ERC REPORT 27

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COMPATIBILITY STUDY BETWEEN MOBILE SATELLITE SERVICE IN THE 1610-1626.5 MHz AND GLONASS

Brussels, June 1994

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COMPATIBILITY STUDY BETWEEN MOBILE SATELLITE SERVICE IN THE 1610-1626.5 MHz AND GLONASS

1. INTRODUCTION

WARC-92 (RR 731 E) allocated the band 1610-1626.5 MHz on a primary basis to the Mobile Satellite Service (MSS) in the earth-to-space direction (uplink) and the band 1613.8-1626.5 MHz on a secondary basis to the MSS in the space-to-earth direction (downlink). This report presents the results of the study concerning the sharing between GLONASS and MSS.

The GLObal NAvigation Satellite System (GLONASS) provides global, 24 hour-a-day, all weather access, precise position, velocity and time position, similarly to the GPS and is operated by the Russian Administration. The channel centre frequencies are in increments of 0.5625 MHz from 1602.5625 MHz to 1615.5 MHz . A Coarse/Acquisition signal (C/A carrier) is phase modulated with a chip rate of 0.511 Mbit/s (1 MHz bandwidth) and a precise signal (P carrier) is phase modulated with a chip rate of 5.11 Mbit/s (10 MHz bandwidth). For the P signal, the maximum power density 1 MHz outside, centred on the carrier, is 10 dB lower than the maximum power density for the C/A signal.

It should be noted that two satellite networks have been submitted to the Radiocommunications Bureau : GLONASS (only C/A carrier) in June 82 and GLONASS M (C/A carrier and P carrier) in January 92. Though there are still some comments and objections to GLONASS M, 12 satellites are operating at this time GLONASS M, and 24 satellites will be operational in 1995.

Below 1610 MHz, GLONASS/GLONASS M is considered as a part of the RadioNavigation Satellite service. Above 1610 MHz, this world-wide system can only operate as an element of the Global Navigation Satellite System (GNSS) and, thus, airborne GLONASS receivers will operate under RR732 (use of airborne electronic aids to air navigation). Since it is coordinated under article 14, GLONASS is protected by RR731E, stating that MSS stations shall not cause interference or claim protection from stations operating under RR732. On the other hand, GLONASS M has not been coordinated with article 14 and can not claim protection. Moreover, according to ICAO (International Civil Aviation Organisation), GLONASS P carrier is not assumed to be part of GNSS and, therefore, has no clear status.

In September 93, the Russian Administration concluded an agreement with radioastronomers and gave a new allotment to existing GLONASS/GLONASS M satellites in order to protect Radioastronomy; but some channels in the MSS band are still used (see annex 1). This new allotment does not fully protect radioastronomy against 10 MHz P carrier and article 7 of this agreement states that "a solution of the interference problem caused by the main emission of class 10M2G7X and out of band emissions of GLONASS transmitters in the frequency band 1610.6-1613.8 MHz will be achieved only if the frequency plans of the GLONASS and GLONASS M systems are modified". The use of 12 channels with centre frequencies from 1599.1875 MHz to 1605.375 MHz is envisaged. If implemented, this would solve the question of sharing between GLONASS and MSS in the band 1610-1626.5 MHz.

Characteristics for MSS are not fully determined at the moment. Both TDMA and CDMA access techniques and both GSO and non GSO satellites are considered in calculations, with technical data already available. MSS systems are referred to by name for ease of identification.

According to RR731E, the MES maximum EIRP should be -15dBW/4kHz when sharing with systems operating under RR732 and -3dBW/4 kHz elsewhere.

For the time being, only the Iridium project intends to use a secondary status downlink allocation in the band 1616 MHz to 1626.5 MHz.

2. INTERFERENCE FROM MES TO GLONASS

According to the aeronautical community, the minimum separation distance between an airborne GLONASS receiver and a MES is 100 m. Usually, aircraft at this altitude would only be found very close to airports. However, in an emergency, it is difficult to assess the lowest en-route altitude. Hence, it is estimated that 100 m should be the minimum required protection distance.

Co-channel interference distance calculations between airborne GLONASS and both CDMA and TDMA MES have been carried out. The Airlines Electronic Engineering Committee (AEEC) indicates in ARINC characteristic 743A that "the GLONASS sensor unit shall acquire and maintain code and carrier lock of a GLONASS signal at -137 dBm in the presence of an in-band wide band (>600 Hz) interfering signal of -116 dBm (-21 dB protection ratio). According to the results of measurements given in an FCC document, the sensitivity of a GLONASS receiver is -145 dBm and the wanted signal ranges from -135 dBm to -132 dBm when a GLONASS satellite is visible. According to a Russian contribution to WARC 92 (Addendum 1 to doc. 184E), the wanted signal value is between
-126 and -131 dBm and the protection ratio is -16 dB.

AEEC figures are used throughout. Then, the protection level for GLONASS is assumed to be -116 dBm.

Considering the -15 dBW/4kHz limit of RR731E for MES power flux density, separation distances vary from 118 km for TDMA MES to 695 km for CDMA MES. TDMA systems tend to use higher powers, which means, according to RR731E, no sharing with GLONASS. CDMA system power could be, at maximum, -25 dBW/4 kHz, leading to a 220 km interference distance. This is obviously not tolerable compared to the 100 m criteria !

Annex 2 provides detailed calculations.

In the reverse order, 100 m protection distance leads to a maximum EIRP of -92 dBW/4kHz for MES having a bandwidth wider than the GLONASS bandwidth (CDMA systems). Considering a narrowband TDMA system (20 kHz), the maximum MES EIRP should be -76 dBW/4 kHz. These two figures are not realistic.

It is interesting to notice that the values of -92 dBW/4 kHz is also the maximum MES out-of-band emission (due to modulation or wideband noise) power in GLONASS band and will therefore establish the frequency separation between MSS and GLONASS, depending on the MES out-of-band specification. Less stringent assumptions (antenna discrimination, shielding etc.) will yield a higher value.

3. INTERFERENCE FROM GLONASS SATELLITES TO MSS SATELLITES

Satellite to satellite interference is a complex matter when taking into account every parameter: satellites location and speed, earth rotation, antenna pattern, wanted signal level etc. Hence, only some very rough calculations have been carried out to assess the order of magnitude of the interference and identify the main problems. Two interference cases have been studied for LEO and ICO space segment configurations : GLONASS satellite into MSS satellite backlobe and the two satellites over the earth horizon. As a conclusion, the first interference case might be solved by appropriate antenna design, when the second interference case cannot be avoided. For GSO space segment configuration, interference is likely to occur when the MSS satellite is visible to the GLONASS backlobe, but also when the two satellites are over the earth horizon.

Detailed calculations are presented in annex 3.

An initial dynamic simulation has been undertaken by Inmarsat to assess the time varying nature of the GLONASS satellite to Inmarsat ICO satellite interference. This initial study assumed the use of CDMA parameters for the Inmarsat MSS system. The provisional results indicate that MSS uplink carriers could be subjected to interference for about 0.5 to 3% of the time with a typical excess interference duration of up to 250 seconds. Further study is required in this respect.

4. INTERFERENCE FROM DOWNLINK MSS TO GLONASS RECEIVERS

The specified GLONASS protection level is -116 dBm for a wanted signal of -137 dBm. Considering a 3 dBi GLONASS maximum antenna gain and a 700 kHz receiver noise bandwidth, this gives a maximum power flux density of -146 dBW/m²/4 kHz. More optimistic assumptions on wanted signal or antenna gain will yield higher values. However, unless there is confirmation by ICAO or the Russian Administration it is more appropriate to use this value, which is below TDMA MES sensitivity. Thus co-frequency sharing between downlink MSS and GLONASS is not possible unless an operational sharing technique is used. It should be noted that the value of -146 dBW/m²/4 kHz is also the maximum downlink MSS out-of-band emission (due to modulation or wideband noise) power in GLONASS band and will therefore lay down the frequency separation between co-located, simultaneous operations of downlink MSS channels and GLONASS, depending on the MSS out-of-band specification.

5. OPERATIONAL SHARING TECHNIQUES

Overlapping coverage and co-channel sharing of MSS uplink carriers with GLONASS carriers will be difficult. As indicated in the introduction of this report, there is currently an attempt to reconfigure GLONASS. Another possibility which may be considered to facilitate MSS operation in the 1610-1620.5 MHz band is a dynamic frequency assignment scheme based on non-overlapping coverage.

5.1 Glonass Reconfiguration

The current GLONASS/GLONASS-M system can use 24 distinct carrier frequencies - one for each satellite. It may be possible for the GLONASS/GLONASS-M system to operate with 12 frequencies - each frequency being used by anti-podal GLONASS satellites. This implies that the last centre frequency used by GLONASS would be 1608.75 MHz. If such a reconfiguration of the GLONASS system could be achieved, GLONASS C/A receivers would be protected against MSS interferers (providing that level of out of band emissions are lower than those calculated in section 2 and 4) and MSS satellites may suffer interference only from the attenuated P signal. The reconfiguration achieved in September by the Russian authorities in order to protect Radio astronomy does not fully comply with these requirements since the three last channels, above the Radio astronomy band, are still used. However, for the first time two anti-podal satellites are using the same channel which proves the feasibility of the required reconfiguration.

As indicated in the introduction of this report, a shift to lower frequencies, which would totally avoid interference to radioastronomy, is likely to be achieved in the near future. This would provide more than 4 MHz frequency separation between GLONASS and MSS which is likely to solve any compatibility issues.

5.2 Non-overlapping Coverage Co-Channel Case

The MES would normally be expected to report its position to the MSS Land Earth Station (LES) via a signalling channel. Generally the MSS operator may come to an agreement with the GLONASS system operator or ICAO or relevant national Civil Aviation Authorities, whereby a minimum coordination distance would typically be assured between the MSS terminal and any GLONASS airborne earth station (AES) receiver. The MSS LES could be equipped to receive and process the orbital ephemeris data of the entire GLONASS satellite constellation. The LES in the call set-up process (i.e. prior to assigning a carrier frequency to a MES) could, knowing the location of the MES terminal and the associated minimum coordination distance, determine for any AES located inside the coordination zone centred on the MES location, which GLONASS satellites would be visible and accordingly which GLONASS frequencies could be used by any AES located inside the MES coordination zone. The frequency selection algorithm would have to determine which GLONASS frequencies would remain "non-visible" to the AES for the expected duration of the MSS call.

Assuming a fully deployed constellation of 24 GLONASS satellites, typically between 4 and 8 GLONASS satellites would be visible to an AES at any given moment. Of these 4 to 8 GLONASS frequencies, only those which are within the MSS band 1610-1626.5 MHz may need to be avoided by the LES in assigning a frequency to the MES. For example all the frequencies used within the 1610-1620.6 MHz band by GLONASS satellites located anti-podally could be potentially used by the MSS system. The above intelligent dynamic frequency allocation by location (D-FABL) scheme, based on determining which GLONASS frequencies are 'non-visible' to the AES and visible to the MES, may be feasible to implement by MSS operators.

Further study is required in particular to assess the impact of such operational schemes on both the MSS and GLONASS system in terms of technical feasibility and aggregate interference levels.

While solving the interferences from MES to GLONASS receivers, simulation results provided in annex 3 show that, with this operational sharing technique, satellite to satellite interference over the Earth horizon could still be a problem for a high percentage of time.

Therefore, sharing based on non-overlapping coverage seems not technically realistic. Then, unless GLONASS reconfigures, introduction of MSS in the 1610-1616 MHz band would cause interference to GLONASS C/A receivers and introduction of MSS in the 1610-1620.5 MHz band would cause interference to GLONASS P receivers.

6. CONCLUSION

Only a full reconfiguration of GLONASS (use of the same frequencies by anti-podal satellites and frequency shifting) would give a satisfactory solution for sharing between GLONASS and MSS. This reconfiguration is likely to be implemented due to the obligation for GLONASS to protect Radio Astronomy in the 1610.6-1613.8 MHz band. If GLONASS is reconfigured without frequency shifting (and because of the very short protection distance), special care should be given to out of band emissions from MES into GLONASS receivers.

ANNEX 1

GLONASS / GLONASS M FREQUENCY DATA

1. FREQUENCY ALLOCATION

	GLONASS	**GLONASS M**
Frequency range	1597-1617	1596.9-1620.6
Max. power density	-44 dBW/Hz	-52 dBW/Hz (1596.9-1620.6 MHz) -42 dBW/Hz (1601.5-1616 MHz)
centre frequency (MHz)	1602 + nx0.5625 n = (1..24)	1602 + nx0.5625 n = (1..24)
carrier chip rate (kbs)	C/A signal : 511	C/A signal : 511 P signal : 5110
bandwidth	1 MHz	10 MHz

2. ORBITAL CONFIGURATION ON SEPTEMBER 93

Twelve GLONASS satellites are currently emitting from orbit (number 1,2,3,4,5,6,7,8,17,19,22,24)

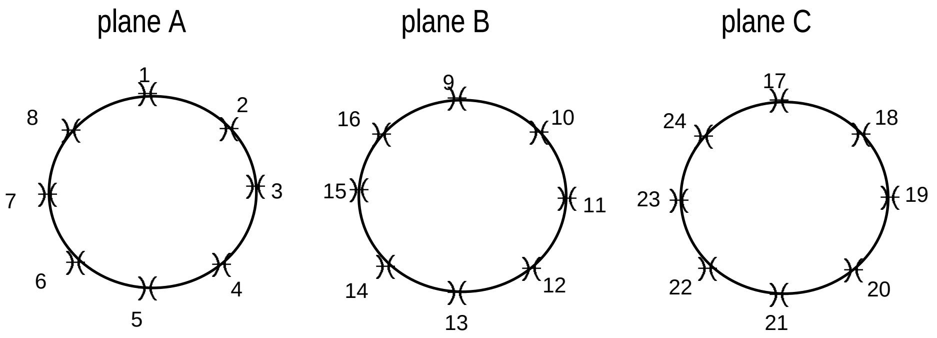

figure 1 : satellite numbers

channel number	1	2	3	4	5	6	7	8	9	10	11	12
centre frequency (MHz)	1602.5625	1603.125	1603.6875	1604.25	1604.8125	1605.375	1605.9375	1606.5	1607.0625	1607.625	1608.1875	1608.75
satellite number	24	8	19	4	2	-	-	-	-	-	22	3

channel number	13	14	15	16	17	18	19	20	21	22	23	24
centre frequency (MHz)	1609.3125	1609.875	1610.4375	1611	1611.5625	1612.125	1612.6875	1613.25	1613.8125	1614.375	1614.9375	1615.5
satellite number	7	-	-	-	-	-	-	-	-	6	5 & 1	17

table 1 : channel allocation

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ANNEX 2

SINGLE-ENTRY CO-CHANNEL MSS MES INTERFERENCE INTO GLONASS RECEIVERS

Glonass Protection Level	dBW	-146
Receiver noise bandwidth	kHz	700
Max. tol. power density	dBW/4kHz	-168
Frequency	MHz	1610

All calculations assumes :

- single interfering MES located on earth surface within field of view of GLONASS receiver
- 0dB GLONASS antenna discrimination towards MES location
- fuselage shielding effects ignored

case 1 : wideband MSS (>700 kHz)

MSS MES EIRP Density (dBW/4kHz)	Required Free Space Loss (dB)	Required Separation Distance (km)
-15	153,4	695
-20	148,4	391
-25	143,4	220
-30	138,4	124
-35	133,4	70

case 2 : narrowband MSS (20 kHz)

MSS MES EIRP Density (dBW/4kHz)	Required Free Space Loss (dB)	Required Separation distance (km)
0	153,0	661
-5	148,0	372
-10	143,0	209
-15	138,0	118
-20	133,0	66

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ANNEX 3

INTERFERENCE FROM GLONASS SATELLITES TO MSS SATELLITES

1. LEO AND ICO SPACE SEGMENT CONFIGURATIONS

1.1 description of scenario

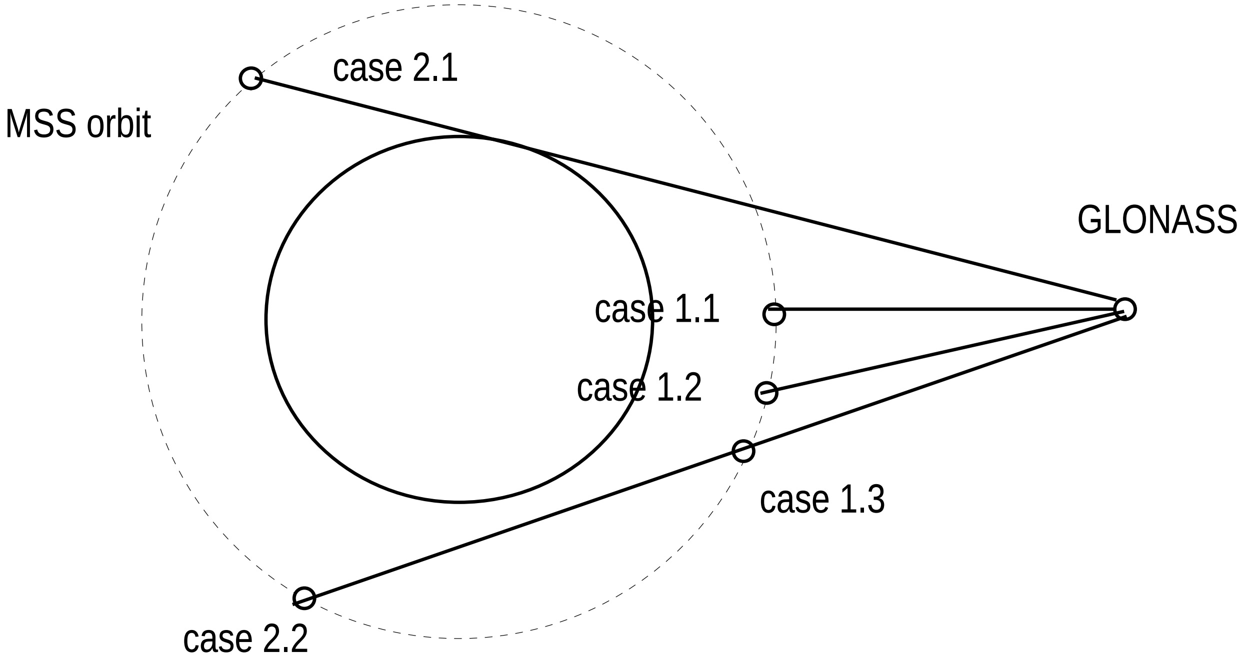
In order to assess potential interference from GLONASS satellites to MSS satellites, 5 worst cases scenarios have been computed.

1) GLONASS satellite is in the backlobe of MSS satellite. Three subcases are considered :

- shortest distance between the 2 satellites (case 1.1)
- MSS satellite at 11° from GLONASS-earth direction : maximum GLONASS antenna gain in the MSS satellite direction (case 1.2)
- MSS satellite at 18° from GLONASS-earth direction : edge of the GLONASS main lobe (case 1.3)

2) Interference over the earth horizon. Two subcases are considered :

- GLONASS satellite in the MSS satellite horizon (case 2.1)
- MSS satellite in the edge of GLONASS main lobe (case 2.2)



Information on GLONASS satellite are taken in IFRB registration, both for GLONASS and GLONASS M. It is interesting to notice the difference between the 2 registrations :

- antenna gain is 16 dB for GLONASS and 11 dB for GLONASS M (maximum at 11° and edge of main lobe at 18° for both registrations)
- the maximum spectrum density is -44 dBW/Hz in the whole GLONASS band. For GLONASS M, the power density is -42 dBW/Hz in a 1 MHz band centred on the carrier and -52 dBW/Hz in the other part of the 10 MHz channel.

In spite of all oppositions against GLONASS M, this is the system currently under used. Therefore, all calculations are based on GLONASS M registration.

Typical MSS systems have been used for calculations : GLOBALSTAR, ODYSSEY and INMARSAT for CDMA and IRIDIUM and INMARSAT for TDMA. Characteristics have been found in various documents.

Chosen interference criterion is a 6 % increase of thermal noise. It corresponds to a tolerable interference on noise ratio of -12.2 dB. For CDMA systems, the criteria of 6 % should preferably apply on the sum of the thermal noise and the intra-system noise (due to other users in the same channel). However, there is a lack of information on the values of this intra-system noise for most systems. For Globalstar, the anticipated intra-system noise is 2.9 dB below the thermal noise, thus leading to an error of 1.8 dB on the value of tolerable level of interference.

Since very few information are available on MSS satellite antenna pattern, results are given in terms of maximum MSS satellite antenna gains in the GLONASS satellite directions.

1.2 calculations

For each scenario, distance between satellites have been calculated with the following equations :

$H1$: GLONASS altitude (19100 km)
$H2$: MSS altitude (km)
R : earth radius (6378 km)

case 1.1 : $d11 = H1-H2$

case 1.2 : $d12 = (H1+R)\cos 11^\circ - \mathrm{sqrt}((H1+R)^2\cos^2 11^\circ-H1^2+H2^2-2R(H1-H2))$

case 1.3 : $d13 = (H1+R)\cos 18^\circ - \mathrm{sqrt}((H1+R)^2\cos^2 18^\circ-H1^2+H2^2-2R(H1-H2))$

case 2.1 : $d21 = \mathrm{sqrt}(2*R*H1+H1^2)+\mathrm{sqrt}(2*R*H2+H2^2)$

case 2.2 : $d22 = (H1+R)\cos 18^\circ + \mathrm{sqrt}((H1+R)^2\cos^2 18^\circ-H1^2+H2^2-2R(H1-H2))$

cases 1.3 and 2.2 only occur for MSS altitude higher than 1495 km

Free space loss Li have been computed with these distances :

$Li = 20\log(di) + 96.56$

Then, the off-axis angle between satellite-earth directions and satellite-satellite directions is defined :
angglo : angle between GLONASS-earth and GLONASS-MSS satellite
angmss : angle between MSS satellite-earth and MSS satellite-GLONASS

case 1.1 : $angglo = 0^\circ$
$angmss = 180^\circ$

case 1.2 : $angglo = 11^\circ$
$angmss = 180^\circ-\mathrm{Arcsin}((H1+R)\sin 11^\circ/(H2+R))$

case 1.3 : $angglo = 18^\circ$
$angmss = 180^\circ-\mathrm{Arcsin}((H1+R)\sin 18^\circ/(H2+R))$

case 2.1 : $angglo = \mathrm{Arcsin}(R/(R+H1))$
$angmss = \mathrm{Arcsin}(R/R+H2)$

case 2.2 : $angglo = 18^\circ$
$angmss = \mathrm{Arcsin}((H1+R)\sin 18^\circ/H2+R))$

GLONASS M antenna gains for these angglo values are determined according to IFRB registration (see attached paper).

A typical total system temperature for MSS satellite receiver is 500°K, which gives a thermal noise density of -202 dBW/Hz. Then, the following equations gives the maximum antenna gain required to have less than 6% noise increase.

* if Bmss>1000 kHz

$$G_{MSS} = N - 12.2 - 10LOG(10^{\frac{P_{glo1}}{10}} x1.10^{6} + 10^{\frac{P_{glo2}}{10}} x \min(4.10^{6}, B_{MSS} - 1.10^{6})) + 10LOGB_{mss} - G_{glo} + L$$

* if Bmss<1000 kHz

$$G_{MSS} = N - 12.2 - P_{glo1} - G_{glo} + L$$

with Gmss (dB) : maximum MSS satellite antenna gain for angmss angle
N (dBW/Hz) : noise spectrum density
Pglo1 (dBW/Hz) : GLONASS M power spectrum density in a 1000 kHz band centred on the carrier
Pglo2 (dBW/Hz) : GLONASS M power spectrum density outside the 1000 kHz band centred on the carrier
Gglo (dB) : GLONASS M antenna gain for angglo angle
L : free space loss
Bmss (Hz): MSS bandwidth

1.3 results

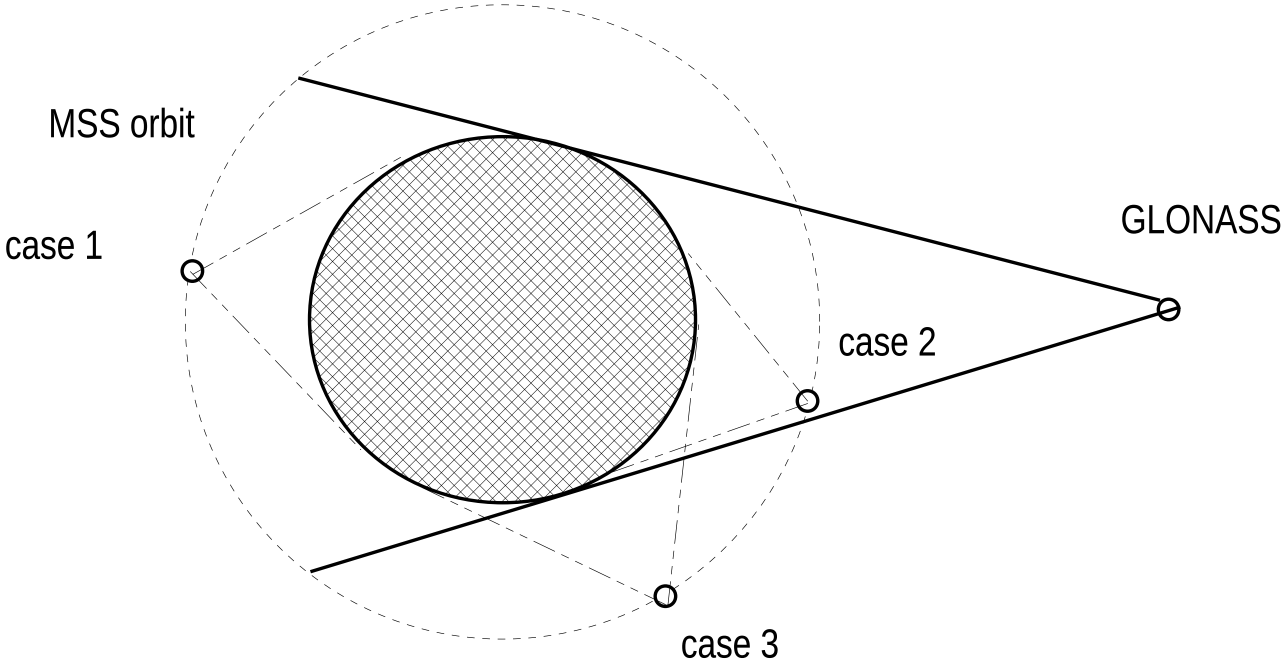
Results are presented in the table attached to this annex.
They show that :

- CDMA and TDMA systems presents the same results. However, if the 6% increase of noise was based on thermal noise+intra-system noise instead of only thermal noise for CDMA systems, there would be an advantage for CDMA.
- For ICO MSS satellites, a good MSS antenna design might enable them not to be interfered when presenting backlobes to GLONASS (cases 1.1, 1.2, 1.3). However, interferences would occur when the MSS satellite is in the GLONASS main lobe (angmss<28°, case 2.2) and not protected by the earth (angmss>22°, case 2.1). This will depend on MSS satellite sidelobes for the calculated range of angmss.
- When not protected by the earth, LEO MSS satellites are always in the GLONASS mainlobe. Thus, backlobes and sidelobes levels have to be specified very carefully in order to avoid interferences.

In fact, it is believed that this is the interference from MES to GLONASS receiver which will prevent the sharing between the two systems. Thus, the interference from GLONASS satellite to MSS satellite will be a problem only when GLONASS receivers can not be interfered by MES. we can roughly distinguish 3 cases;

case 1 : MSS and GLONASS satellites are not in visibility : they have a not-overlapping coverage, and, consequently they can use the same frequency without interfering each other (MES to GLONASS receivers or GLONASS satellite to MSS satellite).
case 2 : MSS satellite coverage is included in the GLONASS coverage. No co-frequency use is possible, due to interference from MES to GLONASS receivers.
case 3 : MSS and GLONASS satellite coverage are overlapping. This is the intermediate case. The MSS satellite can be in a communication with a MES not in the GLONASS satellite coverage. Glonass receivers will not be interfered but MSS satellite might be interfered by GLONASS satellite.

These 3 cases are illustrated below.



To assess the percentage of time for each above condition, a short simulation was carried out.

1.4 simulation

Satellite latitude ϕ and longitude λ are given, when taking into account earth rotation, solar precession and the effect of earth flattening by the following equation

$$D(°) = \frac{T}{240} + \frac{0{,}9856473427}{86400} + 0{,}584424\cos(i)\left(\frac{R}{R+H}\right)^2$$

$$\sin(\phi) = \sin(i)\sin(2\pi\frac{t}{T})$$

$$\cos(\lambda - \lambda_0 + D\frac{t}{T})\cos(\phi) = \cos(2\pi\frac{t}{T})$$

with : i : orbital inclination
T : orbital period
D : drift
λo : longitude origin (time origin is taken at equator)

For GLONASS, we have :

T = 40453 s
i = 64.8°
H = 19100 km

Then, given the orbital inclination and period of each satellite and the difference between the two origins, the statistical percentage of time for having one of the three identified conditions can be derived. The following example have been studied.

ICO case

Characteristics of ICO Inmarsat satellite are used in calculations :

H = 10355 km
i = 50.7 °
T = 21526 s

It leads to the following result :

	MSS satellite-GLONASS distance d (km)	percentage of time
GLONASS-MSS satellite path obstructed by earth (case 1)	d >40125	9.8 %
MSS coverage included in GLONASS coverage (case 2)	9196>d	0.5 %
overlapping of the two coverage (case 3)	40125>d>9196	89.7 %

It means that, in case of sharing based on non overlapping coverage, the use by a MSS satellite of a frequency already used by a GLONASS satellite will be possible during 99.5 % of time. But, in 89.7 % of time, the MSS satellite might be interfered and, also, the MES position-determining equipment will be necessary to check whether it is in the area covered by the GLONASS satellite.

LEO case

Characteristics of Iridium satellite are used in calculations :

H = 780 km
i = 86 °
T = 6017 s

It leads to the following result :

	MSS satellite-GLONASS distance d (km)	percentage of time
GLONASS-MSS satellite path obstructed by earth (case 1)	d>27909	39.8 %
MSS coverage included in GLONASS coverage (case 2)	d<21414	18.5 %
overlapping of the two coverage (case 3)	27909>d>21414	41.7%

It means that, in case of sharing based on non overlapping coverage, the use by a MSS satellite of a frequency already used by a GLONASS satellite will be possible during 81.5 % of time. But, in 41.7 % of time, the MSS satellite might be interfered and, also, the MES position-determining equipment will be necessary to check whether it is in the area covered by the GLONASS satellite.

2. GSO SPACE SEGMENT CONFIGURATION

2.1 description of scenario

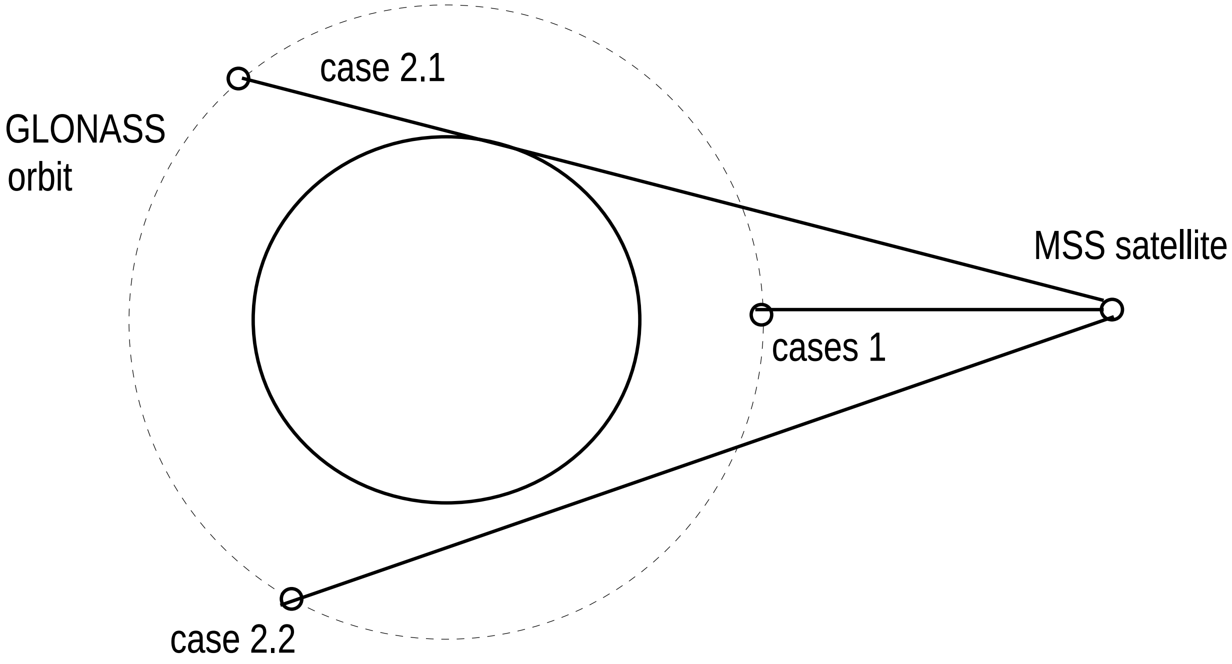
In order to assess potential interference from GLONASS satellites to MSS satellites, reverse scenarios can be envisaged :

1) MSS satellite is in the backlobe of GLONASS satellite. Two subcases are considered :

- GLONASS backlobe gain is 0 dBi (case 1.1)
- GLONASS backlobe gain is -10 dBi (case 1.2)

2) Interference over the earth horizon. Two subcases are considered :

- GLONASS satellite in the MSS satellite horizon (case 2.1)
- GLONASS satellite in the edge of MSS main lobe (case 2.2)



Calculations and simulation have been computed with the same equations as in section 1.

2.2 results

See attached table for results of calculations.

When MSS satellite is in the backlobe of GLONASS, interference could happen, depending on the MSS satellite antenna pattern and on the GLONASS backlobe gain. However, in this case, interference from MES to GLONASS receiver will prevent a co-channel use.

When the two satellites are over the earth horizon, it is likely that interferences would occur, at least in case 2.1 (antenna gain for GSO satellite are generally supposed to be higher than 11 dBi).

As for LEO and ICO space segment configuration, possibility of sharing using non overlapping coverage are envisaged.

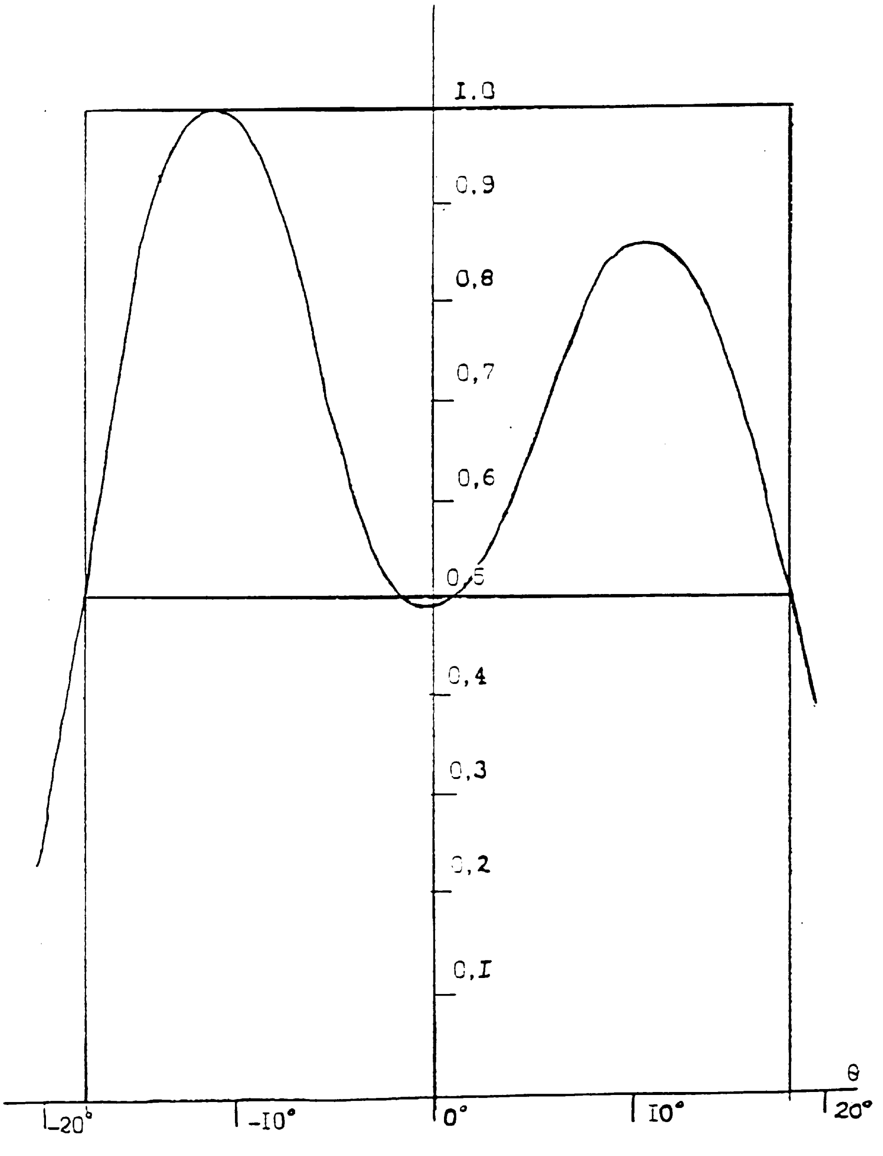
The result of the simulation gives :

	MSS satellite-GLONASS distance d (km)	percentage of time
GLONASS-MSS satellite path obstructed by earth (case 1)	d>66417	2.9 %
GLONASS coverage included in the MSS coverage (case 2)	d<17096	0.2 %
overlapping of the two coverage (case 3)	66417>d>17096	96.9 %

It means that, in case of sharing based on non overlapping coverage, the use by a MSS satellite of a frequency already used by a GLONASS satellite will be possible during 99.8 % of time. But, in 96.9 % of time, the MSS satellite might be interfered and, also, the MES position-determining equipment will be necessary to check whether it is in the area covered by the GLONASS satellite.

DIAGRAMME DE RAYONNEMENT DE L'ANTENNE
ANTENNA RADIATION PATTERN DIAGRAM
DIAGRAMA DE RADIACION DE LA ANTENA
GLONASS-M

Gmax: 11,0 dB



Interfered system	*GLOBALSTAR*	*ODYSSEY*	*IRIDIUM*	*INMARSAT*	*INMARSAT*
multiple access	CDMA	CDMA	TDMA	CDMA	TDMA
space segment configuration	LEO	ICO	LEO	ICO	ICO
H1 (km)	19100	19100	19100	19100	19100
H2 (km)	1406	10370	780	10355	10355
d11 (km)	17694	8730	18320	8745	8745
d12 (km)	18902	8978	19722	8993	8993
d13 (km)		10240		10257	10257
d21 (km)	29120	40141	27908	40125	40125
d22 (km)		38994		38977	38977
L(d11) (dB)	182	175	182	175	175
L(d12) (dB)	182	176	182	176	176
L(d13) (dB)		177		177	177
L(d21) (dB)	186	189	185	189	189
L(d22) (dB)		188		188	188
case 1.1 : angglo°	0	0	0	0	0
case 1.1 : angmss°	180	180	180	180	180
case 1.2 : angglo°	11	11	11	11	11
case 1.2 : angmss°	141	163	137	163	163
case 1.3 : anglo°		18		18	18
case 1.3 : angmss°		152		152	152
case 2.1 : angglo°	14	14	14	14	14
case 2.1 : angmss°	55	22	63	22	22
case 2.2 : angglo°		18		18	18
case 2.2 : angmss°		28		28	28
GLONASS M max. power density (dBW/Hz) in a 1 MHz band centred on carrier	-42	-42	-42	-42	-42
GLONASS M max. power density (dBW/Hz) outside the 1 MHz band centred on carrier	-52	-52	-52	-52	-52
GLONASS M antenna gain					
case 1.1 (dB)	8	8	8	8	8
case 1.2 (dB)	11	11	11	11	11
case 1.3 (dB)	8	8	8	8	8
case 2.1 (dB)	10	10	10	10	10
case 2.2 (dB)	8	8	8	8	8
MSS bandwidth (kHz)	1250	5300	40	1000	20
Thermal noise density (dBW/Hz)	-202	-202	-202	-202	-202
Maximum MSS antenna gain in the GLONASS direction					
case 1.1 (dB)	2	0	2	-5	-5
case 1.2 (dB)	0	-2	0	-8	-8
case 1.3 (dB)		2		-3	-3
case 2.1 (dB)	5	12	3	6	6
case 2.2 (dB)		14		8	8

Interfered system	*INMARSAT*
multiple access	TDMA
space segment configuration	GSO

H1 (km)	19100
H2 (km)	35870
d1 (km)	16770
d21 (km)	66417
d22 (km)	65721
L(d1) (dB)	181
L(d21) (dB)	193
L(d22) (dB)	193

case 1.1 : angglo°	180
case 1.1 : angmss°	0
case 2.1 : angglo°	14
case 2.1 : angmss°	9
case 2.2 : angglo°	18
case 2.2 : angmss°	11

GLONASS M max. power density (dBW/Hz)	
in a 1 MHz band centred on carrier	-42
GLONASS M max. power density (dBW/Hz)	
outside the 1000 kHz band centred on carrier	-52

GLONASS M antenna gain	
case 1.1 (dB)	0
case 1.2 (dB)	-10
case 2.1 (dB)	10
case 2.2 (dB)	8

MSS bandwidth (kHz)	20
Thermal noise density (dBW/Hz)	-202

Maximum MSS antenna gain in the GLONASS direction	
case 1.1 (dB)	9
case 1.2 (dB)	19
case 2.1 (dB)	11
case 2.2 (dB)	13