RECOMMENDATION ITU-R S.1655

Interference mitigation techniques and frequency sharing in the bands 37.5-42.5 GHz and 47.2-50.2 GHz between geostationary-satellite fixed-satellite service networks and non-geostationary-satellite fixed-satellite service systems

(Question ITU-R 231/4)

(2003)

The ITU Radiocommunication Assembly,

considering

a) that the 37.5-42.5 GHz and 47.2-50.2 GHz bands are allocated to the FSS;

b) that there is an emerging interest in operating GSO FSS networks and non-GSO FSS systems which use low Earth orbit (LEO) or medium Earth orbit (MEO) in these frequency bands;

c) that the FSS systems plan to provide data rates ranging from videoconferencing quality through very high speed transmission of STM-1 (155 Mbit/s) or higher, up to 10 STM-4 (6.22 Gbit/s);

d) that most FSS systems planned to operate in these bands are designed to use 3 GHz of spectrum in the Earth-to-space direction and 3 GHz or higher in the space-to-Earth direction;

e) that in some portions of the band 37.5-42.5 GHz, most FSS systems plan to use high gain, narrow-beam earth terminal antennas for their user links, typically 1 m in diameter, and provide at least 99.7% end-to-end link availability;

f) that in some portions of the band 37.5-42.5 GHz, FSS systems may need to use larger earth terminal antennas, of up to 3 m in diameter, for gateway/hub applications involving individually-coordinated earth stations at geographically dispersed points and that these applications require end-to-end link availability of at least 99.9%;

g) that some satellite systems are designed to operate in only a small fraction of the satellite field-of-view, and typically provide less than 5% coverage of their satellites' field-of-view;

h) that the propagation impairments are severe in this frequency range;

j) that most FSS systems designed to operate in the 50/40 GHz bands are not planned to use dual polarization in the same beam in the same area because the depolarization impairments in adverse propagation conditions are severe; however, dual polarizations for FSS systems operating in these bands may be used for different beams which are well separated geographically,

recommends

1 that one mitigation technique which may be used to facilitate frequency sharing between GSO FSS networks and non-GSO FSS systems in the 37.5-42.5 GHz and 47.2-50.2 GHz bands is operation on opposite polarizations. Annexes 1 and 2 to this Recommendation describe this mitigation technique (see Notes 1 and 2);

2 that sharing between non-GSO FSS systems and GSO FSS networks, in a portion of these bands using high gain narrow-beam satellite antennas, can be feasible if appropriate geographical separation between earth stations of the two systems is provided (see Annex 3);

3 that other mitigation techniques, such as those in Annex 3, may be applicable, depending on system characteristics.

NOTE 1 – Application of the mitigation technique described in Annexes 1 and 2 to non-GSO FSS systems which use LEO may require further study due to the different time-varying characteristics of LEO and MEO FSS systems. For a non-GSO FSS system to share frequencies with a GSO FSS network on the basis of each using the opposite polarization, all other non-GSO FSS systems covering the same geographical area would be obliged to use the same type and direction of polarization as the first system, or to employ a method of avoiding main beam-to-main beam coupling of co-polar interference (such as satellite diversity). Furthermore, as non-GSO FSS systems are often designed for global coverage and as confinement of GSO FSS networks to a single polarization is a potential constraint, additional study may be necessary to ensure that the use of this technique does not preclude efficient use of 50/40 GHz bands.

NOTE 2 – For the system studied in Annexes 1 and 2, Annex 3 contains a discussion of the advantages and disadvantages of other mitigation techniques.

Annex 1

Frequency sharing between non-GSO FSS systems and GSO FSS networks operating in the 50/40 GHz bands using high gain narrow-beam earth antennas

1 Introduction

This Annex presents simulation results related to the feasibility of co-directional frequency sharing between a non-GSO FSS system and a GSO FSS network in the 47.2-50.2 GHz and 37.5-42.5 GHz bands. In this study, LEO V2 is used as an example non-GSO FSS system. The GSO V1 characteristics are taken as representative of GSO satellite networks.

Two interference cases will be summarized. The first case presents the simulation results without an interference mitigation technique when systems operate on same and opposite polarizations. In the second case, satellite diversity is used as an interference mitigation technique to reduce the interference levels at the satellite and user terminal receivers.

2 System technical characteristics

The orbital characteristics of the LEO V2 system are given in Table 1. Tables 2 and 3 show the satellite communication and user terminal system parameters for both systems, respectively.

TABLE 1

LEO V2 orbital parameters

Number of satellites	15
Number of orbital planes	3
Number of satellites per plane	5
Altitude	10 355 km
Inclination angle	50°
Period of orbit	6 h
Plane spacing	120°
Plane-to-plane satellite phasing	24°
Walker designation	15/3/1

TABLE 2

Satellite communication system parameters

	LEO V2	**GSO V1**
Receive frequency range (GHz)	47.2 to 50.2	
Receive bandwidth (GHz)	3	
Receive antenna gain (dBi)	46.5	53.0
3 dB beamwidth (degrees)	0.82	0.39
Receive system noise temperature	728 K or 28.6 dBK	
Transmit frequency range (GHz)	37.5 to 42.5	
Transmit bandwidth (GHz)	3	
Transmit e.i.r.p. (dBW)	48.9 to 58.9 Depending on data rate	57.5 to 66.4 Depending on data rate and user antenna size
Transmit antenna gain (dBi)	46.5	53.0
3 dB beamwidth (degrees)	0.82	0.39
Transmit power density into antenna (maximum) (dB(W/Hz))	–81.3	

TABLE 3

User terminal communication system parameters

	LEO V2	**GSO V1**
Transmit frequency range (GHz)	47.2 to 50.2	
Transmit bandwidth (GHz)	3	
Transmit e.i.r.p. (dBW)	54.7 to 78.9 Depending on data rate, propagation condition	56.6 to 80.0 Depending on data rate, propagation condition
Transmit antenna gain (dBi)	59.7	59.7 (2.2 m) 60.8 (2.5 m)

TABLE 3 (*end*)

	LEO V2	GSO V1
3 dB beamwidth (degrees)	0.19	0.19 (2.2 m) 0.17 (2.5 m)
Transmit power density into antenna (dB(W/Hz))	–89.7 to –75.5 Depending on data rate, propagation condition	–87.8 to –75 Depending on data rate, propagation condition
Receive frequency range (GHz)	37.5 to 42.5	
Receive bandwidth (GHz)	3	
Receive antenna gain (dBi)	57.8	57.8 (2.2 m) 59.0 (2.5 m)
3 dB beamwidth (degrees)	0.24	0.24 (2.2 m) 0.21 (2.5 m)
Receive antenna noise temperature	353 K or 25.48 dBK	

3 Interference analysis

In the analysis interference computations have been carried out for two distinct cases:

– with opposite polarization discrimination; and

– use of satellite diversity as a mitigation technique.

Due to the intermittent nature of “in-line” interference, it must be expressed in the form of short-term allowances. Currently, there are no criteria for acceptable interference levels between GSO FSS networks and non-GSO FSS systems in the 38/50 GHz bands. However, the LEO V2 and GSO V1 systems are designed to achieve a minimum link availability of 99.5%. Ten per cent of the 0.5% link outage, or 0.05%, is allocated by the designers to short-term interference from other satellite systems, both GSO FSS networks and non-GSO FSS systems operating in these frequency bands. Half of the latter quantity (0.025%) is allocated to interference from GSO satellite systems.

The LEO V2 and GSO V1 systems are designed to maintain a 3 dB link margin, i.e. the ratio of carrier power to noise power density, C/N_0, is maintained 3 dB above the value corresponding to the requisite link quality. Therefore, the interference criterion appropriate to LEO V2 and GSO V1 is that I_0/N_0 should not exceed 0 dB for more than 0.025% of the time. The calculated uplink and downlink interference was based on the following:

– non-GSO FSS and GSO FSS earth terminals are co-located. The latitude and longitude of the common terminal location are 43.4° N and 70.2° W, respectively;

– both non-GSO FSS systems and GSO FSS networks use adaptive uplink power control to establish a 3 dB clear-sky margin. There is no downlink power control;

– user terminal transmit and receive antenna patterns are based on Recommendation ITU-R S.580;

– user terminal transmit and receive antenna cross-polarized patterns are based on Recommendation ITU-R S.731;

– satellite transmit and receive antenna patterns are based on Recommendation ITU-R S.672;

– satellite transmit antenna cross-polarized patterns are based on Appendix 30 (WRC-2000) of the Radio Regulations;

– required E_b/N_0 is 8.0 dB;

– clear-sky condition;

– a 2.2 m diameter transmit and receive antenna earth terminal is used in this study.

4 Simulation results

A simulation of 15 non-GSO satellites and a GSO satellite located at 82.44° W was performed over a 24 h period, with a time interval of 1 s.

4.1 Case 1: Opposite polarization

– LEO V2 and GSO V1 satellites operate on opposite polarizations.

Figures 1 and 2 are a sample of the results obtained in terms of per cent of time that I_0/N_0 at non-GSO and GSO receivers is exceeded when both systems operate on opposite polarizations. Interference levels exceeded for 0.025% of the time at the GSO user terminal and the non-GSO satellite receivers are respectively $I_0/N_0 = –9$ dB and $I_0/N_0 = –17$ dB.

FIGURE 1

% time I_0/N_0 at GSO earth station receiver is exceeded

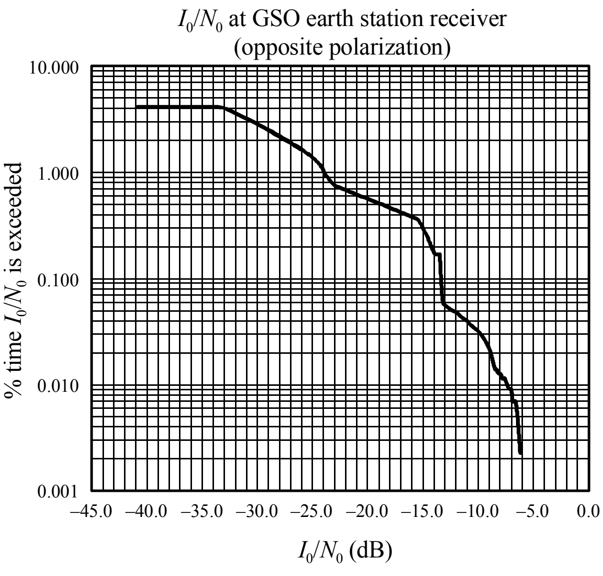
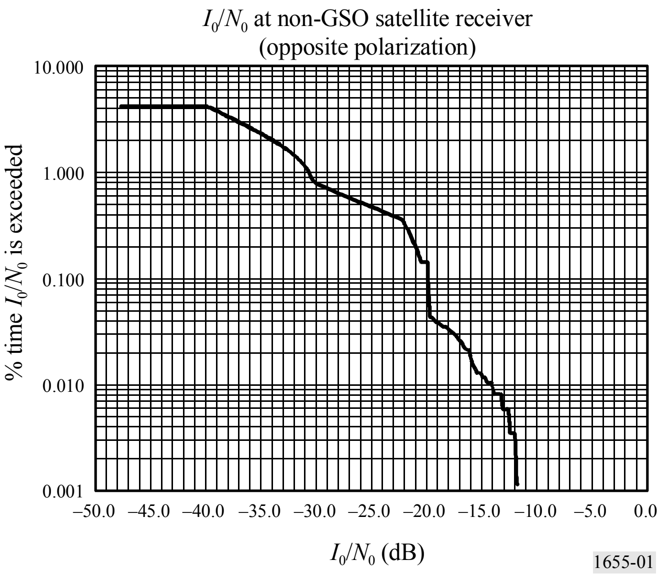


FIGURE 2

% time I_0/N_0 at non-GSO satellite receiver is exceeded



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4.2 Case 2: Satellite diversity

Satellite diversity can be used to reduce the interference levels at satellite and user terminal receivers. In this case, systems are assumed to operate on the same polarization.

It is productive to explore the practicality of using satellite diversity to reduce the interference levels at the non-GSO and GSO satellite and earth terminal receivers. This technique specifies that to avoid in-line interference when the separation angle between a non-GSO satellite and a GSO satellite as seen from an earth station is less than $X°$, the non-GSO user switches the traffic to an alternate in-view satellite.

In this study, the GSO satellite system is assumed to have dual coverage provided by at least two satellites in different orbital locations. In general, it is not usual for GSO satellite systems to have dual coverage provided by at least two satellites in different orbital locations. For non-GSO FSS systems using circular orbits, dual coverage by at least two satellites in different orbital locations is more usual. Also, both systems are assumed to operate on the same polarization, and the user of its system can communicate with any of the system's satellites in view.

Figures 3 and 4 show the interference levels at the GSO earth terminal and non-GSO satellite receivers when the satellite diversity technique is used. In this study, when the separation angle, *X*, between a non-GSO satellite and a GSO satellite as seen from an earth station falls to below 0.5°, the GSO FSS user switches the traffic to an alternate satellite. Interference levels at the non-GSO and GSO FSS user terminal and satellite receivers are below the interference criteria.

A sample of the results are provided in Figs. 3 and 4.

FIGURE 3

% time I_0/N_0 at GSO earth station receiver is exceeded (X = 0.5°)

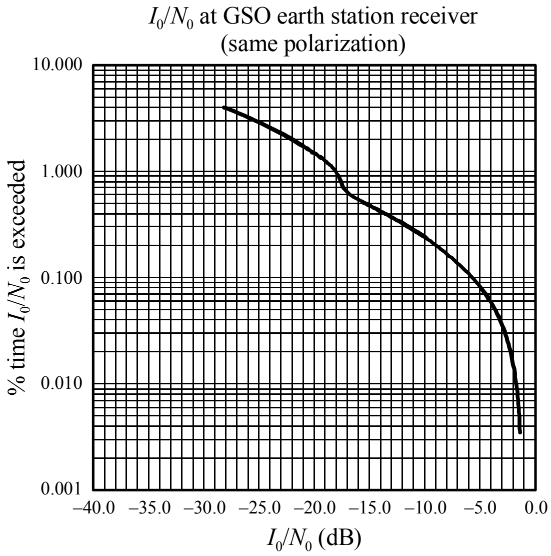
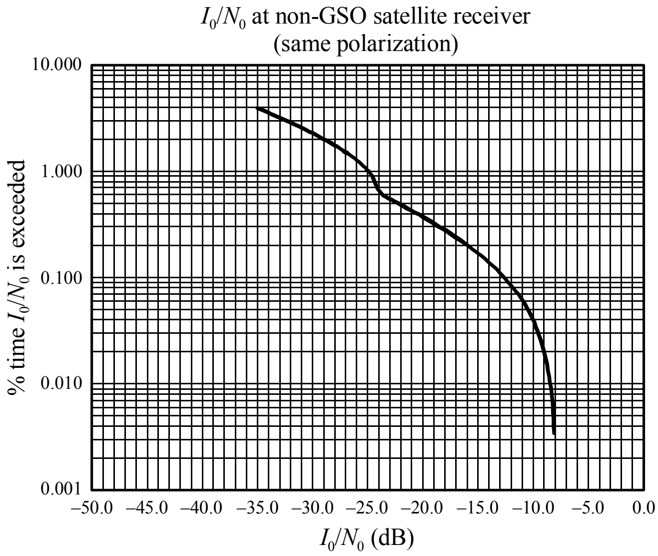


FIGURE 4

% time I_0/N_0 at non-GSO satellite receiver is exceeded (X = 0.5°)



X: the minimum separation angle between the non-GSO and GSO satellite as seen from an earth station.

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5 Conclusion

A summary of the simulation results is provided in the following Table:

	I_0/N_0 (exceeded for 0.025% of the time)		I_0/N_0 (exceeded for 0.025% of the time)
	Same polarization: no mitigation technique (dB)	**Opposite polarization (dB)**	**Same polarization: use of satellite diversity (at 0.5°) mitigation technique (dB)**
Non-GSO user terminal receiver	11	–13	–6
Non-GSO satellite receiver	6	–17	–9
GSO user terminal receiver	15	–9	–2.5
GSO satellite receiver	0	–24	–16

Based on results of the studies, we can draw the following conclusions:

– Frequency sharing between non-GSO FSS systems and GSO FSS networks operating in the frequency bands 47.2-50.2 GHz and 37.5-42.5 GHz may not be feasible, without imposing complex interference mitigation techniques on both GSO FSS networks and non-GSO FSS systems, if both systems operate on the same polarization. However, when the systems operate on opposite polarization, frequency sharing may be feasible.

– If satellite diversity is used as an interference mitigation technique, frequency sharing between non-GSO FSS systems and GSO FSS networks is feasible even when they operate on the same polarization.

Frequency sharing between non-GSO FSS systems and GSO FSS networks operating in the band 47.2-50.2 GHz and 37.5-42.5 GHz is feasible if the systems operate on opposite polarizations or use satellite diversity with a diversity switching angle, *X*, at the earth station is 0.5° or greater.

Annex 2

Frequency sharing between non-GSO FSS systems and GSO FSS networks operating in the 50/40 GHz bands using small earth terminal antennas

1 Introduction

This Annex presents simulation results related to the feasibility of co-directional frequency sharing between non-GSO FSS systems and GSO FSS networks operating with small earth terminal antennas.

Studies have shown that without mitigation techniques, such as satellite diversity, geographic isolation, etc., the frequency sharing between non-GSO FSS systems and GSO FSS networks is not feasible when they operate on the same polarization.

This Annex only presents the simulation results when the systems operate on opposite polarizations.

2 System technical characteristics

The orbital characteristics of a non-GSO FSS system are given in Table 1. Tables 4 and 5 show the satellite communication and user terminal parameters for both a non-GSO FSS system (LEO V2) and for a GSO FSS network (GSO V1), respectively.

TABLE 4

Satellite communication system parameters

Parameters	Non-GSO (LEO V2)	GSO (GSO V1)
Receive frequency range (GHz)	47.2 to 50.2	
Receive antenna gain (dBi)	46.5	53.0
Receive system noise temperature (K)	728	
Transmit frequency range (GHz)	37.5 to 42.5	
Transmit antenna gain (dBi)	46.5	53.0
Transmit power density into antenna (maximum) (dB(W/Hz))	–71	–73

TABLE 5

User terminal communication system parameters

Parameters	Non-GSO (LEO V2)	GSO (GSO V1)
Transmit frequency (GHz)	47.5-50.2	
Receive frequency (GHz)	37.5-42.5	
Transmit antenna gain (dBi) Antenna size (m)	47 0.5	
Uplink required E_b/N_0 (dB)	10	
Other loss (atm, scin, pointing) (dB)	3.4	
Uplink power control margin (dB)	3	
Receive antenna gain (dBi) Antenna size (m)	45 0.5	
Rx antenna noise temperature (K)	800	
Degradation due to interference (dB)	1.5	

3 Interference analysis

The calculated uplink and downlink interference was based on the following:

– non-GSO FSS and GSO FSS earth terminals are co-located. The latitude and longitude of the common terminal location are 43.4° N and 70.2° W, respectively;

– both non-GSO FSS systems and GSO FSS networks use adaptive power control to establish a 3 dB clear-sky margin;

– user terminal transmit and receive antenna patterns are based on Recommendation ITU-R S.580;

– user terminal transmit and receive antenna cross-polarized patterns are based on Recommendation ITU-R S.731;

– satellite transmit and receive antenna patterns are based on Recommendation ITU-R S.672;

– required E_b/N_0 is 10.0 dB;

– clear-sky condition;

– a 0.5 m transmit and receive earth terminal is used in this study.

4 Simulation results

A simulation of 15 non-GSO satellites and a GSO satellite located at 82.44° W was performed over a 24 h period, with a time interval of 1 s.

Figures 5, 6, 7 and 8 show the results obtained in terms of per cent of time that I_0/N_0 at satellite and earth station receivers is exceeded when both systems operate on opposite polarizations. In this simulation, a 0.5 m earth terminal antenna was used. In the worst case I_0/N_0 at non-GSO satellite receiver is –8 dB as shown in Fig. 7. Therefore, the worst-case "in-line" interference degradation is only 0.64 dB.

Based on the simulation results as shown in Figs. 5, 6, 7 and 8, the frequency sharing between non-GSO FSS systems and GSO FSS networks operating with small earth terminal antennas is feasible when they operate on the opposite polarizations.

It should be noted that the polarization isolation may be degraded in a small percentage of time due to rain. However, the probability of "in-line" interference between non-GSO FSS systems and GSO FSS networks (P("in-line")) is very small, as shown below:

$$P\ (\text{"in-line" and Rain}) = P\ (\text{"in-line"})\ P\ (\text{measurable Rain}) = (0.1\%)\ (5\%) = 0.005\%,$$

where:

P ("Rain"): proportion of time for which rainfall typically occurs in temperate climates.

FIGURE 5

% time I_0/N_0 at GSO satellite receiver is exceeded

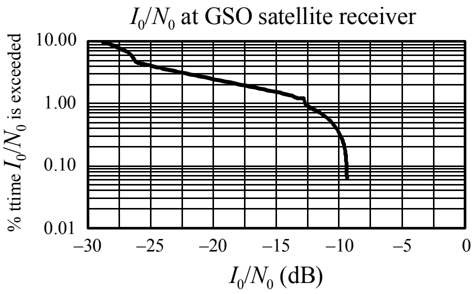


FIGURE 6

% time I_0/N_0 at GSO earth station receiver is exceeded

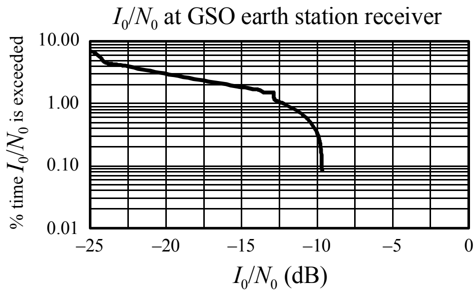


FIGURE 7

% time I_0/N_0 at non-GSO satellite receiver is exceeded

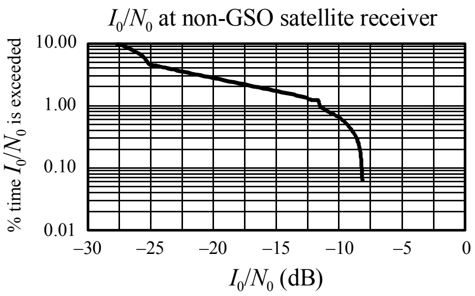
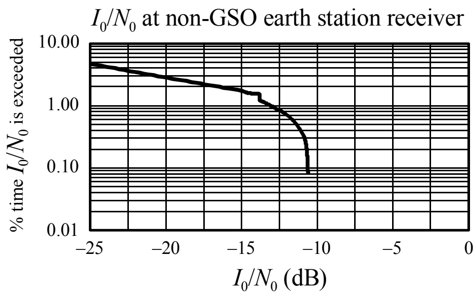


FIGURE 8

% time I_0/N_0 at non-GSO earth station receiver is exceeded



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5 Conclusion

Frequency sharing between non-GSO FSS systems and GSO FSS networks operating in the frequency bands 47.2-50.2 GHz and 37.5-42.5 GHz is feasible even operating with a small earth terminal antenna, if they operate on opposite polarizations.

Annex 3

Other mitigation techniques

1 Introduction

Studies have indicated that the frequency sharing between non-GSO FSS systems and GSO FSS networks is feasible if the systems operate on opposite polarizations or if satellite diversity is used when the separation angle between a non-GSO and GSO satellite and a GSO satellite as seen from an earth station is within X°. Other interference mitigation techniques, such as geographic isolation between earth stations, have been studied. Band segmentation is not considered as an interference mitigation technique; however, this topic will be discussed in this Annex.

2 Background

There were, in October 2001, a considerable number of GSO FSS networks and non-GSO FSS systems planning to operate in the 37.5-42.5 GHz and 47.2-50.2 GHz bands. These systems plan to provide data rates ranging from videoconferencing quality through very high-speed transmission of STM-1 (155 Mbit/s) or higher, up to 10 STM-4 (6.22 Gbit/s). Many of the FSS systems proposed for operation in these bands require 3 GHz spectrum or more in their downlinks and 3 GHz in their uplinks.

In addition, the 37.5-40.0 GHz and 42.0-42.5 GHz bands have been identified for use by the FSS systems for low-density applications in the FSS, such as gateway/hub applications. Therefore, FSS systems operating in these bands may need to operate with an antenna greater than 2 m in diameter and each system may have a small number of gateways/hubs.

The 37.5-42.5 GHz band, or part of it, may be used for high-density applications in the FSS, such as small earth terminal antennas. Most proposed non-GSO FSS systems and GSO FSS networks are planned to use multibeam payload satellite networks providing the service through a multibeam, frequency reuse scheme. At least 500 MHz bandwidth is needed for each beam. In order to achieve the required $C/(N+I)$, a fourfold or higher frequency reuse scheme is needed. Therefore, each system needs at least 2 GHz of spectrum for its user links in each direction.

3 Advantages and disadvantages of each interference mitigation technique

3.1 Opposite polarization

Since the propagation impairments are severe in the 50/40 GHz bands, most systems plan to use a single polarization per beam within a coverage area. The advantages and disadvantages of using single polarization are:

Advantages

– No need for prior coordination between non-GSO FSS systems and GSO FSS networks.

– Low cost implementation.

– Reduced satellite weight/power and cost.

– Reduced earth terminal complexity.

– The burden of implementation (cost, complexity) is equitable between the non-GSO FSS systems and GSO FSS networks.

Disadvantages

– Each system only makes use of a single polarization.

– If demand for GSO FSS networks and non-GSO FSS systems is not equal, the spectrum may not be used to its maximum efficiency.

3.2 Satellite diversity or arc avoidance

The use of satellite diversity or arc avoidance has been considered as an interference mitigation technique to avoid main beam-to-main beam interference by switching traffic to an alternative satellite. The advantages and disadvantages of this technique are:

Advantages

– Each system may be able to use dual polarizations.

Disadvantages

– Satellite diversity is not appropriate for GSO satellite systems; it will impose technical and economic constraints on the GSO FSS networks and reduce orbital/spectrum efficiency.

– It adds complexity and cost to the earth terminal antennas.

– Non-GSO FSS systems must switch to other non-GSO satellites in view to avoid in-line interference. It will impose constraints on the non-GSO FSS systems.

– Requires dual coverage.

3.3 Geographical isolation between earth stations

It has been confirmed through studies that geographic isolation of earth stations is an effective interference mitigation method. The advantages and disadvantages of this technique are:

Advantages

– Each system can use dual polarizations.

– In the gateway/hub case, each system may have a small number of gateway stations. This method is acceptable for the gateway applications.

– The non-GSO FSS and GSO FSS gateways can use dual polarizations for different beams if the separation distance between two gateways is of the order of 200 km.

Disadvantages

– Requires a minimum separation distance between two earth stations.

– This method may not be acceptable for high-density applications in FSS.

4 Conclusion

Based on the studies, it is concluded that the interference mitigation techniques such as satellite diversity, or arc avoidance, will increase the system complexity and cost. Other interference mitigation techniques, such as operating on opposite polarizations or/and geographical isolation for gateway applications may reduce the system complexity and cost. However, if demand for GSO FSS networks and non-GSO FSS systems is not equal, the spectrum may not be used to its maximum efficiency.