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Uplink interference issues associated with closely separated GSO FSS VSAT networks in the 27.5-30 GHz frequency band

S Series

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REPORT ITU-R S.2409-0

Uplink interference issues associated with closely separated GSO FSS VSAT networks in the 27.5-30 GHz frequency band

(2017)

1 Introduction

Recommendation ITU-R S.524-9 stipulates maximum off-axis e.i.r.p. density limits for earth stations operating in geostationary-satellite orbit (GSO) networks in the fixed-satellite service (FSS) and transmitting in the 27.5-30 GHz frequency band. These limits were determined using information regarding GSO/FSS network characteristics provided by administrations prior to 2000. These limits continue to be widely used as a basis for equipment standards and licensing conditions by some administrations for FSS earth stations for particular applications.

Noting the growing divergence of FSS network parameters (see for example Figure 3) partly brought about by advances in satellite technology that support the higher gain-to-noise temperature ratio (*G*/*T*) values at the satellite required to cater for increased capacity and throughput, it is now evident that dealing with FSS network coexistence based just on the off-axis requirements of Recommendation ITU-R S.524 may not provide sufficient guidance for protection of certain later generation satellite networks from unacceptable interference.

NOTE – The objective of this Report is to address the intra-service issues of FSS-FSS.

2 Relevant issues

A number of relevant issues are listed below.

a) The prospect of uplink compatibility is critically dependent on parameters of the respective networks under consideration, and homogenous parameters amongst neighbouring satellite networks can improve sharing.

b) In developing Recommendation ITU-R S.524-9, an objective was “to promote harmonization between geostationary satellite networks”, and therefore a statistical approach was adopted in relation to key FSS parameters in order to derive limits that would adequately protect the majority of networks using existing and planned network parameters relevant at the time the limits in the Recommendation were developed for the period in question.

c) FSS networks in the 27.5-30 GHz frequency band are subject to coordination under the provisions of ITU Radio Regulations (RR) Articles **9** and **11**. The maximum permissible interference levels stipulated in Recommendation ITU-R S.1323-2 are typically used during coordination to assist in determining a level of acceptable interference.

3 Purpose of the Report

This Report identifies a range of mitigation techniques that may assist administrations in dealing with the management of closely separated GSO FSS VSAT networks in the 27.5-30 GHz frequency band. Both the results of the studies of the issue and proposals for suitable mitigation measures are outlined in the following sections.

4 Methodology used for quantifying the coexistence

In broad terms, a two-step approach is used to gain an understanding of the uplink interference for closely separated GSO FSS VSAT networks.

The first step involved extracting filing data from the space radiocommunication stations (SRS) database for the frequency band 27.5-30.0 GHz limited to EC[1] class of space station CR/C filings[2].

Key parameter data such as satellite receive antenna gain and system noise temperature for the beams in the network with the smallest beamwidth are relevant for the worst-case FSS coexistence study. With this information, it is possible to gain a useful understanding of the sensitivity of the uplink beams to interference, and therefore identify the types of networks most at risk. Importantly, it is the beams with the highest *G*/*T* that will determine the sensitivity of the network to interference. By sampling a large pool of networks, a likely overall interference scenario can be generated, and this may assist in developing measures required to manage the risk of interference. The result of the analysis under this step is set out in § 5 (and Figs 3 and 4 in Annex 1) below.

The second step is to calculate the interference that would be caused by terminals of other networks at close orbital locations when applying the maximum permissible off-axis limits in Recommendation ITU-R S.524-9 to those uplink terminals (the worst case).

The criteria in Recommendation ITU-R S.1323-2 may be used in determining levels of interference that may be acceptable. For single-entry interference from other networks in the FSS, this is specified as no more than 6 percent of total system noise. This level of interference would result in a degradation of around 0.25 dB of the uplink *C*/*N*, or a loss of margin of around 0.25 dB for regenerative satellites or when the link is uplink thermal noise limited. An example of the link budget developed to calculate interference impact can be found in Annex 2, and is representative of those used to derive the results shown in § 5 of this Report.

5 Analysis of results

The uplink interference caused by terminals of other networks at close orbital locations when applying the maximum permissible off-axis limits in Recommendation ITU-R S.524-9 is calculated (the worst case) and shown in Figs 1 and 2.

It can be seen that the maximum permissible interference levels stipulated in Recommendation ITU-R S.1323-2 are exceeded in the majority of cases for networks with close orbital separation despite the interfering networks meeting the maximum permissible off-axis levels specified in Recommendation ITU R S.524-9.

Specifically, the results demonstrate that victim networks with satellite *G*/*T* greater than around 10 dB at two degrees' orbital separation and greater than around 14 dB for three degrees of separation from interfering networks operating fixed or mobile earth stations sharing a common service area would be at risk if only the Recommendation ITU-R S.524-9 limits were applied to transmit terminals of the unwanted network. For the networks studied, it can be seen that a majority of them may be at risk for close orbital spacing scenarios.

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[1] Space station in the fixed-satellite service.

[2] SRS database in IFIC 2810 is used.

FIGURE 1

Interference impact from off-axis emissions of other closely spaced FSS networks complying with the maximum limits contained in Recommendation ITU-R S.524-9 for a wide *G*/*T* range

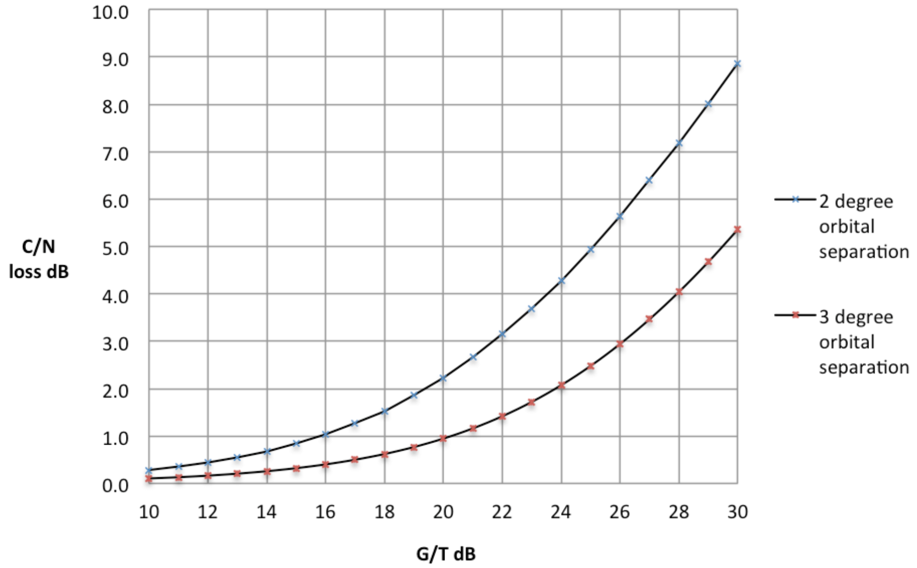
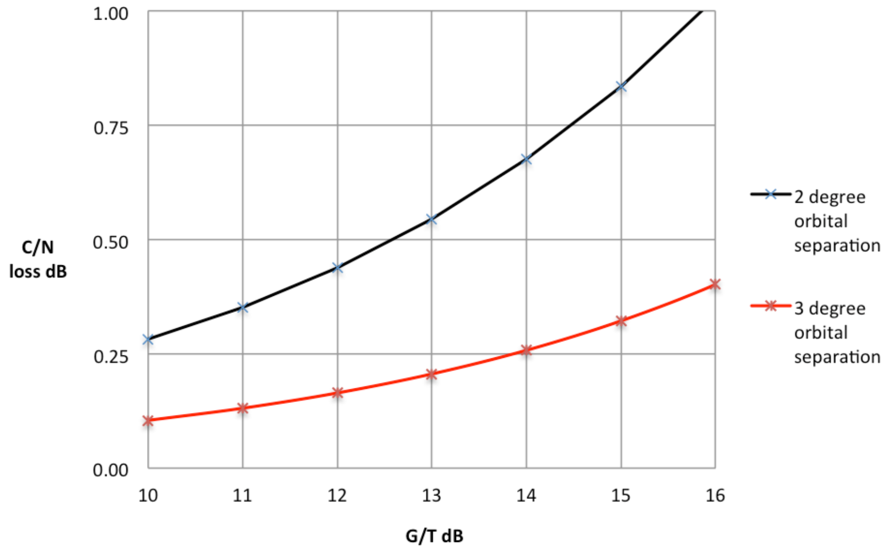


FIGURE 2

Interference impact from off-axis emissions of other closely spaced FSS networks complying with the maximum limits contained in Recommendation ITU-R S.524-9 for a wide *G*/*T* range (zoom-in)



6 Potential mitigation techniques

A range of mitigation techniques and measures can be considered and applied depending on specific circumstances. In this regard the following, either individually or in combination, may be suitable.

6.1 Tolerating higher uplink interference

For some GSO network satellite links, degradation to the uplink transmissions above the recommended values in Recommendation ITU-R S.1323-2 may not be too onerous. For example, those links that have low values of transmission gain as for example when the complete link is dominated by downlink thermal noise, could tolerate more than 6% increase in *I*/*N*, when *N* is the satellite receiver thermal noise. Also, in cases where the link performance is significantly impacted by intra-system interference due to multiple frequency reuse due to a multitude of spot beams, which is typical of satellite networks with very high *G*/*T* with multiple spot beams, even a significant increase in satellite receiver interference noise above the nominal 6% of thermal noise, may only lead to a modest impact on the overall system noise.

6.2 Increasing orbital separations

In certain cases, some flexibility may exist at the planning stage to ensure orbital locations for GSO satellites with high *G*/*T* are selected with sufficient orbital separation to coexist with existing or planned networks with regulatory priority that are operating with off-axis emissions at, or close to, the Recommendation ITU-R S.524-9 limits. The disadvantage of this approach is that it limits the scope for new networks with plans for higher satellite *G*/*T* values, and may lead to less efficient use of the orbital and frequency resources.

6.3 Improving earth station off-axis performance

Recommendation ITU-R S.524-9 stipulates "Maximum permissible levels of off-axis e.i.r.p. density", and includes NOTE 2 – "Enhanced orbit utilization and easier coordination would be attained with lower side-lobe e.i.r.p. density values, and therefore, administrations are encouraged to achieve lower values where practicable (e.g. by using antennas having an improved pattern performance in the GSO plane)". Therefore, a greater emphasis can be placed on this aspect as a means of fostering increased probability of coexistence without undue constraint on all users of the frequency band.

6.4 Increasing uplink on-axis e.i.r.p. density

Particularly in the case of networks with high *G*/*T* satellite receive systems and modest size VSATs, it may be feasible to increase the uplink on-axis e.i.r.p. density in order to maintain an appropriate *C*/*I* ratio in the presence of elevated levels of interference caused by closely spaced networks with off-axis emissions close to the maximum levels permitted under Recommendation ITU-R S.524-9, while still complying with Recommendation ITU-R S.524-9 limits for the wanted emissions.

However, in high satellite *G*/*T* networks, the links are often limited by intra-system interference due to spatial and frequency reuse so this mitigation technique may prove somewhat ineffective.

This mitigation technique could still however be considered when used in combination with the above-mentioned Improving earth station off-axis performance technique (i.e. by using antennas having an improved pattern performance in the GSO plane). In considering this mitigation technique, it should be recognized that a higher on-axis e.i.r.p. density may compromise the ability to successfully coordinate. From a broader regulatory perspective, it also runs counter to the objective of using the minimum power needed to sustain the communications link and of making the most efficient use of scarce orbital and spectrum resources. In addition, in parts of the Ka-band where GSO networks share on a co-primary basis with non-GSO FSS systems, this higher on-axis e.i.r.p. may adversely impact the non-GSO FSS satellite receivers.

6.5 Adaptive coding

Adaptive coding can be used to reduce the required *C*/(*N*+*I*) as a means to maintain communications links that are subject to external interference. Such techniques can maintain availability targets albeit at the expense of capacity and may be appropriate in cases where reduced capacity could be afforded in cases where external interference is time variant and only present for small percentages of the time. In the case of GSO interference, except in the instance of rain fades, the *C*/*I* ratios tend to be time-invariant.

6.6 Selective service area separation

For the case of high *G*/*T* satellite networks, the uplinks from beam areas most susceptible to off-axis interfering emissions from other networks with higher earth station e.i.r.p. density can be readily identified. The areas at risk typically only comprise a small portion of the operational service area, and it may be practical to differentiate the protection requirements for such areas during coordination. In this manner, it may be possible to achieve an appropriate degree of protection for specific portions of high satellite *G*/*T* network service areas while minimizing the constraints on entities wanting to apply Recommendation ITU-R S.524-9 more generally.

7 Conclusions

Managing uplink interference between closely separated GSO FSS VSAT networks in the 27.5-30 GHz frequency band is challenging when the respective networks have widely divergent characteristics, notably with respect to *G*/*T*. This Report identifies the areas of difficulty, and highlights a range of techniques that may assist administrations in addressing planning and coordinating GSO FSS VSAT networks in those cases where close orbital spacing is required.

Annex 1

FIGURE 3

FSS network uplink *G*/*T* samples derived from CR/C filing data (sorted from min to max)

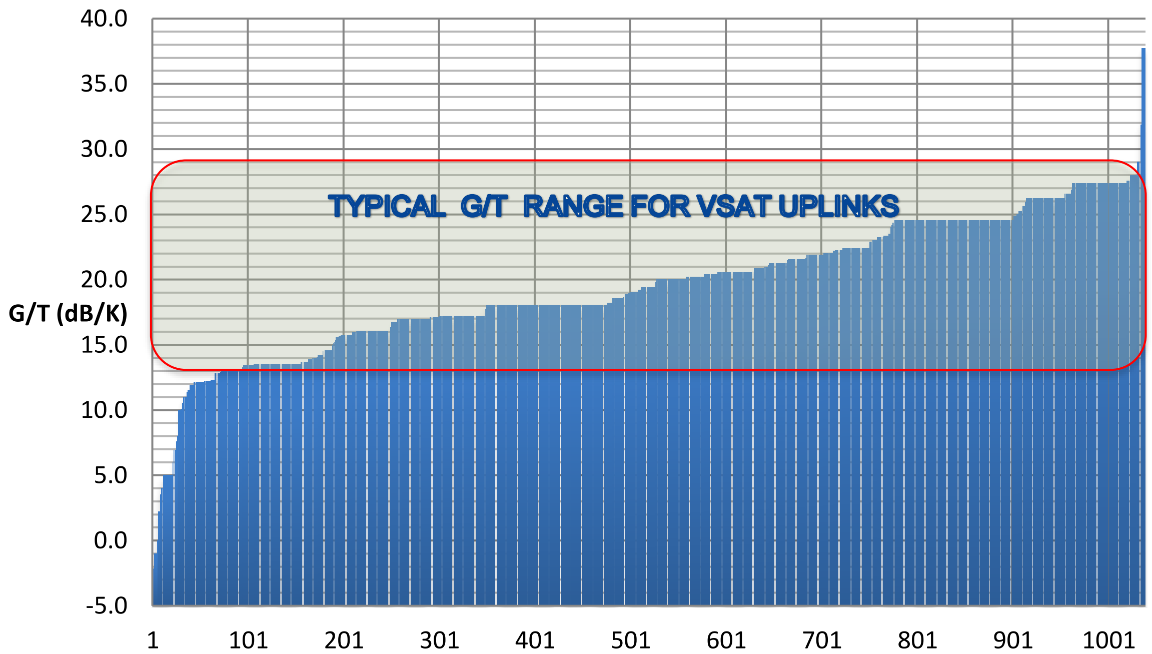
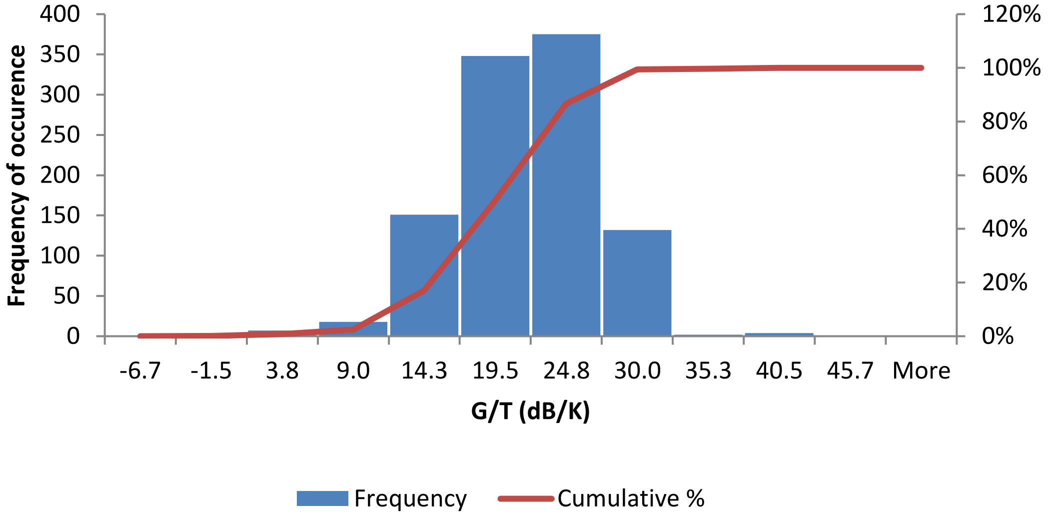


FIGURE 4

Distribution of *G*/*T* (mean value of 19.5 dB/K, standard deviation of 5.25 dB/K)



Annex 2

Example link budget

Calculation of interfering noise into wanted satellite receiver					
Parameter	**Units**	**Global ESIM**	**Typical HDFSS**	**New generation high throughput HDFSS**	**Maximum satellite RX antenna gain for S.1323-2 and S.524-9 alignment**
Wanted pfd	dBW/m^2/MHz	0.0	−125.9	−134.3	−115.4
Orbital separation wanted vs unwanted	degrees	2	2	2	2
Assumed geocentric to topocentric conversion	ratio	1.1	1.1	1.1	1.1
Resulting off-axis (topocentric) angle	degrees	2.2	2.2	2.2	2.2
Unwanted pfd (based on Rec. S.524-9 off-axis limit)	dBW/m^2/MHz	−138.1	−138.1	−138.1	−138.1
Gain of wanted satellite antenna	dBi	40.0	48.0	56.0	37.5
Frequency	GHz	28.5	28.5	28.5	28.5
Effective Aperture of wanted satellite antenna	db-m^2	−10.5	−2.5	5.5	−13.0
Wanted receive signal power	dBW/Mz	–128.1	–128.4	−128.8	−128.4
Noise Temp of wanted satellite system (including Sky noise)	K	700.0	650.0	600.0	650.0
Noise Temp of wanted satellite system	dB-K	28.5	28.1	27.8	28.1
Satellite Station *G*/*T*	Db-k	11.5	19.9	28.2	9.4
Noise Power Density of wanted satellite system	dBW/Mz	–140.1	–140.5	–140.8	–140.5
C/*N* without interference	dB	12.0	12.0	12.0	12.0
C/*I*	dB	20.5	12.2	3.8	22.7
External interference power	dBW/Mz	−148.6	−140.6	−132.6	−151.1

Calculation of interfering noise into wanted satellite receiver					
Parameter	**Units**	**Global ESIM**	**Typical HDFSS**	**New generation high throughput HDFSS**	**Maximum satellite RX antenna gain for S.1323-2 and S.524-9 alignment**
Resulting *C*/(*I*+*N*)	dB	11.4	9.1	3.1	11.7
Derived *I*/*N*	dB	−8.5	−0.1	8.2	−10.6
Derived delta T/T (thermal)	%	14.3	96.9	662.4	8.6
Allowable interfering off-axis e.i.r.p. density using Rec. S.524-9	dBW/Mz	−35.6	−35.6	−35.6	−35.6
Thermal Noise Power Density	dBW/Mz	−140.1	−140.5	−140.8	−140.5
Transmit and other link noise contributions (see Note)	dBW/Mz	−143.6	−144.0	−144.3	−144.0
Total uplink system noise power (Ntot)	dBW/Mz	−138.5	−138.9	−139.2	−138.9
C/*N* including transmit and other link noise contributions	dB	10.4	10.4	10.4	10.4
Resulting C/(I+N)	dB	10.0	8.2	2.9	10.2
Off-axis interfering receive power using Rec. S.524-9	dBW/Mz	−148.6	−140.6	−132.6	−151.1
Rec. S.1323-2 single entry external interference allowance	%	6.0	6.0	6.0	6.0
Rec. S.1323-2 external interference power	dBW/Mz	−150.8	−151.1	−151.4	−151.1
External interference pfd limit under Rec. S.1323-2	dBW/m^2/MHz	−140.2	−148.5	−156.9	−138.0
Allowable interfering off-axis e.i.r.p. density using Rec. S.1323-2	dBW/Hz	−37.7	−46.0	−54.4	−35.5
Deviation from Rec. S.1323-2 permissible interference	dB	2.2	10.5	18.8	0.0
Degradation of *C*/*N* as a result of interference	dB	0.41	2.23	7.47	0.25

NOTE – Depending on the type of link, there may be significant differences in the contributions to total system noise other than from thermal noise. A figure of 45% is assumed in this study but is link type dependent.