European Radiocommunications Committee (ERC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

SHARING STUDIES BETWEEN THE UNWANTED EMISSIONS OF MSS MOBILE EARTH STATIONS, OPERATING IN THE BAND 1610 - 1626.5 MHz AND RADIO NAVIGATION - SATELLITE SERVICE RECEIVERS OPERATING IN THE BAND 1559 - 1610 MHz

Luxembourg, September 1999

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1 INTRODUCTION

The purpose of this report is to synthesise the different studies, which were conducted in SE28 on sharing between the unwanted emissions of mobile earth stations of the Mobile-Satellite Service (MSS), operating in 1610 - 1626.5 MHz, in the Earth-to-space direction with a primary status and the Radio Navigation-Satellite Service receivers (RNSS) operating in the band 1559 - 1610 MHz, in the space-to-Earth direction with a primary status.

The Mobile Earth Stations (MES) considered in this report are covered by TBR041. Thus, this excludes aeronautical earth stations.

The unwanted emissions of the MES spread into the operational band of RNSS, as shown in **Figure 1**. If the level of the unwanted emissions is too high, it will cause harmful interference into the RNSS receiver. The purpose of these studies was to derive an acceptable value for the unwanted emissions of the MSS MES in the band 1559 - 1610 MHz.

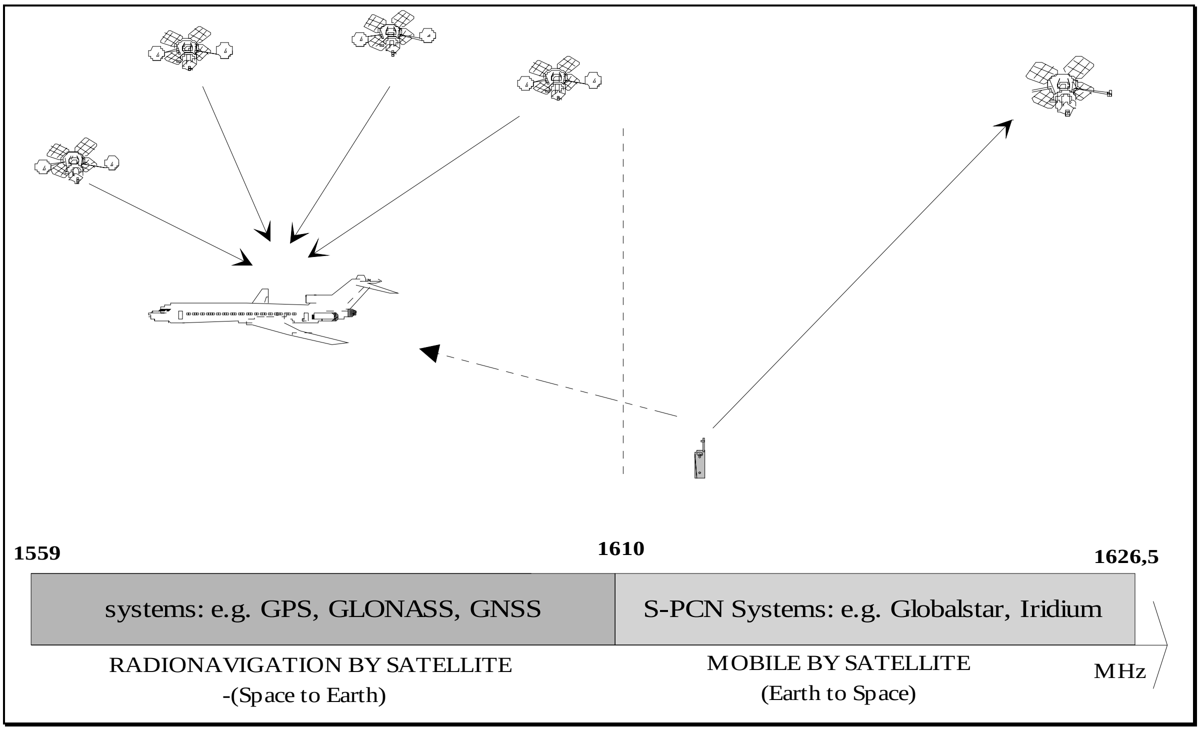


Figure 1: Sharing situation in adjacent bands between MSS and RNSS

In the studies, particular attention has been paid to the fact that the RNSS systems will be used for safety purposes, when on board an aircraft.

2 SYSTEMS PRESENTATION

2.1 MSS system

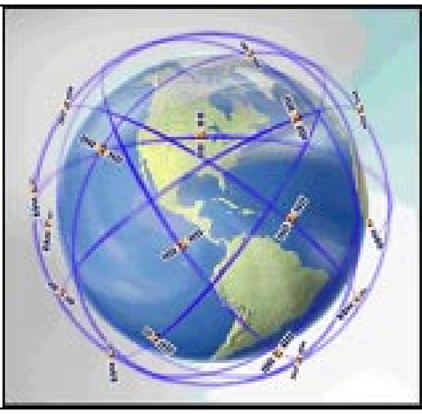
2.1.1 Introduction

As we can see in the **Figure 2**, all the MSS systems operating in the band 1610 - 1626.5 MHz are implied in the sharing situation. However, to allow all the systems wishing to operate in this band to have an equitable access of the spectrum, taking into account the access techniques, a band segmentation has been decided by CEPT. To summarise the ERC decision, we may say that this band segmentation allows CDMA systems to operate in the lower portion of the band (1610 - 1621.35 MHz) and the TDMA systems to operate in the upper part of the band (1621.35 - 1626.5 MHz). That is why in our simulations, we will use the characteristics of the Globalstar system, which uses the CDMA technique and thus which will be directly adjacent to the RNSS band.

2.1.2 Globalstar description

Globalstar system is a satellite-based, wireless telecommunications system designed to provide voice, data, fax, and other telecommunications services to users world-wide. Users of Globalstar will make or receive calls using hand-held or vehicle mounted terminals similar to today's cellular telephones. It should be noted that most of the terminals will be dual-mode, i.e. GSM/Globalstar or IS95/Globalstar. Consequently, when user terminals are within the terrestrial network coverage, they will use the cellular network, when outside this coverage, they will communicate via satellite. Calls will be relayed through the Globalstar satellite constellation, in a 1414 kilometre altitude orbit, to a ground station, and then through local terrestrial systems to their final destinations.

Fifty six Globalstar satellites will be placed into low earth orbit, 48 of which will be operational, with eight in-orbit spares. The satellites will be placed in eight orbital planes of six satellites each with a circular orbit inclined at 52 degrees. The satellite mass is approximately 450 kilograms, and requires some 1,100 watts of power for normal operations. The satellites in the first-generation constellation are designed to operate at full performance for a minimum of seven and one half years.



Globalstar

- 48 LEO satellites + 8 spare in orbit
- «Bent Pipe» relay to local gateway
- 8 planes with 6 satellites each
- 1414 km altitude, 52° inclination
- 113 minutes of period
- 70°N to 70°S coverage
- Multisatellite coverage in temperate zone

Figure 2: Typical MSS system

It is important to note that the Globalstar MES is covered by TBR041 (see Annex 1).

2.2 RNSS systems

2.2.1 GLONASS

The GLONASS Global Navigation Satellite System is designed for position-fixing as well as for velocity and precise time determination for maritime, aeronautical, land and other users. The system service zone provides global continuous and all-weather operation. Three-dimensional user co-ordinates and velocity findings are based on measurements propagation time of the GLONASS satellites transmitted signals and of their frequency Doppler shift.

GLONASS is one of the elements of the Global Navigation Satellite System (GNSS) and is used for providing safety of aircraft flights. RR S4.10 states that safety services require special measures to ensure freedom from harmful interference.

GLONASS operates within the Radionavigation-Satellite Service band (1592 - 1610 MHz) on a primary basis in all three Regions. According to the Russian Federation, GLONASS frequency assignments in the band up to 1610 MHz are completely co-ordinated according to the ITU procedures and based on RR. S4.10, S1.169, S4.5; they require protection from any harmful interference including those produced by unwanted emissions from systems operating in the adjacent frequency band 1610 - 1626.5 MHz.

The GLONASS system consists of three main segments. They are:

- Space segment
- Ground control segment
- User terminals (UT)

The GLONASS space segment consists of 24 operating satellites (and some stand-by ones) that are evenly located in three orbital planes with eight satellites in each. The separation angle of the planes is 120°. The orbit inclination is 64.8°. Its altitude is 19100 km and an orbital period is 11 hours 15 minutes.

The navigation service zone is established by transmitting navigation signals in the two RNSS bands, 1559 - 1610 MHz (called L1) and 1215 - 1260 MHz (called L2) from each satellite. Navigation data is transmitted at a rate of 50 bps. They contain data on satellite location within three rectangular co-ordinates, on velocity vector component and acceleration in a geocentric Earth fixed frame of reference (the ECEF co-ordinate system), on corrections for the GLONASS system time and on-board equipment health information for every half-hour period. For users, the main elements of navigation signals are data for clock corrections and satellite three-dimensional position parameters (ephemerides). For position fixing and time determination users have to track constantly and successively signals from at least four satellites.

The GLONASS system uses frequency division multiple access (FDMA) for navigation signals from satellites in both sub-bands (L1 and L2). Each satellite transmits radio signals on their own frequencies, sub-bands of L1 and L2.

In the downlink of the L1 frequency sub-band, the GLONASS satellites transmit navigation signals of two types, i.e. of a standard accuracy and of a precision one. The standard accuracy signal (SAS) has a chipping rate of 0.511 MHz. The SAS is available for any user who has an appropriate navigation receiver and if certain GLONASS satellites are in its field of view. The precision accuracy signal (PAS) with a chipping rate of 5.11 MHz is modulated with a specific code and is not intended for use without approval of the Russian Federation Ministry of Defence Military Space Force.

The GLONASS ground segment controls satellites, performs management functions and calculates navigation data (ephemerides). The segment consists of the Master Control Station and control and up-loading stations. Data of navigation measurements at each control station are processed at the Master Control Station and are used for computation of ephemerides to be transmitted to the satellites from the up-loading stations. To ensure proper operation of the entire system high precision satellite clock synchronisation is required. It is effected by transmitting clock correction data from the Master Control Station.

The GLONASS-M (GLONASS modernised version post 2005) frequency plan has three stages of transition. Prior to 1998.25 MHz separate frequency carriers were used in the L1 and L2 bands: the L1 band used carrier frequencies 1602.00 MHz (lowest) to 1615.50 MHz (highest) and the L2 band used carrier frequencies 1246.00 MHz (lowest) to 1256.50 MHz (highest). However, carrier frequencies in the 1610.6 - 1613.8 MHz band were not used.

During the second stage, 1998 - 2005.21 MHz carrier frequencies will be used in the L1 and L2 bands. The L1 band will use carrier frequencies 1598.0625 MHz (lowest) to 1609.3125 MHz (highest) and the L2 band will use carrier frequencies 1242.9375 MHz (lowest) to 1251.6875 MHz (highest). The highest carrier frequencies, 1609.3125 MHz and 1251.6875 MHz will be used only under exceptional circumstances.

After 2005, GLONASS-M will use 14 carrier frequencies. The highest two carriers of both L1 and L2 frequency bands will only be used as technical channels (for launch and test). Therefore, the GLONASS-M system in the L1 band will use carrier frequencies 1598.0625 MHz (lowest) to 1605.3750 MHz (highest) and the L2 band will use carrier frequencies from 1242.9375 MHz (lowest) to 1248.6250 MHz (highest). However, carrier frequencies 1604.8125 MHz and 1605.375 MHz in the L1 band and 1248.1875 MHz and 1248.6250 MHz in the L2 band will be used as technical channels when the satellite is over the Russian Federation.

According to the Russian Federation, the total frequency band to be used by the GLONASS system, covering both SAS and PAS, is in the first stage: 1596.89 - 1620.61 MHz in the band L1 and 1240.89 - 1261.61 MHz in the band L2; in the second stage 1592.9525 - 1613.86 MHz and 1237.8275 - 1256.36 MHz; in the third stage 1592.9525 - 1609.36 MHz and 1237.8275 - 1252.86 MHz.

The RF part of the receiver is typically comprised of a bandpass filter, a preamplifier and a multistage down-converter. The bandpass filter is to provide rejection of out-of-band signals. The preamplifier has a diode limiter to protect the receiver from damage when a high-powered interference signal is present.

The digital part of the receiver and the processor provides the signal equalisation, PN code tracking, carrier phase tracking, digital data demodulating and time marking. The receiver input bandwidth is ±20 MHz (-3 dB level) and ±45 MHz (-30 dB level); the noise temperature is 300 K (typical).

The characteristics of the system to be used in sharing studies are described in ITU-R Recommendation: M.1317 (See Annex2).

2.2.2 GPS

Introduction

The Global Positioning System (GPS) consists of 24 satellites with four satellites in each of the six 55° inclined, equally spaced, orbital planes. Each satellite transmits the same two frequencies for navigational signals. These navigational signals are modulated with a predetermined pseudo-random bit stream, modulated with navigation data containing ephemeris data, clock correction, etc. and having a sufficient bandwidth to produce the necessary navigation ranging precision without recourse to two-way transmission or Doppler integration. The system will provide accurate position determination in three dimensions anywhere on or near the surface of the Earth.

Frequency requirements

The frequency requirements for the GPS system are based upon an assessment of user accuracy requirements, space-to-Earth propagation delay resolution, multipath suppression, and equipment cost and configurations. Two channels were selected for GPS operations: 1575.42 MHz (L1) and 1227.6 MHz (L2). The L1 channel is used to enable quick acquisition and in addition can resolve a user's location to better than 150 m. A second signal transmitted on both Ll and L2 channels, provides the necessary frequency diversity necessary for ionospheric delay correction and wider bandwidth for increased ranging accuracy and for multipath suppression to increase the total accuracy by over an order of magnitude. Telemetry and maintenance signals from United States based control facilities to the satellite and return are accommodated in the allocated telemetry band in the United States of America.

GPS will provide a worldwide navigation service. The requirement for navigation safety (refer to Radio Regulation No. S4.10) demanded by such a service underscores the critical importance that other radio services should not cause harmful interference to GPS receivers.

Space Segment

The Space Segment comprises the GPS satellites, which function as "celestial" reference points, emitting precisely time-encoded navigation signals from space. The operational constellation of 24 satellites operates in 12 h circular orbits with a semi-major axis of about 26 600 km. The satellites will be placed in six orbital planes inclined 55° relative to the Equator. The satellites are optimally phased to provide visibility to the users of at least five satellites at elevations greater than 5° above the horizon.

User Segment

The User Segment is the collection of all user sets and their support equipment. The user set typically consists of an antenna, GPS receiver/processor, computer and input/output devices. It acquires and tracks the navigation signal from four or more satellites in view, measures their RF transit times and Doppler frequency shifts, converts them to pseudo-ranges and pseudo-range rates, and solves for three-dimensional position, velocity, and system time. User equipment ranges from relatively simple, lightweight hand-held receivers to sophisticated receivers that are integrated with other navigation sensors or systems for accurate performance in highly dynamic environments.

GPS signal structure

The GPS navigational signal transmitted from the satellites consists of two modulated carriers: Ll at a centre frequency of 1575.42 MHz (154 f_o) and L2 at a centre frequency of 1227.6 MHz (120f_o), where f_o = 10.23 MHz. f_o is generated by the on-board atomic frequency standard to which all signals generated are coherently related.

The Ll signal is modulated with both a precision (P) and a coarse/acquisition (C/A) pseudo-random noise (PRN) code, each of which is modulo-2 added to a 50 bit/s binary navigation data stream prior to phase modulation. The P code is a long binary pseudo-random sequence of zeros and ones with a clock rate of 10.23 MHz and a period of exactly one week. Every Saturday/Sunday midnight, it restarts, serving as a running indicator of time of the week in the space vehicle. The C/A code is a short code, having a clock rate of 1.023 MHz and a period of exactly 1 ms.

2.2.3 GNSS

Current GNSS includes GPS and GLONASS to which various augmentations are added. These augmentations are necessary to improve availability, integrity and accuracy. They could be provided by either space based means (SBAS) or ground based mean (GBAS) or aircraft based mean (ABAS). In this study GNSS is considered as GPS + GLONASS and GPS-SBAS (e.g. EGNOS, WAAS).

The GNSS user segment

The GNSS user segment - the aeronautical receiver - comprises a GPS or a combined GPS/GLONASS multi-standard receiver, which also receives the navigation signals and integrity and other augmentation data transmitted by the GPS-SBAS geostationary overlay satellites.

The navigation signal transmitted from the geo-stationary satellites is in principle the same as the GPS C/A coded signal, but is modulated with a higher data-rate information signal.

Aeronautical GNSS receivers currently operate only with the L1 frequency (1559 – 1610 MHz) band for both GPS and GLONASS reception, as well as for the reception of the geostationary satellite augmentation signals. But GPS and GLONASS operators are considering the possibility of additional signals in the L2 frequency band (1215 – 1260 MHz) for civil users in the near future.

3 SHARING STUDIES SCENARIOS

3.1 Introduction

The RNSS receivers are used in many different applications. This report discusses only the problem of potential interference produced by unwanted emissions from MSS transmitting user earth stations into RNSS aeronautical receivers.

For the MSS transmitting station, Globalstar is used as the example, as it uses wide-band CDMA signals and is immediately adjacent to the 1559 – 1610 MHz RNSS band, as explained in section 2.1.1.

For the RNSS receiver, GLONASS is used as the example, not only because it is closest to the MSS transmission frequency but also because ETSI had initially proposed protection of GPS C/A-code frequencies to –70 dBW/MHz but not to other parts of the band.

The RNSS receiver operates in two nominal modes:

- Acquisition
- Tracking

The acquisition mode requires an I/C figure that enables the RNSS receiver to acquire a new satellite in not more than a specified maximum time.

The tracking mode requires generally a more relaxed I/C figure that enables the RNSS receiver to keep track of the satellite. In this mode, there are two values:

- The nominal I/C tracking value that satisfies the criteria of not losing track and maintaining the precision required for en-route navigation.
- The stringent I/C tracking value that is needed to satisfy the (CAT1) vertical accuracy requirement.

3.2 En-route scenario

3.2.1 Description

In this scenario, the plane is in an en-route phase of flight, i.e. with a typical altitude of 10 000 meters. It can see a large number of MSS MESs. (This number will be derived from the density figure.) The RNSS receiver could be in an acquisition or tracking phase for each of a number of RNSS satellites.

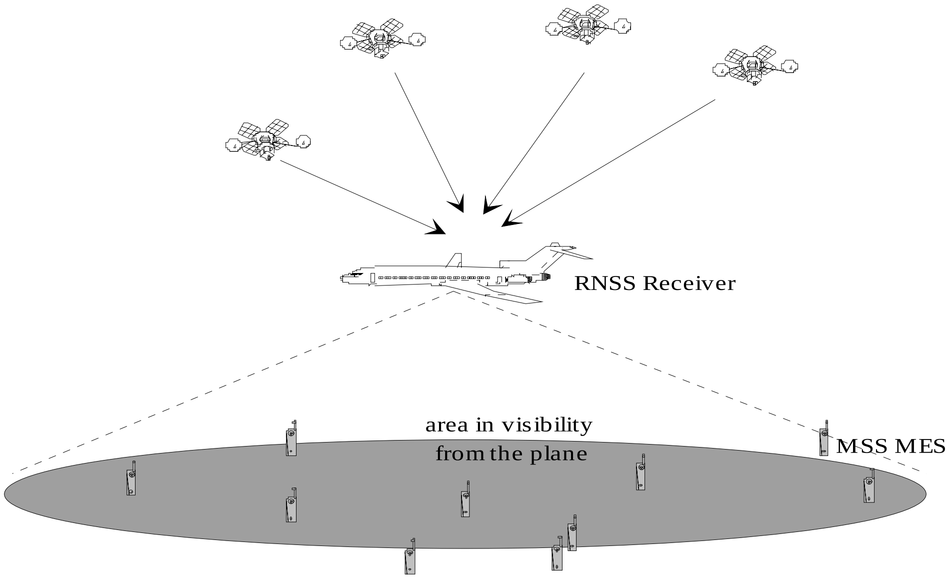


Figure 3: Aircraft en-route scenario

3.2.2 Link budget

a) Minimal guaranteed level of satellite signal at GLONASS receiver.

The minimum guaranteed level of satellite signal at a GLONASS receiver is specified by the Recommendation ITU-R M.1317. This minimum guaranteed level signal is representative of a worst case (end of life of the satellite and maximal free space loss). The agreed value is –161 dBW (assuming a 0 dBic gain circular-polarised RNSS receiver antenna).

b) Differential between antenna gain toward the desired signal and the antenna gain toward the interference.

Based on a value of GLONASS receiver gain toward the wanted signal of –4.5 dBic and gain toward the interference of –10 dBic.

c) I to C ratio.

There are two types of required signal to noise ratio depending on which phase the receiver is in: the acquisition phase or the tracking phase. The acquisition mode requires a higher C/I than the nominal tracking mode. In the en-route scenario, we will consider the worst case, i.e. I/C in acquisition.

The value of 15 dB is specified in the Recommendation ITU-R M.1317 for acquisition. However, that value assumed a situation where the receiver antenna gain in the direction of the wanted signal was -3 dBic and that in the direction of the interfering signal was +3 dBic, so, as proposed in ITU-R Doc. 8D-SRG/12, the value I/C of 21 dB is used in analysis of the acquisition mode.

d) Distance MES/ RNSS receiver.

To evaluate the distance between MESs and the RNSS receiver, we will suppose the very worst case, which is not realistic (but which is very simple), where all the sources are just below the plane and we will only consider the associated free space loss.

e) Number of interference sources.

First, calculate the area visible on the Earth from the plane with an elevation greater than 10 degrees. The diameter of this area is:

$$D = 2 \cdot \frac{10km}{\tan(10\deg)}$$

Thus if we consider the maximum density of MSS user terminals of 0.0013 users/km² (used in previous CEPT studies), it leads to a number of interference sources of 13.14 units, which leads to the factor of 11.18 dB in the link budget.

	Parameters	Symbol	Value	Unit
a)	Minimal guaranteed level of satellite signal at RNSS receiver (assumes a 0 dBic gain circular-polarised antenna)	P min	-161,00	dBW
b)	RNSS receiver antenna gain toward the wanted signal	Gs	-4,5	dB
c) b)	Permitted I/C in 1 MHz (for acquisition) RNSS receiver antenna toward the interference	I/C G	21,00 - 10.00	dB dB
d)	Distance MES/RNSS receiver	d min	10,00	km
	Path Losses from MSS MES to RNSS receiver at 1,6 GHz	Ls	116,52	dB
e)	Factor of several interference sources	N	11,18	dB
	Interference unwanted emission from MSS MES (1 MHz BW), as specified in the TBR041 for band 1559 - 1605 MHz		-70	dBW/MHz
	Link Margin	**M**	**40,84**	**dB**

Table 1. Link budget

3.2.3 Conclusion

The protection of an RNSS receiver is ensured even taking account of overly pessimistic assumptions. Thus, it is clear that this scenario is not critical.

3.3 Landing and landing approach scenario

3.3.1 Description

The approach and landing scenario used in this analysis is based on that for category 1 precision approach. In this case the decision height is a minimum of 200 feet. At this point the aircraft is considered to be at the closest to the MES. The decision height for CAT2 and 3 precision approach is much closer to the ground and is consequently nearer to the runway threshold, and is therefore separated by distances greater than that of CAT1, due to other operational safety reasons. We should notice also that CAT1 scenario is more stringent than Non-Precision Approach. For all these reasons, we will consider CAT1 approach as the studied worst case scenario.

The CAT1 precision approach scenario with 100 feet separation distance between the aircraft and the mobile communication terminal is taken into account in this Report. (Note: see. 3.3.2 § d).

In these conditions, the airborne RNSS receiver is assumed not to operate in acquisition mode.

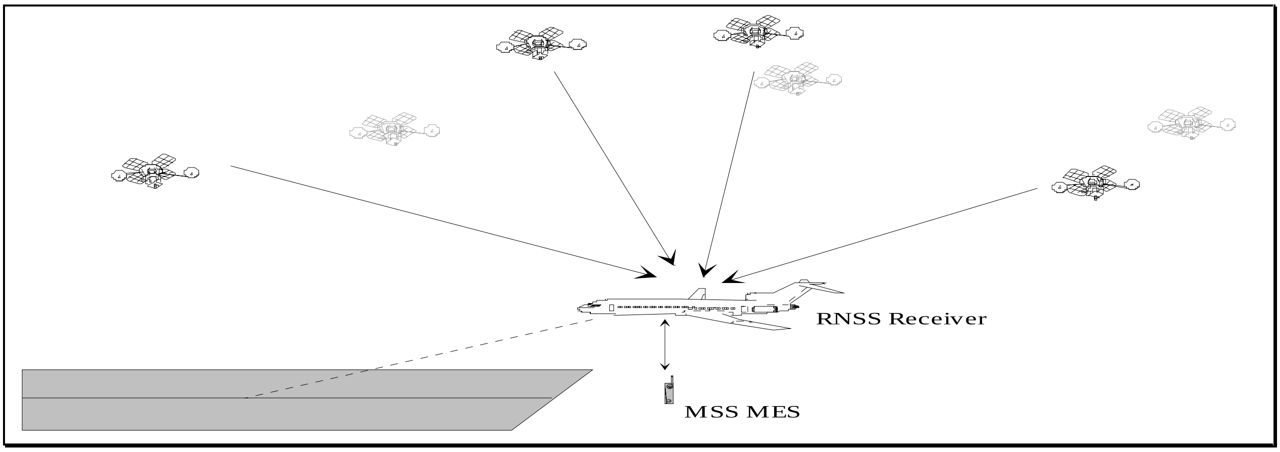


Figure 4: Landing and landing approach scenario

3.3.2 *Link budget****.***

a) Minimal guaranteed level of satellite signal at GLONASS receiver

The minimal guaranteed level of satellite signal at a GLONASS receiver is specified by the Recommendation ITU-R M.1317. This minimal guaranteed level signal is representative of a worst case (end of life of the satellite and maximal free space loss). The agreed value is –161 dBW (assumes a 0 dBic gain antenna).

b) I to C ratio (case of SAS only)

There are two types of the required signal-to-noise ratio depending on which phase (mode) the receiver is operating: the acquisition or the tracking phase (see 3.1). The airborne RNSS receiver is assumed not to operate in acquisition mode in the approach and landing phases.

As presented in section 3.1, two values have been considered for tracking:

- The stringent I/C value in the «accuracy phase»: the figure for this parameter has been chosen as 14.5 dB.

- Two values have been considered for the nominal I/C tracking value in the not-losing track mode.

According to RTCA (Radio Technical Commission for Aeronautics) Paper No. 297-96/SC 159-710, Assessment of Radio Frequency Interference Relevant to the GNSS, the nominal I/C tracking value should be in the range 27.5–31.5 dB. It was reported to project team SE-28 that RTCA tests had observed a reduced interference susceptibility of GLONASS, leading to an I/C value of 29 to 32 dB. The value 29 dB was therefore agreed by both MSS and RNSS communities within SE-28.

NOTE: A value of 25 dB has been proposed by Russian Federation after agreement of the analysis contained in this Report. This value has meanwhile been specified in the ITU-R Doc. 8D-SRG/12 and Addendum 1 of the ITU-R Doc. 8D/200. This figure was also recommended in SARP's GNSS ICAO.

c) Differential between antenna gain toward the desired signal and the antenna gain toward the interference

Based on a value of GLONASS receiver gain toward the wanted signal of –4,5 dBic and gain toward the interference of –10 dBic.

d) distance between MES and RNSS receiver

For Cat 1 operations, the minimum decision height (DH) is 200 ft. Category 1 operations define the runway front course obstacle clearance surface to be 0 to 200 ft along the extended runway centreline. From 200 ft it increases at a slope of 1:34. For a nominal 3-degree glideslope the 200 ft DH is about 3816 ft from runway intercept point (See **Figure 5**). At this point the 1 : 34 obstacle clearance surface height is (3816-D4-200)/34 = 77 feet which leaves about 123 ft from nominal glidepath to the obstacle clearance surface. The RNSS antenna will likely be offset from about 7 feet to 27 feet above the nominal glidepath and the Radio Frequency Interference (RFI) source antenna could be located as high as the obstacle clearance surface. Thus with the minimum Cat 1 RFI protection distance between the RFI source and RNSS antennas of 100 ft a 30 to 50 foot allowance remains for Total System Error. This implies an aircraft might be slightly below that 100-ft minimum separation distance at DH for a small fraction of Cat 1 approaches given a standard 95 % Total System Error allowance of 32 ft.

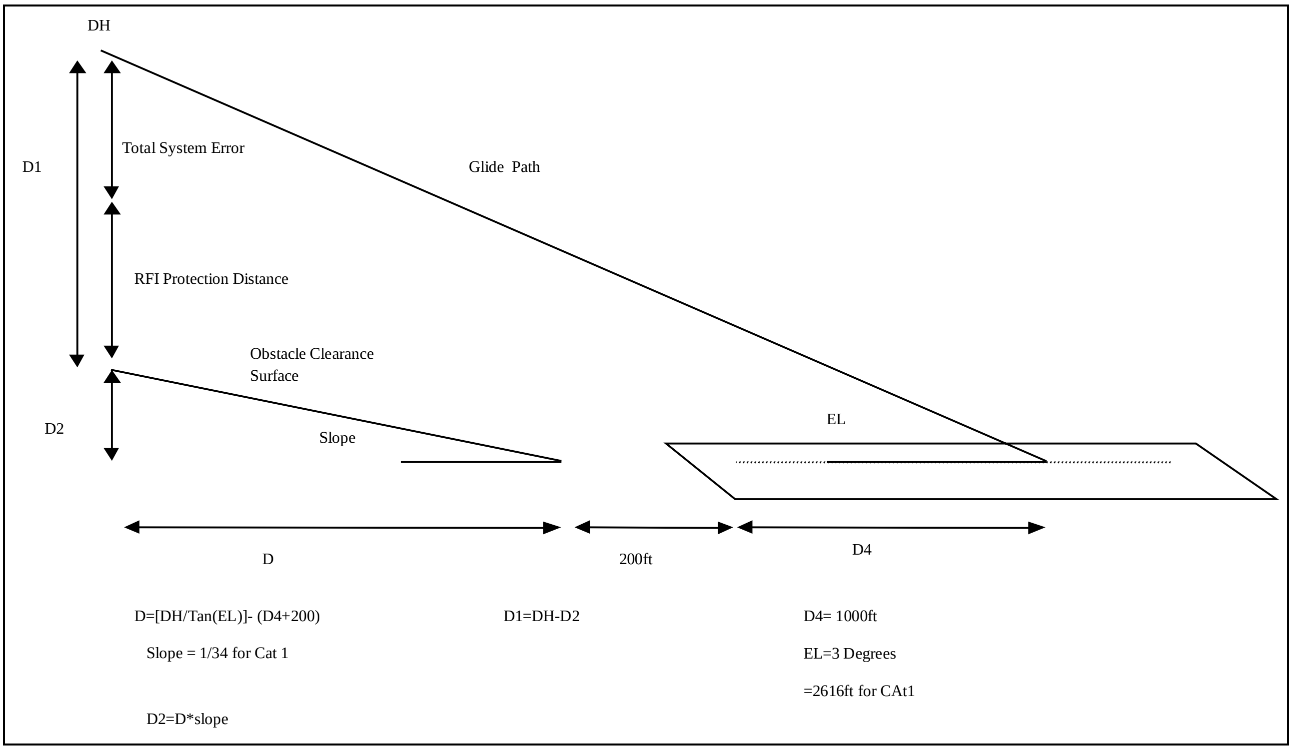


Figure 5: Distance between MES and RNSS receiver

e) Number of interference sources

It is agreed to consider one source.

➢ **Link Budget for band 1559 - 1605 MHz**

	Parameters	Symbol	CAT I		Unit
			tracking	Full accuracy	
a)	Minimal guaranteed level of satellite signal at RNSS receiver	P min	-161.00		dBW
b)	Maximum I/C in 1 MHz	I/C	29	14.5	dB
	Acceptable interference at the receiver input	**I accep.**	**-132.00**	**-148.5**	**dBW/MHz**
c)	RNSS receiver antenna gain in the direction of interference, interpreted as a differential between gain toward the desired signal and the gain toward the interference	G	**–5.50** (-7.00 has been proposed as well)		dB
d)	Distance MES/RNSS receiver[1]	d min	113		feet
			34.44		m
	Path Losses from MSS MES to RNSS receiver at 1.6 GHz	Ls	67.27		dB
e)	Number of interference sources		1		MESs
	Factor of several interference sources	N	0		dB
	Interference unwanted emission from MSS MES (1 MHz BW), as specified in the TBR041		-70		dBW/MHz
	.1.1 Total interference	**I total**	**-142.77**		**dBW/MHz**
	Margin (M = I acceptable – I total)[2]	**M**	**10.77**	**-4.73**	**dB**

Table 2. Link Budget for band 1559 - 1605 MHz

➢ **Budget for band 1605 - 1610 MHz**

For the band 1605 - 1610 MHz TBR041 specifies a level of -70 dBW/MHz for EIRP produced by unwanted emissions from MSS user earth stations at 1605 MHz linearly extrapolated to -10 dBW/MHz at 1610 MHz. The specified spectrum mask ensures the protection of GLONASS SAS receivers for tracking if the receiver is fitted with a suitable pre-correlator filter while it would not ensure the protection of GLONASS PAS receivers in all the possible scenarios (see Annex 4).

NOTE: A DNR (8D/TEMP/145r2) indicates a safety margin for Glonass of 5.6 dB. This figure was not used for the purpose of this calculation because, due to the nature of the scenario, the analysis deals with very short term interference only.

[1] This figure was agreed by SE28 based on analysis of the scenario (see Attachment 4 to Document 8D/200(Add. 1) of the 15th of June 1997). Russian Federation suggested use of the figure of 100 feet, based on Addendum 3 to Circular Letter Radiocommunication Bureau 8/LCCE/40, 25.04.97 - Attachment 9 to the Report of the First Meeting of 8D-SRG. The difference in terms of margin is of about 1 dB.

[2] Russian Federation proposed use of an I/Cof 25 dB as well as safety margin of 5.6 dB. This proposals were not endorsed by SE28. The overall difference in terms of results would be of 9.6 dB. Even considering this value of 9.6 dB, the margin for tracking would remain positive and the margin for high accuracy negative.

4 CONCLUSION

The mask specified in the TBR041 and accepted by CEPT as a compromise provides adequate protection of:

- GPS C/A and P code receivers;
- GPS-SBAS;
- SAS-code GLONASS receivers using carriers below 1605 MHz (i.e. all SAS-coded GLONASS receivers after 2005), provided that full accuracy mode is not required and the receiver is equipped with suitable pre-correlator filter (in absence of such filter the receiver may be interfered with by MES emissions in the MSS band above 1610 MHz).

At the same time, the MES spectrum mask as in TBR041 does not provide full protection to GLONASS receivers in respect of:

- the use of GLONASS receivers using SAS signal on carriers above 1605 MHz for landing up to the end of 2005;
- full system accuracy for CAT 1 landing using SAS;
- the use of PA signal for landing.

It is reiterated that these results were derived using an absolute worst case scenario and that the actual probability of interference is considered to be very low.

As explained in 3.1, only the Globalstar/GLONASS scenario has been analysed in detail, because it is the most critical case among the issues of interference from MSS mobile Earth terminals in the band 1610 – 1626.5 MHz into RNSS in the band 1559 – 1610 MHz.

ANNEXES

- Annex 1: Extracts from TBR041
- Annex 2: Extracts from Rec M.1317 on GLONASS-M
- Annex 3: Extracts from Rec M.1088 on GPS
- Annex 4: Estimation of the impact of Globalstar on PAS and SAS GLONASS in the worst case scenario

ANNEX 1

Annex 1: Extract of TBR041

The maximum EIRP density of the unwanted emissions from the MES outside the band 1610.0 to 1626.5 MHz and the band 1626.5 to 1628.5 MHz shall not exceed the limits in the table.

In **Table A1.1**, whenever a change of limit between adjacent frequency bands occurs, the lower of the two limits shall apply at the transition frequency.

Frequency	**Carrier-on**		
(MHz)	**EIRP (dBW)**	**Measurement bandwidth**	**Measurement method**
0.1 - 30	-66	10 kHz	Peak-hold
30 - 1000	-66	100 kHz	Peak-hold
1000 - 1559	-60	1 MHz	Average
1559 - 1580.42	-70	1 MHz	Average (note 1)
1580.42 - 1605	-70	1 MHz	Average
1605 - 1610	-70 to -10 (note 2)	1 MHz	Average
1610 - 1626.5	Not applicable	Not applicable	Not applicable
1626.5 - 1628.5	Not applicable	Not applicable	Not applicable
1628.5 - 1631.5	-60	30 kHz	Average
1631.5 - 1636.5	-60	100 kHz	Average
1636.5 - 1646.5	-60	300 kHz	Average
1646.5 -1666.5	-60	1 MHz	Average
1666.5 - 2200	-60	3 MHz	Average
2200 - 12750	-60	3 MHz	Peak hold
NOTE 1: In the sub-band 1573.42 - 1580.42 MHz, the average measurement time is 20 ms.			
NOTE 2: Linearly interpolated in dBW vs. frequency offset.			

Table A1. 1. Maximum unwanted emissions outside of the band 1610 to 1626.5 MHz and the band 1626.5 to 1628.5 MHz

ANNEX 2

Annex 2: Extract of Rec. M.1317 ITU-R

GLONASS-M receiver characteristics
(For a typical low-cost receiver)

L1, L2 carrier frequencies	See Section 1.1.1 of Annex 2
P code chip rate	5.11 Mbit/sec
C/A code chip rate	0.511 Mbit/sec
Navigation data rate	50 bit/s
Undetected bit-error rate	10^{-5}
Minimum received power level (L1, P, C/A)	-161 dBW
Minimum received power level (L2, P, C/A)	-167 dBW
Preamplifier limiting level	-80 dBW
Preamplifier burnout level	-1 dBW, average
Overload recovery time	1 s
RF 3 dB filter bandwidth	±20 MHz
RF 30 dB filter bandwidth	±45 MHz
Permissible I/S margin (L1, C/A)	15 dB*
Permissible I/S margin (L1, P)	25 dB*

* For acquisition

ANNEX 3

Annex 3: Extract of Rec. M.1088 ITU-R

GPS receiver characteristics
(for typical, low-cost air-navigation receivers)

L1 carrier frequency:	1575.42 MHz
L2 carrier frequency:	1227.6 MHz
P code chip rate:	10.23 Mbit/s
C/A code chip rate:	1.023 Mbit/s
Navigation data rate:	50 bit/s
Undetected bit-error rate:	10 -5
Minimum received power level (L2, P):	-136 dBm
Minimum received power level (L1, P):	-133 dBm
Minimum received power level (L1, C/A):	-130 dBm
Preamplifier limiting level:	–40 dBm
Preamplifier burnout level:	30 dBm, ave.
	40 dBm, peak
Overload recovery time:	1 s
RF 3-dB filter bandwidth:	± 17 MHz
RF 45-dB filter bandwidth:	± 50 MHz
Isolation between L1 and L2:	40 dB
Receiver noise figure:	3 dB
Normal acquisition I/S margin (L1, C/A):	24 dB
State 5 tracking I/S margin (L1, C/A):	31 dB
State 5 tracking I/S margin (L1, P):	41 dB

ANNEX 4

Annex 4: Estimation of the impact of Globalstar MES into GLONASS PAS and SAS receivers on board of an aircraft for the worst case scenario described in the main body of this report

Introduction

The purpose of this annex is to estimate the impact of Globalstar on tracking of GLONASS receivers for both the SAS and PAS codes. The tracking parameters for the GLONASS receiver in the case of the SAS code and of the critical scenario considered are those used in the main body of the report and agreed in SE28. For the PAS code, the parameters have been provided by Russian administration.

Methodology

For both case of SAS code and PAS code the effect of RF and IF filter are taken into account, as well as the filtering due to the correlator.

The MES out of band emission taken into account is at -70 dBW/MHz in the entire RNSS band 1559 - 1605 MHz and is linearly increasing from -70 to -10 dBW/MHz up to 1610 MHz.

The useful signal is set to -161 dBW for both the SAS and the PAS code.

The presence of one mobile at a distance of 100 feet (30.48 m) from the landing aircraft is taken into account. The required C/I is:

- C/Isas = -29 dB for the SAS code (for tracking, based on justification in the main body of the report)
- C/Ipas = - 35 dB for the PAS code (for tracking, based on input from Russian Administration)

The upper channel is centered at 1604.25 MHz (f_0) for both SAS and PAS.

The correlator is of the form $\text{sinc}^2(f- f_0)$ for both codes (taken into account the different chip rate 0.511 MHz for the C/A code and 5.11 MHz for the P code). The standard correlator is taken into account.

The RF filter is the same for both codes and its bandwidth is equal to RFBW = (1609.36 - 1592.9525) MHz = 16.4075 MHz.
The mask $U1(|f-f_0|)$ is calculated in the following way:

$U1(|f-f_0|) = 0$ $\quad |f- f_0| <= c1 * 10^{(-a1/b1)}$
$U1(|f-f_0|) = a1 + b1 * \log(|f-f_0|/c1)$ $\quad |f- f_0| > c1 * 10^{(-a1/b1)}$

where:

kp = 2;
a1 = -1;
c1 = RFBW/2 (with RFBW expressed in Hz);
b1 = -29/log(RFBW * kp/ (2 * c1))

Furthermore the IF filters for both codes, the mask $U2(f- f_0)$ has been determined in the following way:

$U2(f- f_0) = 0$ $\quad |f- f_0| <= c2 * 10^{(-a2/b2)}$
$U2(f- f_0) = a2 + b2 * \log (|f- f_0|/c2)$ $\quad |f- f_0| > c2 * 10^{(-a2/b2)}$

where:

kp30 = 1.225;
a2 = -1;
c2 = IFBW/2 (with IFBW expressed in Hz);
b2 = -29/log(IFBW * kp30/ (2 * c2))

The IFBW (bandwidth of the IF filter) is different in the case of PAS and SAS (see below, section 'Results').

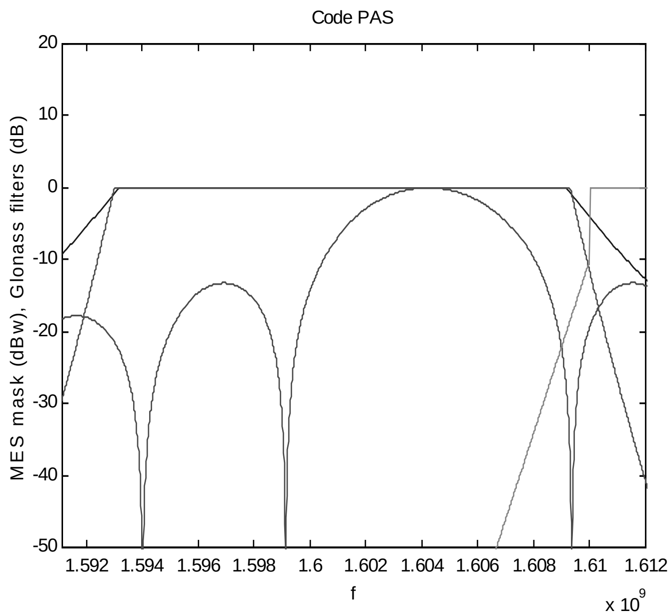
For each sample frequency (step of 1 kHz), the impact of the out of band emission is calculated, taken into account the RF filter, the IF filter and the correlator. Then the interfering contributions are integrated the estimate the overall impact. Two integrations are made for both codes, once on the band for which the RF filtering attenuates less than 30 dB ($|f-f_0| < Df30 = RFBW*kp = 32$ MHz) for the case of Out-Of-Band emissions (OOB) and once on the part of this portion of spectrum which is below 1610 MHz. In the first case the maximum in band power of the MES has a leading impact and this has been set to 0 dBW which is the likely figure for hand-held MES.

Results

PAS code

The IF filter for the PAS code is considered to include all the band and so IFBW = RFBW = 16.4075 MHz (source Russian administration). The central frequency of the filter is at (1609.36 – 1592.9525)/2 MHz = 1601.15625 MHz.

The following figure shows the RF filter, the IF filter and the correlator (in dB) and the interfering signal (in dBW, for the case of MES maximum power at 0 dBW).



The received interference power at the output of the correlator due to OOB MES emissions is –116.5 dBW, for an excess of interference of 14.0 dB.

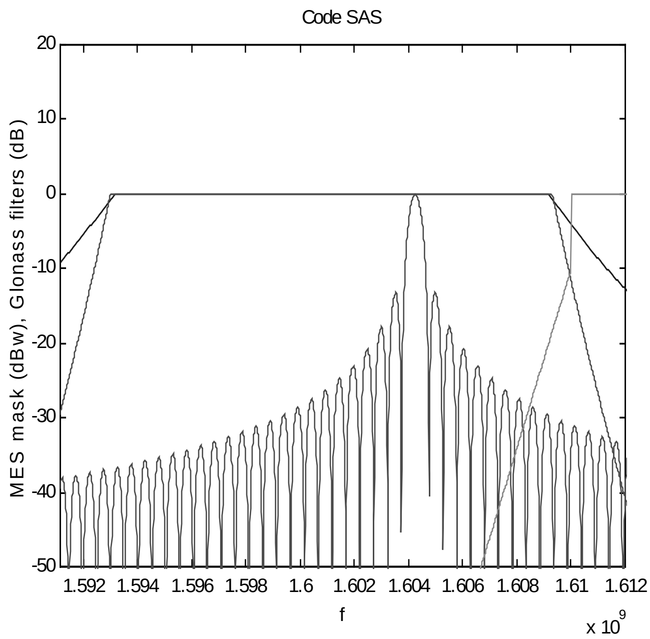
The received interference power at the output of the correlator due to MES emissions is –113.3 dBW in the case of 0 dBW MES (excess of interference of 17.2 dB) and of –106.6 dBW in the case of 9 dBW MES (excess of interference of 23.9 dB).

<u>SAS code</u>

There is no clear specification for the IF filter in the case of SAS code. Here three cases are proposed:

- IFBW = RFBW = 16.4075 MHz, centred at (1609.36 – 1592.9525)/2 MHz = 1601.15625 MHz

The situation is described in the following figure.

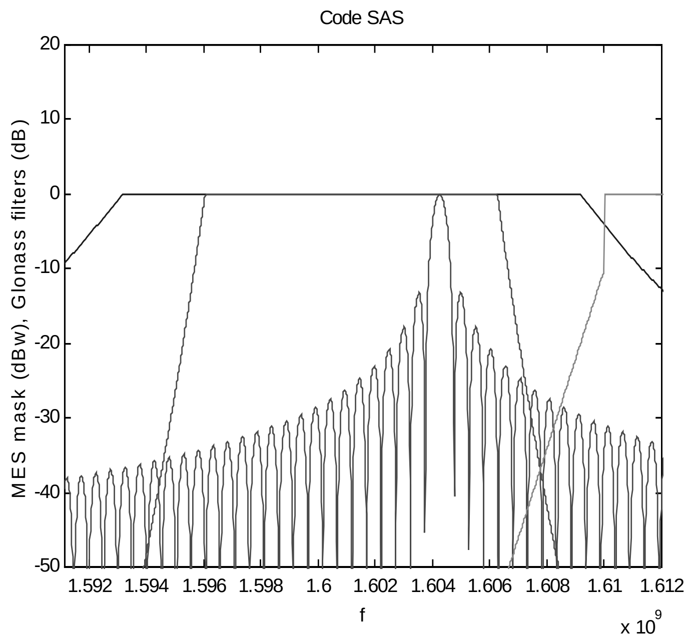


The received interference power at the output of the correlator due to OOB MES emissions is –129.2 dBW, for an excess of interference of 7.3 dB.

The received interference power at the output of the correlator due to MES emissions is –127.3 dBW in the case of 0 dBW MES (excess of interference of 9.2 dB) and of –121.9 dBW in the case of 9 dBW MES (excess of interference of 14.6 dB).

- IFBW = (1606.294 - 1596.019) MHz = 10.275 MHz, centred at (1606.294 + 1596.019)/2 MHz = 1601.1565 MHz.

This is justified by the fact that all the SAS channels are included in the bandwidth of the filter, moreover satisfying the need for a ±2.044 MHz around the edge channels for a narrow correlation.
The situation is described in the following figure.

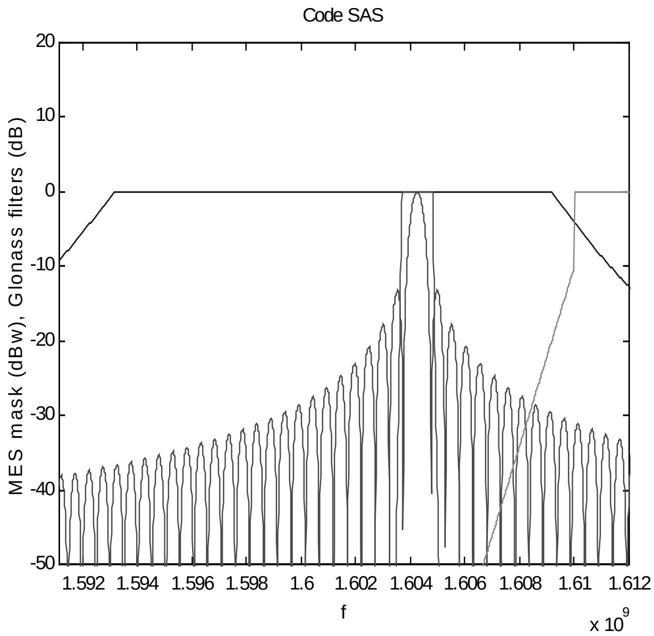


The received interference power at the output of the correlator due to OOB MES emissions is –148.7 dBW, 12.2 dB below the critical level defined by the required C/I.

The received interference power at the output of the correlator due to MES emissions is again –148.7 dBW in both the case of
0 dBW MES and the case of 9 dBW MES (interference 12.2 dB below the critical level defined by the required C/I). This means that the MES emissions in the MSS bands are completely filtered.

- IFBW = 2*0.5625 MHz, centred at 1604.25 MHz (central frequency of the selected channel).

This bandwidth has been chosen as an example for the case where IF filtering applies to each single GLONASS channel (the minimum bandwidth would be 2*0511 MHz). Moreover it is noted that in many cases this filtering is performed using digital technology: the shape of the filter itself may be quite different, but this has no impact on the result of this analysis. The situation is described in the following figure.



The received interference power at the output of the correlator due to OOB MES emissions is of –149.6 dBW, for an interference 13.1 dB below the critical level defined by the required C/I.

The received interference power at the output of the correlator due to MES emissions is again of –149.6 dBW in both the case of 0 dBW MES and the case of 9 dBW MES (interference 13.1 dB below the critical level defined by the required C/I). This means that the MES emissions in the MSS bands are completely filtered.

Summary of the results

Taking into account the worst case assumptions as presented in the main body of the report, we can see that the impact of a "bad-placed" MES on a GLONASS receiver tracking using the SAS code is negligible if a very simple filter is used (i.e. single filter for all the channels, second case considered for SAS): in fact the required C/I for tracking is respected with a margin of more than 10 dB. The MES emissions within the MSS band have no impact on the receiver, unless the IF filter is absent or excessively wideband.

For the PAS code, in the same worst case scenario, the receiver tracking is affected by the MES emissions within the MSS band because the correlator uses a wider bandwidth.

NOTE 1: the Russian Federation has recently proposed a more stringent I/C requirement for tracking of 25 dB for SAS code.

NOTE 2: the analysis presented here is limited to the effect of interference on GLONASS receivers with respect to maintaining nominal signal tracking.