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# INTERNATIONAL BUREAU

Satellite and Radiocommunication Division
Satellite Policy Branch

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**To:** Mr. William F. Caton, Acting Secretary

**Date:** February 7, 1996

**From:** Jennifer M. Gilsenan

**Re:** Ex Parte presentation
CC Docket No. 92-297

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This will serve to indicate that on February 6, 1996 representatives of the International Bureau's Satellite and Radiocommunication Division convened a meeting with participants listed in Attachment A to this memorandum to discuss inter-service sharing issues in the 20/30 GHz frequency band.

The attached documents formed a basis for discussion.

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Attachment A

MOTOROLA

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February 6, 1996

Mr. Thomas S. Tycz
Chief, Satellite and Radio Communication Division
International Bureau
Federal Communications Commission
2000 M Street, N.W. Suite 811
Washington, D.C. 20554

Re: CC Docket No. 92-297

Dear Tom:

Motorola reiterates its willingness to accept the FCC staff Options 3 and 1 as outlined at the January 25, 1996 meeting of all interested parties. At that meeting, the staff also tabled another option -- Option 2 -- which Motorola finds unacceptable primarily because of the proposed sharing rules associated with the LMDS return links in the 29.1-29.25 GHz portion of the 28 GHz band. We appreciate the hard work that the staff has put into this process, however, Motorola believes that there are several significant deficiencies with the proposed sharing rules associated with Option 2.

At a January 31, 1996 meeting/teleconference, the staff attempted to explain the rationale behind the proposed LMDS/MSS sharing rules. At that time, various LMDS interests expressed their concerns about the proposed sharing rules, and in particular the height restriction requirements for the LMDS subscriber antennas. After studying these rules over the past few days, Motorola cannot accept them as written, but for reasons

Government Relations
1350 I Street, N.W., Suite 400, Washington, DC 20005-3305 (202) 371-6900 FAX (202) 842-3578

unrelated to the objections of the LMDS parties. In fact, we believe that the proposed height restriction rule is necessary in order to limit the amount of interference into the IRIDIUM System.

The primary difficulties that Motorola has with the proposed sharing rules are reflected in the analysis of Mr. Doug Gray of Hewlett-Packard,[1] and the rationale behind the proposed sharing rules for LMDS hub-to-subscriber links contained in the Third NPRM in the 28 GHz proceeding. The analysis of Doug Gray established that the number of CPE transmitters **must** be limited, one case showing that a limit of 0.00033 active CPE/km$^2$ is required to meet his proposed rules. This limitation, however, is inconsistent with the marketing projections of the LMDS proponents of 0.001077 to 0.003875 CPE/km$^2$.

Accordingly, the proposed rules are deficient in at least the following respects:

1) A limit on the density of active CPE return links is required. This may be in the range 0.00033 to 0.003875 CPE/km$^2$, as proposed by the LMDS proponents;

---

[1] "Analysis of CPE Tx's fit to proposed rules, 21.1020 & 21.1021 per 3rd NPRM for 28 GHz using proposed rules for CPE Tx's in 150 MHz Band," Doug Gray, Hewlett-Packard Co., Attachment K to Nov. 28, 1995 letter from Gene Robinson, Texas Instruments.

2) The modifications to the sharing rules contained in Motorola's comments to the Third NPRM must be included in any LMDS sharing rules, with necessary changes to account for the lower EIRP (12 dBW/MHz) and power control set forth in the staff's proposal;

3) In order to avoid the IRIDIUM System satellites receiving interference from the subscriber-to-hub links and the hub-to-subscriber links simultaneously, all LMDS transmissions within 1000 km of an IRIDIUM System gateway must be synchronized in time. The staff indicated that the interference from LMDS is time duplexed;

4) In Doug Gray's analysis, the CPE antennas are assumed to be pointing at the horizon. In actual implementation of these LMDS systems, the antennas will be pointed above the horizon, therefore, the density of active CPE return links must be less than that shown in the analysis.

We look forward to discussing our concerns with you at the earliest opportunity.

Yours truly,

David Carroll

cc: William F. Caton (2 copies)
Harry Ng
Karl Kensinger

**Principles For Co-Frequency Sharing Between The Feeder Links Of The Odyssey™ And Iridium™ NGSO MSS Satellite Systems**

1. The Iridium™ system will operate its feeder links in the bands 29.1-29.3 GHz (Earth-to-space) and 19.4-19.6 GHz (space-to-Earth), and the Odyssey™ system will operate its feeder links in the bands 29.1-29.4 GHz (Earth-to-space) and 19.3-19.6 GHz (space-to-Earth). Iridium™ will operate only with right-hand circular polarization in the uplink band and with left-hand circular polarization in the downlink band, while Odyssey™ will operate only with left-hand circular polarization in the uplink band and right-hand circular polarization in the downlink band.

2. Both Odyssey™ and Iridium™ will use power control if and when necessary.

3. Even with the specification that the Odyssey™ and Iridium™ systems will operate feeder links on the opposite sense of polarization, it will be necessary for the earth station complexes of the two systems to be separated from each other by a minimum of [250] kilometers in order to ensure that neither system causes the other unacceptable interference from co-frequency operations.

4. The Odyssey™ system will utilize a maximum of two feeder link earth station complexes in the continental United States, while the Iridium™ system will utilize a maximum of six feeder link earth station complexes in the continental United States.

5. In the western United States, an Iridium™ feeder link earth station complex in the immediate vicinity of Phoenix, Arizona will be compatible with a co-frequency, opposite-polarization Odyssey™ feeder link earth station complex in the immediate vicinity of San Luis Obispo, California. No Iridium™ feeder link earth station complex shall be located within [250] kilometers of the Odyssey™ feeder link earth station complex at San Luis Obispo.

6. In the eastern United States, an Iridium™ feeder link earth station complex will be located in the immediate vicinity of Montpelier, Vermont. The location of an additional Iridium™ feeder link earth station complex in the eastern United States shall not be specified until after an Odyssey™ feeder link earth station complex site in the eastern United States — separated from the Iridium™ Montpelier site by at least the minimum distance specified in Point 3 above — has been selected. Any additional Iridium™ feeder link earth station complex shall be separated from the Odyssey™ site to be selected by at least the minimum distance specified in Point 3 above.

```
Const pi As Double = 3.141592654
Const deg_radians As Single = pi / 180
Const radians_deg As Single = 180 / pi

Function dBx(x As Single) As Double
dBx = 10 * Application.Log10(x)
End Function

Function adBx(x As Single) As Double
adBx = 10 ^ (x / 10)
End Function

Function axial_ratio(retard_deg As Single) As Double
axial_ratio = dBx((Tan(pi / 4 + pi * retard_deg / 360)) ^ 2)
End Function

Function retard(AR_dB As Single) As Double
retard = (360 / pi) * (Atn(Sqr(adBx(AR_dB))) - pi / 4)
End Function

Function pol_loss(retard_deg As Single) As Double
pol_loss = dBx(Cos(retard_deg * pi / 360) ^ 2)
End Function

Function crosspol_loss(retard_deg As Single) As Double
crosspol_loss = dBx(Sin(retard_deg * pi / 360) ^ 2)
End Function

Function retard_xpd(xpd_dB As Single) As Double
retard_xpd = (360 / pi) * Atn(10 ^ (-xpd_dB / 20))
End Function

Function xpd_atmos_ccir(F_GHz As Single, CPA_dB As Single, Elev_deg As
 Single, Tilt_deg As Single, Avail_pct As Single) As Double
Dim V As Single, Cf As Single, Ca As Single, Ctau As Single, Ctheta As
 Single
Dim sigma As Single, Csigma As Single, XPDrain As Single, Cice As Sing
le
If (F_GHz > 20) Then
    V = 22.6
Else
    V = 12.8 * (F_GHz ^ 0.19)
End If
Cf = 30 * Application.Log10(F_GHz)
Ca = V * Application.Log10(Abs(CPA_dB))
Ctau = -10 * Application.Log10(1 - 0.484 * (1 + Cos(4 * Tilt_deg * deg
_radians)))
Ctheta = -40 * Application.Log10(Cos(Elev_deg * deg_radians))
sigma = -5 * Application.Log10(100 - Avail_pct)
Csigma = 0.0052 * (sigma ^ 2)
XPDrain = Cf - Ca + Ctau + Ctheta + Csigma
Cice = XPDrain * (0.15 + 0.05 * Application.Log10(100 - Avail_pct))
xpd_atmos_ccir = XPDrain - Cice
End Function
```

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## Analysis Of Effect Of Rain Depolarization

According to "Propagation Effects Handbook For Satellite Systems Design - NASA Reference Publication 1082(04) - 1989), the cross-polarization due to rain can be calculated as follows:

$$XPD = 30Log(f) - 40Log(\cos\varepsilon) - 10Log\left[1 - 0.484\left(1 + \cos(4\tau)\right)\right] - 23Log(CPA) + 0.0052\sigma_\theta^2$$

Where

- $f$ = frequency (GHz)
- $\varepsilon$ = elevation angle
- $\tau$ = polarization tilt angle (for circular polarization $\tau = 45°$)
- CPA = co-polarized path attenuation (dB)
- $\sigma_\theta$ = effective standard deviation of the raindrop canting angle distribution (for 0.1% of time $\sigma_\theta = 5°$)

**Ground Station: London, Elevation Angle = 5°**

*** Frequency = 19.75 GHz**

XPD = 18.3 dB

*** Frequency = 29.55 GHz**

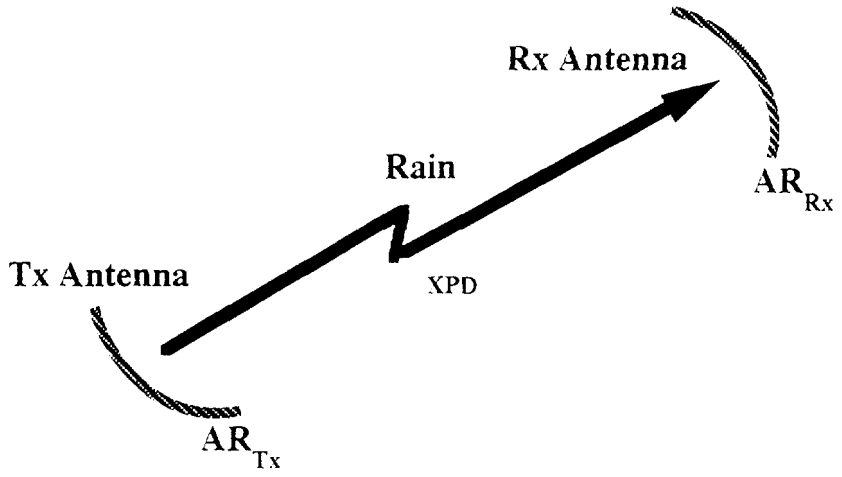
XPD = 15.44 dB

The reciprocal of XPD is called the cross-polarization isolation (XPI), and is measure of the isolation between the two polarization at the receiver.

The uplink, and the downlink cross-polarization isolation are 15.44, and 18.3 dB, respectively.

## Polarization Loss

Polarization loss is the net reduction in power caused by the worst-case misalignment of the transmit and the receive antenna palarizations, and the polarization effects due to the rain.. The polarization loss can be calculated as the following:




Where

$AR_{Tx}$ = axial ratio of transmitting antenna (dB)
$AR_{Rx}$ = axial ratio of reveiving antenna (dB)
XPD = cross-polarization

$$\text{Polarization Loss} = 10\text{Log}\left[\text{Cos}^2\left(\frac{\delta_{net}}{2}\right)\right]\text{dB}$$

$$\delta_{Net} = \delta_{Transmit} + \delta_{Receive} + \delta_{Rain}$$

Where

$\delta_{Transmit}$ = Transmit antenna polarization retardance (deg)
$\delta_{Receive}$ = Receive antenna polarization retardance (deg)
$\delta_{Rain}$ = Rain polarization retardance (deg). The polarization retardance of the rain is based on the polarization effects of rain droplets as the signal propagates through the rain.

The $\delta_{Transmit}$, or $\delta_{Receive}$ is calculated using the following equation:

$$\delta_{Transmit/Receive} = 2\text{Tan}^{-1}\left(10^{\frac{AR_{Tx,Rx}}{20}}\right) - 90$$

The $\delta_{Rain}$ can be calculated as follow:

$$\delta_{Rain} = 2\text{Tan}^{-1}\left[10^{\frac{XPD}{20}}\right]$$

## Polarization Loss Of The Forward Link

In the appendix A-15 shows the axial ratio of transmit and receive antenna is 1.8 dB. The rain attenuational is 18 dB. The polarization loss can be shown as the follows:

**- Clear Sky:**

$$\delta_{Net} = \delta_{Transmit} + \delta_{Receive} + \delta_{Rain}\ (=0)$$

$$= \left(2\mathrm{Tan}^{-1}\left(10^{\frac{1.8}{20}}\right) - 90\right) + \left(2\mathrm{Tan}^{-1}\left(10^{\frac{1.8}{20}}\right) - 90\right)$$

~ 24 degrees

$$\text{Polarization Loss} = 10\mathrm{Log}\left[\mathrm{Cos}^2\left(\frac{24}{2}\right)\right]$$

**= 0.2 dB which is shown in A-15 (forward link)**

**- Rain**

$$\delta_{Net} = \delta_{Transmit} + \delta_{Receive} + \delta_{Rain}$$

$$= \left(2\mathrm{Tan}^{-1}\left(10^{\frac{1.8}{20}}\right) - 90\right) + \left(2\mathrm{Tan}^{-1}\left(10^{\frac{1.8}{20}}\right) - 90\right) + 2\mathrm{Tan}^{-1}\left(10^{\frac{-15.44}{20}}\right)$$

~ 43.2 degrees

**Then the polarization loss is equal to 0.63 db, which is shown in A-15**

## Polarization Loss Of The Return Link

The polarization loss of the return link is shown in A-7 as follows:

- **Clear Sky: Polarization Loss = 0.19 dB**
- **Rain: Polarization Loss = 0.48 dB**

## Effect Of Depolarization On Dual Polarized Communications

The system degradation of the uplink, and the downlink can be shown as follows:

$$\text{Degradation} = CNR - CNR_{dp}$$

Where

CNR = uplink or downlink signal-to-noise ratio

$CNR_{dp}$ = CNR and depolarization

$$\text{Degradation} = (CNR)_{dB} - \left(CNR\left[\frac{1}{1 + CNR(XPD)}\right]\right)_{dB}$$

$$\text{Degradation} = 10\mathrm{Log}\left(1 + 10^{\frac{CNR_{dB} - XPD_{dB}}{10}}\right)$$

*** Uplink:** In appendix A-15(volume 2- Payload Design), the uplink, gateway-to-satellite CNR is equal to 18.8 dB (= C/No - 10Log(BW=30KHz)), then uplink degradation is 5.0 dB, but the overall system degradation is only **0.3 dB** (See A-

22, replace gateway-to-satellite C/No from 63.56 to 58.55 dB Hz, and re-calculate the received Eb/No)

* **Downlink:** In appendix A-7(volume 2- Payload Design), the downlink, satellite-to-gateway CNR is equal to 18.9 dB (= C/No - 10Log(BW=30KHz)), then downlink degradation is 3.32 dB, but the overall system degradation is only **0.2 dB** (See A-14, replace gateway-to-satellite C/No from 63.68 to 60.38 dB Hz, and re-calculate the received Eb/No)

In the link budgets, we allocate the transmit power of each polarization which can support to the total system capacity. If this is a case, then cross polarization doesn't degrade the performance, because only one polarization operates at any given time. Suppose, each polarization can support up to 75% system capacity, and recalculate the signal-to-noise ratio. We can see that cross polarization doesn't degrade the overall system performance, because the allocated power can compensate for the loss due to cross polarization

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# Co-Directional Frequency Sharing Between the Odyssey™ and the Iridium Feeder Link Systems in the 29.1 - 29.4 GHz and 19.3 - 19.6 GHz Bands


P. Cress
H. Ho
M. Horstein
R. Rusch


February 6, 1996


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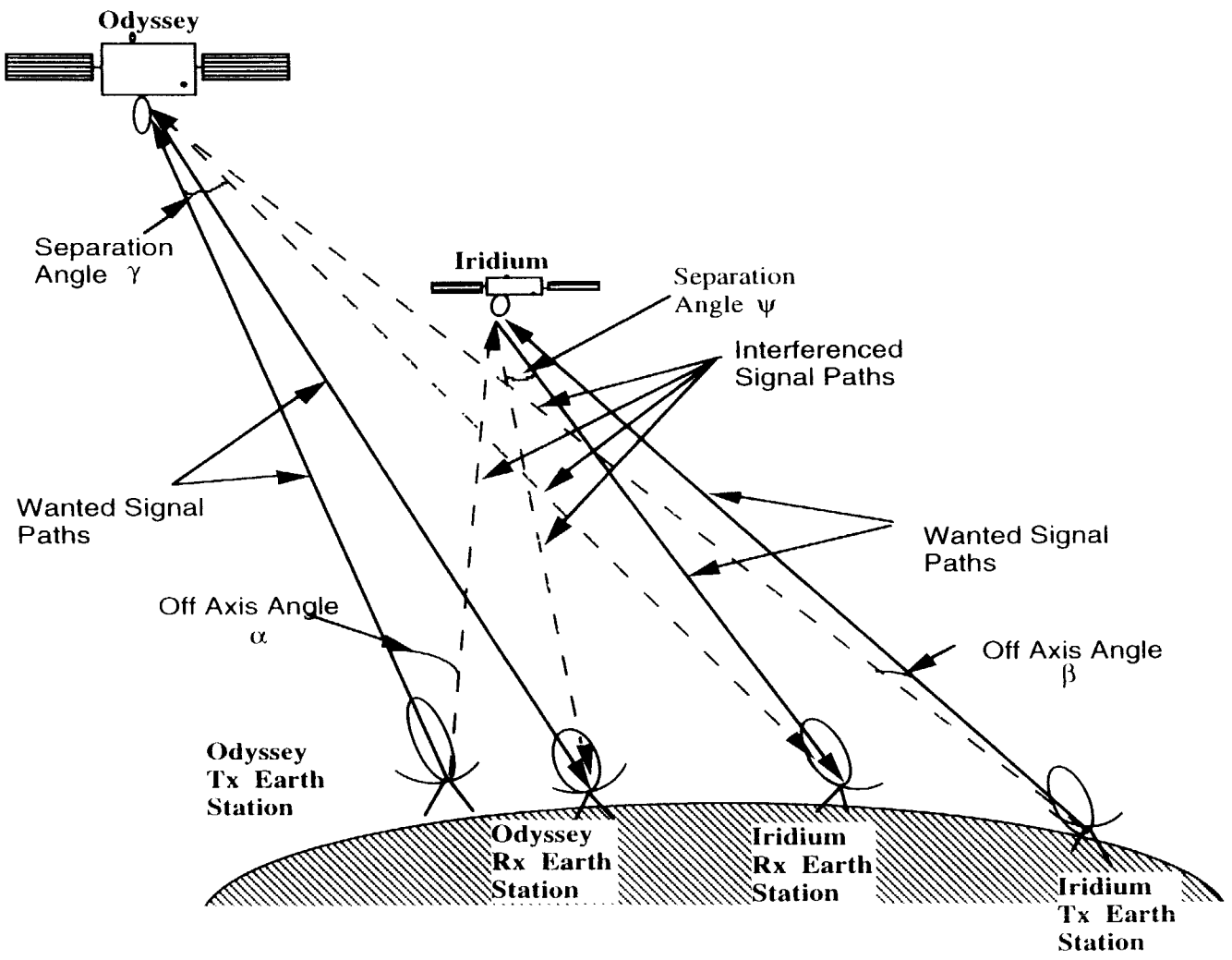
# Interference Geometry



# Interference Geometry (Cont.)

$\alpha$ : Angular separation between the Odyssey satellite and the Iridium satellite as viewed by the Odyssey earth station

$\beta$ : Angular separation between the Odyssey satellite and the Iridium satellite as viewed by the Iridium earth station

$\gamma$ : Angular separation between the Odyssey earth station and the Iridium earth station as viewed by the Odyssey satellite

$\psi$ : Angular separation between the Odyssey earth station and the Iridium earth station as viewed by the Iridium satellite

# Summary

- **In order to meet interference level $I_o$ at the Iridium satellite receiver or at the Odyssey earth station receiver, the off axis angle $\alpha$ or the separation angle $\psi$ must be greater than or equal to the following values**

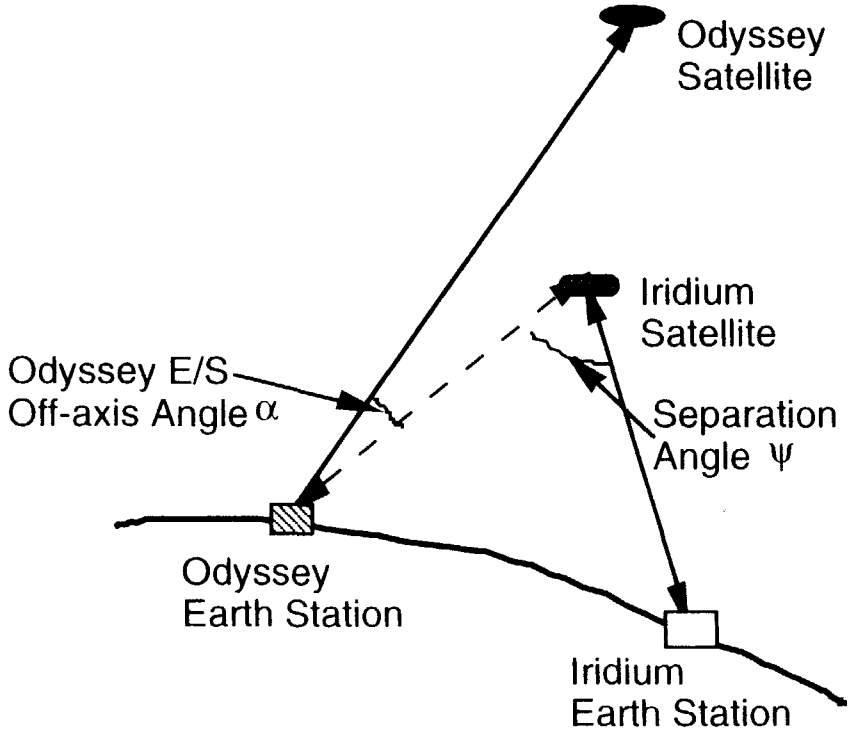
| Parameters | **At the Iridium Satellite Receiver** The Odyssey transmit earth station causes interference to the Iridium satellite receiver | |
|---|---|---|
| | Off axis angle from the Odyssey E/S $\alpha$ | Separation Angle @ Iridium S/C $\psi$ |
| Clear Sky<br>* Normal transmission (-73.5 dBW/Hz)<br><br>* 4 dB more power (-69.5 dBW/Hz) | 0.0°<br>0.05°<br><br>0.0°<br>0.1° | 5.9°<br>0.0°<br><br>8.6°<br>0.0° |
| Rain: 18 dB margin | 0.0°<br>0.15° | 8.3°<br>0.0° |
| | **At The Odyssey Earth Station Receiver** The Iridium satellite causes interference to the Odyssey Earth Station | |
| Worst case | 0°<br>0.1° | 8.6°<br>0° |

# Summary

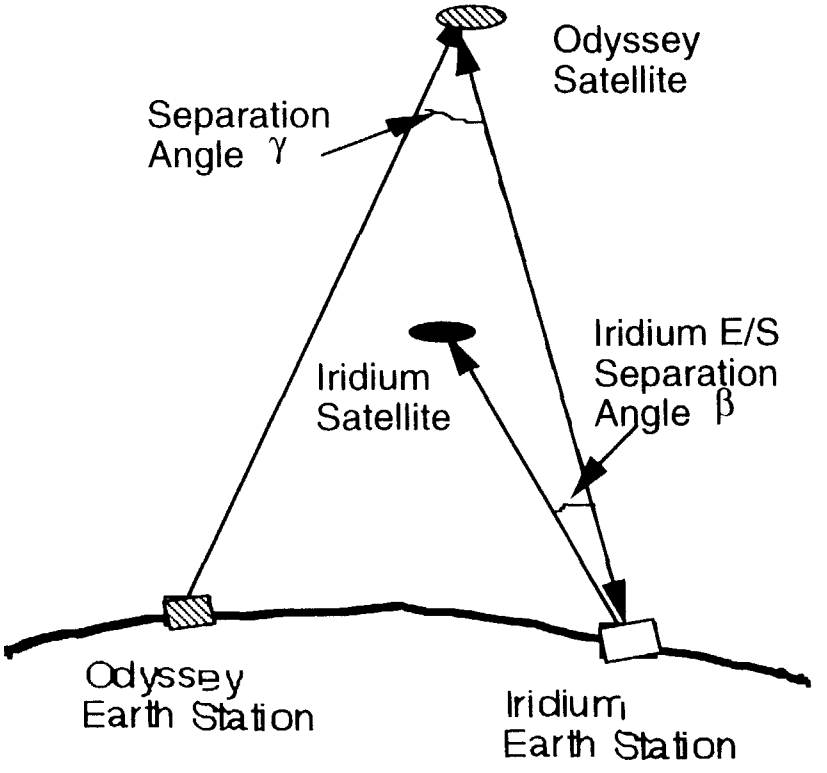
- **In order to meet interference level $I_o$ at the Odyssey satellite receiver or at the Iridium earth station receiver, the off axis angle $\beta$ or the separation angle $\gamma$ must be greater than or equal to the following values**

| Parameters | **At the Odyssey Satellite Receiver** The Iridium transmit earth station causes interference to the Odyssey satellite receive | |
|---|---|---|
| | Off axis angle from the Iridium E/S $\beta$ | Separation Angle @ Odyssey S/C $\gamma$ |
| Clear Sky<br>* Normal transmission (-78.0 dBW/Hz)<br>* 10 dB more power (-68 dBW/Hz) | 0°<br>0° | 0°<br>1.5° |
| Rain: 23.8 dB margin | 0°<br>0.3° | 0.75°<br>0° |
| | **At The Iridium E/S Receiver** The Odyssey satellite causes interference to t Iridium Earth Station | |
| Worst case | 0° | 0° |

# Odyssey/Iridium Conjunctions




Case 1




Case 2

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# Summary

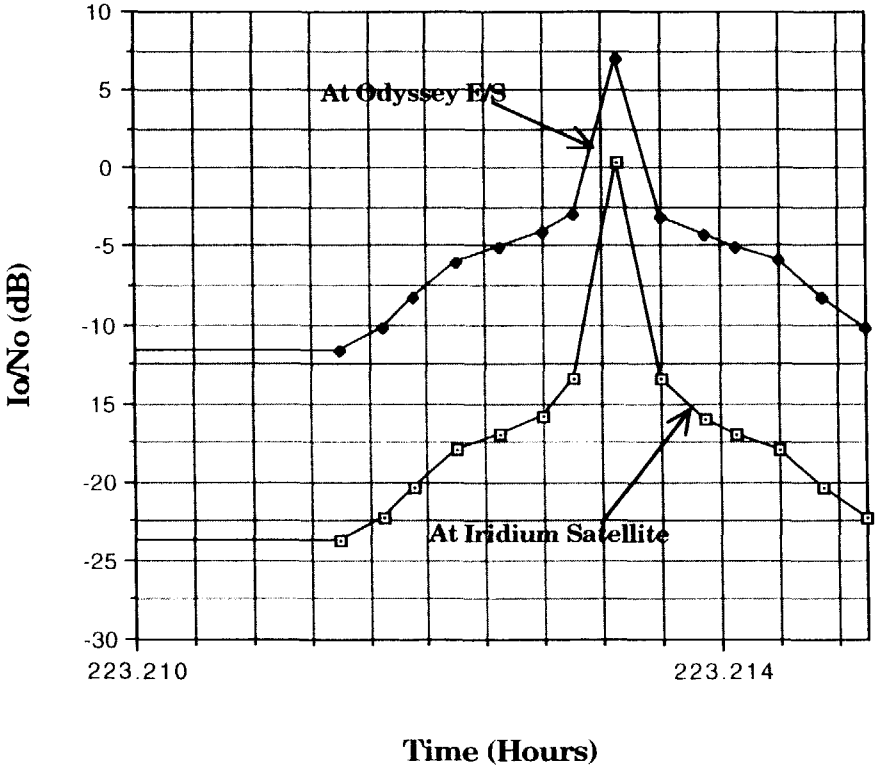
- A simulation of 12 Odyssey satellite and 66 Iridium satellite as over 30-days period, with time interval of 1 second. In this simulation, the off-axis angles $\alpha$, $\beta$ and the separation angles $\gamma$, $\psi$ were computed.
- Number of occurrences:
  - Both $\alpha \leq 0.15°$ and $\psi \leq 8.6°$
  - Both $\beta \leq 0.15°$ and $\gamma \leq 8.6°$
  - The resulting statistics are conservative, since many such angular combination results in acceptable interference levels

| Parameters | Case 1 | Case 2 |
|---|---|---|
| Angle of line of sight from E/S (off-axis angle $\alpha$ or $\beta$) | $\leq 0.15°$ ($\alpha$) | $\leq 0.5°$ ($\beta$) |
| Angle of line of sight to E/S from satellite (separation angle $\psi$ or $\gamma$) | $\leq 8.6°$ ($\psi$) | $\leq 1.5°$ ($\gamma$) |
| Minimum elevation angle | 10° (Odyssey) | 5° (Iridium) |
| # Occurrences (Per 30 days) | | |
| * San Luis Obispo / Las Vegas | 12 | 31 |
| * Portland / Montpelier | 34 | 75 |

# Maximum Interference Level Io/No

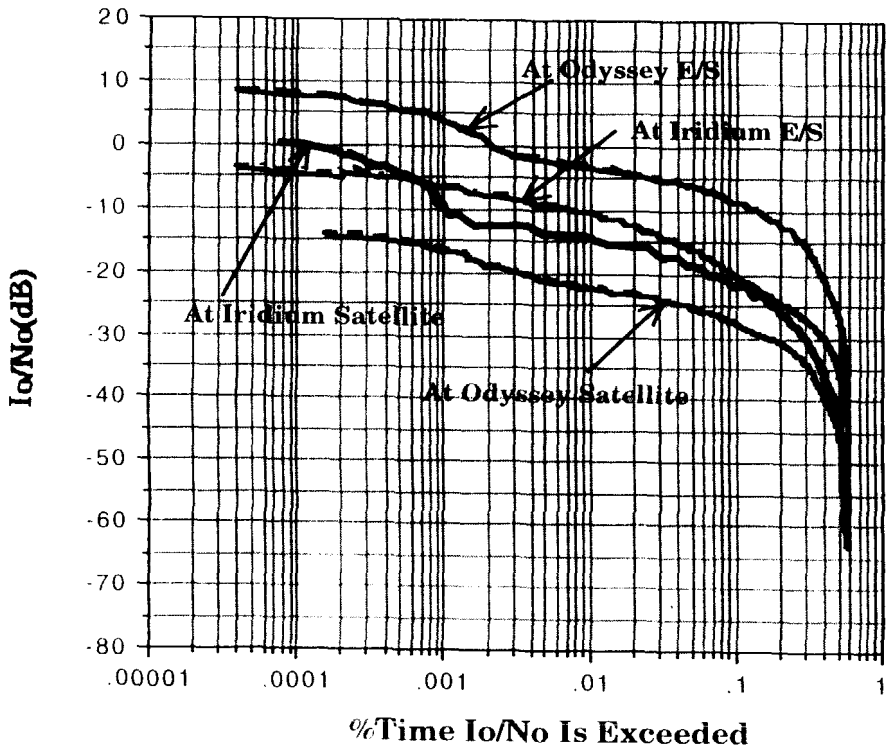
- San Luis Obispo / Las Vegas
  - At the Iridium satellite receiver: -4.36 dB
  - At the Odyssey earth station receiver: 6.12 dB
  - At the Odyssey satellite receiver: -13.61 dB
  - At the Iridium earth station receiver: -7.10 dB
- Portland / Montpelier
  - At the Iridium satellite receiver: 0.31 dB
  - At the Odyssey earth station receiver: 8.19 dB
  - At the Odyssey satellite receiver: -14.34 dB
  - At the Iridium earth station receiver: -3.86 dB

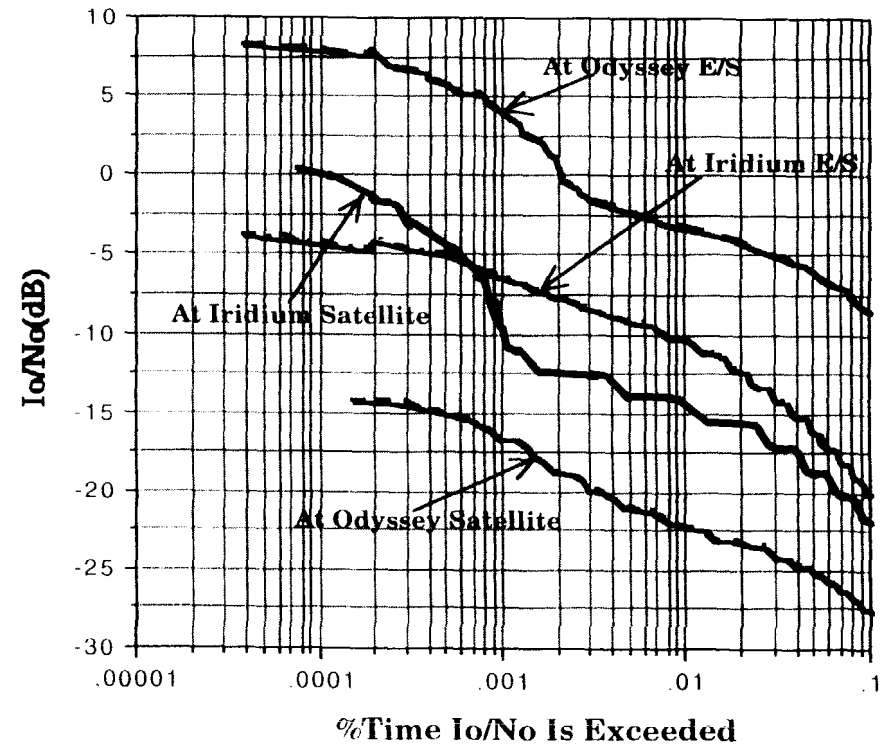
# Maximum Interference Level Io/No At Iridium Satellite & At Odyssey Earth Station Receiver



# Potential Odyssey/Iridium Interference Based On Odyssey E/S Portland & Iridium E/S Montpelier

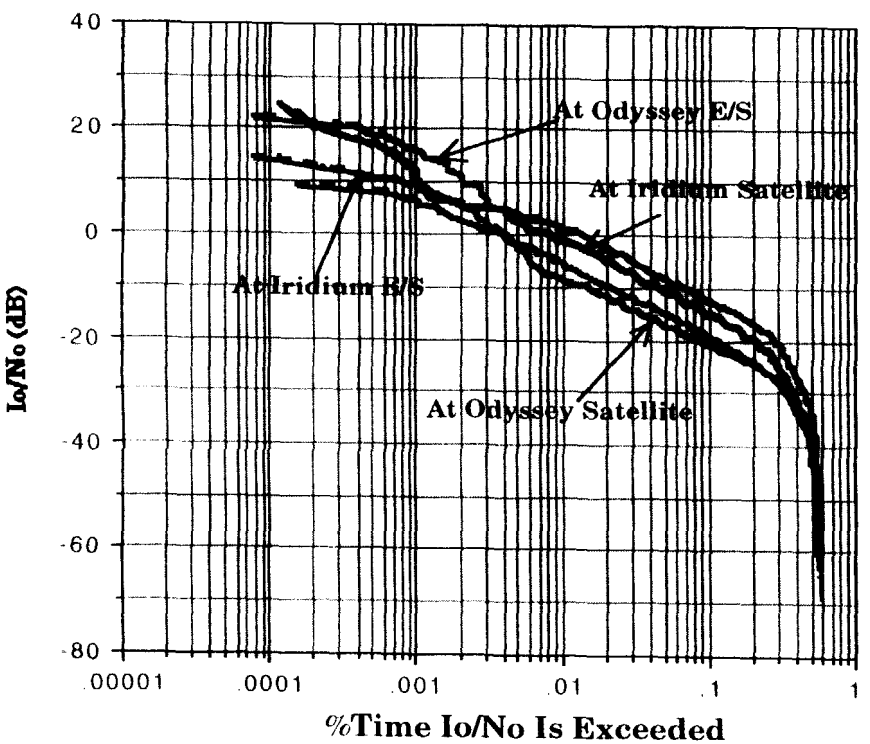
- when both systems operate on opposite polarization
  - Both Odyssey and Iridium satellite transmit at the full power

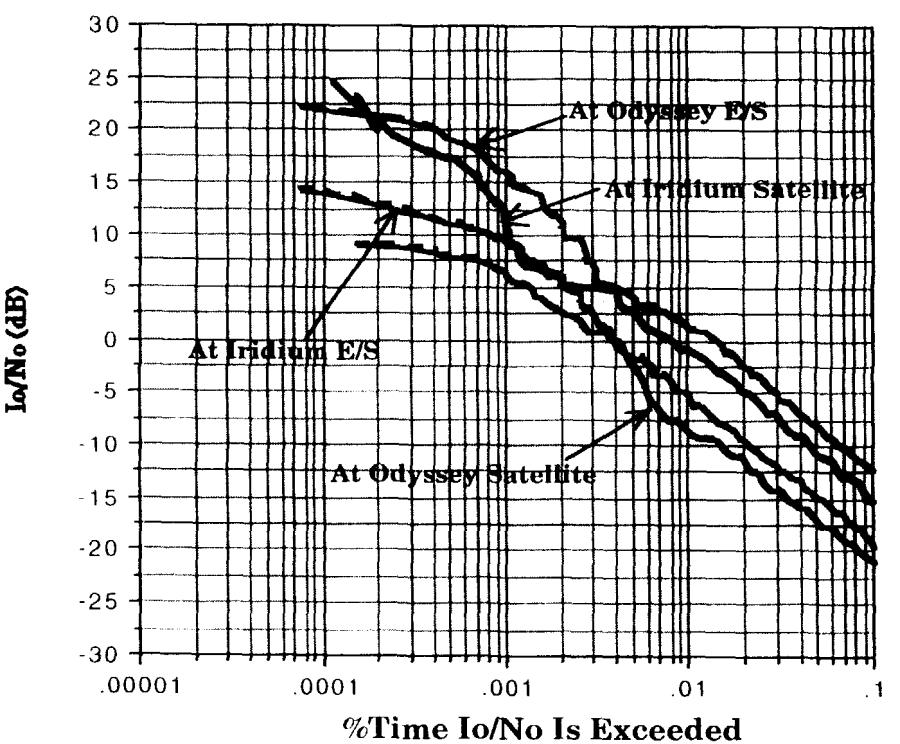


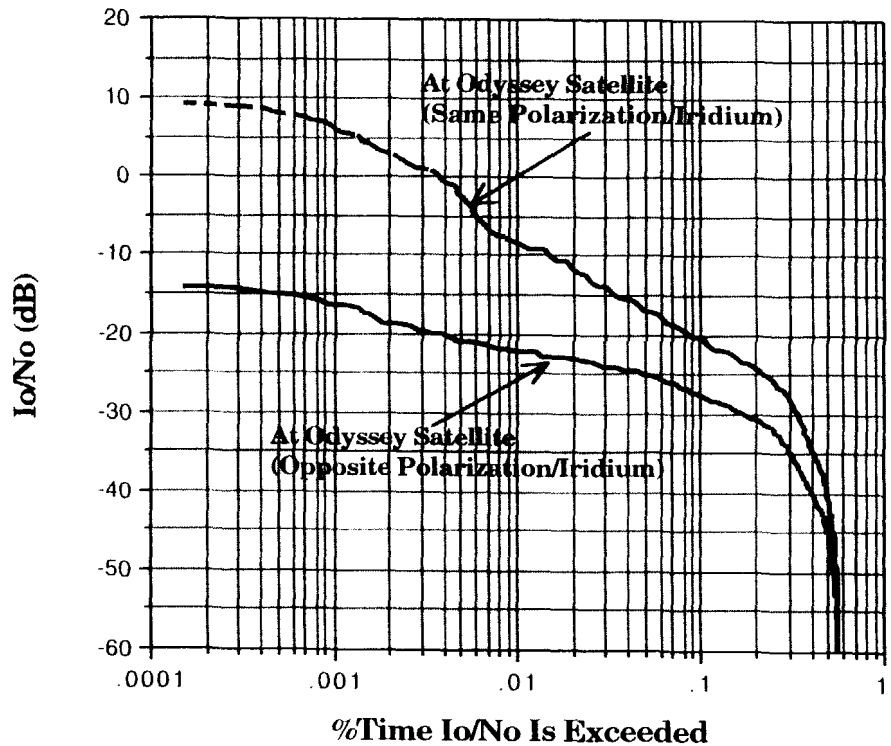
# Potential Odyssey/Iridium Interference Based On Odyssey E/S Portland & Iridium E/S Montpelier

- when both systems operate on same polarization



# Io/No At The Odyssey Satellite Receiver



# Conclusion

- Based on our analysis, the levels of interference at either the Odyssey satellite/earth station receiver or the Iridium satellite/ earth station receiver are well below the Iridium interference criteria.
- We conclude that the Odyssey system and the Iridium system can share the 29.1 - 29.4 GHz and 19.3 - 19.6 GHz bands directional for their feeder links if the Odyssey earth station and the Iridium earth station are separated by 250 Km.

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# Co-Directional Frequency Sharing Between the Odyssey™ and the Iridium Feeder Link Systems in the 29.1 - 29.4 GHz and 19.3 - 19.6 GHz Bands


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