured sensitivity levels of the search-and-rescue receivers. They do not by themselves degrade the performance of the LEO space component. For the non GSO DCP, the aggregate power at most is only about 1% of the aggregate interference power level for the LEO space component receiver.

The operation of the data collection system would generally contribute only a small fraction of interference to the wide-band interference budget for most of the LEO, MEO and GSO satellites. However, it is about 10% of maximum interference caused to SAR receivers on GLONASS.

The spurious levels are far below the narrow-band threshold for the SAR receivers.

6.1.7 Conclusion for MSS within the in the 399.9-400.05 MHz frequency band (Earth-to-space)

Since the characteristics of the MSS terminals in this band are similar to the PCM/FM data collection platforms as in Table 5-1, taking into account the previous conclusion, and noting that that this MSS band is further than the DCP band 401-403 MHz from the 406-406.1 MHz band, MSS terminals are therefore not likely to cause interference to the 406-406.1 MHz band.

6.2 Assessment of interference from radiosondes operating in the meteorological aids service

Radiosondes are devices that measure environmental parameters and transmit the measurements directly to terrestrial receivers. Characteristics of the radiosondes were presented in § 5.3.

The majority of measurements are synoptic and come from balloon borne radiosondes released at worldwide stations. Table 6-8 shows the distribution of these stations in different locations. This Table is used as a basis to determine how many radiosondes might be within view of each satellite carrying a search and rescue receiver.

TABLE 6-8

Summary of radio frequency use for radiosondes for daily synoptic[1] operations

Region	Number of sites using 403 MHz
Europe and Western Russia	122
Asia and Eastern Russia	139
Africa	65
North America	55
South America and Antarctica	63
Australia and Oceania	73
Ship systems	36
Overall	553

6.2.1 Low Earth Orbit Satellites

6.2.1.1 Interference criteria

The interference criteria for the analysis of interference to low earth orbiting satellites come from Table 3-1 and Table 3-4.

6.2.1.2 Radiosonde interference assessment for satellites in Low Earth Orbit

Similarly to the data collection analysis, the meteorological aid analysis starts with an integration to determine the mean value of interference power that a single radiosonde transmitter would produce at the satellite receiver. In this particular case, the antenna gain of the radiosonde transmitter is taken into account, as well as the SARP receiver antenna and the range between the systems.

Radiosondes transmit continuously until after the balloon which lifts then bursts. Although all the data from the flight are used, data from the surface to the 400 hPa pressure level (about 7 km or 23 000 feet) are considered minimally acceptable for NWS operations. Thus, a flight may be deemed a failure and a second radiosonde released if the balloon bursts before reaching the 400 hPa pressure level or if more than 6 minutes of pressure and /or temperature data between the surface and 400 hPa are missing. An altitude of 23 km makes a 0.23 dB difference in the propagation loss between the earth-to-satellite path and the balloon-to-satellite, which is not significant in the calculations in Table 6-7. The altitude of the LEO satellite is used in the calculations. The results of the calculations are shown in Table 6-9.

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[1] Synoptic operations are coordinated worldwide, measurements are performed at the same time.

TABLE 6-9

Calculation of Mean value of interference contributed to the LEO SARP receiver of a single Radiosonde

LEO									
Off Nadir angle	**Earth Incident Angle**	**Range**	**Recv Gain**	**Gain of Sonde**	**Transmitter e.i.r.p. (dBW)**	**Free space loss**	**Received signal (dBW)**	**Proportional (PSD W)**	**Mean Interference Power (W)**
0.01	89.98867	850	–3.96	–0.368	–9.37	–143.11	–161.04	7.87E-17	9.37E-30
5	84.33159	854	–3.8	–0.149	–9.15	–143.15	–160.70	8.51E-17	1.28E-21
13	75.23054	875	–3.08	0.205	–8.79	–143.37	–159.85	1.04E-16	2.73E-20
22	64.87904	927	–2.24	0.600	–8.40	–143.87	–159.11	1.23E-16	1.54E-19
31	54.29038	1017	–1.33	0.979	–8.02	–144.67	–158.62	1.37E-16	5.11E-19
39	44.50492	1146	–0.17	1.292	–7.71	–145.71	–158.19	1.52E-16	1.29E-18
47	34.02212	1361	–1.24	1.575	–7.42	–147.20	–160.47	8.98E-17	2.02E-18
54	23.53229	1702	2.62	1.793	–7.21	–149.15	–158.33	1.47E-16	8.84E-18
59	13.73542	2208	3.54	1.928	–7.07	–151.41	–159.54	1.11E-16	1.74E-17
61.93	0.459727	3350	3.85	2.000	–7.00	–155.03	–162.78	5.28E-17	3.94E-17
				–3 dB pol loss			Mean power	6.97E-17	

The mean power received at the SARP receiver for a single radiosonde is –161.57 dBW (6.97E-17 W).

The number of radiosondes is determined for three frequency ranges because the three sensitivity ranges from Table 3-6, overlap the operating range of the radiosondes.

The average number of radiosondes that appear in the LEO field-of-view is about 2, based upon a population of 553 radiosondes worldwide that appear in 2.64% of the earth’s area. The number 16 was chosen because it is the number of channels in the channel plan for some of these systems. It would provide for the population being concentrated rather than evenly spread over the earth. A summary of the calculated number of radiosondes that appear in the LEO field-of-view can be found in Table 6-10.

TABLE 6-10

Calculation of the number of radiosondes that are anticipated to be transmitting at the same time in view of the LEO SARP receiver

Capacity Calculations for LEO Satellites	
16	Synoptic Radiosondes in view
400.15-406 MHz	Frequency range of Radiosondes
2.735043	Radiosondes per MHz
1.367521	50% Additional non-synoptic
4.102564	Total radiosondes per MHz
390-401	Frequency range for first sensitivity level
400-401	Frequency range radiosondes in first sensitivity range
4.10	Radiosondes in first sensitivity range

TABLE 6-10 (*end*)

Capacity Calculations for LEO Satellites	
401-405	Frequency range for second sensitivity level
401-405	Frequency range of Radiosondes in second sensitivity range
4	MHz
16.41	Radiosondes in second sensitivity range
405.0-405.9	Frequency range for third sensitivity level
405.0-405.9	Frequency range of Radiosondes in third sensitivity range
0.9	MHz
3.69	Radiosondes in third sensitivity range

The percentage of the interference threshold is determined from the ratio of the interference power contributed by the radiosonde transmitters and the threshold value. The following table shows these calculations.

The Mean Interference Power was evaluated in Table 6-9. The number of simultaneous transmitters is calculated in Table 6-10. The bandwidth is the frequency range of the radiosondes within the frequency range of the interference criterion. The Mean interference power, bandwidth, and the number of simultaneous transmitters are used to calculate the power density in dB (W/Hz). The difference between this latter and the threshold is the margin. The percentage of power is converted from the margin. The results of the calculation of the percentage of the interference threshold that the anticipated number of transmitters contributes to the LEO SARP are listed in Table 6-11.

TABLE 6-11

Calculation of the percentage of the interference threshold that the anticipated number of transmitters contributes to the LEO SARP

Sensitivity Range	**Mean Interference Power dBW**	**Bandwidth (Hz)**	**Number of simultaneous transmitters**	**Density dB (W/Hz)**	**Threshold dB (W/Hz)**	**Margin dB**	**Percent total (%)**
400.15-401	–161.57	850 000	4.10	–214.732	–133.1	–81.6324	0.00000069
401-405	–161.57	4 000 000	16.41	–215.438	–143.1	–72.3382	0.00000584
405.0-405.9	–161.57	900 000	3.69	–215.438	–173.1	–42.3382	0.00583680
400.15-406							0.0058433

6.2.1.3 Results of Radiosonde Interference to Low Earth Orbiting (LEO) Satellites

From the above calculations it can be seen that the interference contribution to Low Earth Orbiting Search and Rescue receivers is only a fractional percentage. The total percentage is the sum of the individual percentages which implies simultaneous operation. This may sometimes be true, for instance at the beginning of each hour as the synoptic measurement platforms report. However, the LEO satellite would receive this interference only if it were in the path of the DCPs to GEO uplink signal during transmission times.

6.2.2 Geostationary orbiting satellites

6.2.2.1 Interference criteria

The interference criteria for the analysis of geostationary orbiting satellites comes from Table 3-2, Table 3-3, Table 3-7, Table 3-8, and Table 3-9.

6.2.2.2 Radiosonde interference assessment for satellites in geostationary Earth orbit (GEO)

For the GOES satellite, the population of radiosondes is based on what would be within view in North and South America. The results of the calculation of the number of radiosondes that are anticipated to be transmitting at the same time in view of the GEO SARR and GOES-R are listed in Table 6-12.

TABLE 6-12

Calculation of the number of radiosondes that are anticipated to be transmitting at the same time in view of the GEO SARR and GOES-R

Capacity Calculations for GOES satellites	
55	Synoptic Radiosondes in view from North America
63	Synoptic Radiosondes in view from south America and Antarctica
118	Synoptic Radiosondes in view total
6	MHz Frequency range of Radiosonde operation
19.66667	Radiosondes per MHz in view of GOES
9.833333	50% Additional non-synoptic
29.5	Total Radiosondes per MHz in view of GOES
390-401	Frequency range for first sensitivity level
0.85	MHz Frequency range radiosondes in first sensitivity range
25.08	Radiosondes in first sensitivity range
401-405	Frequency range for second sensitivity level
4	Frequency range radiosondes in second sensitivity range
118.00	Radiosondes in second sensitivity range
405.0-405.9	Frequency range for third sensitivity level
0.95	Frequency range radiosondes in third sensitivity range
28.03	Radiosondes in third sensitivity range

For the MSG satellite, the population of radiosondes is based upon the number of stations in Europe and Africa. The results of the calculation of the number of radiosondes that are anticipated to be transmitting at the same time in view of the MSG GEOSAR are listed in Table 6-13.

TABLE 6-13

Calculation of the number of radiosondes that are anticipated to be transmitting at the same time in view of the MSG GEOSAR

Capacity Calculations	
122	Synoptic radiosondes in view from Europe and Western Russia
63	Synoptic radiosondes in view from Africa
185	Synoptic radiosondes in view total
6	MHz Frequency range of sonde operation
30.83333	Radiosondes per MHz in view of MEO
15.41667	50% Additional non-synoptic
46.25	Total radiosondes per MHz in view of MEO
390-401	Frequency range for this sensitivity level
0.85	MHz Frequency range radiosondes in this sensitivity range
39.31	radiosondes in this sensitivity range
401-405	Frequency range for this sensitivity level
4	Frequency range radiosondes in this sensitivity range
185	radiosondes in this sensitivity range
405.0-405.9	Frequency range for this sensitivity level
0.95	Frequency range radiosondes in this sensitivity range
43.94	radiosondes in this sensitivity range

The sensitivity levels are taken from § 6.1.3.1. The mean interference power was calculated from integration similarly to the LEO case.

The results of the calculation of the percentage of the interference threshold that the anticipated number of transmitters is contributing to the MSG GEOSAR are listed in Table 6-14.

TABLE 6-14

Calculation of the percentage of the interference threshold that the anticipated number of transmitters is contributing to the MSG GEOSAR

MSG Sensitivity Range (MHz)	**Mean Interference Power (dBW)**	**Bandwidth (Hz)**	**Number of simultaneous transmitters**	**Density dB (W/Hz)**	**Threshold dB (W/Hz)**	**Margin (dB)**	**Percent total (%)**
400.15-401	–182.74	850 000	39.31	–226.085	–172	–54.08	0.00039
401-405	–182.74	4 000 000	185.00	–226.085	–177	–49.08	0.00123
405.0-405.9	–182.74	900 000	43.94	–225.85	–182	–43.85	0.00412
400.15-406							0.0057460

6.2.2.3 Results of radiosonde interference to geostationary orbiting satellites (GEO)

In all cases the percentage of interference power to the SAR receivers is less than 6 x10^{-3} percent of the interference threshold. The worst case seems to be the MSG but it still is a very low portion of the interference power.

6.2.3 Medium altitude Orbiting Satellites (MEO)

6.2.3.1 Interference criteria

The interference criteria for the analysis of intermediate orbiting satellites come from Tables 3-4 and 3-5.

6.2.3.2 Radiosonde Interference Assessment for Satellites in Medium Earth Orbit (MEO)

The population of radiosondes visible to the MEO satellite is based upon Table 6-17 in the report. The maximum number of visible radiosondes is the sum from Europe, Western Russia and Africa. This is proportioned by the ratio of the field-of-view of the MEO to the field-of-view of a GEO. The results of the calculation of the number of radiosondes that are anticipated to be transmitting at the same time in view of the MEO SARR receiver are listed in Table 6-15.

TABLE 6-15

Calculation of the number of radiosondes that are anticipated to be transmitting at the same time in view of the MEO SARR receiver

Capacity Calculations for MEO Satellites	
122	Synoptic Radiosondes in view from Europe and Western Russia
65	Synoptic Radiosondes in view from Africa
187	Synoptic Radiosondes in view total
0.735653	Proportion of field-of-view MEO to GEO
5.85	MHz Frequency range of sonde operation
23.51575	Radiosondes per MHz in view of MEO
11.75787	50% Additional non-synoptic
35.27362	Total Radiosondes per MHz in view of MEO
390-405.05	Frequency range for first sensitivity level
5.05	MHz Frequency range Radiosondes in this sensitivity range
178.13	Radiosondes in this range
405.05-406	Frequency range for second sensitivity level
0.95	Frequency range Radiosondes in this sensitivity range
33.51	Radiosondes in this sensitivity range

There are only two sensitivity ranges for the MEO. The mean interference power was obtained from an integration calculation similar to that in Table 6-18. The results of the calculation of the percentage of the interference threshold that the anticipated number of transmitters is contributing to the MEO SARR are listed in Table 6-16.

TABLE 6-16

Calculation of the percentage of the interference threshold that the anticipated number of transmitters is contributing to the MEO SARR

Sensitivity Range (MHz)	**Mean Interference Power (dBW)**	**Bandwidth (Hz)**	**Number of simultaneous transmitters**	**Density dB (W/Hz)**	**Threshold dB (W/Hz)**	**Margin (dB)**	**Percent total**
400.15-405.05	–166.93	4 900 000	178.13	–211.32	–157.52	–53.80	0.00042%
405.05-406	–166.93	950 000	33.51	–211.46	–163.02	–48.44	0.00143%
400.15-406							0.00185%

6.2.3.3 Results of radiosonde interference to medium Earth orbiting satellites (MEO)

The result is that the aggregate power from the radiosondes is only 0.00185% of the interference threshold.

6.2.3.4 Conclusion for interference from radiosondes to the wide-band criterion

The interference contribution of radiosondes in the meteorological aids service is in the order of six one-thousand of a percent. Their contribution to the interference problem with the search and rescue receivers is minimal.

6.3 Application of a single radiosonde to the narrow-band interference criterion

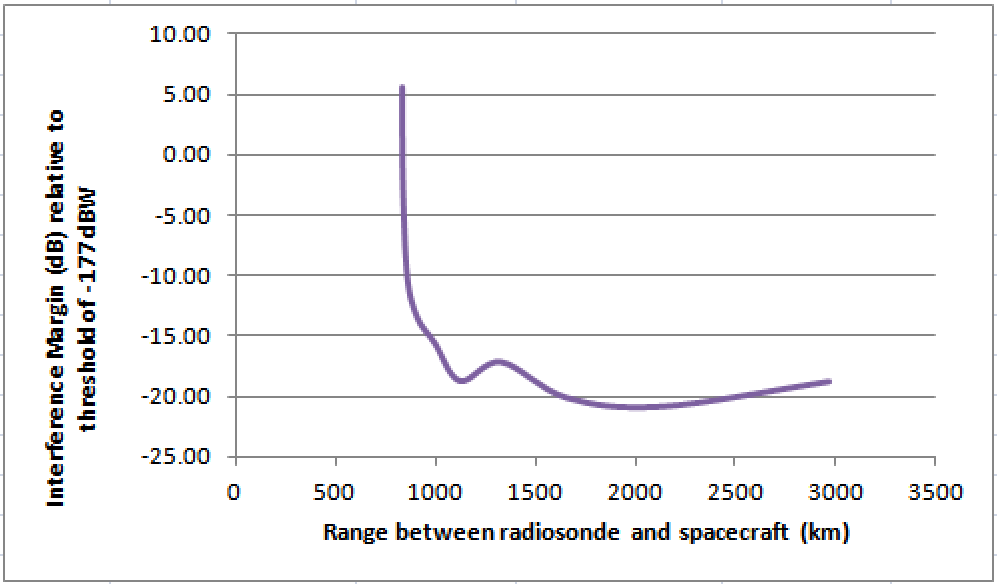
This interference criterion applies to only spurious emissions from the radiosonde transmitter. The criterion applies to signals with bandwidth lower than 2 kHz and usually to single frequency spikes that may look like a carrier from an emergency beacon and mislead the SAR receiver.

The in-band narrow-band maximum interference level, referred to as threshold, is –147 dBm, from Table 3-1. Converting dBm to dBW, this level is –177 dBW and applies at the receiver. Figure 6-1 shows the power of the radiosonde signal relative to the narrow-band threshold. The figure indicates a margin of –21 dB at worst. The spurious emissions specifications are shown in Table 5-10.

These indicate that the spurious levels are less than –43 dB for the analogue radiosondes and less than –45 dB for the digital radiosondes. The resulting power levels would be below the interference threshold.

FIGURE 6-1

In-band interference margin of radiosonde to narrow-band criterion



At this point, it appears that at the worst situation the radiosonde, if operating in its assigned frequency range, does not interfere with the SAR receiver.

6.3.1 Received frequency drift

There are two phenomena that could make the received signal from the radiosonde to appear in the SAR receiver pass-band filter above 406.0 MHz. The first is the Doppler shift due to the relative motion between the two platforms. The second is instability of the radiosonde frequency due to temperature extremes. However, frequency instability does not contribute to the long term background noise in the SARR.

The highest channel of the radiosondes is 405.875 MHz and if the bandwidth is 16.8 kHz, the highest frequency of the radiosonde pass-band filter is 405.8834 MHz. The signal would have to drift up 16.6 kHz before it overlaps 405.9 MHz. It would have to drift 33.4 kHz before the entire emissions of the highest channel be totally above 405.9 MHz.

The Doppler shift would occur from the combined motion of the spacecraft and the radiosonde. The worst case differential velocity occurs when they are directly approaching or departing. The speed of a spacecraft at 850 km altitude is 7 426 km/s, according to Recommendation ITU-R M.1478-3. The radiosonde can reach speeds up to 103 m/s. The Doppler shift is calculated by the ratio of the spacecraft velocity, V_B, to the speed of light, c, times the centre frequency, F_A.

$$F_A(V_B/c) = 10.2 \text{ kHz}$$

This frequency shift by itself would not be sufficient to cause the signal of the highest radiosonde channel to appear above 406.0 MHz.

The instability of older radiosondes has been as much as 800 kHz. This would cause the radiosonde to drift into the SAR receiver bandwidth if it were tuned to one of the higher channels. Any radiosonde that is tuned below 405 MHz would not drift into the RAS receiver bandwidth.

6.3.2 Results

1) The interference power contribution of any single radiosonde operating within the frequency range from 401 to 405.9 MHz to the SAR receiver is far below the measured threshold levels.

2) Doppler shift of the radiosonde signal at the SAR receiver is sufficiently small that the radiosondes should not be transmitting in the SAR receiver range from 406 to 406.1 MHz.

3) Sondes that are tuned below 405 MHz will not drift above 406 MHz.

4) Spurious emissions from the radiosondes, as specified, are far below the interference threshold.

6.3.3 Conclusion

Operation of radiosondes will not contribute high levels of long term interference to the SARP on LEO, MEO or GEO satellites.

6.4 Assessment of interference from the operation of mobile systems in the 390-420 MHz range in CEPT countries

6.4.1 Impact of mobile service in operation within the band 406.1 to 408 MHz

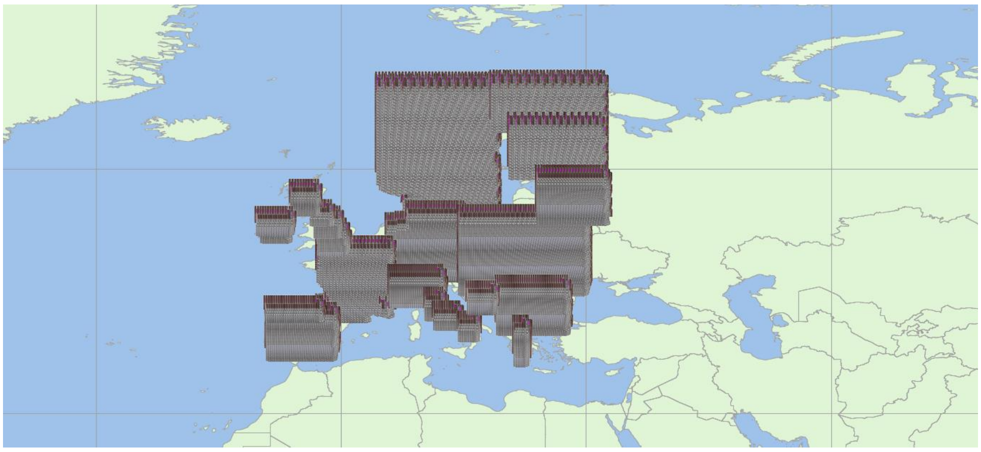
6.4.1.1 Impact on the LEO satellite

The following dynamic analysis studies the impact of the land mobile deployment for the frequency band 406.1-408 MHz on the LEO satellites. The characteristics of the deployment are based on the outputs of the questionnaire as mentioned in Annex 2.

Concerning CEPT countries, the simulation implements about 21 000 mobile and base stations in Europe. Figure 6-2 illustrates the implementation of the mobile/base stations as used in the dynamic simulation.

FIGURE 6-2

Implementation of mobile/base stations in a dynamic simulation



According to Annex 2, it is proposed to use the following set of typical mobile/base stations characteristics for a bandwidth of 25 kHz, representative for the CEPT countries:

– transmit power 0 dBW and 0 dBi antenna gain for mobile stations (every 15 km);

– transmit power 0 dBW and 6 dBi antenna gain for base stations (every 40 km). In that case, both, mobiles and base stations share the same band since the 406.1-408/410 MHz is a simplex band according to ECC decision;

– transmit power 5 dBW and 0 dBi antenna gain for mobile stations (every 20 km);

– transmit power 0 dBW and 0 dBi antenna gain for mobile stations (every 15 km), transmit power 3 dBW and 6 dBi antenna gain for base stations (every 30 km).

It is to be noted that the characteristics of this deployment are less stringent than those detailed in Annex 2 in terms of output power, antenna gain and density.

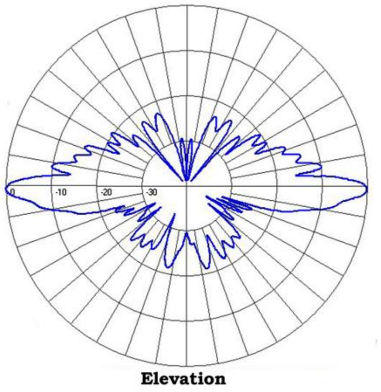
In addition to these deployment characteristics, it is to be mentioned that the mobile networks generally use vertical or horizontal polarizations and the SARSAT antenna is RHCP (Right Hand Circular Polarization). Therefore, the simulation considers the consequent losses (3 dB typical between circular versus vertical/horizontal), plus 2 dB of feeder losses.

Mobile stations are supposed to look at base stations and usually have elevation angles of a few degrees.

Figure 6-3 illustrates the typical 400 MHz antenna pattern that is used for various stations. At high elevation angles, the corresponding antenna gains are as low as –30 dBi with a maximum antenna gain of 0 dBi.

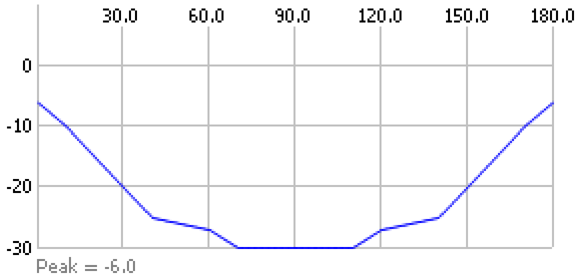
FIGURE 6-3

Typical 400 MHz antenna pattern



In addition, as most of the infrastructures are located in cities, at low elevation angles the antenna pattern suffers from masking effects and therefore, the antenna gain is lower than expected. For this simulation, the corresponding antenna pattern for mobile stations is as shown in Fig. 6-4.

FIGURE 6-4



For the base stations, which are supposed to look downwards and which also suffer from masking effects at low elevation angles, the corresponding antenna pattern is shown is Fig. 6-5.

FIGURE 6-5

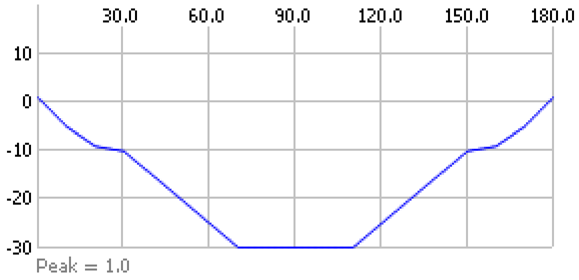
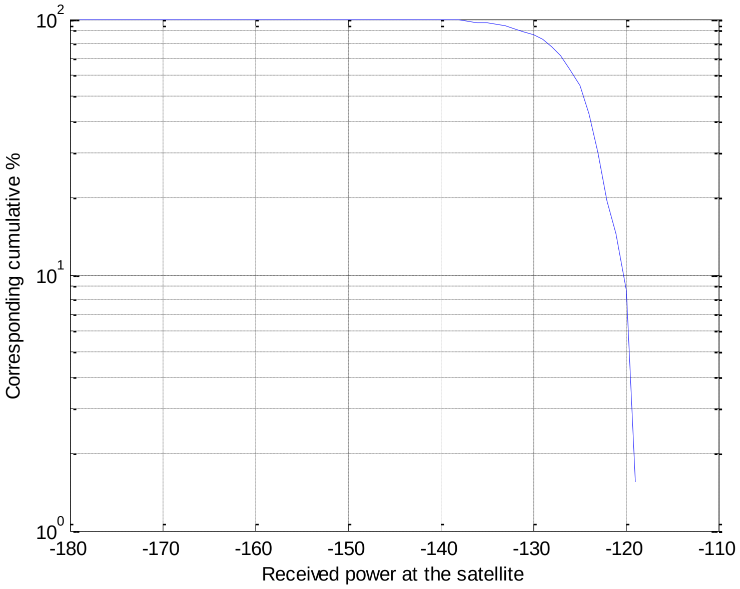


Figure 6-6 presents the result of the dynamic simulation, valid for the satellite footprint over Europe.

FIGURE 6-6

Cumulative density function showing the impact of mobile systems in the band 406.1-408 MHz on the LEO satellite over Europe



An activity factor of 10% is actually applied to the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time. The power flux density is –147 dBW/m^2/Hz. The resulting pfd is –157 dBW/m^2/Hz. Using the maximum permissible levels of interference measured on the SARP instrument (LEO space component), as shown in Table 3-6, the following corresponding margins are valid for 4% of the time over Europe.

For the band 406.1-406.2 MHz, it is equivalent to a 196-157 = 39 dB negative margin[2].

For the band 406.2-407 MHz, it is equivalent to a 161-157= 4 dB negative margin.

For the band 407-408 MHz, it is equivalent to a 157-131 = 26 dB positive margin.

---

[2] A negative margin means that the pfd received on board the satellite exceeds the maximum permissible level of interference.

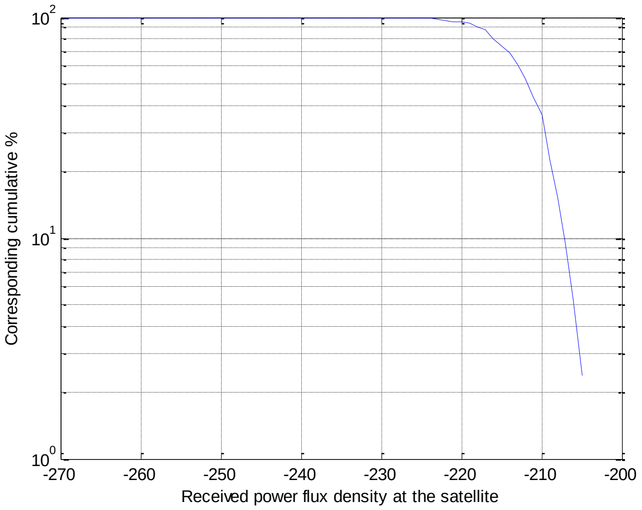
A positive margin means that the pfd received on board the satellite is below the maximum permissible level of interference.

Due to the filtering pattern, it can be seen that interference levels in the frequency band 406.1-406.2 MHz provide a significant amount of noise that will be detrimental to the reception of distress signals in the 406-406.1 MHz frequency band. The frequency band 406.2-407 MHz also provides noise well above the threshold. Above 407 MHz, the filtering pattern is sharp enough to eliminate all the out of band emissions.

An additional simulation was conducted to evaluate the impact of the spurious emissions as derived from § 5.2.4. The results, valid for Europe, are presented in Fig. 6-7.

FIGURE 6-7

Cumulative density function showing the impact of the spurious emissions of mobile systems in the band 406.1-408 MHz on the LEO satellite over Europe



The power flux density is –203 dBW/m^2. Taking into account a 10% activity factor, the resulting pfd is –213 dBW/m^2. Using the maximum permissible levels of interference measured on the SARP instrument (LEO space component) as shown in Table 3-1, the following corresponding margins result.

For the band 406.1-406.2 MHz, it is equivalent to a 213 – 164 = 49 dB positive margin.

For the band 406.2-407 MHz, it is equivalent to a 213 – 129 = 84 dB positive margin.

Therefore, the spurious emissions created by the land mobile systems deployed above 406.1 MHz do not create any interference within 406.1-406.2 MHz and above.

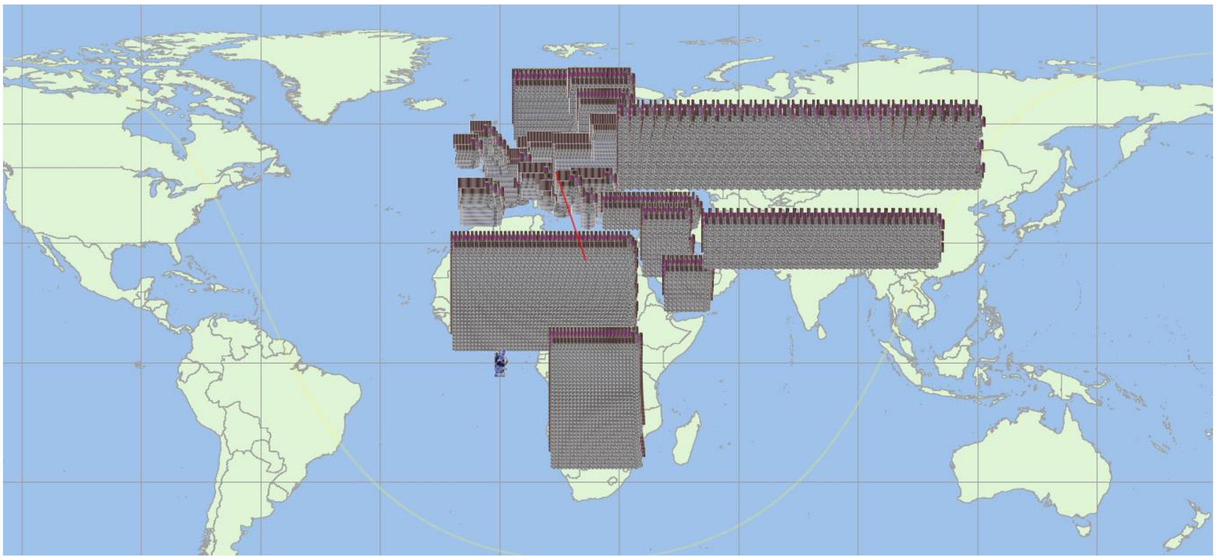
6.4.1.2 Impact on the MEO satellites

The following dynamic analysis studies the impact of the land mobile deployment valid for the frequency band 406.1-408 MHz on the MEO satellites. The deployment is exactly the same as for § 6.4.1.1.

Since the MEO (and also the GSO) satellites cover large areas much wider than Europe, additional deployment has been added to Africa, Middle East and Russia, with a mobile station (5 dBW, 0 dBi) every 160 km. Figure 6-8 illustrates the implementation of mobile and base stations used in the dynamic simulation.

FIGURE 6-8

Implementation of mobile/base stations in a dynamic simulation

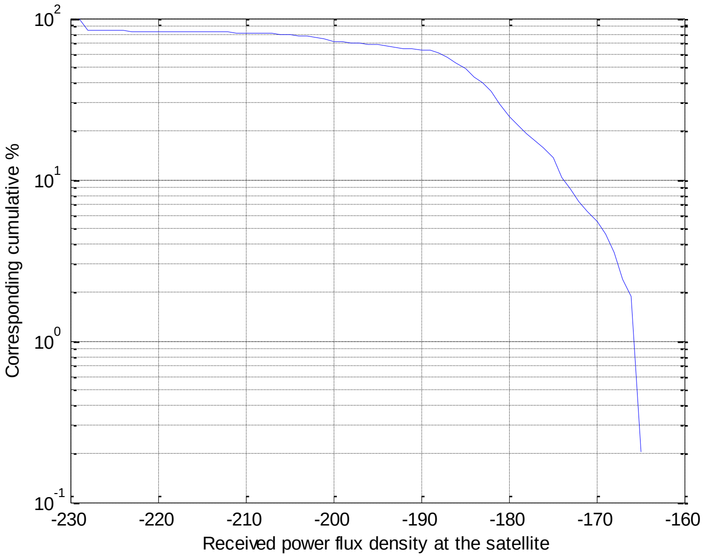


The hypothesis for the simulation (antenna pattern, polarization losses…) are as noted in § 6.4.1.1.

Figures 6-9 and 6-10 present the results for GALILEO and GLONASS, respectively. The results are, valid for the satellite footprint over Europe. It is to be noted that the incorporation of the deployment in Africa, Middle East and Russia within the simulation does not have any consequence on the pfd level received on board the satellite. The only consequence is that the cdf (cumulative density function) has higher values (in percentage of time) when Africa, Russia and the Middle East are considered.

FIGURE 6-9

Cumulative density function showing the impact of mobile systems in the band 406.1-408 MHz for the GALILEO satellite covering Europe



An activity factor of 10% is applied at the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time. The power flux density is –165 dBW/m^2/Hz.

The resulting pfd is –175 dBW/m^2/Hz. Using the maximum permissible levels of interference measured for GALILEO as shown in Table 3-10, the following margins are obtained.

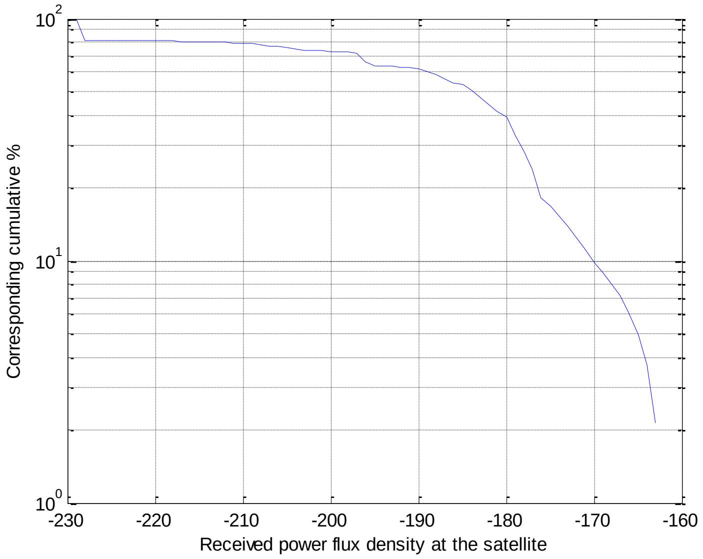
For the band 406.1-407.05 MHz, it is equivalent to a 175 – 166 = 9 dB positive margin.

For the band 407.05-408 MHz, it is equivalent to a 175 – 158 = 17 dB positive margin.

Due to the sharp filtering pattern, it can be seen that all the unwanted emissions can be eliminated for the deployment and activity factor hypothesis used in this simulation.

FIGURE 6-10

Cumulative density function showing the impact of mobile systems in the band 406.1-408 MHz for the GLONASS satellite covering Europe



An activity factor of 10% is applied at the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time.

The power flux density is –163 dBW/m^2/Hz. The resulting pfd is –173 dBW/m^2/Hz. Using the maximum permissible levels of interference measured for GLONASS as shown in Table 3-11, the following corresponding margins, valid for 2% of the time for the whole world, are obtained.

For the band 406.1-407.05 MHz, it is equivalent to a 202 – 173 = 29 dB negative margin.

For the band 407.05-408 MHz, it is equivalent to a 175 – 173 = 2 dB negative margin.

Due to the filtering pattern, it can be seen that the frequency band 406.1-407 MHz provides a significant amount of noise that will be detrimental to the reception of distress signals in the 406-406.1 MHz frequency band. Above 407 MHz, there is a small negative margin.

6.4.1.3 Impact on the GSO satellites

Using the same deployment model as for the MEO, the impact of the GSO is as follows.

For MSG, the resulting power flux density is –177 dBW/m^2/Hz. A 10% activity factor, which is equivalent to a –187 dBW/m^2/Hz, is taken into account since it is supposed that not all the transmitters are in operation at the same time.

For the band 406.1 to 406.2 MHz, it is equivalent to a 200 – 187= 13 dB negative margin.

For the band 406.2 to 407 MHz, it is equivalent to a 187 – 171 = 16 dB positive margin.

However, we do not have South America and North America in the MSG beam that would provide additional power. It can be seen that the frequency band 406.1-406.2 MHz provides a significant amount of noise that will be detrimental to the reception of distress signals in 406-406.1 MHz frequency band. Above 406.2 MHz, unwanted emissions are eliminated due to the sharp filtering pattern.

For Electro satellite, the calculation needs to be done (position of Electro to be known).

6.4.2 Impact of mobile service in operation within the band 408 to 410 MHz

6.4.2.1 Impact on the LEO satellite

The following dynamic analysis studies the impact of the land mobile deployment valid for the frequency band 408-410 MHz on the LEO satellites. The characteristics of the deployment are based on the outputs of the questionnaire as mentioned in Annex 2. Concerning CEPT countries. The simulation implements about 21 000 mobile and base stations in Europe.

According to Annex 2, it is proposed to use the following set of typical mobile/base stations characteristics for a bandwidth of 25 kHz, representative of the CEPT countries

– transmit power 0 dBW and 0 dBi antenna gain for mobile stations (every 15 km);

– transmit power 6 dBW and 6 dBi antenna gain for base stations (every 40 km);

– transmit power 5 dBW and 0 dBi antenna gain for mobile stations (every 20 km);

– transmit power 3 dBW and 0 dBi antenna gain for mobile stations (every 10 km) for a bandwidth of 10 kHz.

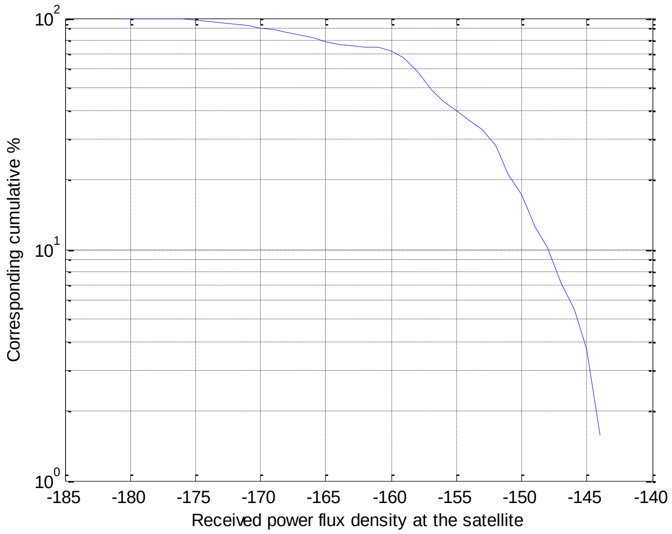
It is to be noted that the characteristics of this deployment are less stringent than those detailed in Annex 2 in terms of output power, antenna gain and density.

The hypothesis for the simulation (antenna pattern, polarization losses,…) are as noted in § 6.4.1.1.

Figure 6-11 shows the result of the dynamic simulation, valid for the satellite footprint over Europe.

FIGURE 6-11

Cumulative density function showing the impact of mobile systems in the band 408-410 MHz for the LEO satellite over Europe



An activity factor of 10% is applied at the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time.

The power flux density is –144 dBW/m^2/Hz.

The resulting pfd is –154 dBW/m^2/Hz. Using the maximum permissible levels of interference measured on the SARP instrument (LEO space component) as shown in Table 3-6, we have the following corresponding margins valid for 4% of the time over Europe.

For the band 408-410 MHz, it is equivalent to a 154 – 131 = 23 dB positive margin.

Above 408 MHz, the filtering pattern is sharp enough to eliminate all the unwanted emissions.

6.4.2.2 Impact on the MEO satellites

The following dynamic analysis studies the impact of the land mobile deployment, valid for the frequency band 408-410 MHz on the MEO satellites. The deployment is as for § 6.4.2.1 for CEPT countries.

Since the MEO (and also the GSO) satellites cover large areas much wider than Europe, additional deployment has been added to Africa, Middle East and Russia, with a mobile station (5 dBW, 0 dBi) every 160 km in average. Figure 6.8 illustrates the implementation of the mobile and base stations used in the dynamic simulation.

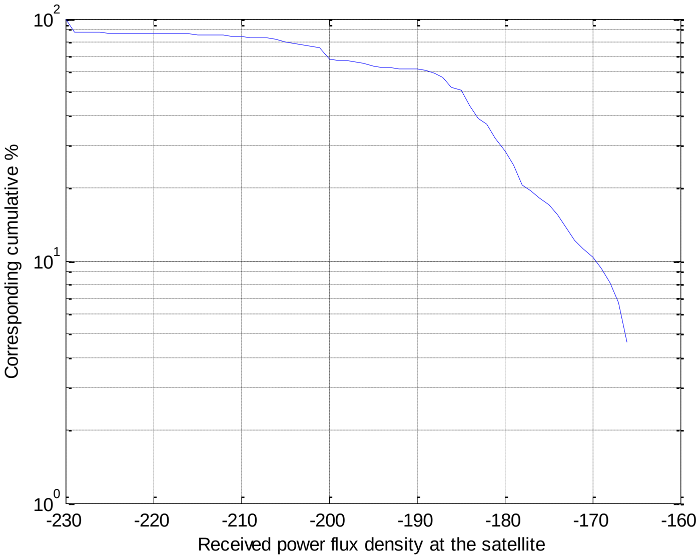
The hypothesis for the simulation (antenna pattern, polarization losses…) are the same as noted in § 6.4.1.1.

The following curves show the result of the dynamic simulation, valid for the satellite footprint over Europe. The results in Fig. 6-12 correspond to GALILEO and those in Fig. 6-13, correspond to GLONASS.

It is to be noted that the incorporation of the deployment of Africa and Middle East and Russia within the simulation does not have any consequence on the maximum pfd received on board the satellite. The only consequence is that the cdf (cumulative density function) has higher values (in percentage of time) when these territories are included. The results illustrated in the figures below include Africa, Middle East and Russia.

FIGURE 6-12

Cumulative density function showing the impact of mobile systems in the band 408-410 MHz for the GALILEO satellite over Europe



An activity factor of 10% is applied to the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time.

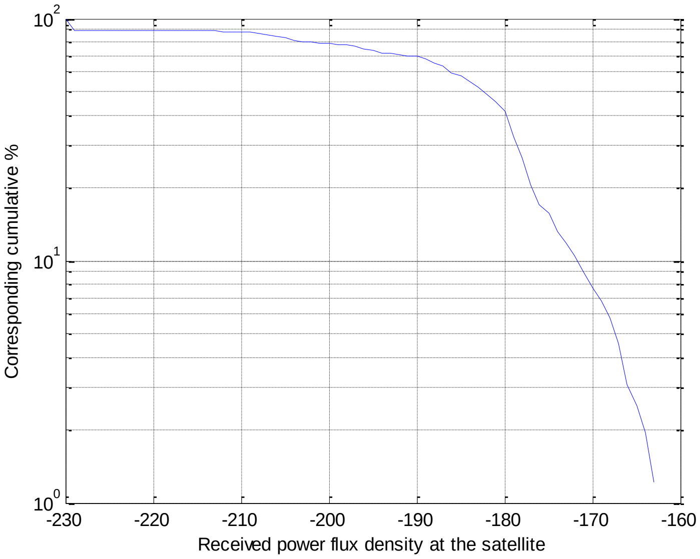
The power flux density is –166 dBW/m^2/Hz. The resulting pfd is –176 dBW/m^2/Hz. Using the maximum permissible levels of interference measured for GALILEO as shown in Table 3-10, we have the following corresponding margins.

For the band 408-410 MHz, it is equivalent to a 176 – 158 = 18 dB positive margin.

Due to the sharp filtering pattern, it can be seen that all unwanted emissions can be eliminated taking into the deployment/activity factor hypothesis used in this simulation.

FIGURE 6-13

Cumulative density function showing the impact of mobile systems in the band 408-410 MHz for the GLONASS satellite covering Europe



An activity factor of 10% is applied at the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time.

The power flux density is –163 dBW/m^2/Hz. The resulting pfd is –173 dBW/m^2/Hz. Using the maximum permissible levels of interference measured for GLONASS as shown in Table 3-11, we have the following corresponding margins valid for 1% of the time for the whole world.

Within the band 408-410 MHz, it is equivalent to a 175 – 173 = –2 dB negative margin.

The mobile systems deployed in the frequency band 408-410 MHz still provides some noise to the reception of distress signals on board GLONASS in 406-406.1 MHz frequency band.

6.4.2.3 Impact on the GSO satellites

Using the same deployment model as for the MEO, the impact of the GSO is as follows.

The power flux density is –177 dBW/m^2/Hz. We have to take into account a 10% activity factor, which is equivalent to a –187 dBW/m^2/Hz, since it is supposed that all the transmitters are not in operation at the same time.

For the band 408 to 410 MHz, it is equivalent to a 187 – 166 = 21 dB positive margin.

Out of band emissions are eliminated due to the sharp filtering pattern.

For Electro satellite, the calculations are to be done (position of Electro to be known).

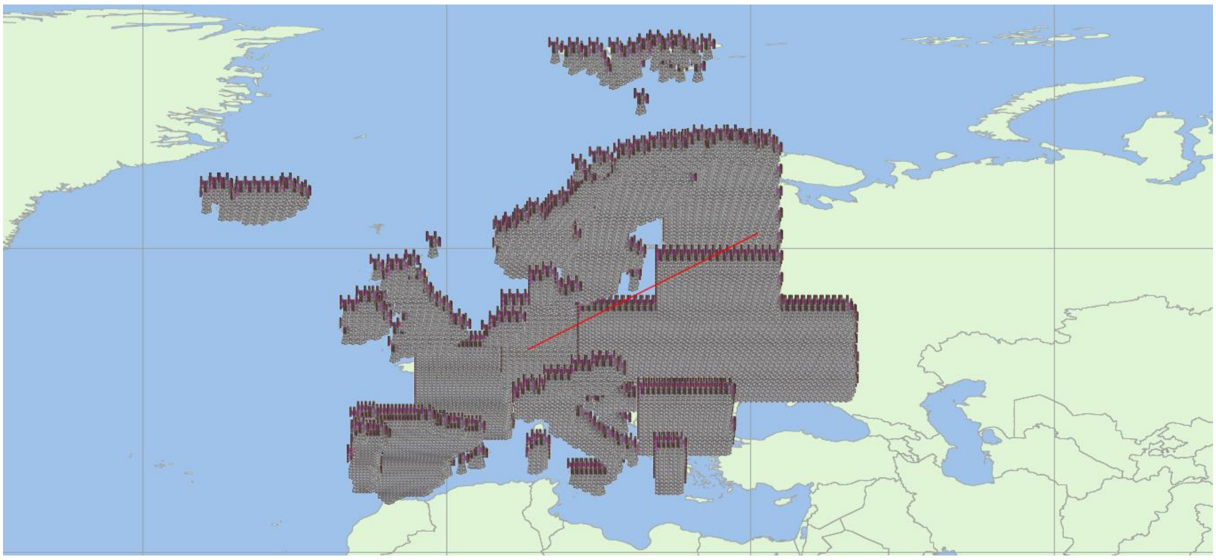
6.4.3 Impact of mobile service in operation within the band 410 to 414.5 MHz

6.4.3.1 Impact on the LEO satellite

The following dynamic analysis studies the impact of the land mobile deployment valid for the frequency band 410-414.5 MHz on the LEO satellites. The characteristics of the deployment are based on the outputs of the questionnaire as mentioned in Annex 2. Concerning CEPT countries, the simulation implements about 15 000 mobile and base stations in Europe, as shown in Fig. 6-14.

FIGURE 6-14

Implementation of mobile/base stations in a dynamic simulation



According to Annex 2, it is proposed to use the representative following set of typical mobile stations characteristics for a bandwidth of 25 kHz, representative of systems in operation in CEPT countries:

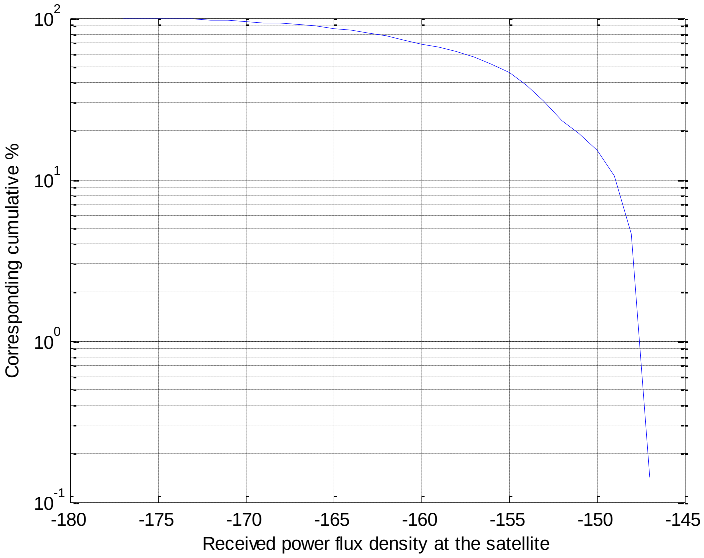
- transmit power 12 dBW and 0 dBi antenna gain for mobile stations (every 40 km);
- transmit power 13 dBW and 0 dBi antenna gain for mobile stations (every 50 km);
- transmit power 3 dBW and 0 dBi antenna gain for mobile stations (every 10 km) for a 10 kHz bandwidth.

It is to be noted that the characteristics of this deployment are less stringent than those detailed in Annex 2 in terms of output power, antenna gain and density.

Figure 6-15 shows the result of the dynamic simulation, valid for the satellite footprint over Europe.

FIGURE 6-15

Cumulative density function showing the impact of mobile systems in the band 410-414.5 MHz for the LEO satellite over Europe



An activity factor of 10% is actually applied at the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time.

The pfd is –147 dBW/m^2/Hz. The resulting pfd is –157 dBW/m^2/Hz. Using the maximum permissible levels of interference measured on the SARP instrument (LEO space component) as shown in Table 3-6, we have the following corresponding margins valid for 1% of the time over Europe.

In the band 410-411 MHz, it is equivalent to a 157 – 131 = 26 dB positive margin.

Above 411 MHz, it is equivalent to a 157 – 121 = 36 dB positive margin.

Above 410 MHz, the filtering pattern is sharp enough to eliminate all the unwanted emissions.

6.4.3.2 Impact on the MEO satellites

The following dynamic analysis studies the impact of the land mobile deployment, valid for the frequency band 410-414.5 MHz on the MEO satellites. The deployment is as for § 6.4.3.1 for CEPT countries.

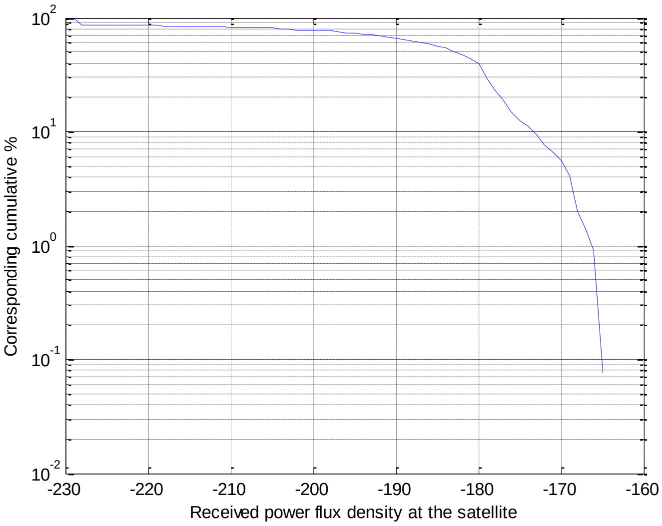
Since the MEO (and also the GSO) satellites cover large areas much wider than Europe, additional deployment has been added to Africa, Middle East and Russia, with a mobile station (5 dBW, 0 dBi) every 160 km in average.

The hypothesis for the simulation (antenna pattern, polarization losses…) are the same as noted in § 6.4.1.1.

The following curves show the result of the dynamic simulation, valid for the whole world. The results in Fig. 6-16 correspond to GALILEO and those in Fig. 6-17, correspond to GLONASS.

FIGURE 6-16

Cumulative density function showing the impact of mobile systems in the band 410-414.5 MHz for the GALILEO satellite



An activity factor of 10% is applied to the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time.

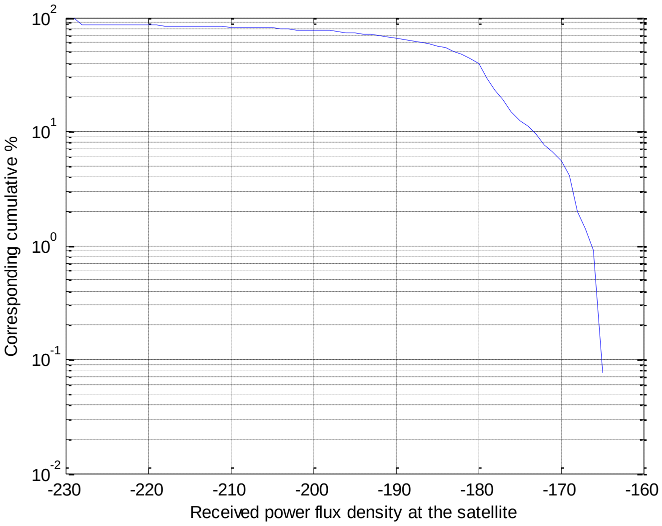
The power flux density is –166 dBW/m^2/Hz. The resulting pfd is –176 dBW/m^2/Hz. Using the maximum permissible levels of interference measured for GALILEO as shown in Table 3-10, we have the following corresponding margins.

In the band 410-414.5 MHz, it is equivalent to a 176 – 157 = 19 dB positive margin.

Due to the sharp filtering pattern, it can be seen that all unwanted emissions can be eliminated taking into the deployment/activity factor hypothesis used in this simulation.

FIGURE 6-17

Cumulative density function showing the impact of mobile systems in the band 410-414.5 MHz for the GLONASS satellite



An activity factor of 10% is applied at the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time.

The power flux density is –166 dBW/m^2/Hz. The resulting pfd is –176 dBW/m^2/Hz. Using the maximum permissible levels of interference measured for GLONASS as shown in Table 3-11, we have the following corresponding margins valid for 1% of the time for the whole world.

In the band 410-414.5 MHz, it is equivalent to a 176 – 157 = 19 dB positive margin.

Due to the filtering pattern, it can be seen that all unwanted emissions can be eliminated taking into the deployment/activity factor hypothesis used in this simulation.

6.4.3.3 Impact on the GSO satellites

Using the same deployment model as for the MEO, the impact of the GSO is as follows.

The power flux density received by MSG is –181 dBW/m2/Hz. We have to take into account a 10 % activity factor, which is equivalent to –191 dBW/m2/Hz, since it is supposed that all the transmitters are in operation all at the same time.

For the band 410 to 414.5 MHz, it is equivalent to a 191 – 161 = 30 dB positive margin.

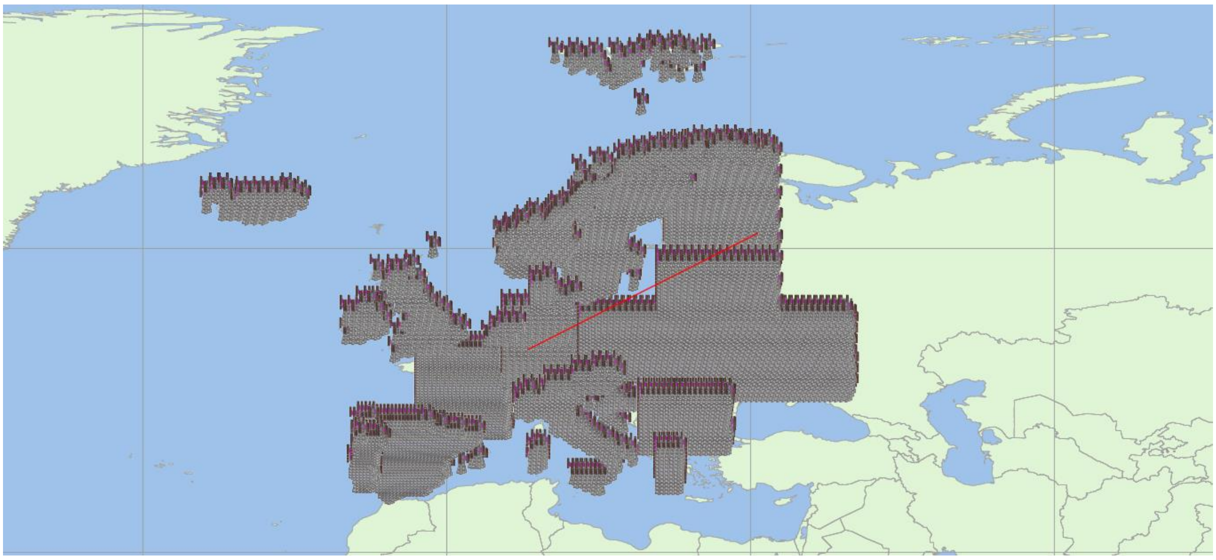
6.4.4 Impact of mobile service in operation within the band 414.5 to 420 MHz

6.4.4.1 Impact on the LEO satellite

The following dynamic analysis studies the impact of the land mobile deployment valid for the frequency band 414.5-420 MHz on the LEO satellites. The characteristics of the deployment are based on the outputs of the questionnaire as mentioned in Annex 2.

FIGURE 6-18

Implementation of mobile/base stations in a dynamic simulation



According to Annex 2, it is proposed to use the representative following set of typical mobile stations characteristics for a bandwidth of 25 kHz, representative of systems in operation in CEPT countries:

– transmit power 12 dBW and 0 dBi antenna gain for mobile stations (every 40 km);

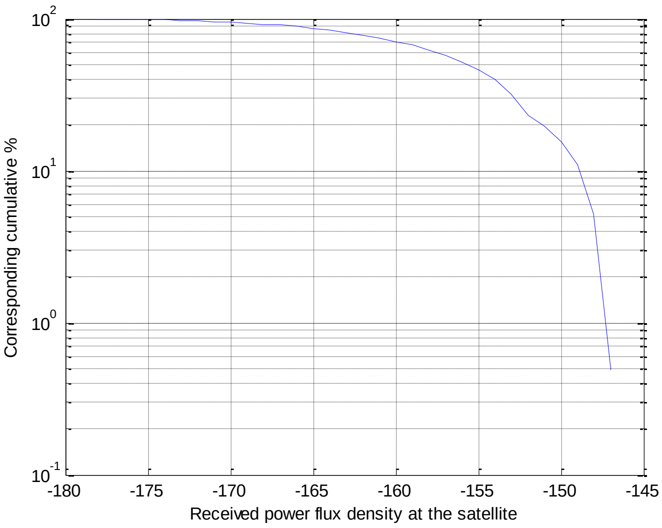
– transmit power 5 dBW and 0 dBi antenna gain for mobile stations (every 15 km);

It is to be noted that the characteristics of this deployment are less stringent than those detailed in Annex 2 in terms of output power, antenna gain and density.

Figure 6-19 shows the result of the dynamic simulation, valid for the satellite footprint over Europe.

FIGURE 6-19

Cumulative density function showing the impact of mobile systems in the band 414.5-420 MHz for the LEO satellite over Europe



The power flux density is –148 dBW/m2/Hz. We have to take into account a 10 % activity factor, which is equivalent to –158 dBW/m2/Hz, since it dBW/m2/Hz it is supposed that all the transmitters are in operation all at the same time. It is assumed that not all the land mobile transmitters are active at the same time.

In the band 414.5-420 MHz, it is equivalent to a 158 – 121 = +37 dB positive margin.

It can noted that the filtering pattern is sharp enough to eliminate all the unwanted emissions.

6.4.4.2 Impact on the MEO satellites

The following dynamic analysis studies the impact of the land mobile deployment, valid for the frequency band 414.5-420 MHz on the MEO satellites. The deployment is as for § 6.4.4.1 for CEPT countries.

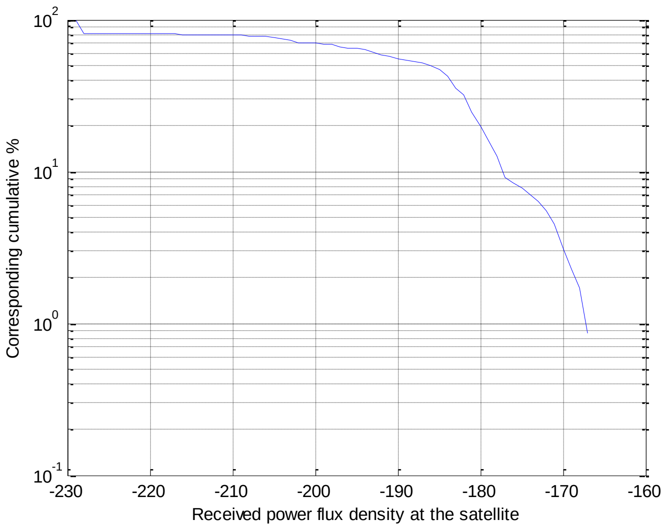
Since the MEO (and also the GSO) satellites cover large areas much wider than Europe, additional deployment has been added to Africa, Middle East and Russia, with a mobile station (5 dBW, 0 dBi) every 160 km in average.

The hypothesis for the simulation (antenna pattern, polarization losses…) are the same as noted in § 6.4.1.1.

The following curves show the result of the dynamic simulation, valid for the whole world. The results in Fig. 6-20 correspond to GALILEO and those in Fig. 6-21, correspond to GLONASS.

FIGURE 6-20

Cumulative density function showing the impact of mobile systems in the band 414.5-420 MHz for the GALILEO satellite



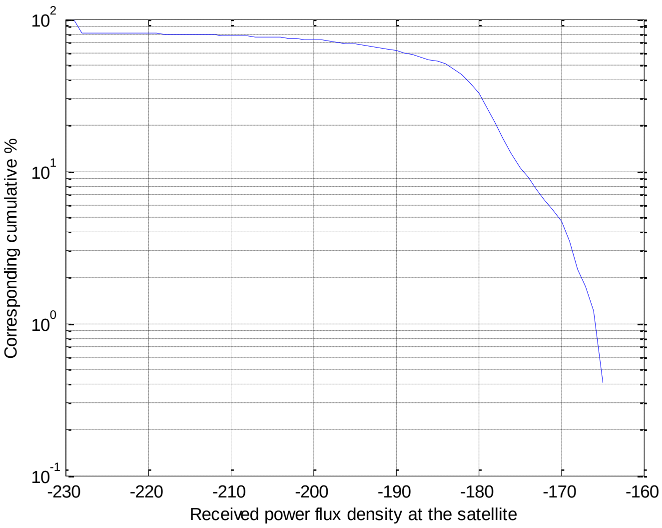
The power flux density is –168 dBW/m^2/Hz. We have to take into account a 10 % activity factor, which is equivalent to –178 dBW/m^2/Hz, since it dBW/m^2/Hz it is supposed that all the transmitters are in operation all at the same time. It is assumed that not all the land mobile transmitters are active at the same time.

In the band 414.5-420 MHz, it is equivalent to a 178 – 157 = 21 dB positive margin.

Due to the sharp filtering pattern, it can be seen that all unwanted emissions can be eliminated taking into the deployment/activity factor hypothesis used in this simulation.

FIGURE 6-21

Cumulative density function showing the impact of mobile systems in the band 414.5-420 MHz for the GLONASS satellite



The power flux density is –166 dBW/m^2/Hz. We have to take into account a 10 % activity factor, which is equivalent to –176 dBW/m^2/Hz, since it dBW/m^2/Hz it is supposed that all the transmitters are in operation all at the same time. It is assumed that not all the land mobile transmitters are active at the same time.

In the band 414.5-420 MHz, it is equivalent to a 176 – 145 = 31 dB positive margin.

Due to the filtering pattern, it can be seen that all unwanted emissions can be eliminated taking into the deployment/activity factor hypothesis used in this simulation.

6.4.4.3 Impact on the GSO satellites

Using the same deployment model as for the MEO, the impact of the GSO is as follows.

The power flux density received by MSG is –181 dBW/m^2/Hz. We have to take into account a 10 % activity factor, which is equivalent to –191 dBW/m^2/Hz, since it is supposed that all the transmitters are in operation all at the same time.

For the band 414.5 to 420 MHz, it is equivalent to a 191 – 161 = 30 dB positive margin.

6.4.5 Impact of mobile service in operation within the band 395 to 399.9 MHz

This band is usually dedicated to government usage and its deployment is not precisely well known. Therefore, no compatibility analysis has been performed. However, due to the fact this band is 16 MHz away from the 406-406.1 MHz band, and taking into account the decrease of the filtering pattern, it is not expected that unwanted emissions from this band would create interference to the 406-406.1 MHz band.

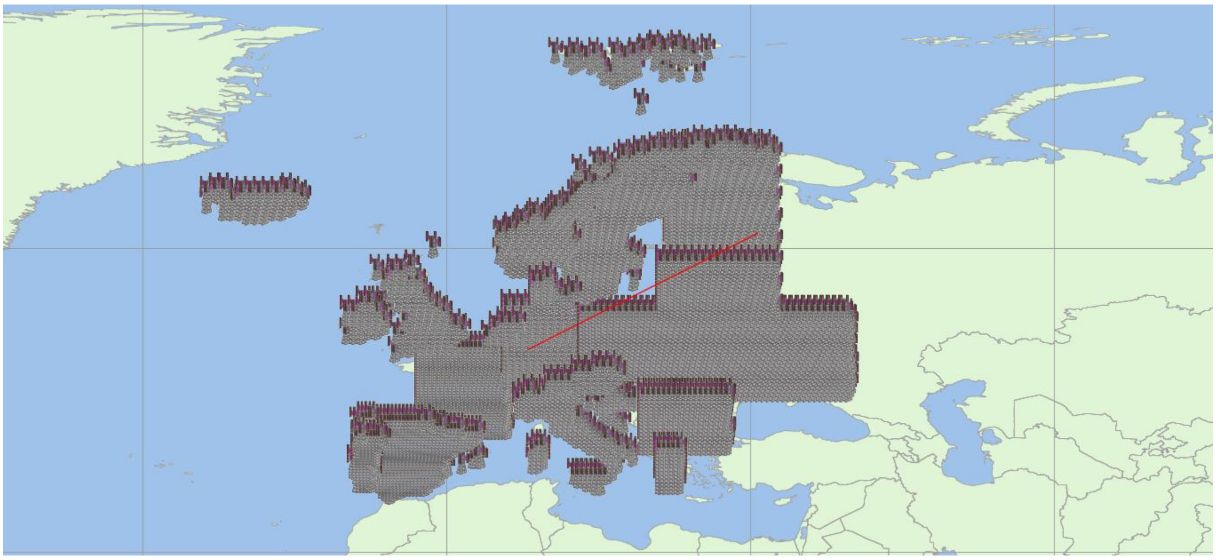
6.4.6 Impact of mobile service in operation within the band 390 to 395 MHz

6.4.6.1 Impact on the LEO satellite

The following dynamic analysis studies the impact of the land mobile deployment valid for the frequency band 390-395 MHz on the LEO satellites. The characteristics of the deployment are based on the outputs of the questionnaire as mentioned in Annex 2.

FIGURE 6-22

Implementation of mobile/base stations in a dynamic simulation



According to Annex 2, it is proposed to use the representative following set of typical mobile stations characteristics for a bandwidth of 25 kHz, representative of systems in operation in CEPT countries:

– transmit power 12 dBW and 9 dBi antenna gain for mobile stations (every 50 km);

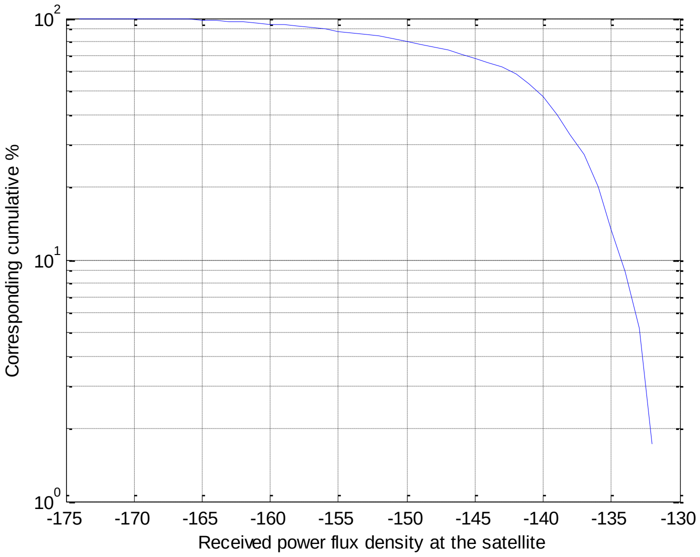
– transmit power 21 dBW and 9 dBi antenna gain for mobile stations (every 60 km);

It is to be noted that the characteristics of this deployment are less stringent than those detailed in Annex 2 in terms of output power, antenna gain and density.

Figure 6-23 shows the result of the dynamic simulation, valid for the satellite footprint over Europe.

FIGURE 6-23

Cumulative density function showing the impact of mobile systems in the band 414.5-420 MHz for the LEO satellite over Europe



The power flux density is –133 dBW/m^2/Hz. We have to take into account a 10 % activity factor, which is equivalent to –143 dBW/m^2/Hz, since it is supposed that all the transmitters are in operation all at the same time. It is assumed that not all the land mobile transmitters are active at the same time.

In the band 390-395 MHz, it is equivalent to a 143 – 121 = +22 dB positive margin.

It can be noted that the filtering pattern is sharp enough to eliminate all the unwanted emissions.

6.4.6.2 Impact on the MEO satellites

The following dynamic analysis studies the impact of the land mobile deployment, valid for the frequency band 390-395 MHz on the MEO satellites. The deployment is as for § 6.4.4.1 for CEPT countries.

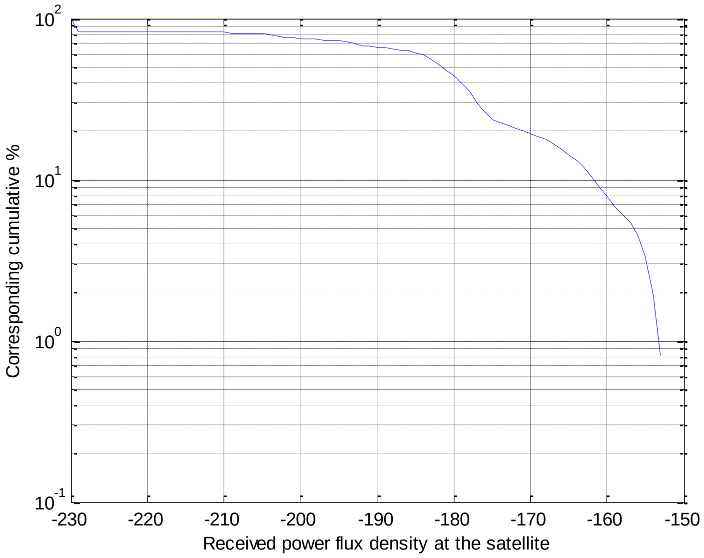
Since the MEO (and also the GSO) satellites cover large areas much wider than Europe, additional deployment has been added to Africa, Middle East and Russia, with a mobile station (5 dBW, 0 dBi) every 160 km in average.

The hypothesis for the simulation (antenna pattern, polarization losses…) are the same as noted in § 6.4.1.1.

The following curves show the result of the dynamic simulation, valid for the whole world. The results in Fig. 6-24 correspond to GALILEO and those in Fig. 6-25, correspond to GLONASS.

FIGURE 6-24

Cumulative density function showing the impact of mobile systems in the band 390-395 MHz for the GALILEO satellite



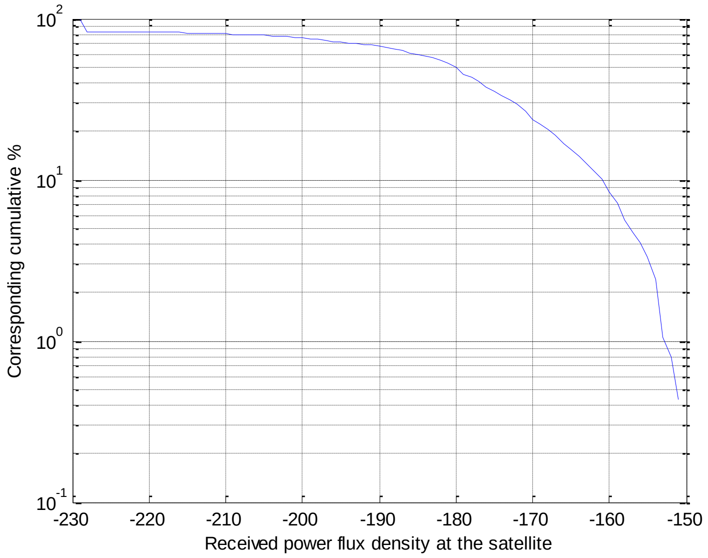
The power flux density is –154 dBW/m^2/Hz. We have to take into account a 10 % activity factor, which is equivalent to –164 dBW/m^2/Hz, since it is supposed that all the transmitters are in operation all at the same time. It is assumed that not all the land mobile transmitters are active at the same time.

In the band 390-395 MHz, it is equivalent to a 164 – 157 = 7 dB positive margin.

Due to the filtering pattern, it can be seen that all unwanted emissions can be eliminated taking into the deployment/activity factor hypothesis used in this simulation.

FIGURE 6-25

Cumulative density function showing the impact of mobile systems in the band 390-395 MHz for the GLONASS satellite



The power flux density is –152 dBW/m^2/Hz. We have to take into account a 10 % activity factor, which is equivalent to –162 dBW/m^2/Hz, since it is supposed that all the transmitters are in operation all at the same time. It is assumed that not all the land mobile transmitters are active at the same time.

In the band 390-395 MHz, it is equivalent to a 162 – 145 = 17 dB positive margin.

Due to the filtering pattern, it can be seen that all unwanted emissions can be eliminated taking into the deployment/activity factor hypothesis used in this simulation.

6.4.6.3 Impact on the GSO satellites

Using the same deployment model as for the MEO, the impact of the GSO is as follows.

The power flux density is –167 dBW/m^2/Hz. We have to take into account a 10 % activity factor, which is equivalent to –177 dBW/m^2/Hz, since it is supposed that all the transmitters are in operation all at the same time.

For the band 390 to 395 MHz, it is equivalent to a 177 – 161 = 16 dB positive margin.

6.5 Impact of mobile service in operation within the band 403 to 420 MHz in China

The following analysis studies the impact of the land mobile deployment in China for the frequency band 403-420 MHz on the LEO satellites.

The technical characteristics and the deployment information are based on the liaison statement from WP 5A.

According to information from WP 5A, it is proposed to use the following set of typical mobile/base stations characteristics for a bandwidth of 12.5 kHz, representative in China:

- frequency band 403~406 MHz, 406.1~406.5 MHz, 409.5~409.75 MHz, 409.9875~423.5 MHz;
- transmit power 20 dBW (e.i.r.p.) for base stations;
- transmit power 0 dBW (e.i.r.p.) for mobile stations.

It is to be noted that the characteristics of this deployment are the less stringent than those detailed in terms of output power, antenna gain and density. Due to the realistic deployment in China, the number of stations in the band 405.9-406 MHz and 406.1-406.2 MHz, is much less than the other bands. For the consideration of worst case, the same value of deployment density is used for assessment analysis in all operation bands.

In addition to these deployment characteristics, it is to be mentioned that the mobile networks generally use vertical or horizontal polarizations and the SARSAT antenna is RHCP (Right Hand Circular Polarization). Therefore, the simulation considers the consequent losses (3 dB typical between circular versus vertical/horizontal), plus 1.6 dB attenuation of feeder losses.

6.5.1 Impact of mobile service in operation from 403 to 420 MHz

An activity factor of 10% is actually applied to the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time. Due to the calculation, the resulting pdf is –165 dBW/m^2/Hz. Using the maximum permissible levels of interference measured on the SARP instrument (LEO space component), the following corresponding margins are shown as below:

For the band 403-405 MHz, it is equivalent to a 165 – 131 = 34 dB positive margin[3].

For the band 405-405.9 MHz, it is equivalent to a 165 – 161= 4 dB positive margin.

For the band 405.9-406 MHz, it is equivalent to a 196 – 165 = 31 dB negative margin[4].

For the band 406.1-406.2 MHz, it is equivalent to a 196 – 165 = 31 dB negative margin.

For the band 406.2-406.5 MHz, it is equivalent to a 165 – 161= 4 dB positive margin.

For the band 409.5-409.75 MHz, it is equivalent to a 165 – 131= 34 dB positive margin.

For the band 409.9875-411 MHz, it is equivalent to a 165 – 131= 34 dB positive margin.

For the band 411-420 MHz, it is equivalent to a 165 – 121= 44 dB positive margin.

Due to the shape of the filtering pattern, it can be seen that interference levels in the frequency band 405.9-406 MHz and 406.1-406.2 MHz provide a significant amount of noise that will be detrimental to the reception of distress signals in the 406-406.1 MHz frequency band. In the other frequency bands, the filtering pattern is sharp enough to eliminate all the out of band emissions.

In particular, for the frequency band 406.5-409.5 MHz, the impact of the land mobile deployment in China on the SARP instruments on board the LEO satellites is as follows.

The technical characteristics and the deployment information are based on the liaison statement from WP 5A. According to information from WP 5A, it is proposed to use the following set of typical mobile/base stations characteristics for a bandwidth of 250 kHz, representative in China:

– transmit power 0 dBW (e.i.r.p.) for base stations;

It is to be noted that the license is only required for the base stations, furthermore, the deployment information of mobile stations are not considered in this contribution.

In addition to these deployment characteristics, it is to be mentioned that the mobile networks generally use vertical or horizontal polarizations and the SARSAT antenna is RHCP (Right Hand Circular Polarization). Therefore, the simulation considers the consequent losses (3 dB typical between circular versus vertical/horizontal), plus 1.6 dB attenuation of feeder losses.

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[3] A positive margin means that the pfd received on board the satellite is below the maximum permissible level of interference.

[4] A negative margin means that the pfd received on board the satellite exceeds the maximum permissible level of interference.

An activity factor of 10% is actually applied to the corresponding results since it is assumed that not all the land mobile transmitters are active at the same time. Due to the calculation, the resulting pdf is –179 dBW/m^2/Hz. Using the maximum permissible levels of interference measured on the SARP instrument (LEO space component), the following corresponding margins are shown as below:

For the band 406.5-407 MHz, it is equivalent to a 179 – 161= 18 dB positive margin.

For the band 407-409.5 MHz, it is equivalent to a 179 – 131= 48 dB positive margin.

Due to the shape of the filtering pattern, it can be seen that interference levels in the frequency band 406.5-407 MHz and 407.1-409.5 MHz is lower than the Maximum permissible interference level of LEO.

6.6 Effect of increased land mobile system deployment in the 406.1–420 MHz band on the Cospas-Sarsat systems in Region 2

The maximum spectral power flux density levels produced by systems operating in bands adjacent to the 406-406.1 MHz band that the LEOSAR and MEOSAR (Galileo) instruments can tolerate are:

LEOSAR

–196.6 dBW/m²·Hz	for	406.1–406.2 MHz, and
–161.6 dBW/m²·Hz	for	406.2-407 MHz

MEOSAR (Galileo)

–165.5 dBW/m²·Hz	for	406.1–407.05 MHz, and
–157.5 dBW/m²·Hz	for	407.05–420 MHz

MEOSAR (GLONASS)

–202.2 dBW/m²·Hz	for	406.1–407.05 MHz, and
–175.2 dBW/m²·Hz	for	407.05–410.05 MHz

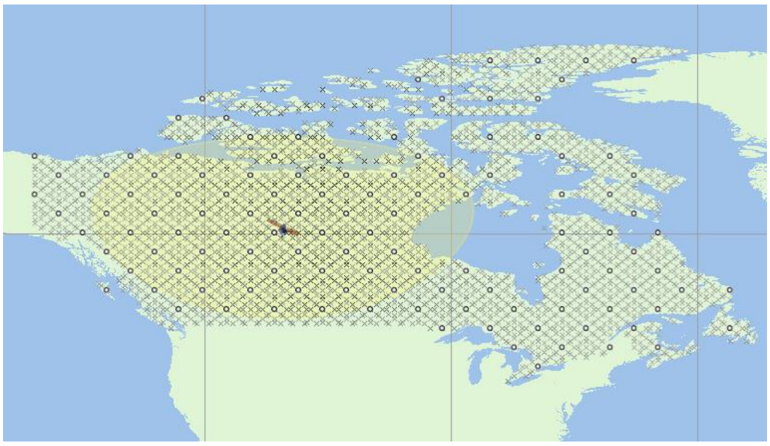
With these levels, the margin to protect the Cospas-Sarsat system against potential interference in a specific frequency range can be derived. A negative margin means that the interference level is above the maximum permissible level.

Eighty percent (80%) of Canada's population is within 120 km of the Canada – United States Border. Deployment of stations within the 406.1-420 MHz band also follows this trend (i.e. there is dense deployment of stations within 120 km of the border). However, since this is spread-out along the Canada-United States border and Canada's population in large population centres is much less than those in some of the CEPT countries, the deployment density for land mobile and fixed stations in Canada is less than the density for land mobile networks in CEPT countries. In Canada, the 406.1-420 MHz band is also popular for natural resource users (e.g. forestry, oil and gas) since the band has favourable propagation characteristics, equipment is cost effective and suitable for a variety of applications such as dispatching and diverting personnel or work vehicles, coordinating the activities of workers and machines on location, or remotely monitoring and controlling equipment. Consequently, there is also a dense deployment of land mobile and fixed stations in areas that draw upon Canada's natural resources. (These areas are beyond the Canada-United States border and are generally, in the provinces of British Columbia, Alberta, Ontario, Quebec, and New Brunswick).

For the purpose of the simulation, a grid of 122 land mobile base stations and 3 096 mobile stations were created in Canada (Fig. 6-26). This deployment scenario is assumed to be the baseline level representing a hypothetical deployment scenario. As noted above, it is not indicative of current deployment of Canadian stations in the 406.1-420 MHz band. However, typical Canadian system characteristics were used and aligned with the typical parameters in § 5.2.3.

FIGURE 6-26

Distribution of land mobile stations for LEOSAR simulation



Given the uncertainties relative to the possible global average growth rate for land mobile systems at the time of the simulation, an assumption consisting in a 20% increase of land mobile base station deployment and a 50% increase of mobile station from the assumed baseline (which would generate more than 1 500 mobile stations in addition to the existing ones for the Canadian scenario), was made for the purpose of the LEOSAR and MEOSAR simulations to investigate the possible future impact of a land mobile base and mobile stations growth on LEOSAR and MEOSAR over their life time. This growth rate was higher than the Canadian statistics for the past 12 years and may not be indicative of future Canadian land mobile deployments in the 406.1–420 MHz band. However, according to recent industry forecasts, land mobile systems will experience a significant growth in the upcoming years in North and South Americas as the shipment of TETRA terminals (which include terminals that operate in the 400, 700 and 800 MHz range) to North America alone is expected to be more than double from 2014 to 2019 with more than 30,000 units[5].

Since the MEOSAR has a significantly larger footprint, the MEOSAR simulation included 1 450 land mobile base stations in the remaining parts of the Americas as a baseline deployment in addition to the baseline deployment in Canada. Two additional simulations were done to investigate the effect of increased deployment in North America for the MEOSAR case. The first of these additional simulations only investigated increase of deployment in Canada. In the second simulation, over 3 800 handheld mobiles were added to the United States, which was assigned only mobile base stations in the first additional simulation. It should be noted again that this deployment and growth rate scenario are estimations which may not represent existing or future growth rates and deployment in the United States or other countries in Region 2. The simulation also assumes that radio characteristics are the same for all land mobile stations and handheld which may not be representative of mobile stations currently used in the United States.

6.6.1 Station distribution for LEOSAR simulation

Land mobile base station and mobile station system characteristics similar to § 5.2.3 were used in the simulation. In the frequency range between 406.1-407 MHz, the ERP of the base stations was assumed to be between 8–16 dBW. For mobile stations, the ERP range was assumed to be between 5–7 dBW for handheld and 10–15 dBW for vehicle stations. The ERP of each station was randomly generated for each type of station using a uniform distribution. The land mobile base stations and mobile stations were evenly distributed across Canada on a grid. A baseline deployment of 122 base stations and 3 096 mobile stations were generated in the simulation. The base stations are distributed

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[5] http://www.tetratoday.com/news/predicted-growth-in-tetra-by-ihs-ahead-of-iwce-2015.

evenly at a distance of 300 km, and the mobile stations are separated at a distance of 75 km for handheld and 100 km for vehicle mobile stations. All antennae are oriented at 0° elevation. This deployment scenario was used as the starting point for this study.

6.6.2 Station distribution for MEOSAR simulation

For the case of MEOSAR, 1 450 additional base stations using the same system characteristics were generated for the remaining part of the Americas (Fig. 6-27). The base stations have a separation distance of 150 km, similar to the distribution used in § 6.4.1.2. Since the deployment of land mobile stations in Europe was not considered in this study, no station was generated for Europe which would become visible to the MEOSAR at certain point in the simulation.

FIGURE 6-27

Distribution of land mobile stations for MEOSAR simulation

6.6.3 Results

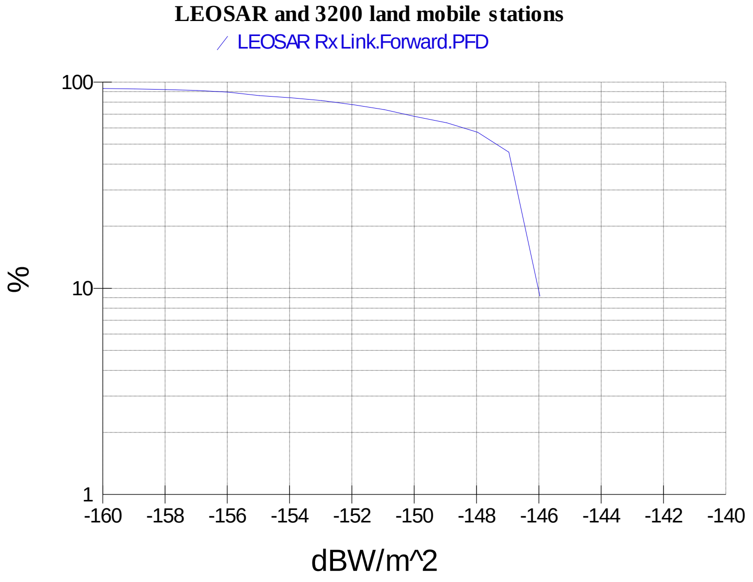
6.6.3.1 LEOSAR Results

The simulation result for LEOSAR is shown in Fig. 6-28 below. The maximum spectral power flux density (spfd) level is at –146 dBW/m²·Hz. Using a 10% active factor as in § 6.4.1.1, the maximum spfd level becomes –156 dBW/m²·Hz. Therefore, the margin to meet the maximum permissible level of interference is:

406.1–406.2 MHz: –196.6 + 156 = –40.6 dB

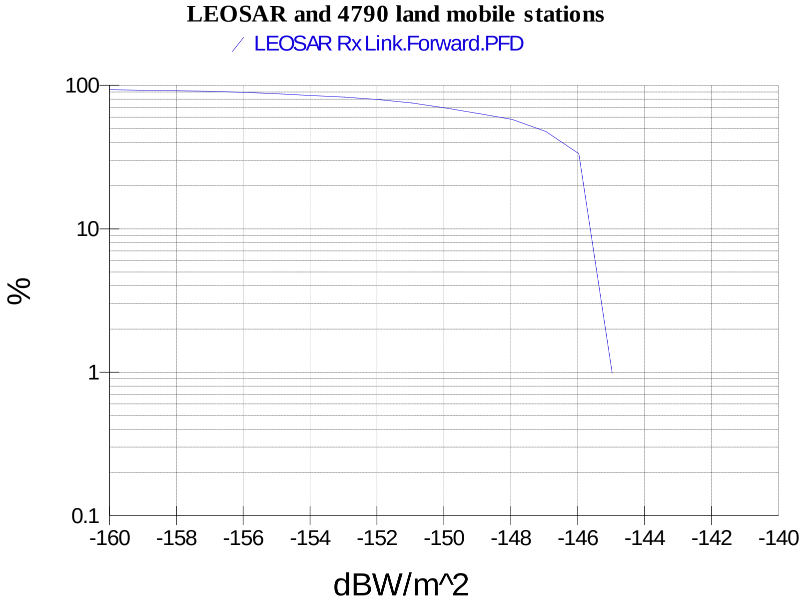
406.2–407 MHz: –161.6 + 156 = –5.6 dB

FIGURE 6-28



The result shows that in the 406.1–406.2 MHz range, the emissions from land mobile stations as deployed in the simulation, are highly likely to exceed the maximum permissible level of interference. In the 406.2-407 MHz range, the land mobile stations as deployed in the simulation are also likely to produce out-of-band emissions that exceed the maximum level, but at a much smaller The figures show the result of increased deployment of land mobile stations.

FIGURE 6-29



The result shows that increasing the number of base stations by 20% and mobile stations by 50% will increase the maximum permissible level of interference by at least 1 dB. Since LEOSAR has a small footprint, the spfd it will experience depends on the density of the land mobile stations in the location visible to the LEOSAR. In areas where the deployment density is higher, an increase in stations may generate more impact to the LEOSAR. With the negative margins shown above, increasing the number of land mobile stations will only further degrade the performance of the LEOSAR SARP processor.

6.6.3.2 MEOSAR (Galileo) results

The simulation result for MEOSAR GALILEO is shown in Fig. 6-30 below. The maximum spfd level is at –162 dBW/m²·Hz. By taking a 10% active factor, the maximum spfd level becomes –172 dBW/m²·Hz. Therefore, the margin to meet the maximum permissible level of interference is:

406.1–407.05 MHz: –165.5 + 172 = 6.5 dB

407.05–420 MHz: –157.5 + 172 = 14.5 dB

The positive numbers indicate that in 406.1–420 MHz range, the land mobile stations as deployed in the simulation are not likely to cause unwanted emissions to the MEOSAR.

FIGURE 6-30

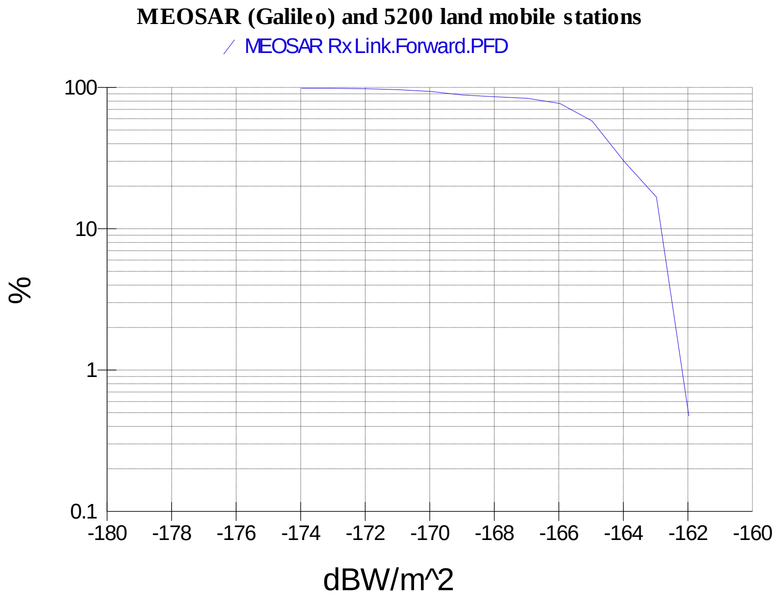


Figure 6-31 shows the result of increased deployment of land mobile stations in Canada only. Figure 6-32 shows the results of having additional 3 800 handheld mobile stations in the United States.

FIGURE 6-31

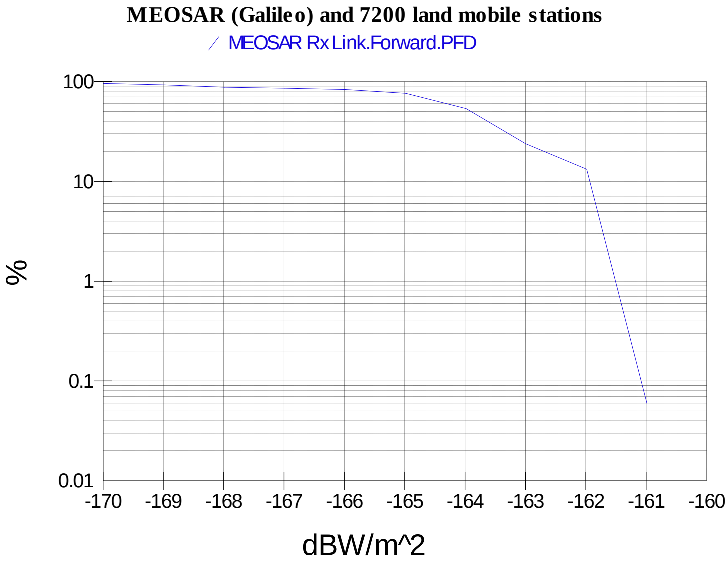
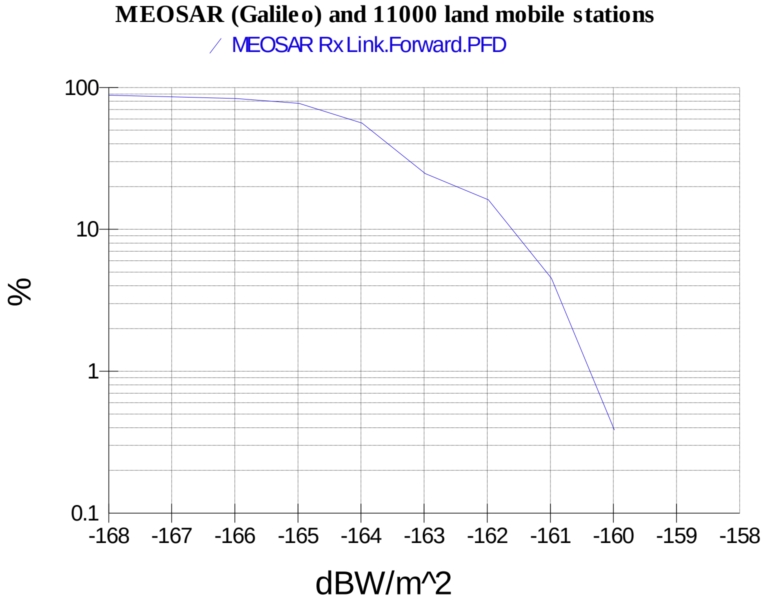


FIGURE 6-32



The simulation result for GLONASS is shown in Fig. 6-33 below. The maximum spfd level is at −161 dBW/m²·Hz. By taking a 10% active factor, the maximum spfd level becomes –171 dBW/m²·Hz. Therefore, the margin to meet the maximum permissible level of interference is:

406.1-407.05 MHz:	–202.2 + 171 = –31.2 dB
407.05-410.05 MHz:	–175.2 + 171 = –4.2 dB

The negative numbers indicate that in 406.1-410.05 MHz range, the land mobile stations as deployed in the simulation are likely to cause unwanted emissions to the GLONASS system. The large negative margin also indicates that GLONASS is highly susceptible to out-of-band interference in the range 406.1-407.05 MHz and to a lesser extent to the range 407.05-410.05 MHz.

FIGURE 6-33 (GLONASS)

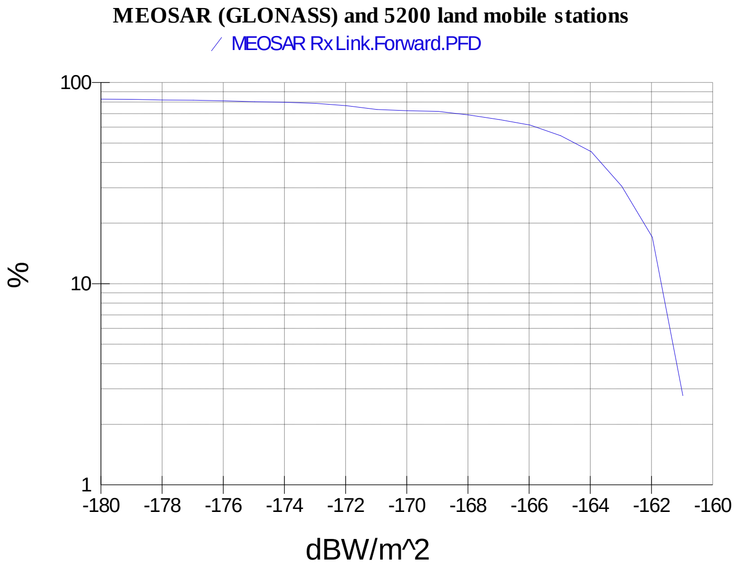


Figure 6-34 shows the result of increased deployment of land mobile stations in Canada only. Figure 6-35 shows the result of having additional 3800 handheld mobile stations in the United States of America.

FIGURE 6-34 (GLONASS)

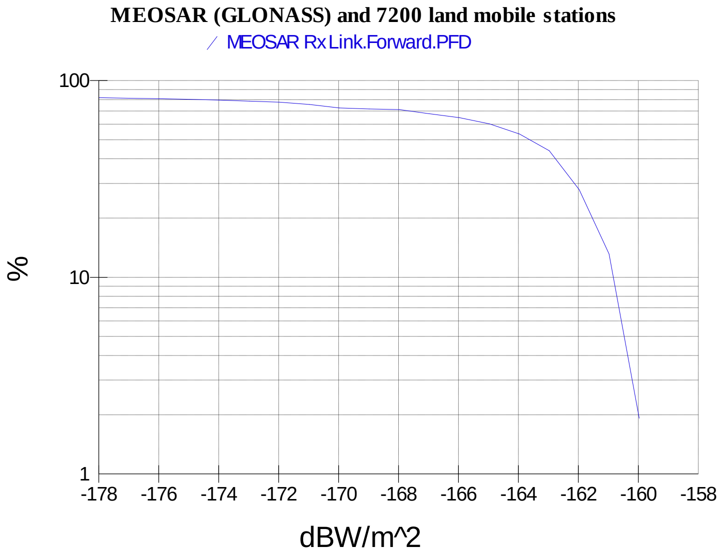
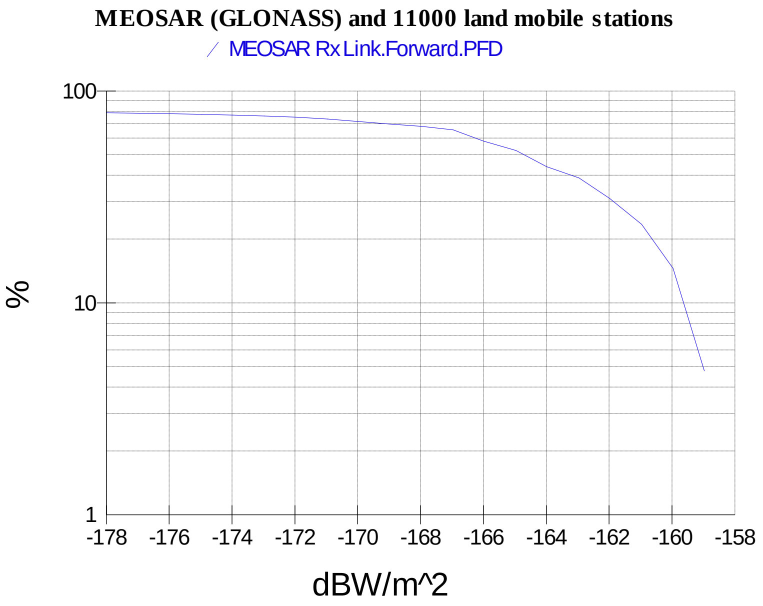


FIGURE 6-35



Similar to LEOSAR, in both MEOSAR cases, increasing number of land mobile base stations and mobile stations by 20% and 50% will increase the maximum permissible level of interference by at least 1 dB. By including 3 800 handheld mobile stations in the United States, the maximum permissible level of interference will increase by another 1 dB. If mobile stations in the remaining part of the Americas were also considered, the positive margin for GALILEO the 406.1-407.05 MHz band may eventually disappear. System-wide, emissions in the 406.1 to 420 MHz are of concern to current Cospas-Sarsat GLONASS payloads particularly for the 406.1-407.05 MHz range. Given their high susceptibility to out-of band emission, it is anticipated that the design of future GLONASS space payloads should be enhanced in the future to make them less susceptible to these emissions.

6.6.4 Summary

The effect of increased land mobile system deployment in the 406.1-420 MHz band on the Cospas-Sarsat systems was studied by assuming land mobile system characteristics from Canada. Although the Canadian land mobile system characteristics and hypothetical baseline deployment and growth rate scenario may not be fully representative of other Region 2 countries, this study nevertheless provides an estimation of the impact of the potential increase of interference levels in the 406-406.1 MHz band resulting from possible deployment scenarios of land mobile systems in Region 2. This study finds the following:

- In general large deployment of mobile stations operating in the vicinity of the 406-406.1 MHz band within a satellite footprint could significantly impact some Cospas-Sarsat satellite payloads.
- Emissions from systems operating at frequencies closer to the 406-406.1 MHz band produce a larger impact to the Cospas-Sarsat satellite payloads.
- LEOSAR would receive unwanted emissions in excess of the maximum permissible level from land mobile stations as simulated (i.e. uniform distribution with 122 base stations and 3,096 mobiles) operating in the 406.1–407 MHz band. Stations in the 406.1–406.2 MHz band in this simulation were most likely to exceed the maximum permissible levels.

- Increased deployment of the land mobile stations in the 406.1-420 MHz range may cause performance degradation for the LEOSAR SARP processor.
- Depending on the constellation, MEOSAR space payloads could also receive unwanted emissions in excess of their permissible level from land mobile stations within their larger footprints. Mobile stations operating within the 406.1-407.05 MHz band are most likely to exceed the maximum permissible levels of the current GLONASS space payloads.

7 Overall summary

7.1 EESS (Earth-to-space) service (platforms data collection)

Data collection transmissions operate in the band from 401 to 403 MHz. Argos transmissions are intended for Low Earth Orbiting satellites and have low e.i.r.p values. The data collection transmissions intended for geostationary satellites have higher e.i.r.p. values and have directional antennas directly aimed at geostationary satellites that are receiving SAR transmissions. The analysis concluded that the aggregate data collection systems do not produce enough power in the SAR receivers of the LEO, GEO or MEO satellites to exceed their respective wide-band interference thresholds. The power contributed to the LEO SAR receivers is only 0.01564% of the threshold value. The power contributed to the threshold of the GEO receivers is about 0.673% of wide-band interference threshold. The majority of this power is contributed by the earth platforms that are aimed directly at the satellite. The results are significantly different between the two MEO satellites. The report calculated that the data collection platforms only contribute up to 1.84% of the wide-band interference threshold for the Galileo satellite. The data collection platforms contribute 93.48% of the wide-band interference value of the GLONASS receiver, which has a higher sensitivity. In addition it should be noted that if the entire frequency band for which the threshold interference density value is applied is taken into account, then the interference percentage of the total allowable level will be the following: for Galileo – 0.258% of the threshold power value in the frequency band 390-405.05 MHz; for GLONASS – 0.00068% of the threshold power value in the frequency band 390-402.05 MHz and 10.91% of the threshold power value in the frequency band 402.05-405.05 MHz. However these values are valid for the case when there is no interference from other systems operating in these frequency bands.

The data collection systems do not contribute to the narrow-band interference threshold levels.

7.2 Meteorological Aids

The interference contribution of radiosondes in the meteorological aids service is on the order of 0.001% of the wide-band threshold. The spurious emission levels are far below the narrow-band interference threshold. The Doppler shift of the radiosonde signal due to the movement of the LEO satellite is not enough to cause the radiosonde signal to appear in the 406.0 to 406.1 MHz range. Their contribution to the interference problem with the search and rescue receivers is minimal.

7.3 Land mobile service

The impact of the operation of the mobile systems has been assessed through simulations using realistic deployment within the CEPT countries, China and Canada. The results show that the LEO component experiences interference due to mobile deployment from 405.9 to 406 MHz, 406.1 to 407 MHz, while the MEO component receives interference up to 410 MHz depending on the constellation.

The geostationary component shows severe interference due to mobile deployment within the band 406.1 to 406.2 MHz, in particular within CEPT countries. Concerning the impact of spurious emissions on the band 406-406.1 MHz, no impact has been demonstrated.

7.4 Overall interference

The aggregate interference to SAR receivers is a combination of interference power from all systems. The power levels for the Data Collection System and Meteorological Aids systems are relatively low except for certain times when synoptic measurements are being performed. The mobile services are more evenly spread in time and in geographical area, thus they would contribute a more even background noise to the SAR receivers. These mobile systems mainly contribute to the exceeding of the interference threshold and should be the focus of further consideration. The following paragraph proposes further mitigation techniques.

8 Considered interference mitigation measures

8.1 List of mitigation measures concerning the radiosondes in operation below 406 MHz

Concerning radiosondes (also called metaids), it is recognized that they are not a significant contributor to the broadband interference levels to COSPAS-SARSAT receivers. However, it is acknowledged that a frequency drift of older less stable radiosondes could be a cause of narrow-band interference to the SAR receiver for radiosondes operating above 405 MHz.

It is therefore proposed that administrations have to take into account frequency drift characteristics of radiosondes when selecting their operating frequencies above 405 MHz to avoid transmitting in the 406-406.1 MHz frequency band.

8.2 List of mitigation measures concerning the mobile services in operation above 406.1 MHz

Given the results of the studies and spectrum monitoring program, some sort of mitigation may be required. The following list, though, not exhaustive, identifies some mitigation measures that could be used alone or in combination to protect the Cospas-Sarsat system. Their feasibility to implement and be effective is discussed below.

1) Space receiver redesign

LEOSAR, GEOSAR and MEOSAR systems space receivers could be designed with improved filters. This will be accomplished in the future generation of satellites, likely in one or more decades.

2) Channel coding

The use of more efficient forward error-correction (FEC) in the data transmission from the beacons is a possible mitigation technique. However, this technique would imply longer distress messages therefore leading to higher collision rates, and decreasing the overall system capacity.

Therefore, alternative more efficient FEC is not a viable mitigation technique for combating interference and will not improve the operation of current and future MSS systems.

3) Guard bands

This mitigation technique is to establish guard bands just above and below the frequency band 406-406.1 MHz, and this mitigation technique is likely to improve the protection of the space receivers in the 406-406.1 MHz. The implementation of guard bands would require regulatory measures which should apply only to new frequency assignments, not to existing ones, under the fixed and mobile services. According to RR No. **1.18**, an assignment (of a radio frequency or radio frequency channel) is an authorization given by an administration for a radio station to use a radio frequency or radio frequency channel under specified conditions. It is recognized that a too small guard band may not ensure the protection of the 406-406.1 MHz from unwanted emissions, while a too large of a guard band may not be feasible to be implemented by administrations. Such a mechanism may be beneficial to MSS systems on a long-term basis, and administrations are invited to assign new stations/systems to mobile and fixed services to frequency bands outside this guard band.

To be most effective, the implementation of the guard band should also be monitored to ensure its compliance. This could be done for example by extending the frequency range of the current 406-406.1 MHz space monitoring program to include the new guard band range.

4) Reduction of the e.i.r.p. levels radiated by terrestrial systems towards Space

Reduction in e.i.r.p. to space from adjacent band systems may, in some limited cases, be another measure to protect Cospas-Sarsat. When possible and, with respect to terrestrial systems, the method would be to adjust antennae, or to reduce the output power at the antenna port. However, taking into account that thousands of terrestrial systems are already in use in adjacent bands to 406-406.1 MHz it is not realistic to expect that the operators/users of these systems would/could modify their existing networks. Thus this mitigation measure is not feasible due to the high number of existing systems operating in the 406.1-410 MHz, but might be considered for existing systems operating over a very limited portion of that band such as 406.1-406.2 MHz in geographical locations where terrestrial deployment is low. Depending on the design of adjusted antenna pattern, the Cospas-Sarsat system may not entirely benefit from the e.i.r.p. reduction, since this mitigation technique may not be applied in every direction. Some MSS systems may still receive interfering signals from other directions that do not take advantage of antenna pattern improvement.

5) Additional regulatory measures on adjacent bands

Mobile systems in the adjacent bands may be able to operate in other mobile channels nearby but further away from the 406-406.1 MHz band. Therefore, there may be some regulatory measures that could be further explored. These measures could include voluntary temporary measures, such as encouraging administrations to authorize new stations starting from channels that are further away from the band edges of the 406-406.1 MHz band or reducing the output power at the antenna port of mobile systems, to use mobile antenna patterns having reduced antenna gains at high elevation angles, or to more permanent and stable measures through regulation.

8.3 Calculation of the guard band above 406.1 MHz

The following table provides the potential increase of noise due to the characteristics of the on board filtering for the various types of payloads and of the results of the compatibility analysis conducted. These analyses were conducted using an activity factor of 10%, since it is assumed that not all the land mobile transmitters are active at the same time.

For the sake of having a complete picture, the overall increase of noise is also provided for an activity factor 50%, even if it is considered to be a high factor. Table 8-1 is based on assumptions that apply to CEPT countries.

TABLE 8-1

Increase of noise within the 406-406.1 MHz band in dB

Case of the LEO satellite payloads	**Activity factor 50%**	**Activity factor 10%**
0 kHz guard band	50.1	43.6
406.1-406.15 MHz guard band: 50 kHz	46.6	40.6
406.1-406.2 MHz guard band: 100 kHz	11.9	5.9
406.1-406.3 MHz guard band: 200 kHz	11.3	5.5
406.1-406.7 MHz guard band: 900 kHz	0.1	0.0
Case of the GSO MSG satellite payloads	**Activity factor 50%**	**Activity factor 10%**
0 kHz guard band	26.3	19.3
406.1-406.15 MHz guard band: 50 kHz	20.4	13.6
406.1-406.2 MHz guard band: 100 kHz	1.1	0.2
406.1-406.3 MHz guard band: 200 kHz	0.7	0.1
406.1-406.7 MHz guard band: 900 kHz	0.2	0.0
Case of the MEO GALILEO satellite payloads	**Activity factor 50%**	**Activity factor 10%**
0 kHz guard band	2.2	0.5
406.1-406.15 MHz guard band: 50 kHz	2.1	0.5
406.1-406.2 MHz guard band: 100 kHz	2	0.5
406.1-406.3 MHz guard band: 200 kHz	1.9	0.4
406.1-406.7 MHz guard band: 900 kHz	0.4	0.1
Case of the MEO GLONASS satellite payloads	**Activity factor 50%**	**Activity factor 10%**
0 kHz guard band	36.2	29.2
406.1-406.15 MHz guard band: 50 kHz	36	29
406.1-406.2 MHz guard band: 100 kHz	35.7	28.7
406.1-406.3 MHz guard band: 200 kHz	35.2	28.2
406.1-406.7 MHz guard band: 900 kHz	9.7	4.2

These above calculations show a guard band of 100 kHz (406.1-406.2 MHz) would be suitable for frequencies higher than 406.1 MHz in order to adequately protect the 406-406.1 MHz frequency band. A 406.1-406.2 MHz guard band (100 kHz bandwidth) could provide a significantly improved protection to the Cospas-Sarsat payloads on-board various satellites against emissions from radio systems studied in this Report, except for the GLONASS satellite payloads.

8.3 Calculation of the guard band below 406 MHz

The computations performed over China (see § 6.5) clearly show that there is also a need for a guard band of 100 kHz just below 406 MHz.

Observations (as shown from the monitoring activities of the 405.9-406.2 MHz band in Fig. A1-31 of Annex 1) made through GLONASS, GPS and GALILEO have also shown that strong interferers exist below 406 MHz. Examples in Annex 1 illustrate how adjacent-channel emissions can increase the effective noise floor for beacon transmissions within the 406 MHz band. These adjacent-channel emissions, although having lower amplitude than at frequencies higher than 406.1 MHz, can have a harmful impact on the reception of effective distress beacons in the 406 MHz band.

Therefore, a guard band of 100 kHz (405.9-406 MHz) would be desirable for frequencies lower than 406 MHz in order to adequately protect the 406-406.1 MHz frequency band.

9 Conclusion

Detailed studies have been undertaken to examine the impact of radio services in operation within the frequency bands 390-406 MHz and within the upper adjacent bands 406.1-420 MHz on the MSS systems within the 406-406.1 MHz band. These studies clearly demonstrated the negative impacts to the Cospas-Sarsat space payloads operating in the 406-406.1 MHz band resulting from the additional deployment of land and mobiles services operating in adjacent bands, as emissions from these systems would exceed the maximum permissible level of interference.

Given the severity of the issue and the growth of land mobile systems operating in the UHF band (including the 400 MHz band) forecasted by the land mobile industry, the following mitigation measures described in § 8 should be considered.

1. The implementation of guard bands of 100 kHz above 406.1 MHz and below 406 MHz improves the protection of the space receivers operating in the 406-406.1 MHz. Guard bands below 406 MHz and above 406.1 MHz would potentially freeze the level of emissions most detrimental to the Cospas-Sarsat systems. This mitigation technique only applies when making new frequency assignments.
2. Whenever practical, encouragement for Administrations deploying new fixed and mobile systems operating near the 406-406.1 MHz to reduce the e.i.r.p. directed towards space, thereby reducing unwanted emissions to Cospas-Sarsat systems.
3. Encouragement for Administrations deploying new systems operating near the 406-406.1 MHz band to consider system deployment in priority to channels with greater frequency separation from the 406-406.1 MHz.
4. Request that Administrations providing Cospas-Sarsat payloads ensure that their payloads are, as much as possible, immune to out-of-band emission as it may not be practically possible to request limitation or freeze of unwanted emissions directed towards Cospas-Sarsat payloads over an extended frequency range on a global basis. This is particularly applicable to some MEOSAR payloads which have low level of permissible emissions over a wide spectrum range.

In addition, administrations need to take into account frequency drift characteristics of radiosondes when selecting their operating frequencies above 405 MHz to avoid transmitting in the 406-406.1 MHz frequency band.

It is also essential to continue to organize monitoring programmes in the frequency band 406-406.1 MHz in order to identify the source of any unauthorized emission in that frequency band, and to organize monitoring programmes on the impact of the unwanted emissions from systems operating in the frequency bands 405.9-406 MHz and 406.1-406.2 MHz on the MSS reception in the frequency band 406-406.1 MHz.

Annex 1

Spectrum monitoring activities regarding the band 406-406.1 MHz

TABLE OF CONTENTS

Page

This Annex provides results from spectrum-monitoring activities undertaken by Canada in response to Resolution **205 (Rev.WRC-12)**. Spectral images are provided that show interference adjacent to the 406-406.1 MHz band that is adversely affecting it, illustrating the need for out-of-band protection criteria.

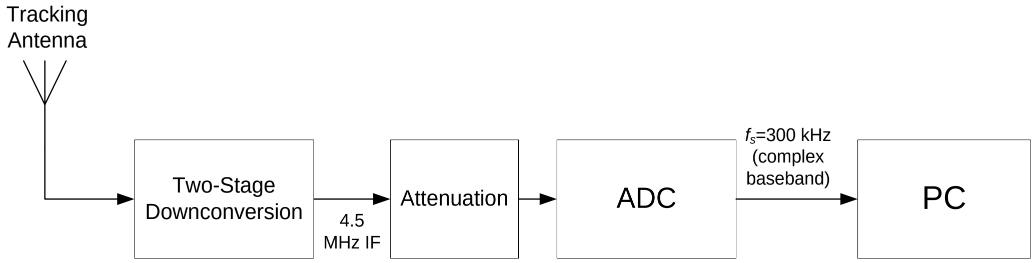
A1.1 Goals, objectives, and description of tests

Knowledge of (i) interference traffic in and around the 406 MHz SAR band (ii) how interference levels vary between different geographical regions, and (iii) where those interference signals originate would be of value in supporting the above initiative. To fully characterize this is a large undertaking. A more modest goal, adopted for the studies reflected below, is to observe the radio spectrum in and around the SAR band to identify some typical cases of interference to illustrate the need for protection criteria. More specifically, this work had the following objectives:

1) investigate differences in interference levels between the Americas and Eurasia;
2) determine approximate (i.e. regional) locations of specific out-of-band interference signals;
3) provide examples of out-of-band interference adversely impacting signal conditions inside the SAR band that potentially impact the detection and location of Cospas-Sarsat distress radio beacons (“beacons”).

FIGURE A1-1

Data collection apparatus (single-channel; up to 4 simultaneous channels possible)



Testing consisted of tracking different satellites (GEO and MEO), down-converting and filtering the downlink signals available at the satellite ground station at the Communications Research Centre (CRC) Canada in Ottawa, Canada, and collecting sampled complex-baseband data characterizing a 300 kHz bandwidth (Fig. A1-1). The data collection software ran on a personal computer (PC) and is part of Spectrum Explorer™, a spectrum-monitoring and analysis software package developed at the Communications Research Centre (CRC) Canada. The satellite footprint images below were all captured from Nova for Windows[6]. Data was gathered from both S-band ("experimental") SAR transponders carried on GPS DASS satellites and L-band ("operational") SAR transponders carried on Galileo and Glonass-K satellites, where the L-band devices will form part of the operational MEOSAR space segment. No correction for Doppler shifts was applied to the collected data, so the frequency offsets relative to 406.0 or 406.1 MHz given below are approximate.

The 406 MHz SAR band was observed via both geostationary-earth-orbit (GEO) and medium-earth-orbit (MEO) satellites carrying SAR transponders as follows:

a) Geostationary Operational Environmental Satellite (GOES)-13 (GOES-E).

This is a GEO satellite whose coverage area ("footprint") is focussed on North and South America but also covers a part of western Europe and much of West Africa.

b) Distress Alerting Satellite System (DASS) BIIRM-1 (PRN17), BIIR-7 (PRN18), BIIR-16M (PRN12), and BIIR-12 (PRN23).

These are MEO satellites comprising part of the GPS constellation.

c) Global Navigation Satellite System (Glonass)-K 1

Glonass-K 1 is the first of this constellation in orbit with a SAR transponder.

The GEO and MEO transponders use different signal formats on the downlink. The GOES-13 downlink signal for SAR is centred on a strong carrier with the 406.0-406.1 MHz band both above and below it, i.e., the 100 kHz of the SAR band appears on one side of the carrier and its mirror image appears on the other (see Fig. A1-2). The collected GEO data is centred on the carrier. The DASS downlink signal for SAR consists of only one replica of the SAR band; the collected data is centred on the midpoint of this 100 kHz band.

Captured data is presented via "Spectrum Graphics," modified spectrograms developed at CRC that show both short-duration signals (e.g. beacon transmissions of approximately 0.5 seconds) and longer-duration signals. For each spectral image below, frequency is on the vertical axis, time is on the horizontal axis, and colour shows relative power (red/yellow is strong, blue/black is weak). The frequency boundaries of the SAR band are denoted by yellow arrows and text labels on the vertical axis ("406.0 MHz" and "406.1 MHz"). Specific times discussed in the text are denoted by yellow

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[6] http://www.nlsa.com/nfw.html.

arrows and text labels (“A”, “B”, or “C”) on the horizontal axis. Small tick marks on the horizontal axis are spaced at 1 hour relative to the start of the original data file. Time references are in universal coordinated time (UTC).

A1.2 Test results and analysis

A1.2.1 GEO Data

Figure A1-2 shows a Spectrum Graphic of the SAR band relayed by GOES-13 for a four-hour period on August 20, 2012 (10:00:01 – 14:00:01 UTC). The downlink carrier is in the centre of the image. The positive replica of the 406 MHz SAR band is below the carrier, with frequency increasing downwards, while the negative replica is above the carrier, with frequency increasing upwards. Again, the regular ticks at the top and bottom of the figure mark off hours, i.e., there is one hour between ticks. The boundaries of the SAR distress band are marked with their uplink frequencies. Figure A1-3 shows the satellite footprint.

In terms of spectral content, the image depicts largely what one would expect from the SAR distress band. The lighter blue regions are the uplink noise floor. The lower half of the band contains short, repetitive bursts of signal spaced approximately 50 seconds apart (this appears more clearly in the detail of Fig. A1-4). These are bursts from Cospas-Sarsat beacons with a burst repetition period of approximately 50 seconds operating within active Cospas-Sarsat channels in the frequency range 406.0-406.05 MHz. The line of signals at roughly 406.022 MHz does not appear to fit this pattern; however, some of the system orbitography beacons assigned to this channel transmit with a period of approximately 30 seconds and the satellite is probably viewing more than one of these system beacons simultaneously during this time interval.

Such beacon traffic is all that should be present in this band. In terms of interference, two signals are apparent.

First are the “s-curves” that cut across the carrier. These have been introduced on the downlink, since they are not “mirrored” around the carrier; the source of these emissions is unknown, but may be due to transmissions from satellites in lower orbits. Second, there are faint signals at approximately 406.05 MHz and 406.025 MHz. The nature and origin of these signals is unknown, but they are certainly not distress beacon transmissions.

FIGURE A1-2

Spectrum Graphic (frequency versus time, power denoted by colour) of the frequency band 406-406.1 MHz relayed by GOES-13 (GEO). The left edge of the image corresponds to August 20, 2012, at 10:00:01 UTC. The Note that the same uplink spectrum appears on both sides of the strong carrier in the centre of the diagram

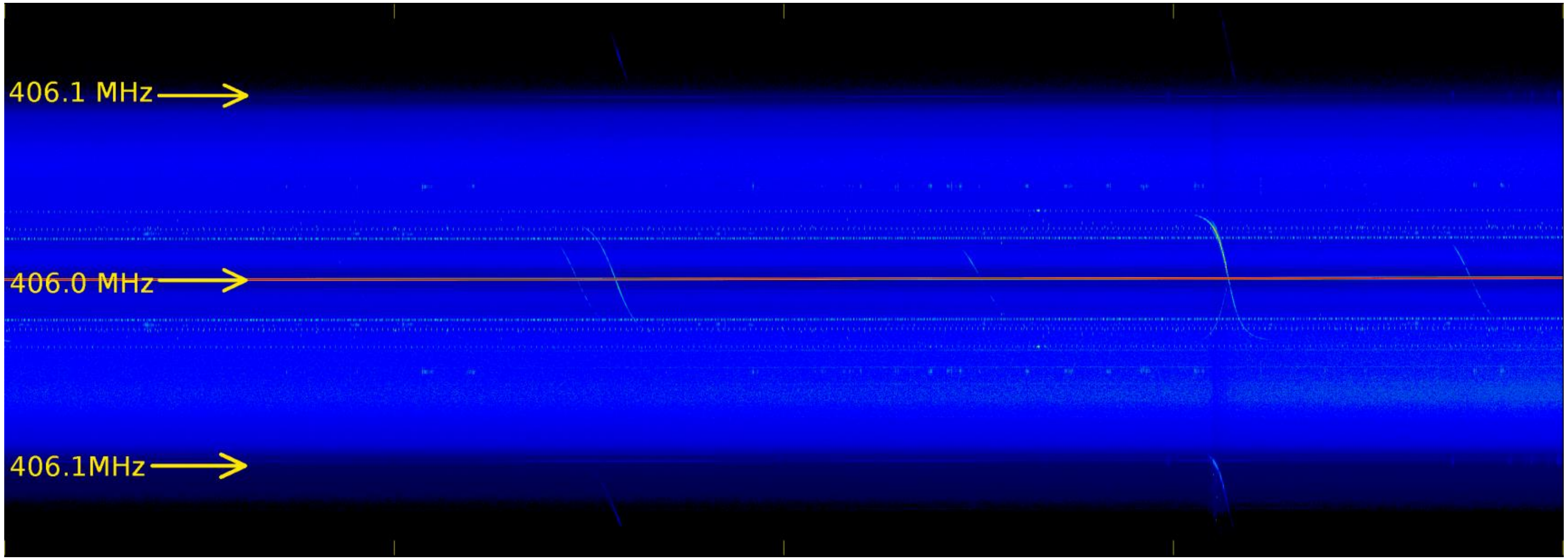


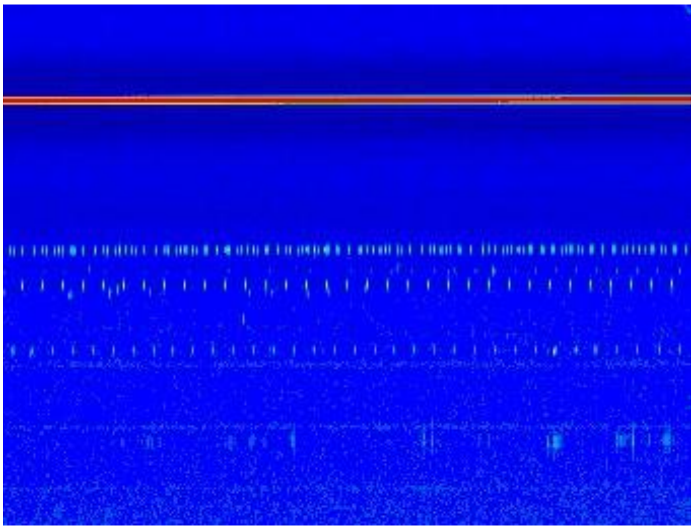
FIGURE A1-3

Satellite footprint of GOES-13 (GEO) to an elevation angle of 0°

1 Sat	GOES 13
Azimuth	178.8°
Elevation	37.7°
Range	37,944.0 km
Height	35,780.0 km
AOS time	Geostat UTC
LOS time	Geostat UTC
Until	05:00:01
Duration	--------
AOS Az.	---
Max El.	---
LOS Az.	---
Visual	Sun
Orbit #	2,288

FIGURE A1-4

Detail of Fig. A1-2 showing Cospas-Sarsat beacon bursts separated by approximately 50 seconds as well as weak interference signals. The left edge of the image corresponds to August 20, 2012, at 12:00:01 UTC. The downlink carrier (in red) corresponds to 406.0 MHz on the uplink



A1.2.2 MEO Data– Spectral activity via DASS

Figure A1-5 shows data obtained via DASS PRN17 for a four-hour period on August 20, 2012 (17:00:05 – 21:00:05 UTC). The characterized bandwidth and hour markers are as for the previous plot. Four specific times (A, B, C, and D) are marked; the satellite footprints for these times are shown in Figs A1-6 to A1-9, respectively. The ground station began tracking PRN17 at time A.

As before, the lighter blue regions are the uplink noise floor. Beacon traffic is apparent in the lower half of the SAR distress band, as expected. The additional signal content is striking.

Numerous strong signal channels that did not appear via GOES-13 are visible throughout the pass above 406.1 MHz. Neither the source of these signals nor why they are not visible via GOES-13

(Fig. A1-2) is clear. Several examples of analogue frequency-modulation (FM) voice are apparent at roughly 406.1, 406.075, and 405.975 MHz. Numerous other intermittent signals are visible below 406.0 MHz. Starting at approximately time B, there is an increase in the noise floor. There is no dramatic change when Europe first comes into view (time C), but around time D interference levels increase noticeably across the band. Figure A1-10 is a detail of Fig. A1-5 showing these spectral “striations”. The horizontal line spectra are roughly symmetric around the strong interferer at 406.0 MHz and appear to be related to it. As well, a known radar interferer in western Russia came into view about 10 minutes before time D and may contribute to these effects.

FIGURE A1-5

Spectrum Graphic frequency versus time, power denoted by colour) of the 406.0-406.1 MHz frequency band relayed by PRN17 (MEO).). The left edge of the image corresponds to August 20, 2012, at 17:00:05 UTC

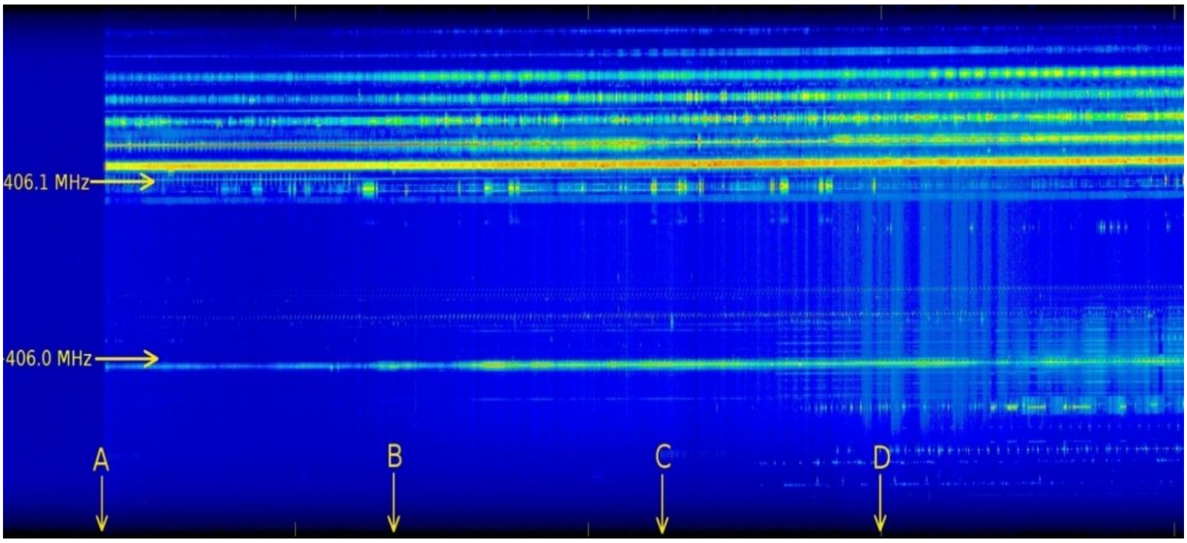
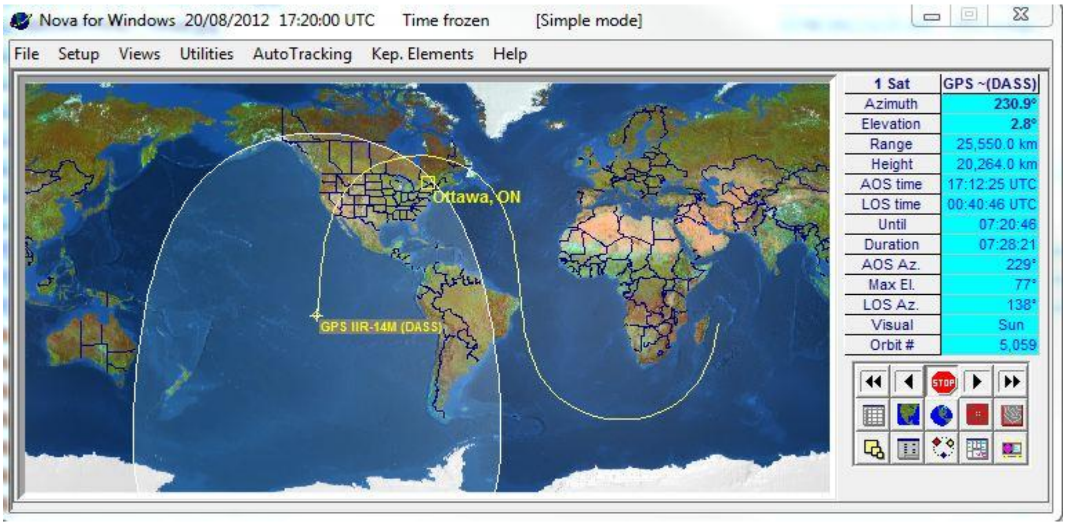


FIGURE A1-6

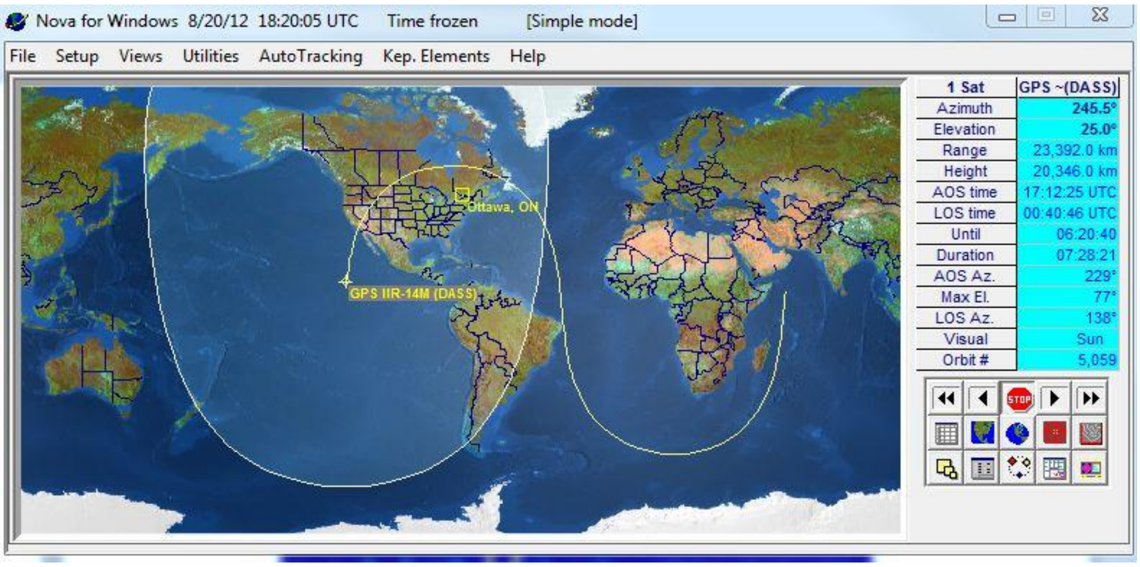
Satellite footprint of PRN17 to an elevation angle of 0° (highlighted) at time A of Fig. A1-5



1 Sat	GPS ~(DASS)
Azimuth	230.9°
Elevation	2.8°
Range	25,550.0 km
Height	20,264.0 km
AOS time	17:12:25 UTC
LOS time	00:40:46 UTC
Until	07:20:46
Duration	07:28:21
AOS Az.	229°
Max El.	77°
LOS Az.	138°
Visual	Sun
Orbit #	5,059

FIGURE A1-7

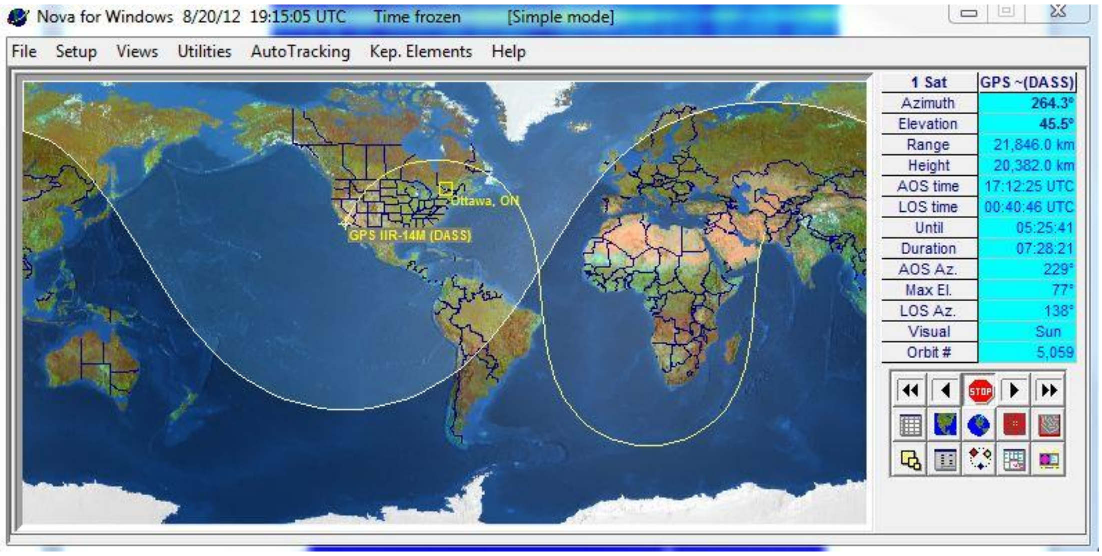
Satellite footprint of PRN17 to an elevation angle of 0° (highlighted) at time B of Fig. A1-5



1 Sat	GPS ~(DASS)
Azimuth	245.5°
Elevation	25.0°
Range	23,392.0 km
Height	20,346.0 km
AOS time	17:12:25 UTC
LOS time	00:40:46 UTC
Until	06:20:40
Duration	07:28:21
AOS Az.	229°
Max El.	77°
LOS Az.	138°
Visual	Sun
Orbit #	5,059

FIGURE A1-8

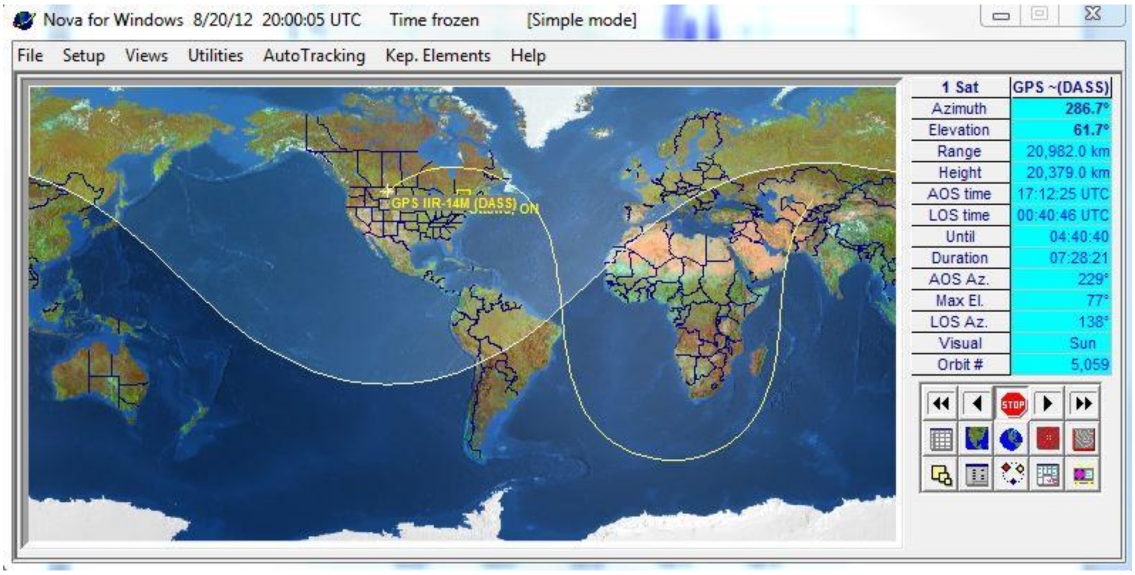
Satellite footprint of PRN17 to an elevation angle of 0° (highlighted) at time C of Fig. A1-5



1 Sat	GPS ~(DASS)
Azimuth	264.3°
Elevation	45.5°
Range	21,846.0 km
Height	20,382.0 km
AOS time	17:12:25 UTC
LOS time	00:40:46 UTC
Until	05:25:41
Duration	07:28:21
AOS Az.	229°
Max El.	77°
LOS Az.	138°
Visual	Sun
Orbit #	5,059

FIGURE A1-9

Satellite footprint of PRN17 to an elevation angle of 0° (highlighted) at time D of Fig. A1-5



1 Sat	GPS ~(DASS)
Azimuth	286.7°
Elevation	61.7°
Range	20,982.0 km
Height	20,379.0 km
AOS time	17:12:25 UTC
LOS time	00:40:46 UTC
Until	04:40:40
Duration	07:28:21
AOS Az.	229°
Max El.	77°
LOS Az.	138°
Visual	Sun
Orbit #	5,059

FIGURE A1-10

Detail of Fig. A1-5 showing beacon burst traffic and interference in and around the SAR band via PRN17. The dashed line is at 406.0 MHz. Time D from Fig. A1-5 is shown (August 20, 2012, at 20:00:05 UTC)

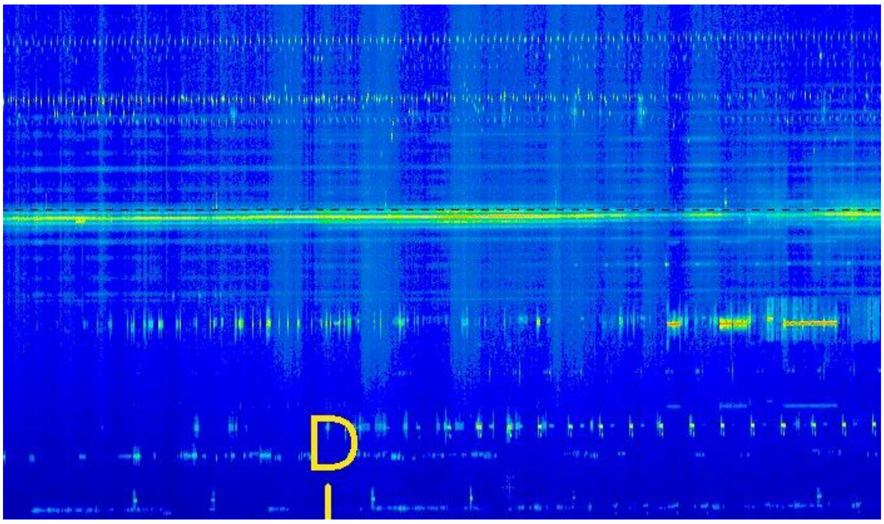


FIGURE A1-11

Power spectrum 406.0-406.1 MHz frequency band relayed by PRN17 (MEO) on August 20, 2012, at 18:00:05 UTC (i.e. 1 hour after the start of the image in Fig. A1-5)

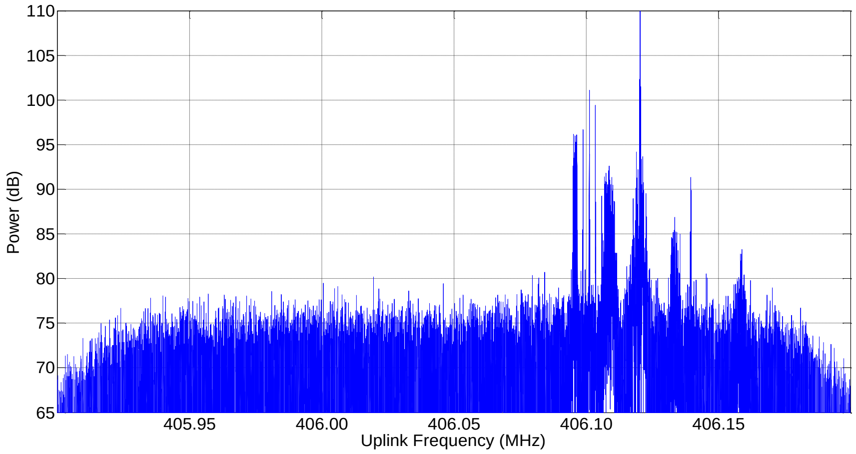
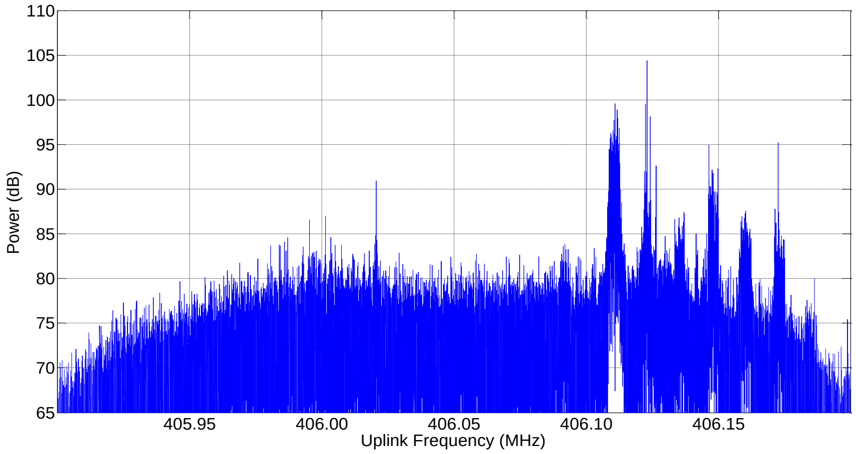


FIGURE A1-12

Power spectrum 406.0-406.1 MHz frequency band relayed by PRN17 (MEO) on August 20, 2012, at 20:00:05 UTC (i.e. at time D, 3 hours after the start of the image in Fig. A1-5)



Figures A1-11 and A1-12 show power spectra (power versus uplink frequency) for two specific times in the range covered by Fig. A1-5. These are instantaneous spectral plots that do not include all of the signal processing used to generate the Spectrum Graphic of Fig. A1-5; however, they are still approximate cross-sections of Fig. A1-5 at the times noted. Figure A1-11 shows the power spectrum at 18:00:05 UTC; 1 hour after data collection began. The strong channels above 406.1 MHz are apparent and, as expected, the SAR band is approximately flat. Figure A1-12 shows the power spectrum at 20:00:05 UTC; 3 hours after data collection began (time D of Fig. A1-5). The small spectral "hump" at 406.0 MHz is the same interferer shown at 406.0 MHz in Fig. A1-5; this interferer is not visible in Fig. A1-11 due to the differences in signal processing already noted. As well, in Fig. A1-12 the noise level across the whole SAR band is approximately 4-5 dB higher than in Fig. A1-11, apparently corresponding to the "striations" shown in Fig. A1-5. This higher noise floor will definitely have a negative impact on distress beacon performance.

Figure A1-13 shows data obtained via DASS PRN18 for a three-hour period on August 21, 2012 (02:00:05 – 05:00:05 UTC). Again, four specific times (A, B, C, and D) are marked; the satellite footprints for these times are shown in Figs A1-14 to A1-17, respectively.

Figure A1-13 shows similarities to Fig. A1-5: the beacon traffic in expected areas; the strong channels above the SAR band; the higher noise floor that seems to be due in part to strong non-beacon signals; and the correlation between higher levels of interference and Eurasia being in view. Some interesting differences are also apparent. Some of the same signals as in Fig. A1-5 are stronger, for example the signal at 406.0 MHz and especially the very strong interferer (likely an FM voice signal) at approximately 405.975 MHz. This latter signal is of particular note because, while it is outside the SAR band, it generates responses from the transponder’s gain control mechanism, pushing down the content of the SAR band. This clearly illustrates that out-of-band signals can adversely affect the 406.0-406.1 MHz band.

FIGURE A1-13

Spectrum Graphic of the 406.0-406.1 MHz frequency band relayed by PRN18 (MEO). The left edge of the image corresponds to August 21, 2012, at 02:00:05 UTC

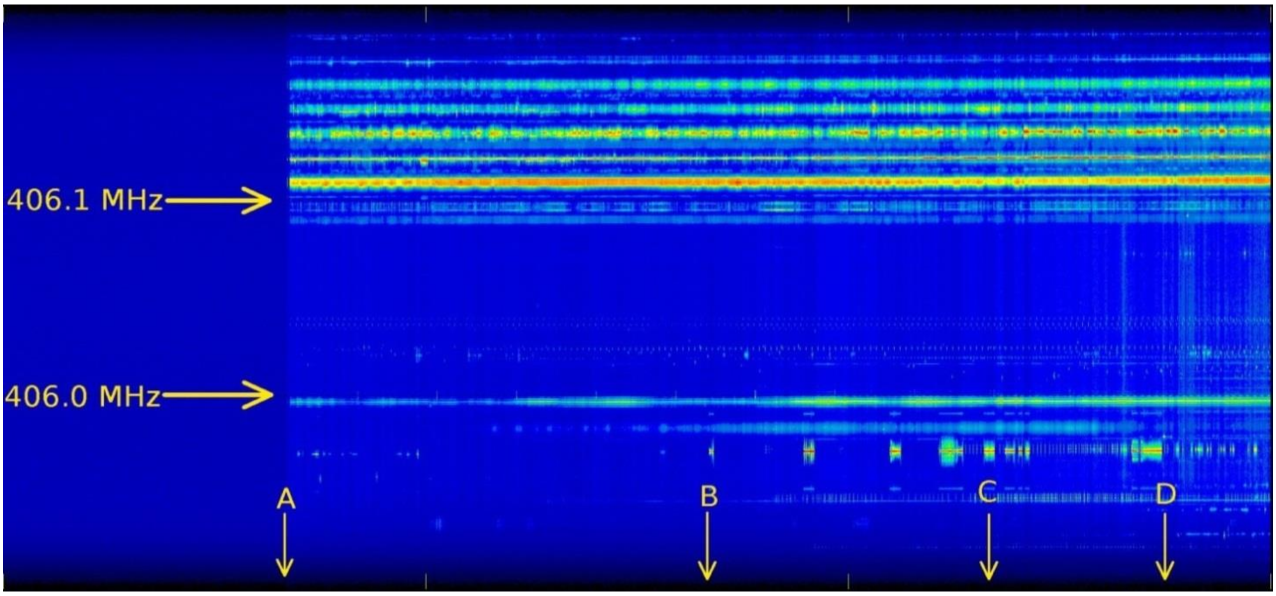


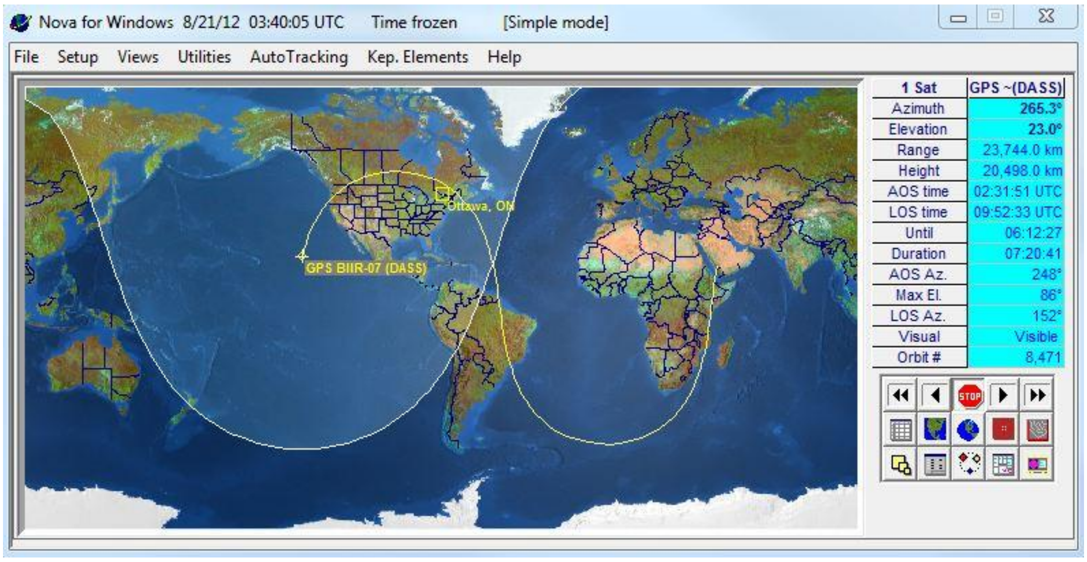
FIGURE A1-14

Satellite footprint of PRN18 to an elevation angle of 0° (highlighted) at time A of Fig. A1-13

1 Sat	GPS ~(DASS)
Azimuth	249.7°
Elevation	2.7°
Range	25,662.0 km
Height	20,363.0 km
AOS time	02:31:51 UTC
LOS time	09:52:33 UTC
Until	07:12:27
Duration	07:20:41
AOS Az.	248°
Max El.	86°
LOS Az.	152°
Visual	Visible
Orbit #	8,471

FIGURE A1-15

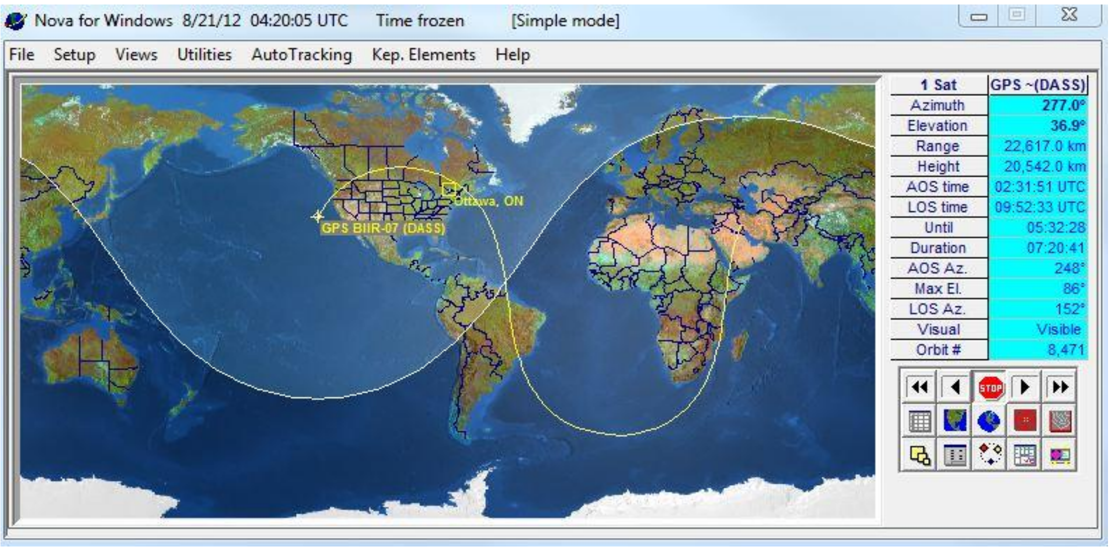
Satellite footprint of PRN18 to an elevation angle of 0° (highlighted) at time B of Fig. A1-13



1 Sat	GPS ~(DASS)
Azimuth	265.3°
Elevation	23.0°
Range	23,744.0 km
Height	20,498.0 km
AOS time	02:31:51 UTC
LOS time	09:52:33 UTC
Until	06:12:27
Duration	07:20:41
AOS Az.	248°
Max El.	86°
LOS Az.	152°
Visual	Visible
Orbit #	8,471

FIGURE A1-16

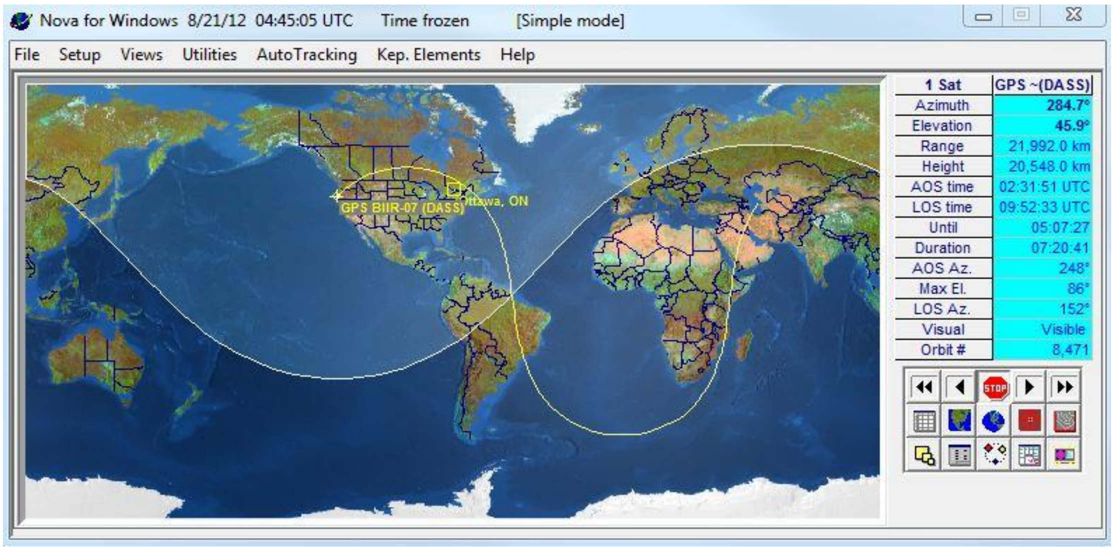
Satellite footprint of PRN18 to an elevation angle of 0° (highlighted) at time C of Fig. A1-13



1 Sat	GPS ~(DASS)
Azimuth	277.0°
Elevation	36.9°
Range	22,617.0 km
Height	20,542.0 km
AOS time	02:31:51 UTC
LOS time	09:52:33 UTC
Until	05:32:28
Duration	07:20:41
AOS Az.	248°
Max El.	86°
LOS Az.	152°
Visual	Visible
Orbit #	8,471

FIGURE A1-17

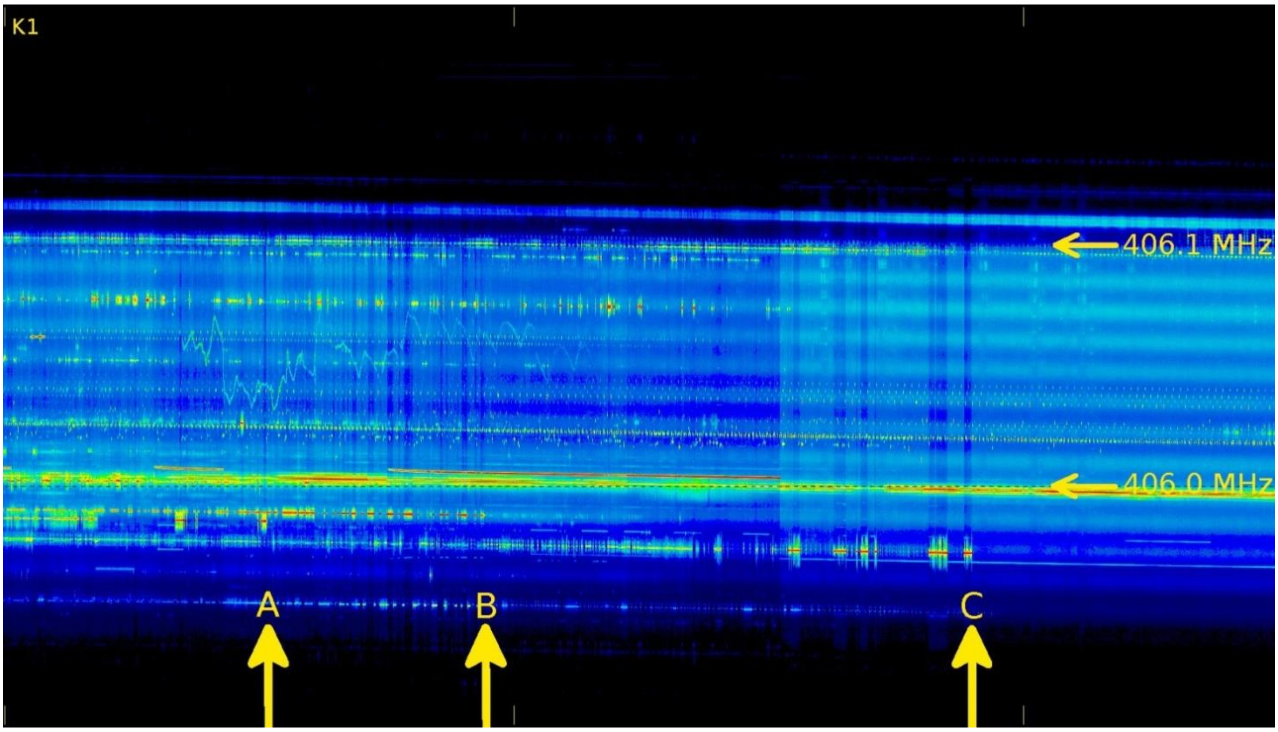
Satellite footprint of PRN18 to an elevation angle of 0° (highlighted) at time D of Fig. A1-13



1 Sat	GPS ~(DASS)
Azimuth	284.7°
Elevation	45.9°
Range	21,992.0 km
Height	20,548.0 km
AOS time	02:31:51 UTC
LOS time	09:52:33 UTC
Until	05:07:27
Duration	07:20:41
AOS Az.	248°
Max El.	86°
LOS Az.	152°
Visual	Visible
Orbit #	8,471

FIGURE A1-18

Spectrum Graphic (frequency versus time, power denoted by colour) of the 406.0-406.1 MHz band relayed by Glonass-K 1. The start of the image corresponds to July 17, 2013, at 04:30:00 UTC



A1.2.3 MEO Data – Spectral activity via by Glonass

Figure A1-18 shows the SAR band relayed via the Glonass-K 1 satellite (L-band). The satellite footprints at (i) the start of the image (left edge), (ii) the labelled times A, B, and C, and (iii) the end of the image (right edge) are shown in Figs A1-19 to A1-23, respectively. Multiple interferers are visible adjacent to the SAR band, including:

– the continuous channel approximately 12 kHz above the band;

– a combination of intermittent digital transmissions and FM voice at approximately 406.1 MHz;

– a strong signal straddling 406.0 MHz;

– a very strong signal, possibly FM-modulated voice, appearing approximately 12 kHz below the SAR band and ending at time B (“FM1”);

– a very strong signal, probably FM-modulated voice, appearing approximately 15 kHz below the SAR band and ending at time A (“FM2”); and

– a very strong signal, probably FM-modulated voice, appearing approximately 25 kHz below the SAR band and ending at time C (“FM3”).

The latter two signals are clearly affecting the transponder AGC, resulting in the vertical stripes of darker colour across the SAR band preceding time C.

FIGURE A1-19

Satellite footprint of Glonass-K 1 to an elevation angle of 0° (highlighted) at the start of Fig. A1-18

FIGURE A1-20

Satellite footprint of Glonass-K 1 to an elevation angle of 0° (highlighted) at time A of Fig. A1-18

FIGURE A1-21

Satellite footprint of Glonass-K 1 to an elevation angle of 0° (highlighted) at time B of Fig. A1-18

FIGURE A1-22

Satellite footprint of Glonass-K 1 to an elevation angle of 0° (highlighted) at time C of Fig. A1-18

FIGURE A1-23

Satellite footprint of Glonass-K 1 to an elevation angle of 0° (highlighted) at the right edge of Fig. A1-18

A1.2.4 MEO Data – Approximate Localization

This section proposes candidate regions where specific interference signals originate. In the following, it is assumed that:

i) the sources of interference are at least approximately stationary, and

ii) the sources of interference transmit frequently enough that their transmissions may be approximated as continuous.

These assumptions are not always valid but the signals examined here are active enough that they are approximately true. In particular, the sudden appearance of strong signals is interpreted as meaning that the source of that signal has entered the satellite footprint at that time, though this cannot be definitely established solely from these images. Obviously, these regional locations are subject to revision based on additional data.

A1.2.4.1 Interferer near 406.0 MHz

This strong interferer straddles 406.0 MHz, emitting sometimes inside the SAR band, sometimes outside, and often both simultaneously (Fig. A1-18). It is always visible from Ottawa, though sometimes at very low power levels. From Figs A1-19 through A1-23, the signal is present when (at different times) South America, Africa, Europe, Australia, and virtually all of Asia are outside the satellite footprint. This indicates that the source of the signal is in North America.

This signal is of particular interest because it illustrates how adjacent-channel interference can increase the effective noise floor for beacon transmissions within the SAR band. An example is shown in Fig. A1-24, where the effective noise floor differs between time A and time B due to this signal. Figures A1-25 and A1-26 show plots of power versus uplink frequency at time A and time B, respectively. At 406.025 MHz (i.e. in the operational band[7]), the effective signal noise floor is approximately 2.0-2.5 dB higher with the interferer present.

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[7] Cospas-Sarsat beacons are assigned to 3 kHz frequency channels. System (orbitography and reference) beacons are assigned to the channel centred at 406.022 MHz. Operational beacons are in channels centred at 406.025, 406.028, 406.037, and 406.040 MHz (C/S T.012, "Cospas-Sarsat 406 MHz Frequency Management Plan," October 2012, Annex H).

This will reduce the signal-to-noise ratio (C/N_0) for beacon transmissions near 406.025 MHz by the same amount, where the C/N_0 is the principle quantity determining Cospas-Sarsat system performance in terms of both beacon detection rates and independent location accuracy. Specifically, based on measured data gathered during MEOSAR Demonstration & Evaluation (D&E) testing conducted in July-August 2013, a 2.5 dB reduction in C/N_0 can reduce the probability of detection from approximately 80% to below 60% (TG-1/2013/2/4, Attachment 1, Fig. A1a). The impact of such a reduction is magnified by the geolocation method used in the MEOSAR system. In contrast to the Doppler geolocation approach used in LEOSAR, which relies on measurements from a single satellite to compute a location, MEOSAR geolocation relies on observing the same beacon burst as relayed by multiple satellites simultaneously. Location accuracy is therefore a function of the number of satellites that successfully detect a given burst, and failure to detect a given burst will yield poorer location accuracies. Moreover, since a burst must be detected by four satellites simultaneously to generate a 3-dimensional location, degraded detection rates could result in cases where no location is generated at all.

FIGURE A1-24

Spectrum Graphic (frequency versus time, power denoted by colour) of the 406-406.1 MHz band relayed by DASS PRN-17. The start of the image corresponds to July 16, 2013, at 21:21:03 UTC

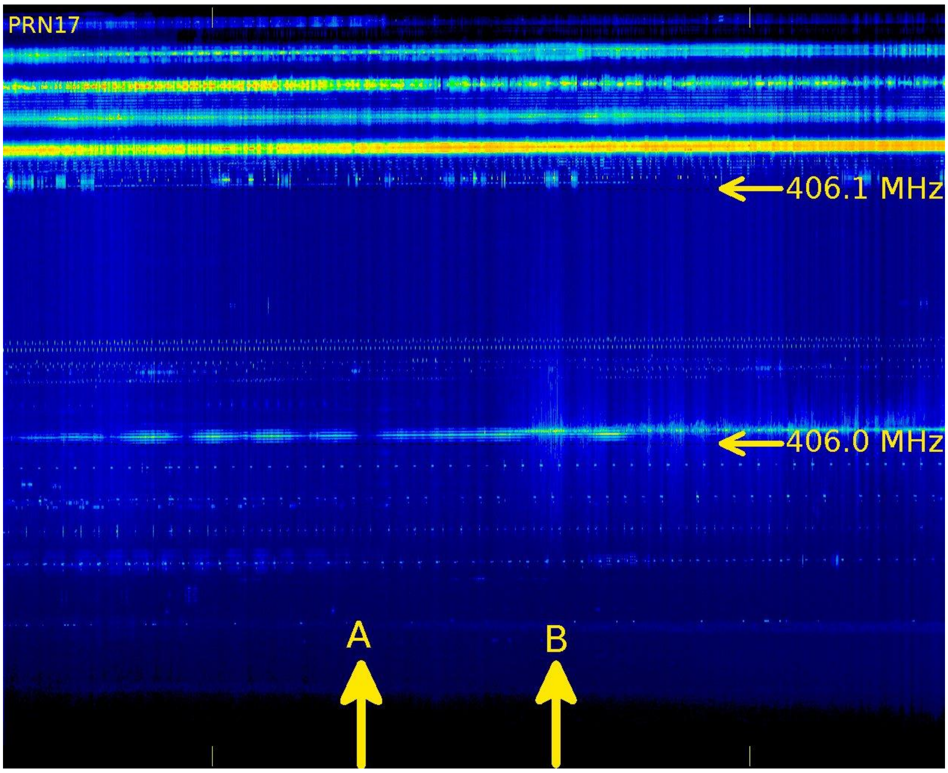


FIGURE A1-25

Plot of power versus frequency corresponding to time A of Fig. A1-24

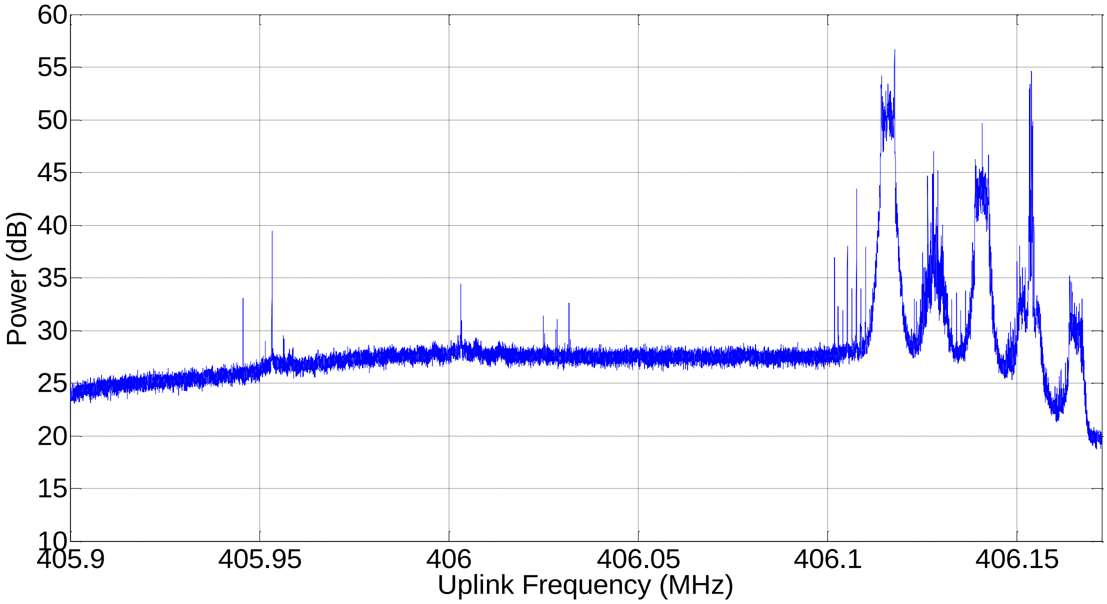
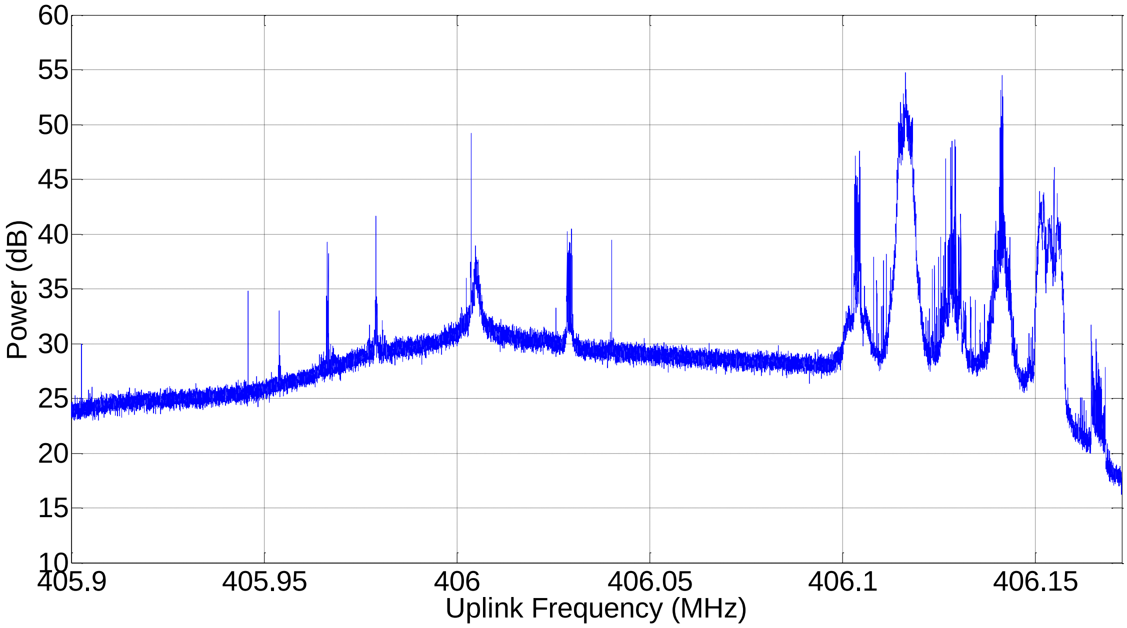


FIGURE A1-26

Plot of power versus frequency corresponding to time B of Fig. A1-24



A1.2.4.2 Interferer "FM1"

Figure A1-18 shows FM1 strongly present until time B; the satellite footprints for Glonass-K 1 at times A and B are shown in Figs A1-20 and A1-21, respectively. Between these two times, a swath of territory including parts of southern Europe, central Asia, the northern Philippines, and southern China goes out of view.

Figure A1-27 shows FM1 relayed via DASS PRN-12; the satellite footprints for PRN-12 at the start of the image (left edge) and at time A are shown in Figs A1-28 and A1-29, respectively. This signal is strongly present starting at time A. It is unclear whether the strong transmission is linked to the weaker signal that appears before this at roughly the same frequency. If the strong signal begins at time A, then combining Figs A1-27, A1-28, and A1-29 with Figs A1-18, A1-20, and A1-21 suggests that the source is located in central Russia or west-central Asia.

FIGURE A1-27

Spectrum Graphic (frequency versus time, power denoted by colour) of the 406-406.1 MHz band relayed by DASS PRN-12. The start of the image corresponds to July 24, 2013, at 08:30:00 UTC

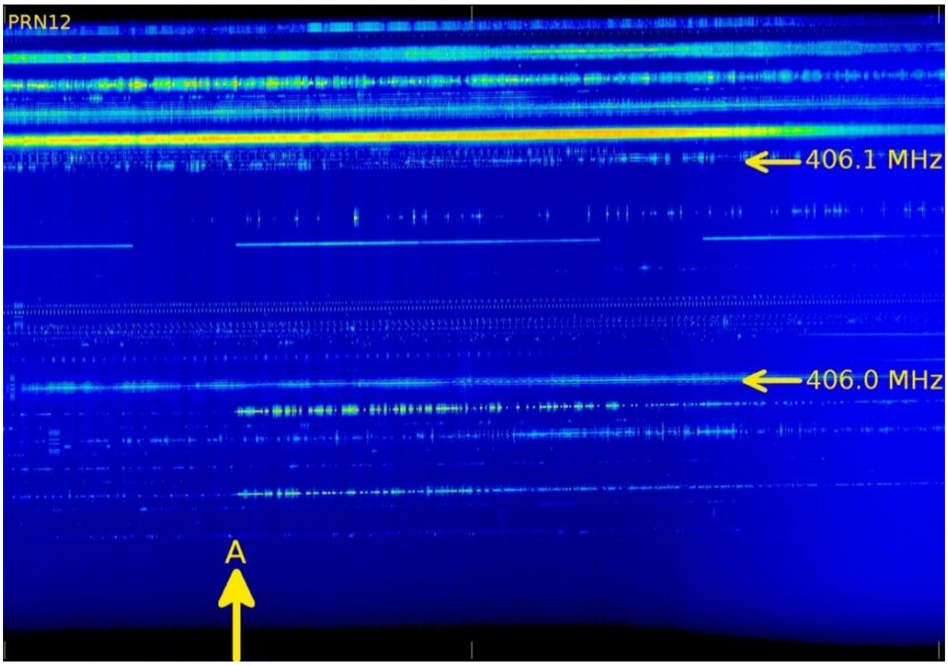


FIGURE A1-28

Satellite footprint of PRN-12 to an elevation angle of 0° (highlighted) at the start of Fig. A1-27

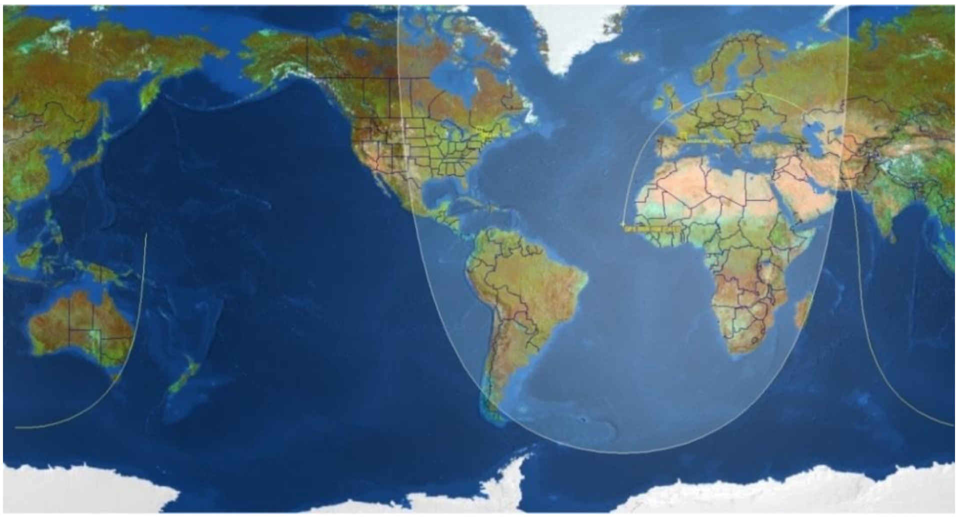


FIGURE A1-29

Satellite footprint of PRN-12 to an elevation angle of 0° (highlighted) at time A of Fig. A1-27

A1.2.4.3 Interferer "FM2"

Figure A1-18 shows FM2 strongly present until time A; the satellite footprints for Glonass-K 1 at the start of the image (left edge) and at time A are shown in Figs A1-19 and A1-20, respectively. Between these two times, a swath of territory including parts of the Middle East, northern India, Southeast Asia, and southern China goes out of view.

Figure A1-30 shows FM2 relayed via DASS PRN-23, where it is last visible at time A. The satellite footprints are shown in Figs A1-31 and A1-32 for the start of the image and time A, respectively. South America, Africa, the Middle East, India, and most of Europe are never in view of the satellite. Combined with Figs A1-18, A1-19, and A1-20, these images suggest a source location in either Southeast Asia or southern China.

FIGURE A1-30

Spectrum Graphic (frequency versus time, power denoted by colour) of the 406-406.1 MHz band relayed by DASS PRN-23. The start of the image corresponds to July 18, 2013, at 15:29:57 UTC

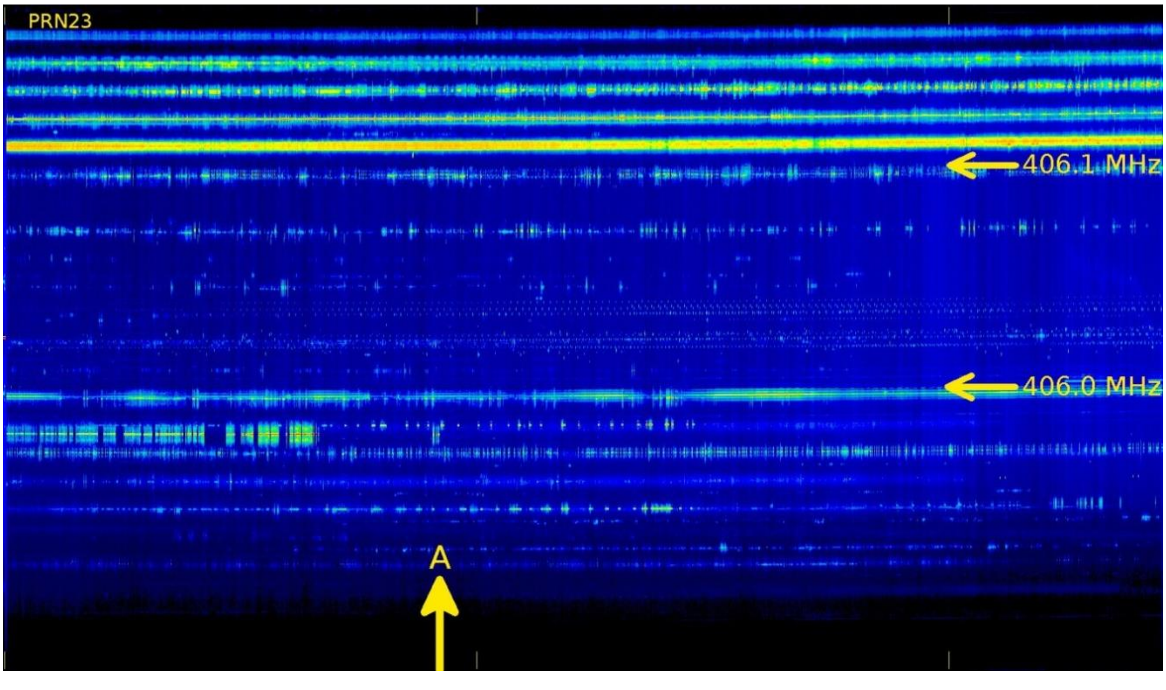


FIGURE A1-31

Satellite footprint of PRN-23 to an elevation angle of 0° (highlighted) at the start of Fig. A1-30

FIGURE A1-32

Satellite footprint of PRN-23 to an elevation angle of 0° (highlighted) at time A of Fig. A1-30

A1.2.4.4 Interferer "FM3"

Figure A1-33 shows this interferer to be present strongly until time C; the satellite footprint for Glonass-K 1 at time C is shown in Fig. A1-22.

Figure A1-33 shows the same signal detected via DASS PRN-17. The satellite footprints are shown in Figs A1-34 and A1-35 for the start of the image (left edge) and for time A, respectively. The footprint in Fig. A1-18 indicates that the source is not in North America or the majority of South America. The footprint of Fig. A1-35 indicates that the source is not in Europe, since Europe is not in view when the signal appears. Taken together, these images suggest that the source is in either Greenland or the region covering North-eastern Siberia and northern Japan, where the latter hypothesis seems more likely to be true.

FIGURE A1-33

Spectrum Graphic (frequency versus time, power denoted by colour) of the 406-406.1 MHz band relayed by DASS PRN-17. The start of the image corresponds to July 17, 2013, at 19:30:00 UTC

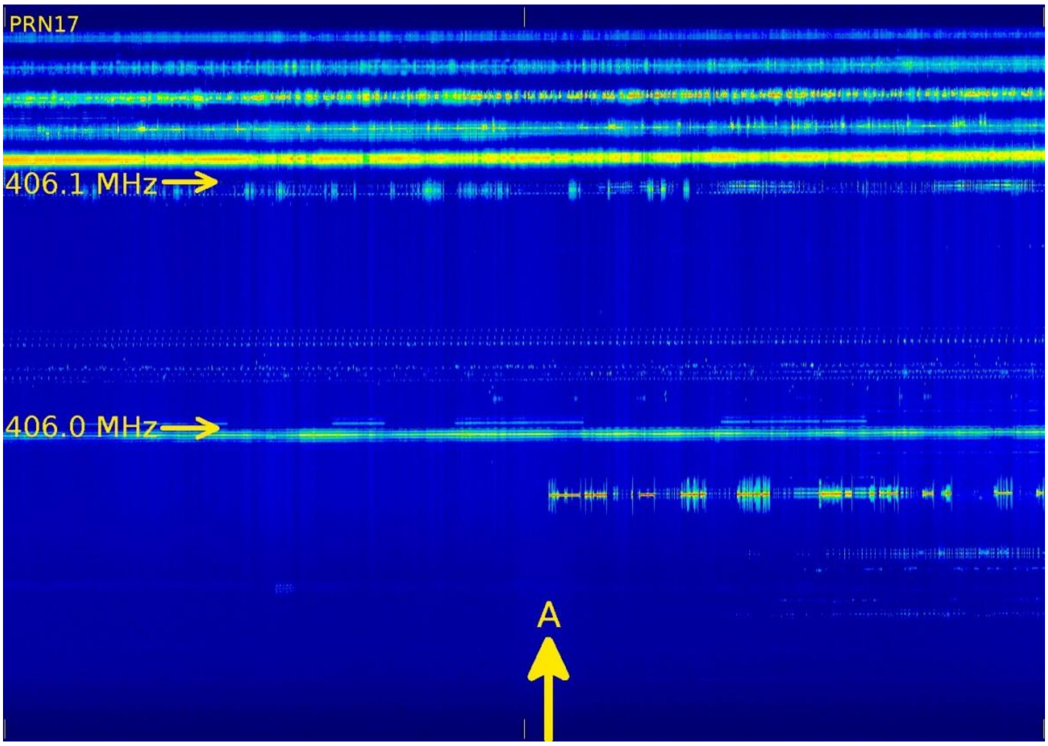
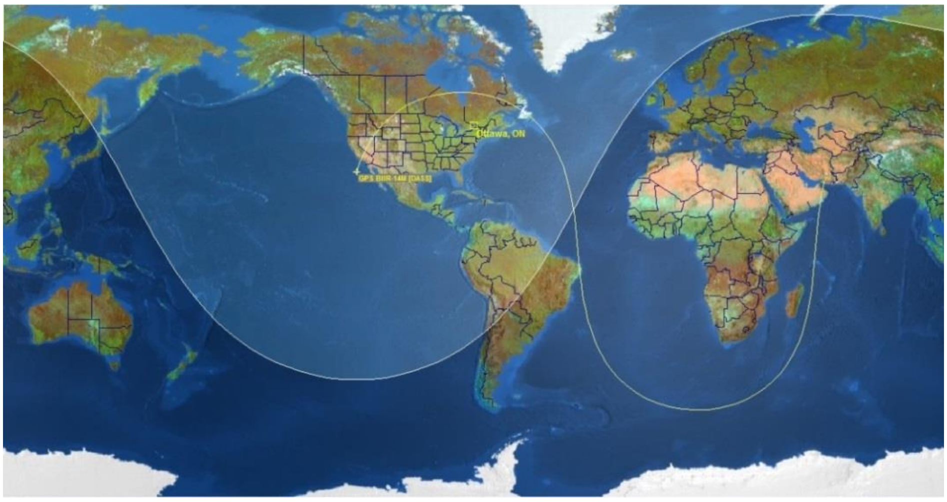


FIGURE A1-34

Satellite footprint of PRN-17 to an elevation angle of 0° (highlighted) at the start of Fig. A1-33

FIGURE A1-35

Satellite footprint of PRN-17 to an elevation angle of 0° (highlighted) at time A of Fig. A1-33



A1.2.4.5 Channelized signals above 406.1 MHz

The DASS spectra above show a number of strong signal spaced regularly at 12.5 kHz; some are also visible via Glonass-K 1 (Fig. A1-18). These appear to be assigned channels and are always visible from Ottawa, Canada, regardless of time of day or which satellite is tracked. This indicates that these signals originate in North America.

A1.3 Conclusions

Data collection and analysis was performed to further investigate interference signal traffic adjacent to the SAR band (406.0-406.1 MHz) and assess its impact. A number of key observations arise from this data:

1) There is significant signal activity outside the SAR band but very close to it (within a few tens of kilohertz).

2) Some of this adjacent signal traffic is very strong, much stronger than signals (e.g. transmissions from distress radio beacons) appearing within the band.

3) The strength of this interference adversely impacts the Cospas-Sarsat system. This is apparent in terms of:

   a) the effect on the satellite transponder AGC/ALC, and

   b) the effective noise floor (equivalently, the effective signal-to-noise ratio) within the SAR band.

The latter has a direct relationship to both beacon detection rate and independent location accuracy.

4) The type and level of out-of-band interference varies with geographical region. In particular, the Americas often appear to be spectrally “cleaner” than Eurasia.

5) Out-of-band interference appears to originate in multiple regions of the world, including North America, southeast Asia, and the northwest Pacific rim.

These observations are confirmed by previous work on interference in the SAR band done by Canada in support of Cospas-Sarsat, and are consistent with the plot of noise power as a function of geography measured by the SAR processor on the Metop-A satellite. It is crucial to recall that these results are illustrative rather than exhaustive; there is no guarantee that they represent the worst case.

Annex 2

CEPT utilization of the 390-420 MHz frequency band

Information about the usage of frequency bands between 390 and 420 MHz within CEPT countries

Country	**Types of standards**	**Bandwidth, kHz**	**Transmit power**	**Antenna pattern**	**Density of stations per km²**	**Relevant specification**
Frequency range: 390-395 MHz (Base stations (TX) in the mobile service used for PPDR)						
Croatia	TETRA standard	25	ERP: 15 dBW	Non-directional	0.003 BS/km^2	
Cyprus	No authorizations/ no usage					
Czech Republic	TETRAPOL	12.5	e.r.p. 100 W	Vertical polarization only, max. 14 dBi antenna gain	0.0028325 / km^2	Specification: TETRAPOL forum (http://www.tetrapol.com/community/contact_us/) (Note: UT transmit: 380-385 MHz, BS transmit: 390-395 MHz)
Germany	TETRA	25	Transmit power: 45 W e.i.r.p. (BS); typical: 16 W e.i.r.p. (BS) Transmit power: 12 W e.i.r.p. (for transportable BS)	non-directional	n/a and/or average distance between base and mobile stations: 5 km	ETSI EN 300 113 ETSI EN 300 390 ETSI EN 300 392 ETSI EN 300 393 ETSI EN 300 394 ETSI EN 300 396 ETSI TR 102 459 ETSI TR 102 021
Finland		25	e.r.p. 25 W			More technical details can be found in FICORA's Radio Frequency Regulation No. 4: http://www.ficora.fi/attachments/-englantiav/6FQWEelzL/-Taajuusjakotaulukko_en_26032013.pdf

Country	Types of standards	Bandwidth, kHz	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
Hungary	TETRA		On channels defined for DMO applications the maximum transmitted effective power shall be not higher than 4 W		0.007 per km²	
Ireland	Trunked Radio use, TETRA (Emergency) (paired with 380-385 MHz)	25	23.5	N/A	N/A	ETS 300 392 ETS 300 393 EN 300 086 EN 300 113 EN 300 219 Specifications: ETSI ERT 053 National Legislation S.I. 324 of 2008
Latvia	The PPDR system has not yet been deployed.					
Lithuania	EN 300 113 EN 300 390 EN 300 392 EN 303 035	25	34-43 dBm	SWIFTOF390T0, JAYBEAM758380	Total 228 BS located mainly in the border zone.	
Montenegro	TETRA	25	50 (e.i.r.p.)	5 dBi (Omni)	0.0005	ETSI TETRA standards
Russian Federation		12.5 and 25	From 3 to 10 dBW	From 0 to 7 dBi		This band is not used specifically for PPR. It is also used for public trunk, land mobile, technology networks and radio extenders.

Country	Types of standards	Bandwidth, kHz	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
Slovak Republic	TETRAPOL	5	30-42 dBm	Directional, ND (Kathrein – K 732327, K733037, K739504, K739506, K751637)	0.002	
Sweden	TETRA	25	100 W	Omni	Dense urban 1 BS/km²; Rural 0.25 – 0.01 BS/km²	ETSI EN 300 392 Note that the duplex band for the mobile
Switzerland	Emergency services					
Ukraine		12.5 and 25	Up to 20 W	Directional and non-directional	1 – 4 BS per km^2	

Country	Types of standards	Bandwidth, kHz	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
Frequency range: 395-399.9 MHz (Standard mostly used density deployment)						
Croatia	Small local TETRA networks	25		non-directional	20 dB	
Cyprus	No authorizations / no usage					
Czech Republic	In accordance with Act No. 127/2005 Coll., on Electronic Communications, required information on defence systems (harmonized NATO band) is not publicly available. Such information is not at CTO's disposal.					
Germany	Harmonized NATO band					
Hungary	We cannot give information about the technical parameters of the applied NATO systems.					
Ireland	Trunked Radio use, TETRA (Emergency)	25	14 dBW	N/A	N/A	• ETS 300 392 • ETS 300 393 • EN 300 086 • EN 300 113 • EN 300 219 Specifications: ETSI ERT 053 National Legislation S.I. 324 of 2008. ComReg Document 07/57
Finland	TETRA	25		25 W e.r.p.		Frequency band 395-396 MHz is extension band for VIRVE emergency service network. Technical details in FICORA's Radio Frequency Regulation No. 4: http://www.ficora.fi/-attachments/englantiav/6FQWEelzL/Taajuusjakotaulukko_en_26032013.pdf
Latvia				14 dBW		
Lithuania	No data					

Country	Types of standards	Bandwidth, kHz	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
NATO	395-396.525 MHz military PPDR (DPMR) The systems deployed are national assets and should have the same technical characteristics as those used by civil PPDR entities in the band 390-395 MHz.					
	396.525-399.9 MHz a multitude of applications within NATO Nations It needs to be understood that NATO as an organization does not own and operate the systems used in these bands. The equipment is nationally operated, and this HQ has no authorization to disclose technical characteristics as far as they are known here. For AMS applications alone there are daily assignments exceeding 500 spread all over NATO Europe.					
Slovak Republic	In The Slovak Republic this frequency band is allocated to the Aeronautical MOBILE mil., and FIXED and MOBILE mil. service. The whole band 220-400 MHz is managed by the NATO Capability Panel CaP / 3. Preliminary opinion members of NATO to WRC-15 states that: "NATO is supporting the adequate protection of MSS in the frequency band 406-406.1 MHz while not putting undue constraints to the radio services allocated in the adjacent frequency bands".					
Sweden	Defence (no details are available) Some individual use based on TETRA technology					
Switzerland	Military use by aeronautical military systems					
Ukraine	Not applicable					

Country	Types of standards	Bandwidth	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
Frequency range: 399.9-400.05 MHz (Mobile Satellite)						
Cyprus	No authorizations / no usage					
Czech Republic	Mobile-satellite as well as radionavigation-satellite service have no utilization in the Czech Republic.					
Germany	Studies to be done					
Ireland	National usage: • Aeronautical UHF communications; • Radionavigation Satellite; and • Satellite Personal Communication System.					
Lithuania	No assignments in Lithuania					
Russian Federation	Data unavailable					
Slovak Republic	Allocated for Radionavigation but not used					
Switzerland	MSS Earth stations (LEO MSS)					
Ukraine	Not applicable					
Frequency range: 401-406 MHz (EESS, Metaids, Metsat)						
Cyprus	No authorizations/no usage					
Czech Republic	Transmitters of balloon probes for weather monitoring launched four times per day use frequencies 401.1 MHz and 403.5 MHz		1 W			
	In the band 401.6-402.2 MHz (uplink) data from automatic meteorological observation stations are transmitted via satellites.					

Country	Types of standards	Bandwidth	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
Germany	**401-406 MHz:** EESS, Metaids, Metsat					
	401-402 MHz: ULP-AMI	25-100 kHz	25 µW e.r.p.	non-directional	n/a- and/or average distance between mobile stations: n/a-	ECC/DEC/(01)17 ETSI EN 302 537 ITU-R RS.1316
	402-403 MHz: ULP-AMI: N/A	25-300 KHz	25 µW e.r.p.	non-directional	-n/a- and/or average distance between mobile stations: n/a-	ECC/DEC/(01)17 ETSI EN 301 839 ITU-R RS.1316
	402.1-403.1 MHz: Medical data transmissions (indoor use only) Types of standard: – n/a -	1 MHz	10 mW e.r.p	Non-directional	-n/a- and/or average distance between stations: -n/a-	ETSI EN 300 113-2 ETSI EN 300 220-2 ETSI EN 300 390-2 ETSI EN 300 440-2
	403-405 MHz: ULP-AMI Types of standard: -n/a-	25-300 kHz	25 µW e.r.p.	Non-directional	-n/a- and/or average distance between stations: -n/a-	ECC/DEC/(01)17 ETSI EN 301 839 ITU-R RS.1316
	405-406 MHz: ULP-AMI Types of standard: -n/a-	25-100 kHz	25 µW e.r.p.	Non-directional	-n/a- and/or average distance between stations: -n/a-	ECC/DEC/(01)17 ETSI EN 302 537 ITU-R RS.1316
Hungary	<u>401-403 MHz:</u> • Primary services: Shared Civ/Mil METEOROLOGICAL AIDS, EARTH EXPLORATION-SATELLITE (Earth to space) and METEOROLOGICAL-SATELLITE (Earth to space) • Secondary services: Non-civil Fixed, Non-civil Mobile except aeronautical mobile, <u>403-406 MHz:</u> • Primary services: Shared Civ/Mil METEOROLOGICAL AIDS • Secondary services: Non-civil Fixed, Non-civil Mobile except aeronautical mobile					

Country	Types of standards	Bandwidth	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
Ireland	National usage: Metaids and SRDs – 401-406 MHz EPIRBs – 406-406.1 MHz					
Lithuania	Used by radiosondes. Operating time – 2 hours per day.	50 kHz	e.r.p.: 100 mW	ND		
Netherlands	For meteorological radio probes: usage at 403.0 and 403.9 MHz					
Russian Federation	400-406 MHz – Metaids		Type of emission: continuous Classes of emission: G1D, F1D	Polarization: vertical Antenna gain: 3 dBi Antenna pattern width: 60° in vertical plane, 360° in horizontal plane.	N/A	Out-of-band emission: –50 dB Spurious emission: –60 dB
	401-403 MHz – Metsat	Data rate: 100-1 200 bit/s	Transmit power: up to 12 dBW Antenna gain: up to 6 dBW	Antenna pattern width: 60° in vertical plane 30° in horizontal plane. Polarization: circular right-hand	N/A	Type of modulation: PSK, QPSK Access method: FDMA, TDMA Out-of-band emission: –54 dB Spurious emission: –60 dB

Country	Types of standards	Bandwidth	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
Slovak Republic	Used for Fixed/Mobile Defense systems.	25 kHz	ULP/AMI applications 25 µW e.r.p. (allowed through General Authorization			
Switzerland	Meteorological aids (Sondes); Ultra Low Power Active Medical Implant communication systems (ULP-AMI).					
Ukraine	Not applicable					

Country	Types of standards	Bandwidth	Transmit power	Antenna pattern	Density of stations per km^2	Relevant specification
Frequency range: 406.1-420 MHz (Mobile/Fixed)						
CRAF	406.1–410 MHz Radio Astronomy • Passive service: This band is used intensively for solar observations and other radio astronomical observations					
Croatia	No assignments in this band					
Cyprus	93 frequency authorizations have been granted starting from the 408 MHz (36 national and 57 local)	12.5 kHz	17 dBW e.r.p.	omni	no data	Types of standards: F3E
Czech Republic	406.1-410 MHz Simplex mobile networks and fixed links;	25 kHz	Max. 10 W e.r.p.	Omnidirectional for terminals, directional for BS	0.0088 / km^2	ETSI Standard does not exist.
	410-420 MHz PMR/PAMR, also e.g. TETRA;	200 kHz, 25 kHz	Terminal’s max. e.r.p. 10 W (BS operates in duplex sub-band above 420 MHz)	Omnidirectional antenna;	Unknown density (terminals operate on basis of General Licence No. VO-R/1/04.2014-2)	ECC/DEC/(04)06 Details on the use of the band: http://www.ctu.eu/164/download/Measures/General_Nature/RSUP/CZE_RSUP-P-15-02-2009-04_eng.pdf

Country	Types of standards	Bandwidth	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
Finland	406.1-410 MHz fixed and mobile stations	12,5 kHz or 25 kHz	Max 2 W ERP. For PMR base station and mobile stations radiated powers are typically max 5 W ERP.			Frequency band 406.1-410 MHz is heavily used in whole Finland
	410-420 MHz PMR, digital PMR, digital wide-band PMR networks, fixed radio links and civil TETRA	from 6.25 kHz up to 200 kHz	max. 25 W ERP			Technical details in FICORA’s Radio Frequency Regulation No. 4: http://www.ficora.fi/attachments/englantiav/6FQWEelzL/Taajuusjakotaulukko_en_26032013.pdf
Germany	406.1-410 MHz Mobile stations (handhelds) TETRA The use of this band is limited to direct mode operation from mobile to mobile of PPDR	25 kHz	Transmit power: 3 W e.r.p. typical: 1 W e.r.p.	Non-directional	and/or average distance between the fixed stations: 10 km 1.5 km	ETSI EN 300 113-2 ETSI EN 300 219-2 ETSI EN 300 296-2 ETSI EN 300 341-2 ETSI EN 300 390-2 ETSI EN 300 471-2
	410-410.8 MHz Fixed stations (Single-Channel Radio Relay) Point-to-Point (Duplex-frequency range: 420-420.8 MHz)	20 kHz	38 dBm Typical: 30 dBm	Yagi (max. 15 dBi)	-n/a- average distance between the fixed stations: 10 km 10 km	ETSI EN 300 086-2 ETSI EN 300 113-2 ETSI EN 301 489-1 ETSI EN 300 753
	410-420 MHz (Duplex-frequency range: 420-430 MHz) Mobile stations (Tx) Trunked PMR	12,5 kHz or 25 kHz	6 W e.r.p. (for 12.5 kHz System 12 W e.r.p. (for 25 kHz Systems)	non-directional	n/a- average distance between base and mobile station: 8 km 8 km	ETSI EN 300 086-2 ETSI EN 300 113-2 ETSI EN 300 219-2 ETSI EN 300 296-2 ETSI EN 300 341-2 ETSI EN 300 390-2

Country	Types of standards	Bandwidth	Transmit power	Antenna pattern	Density of stations per km^2	Relevant specification
	(analogue and digital)					ETSI EN 300 471-2
	419.72-419.8 MHz Mobile stations PMR (Duplex-frequency range: 429.72-429.8 MHz)	20 kHz	10 W e.r.p.	Non-directional	n/a- average distance between base and mobile stations: 15 km 15 km	ETSI EN 300 086
	419.83125-419.98125 MHz Mobile stations PMR	12.5 kHz	12 W e.r.p.	Non-directional	-n/a- and/or average distance between base and mobile stations: 15 km 15 km	ETSI EN 300 086
	419.99775-420.00625 MHz Mobile stations PMR (handhelds)	12.5 kHz	1 W e.r.p.	Non-directional	-n/a- and/or average distance between base and mobile stations: 1.5 km 15 km	ETSI EN 300 086-2 The use of this frequency is limited to direct mode operations from mobile to mobile
Hungary		Max: 25 kHz	Approximately 5 dBW e.r.p.	Omnidirectional	0.027 mobile terminal station per km^2 (concentrated to the capital)	MSZ EN 300 113 2; MSZ EN 300 390 2 MSZ EN 303 035 1; MSZ EN 303 035 2
Ireland	The frequency range 410-414 MHz / 420-424 MHz is assigned for Wide-band Digital Mobile Data Services (WDMDS). The current 10-year WDMDS licences are due to expire on the 05/12/2015 and 07/12/2015.	4 MHz	Max e.i.r.p.: 14 dBW	N/A	N/A	Specifications: ETSI ERT 053 National Legislation S.I. No. 642 of 2005

Country	Types of standards	Bandwidth	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
	The frequency ranges 406.1-410 MHz and 414-420 MHz are unused.					
Latvia	406.1-410 MHz	12.5 kHz and 25 kHz.	Base station maximum e.r.p. 14 dBW; mobile station maximum e.r.p. 13 dBW	Mostly omnidirectional antennas	up to 4 BS per km^2 in two cities – Riga (capital) and Ventspils	
	410-420 MHz	12.5 kHz and 25 kHz	Mobile station maximum e.r.p. 13 dBW			
Lithuania		12.5 kHz and 25 kHz	14 dBW	ND	No data on number of terminals used in Land Mobile systems.	EN 300 086 EN 300 113 EN 300 219 EN 300 296 EN 300 341 EN 300 390 EN 300 471 EN 301 166 EN 302 561 EN 300 392 EN 303 035 EN 301 449 EN 301 526 EN 302 426
Montenegro	Type of applications: 410-430 MHz: Mobile station (Tx) in the Mobile service used for CDMA PAMR *CDMA2000*	1.25 MHz channel	max 23 dBm (e.i.r.p.)	integrated		
Netherlands	406.1-410 MHz Radio Astronomy: This band is used intensively for solar observations and other radio astronomical observations					

Country	Types of standards	Bandwidth	Transmit power	Antenna pattern	Density of stations per km²	Relevant specification
Russian Federation	Types of standards: TETRA, MPT1327	12.5/25 kHz	base station – 60 W – transportable station – 20 W – portable station – 5 W		N/A	ETSI specification: EN 300392
Slovak Republic	406,1-410 MHz, Telemetry,	25 kHz	E.R.P max 3 W	ND		
	410-420 MHz TETRA,	12.5 kHz	E.R.P max 10 W	ND		
Sweden	Tetra, DMR and analog PMR.	12,5 / 25 kHz	Depending on license conditions. Generally less than 25 W ERP	No information available, mainly portable/mobile transmitters	Mainly mobile stations. No exact information available	Relevant ETSI specification or similar: EN 300 113-2, EN 302 561, EN 300 392
Switzerland	PMR/PAMR	6.25, 12.5 kHz	Up to 25 W			EN 300 086-2, EN 300 296-2 EN 300 113-2, EN 300 390-2
Ukraine	406.1-420 MHz	12.5 kHz, 25 kHz and 200 kHz.	up to 20 W	directional and non-directional	from 1 to 10 per km^2	
	413-420 MHz Types of standards: Analogue and digital, PMR, TETRA	corresponding to 12.5 kHz and 25 kHz channel spacing	1 – 4 W for mobile stations, 1 – 25 W for land stations (duplex stations with fixed locations which have transmission frequencies in 413-420 MHz band, operating with BS transmitting in 423-430 MHz band).	non directional for mobile stations, directional and non- directional for land stations (antennas gain from 2 to 14 dB)	density of stations per km²: 0.0016647 stations per km² for land stations.	digital PMR: EN 300 113, EN 300 390, EN 301 166, TS 102 361; analogue PMR: EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341, EN 300 390; TETRA: EN 303 035, EN 300 392

Russian Federation

390-420 MHz (except 406-406.1 MHz)	Fixed (RRS)	e.i.r.p. Bandwidth Antenna pattern width Density of stations per km²	e.i.r.p.: up to 20 dBW Bandwidth: 1.6 MHz Antenna pattern width: up to 40 deg. Density of stations per km²: See Note* *NOTE – Deployment density of base/fixed stations in land mobile and fixed services on the territory of the Russian Federation is extremely unequal. And thus such index as "density of stations per km²" cannot be considered correct

Glossary

A-DCS	Advanced data collection and location system
ARGOS	Satellite-based location and data collection system
CEPT	Central European Post and Telegraph
Cospas	Cosmitscheskaja sisterna poiska awaarinitsch sudow (space system for search of vessels in distress)
dBc	Ratio of power density of spectra to the carrier power in decibels
dBd	Ratio of antenna gain relative to a dipole antenna in decibels
dBi	Ratio of antenna gain relative to an isotropic antenna in decibels
dBm	Rower ratio relative to one milliwatt in decibels
dBsd	Power ratio of power spectral density in the sidelobes of a spectra to the maximum power spectral density in decibels
dBW	Power ratio relative to one watt in decibels
DCP	Data collection platform
DCS	Data collection system
DRU	Data recovery unit
e.i.r.p.	Equivalent isotropically radiated power
EESS	Earth exploration-satellite system
erp	Effective radiated power
ETSI	European Telecommunications Standards Institute
EUMETSAT	European meteorological satellite agency
Field of view	Area on the earth within the beam of a satellite antenna
Galileo	Global navigation satellite system built by ESA
GEO	Geostationary orbit
GLONASS	Globalnaya navigatsionnaya sputnikovaya sistema (global navigation satellite system)
GMSK	Gaussian Minimum Shift Keying
GOES	Geostatiojnary Earth Orbiting Satellite
GOES-East	GOES satellite at 75 degrees West latitude
GOES-R	Series of GOES satellites from series R through U
GOES-West	GOES satellite at 135 or 137 degrees West latitude
GPS	Global positioning system
Io	Interference power density
LEO	Low Earth orbit
MEO	Medium Earth orbit
Metaids	Meteorological aids

Metaids	Instruments such as radiosondes that measure physical parameters of the atmosphere
MetOp	Meteorological operational satellite
MetOp	European meteorological operational satellite
MetSat	Meteorological satellite
MSG	Meteosat second generation
No	Noise power density
NOAA	National Oceanographic and Atmospheric Administration
OoB	Out of band
PCM/FM	Pulse code modulation/frequency modulation
psd	Power spectral density in watts per hertz expressed in decibels
psfd	Power spectral flux density in watts per Hertz per meter squared in decibels
QPSK	Quadra phase shift keying
Radiodonde	sonde with a radio data link
SAR	Search and rescue
SARAL	Satellite with Argos and Altika
SARP	Search and rescue processor
SARR	Search and rescue repeater
Sarsat	Search and rescue satellite
Sonde	device for testing physical conditions in the atmosphere at altitude
spfd	spectral power flux density
TETRA	ETSI standard for cell phones
TETRAPOL	ETSI standard for cell phones
UHF	Ultra high frequency (300 to 3 000 MHz)