REQUEST FOR MODIFICATION
(Call Signs E070023, E100080, E100120)

DIRECTV Enterprises, LLC ("DIRECTV") hereby requests modification of the above referenced earth station authorizations to add ALSAT as a point of communication. The underlying antennas are located at DIRECTV's Southwest Diversity Facility ("SWDF") in Benson, AZ, and are currently authorized to communicate with specific DIRECTV Ka-band satellites. In last year's *Ka-Band ALSAT Order*, the Commission adopted a new policy under which it would consider applications for modification of existing Ka-band earth station licenses seeking to add "ALSAT" as a point of communication so that it may communicate with any satellite on the Ka-band Permitted Space Station List.[1] DIRECTV hereby requests that its SWDF authorizations be so modified. DIRECTV also hereby certifies that the remaining information in its earth station license and associated application will has not changed.

The requested modification will serve the public interest by enhancing these earth stations' capabilities to support DIRECTV's provision of satellite video services to consumers throughout the United States, and by reducing the administrative burden on the Commission of repeated modifications whenever DIRECTV launches a new Ka-band satellite.

---

[1] *See 2006 Biennial Regulatory Review – Revision of Part 25*, 25 FCC Rcd. 1542, ¶¶ 12, 17 (2010) ("*Ka-Band ALSAT Order*"). As required in footnote 31 of that order and Section 25.203(k) of the Commission's rules, DIRECTV is submitting with this application an analysis to demonstrate that its proposed operations will not cause unacceptable interference to co-primary, co-frequency feeder link operations.

ASSESSMENT OF POTENTIAL INTERFERENCE TO IRIDIUM FEEDER LINKS IN THE 29.25-29.3 GHZ BAND FROM DIRECTV UPLINKS USING THAT SPECTRUM[1]

1. Introduction

In this application, DIRECTV requests modification of its earth station authorization to add Ka-band ALSAT as a point of communication, pursuant to the *Ka-Band ALSAT Order* adopted by the Commission.[2] This earth station is currently authorized to transmit in the 29.25-29.5 GHz band, which is allocated on a co-primary basis to both GSO/FSS and NGSO/MSS feeder links. As required under Section 25.203(k), and as directed in footnote 31 to the *Ka-Band ALSAT Order*, DIRECTV is submitting the following interference analysis to address the potential interference from this earth station to feeder links of NGSO/MSS systems.

DIRECTV understands that there is presently only one known NGSO/MSS feeder link earth station in CONUS licensed to use any portion of the 29.25-29.5 GHz band, that being the Iridium feeder link station located in Tempe, AZ which is authorized to operate in the 29.25-29.3 GHz band.[3] The closest DIRECTV Ka-band uplink facility to this Tempe, AZ facility is DIRECTV's Southwest Uplink Facility (SWUF)[4] which is approximately 168 km away. There is one additional license for an NGSO/MSS feeder link earth station in Fairbanks, AK however, as will be discussed later in this analysis, the significantly greater distance between this licensed earth station and DIRECTV's facility only serves to further mitigate any potential interference. [5]

2.0 Analysis for Operations at Current DIRECTV Licensed Orbital Locations

The following analysis evaluates the potential interference from DIRECTV's Ka-band GSO feeder link operation in the 29.25-29.3 GHz band from its SWUF to the Iridium MSS/LEO feeder link system during worst case in-line events. An in-line event is the condition where the DIRECTV earth-station, LEO-satellite and GSO-satellite form a straight line, in space. The approach entails:

- determining frequency overlap between the two systems;
- simulating the in-line events for a set of geostationary orbital locations:
- estimating the potential interference, using a worst case maximum/minimum method during the in-line events;

---

1 Note that the simulation analyses contained in this supplement were conducted for DIRECTV by Harry Ng Consulting LLC.

2 *See 2006 Biennial Regulatory Review – Revision of Part 25*, 25 FCC Rcd. 1542 (2010) ("*Ka-Band ALSAT Order*").

3 *See* Call Sign E960131.

4 This facility has three licensed antennas. *See* Call Signs E070111, E100079, E100121.

5 DIRECTV also observes that while the Iridium feeder link stations are licensed for the 29.25-29.3 GHz band, the ITU Notification information for the Iridium feeder links (ITU designator HIBLEO-2FL) includes frequency assignments only up to a maximum frequency of 29.2853805 GHz, and not 29.3 GHz.

- estimating the transit time of the LEO satellite crossing the in-line line, within the earth station antenna beamwidth; and
- estimating the time between in-line transits.

2.1 Operating Frequency Bands and Overlapping Frequency Segments

The use of the spectrum by the Iridium feeder link was assumed to be consistent with the ITU Appendix 4 Notification information for HIBLEO-2FL, as published by the ITU/BR in IFIC No. 2591. In the ITU Appendix 4 information there are twelve Ka-band Earth-to-space frequency assignments (*i.e.*, item C2a1 of ITU Appendix 4) and the associated bandwidth for each assignment is 5.761 MHz (*i.e.*, item C3a of ITU Appendix 4). The three uppermost assigned frequency bands are:

- 29.2796195 – 29.2853805 GHz #12
- 29.2646195 – 29.2703805 GHz #11
- 29.2496195 – 29.2553805 GHz #10

As detailed in DIRECTV's various FCC applications, the uplink feeder link plan for different DIRECTV Ka-band satellites differs across the 29.25-29.5 GHz band. In some cases there is overlap with all three uppermost Iridium feeder link assigned frequencies, whereas in other cases there is only partial (or even no) frequency overlap with these channels. Nevertheless, consistent with a worst case interference analysis, it was assumed that there is complete overlap of the DIRECTV feeder link uplinks with all three uppermost Iridium feeder link assigned frequency bands.

2.2 The In-line Environment

Potential interference coupling between a LEO satellite and a GSO system would only occur during an in-line event. An in-line event is a physical phenomenon where the earth-station, the LEO satellite and the GSO satellite form a straight line, in space. Since the earth station and the GSO space station are stationary, relative to each other, the in-line event occurs when the LEO satellite moves into the line formed by the earth station and the GSO space station. The word "moves" describes the LEO satellite motion in space and follows the planetary motion as described by Kepler's Laws.

The LEO spacecraft motion in space can be illustrated by the ground track (*e.g.*, the LEO satellite sub-satellite points on Earth) generated by the LEO constellation. The ground track identifies the location of the LEO satellites (*e.g.*, the sub-satellite point) on the surface of the Earth as the LEO spacecraft moves in space. Therefore, the specific location of the LEO spacecraft is obtained from the sub-satellite point and the altitude of the spacecraft, at any particular instant of time. Figure 1 illustrates the ground track for the HIBLEO-2FL constellation, in one particular orbital period. The orbital parameters used in the orbit simulation software were based on the HIBLEO-2FL ITU filing (IFIC No. 2591).

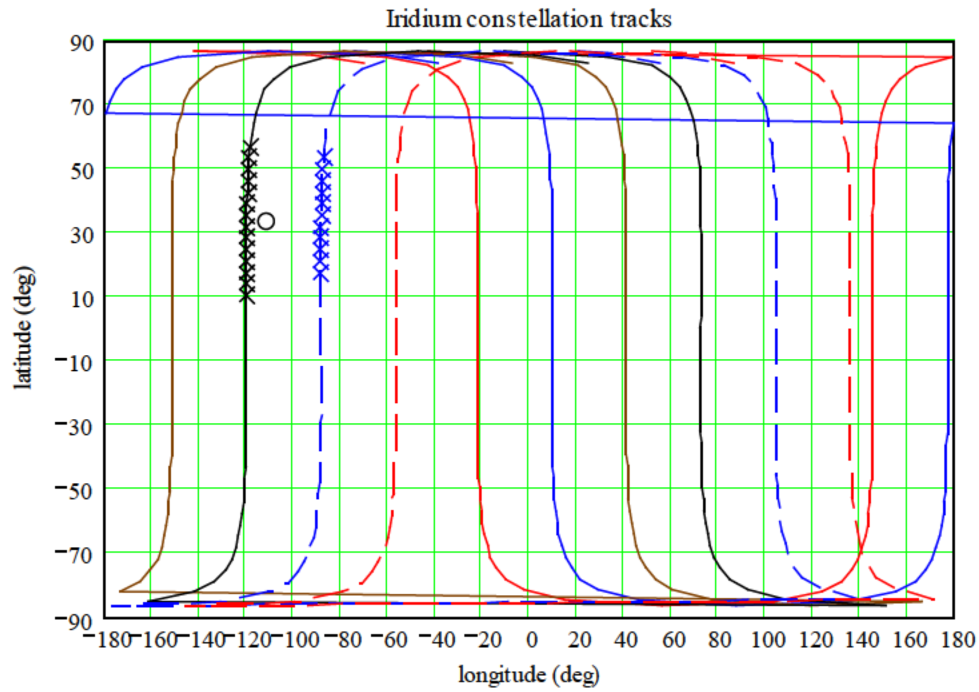

Figure 1. HIBLEO-2FL Constellation Orbital Tracks

This figure shows there are six orbital planes in the Iridium constellation and the constellation has a high inclination angle of 86.4 degrees. Because of the relatively low spacecraft altitude (775 km), the LEO spacecraft visibility to a point on Earth is limited. The portion of the Iridium satellite tracks visible to the Tempe, AZ Iridium feeder link site are marked by the "x" segments of the orbital tracks in the figure and the Tempe location on Earth is marked by the "0" in the figure. Even though the tracks cross the GSO, as illustrated in the above figure where the tracks have 0 degrees latitude, there would be no in-line event for the Tempe site with a GSO satellite at, for example, 101WL for this set of ground tracks. In other words, an in-line event requires a special combination of earth station, LEO satellite and GSO satellite locations.

To focus the search for in-line events between DIRECTV's Ka-band GSO satellites and the Iridium LEO constellation, the following location set was selected:

GSO satellite locations: 99.2 WL, 101.0 WL and 102.8 WL

DIRECTV uplink earth station site: SWUF (Tucson, AZ)

Iridium uplink earth station site: Tempe, AZ

The potential in-line interference geometry is shown in Figure 2 below. This figure identifies the "LEO-angle" at the LEO satellite (shown in red). The LEO-angle is formed by two vectors with the vertex at the LEO-satellite: one vector is from the LEO satellite to the Iridium feeder link earth station in Tempe, AZ and the second vector is from the LEO satellite to DIRECTV's feeder link earth station in Tucson, AZ.[6] This is the LEO spacecraft antenna discrimination angle towards the Tucson uplink earth station.

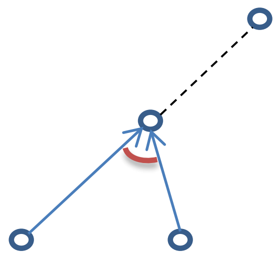

Figure 2. Diagram Representing the In-line Event Geometry

Identification of in-line events required the following computer simulation:

a) simulate the LEO orbital tracks for a two to three day period, in one minute step increments;
b) search all tracks for the "minimum earth station topocentric angle" towards the GSO and LEO;
c) expand the "minimum earth station topocentric angle" events, in 1/100 minute increments;
d) increment or decrement the LEO orbital plane ascending node, in 1/10 or 1/100 degree increments, and re-run the simulation, at each increment step; and
e) continue the simulation until the "minimum earth station topocentric angle" reaches zero or very close to zero.

Table 1 contains the LEO location (*e.g.*, latitude and longitude) plus other orbital parameters, including LEO-angle, GSO-angle and the motion rate of the LEO satellite when it crosses the in-line line, following the above steps (a) to (e) assuming DIRECTV Ka-band satellites at 99.2 W.L., 101.0 W.L. and 102.8 W.L. This set of parameters is necessary for the potential interference calculation between the DIRECTV and Iridium systems.

[6] Note that DIRECTV also operates a diverse site in Benson, AZ that is associated with the Tucson site. This diverse site only transmits when the rain attenuation at the Tucson site exceeds a given threshold, at which point the Tucson site stops transmitting until the rain event has ended. Given the close proximity of these two sites, the results obtained for the Tucson site are equally applicable to the Benson diverse site.

In-line GSO satellite location (W)	99.2	101.0	102.8
In-line LEO satellite location: lat(N)/long(E) (deg)	27.5/251.2	27.5/250.9	27.5/250.6
In-line earth station location: lat(N)/long(E) (deg)	32.1/-110.8		
In-line earth station site	Tucson, AZ (SWUF)		
LEO-angle towards the Tucson and Tempe sites (deg)	7.05	7.22	7.39
Distance from the Tucson, AZ site to the LEO satellite (km)	967.6	961.6	956.6
Path loss between Tucson and LEO satellite (dB)	181.5	181.45	181.40
Distance from the Tempe, AZ site to the LEO satellite (km)	1080.2	1071.7	1064.0
Path loss between Tempe and LEO satellite (dB)	182.5	182.4	182.3
Great-circle distance between Tempe and Tucson(km)	168.7	168.7	168.7
LEO satellite transit time crossing the in-line line (sec/deg)	2.7	2.68	2.65

Note: The Tempe, AZ site latitude = 33.34° N and longitude = 111.90° W

Table 1. Tucson-LEO-GSO In-line Scenario

2.3 Potential Interference Assessment During the In-line Event

2.3.1 Methodology

The previous section contains the coupling geometry and the spacecraft antenna discrimination angles for the potential interference assessment between the DIRECTV and Iridium systems during in-line events. The potential interference assessment was performed by calculating the ratio of desired to interference power densities, namely:

C_o/I_o : carrier density -to- interference density ratio.

In other words, the C_o/I_o approach assumes complete frequency overlap between both the desired and victim carriers. In addition, according to the ITU Appendix 4 information, the Iridium carriers have a maximum and minimum power and power density into the earth station antenna flange. According to standard worst case analysis practice, the maximum power density was used for the interfering source and the minimum power density was used for the victim signal level. In particular, for the Iridium system (*i.e.*, HIBLEO-2FL):

- minimum power into antenna:	Pmin =	-12.8 dBW
- min-power plus antenna gain:	EIRPmin =	43.5 dBW
- minimum power density into antenna:	PDmin =	-77.7 dBW/Hz
- min-power density plus antenna gain:	EIRPmin-density =	-21.4 dBW/Hz
- emission designator:	4M38Q7W	
- earth station antenna gain:	Ge =	56.3 dBi
- spacecraft receiving antenna gain:	Gs =	30.1 dBi

For the DIRECTV system, the maximum licensed uplink EIRP for the digital video carrier from the Tucson uplink site is as follows:

- digital video carrier (36M0G7W):	EIRPmax =	83 dBW
	EIRPmax-density =	7.4 dBW/Hz

To compute the LEO spacecraft antenna discrimination towards the uplink interfering earth station site, the spacecraft antenna pattern was based on ITU-R Recommendation S.672-4 with an adjustment for the near-in-side-lobe level of -30 dB relative to the peak gain and the far-away side-lobe level of -10 dBi. The related parameters a, b and α of Table-1 in ITU-R Recommendation S.672-4 were also modified by following a Bessel function antenna pattern, in particular in the near-in side-lobe region. In particular, for this assessment, it was assumed that the main-lobe of the spacecraft antenna follows a Bessel function, and the near-in side-lobe and far-away side-lobe levels were based on the modified ITU-R Recommendation S.672-4. The assumed Iridium spacecraft antenna patterns were as follows:

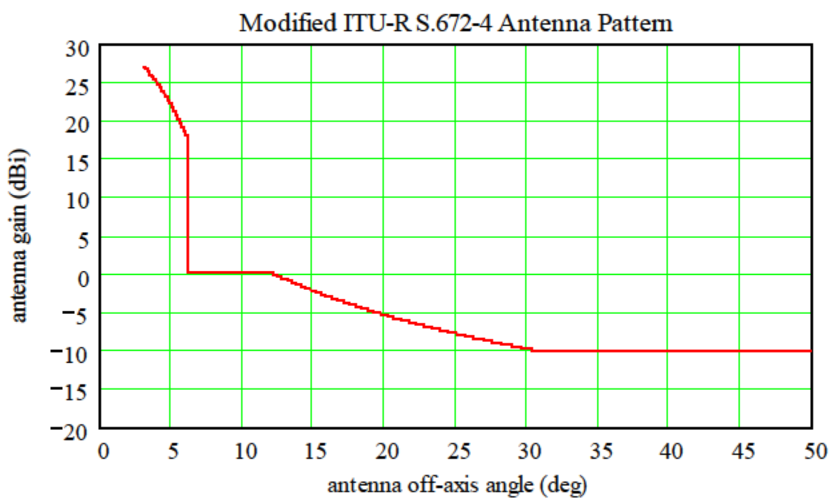

Figure 3A. Modified ITU-R Recommendation S.672-4 Iridium Spacecraft Antenna Pattern

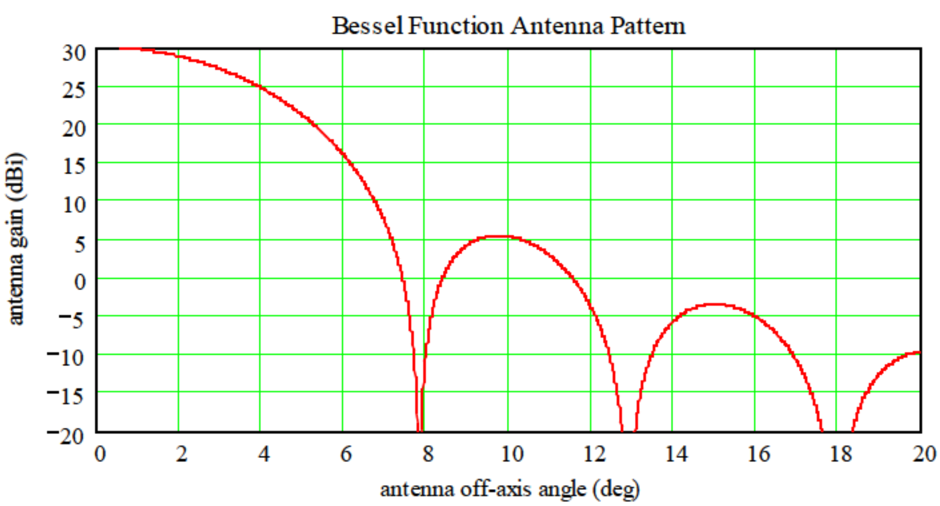

Figure 3B. Bessel Function Iridium Spacecraft Antenna Pattern

The potential interference level was assessed with the interfering signal as the DIRECTV earth station uplink and the victim as the Iridium spacecraft receiver. Since the Iridium uplink earth station was not within the in-line environment (see Figure 2) there is LEO spacecraft antenna discrimination towards the interfering source (*i.e.*, the DIRECTV uplink earth station).

2.3.2 Potential Interference Assessment

The corresponding in-line geometry parameters are given in Table 1. The carrier-to-interference density formulation is as follow:

$$C_o/I_o = EIRP_{min\text{-}density} - PL_{desired\text{-}link} + G_{sat}(0) - (EIRP_{max\text{-}density} - PL_{interfering\text{-}link} + G_{sat}(\xi))$$

Where:

PL = the path loss between the earth station and the spacecraft (dB)

$G_{sat}(\xi)$ = the spacecraft antenna gain at an offset angle ξ (dBi)

ξ = the spacecraft antenna off-axis angle towards the interfering earth station (deg), *e.g.*, the LEO-angle.

Consistent with a worst-case approach, the analysis also assumed there is no cross-polarization isolation between the desired and interfering signals at the spacecraft. Using the parameters identified in the above sections, the resultant C_o/I_o is shown in Table 2.

In-line GSO satellite location (W)	99.2	101	102.8
In-line LEO satellite location: lat/long (deg)	27.5/251.2	27.5/250.9	27.5/250.6
In-line earth station location: lat/long (deg)	32.1/118.8		
In-line earth station site	Tucson, AZ (SWUF)		
LEO-angle towards the Tucson and Tempe sites (deg)	7.05	7.22	7.39
Iridium uplink desired signal designator	4M38Q7W		
Iridium desired uplink EIRP min-density (dBW/Hz)	-21.4		
Path loss from Tempe earth station to LEO sat (dB)	182.5	182.4	182.3
Iridium spacecraft ant-gain towards Tempe (dBi)	30.1		
DIRECTV uplink interferer designator	36M0G7W	36M0G7W	36M0G7W
DIRECTV uplink EIRP max-density (dBW/Hz)	7.4	7.4	7.4
Path loss from Tucson earth station to LEO sat (dB)	181.5	181.45	181.40
Iridium spacecraft ant-gain towards Tucson (dBi)	6.3	3.8	0.5
C_o/I_o (dB)	-6	-3.4	-0.1

Table 2. Potential Interference (C_o/I_o) for the Tucson-LEO-GSO In-line Scenario
(Potential Uplink Interference from the DIRECTV Tucson Earth Station into the Iridium Satellite)

The worst case result in Table 2 suggests that there is potentially unacceptable interference from the DIRECTV Tucson earth station uplink into the Iridium satellite during the Tucson-LEO-GSO in-line event. In fact, the actual C_o/I_o ratio would be significantly higher (*i.e.*, implying lower interfering power into the victim) since:

- The analysis is based on the worst case maximum/minimum concept
- Any increase in Iridium clear sky EIRP above the minimum EIRP would improve the situation dB for dB
- Any decrease in the DIRECTV clear sky EIRP below the maximum licensed EIRP would improve the situation dB for dB
- No allowance has been made for cross-polarization discrimination

Consistent with Section 25.203(g), DIRECTV feeder links employ uplink power control and, as such, it must be recognized that the authorized EIRP of 83 dBW is the maximum for rain faded conditions. The purpose of uplink power control is to maintain the power flux density at the satellite at a prescribed "clear sky" level. Indeed, for the case of DIRECTV communications carriers, the nominal clear sky EIRP is approximately 17 dB below the maximum licensed EIRP, which would improve the results above by 17 dB (on a dB for dB basis) resulting in a real world worst case C_o/I_o of approximately 11 dB. Likewise, for the Iridium system, any increase in gateway transmit power above the minimum value would increase the C_o/I_o on a dB for dB basis. In addition, given that multiple Iridium satellites are typically in view of the Iridium gateway site at any given time, there is a considerable probability that a satellite other than the one experiencing an in-line event would be actively supporting the feeder link communications. Finally, as discussed in the following section, in-line events are infrequent and the duration of any particular event is extremely short (*i.e.*, a small fraction of a second) owing to DIRECTV's use of large feeder link antennas with extremely narrow beamwidths.

2.4 The Transit Time of the LEO Satellite Crossing the In-line Line

In order to determine the transit time of the LEO satellite when it passes through the main-lobe of the DIRECTV feeder link earth station antenna, the transit rate was determined in terms of seconds per degree of off-axis angle (sec/deg) of the earth station antenna. In other words, the transit rate represents how long it takes for the LEO satellite to pass through the earth station antenna main-lobe. The transit rate for in-line events is identified in the last row of Table 1. The following table shows the transit time of the LEO satellite crossing the DIRECTV feeder link earth station antenna half power beamwidth and 10 dB beamwidth for the three in-line scenarios of Table 1 for the 9m feeder link antennas at DIRECTV's Tucson site. As can be seen, the transit time for the 10 dB beamwidth, outside of which the Iridium feeder link C_o/I_o ratio would be greater than 20 dB for DIRECTV's nominal clear sky EIRP, is approximately 1/3 of a second.

In-line GSO satellite location (W)	99.2	101.0	102.8
In-line LEO satellite location: lat(N)/long (E) (deg)	27.5/251.2	27.5/250.9	27.5/250.6
In-line earth station location: lat(N)/long(E) (deg)	32.1/-110.8		
In-line earth station site	Tucson, AZ (SWUF)		
LEO satellite transit time crossing the in-line line (sec/deg)	2.7	2.68	2.65
Earth station antenna size (m)/gain (dBi)	9.1/66.4		
3-dB beamwidth (deg)	0.081		
Transit time for the 3-dB beamwidth (sec)	0.221	0.220	0.217
10-dB beamwidth (deg)	0.14		
Transit time for the 10-dB beamwidth (sec)	0.383	0.381	0.376

Table 3. Transit Time for the Tucson-LEO-GSO In-line Scenario

2.5 Rate of Occurrence of the LEO Satellite Crossing the In-line Line

Further simulations were conducted in order to quantify the rate of occurrence of in-line events. The orbital parameters from the ITU HIBLEO-2FL filing were again used to evaluate the occurrence of in-line events over a typical 21-day period. In order to accelerate the simulation process, only a single satellite was assumed in each orbital plane. During this period, the first in-line event occurred at the 1.5-day mark into the simulation, and the second occurred at the eighth day of simulation. The next in-line event occurred at the twenty first day of simulation;

however, this event was actually a repeat of the first event, as it took approximately 19.5 days for the same satellite to encounter another in-line event. Viewed another way, these results imply that the absolute worst case fraction of time that the Iridium feeder uplink would potentially experience a C/I of less than 20 dB and 14 dB due to interference from the geographically closest DIRECTV feeder link uplink transmission would be:

C/I < 20 dB: (0.38 secs * 2)/(19.5 days * 86400 secs/day) = 4.51 x 10^{-7} = 0.0000451%
C/I < 14 dB: (0.22 secs * 2)/(19.5 days * 86400 secs/day) = 2.61 x 10^{-7} = 0.0000261%

Realizing that there are actually 11 satellites in each Iridium orbital plane, it is reasonable to assume that the fraction of time figures above would be increased by a factor of 11 to:

C/I < 20 dB: 0.000496%
C/I < 14 dB: 0.000287%

The Iridium FCC application states a feeder link unavailability of 0.5%. As such, any potential interference impact from DIRECTV's feeder link uplink transmissions would be three orders of magnitude less than the Iridium design unavailability. This result is further supported by the fact that DIRECTV has been operating on a 24/7 basis from the Tucson, AZ SWUF uplink location for over three years without any interference issues with Iridium.

3. Extension of Results to Other Possible Orbital Locations

Now that results have been computed for a particular interference scenario, these results can be extended for the case of the DIRECTV SWUF feeder link site communicating with other locations along the GSO. The only additional parameter required for this analysis is the LEO angle as a function of GSO orbital location, as this is the only parameter that changes materially as the feeder link antenna points to different locations in the sky. Figure 4 below illustrates the relationship between the LEO angle and GSO orbital location for GSO locations from 70º WL to 140º WL.

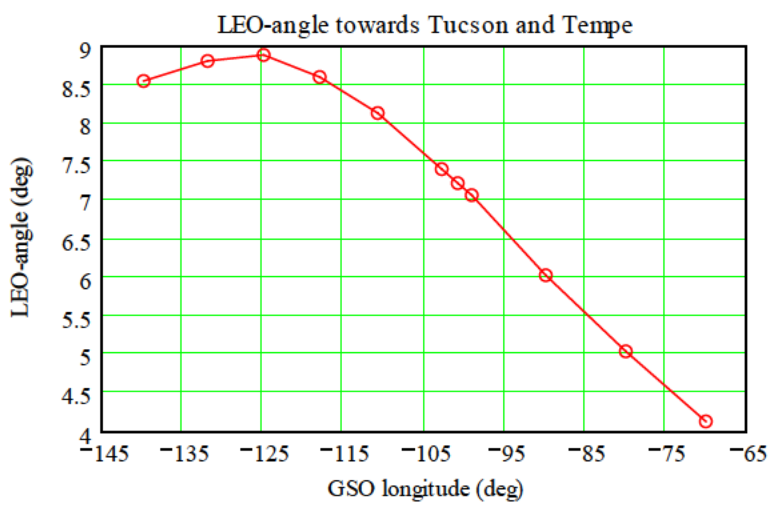

Figure 4. LEO Angle as a Function of GSO Longitude

As can be seen in Figure 4, the LEO angle for the SWUF site and the 101º WL location is 7.2 degrees, consistent with Table 1. As the GSO location moves westward from 101 WL the angle increases to a maximum of almost 9 degrees at 125° WL. This means that interference levels received by Iridium satellites would decrease as the SWUF antennas point westward from 101° WL. As the GSO location moves eastward from 101° WL, the LEO angle decreases to a minimum value of approximately 4.1 degrees at 70° WL. With this LEO angle the Iridium satellite gain would be approximately 24 dBi (*see* Figure 3B). Scaling the results obtained in Table 2 by this amount, and accounting for realistic DIRECTV clear sky EIRP levels, results in worst case C_o/I_o values of approximately -7 dB. As explained earlier, any Iridium gateway transmit power in excess of the minimum value would increase this C_o/I_o, any occurrence of this interference would only last for a fraction of a second, and any such occurrences would be infrequent (*i.e.*, they would represent a fraction of time that is three orders of magnitude less than the Iridium design unavailability), as explained in Section 2.5.[7]

4. Summary

This document provides an extensive analysis of the potential interference from DIRECTV's Ka-band GSO feeder link operations at its Southwest Uplink Facility (SWUF) site in the 29.25-29.3 GHz band to the Iridium MSS/LEO feeder link system during worst case in-line events.[8] This analysis was initially conducted for DIRECTV's current Ka-band operational orbital locations and then those results were extended to other orbital locations across the domestic arc. A significant amount of computer simulation has been conducted to characterize the nature of these in-line events.

The analysis shows that, for the DIRECTV feeder link site closest to the Iridium gateway facility, and using realistic clear sky operating condition assumptions, the potential interference levels during an in-line event would result in a C/I for Iridium satellites of approximately 10 dB. Furthermore, the simulation analysis also shows that the duration of any such in-line event is very short (on the order of 0.3-0.4 seconds), and the occurrence of such events is extremely infrequent. As such, the overall percentage of time represented by these events is on the order of 0.0003% to 0.0005%. This percentage of time is approximately three orders of magnitude less than the feeder link design unavailability stated in the Iridium FCC application. As such, the uplink transmissions from DIRECTV's closest feeder link site will have no material impact on the operation of the Iridium feeder link uplinks. These results were also extended to GSO locations across the orbital arc, with similar results.

---

[7] As explained previously, DIRECTV also operates a diverse site in Benson, AZ that is associated with the Tucson site. This diverse site only transmits when the rain attenuation at the Tucson site exceeds a given threshold, at which point the Tucson site stops transmitting until the rain event has ended. As such, only one of the feeder link sites (primary or diverse) is transmitting at any given time. Given the close proximity of these two sites, the results obtained for the Tucson site are equally applicable to the Benson diverse site.

[8] Note that the results of this analysis are equally applicable to DIRECTV's Southwest Diversity Uplink Facility (SWDF) which is located relatively near to the main SWUF facility.