# APPENDIX B: INTERFERENCE AND SHARING ANALYSIS

## 1. Introduction

This Appendix presents the results of interference studies conducted to assess the sharing potential between the Celestri LEO System satellite network and other communication networks, including an NGSO/FSS system ("Teledesic"), a GSO/FSS system, and Fixed Service ("FS") systems. The methodology employed to compute interference between FSS networks is described in the Draft New Recommendation ITU-R [4A/XR].[1]

Section 2 addresses intraservice sharing between the Celestri LEO System, Teledesic and a GSO system. This section demonstrates that mitigation techniques such as satellite diversity can prevent mutual interference and allow co-frequency, co-coverage spectrum sharing. Section 2.1 addresses interference between the Celestri LEO System and a generic GSO system, and mitigation techniques that can be used to reduce interference between the two systems. An exclusion zone of ±4° is shown to reduce interference into the GSO system to below the acceptable interference levels indicated in the CPM Report to WRC-95.[2] In Section 2.2, interference between the Celestri LEO System and the Teledesic network is examined. This section also demonstrates that mitigation using satellite diversity can reduce interference. This analysis agrees with U.S. contributions to ITU-R Study Group 4A,[3] which show that two NGSO/FSS

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[1] Draft New Recommendation ITU-R [4A/XR], "Simulation Methodology for Assessing Short-Term Interference Between Co-directional Non-GSO FSS Networks and Other Non-GSO FSS or GSO FSS Networks," ITU-R Study Group Document 4/52(rev.1)-E, (February 10,1997).

[2] CPM Report to WRC-95, Chapter 2, Section 1, Part 1.

[3] United States of America, "Contribution to CPM-97 on Co-directional Frequency Sharing Between Non-GSO FSS Systems Operating in the

systems can share the same frequencies when a fixed minimum separation angle between the two systems is maintained. The analysis also indicates that sharing with the Teledesic network and avoiding the ±4° exclusion zone in the GSO orbital arc is possible.

Section 3 addresses sharing considerations with FS. The primary cause of interference into the Celestri LEO System CPE comes from nearby FS installations. Characteristics for the FS station transmitter are taken from Sections 101.113 and 101.115 of the Commission's Rules. These characteristics are used to derive a geographical interference zone near the mainlobe of the FS transmitter's antenna. Within this zone, Celestri LEO System CPE may suffer a loss of sensitivity due to interference from FS transmitters unless interference mitigation techniques are employed.

Due to anticipated widespread deployment of Celestri LEO System low data rate terminals, various CPE shielding, antenna design techniques, and frequency avoidance techniques will be used to avoid unacceptable interference from FS, in lieu of site coordination procedures. It is expected that the larger, high data rate terminals will be coordinated with FS using standard coordination procedures.

The Celestri LEO System downlinks meet the power flux density limits defined in Section 25.208(c) of the Commission's Rules, and there is no domestic FS allocation in the Celestri LEO System uplink bands. These links, therefore, do not constitute a potential source of harmful interference to FS receivers.

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Band 18.8-19.3 and 28.6-29.1 GHz Bands," Document 4A/124-E, (September 19, 1996).

## 2. Intraservice Sharing

### 2.1 NGSO-GSO Sharing

#### 2.1.1 Results With No Mitigation

This section provides the results of the interference simulation using the geometric analysis described in Draft New Recommendation ITU-R[4A/XR] between a co-frequency non-GSO system (Celestri LEO System) with an earth terminal located near Jodhper, India and a generic GSO satellite system also with an earth terminal in Jodhper, India. The input parameters for the constellations appear in Table 2-1, and Table 2-2 shows the radio frequency parameters for the Celestri LEO System and GSO links. The characteristics for the generic GSO system are those recommended for sharing of the GSO orbital arc as indicated in Draft New Recommendation ITU-R [4A/XA].[4]

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[4] Draft new Recommendation. ITU-R [4A/XA], “Frequency Sharing of the Bands 19.7-20.2 GHz and 29.5-30.0 GHz Between Systems in the Mobile-Satellite Service and Systems in the Fixed-Satellite Service,” Document 4A/67-r1 (February 10, 1997).

### Table 2-1: Celestri LEO System and GSO Simulation Input Parameters

| Input Parameter | Celestri LEO System | GSO |
|---|---|---|
| Number of space stations | 63 | 1 |
| Number of planes | 7 | 1 |
| Orbit altitude (km) | 1400 | 35785.4 |
| Inclination (deg) | 48 | 0 |
| Right ascension of ascending node (deg) | (Plane No.)*51.43 | 83 |
| Anomaly of first space station in each plane (deg) | (Plane No.)*28.57 | 0 |
| Minimum elevation (deg) | 16[5] | - |
| Space station antenna pattern | ITU Appendix S8 | ITU-R S.672-3[6] (-25) |
| Space station maximum transmit gain (dBi) | 32.8 | 45[7] |
| Space station maximum receive gain (dBi) | 35.3 | 45[7] |
| Ground station North Latitude (deg:min:sec) | 25:00:00 | 25:00:00 |
| Ground station West Longitude (deg:min:sec) | 74:00:00 | 74:00:01 |
| Ground station antenna pattern | ITU Appendix S8 | ITU-R S.672-3[6] (-25) |
| Ground station maximum transmit gain (dBi) | 35.6 | 45 |
| Ground station maximum receive gain (dBi) | 34.2 | 45 |
| Simulation time | 7 Days | |
| Simulation time increment | 1 second | |

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[5] The satellite selection process is based upon preference for the satellite with the greatest elevation angle as measured from the ground.

[6] Recommendation ITU-R S.672-3, “Satellite Antenna Radiation Pattern for Use as a Design Objective in the Fixed-Satellite Service Employing Geostationary Satellites,” 1995.

[7] Space station peak transmit and receive gain is assumed to be pointed towards GSO ground station, and follows the roll-off specified in ITU-R S.672-3.

## Table 2-2: System Radio Frequency Parameters

| **Parameter** | **Celestri Space Station** | **Celestri Ground Station** | **GSO Space Station** | **GSO Ground Station** |
|---|---|---|---|---|
| $P_t / BW_{tx}$ (dBW/Hz) | N/A | N/A | -67 | N/A |
| Co/No (dB) | 11 | 9 | 10 | N/A |
| $L_p$ | 1 | 1 | 1 | 1 |
| Transmit $\lambda$ (m) | 0.0154 | 0.0103 | 0.0154 | 0.0103 |
| $T$ (deg K) | 649.2 | 678.4 | 575 | 250 |

Figures 2-1 and 2-2 show the results of the simulation as a function of the percentage of time interference occurs. Also illustrated in Figure 2-2 are the acceptable interference levels indicated for GSO/FSS systems as contained in the CPM Report to WRC-95.

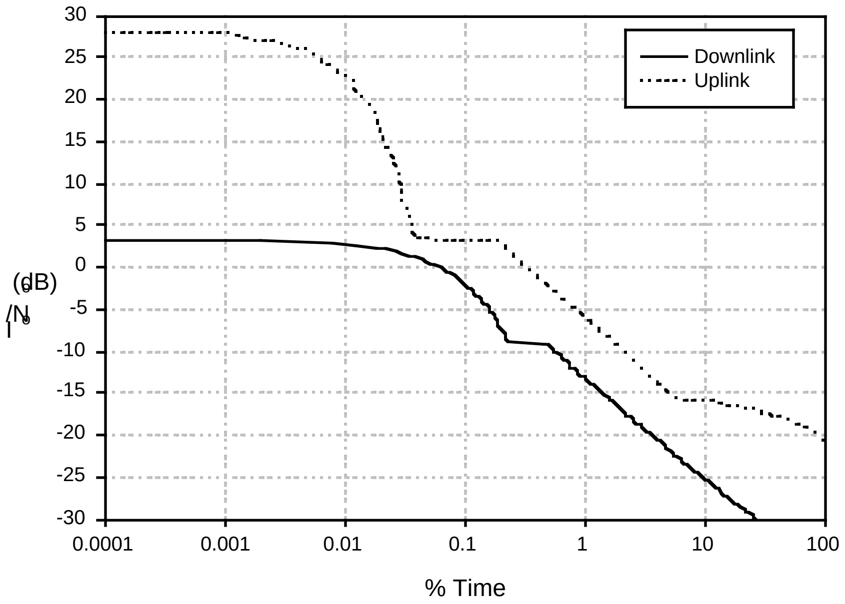

**Figure 2-1**
**Interference from the GSO Network into Celestri LEO System without Mitigation**

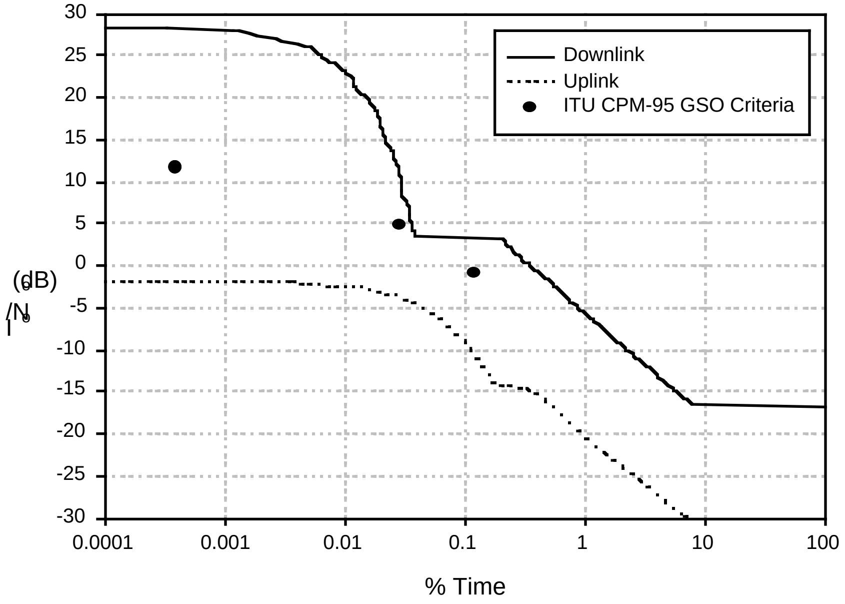

**Figure 2-2**
**Interference from the Celestri LEO System into GSO Network without Mitigation**

### 2.1.1.1 Interference Duration Without Mitigation

Figure 2-3 shows a time sample of the interference experienced by the Celestri LEO System from a GSO system. Figure 2-4 shows a time sample of interference experienced by the GSO system from the Celestri LEO System. (Note that the same period of time is referenced in both figures.)

Figures 2-5 and 2-6 show the number of events as a function of the duration of those events. Figure 2-5 shows the events of interference into the Celestri LEO System, and Figure 2-6 shows the interference events into the GSO system. An "event" occurs when the interference level at the receive location creates an interference-to-noise density ratio (Io/No) above 0 dB; the duration of the event is the amount of time that the interference ratio remains above 0 dB. The 0 dB level is used only for illustration purposes. Table 2-3 summarizes the results of all interference paths.

**Table 2-3: Summary of Interference Event Durations**

| Interference Path | Number of Events | Total Time of Events (sec) | % Time of Simulation | Average Event Length (sec) |
|---|---|---|---|---|
| Celestri Uplink into GSO Uplink | 0 | N/A | N/A | N/A |
| Celestri Downlink into GSO Downlink | 76 | 2029 | 0.34 | 26.7 |
| GSO Uplink into Celestri Uplink | 74 | 1925 | 0.32 | 26.0 |
| GSO Downlink into Celestri Downlink | 30 | 329 | 0.05 | 11.0 |

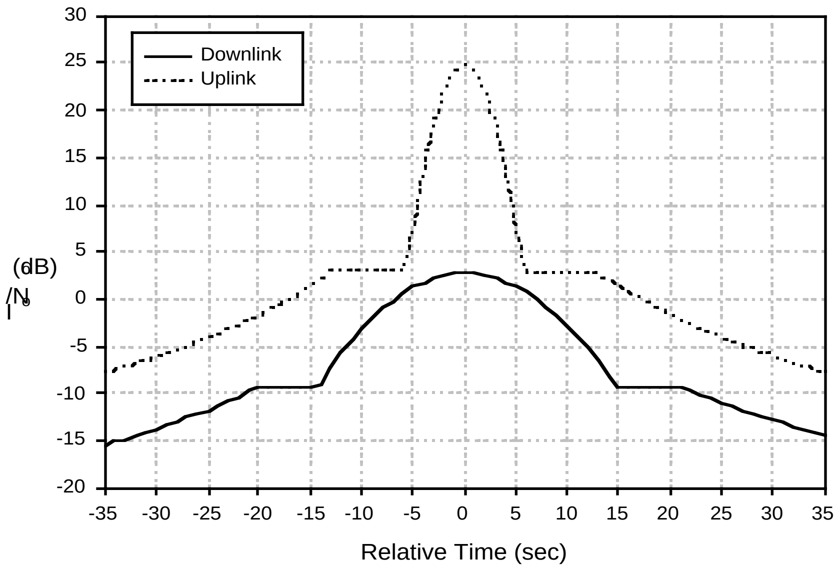

**Figure 2-3**
**Time History of Interference from GSO Network into Celestri LEO System without Mitigation**

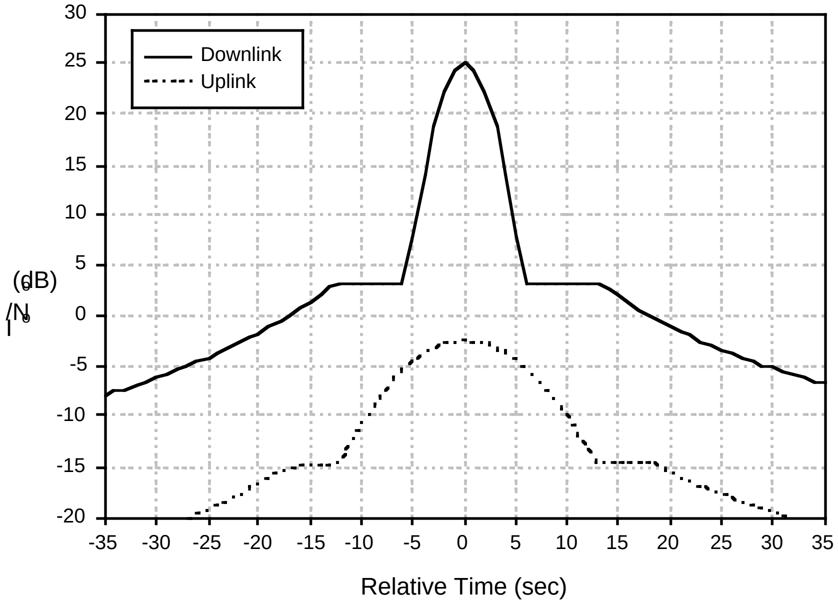

**Figure 2-4**
**Time History of Interference from Celestri LEO System into GSO Network Without Mitigation**

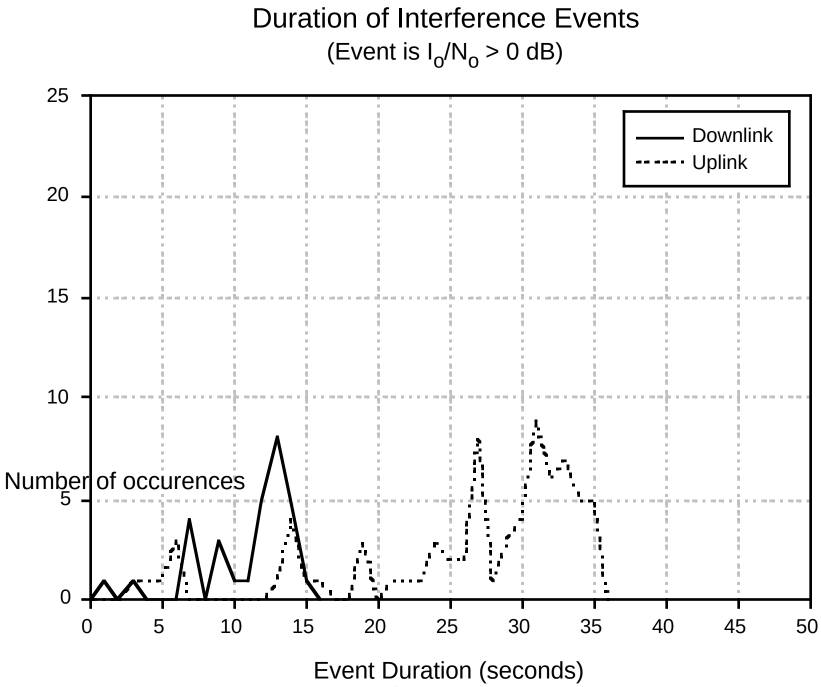

**Figure 2-5**
**Event Durations for Interference from GSO Network into Celestri LEO System Without Mitigation**

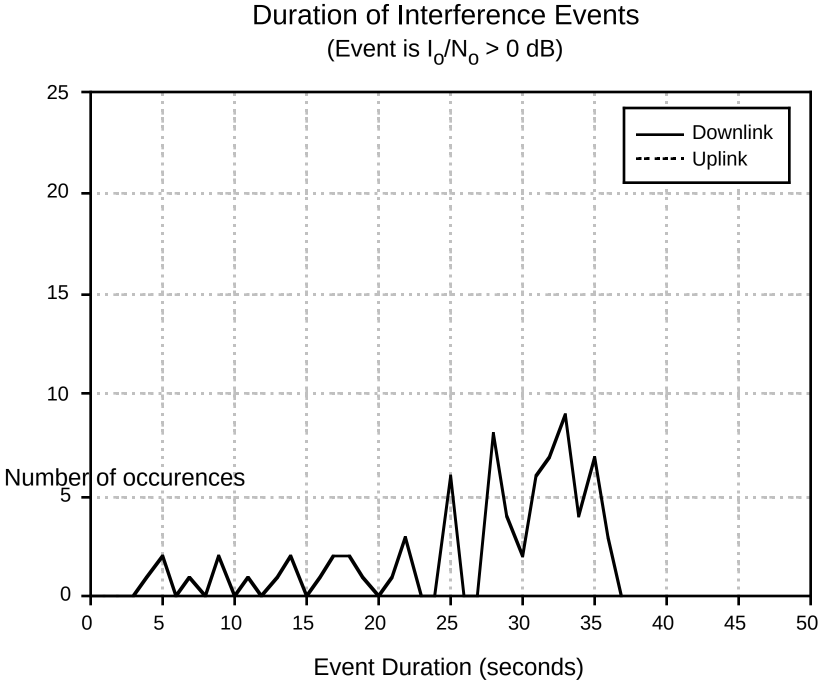

**Figure 2-6**
**Event Durations for Interference from Celestri LEO System into GSO Network Without Mitigation**

### 2.1.2 Results With Mitigation

Figures 2-7 and 2-8 show the results of satellite diversity interference mitigation between the Celestri LEO System and a GSO satellite, as described in Section 2.1.1. The mitigation was applied so that the vector from the Celestri LEO System ground station to the Celestri LEO System satellite is not within 4° of the GSO orbital arc. Figures 2-9 and 2-10 show time domain samples corresponding to the interference levels shown in Figures 2-3 and 2-4, respectively. As the interference level for the path between a GSO uplink and the Celestri LEO System satellite (Figure 2-9) approaches -3 dB, interference drops by 18 dB in response to satellite diversity mitigation. After about 48 seconds, when the interference level from the original satellite no longer creates an interference risk, the system transfers the link back to the original satellite. As shown in Figure 2-8, avoiding the GSO orbital arc by ±4° allows the interference levels experienced by the GSO system to remain within acceptable levels.

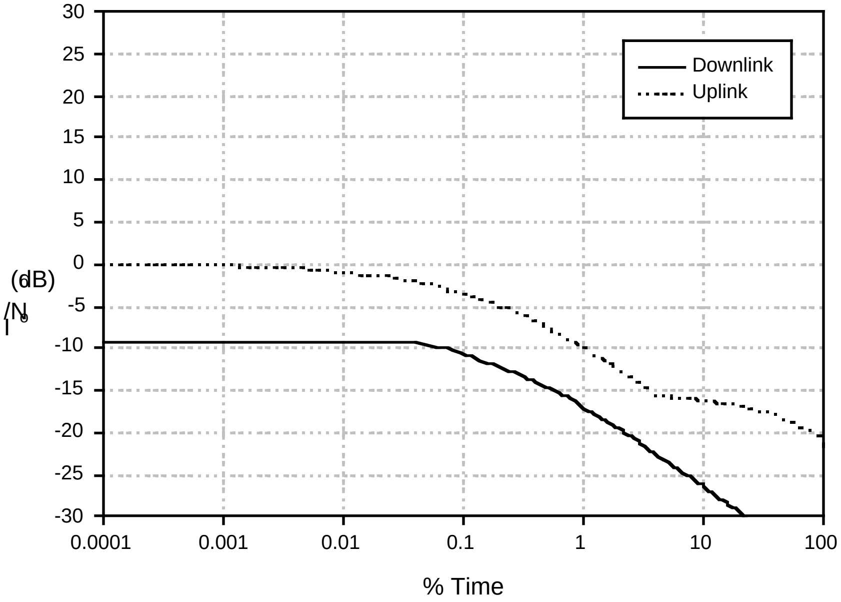

Figure 2-7
Interference from GSO Network into Celestri LEO System with Mitigation Applied

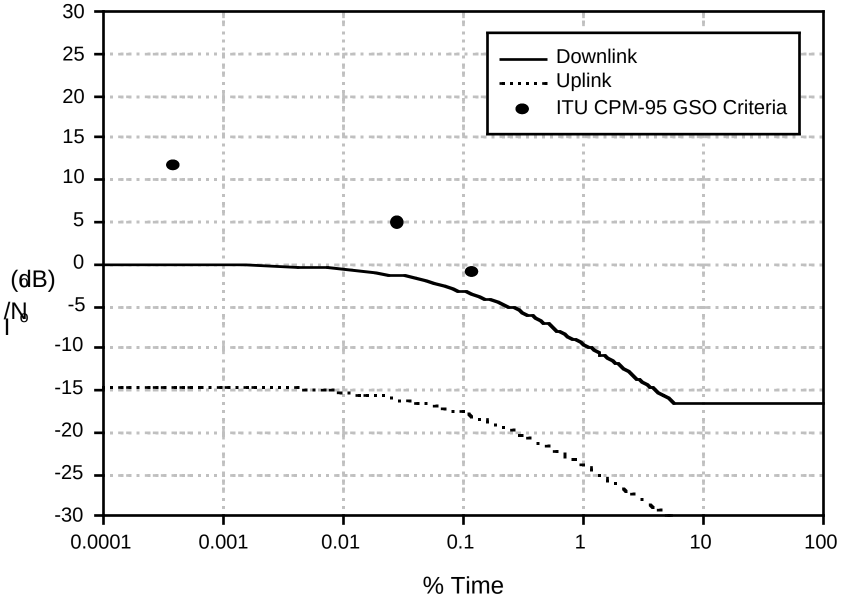

Figure 2-8
Interference from Celestri LEO System into GSO Network with Mitigation Applied

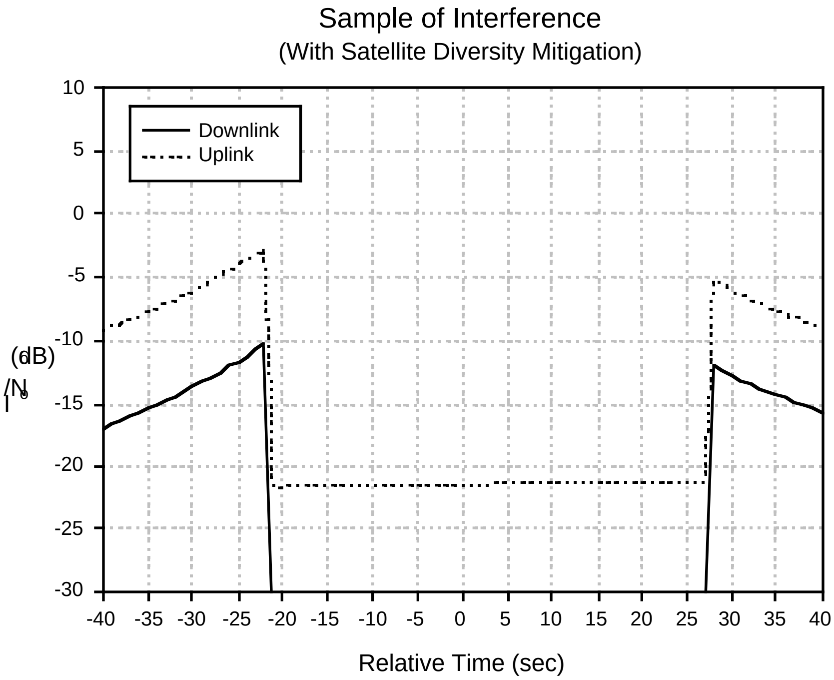

**Figure 2-9**
**Time History of Interference from GSO Network into Celestri LEO System**

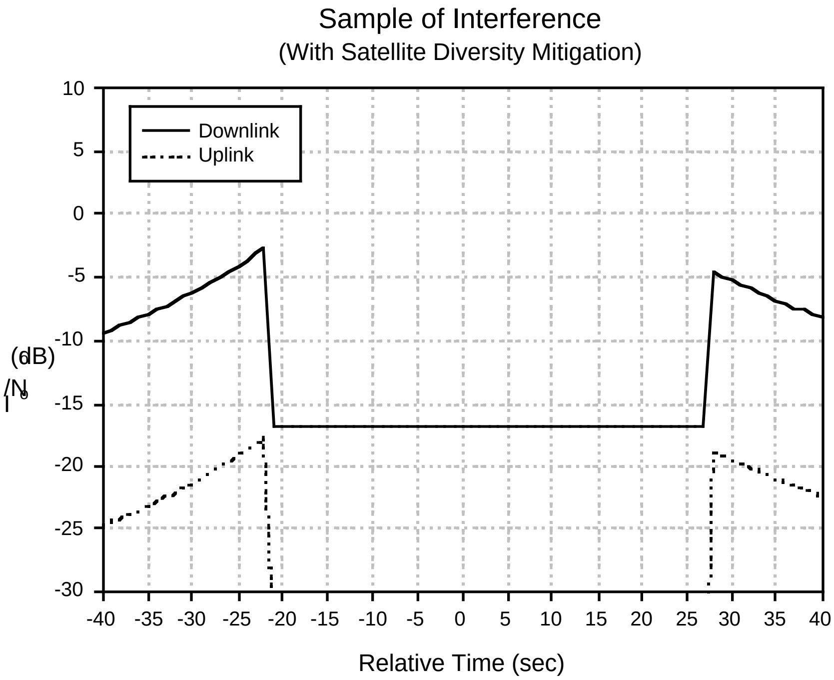

**Figure 2-10**
**Time History of Interference from Celestri LEO System into GSO Network**

## 2.2 NGSO-NGSO Sharing

### 2.2.1 Results With No Mitigation

This section provides the results of the interference simulation using the geometric analysis described in ITU-R[4A/XR] between a co-frequency NGSO system (Celestri LEO System) with an earth terminal located in Phoenix, Arizona and another NGSO satellite network (Teledesic) also with an earth terminal in Phoenix. The input parameters for the constellations are in Table 2-4, and Table 2-5 shows the radio frequency parameters for the Celestri LEO System and Teledesic network links.

### Table 2-4: Celestri LEO System and Teledesic Simulation Input Parameters

| Input Parameter | Celestri LEO System | Teledesic |
|---|---|---|
| Number of space stations | 63 | 840 |
| Number of planes | 7 | 21 |
| Orbit altitude (km) | 1400 | 700[8] |
| Inclination (deg) | 48 | 98.2 |
| Right ascension of ascending node (deg) | (Plane Number)* 51.43 | (Plane Number)*9.5 |
| Anomaly of first space station in each plane (deg) | (Plane Number)*28.57 | (Plane Number)*0.43 |
| Minimum elevation (deg) | 16[9] | 40 |
| Space station antenna pattern | ITU Appendix S8 | ITU Appendix S8 |
| Space station maximum transmit gain (dBi) | 32.8 | 32 (0.25m) |
| Space station maximum receive gain (dBi) | 35.3 | 32 (0.15 m) |
| Ground station North Latitude (deg:min:sec) | 33:26:54 | 33:26:55 |
| Ground station East Longitude (deg:min:sec) | 112:04:24 | 112:04:24 |
| Ground station antenna Pattern | ITU Appendix S8 | ITU Appendix S8 |
| Ground station maximum transmit gain (dBi) | 35.6 | 36 (0.3m) |
| Ground station maximum receive gain (dBi) | 34.2 | 33 |
| Simulation time | 7 Days | |
| Simulation time increment | 1 second | |

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[8] This is a nominal value; actual values range from 695 km to 705 km.

[9] The satellite selection process is based upon preference for the satellite with the greatest elevation angle as measured from the ground.

**Table 2-5: System Radio Frequency Parameters**

| Parameter | Celestri LEO System Space Station | Celestri LEO System Ground Station | Teledesic Space Station | Teledesic Ground Station |
|---|---|---|---|---|
| Co/No (dB) | 11 | 9 | 15 | 10 |
| $L_p$ | 1 | 1 | 1 | 1 |
| Transmit $\lambda$ (m) | 0.0154 | 0.0103 | 0.0154 | 0.0103 |
| $T$ (deg K) | 649.2 | 678.4 | 652 | 371 |

#### 2.2.1.1 Validation Of Interference Results

To validate the interference levels computed in this section, the maximum interference levels for the co-located earth terminals are compared with the interference level computed when the Celestri LEO System satellite is at 90° elevation and is in line with the path between the Teledesic earth terminal and the Teledesic satellite.

Tables 2-6 and 2-7 contain the in-line interference computations between the Teledesic network and the Celestri LEO System, using the parameters shown in Tables 2-4 and 2-5. (Note that the Teledesic network earth terminal is separated from the Celestri LEO System earth terminal by approximately 30 meters.) Figures 2-11 and 2-12 show the results of the simulation as a function of the percentage of time interference occurs. The peak values shown in these figures concur with the interference values computed in the tables.

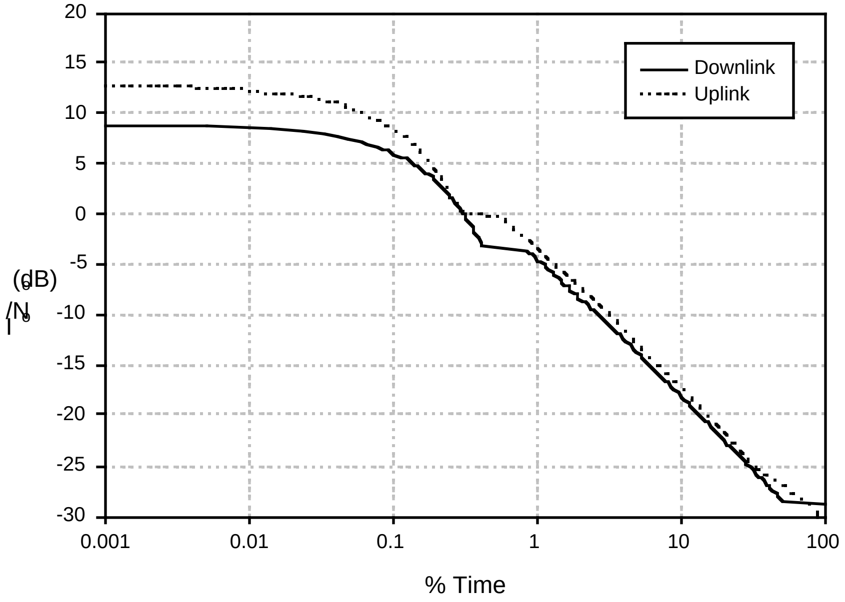

**Figure 2-11**
**Interference from Teledesic Network into Celestri LEO System**

**Table 2-6: In-line Computation of Interference Level from Teledesic Network into Celestri LEO System**

| | Teledesic uplink into Celestri LEO System uplink | Teledesic downlink into Celestri LEO System downlink |
|---|---|---|
| Wanted Co/No (dB) | 15 | 10 |
| Wanted receive gain (dBi) | 32 | 33 |
| Wanted Tsys (K) | 652 | 371 |
| $P_r$ (dBW/Hz) | -217.5 | -225.9 |
| Wanted path length (km) | 700 | 700 |
| Wanted transmit gain (dBi) | 36 | 32 |
| $P_t / BW_{tx}$ (dBW/Hz) | -74.8 | -82.8 |
| Interference path length (km) | 1400 | 700 |
| $L_p$ | 1 | 1 |
| Receive gain (dBi) | 35.5 | 34.2 |
| Io (dBW/Hz) | -188.2 | -191.7 |
| Receiver noise $T$ (deg K) | 649.2 | 678.4 |
| Io/No (dB) | 12.3 | 8.5 |

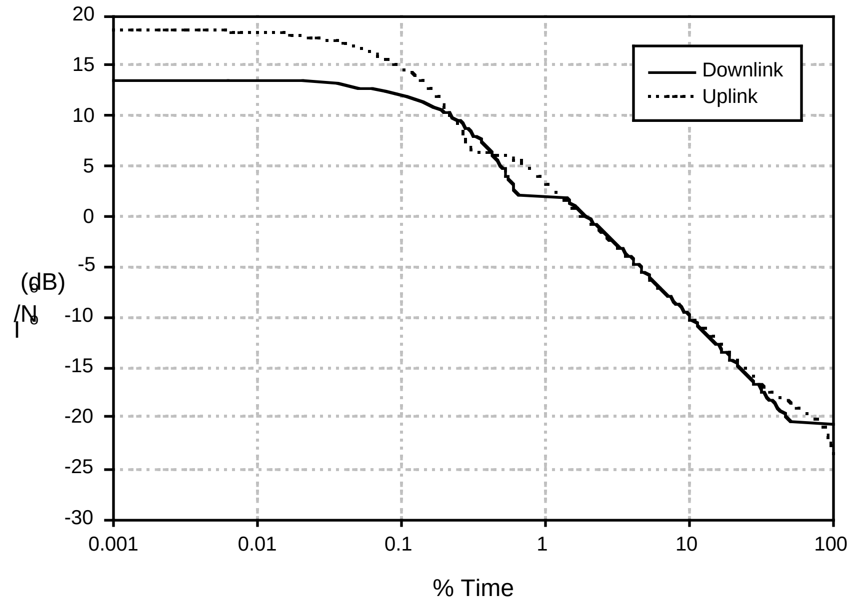

**Figure 2-12**
**Interference from Celestri LEO System into Teledesic Network**

**Table 2-7: In-line Computation of Interference Level from Celestri LEO System into Teledesic Network**

| | Celestri LEO System uplink into Teledesic uplink | Celestri LEO System downlink into Teledesic downlink |
|---|---|---|
| Wanted Co/No (dB) | 11 | 9 |
| Wanted receive Gain (dBi) | 31.3[10] | 34.2 |
| Wanted Tsys (K) | 649.2 | 678.4 |
| $P_r$ (dBW/Hz) | -220.8 | -225.5 |
| Wanted path length (km) | 1400 | 1400 |
| Wanted transmit gain (dBi) | 35.6 | 28.2[10] |
| $P_t / BW_{tx}$ (dBW/Hz) | -71.7 | -73.1 |
| Interference path length (km) | 700 | 1400 |
| $L_p$ | 1 | 1 |
| Receive gain (dBi) | 32 | 33 |
| Io (dBW/Hz) | -182.7 | -188.5 |
| Receiver noise $T$ (deg K) | 652 | 371 |
| Io/No (dB) | 17.7 | 14.4 |

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[10] Reduced by 4 dB due to edge of coverage.

### 2.2.1.2 Additional Results Without Mitigation

A time history of the interference levels and a histogram of the duration of interference can be derived from the simulation. Shown in Figure 2-13 is a sample of the time history of interference experienced by the Celestri LEO System. Shown in Figure 2-14 is the time history of interference experienced by the Teledesic network, using the same time line as in Figure 2-13. Figures 2-15 and 2-16 show the number of events and the duration of those events. An “event” occurs when the interference level at the receive location creates an interference-to-noise density ratio (Io/No) above 0 dB; the duration of the event is the amount of time that the interference ratio remains above 0 dB. The 0 dB level is used only for illustration purposes. Table 2-8 summarizes the results of this simulation.

**Table 2-8: Summary of Interference Event Durations**

| Interference Path | Number of Events | Total Time of Events (sec) | % Time of Simulation | Average Event Length (sec) |
|---|---|---|---|---|
| Celestri LEO System uplink into Teledesic uplink | 617 | 10736 | 1.78 | 17.4 |
| Celestri LEO System downlink into Teledesic downlink | 632 | 11306 | 1.87 | 17.8 |
| Teledesic uplink into Celestri LEO System uplink | 257 | 1936 | 0.32 | 7.5 |
| Teledesic downlink into Celestri LEO System downlink | 230 | 1826 | 0.30 | 7.9 |

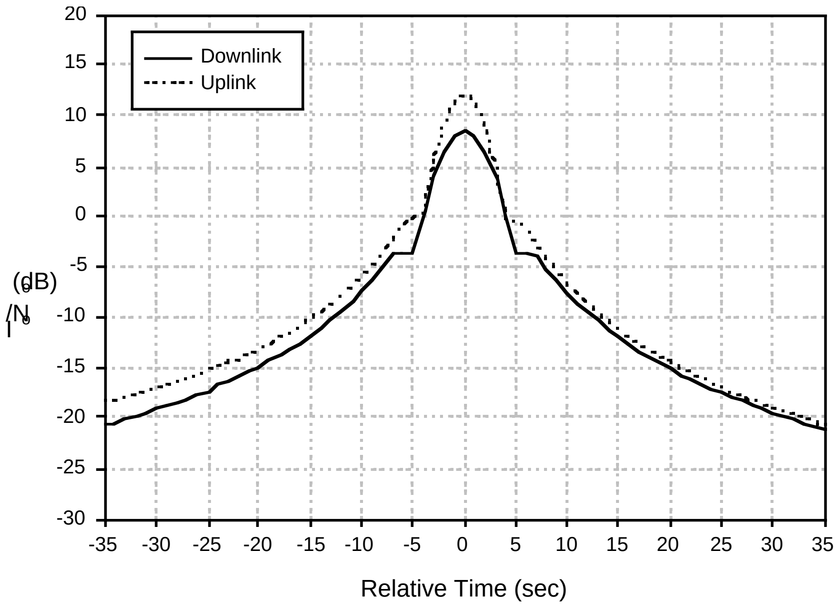

**Figure 2-13**
**Time History of Interference from Teledesic Network into Celestri LEO System**

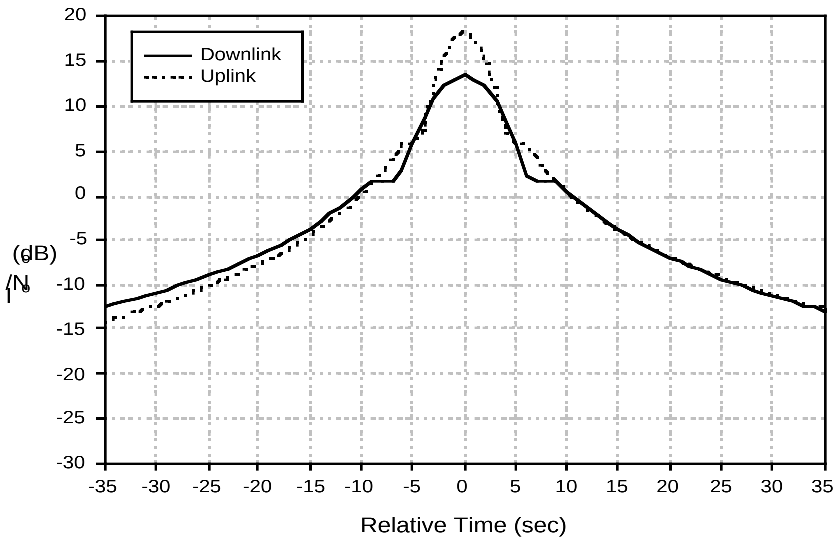

**Figure 2-14**
**Time History of Interference from Celestri LEO System into Teledesic Network**

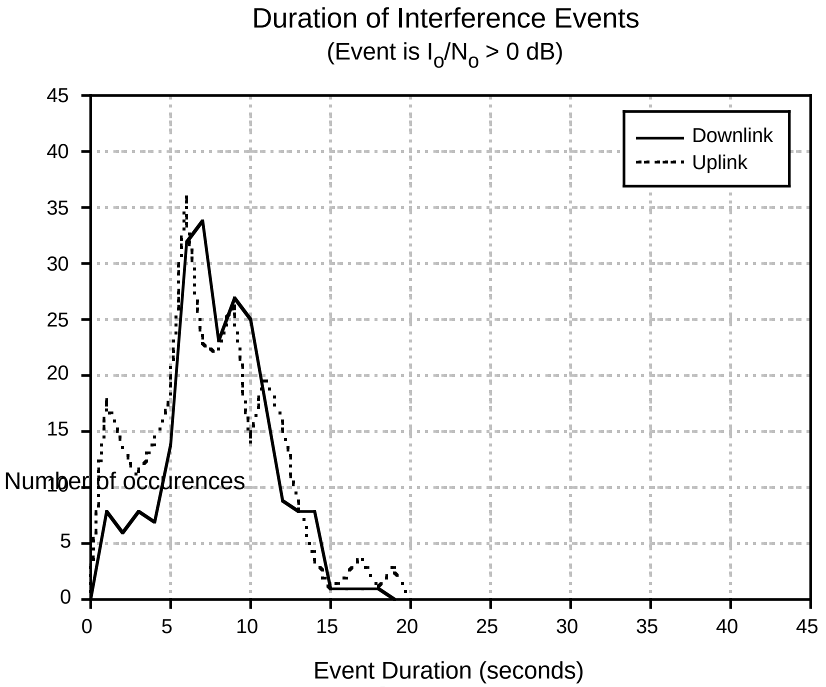

**Figure 2-15**
**Event Durations for Interference from Teledesic Network into Celestri LEO System**

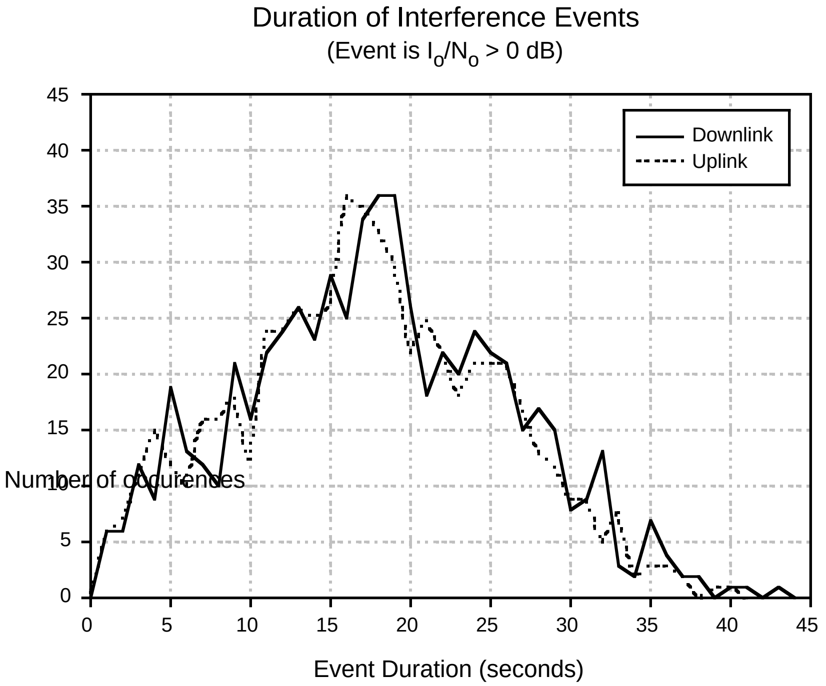

**Figure 2-16**
**Event Durations for Interference from Celestri LEO System into Teledesic Network**

### 2.2.2 Results With Satellite Diversity Mitigation

Satellite diversity is one of several mitigation techniques that may be used to reduce the interference between the Celestri LEO System and another co-channel, co-coverage NGSO system.[11] It relies on two or more Celestri LEO System satellites being within view of an earth terminal at all times. When an interference event is about to affect one of those satellites, the earth terminal switches to the other satellite.

The use of satellite diversity for interference mitigation among more than two NGSO systems introduces system complexities that produce diminished overall benefits. For example, there may not be another satellite available in a non-interfering location to avoid the impending interference. In addition, the presence of two or more satellites from other systems within view of an earth station will require real-time inter-satellite hand-offs at a rate that will increase system overhead and adversely affect overall system capacity.

Figures 2-17 and 2-18 show the results of satellite diversity mitigation of interference to the Celestri LEO System from the Teledesic network, and vice versa. The diversity rules in this analysis include avoiding the GSO arc by ±4°, as discussed in Section 2.1.2, and avoiding in-line interference events between the Celestri LEO System and Teledesic network. In this example, mitigation is applied to predicted levels of interference caused by the uplink of the Teledesic ground terminal to the Celestri LEO System satellite. When the interference-to-noise ratio of this link is expected to exceed -15 dB, the Celestri LEO System selects another satellite that is above 16 degrees in elevation, always maintaining a preference for the

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[11] Other potential mitigation techniques are available, but they have not yet been accepted for the NGSO-to-NGSO case. Several of these potential mitigation strategies are listed in Section V of this Application.

satellite with the highest elevation.[12] If the alternate satellite will cause harmful interference at a level above -15 dB, another satellite is selected. If all available satellites are checked and none is able to mitigate the interference to below the required -15 dB level, communications are maintained with the original satellite. At least one satellite should always be available to avoid interference between the systems.

Figures 2-19 and 2-20 show time domain samples corresponding to Figures 2-13 and 2-14, respectively. As the interference level for the path between the Teledesic uplink and the Celestri LEO System satellite approaches -15 dB, interference drops by about 15 dB in response to imposition of satellite diversity mitigation. After about 45 seconds, when the predicted interference level from the original satellite is no longer above the -15 dB level, the system transfers the link back to the original satellite.

The results of this analysis indicate that the application of satellite diversity should avoid unacceptable interference levels between the Celestri LEO System and the Teledesic network. Further, such diversity techniques can simultaneously be applied to avoid interference with GSO FSS satellites.

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[12] The choice of -15 dB is for illustrative purposes. The actual levels used for mitigation will be coordinated among the system operators.

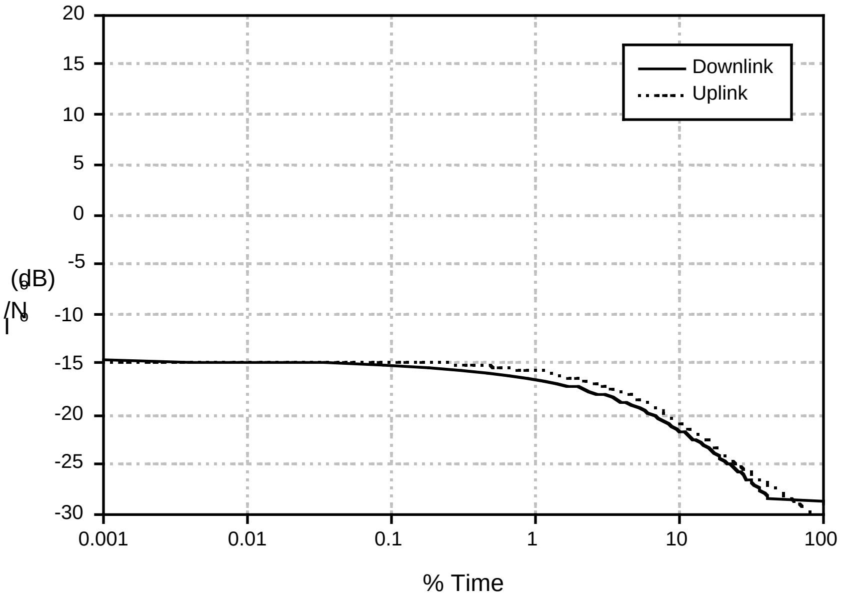

**Figure 2-17**
**Interference from Teledesic Network into Celestri LEO System with Mitigation Applied**

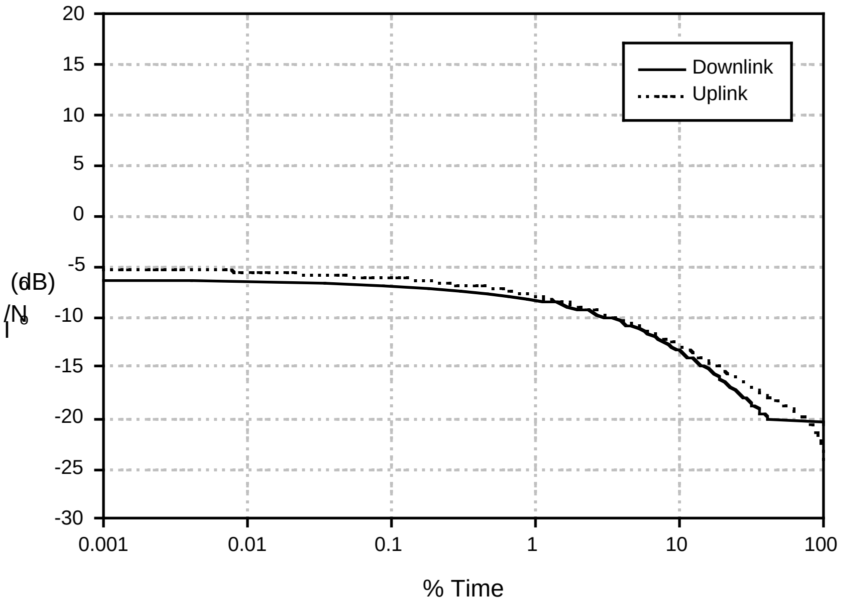

**Figure 2-18**
**Interference from Celestri LEO System into Teledesic Network with Mitigation Applied**

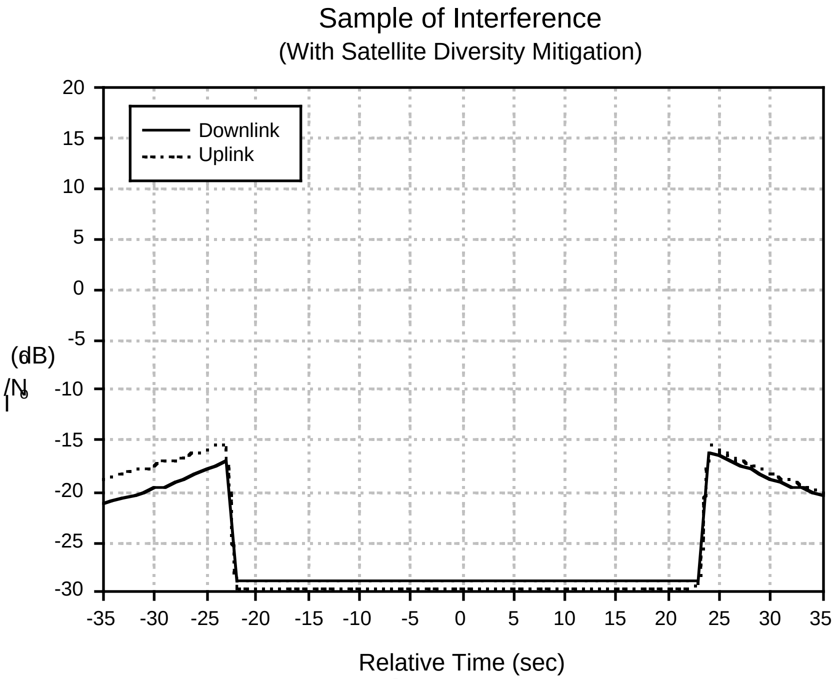

Figure 2-19
Time History of Interference from Teledesic Network into Celestri LEO System

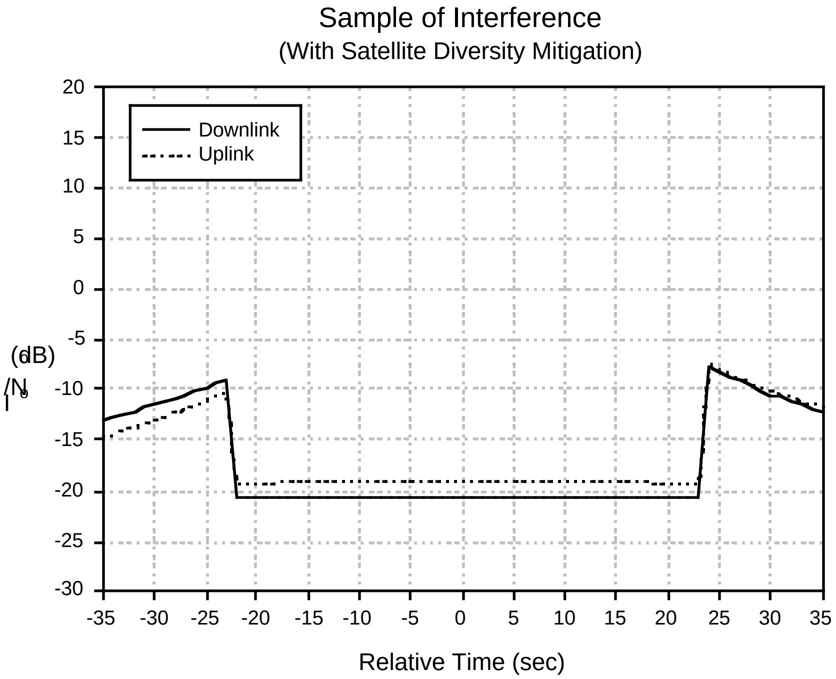

Figure 2-20
Time History of Interference from Celestri LEO System into Teledesic Network

### 2.2.3 Conclusions on Sharing between NGSO FSS Systems

As shown above, interference between two NGSO systems can be mitigated with the use of satellite diversity techniques. This conclusion is consistent with analyses approved in the U.S. ITU-R process. In fact, a U.S. contribution to ITU-R Study Group 4 demonstrates that if a separation angle is maintained, it is possible for three NGSO FSS systems to share the same frequencies.[13] The U.S. contribution, however, assumed that the systems were physically interleaved to achieve sharing, as opposed to the use of dynamic resource allocation techniques to maintain a separation angle. Nevertheless, both techniques rely on the principle of sharing and space diversity to avoid in-line interference events. Once the actual interference criteria have been developed and are accepted by two NGSO system operators, applying interleaving or dynamic resource allocation techniques to three NGSO systems may be possible.

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[13] See n.3, supra.

## 3.0 Spectrum Sharing Between the Celestri LEO System and FS Systems

### 3.1 General

FSS and FS systems intending to use the same frequency bands risk causing mutual interference. The Celestri LEO System will use the 18.8-19.3 GHz and 19.7-20.2 GHz bands for downlink (space-to-Earth) transmissions. FS currently uses the 18.8-19.3 GHz band for point-to-point and point-to-multipoint communications. In order to assess spectrum sharing in these bands, as well as the corresponding uplink bands, four interference cases need to be considered:

(a) FS into Celestri LEO System downlink receiver
(b) Celestri LEO System downlink into FS receiver
(c) FS into Celestri LEO System uplink receiver
(d) Celestri LEO System uplink into FS receiver

Cases (a) and (b) are discussed in detail below. Cases (c) and (d), however, are not germane to this Application because there is no FS allocation in the Celestri LEO System uplink bands in the U.S. Internationally, where terrestrial microwave stations are located near one or more Celestri LEO System earth stations in relatively high densities, coordination between FS and the Celestri LEO System may be difficult to achieve. Nevertheless, mitigation techniques may be employed to reduce the effects of interference under these circumstances. Interference into the Celestri LEO System uplinks from terrestrial microwave sites is not expected due to the low elevation of the microwave links and the large path losses involved.

## 3.2 FS into Celestri LEO System Downlink Receiver

The analysis in this section examines the case of interference into a direct-to-home Celestri LEO System CPE terminal from a single FS transmitter. This represents the most likely interference scenario. It also represents a reasonable worst case scenario because the direct-to-home CPE terminal is more susceptible to interference than other CPE terminals used with the Celestri LEO System because it is subject to severe antenna constraints.

The analysis is based on the FS transmitter characteristics defined in Part 101 of the Commission's Rules. The geometry assumed for the analysis is given below:

- The FS boresight is aimed directly at the CPE in azimuth, but is aimed at 0° (local-horizontal) in elevation;
- The analysis assumes a low level of refraction beyond the local horizon of the FS station;
- Propagation loss is based on free-space ($1/r^2$) for clear line of sight conditions; and
- The CPE antenna sidelobe is 20 dB below the peak mainlobe gain (Sidelobe gain = 18.7 dBi). This assumption holds for all geometries where the elevation angle between the CPE and the FS transmitter is less than 14°.

The Celestri Architecture will begin to lose front-end sensitivity and experience harmful interference when the signal received from the interfering FS transmitter is -142 dBW or greater. This power level defines a zone in which the CPE will not function acceptably unless the interference is mitigated. The size and shape of the zone depends largely on the characteristics of the line-of-sight path between the CPE and the FS transmit antenna, including the extent and nature of obstructions in the path and the relative heights of the FS and CPE antennas to each other.

Figure 3-1 shows the effect of the FS antenna height relative to the CPE antenna on the size of the interference zone. The vertical axis, called the cross range, is one half the width of the zone shown in Figure 3-2. Figure 3-1 shows the boundary of one half of the width of the interference zone as defined by the mainlobe of the FS antenna. The zone is symmetrical about the axis of the FS antenna mainlobe. The zone boundaries shown in Figure 3-1 assume that there is a clear line of sight from the FS antenna to every point in the zone. As Figure 3-1 demonstrates, the interference zone falls rapidly once the CPE moves beyond the horizon of the FS site. Thus, the extent of the zone is a strong function of the height of the FS antenna.

The curve in Figure 3-1 denoted by squares shows the interference zone boundary for an FS antenna located 10 meters above the CPE antenna. The curve in Figure 3-1 denoted by diamonds is for an FS antenna 25 meters higher than the CPE antenna, and the curve by triangles is for an FS antenna 1 meter higher than the CPE antenna.

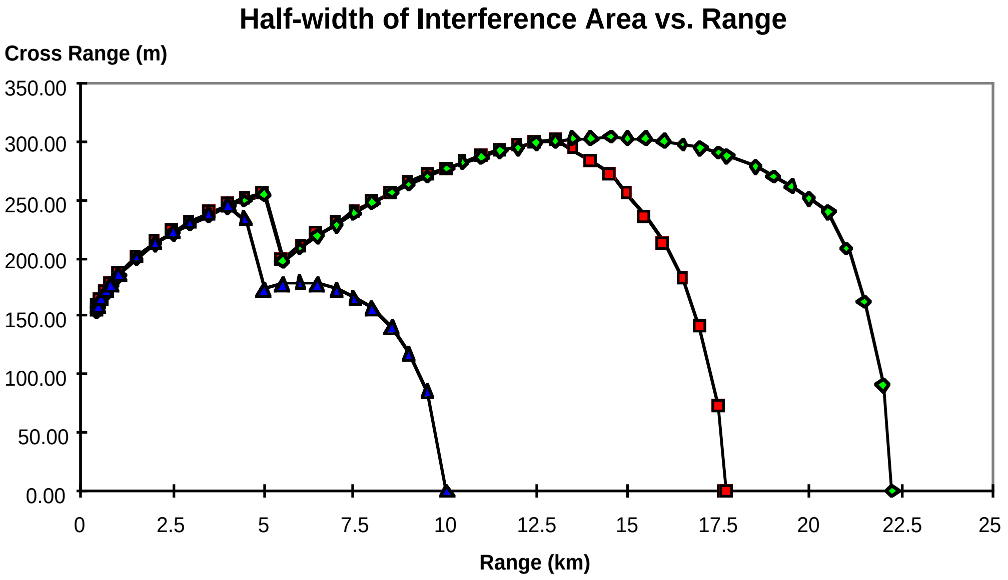

**Figure 3-1**
**CPE Interference Zone Versus FS Antenna Height**

Figure 3-2 shows an azimuthal view of the interference zone for the case where the FS transmit antenna is 10 m above the Celestri LEO System CPE receive antenna.

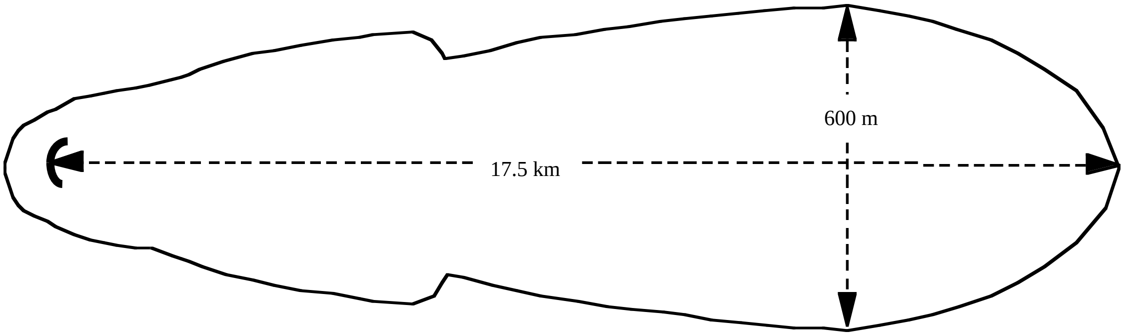

**Figure 3-2**
**CPE Interference Zone**

As Figure 3-2 illustrates, the worst case interference zone where the FS transmit antenna height is 25 meters above the Celestri LEO System CPE receive antenna is roughly 600 meters wide and about 17.5 kilometers long.

It is evident from this analysis that the anticipated widespread site-by-site deployment of small Celestri LEO System CPE terminals in an environment of broadly distributed FS transmitters will require interference mitigation at the CPE. However, within the United States, the normal elevation angle for CPE reception of Celestri LEO System satellite transmissions is 25°, which obviates the need for mitigation in most cases, i.e., where the CPE is outside an interference zone. For those cases where there is a need for mitigation, any of several techniques can be used, including antenna sidelobe control, general shielding, site-specific shielding and frequency avoidance.

The larger, higher data rate Celestri LEO System CPE terminal classes will not be deployed nearly as widely as the smaller CPE terminals and therefore will less frequently be located within FS interference zones. To the extent there are interference zone incursions, detailed site-specific coordination and/or mitigation techniques can be applied to achieve reliable reception in proximity to FS sites.

For other classes of FS transmitters with substantially different EIRP and/or antenna-directivity parameters, the above analysis can be used to develop new criteria around which new coordination procedures or mitigation techniques may be applied.

### 3.3 Celestri LEO System Downlink into FS Receiver

The Celestri LEO System downlink PFD level complies with the PFD limits defined in Section 25.208(c) of the Commission's Rules in any 1 MHz bandwidth, at all elevation levels. The PFD levels are given in Table 3-1.

**Table 3-1: Maximum PFD Levels on Earth**

| Elevation Angle (degrees) | Maximum Celestri LEO System PFD ($dBW/m^2/MHz$) | PFD Limits Per Section 25.208(c) ($dBW/m^2/MHz$) |
|---|---|---|
| 5 | -140 | -135 |
| 10 | -135 | -128 |
| 15 | -125 | -115 |
| 20 | -115 | -108 |
| 25 | -110 | -105 |
| Above 25 | -110 | -105 |

Studies at the ITU-R[14] have indicated that the PFD limits of Section 25.208(c) are adequate to protect FS from harmful interference due to NGSO constellations similar to the Celestri Leo System. Based on these studies and on the PFD levels on Earth from the Celestri LEO System, there will be no harmful interference caused to FS receivers.

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[14] WRC-97 CPM Report, Chapter 4.34.