RECOMMENDATION ITU-R S.1326

FEASIBILITY OF SHARING BETWEEN THE INTER-SATELLITE SERVICE AND THE FIXED-SATELLITE SERVICE IN THE FREQUENCY BAND 50.4-51.4 GHz

(Question ITU-R 246/4)

(1997)

The ITU Radiocommunication Assembly,

considering

a) that Resolution 643 of the World Radiocommunication Conference (Geneva, 1995) (WRC-95) instructs the ITU-R to carry out the necessary studies to identify the bands most suitable for the inter-satellite service (ISS) in the frequency range from 50 to 70 GHz in order to enable WRC-97 to make appropriate allocations to that service;

b) that the frequency band 50.4-51.4 GHz is currently allocated on a co-primary basis to the fixed-satellite service (FSS) (Earth-to-space), the fixed service (FS) and the mobile service;

c) that any potential new allocation to the ISS in this band would need to take into account the feasibility of co-frequency sharing with the FSS;

d) that studies have been conducted into the feasibility of sharing between geostationary (GSO) fixed-satellite networks operating in the Earth-to-space direction and inter-satellite links (ISL) of GSO and non-GSO satellite networks as detailed in Annex 1,

recommends

1 that sharing is made feasible in the band 50.4-51.4 GHz between the GSO FSS (Earth-to-space) and the ISS employing links between GSO satellites by employing certain mitigation techniques as detailed in Annex 1.

NOTE 1 – Sharing is likely to be difficult between such FSS Earth-to-space links and ISL of non-GSO satellite networks.

NOTE 2 – Further study is needed on the feasibility of sharing between non-GSO FSS or mobile satellite service (MSS) feeder link networks and the ISS, but that this is likely also to be difficult.

ANNEX 1

This Annex analyses the interference potential between GSO FSS networks and GSO ISS links, and between GSO FSS networks and non-GSO ISS links. The categories are sub-divided as follows:

Case 1 – GSO ISS satellite transmitters (Tx’s) interfering into GSO FSS satellite receivers (Rx’s).

Case 2 – GSO FSS earth station Tx’s interfering into GSO ISS satellite Rx’s.

Case 3 – Non-GSO ISS satellite Tx’s interfering into GSO FSS satellite Rx’s.

Case 4 – GSO FSS earth station Tx’s interfering into non-GSO ISS satellite Rx’s.

For each case the maximum allowable interference power spectral density (PSD) was calculated. This was based on either a percentage increase in the equivalent system noise temperature or from a received level of wanted carrier and a wanted carrier-to-noise ratio value to which a required interference margin is added. The maximum likely received interference PSD was then estimated using geometrical considerations. This permitted an estimate of the minimum margin of received interference power to the allowable interference power to be made.

At the time of drafting this Recommendation there were no FSS systems notified to the Radiocommunication Bureau in the 50 GHz band. In order to investigate the potential for sharing between the FSS and the ISS it was necessary to frequency scale FSS system parameters notified in other bands. FSS system parameters were available at 30 GHz and it is possible to scale the FSS parameters from 30 to 50 GHz by making the necessary assumptions regarding increased atmospheric attenuation in the 50 GHz band. However, to minimize the assumptions used in scaling parameters, it was thought easier to scale down ISS link parameters from 60 to 30 GHz since they largely operate free of atmospheric attenuation effects. In scaling down ISS parameters it is noted that the FSS will use higher e.i.r.p.s at 50 GHz to overcome increased atmospheric attenuation and it is assumed that power control will be used by FSS earth stations at 50 GHz to avoid excess interference to the ISS in “clear air” conditions.

The parameters used in the study are given in Tables 1 and 2.

1 Results of the analysis

The analysis considers four geometric cases of interference potential. For each of the cases, the minimum margin of likely interference over allowable interference was estimated.

Case 1 – GSO ISS satellite transmitters (Tx’s) interfering into GSO FSS satellite receivers (Rx’s)

Case 1 considers three scenarios of interference from GSO ISLs to GSO FSS satellites. These are outlined below with the geometry for the case shown in Fig. 1.

For scenarios considered in Case 1, the margin was found to be positive indicating interference to FSS satellites from GSO ISS would be acceptable.

The parameters used in the analysis for Case 1 are those of FSS network 1 from Table 1 and the GSO ISS Network from Table 2. The method assumed that the FSS satellite received a “wanted” carrier from an earth station operating at a minimum elevation angle of 10° and interference resulted to the FSS receiver from a GSO inter-satellite link. Also, the geocentric angle between a FSS satellite and an ISS satellite was assumed to be 0.1°.

For interference to the GSO FSS network 1, the minimum received carrier PSD was calculated to be –183.98 dB(W/Hz) on the basis of an earth station operating to a GSO satellite at the minimum elevation angle of 10°. The required carrier-to-noise ratio for the FSS network is 5.8 dB, with a propagation margin of 2.5 dB. Assuming that a single entry interference limit of 6% of thermal noise is applicable, the maximum allowable interference PSD is therefore calculated to be 20.52 dB lower than the minimum received carrier PSD, making the maximum allowable interference PSD for the GSO FSS network to be –204.5 dB(W/Hz).

Scenario 1a: FSS satellite Rx near GSO ISS satellite Tx, “minimum” distance

In scenario 1a, the geocentric angle between the GSO FSS satellite Rx and the GSO ISL satellite Tx is assumed to be 0.1°, with the separation between the GSO ISS satellites assumed to be 1°. This situation represents a minimum distance of interference between the ISS satellite and the FSS satellite. Interference from the ISS antenna occurs *via* its main lobe, with the interference received by the FSS satellite antenna *via* its rear lobe.

The maximum received interfering PSD was calculated to be –211.03 dB(W/Hz), giving the margin for scenario 1a to be 6.53 dB.

Scenario 1b: FSS satellite Rx near GSO ISS satellite Rx, “minimum” distance

In scenario 1b, the geocentric angle between the GSO FSS satellite Rx and the GSO ISL satellite Tx is assumed to be 0.9°, with the separation between the GSO ISS satellites assumed to be 1°. This scenario is similar to scenario 1a but represents a reduced offset discrimination angle at the FSS satellite antenna. The margin for scenario 1b was found to be 5.94 dB.

Scenario 1c: FSS satellite Rx near GSO ISS satellite Rx, “maximum” distance

The geocentric angle between the GSO FSS satellite Rx and the GSO ISL satellite Tx is assumed to be 159.9°, with the separation between the GSO ISS satellites assumed to be 160°. The case represents a maximum distance of interference between the ISS satellite and the FSS satellite. Interference is from the ISL antenna’s main lobe with interference received by the FSS antenna through its main lobe. The margin for scenario 1c was found to be 10.21 dB.

Case 2 – GSO FSS earth station Tx's interfering into GSO ISS satellite Rx's

Case 2 considers two scenarios of interference from GSO FSS earth stations to GSO ISLs. These are outlined below with the geometry for the case shown in Fig. 2.

For the scenarios in Case 2, the margin was found to be positive in all but the extreme case of interference to very long ISLs indicating that the interference to GSO ISLs from the FSS would be acceptable.

The parameters used in the analysis are those of FSS network 2 from Table 1 and the GSO ISS network from Table 2. For both of the scenarios of Case 2, the geocentric angle between the GSO ISS satellites is assumed to be 160°.

The maximum allowable interference PSD was calculated using the formula:

$$k\,T\,B$$

where:

- k: Boltzmann's constant = –228.6 dB(J/K)
- T: system noise temperature, taken to be 6% of the notified system noise of 630 K
- B: reference bandwidth of 1 Hz.

The maximum allowable interference PSD is calculated to be –212.83 dB(W/Hz).

Scenario 2a: FSS earth station Tx operating at an elevation angle of 90° to an FSS satellite near a GSO ISS satellite Rx (represents minimum distance)

For this scenario, the FSS earth station was assumed to be located at the equator and operating to a FSS satellite with an elevation angle of 90°. The geocentric angle between GSO FSS satellite and the GSO ISS satellite Rx was assumed to be 0.1°. This situation represents the minimum separation distance between the earth station and the ISL.

The maximum received interfering PSD was calculated to be –221.83 dB(W/Hz), giving the margin for scenario 2a as 9.0 dB.

Scenario 2b: FSS earth station Tx operating at an elevation angle of 10° to an FSS satellite near a GSO ISS satellite Rx (represents maximum distance)

The earth station is assumed to be operating to the FSS satellite with an elevation angle of 10°, with the geocentric angle between the GSO FSS satellite and the GSO ISS satellite Rx assumed to be 0.1°. This configuration represents the minimum antenna discrimination by a FSS earth station when causing interference, with the minimum discrimination at the GSO ISL antenna when receiving interference.

The margin for scenario 2b was found to be negative at –13.82 dB. In order to make the margin positive, it was found that the maximum geocentric angle between the ISLs must not exceed 152°, or the geocentric angle between the GSO FSS satellite and the GSO ISS satellite Rx link must be a minimum of 0.2°.

Case 3 – Non-GSO ISS satellite Tx's interfering into GSO FSS satellite Rx's

Case 3 considers two scenarios of interference from non-GSO ISS satellite Tx to GSO FSS satellites Tx. These are outlined below with the geometry for the case shown in Fig. 3. The parameters used in the analysis are those of FSS network 1 from Table 1 and the non-GSO ISS network from Table 2.

To provide a minimum offset angle at the non-GSO ISL when interfering into an GSO FSS satellite Rx, the case assumes that the inter-satellite link is between two adjacent non-GSO satellites communicating with each other in the same orbital plane. The maximum allowable interference PSD to GSO FSS satellites has been previously calculated for the GSO FSS network 1 (in Case 1) as –204.5 dB(W/Hz).

For the scenarios considered in Case 3, the margin was found to be positive indicating interference to GSO FSS satellites from non-GSO ISS would be acceptable.

Scenario 3a: Non-GSO ISS satellite Tx interfering with a GSO FSS satellite Rx at a minimum separation distance. The interference is ISS satellite Tx antenna rear-lobe to FSS satellite Rx antenna main lobe

This scenario considers an earth station operating to a FSS satellite with an elevation angle of 90°, with the non-GSO ISS satellite located directly above the earth station. The situation represents the minimum interference distance between the networks. The margin for scenario 3a was found to be 53.29 dB.

Scenario 3b: Non-GSO ISS satellite Tx link antenna main lobe interference to GSO FSS satellite Rx

This scenario considers interference from a non-GSO ISL through its main lobe to a GSO FSS satellite that is operating to an earth station which is at an elevation angle of 10°. The interference to the FSS satellite is received through the antenna's "first" side lobe region. The scenario represents a maximum interference power received at the FSS satellite. The margin for scenario 3b was found to be 19.89 dB.

Case 4 – GSO FSS earth station Tx's interfering into non-GSO ISS satellite Rx's

Case 4 considers two scenarios of interference from a GSO FSS earth station transmitter into a non-GSO ISL. These are outlined below with the geometry for the case shown in Fig. 4. The parameters used in the analysis are those of FSS network 2 from Table 1 and the non-GSO ISS Network from Table 2. In the analysis, to provide the minimum offset angle at the non-GSO ISL when receiving interference from a FSS earth station, the inter-satellite link is taken to be from a non-GSO satellite communicating to another satellite two orbital planes away.

The maximum allowable interference PSD was calculated using the formula:

$$k\,T\,B$$

where:

k: Boltzmann's constant = –228.6 dB(J/K)

T: system noise temperature, taken to be 6% of the notified system noise of 438 K

B: reference bandwidth taken to be 1 Hz.

The maximum allowable interference PSD was calculated to be –214.40 dB(W/Hz).

For the scenarios in Case 4, the margin was found to range from –19.80 dB for a FSS earth station operating at elevation angle of 90° to –25.70 dB for a FSS earth station operating at an elevation angle of 10°. These were derived from a maximum allowable interference power based on an allowable increase in system noise temperature of 6%. If the interference could be considered to be short term, it would allow the maximum interference power to be derived from an increase in system noise temperature of up to 1 480%. This will increase the margins by 23.92 dB. However, the margin for scenario 4b will still be slightly negative at –1.78 dB, concluding that unacceptable interference may be caused by FSS earth stations to non-GSO ISLs.

Scenario 4a: GSO FSS earth station Tx's *interfering into non-GSO ISLs at a minimum separation distance. The interference is FSS earth station antenna main lobe to ISS satellite Rx antenna rear lobe*

This scenario considers an FSS earth station operating to a GSO satellite with an elevation angle of 90°. Interference is through a FSS earth station antenna main lobe to an ISS satellite Rx antenna rear lobe. The margin for scenario 4a is found to be negative at –19.80 dB (for a protection ratio based on 6% of system noise temperature). If the interference can be considered to be short term, it may be appropriate to base the protection ratio on up to 1 480% of noise thereby increasing the maximum allowable interference by 23.92 dB, making the margin for scenario 4a to be 4.12 dB.

Scenario 4b: GSO FSS earth station Tx's *interfering into non-GSO ISLs at a minimum elevation angle. The interference is FSS earth station antenna main lobe to ISS satellite Rx antenna side lobe*

This scenario considers an earth station Tx operating to a FSS satellite with a minimum elevation angle elevation angle of 10°. Interference is from the FSS earth station antenna main lobe to the ISS satellite Rx antenna side lobe. The margin for scenario 4b is found to be at –25.70 dB (for a protection ratio based on 6% of system noise temperature). If the interference is considered to be short term, it may be appropriate to base the protection ratio on up to 1 480% of noise temperature and thereby increase the margin by 23.92 dB. However, the margin for scenario 4b will still be slightly negative at –1.78 dB (for a protection ratio based on 1 480% of system noise temperature).

FIGURE 1

Interference scenario of Case 1
GSO ISS satellite Tx interference to a GSO FSS satellite Rx

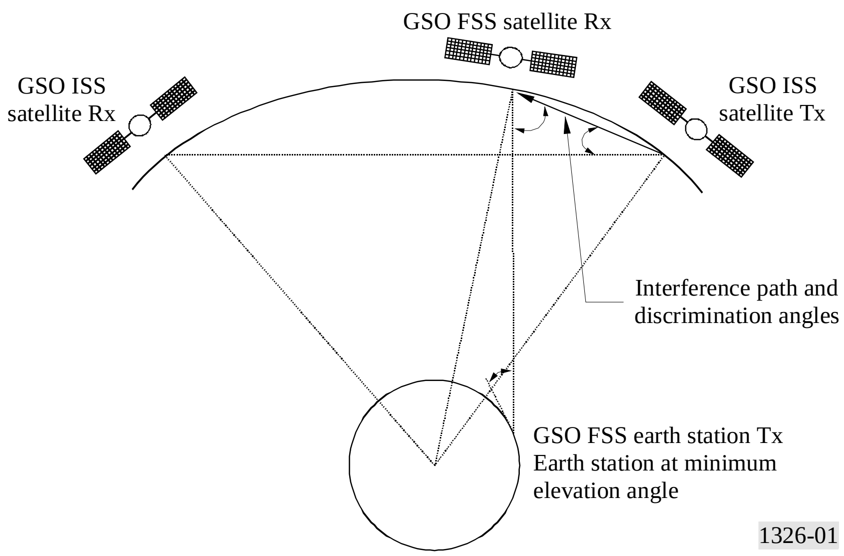


FIGURE 2

Interference scenario of Case 2
GSO FSS earth station Tx interference to a GSO ISS satellite Rx

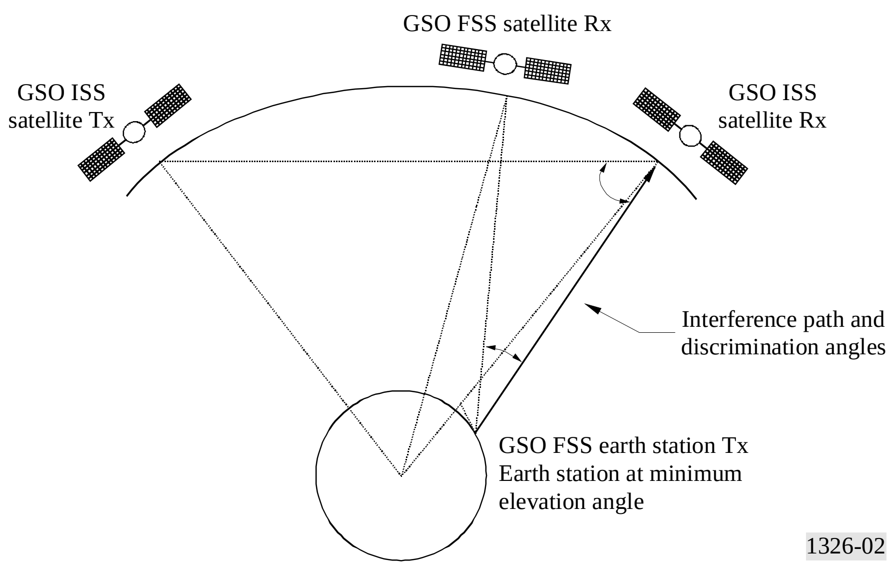


FIGURE 3

Interference scenario of Case 3
Non-GSO ISS satellite Tx interference to a GSO FSS satellite Rx

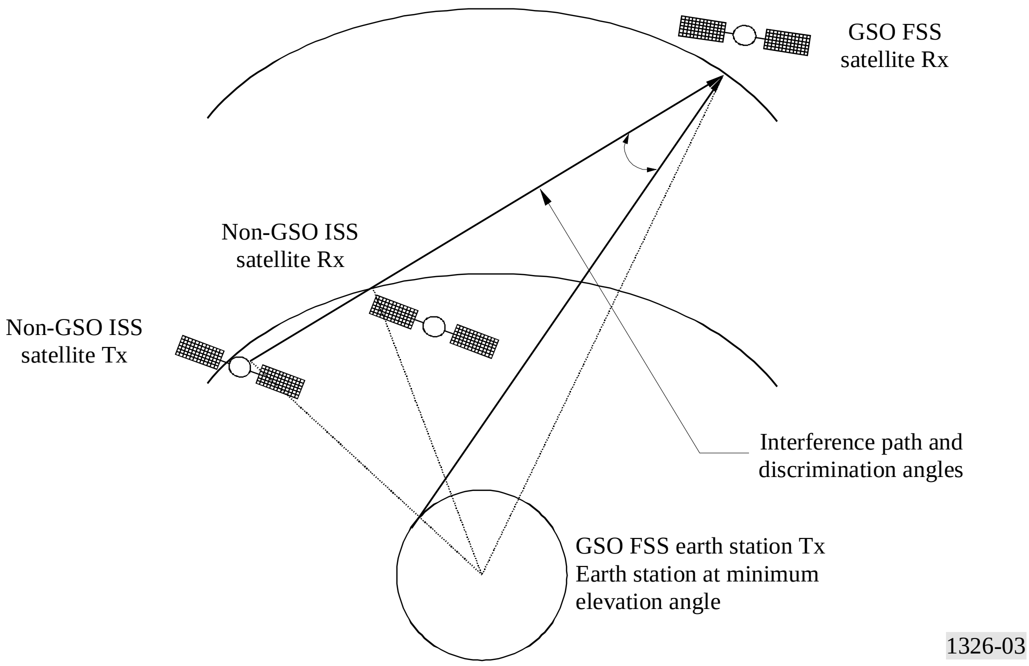
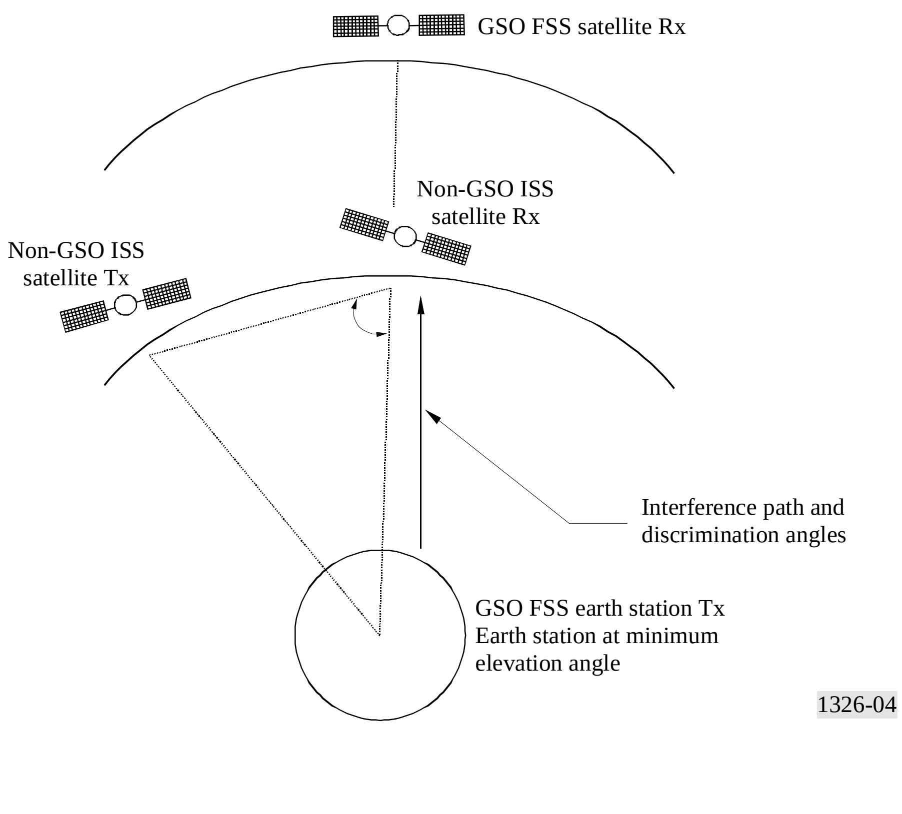


FIGURE 4

Interference scenario of Case 4
GSO FSS earth station Tx interference to a non-GSO ISS satellite Rx



2 Discussion of results

The analysis in this Annex shows that sharing should be feasible between GSO FSS networks operating in the Earth-to-space direction and GSO ISLs provided that certain interference reduction techniques are adopted. These techniques include the use of narrow beamwidth antennas by the ISS, employment of good off-axis antenna radiation pattern characteristics by both the ISS and FSS, the avoidance of very long ISLs, specification of a minimum angular separation between GSO ISS satellites and GSO FSS satellites, and the use of uplink power control for large FSS earth stations.

Also, the analysis shows that there is scope for interference from FSS earth stations to ISLs of non-GSO networks in low-Earth orbits. Considering the possibility of large numbers of such links, sharing may be difficult between GSO FSS networks and non-GSO ISS networks.

Furthermore, it must be noted the analysis has not considered the potential use of the band 50.4-51.4 GHz for feeder links of other services (for example non-GSO networks in the MSS) or the use of the band by non-GSO FSS networks. If such networks were employed in this band, this may lead to difficulties in sharing which would require further study.

3 Parameters used in the analysis

TABLE 1

Transmitting and receiving GSO FSS network parameters

Analysis frequency (GHz)	30.0
Maximum allowable increase in system noise temperature for the ISS networks (%)	6.0
GSO FSS network 1 (for calculation of interference to FSS satellites)	
Earth station boresight Tx gain (dBi)	45.1
Carrier power at earth station (dBW)	–7.4
Satellite Rx boresight gain (dBi)	47.4
Satellite Rx rear lobe gain (dBi)	–10.0
Satellite Rx antenna pattern	Rec. ITU-R S.672
Minimum elevation angle of earth station (degrees)	10.0
Carrier occupied bandwidth (MHz)	0.333
Required *C*/*N* (dB)	5.8
Propagation margin (dB)	2.5
GSO FSS network 2 (for calculation of interference from FSS earth stations)	
Earth station boresight Tx gain (dBi)	63.7
Earth station rear lobe gain (dBi)	–10.0
Earth station antenna pattern	RR Appendix 30B (29-25 roll-off)
Carrier power at earth station (dBW)	13.3
Minimum elevation angle of earth station (degrees)	10.0
Carrier occupied bandwidth (MHz)	186.6

TABLE 2

Parameters for GSO ISS and non-GSO ISS networks

GSO ISS networks	
Satellite Rx/Tx boresight gain (dBi)	54.3 (scaled)
Satellite Rx/Tx rear lobe gain (dBi)	–10
Satellite Rx/Tx antenna pattern	Rec. ITU-R S.672
Carrier power at satellite Tx (dBW)	14.0 (scaled)
Maximum longitude separation between satellites (degrees)	160
Carrier occupied bandwidth (MHz)	1 000
ISS bandwidth required (MHz)	4 000
System noise temperature (K)	630
Non-GSO ISS networks	
Satellite Rx/Tx boresight gain (dBi)	45.0 (scaled)
Satellite Rx/Tx rear lobe gain (dBi)	–10
Satellite Rx/Tx antenna pattern	Rec. ITU-R S.672
Carrier power at satellite Tx (dBW)	7.4
Maximum ISL separation between planes (degrees)	19
Minimum ISL separation within planes (degrees)	9
Carrier occupied bandwidth (MHz)	1 000
ISS bandwidth required (MHz)	2 000
System noise temperature (K)	438