onerous situation is not adequately addressed by the current PFD limits. The PFD limits in the ITU RR Article 28 were derived with respect to geostationary satellites, assuming that the mainbeams of terrestrial fixed systems could be directed sufficiently away from geostationary satellites in order to avoid receiving the entire PFD and the associated interference. In the absence of a stationary reference for the PFD (i.e., the geostationary orbit), designers of terrestrial systems will be unable to avoid receiving the full brunt of the PFD. This problem is compounded by the fact that Ellipsat and Motorola propose to operate multiple satellites, each of which would impose the full brunt of their PFD on terrestrial systems. Thus, even if Ellipso and Iridium were able to meet current PFD limits, there nonetheless would be a serious interference problem created by this operation.[5]

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[5] See Comments of AMSC on Supplemental NOI for WARC-92 Technical Appendix, n. 12 (April 12, 1991). AMSC established that PFD limits developed for geostationary satellites, when applied to constellations of non-geostationary satellites, would provide inadequate protection of terrestrial systems. This has not been disputed by either Ellipsat or Motorola or by any operator of terrestrial systems.

Table 3 - Ellipso Power Flux Density
In The 2483.5-2500 MHz Band

Total Satellite EIRP (Note 1):	27.0 dBW	
Number of Channels (Note 2):	10 ch.s	
Power Imbalance Factor (Note 2):	3 dB	
EIRP (Forward Channel):	20 dBW/ch	
Signal Bandwidth (Note 3):	1.13 MHz	
Elevation Angle at Earth (Note 4):	90°	0°
Satellite EIRP Density:	-7.4	-4.4 dBW/4 kHz
Spreading Loss (nadir/limb):	133	143 dB
Power Flux Density (nadir/limb):	-140	-147 dBW/m^2/4 kHz
Power Flux Density Limit:	-144	-154 dBW/m^2/4 kHz
Amount of Violation:	4 dB	7 dB

Note 1: Ellipsat Application, Appendix A, at 3. The indicated EIRP is interpreted at an edge-of-coverage value.

Note 2: The satellite transponder power is unevenly divided among four return and four forward communications channels and two signaling channels. The uplink total EIRP per forward channel is 18.8 dB higher than the total EIRP of 25 users of a return channel. However, so as to not overstate Ellipso's violation of the PFD limit, a power difference of only 10 dB is assumed between forward and return channels. Further, it is assumed that signaling channels require substantially less power than communications channels in the same direction of transmission since code noise in the signaling channel would be low or non-existent.

Note 3: The bandwidth and chip rate parameters are not clearly stated in the Ellipsat application.

Note 4: The satellite is assumed to be located at perigee so as to yield the lowest possible power flux density.

B. Ellipso and Iridium Would Cause Harmful Interference To Other Systems

A number of services are allocated throughout the 1610 1626.5 MHz and 2483.5-2500 MHz bands with secondary and primary status; the MSS has absolutely no international allocation status at this time and would have to operate strictly on a non-protected, non-interfering basis. However, it is not possible for MSS systems of the type proposed by Ellipsat and Motorola to operate on a non-interfering basis. The analyses below demonstrate that Ellipso and Iridium would cause harmful interference to systems in the Fixed, Radionavigation-Satellite, and Radiodetermination-Satellite services to which the subject bands are allocated. In addition, it is shown that Ellipso and Iridium each would cause harmful interference to MSS systems operating under the 1616.5-1626.5 MHz (Earth-to-space) allocation that has been suggested by AMSC and others in preparations for WARC-92. While the analyses that follow do not address the potential interference to other allocated services in the 1610-1626.5 MHz and 2483.5-2500 MHz bands, it is apparent that systems in those services also would suffer harmful interference from Ellipso and Iridium.[6] Further, it is shown that Iridium would

[6] Portions of the 1610-1626.5 MHz band also are allocated to the Aeronautical Radionavigation, Aeronautical Mobile, Aeronautical Mobile-Satellite (R), and Radio Astronomy services. The 2483.5-2500 MHz band also is allocated to the Mobile and Radiolocation services. It is likely that Ellipso and Iridium sharing with these services is not possible on the basis of the levels of interference that would occur with respect to the services that are addressed in the ensuing

cause harmful interference to systems operating in the Fixed-Satellite service at 20/30 GHz, despite the system design changes Motorola has discussed in attempting to reduce the interference to tolerable levels.

1. Ellipso and Iridium Would Cause Harmful Interference to Systems in the Fixed Service

The Fixed service is allocated in the 1610-1626.5 MHz band on a primary basis under RR 730 in 16 countries and on a secondary basis under RR 727 in 30 countries. In the 2483.5-2500 MHz band, the fixed service has a worldwide primary allocation. As shown in Section I.A, above, Ellipso and Iridium both would exceed the internationally adopted PFD limits in their proposed operating bands and larger coordination distances would be needed. To make matters worse, Ellipsat and Iridium employ non-geostationary satellites that while transmitting will spend significant percentages of the time within the antenna mainbeams

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analyses.

of Fixed service receivers.[7] The problem is still further exacerbated with respect to potential operations abroad, in that frequency assignments for Ellipso and Iridium transmitting mobile earth stations would have to be coordinated with all 46 administrations for which the Fixed service allocations pertain. However, Ellipsat would be unable to coordinate because of its earth station violations of the EIRP limit.

The calculations in Table 4 show that the level of interfering signal power produced by Ellipso downlink transmissions entering the mainbeam of a fixed station antenna would exceed the permissible levels by about 10 dB and 24 dB for fixed stations using analog and digital modulation, respectively. Table 5 shows that an Iridium satellite located in the mainbeam of a fixed station receiver would generate interfering signals at levels exceeding the permissible level by 23 dB and 37 dB for fixed stations using analog and digital modulation, respectively. These interference levels are so high as to cause not only outages during satellite transit of the mainbeam, but also would

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[7] Typical fixed station antennas in the subject frequency ranges have a gain of 35 dBi, according to CCIR Report 382-6. The beamwidth of such an antenna would be about 3 degrees which when projected onto the Iridium orbital sphere would cover 0.01% of that orbital sphere. Given that there are 77 Iridium satellites, at low to mid latitudes there would be an Iridium satellite in the fixed station mainbeam for on the order of 1% of the time. At mid to high latitudes, Iridium satellites would be in the mainbeam for a larger percentage of time. Ellipsat did not indicate in its application which portion of its proposed ellipcal orbit would be used for transmission. Nonetheless, an Ellipso transmitting satellite likely would be in the mainbeam of a fixed station in the northern hemisphere for on the order of 1% of the time or greater.

cause reduced fixed radio relay link availabilities at other times when a satellite is located even 15-20 degrees or further from the receiver mainbeam axis. Thus, systems in the fixed service operating throughout the 2483.5-2500 MHz and 1610-1626.5 MHz bands would be severely and repeatedly disrupted by Ellipso or Iridium interference.

The uplinks of Ellipso and Iridium also could cause harmful interference. If appropriate coordination criteria were developed to replace current predetermined coordination distances, it would be possible to prevent this interference through administrative procedures. See RR Article 11, Section III.

Table 4 - Calculation of Interference to Fixed Service Receivers from Ellipso Satellite Emissions

Ellipso PFD at Earth Limb (from Table 3):	-147 dBW/m²/4 kHz	
Effective Aperture Area of Fixed Station Antenna (Note 1):	11.6 dBm2	
Polarization Mismatch:	3 dB	
Received Interfering Signal Level:	-138.4 dBW/4 kHz	
Fixed Station Modulation:	<u>Analog</u>	<u>Digital</u>
Maximum Permissible Level of Interference (Note 2):	-148	-162 dBW/4 kHz
Amount by Which Ellipso Interference Exceeds the Permissible Level:	9.6	23.6 dB

Note 1: CCIR Report 382-6 lists a typical fixed station antenna gain of 37 dBi for the subject frequency range. Assuming slightly better than 60% antenna efficiency, the effective aperture would be 14.4 m^2. The Ellipso satellite is assumed to be located in the mainbeam of the fixed station.

Note 2: The maximum permissible level of interference is based on the long-term interference criteria specified in CCIR Report 382-6 for fixed stations using analog modulation (-148 dBW/4 kHz) and digital modulation (-138 dBW/MHz, or -162 dBW/4 kHz).

Table 5 - Calculation of Interference to Fixed Service Receivers from Iridium Satellite Emissions

Iridium PFD (from Table 2):	-125 dBW/m²/4 kHz	
Iridium Satellite Antenna Discrimination Towards the Earth Limb (Note 1):	6 dB	
Effective Aperture Area of Fixed Station Antenna (Note 2):	9 dBm²	
Polarization Mismatch Loss:	3 dB	
Received Interfering Signal Level:	-125 dBW/4 kHz	
Fixed Station Modulation:	<u>Analog</u>	<u>Digital</u>
Maximum Permissible Level of Interference (Note 3):	-148	-162 dBW/4 kHz
Amount by Which Iridium Interference Exceeds the Permissible Level:	23	37 dB

Note 1: Iridium beam type 1 is estimated to have no more than 6 dB discrimination towards the Earth's limb over wide azimuth sectors based on the radiation patterns shown in the Motorola application.

Note 2: CCIR Report 382-6 lists a typical fixed station antenna gain of 35 dBi for the subject frequency range. Assuming slightly better than 60% antenna efficiency, the effective aperture would be 9 m^2. The Ellipso satellite is assumed to be located in the mainbeam of the fixed station.

Note 3: The maximum permissible level of interference is based on the long-term interference criteria specified in CCIR Report 382-6 for fixed stations using analog modulation (-148 dBW/4 kHz) and digital modulation (-138 dBW/MHz, or 162 dBW/4 kHz in the case of Ellipso's wideband emission).

2. Ellipso and Iridium Would Cause Harmful Interference to the Planned Global Navigation Satellite System

The USSR global navigation satellite system ("GLONASS") is being developed in conjunction with the International Civil Aviation Organization ("ICAO") as part of the Global Navigation Satellite System ("GNSS"), which also will integrate the U.S. Global Positioning System ("GPS"). GLONASS downlinks will operate in the 1610-1616.5 MHz portion of the 1610-1626.5 MHz band to provide critical radionavigation signals to aircraft and other platforms on a worldwide basis. However, as shown in Table 6, transmissions from just one of the proposed Ellipso earth stations in the 1610-1618 MHz band (i.e., half the Ellipso channels) would interfere with reception of GLONASS signals over large areas, each with a radius of at least 500 km (i.e., more than 785,400 km2 or 306,800 square miles). Thus, radionavigation using GLONASS would be virtually impossible within more than 500 km of an area served by Ellipsat. Iridium uplinks present the same type of interference problem as Ellipso uplinks, but Iridium would compound the problem with its proposed downlink operations in the 1610-1626.5 MHz band.

As shown in Table 7, Iridium downlinks operating in the 1610-1617 MHz band (twenty lowest Iridium downlink channels) would render GLONASS-based radionavigation impossible throughout the world.[8] Significantly, the U.S. recently refused to consider a far less onerous MSS downlink sharing situation with respect to the GPS system in the 1559-1610 MHz band.[9] The Commission should protect the GLONASS element of the GNSS system with the same vigor applied to the GPS element.

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[8] Motorola states that it could share frequencies with the Radionavigation-Satellite service on a dynamic time and geographical basis. Supplemental Information to Iridium Application, Appendix C, Doc. JIWP USA-6A, at 13. Motorola has not, however, included in its design any provisions for effecting this type of sharing. Motorola also has not quantified the transmission constraints needed to effect this sharing, nor has it indicated the loss of Iridium capacity resulting from the necessary transmission constraints.

[9] Inmarsat introduced a paper addressing MSS downlink sharing with GPS at the Joint Interim Working Party ("JIWP") of the International Radio Consultative Committee ("CCIR"). Doc. JIWP92/17, February 20, 1991. While the subject analysis showed that MSS downlinks would cause only a small increase in GPS receiver noise and virtually no disruption of radionavigation under favorable operating conditions, the U.S. considered the subject sharing to be unworkable because the MSS downlinks could occasionally contribute to GPS disruptions under unfavorable operating conditions. The interference levels posed by Iridium to GLONASS are over a thousand times more onerous than those considered with respect to GPS at the CCIR JIWP.

Table 6 - Ellipsat Uplink Interference to Radionavigation

Ellipsat Earth Station:	Gateway	Mobile
Ellipsat Uplink EIRP (Note 1):	47.1	8.3 dBW/ch
Ellipsat Bandwidth (Note 2):	1.13	1.13 MHz
EIRP Density (Note 3):	-13.4	-52.4 dBW/Hz
Line-of-Sight Path Length to En Route Aircraft (Note 3):	500	13 km
Basic Transmission Loss:	150	119 dB
GLONASS Receiver Antenna Gain (Note 4):	0	-2 dBi
Interference Power Density at GLONASS Receiver:	-163	-172 dBW/Hz
Noise Power Density Level at GLONASS Receiver (Note 4):	-200	-200 dBW/Hz
Reduction in GLONASS Signal-to-Noise Power Ratio:	37	28 dB
GLONASS Signal-to-Noise Power Ratio With Ellipso Interference (Note 4):	-15	-6 dB

Note 1: Application, Appendix B, p1, "Link Noise Budget."

Note 2: Ellipso's bandwidth is not clearly stated in the Ellipsat Application. See Note 2 of Table 1.

Note 3: The calculations are performed for the minimum and maximum radio line-of-sight path lengths between the Iridium earth station and aircraft flying at 12 km altitude.

Note 4: GLONASS parameters are taken from "The GLONASS System Technical Characteristics and Performance," ICAO FANS, Fourth Meeting, Montreal, 2-20 May 1988, Doc. FANS/4-WP/75.

Table 7 - Iridium Downlink Interference to Radionavigation

Iridium Satellite EIRP (Note 1):	31.7	26.4 dBW/carrier
Iridium Downlink Bandwidth:	280	280 kHz
Number of Simultaneous Interference Entries (Note 2):	1	100
Downlink EIRP Density:	-22.8	-8.1 dBW/Hz
GLONASS Receiver Noise Power Density (Note 3):	-200	-200 dBW/Hz
Maximum Acceptable Interference-to-Noise Power Ratio:	-10	-10 dB
GLONASS Receiver Antenna Gain:	2	0 dBi
Required Basic Transmission Loss:	187.2	210.2 dB
Available Basic Transmission Loss (Note 4):	154.1	160 dB
Amount By Which Acceptable Interference Level is Exceeded:	33.1	50.2 dB

Note 1: The EIRP level of 31.7 dBW is used in one beam type 1 of the Iridium system. This represents only one of numerous simultaneous interference entries. The EIRP level of 26.4 dBW is the average EIRP figure used by Motorola in an interference analysis. Supplemental Information to Iridium System Application, Appendix C, at Table A-2. While Motorola's calculations of the average level of interference are not indicative of the extent of the problem, calculations based on both the beam 1 and the alleged average levels of EIRP are presented.

Note 2: From the vantage point of an aircraft, Iridium satellites transmitting over 100 carriers are visible.

Note 3: GLONASS parameters are taken from "The GLONASS System Technical Characteristics and Performance," ICAO FANS, Fourth Meeting, Montreal, 2-20 May 1988, Doc. FANS/4-WP/75.

Note 4: The available basic transmission loss of 160 dB is an estimated average value suitable for use with Motorola's "average" level of interfering EIRP.

3. Ellipso and Iridium Would Cause Substantial Capacity Reductions in Other Radiodetermination Satellite Systems

The Commission established a number of technical standards for domestic RDSS systems in order to promote compatibility among multiple systems such that it would be unlikely that any particular RDSS system would consume the entire available spectrum capacity.[10] These standards include (1) a requirement that non-RDSS services be ancillary to the RDSS communications, thus ensuring that communications such as voice and messaging would not consume a high percentage of the spectrum resource that is available to RDSS; (2) a requirement that the PFD levels be reduced as may be necessary for sharing with licensed RDSS systems; (3) use of pseudorandom-noise ("PN") codes in conjunction with spread spectrum modulation in a manner that helps ensure compatibility with other RDSS systems; and (4) use of random access, time division multiplex techniques in order to minimize system signaling requirements and the associated demands upon the limited available spectrum. Neither Ellipsat nor Iridium comply with the RDSS technical standards.[11]

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[10] See Second Report and Order, Gen. Docket 84-689, (May 8, 1986). The Commission did not, through its technical standards, preclude the possibility that one RDSS system could consume the entire available spectrum resource, but this possibility could be later prevented through limits on the numbers of RDSS user terminals that would be permitted to be deployed in each system.

[11] As shown earlier, Ellipso and Iridium do not meet the applicable power limits. Ellipsat also does not use a PN code that spreads its signals over the entire band (i.e., the Ellipso chip rate is less than one tenth the rate needed to achieve full spreading) and it apparently does not employ random access (i.e.,

As shown below, the systems proposed by Ellipsat and Motorola would severely reduce the capacity of RDSS systems. The methods of CCIR Report 1050 are applied with respect to an RDSS system similar to the system that Geostar had planned to construct. Two RDSS systems are assumed to be operating initially in the absence of interference from Ellipso or Iridium; each RDSS system could serve up to 52 users simultaneously assuming 6 dB polarization discrimination exists between the systems. The capacity reduction caused by Ellipsat and Iridium with respect to the co-polar RDSS system would be about 4 times greater than the capacity reductions of the cross-polar RDSS system.

a. Ellipso interference to RDSS

Ellipsat claims that its system can coexist with other RDSS systems in the 1610-1626.5 MHz and 2483.5-2500 MHz bands by virtue of its use of code division multiple access ("CDMA") techniques, but no analysis has been provided to support this assertion.[12] The fact is, interference from Ellipsat would render communications and radiodetermination impossible over RDSS

20% of Ellipso's spectrum usage is for signaling, thus implying that demand assignment multiple access ("DAMA") is used instead of random access CDMA). Motorola does not comply with any of the technical standards for RDSS, but requests waivers with respect to most of the requirements it wishes to avoid.

[12] Ellipsat's interference analysis is not an analysis at all; instead, Ellipsat states its conclusion that it is compatible with other users of the bands. Ellipsat Application, at 29.

systems serving the same area.

Table 8 presents the results of standard calculations of the reduction in RDSS system capacity caused by the interference that would be generated by a co-polarized Ellipso satellite. It is shown that the interference caused by the Ellipso uplinks would reduce the capacity of an RDSS system to zero, i.e., no communications would be possible over the RDSS system. The same result is obtained even if Ellipso were cross-polarized from an RDSS system. The principle reason that Ellipso's interference is so onerous is that the gateway earth stations greatly exceed the EIRP limit.

Table 8 - Ellipso interference to RDSS systems

Polarization Relationship:	Co-Polar	Cross-Polar
Capacity Reduction From Ellipso Uplinks (Note 1):		
- Gateway	100%	100%
- Mobiles	14%	3.5%
- Uplink Total	100%	100%
Capacity Reduction From Ellipso Downlink (Note 2):	12%	3%
Total Capacity Reduction For Two Way RDSS Communications:	100%	100%

Note 1: The interference levels from co-polar Ellipso uplinks exceed by 9 dB the level that results in loss of all RDSS communications capacity. For the cross-polar case, the interference is 3 dB in excess of the amount leading to loss of all RDSS capacity. In the case of Ellipso gateway earth stations, the antenna is assumed to be pointed at the RDSS satellite.

Note 2: The stated capacity reductions are based on a favorable distribution of Ellipso power among its ten channels. See Note 2 of Table 3.

b. Iridium interference to RDSS systems

Motorola submitted with its application an analysis of interference to RDSS systems that has since been amended several times in the course of WARC-92 preparations. The latest Motorola analysis was submitted to the CCIR Joint Interim Working Party meeting, but was found by the CCIR to be deficient in several respects.[13/]

Table 9 presents the results of standard capacity loss calculations for the case of Iridium interfering with RDSS systems. It is shown that an RDSS system that is co-polarized with respect to Iridium would suffer a capacity loss of between 31% and 100%, depending on the in situ distribution of power levels that exist in Iridium power-controlled links. As will be further discussed below, Iridium links will experience significant fading for large percentages of the time and locations, which when compensated by Iridium's power control will result in 100% capacity loss.[14/]

13/ See Doc. U.S. JIWP92/54, which presents the latest version of Motorola's analysis of interference from Iridium to RDSS systems. See also Doc. JIWP92/110, which presents a summary of the CCIR findings based on Motorola's analysis. The problems with Motorola's analysis include: (1) averaging over time of the interference levels in a manner that disguises the fact that Iridium's peak instantaneous interference levels are relatively high; (2) disregard of the additive effects of Iridium uplinks and downlinks resulting from dispersed Iridium burst propagation delays to the geostationary satellite orbit; (3) use of unrealistically low Iridium power levels; and (4) complete omission of the majority of interference entries from Iridium satellites and mobile earth stations, including the most onerous downlinks associated with Iridium satellites located near the Earth limb.

14/ If the distribution of Iridium link power levels were such that the average of the instantaneous power levels were only 4 dB higher than the minimum value, then 100% RDSS capacity loss would occur.

Table 9 - Iridium interference to RDSS systems

Polarization Relationship:	Co-Polar	Cross-Polar
Capacity Reduction From Iridium Uplinks (Note 1):		
- Minimum Iridium Power:	7.3%	1.8%
- Maximum Iridium Power:	26.0%	6.5%
Capacity Reduction From Iridium Downlink (Note 2):		
- Minimum Iridium Power:	30.7%	7.7%
- Maximum Iridium Power:	100%	48.7%
Total Capacity Reduction For Two Way RDSS Communications:	100%	48.7%

Note 1: The interference power levels generated by Iridium are as computed using AMSC's actuarial method as opposed to Motorola's averaging method. Because Iridium uses power control, computations have been performed assuming Iridium operation at its minimum and maximum power levels.

Note 2: The Iridium downlink interference assuming maximum downlink power levels results in co-polar interference that is almost 3 dB in excess of the level that causes complete loss of RDSS communications.

4. Ellipso and Iridium Would Cause Harmful Interference to Mobile-Satellite Systems

AMSC and others have proposed that an MSS (Earth-to-space) allocation be established in the 1616.5-1626.5 MHz band.[15] Ellipsat provided no analysis of the potential interference Ellipso would cause to MSS systems that may use the 1610-1626.5 MHz band. As will be shown below, the high EIRP density levels used in Ellipso feeder uplinks and the large numbers of mobile earth station uplinks anticipated by Ellipsat would result in harmful interference to geostationary MSS systems. Similarly, Motorola's application also does not include an analysis of potential interference levels that Iridium would cause to other MSS systems, despite its plan to eventually expand its frequency usage into the 1626.5-1660.5 MHz range that is already heavily populated with geostationary MSS systems.[16] However, analyses

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[15] See Comments of AMSC, Supplemental NOI, p. 4-6 (April 12, 1991). The frequency 1616.5 MHz was proposed as the lower edge of the MSS allocation in order to avoid interference to GLONASS and the Radio Astronomy service.

[16] Motorola Application, p. 57, n. 31. In the supplement to its application, Motorola did file an analysis of the geometric conditions under which mainbeam downlink emissions of Iridium would intersect the geostationary orbit and, hence, when particularly high individual entries of interference could occur. Motorola concluded that it could deactivate Iridium downlink beams whenever they would radiate directly towards the geostationary orbit. However, those mainbeam interference cases represent only a small fraction of the overall Iridium interference sources, which include numerous other downlink signals that are radiated via sidelobes and propagated via line-of-sight paths, and that are radiated via mainbeams and propagated via Earth backscatter and reflections, as well as uplink signals from the anticipated large deployment of mobile earth stations.

presented in the course of CCIR and Commission WARC-92 preparations have shown that Iridium would cause harmful interference to geostationary MSS systems.

a. Interference to geostationary MSS systems from Ellipso

Ellipsat would cause unacceptable interference to other MSS systems using the 1616.5-1626.5 MHz band as a result of the high power of its feeder link earth stations and the large numbers of mobile earth stations it expects to serve. The calculations in Table 10 indicate that Ellipso feeder link earth stations and mobile terminals would cause nominal C/I levels of -17.3 dB and 7.0 dB, respectively, in current types of MSS systems using geostationary satellites with spot beam antennas. Thus, interference from Ellipso feeder link earth stations would render communications impossible and interference from Ellipso mobile terminals would severely degrade MSS communications. Significantly, even lower C/I levels would occur in later generations of MSS systems using geostationary satellites with lower uplink EIRP levels. Thus, this sharing situation ultimately would become even more onerous.

Ellipso also could not share frequencies with another MSS system using the Ellipso design unless the peak capacity levels of both systems were essentially halved. Generally, it is assumed that interference between or within systems using orthogonal pseudo-noise ("PN") codes has about 2/3 the effect of thermal noise of the same power level.[17] Consequently, the capacity of these CDMA systems is generally defined as the number of users that could be supported simultaneously by allocating 3/2 of the excess system margin to self-interference. In Ellipsat's system, which uses Earth-coverage satellite antennas and omnidirectional earth station antennas, the interference from each user of an identical MSS system would have the same effect as the self-interference generated by a user of Ellipso. Thus, in a given service area such as the United States, the number of users that can be supported by one CDMA system decreases in direct proportion to the number of users of the other system. In other words, there really can be no frequency reuse among systems of Ellipsat's design.

[17] See CCIR Report 1050.

Table 10 - Ellipso gateway and mobile terminal uplink interference to MSS uplinks to geostationary satellites

Ellipso Earth Station:	Gateway	Mobile	
Ellipso Uplink EIRP (Note 1):	47.1	22.7	dBW
Geostationary MSS Receiver Noise Bandwidth (Note 2):	3	3	kHz
Ellipso Bandwidth:	1.13	1.13	MHz
Ellipso Uplink EIRP Density:	21.3	-3.1	dBW/3 kHz
Geostationary MSS Uplink EIRP Density (Note 2):	4.0	4.0	dBW/3 kHz
Carrier-to-Interference Power Ratio:	-17.3	7.0	dB

Note 1: Parameters for Ellipso gateways and mobile terminals are taken from the Ellipsat application, Appendix B, p1, "Link Noise Budget." Ellipsat indicates that each satellite can carry 200 carriers. Application, at 28. Assuming optimistically that the carriers are uniformly distributed, there would be 25 carriers per communications channel. Thus, 25 mobile terminals may be transmitting in the same Ellipso channel; the aggregate EIRP from these mobile terminals is 8.8 + 10 log 25 = 22.7 dBW.

Note 2: The noise bandwidth and EIRP assumed for uplinks to geostationary MSS satellites is based on the link dubbed "Configuration 4" in AMSC's system. Request for Modification and Supplemental Information of AMSC, Gen. Docket 84-1234, December 4, 1989. It is expected, however, that later generations of MSS satellites will employ larger antennas that will enable use of EIRP levels of -2.2 dBW or less. Thus, the C/I levels caused by Ellipso would be on the order of 6 dB lower that the C/I levels computed above.

b. Interference to MSS systems from Iridium

In the course of preparations for WARC-92, Motorola presented an analysis of interference from Iridium to uplinks of geostationary MSS satellites that use spot beam antennas.[18] Motorola's analysis is severely flawed in several respects. The biggest problem is its objective of evaluating an "average" level of interfering signals. The levels of interference generated by Iridium would vary greatly over time, such that "average" interference levels do not convey the extent of communication degradation. Thus, even if there were no other errors in Motorola's analysis, no valid conclusion could be drawn from its results. However, Motorola's analysis contains several other serious errors, including application of system loading factors to artificially reduce the interference level; use of unrealistically low Iridium transmission power levels; omission of interference from Iridium satellite antenna beams whose downlinks are covering areas outside the geostationary satellite spot beam coverage; complete disregard of Iridium uplink interference occurring through the sidelobes of the geostationary satellite antenna; ignorance of any Iridium communications to its oceanic service areas; and, in defiance of a Commission request,

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[18] See Motorola's Supplemental Reply Comments to the Supplemental Notice of Inquiry (May 10, 1991), Gen. Docket No. 89-554. Motorola also performed an analysis of Iridium interference to geostationary MSS systems for submission to the CCIR JIWP meeting. <u>See</u> n.13, <u>infra</u>.

disregard of interference from Iridium downlink mainbeam emissions coupled via Earth backscatter and reflection.

In sharp contrast to Motorola's analysis, AMSC's interference analysis reveals that Iridium would cause severe interference to AMSC's system during conditions that will exist for substantial percentages of the time. The analysis is presented in Exhibits 1 and 2 and summarized in Table 11. AMSC's approach has conservatively assumed that the temporal (time) variations in the interference caused by Iridium would predominantly be caused by variations in Iridium spectrum occupancy and power levels. Thus, in considering the short-term interference levels that would occur, propagation losses and other statistical variables not involving Iridium system parameters have been set at their expected median values, and Iridium channel occupancy and power levels have been set at higher-than-average levels to yield estimates of the interference that would occur for less than 50% of the time. The results so obtained are not the "worst case", but are representative of interference levels occurring for substantial portions of the busy hour of Iridium usage.

As shown in Table 11, Iridium would cause low carrier-to-interference power ratios ("C/I") that would result in harmful interference to AMSC's system if these systems were to use the same band. Specifically, even if it were assumed that all Iridium transmitters were operating at their minimum power levels, co-channel sharing would be impossible. Further, if the geostationary MSS system channels were tuned several hundred kilohertz from the Iridium channels, the C/I levels occurring when the desired signal is unfaded still would cause high bit error ratios, and normal fading would result in outages that would not occur in the absence of Iridium interference. Similar results likely would be found for sharing between Iridium and Inmarsat or other MSS systems. Thus, Iridium and geostationary MSS systems simply cannot share the same frequency band.

Table 11 - Summary of Iridium interference levels computed in Exhibits 1 and 2 with respect to an MSS system using geostationary satellites with spot beams

Iridium Power Levels (Note 1):	Maximum	Minimum	Expected
Co-channel C/I (dB) Generated By Iridium (Note 2):	-0.7	2.7	0.7
Non-co-channel C/I (dB) Generated By Iridium (Notes 2 and 3):	6.2	9.7	7.7

Note 1: Results are presented for Iridium transmitters operating at the maximum and minimum power levels, as well as the expected levels. The expected level assumes that the average value of the instantaneous fading on Iridium signal paths is 4 dB on downlink paths and 3 dB on uplink paths.

Note 2: The desired signal is not faded. The interference power levels are averaged only over the symbol transmission period assumed for a geostationary satellite (i.e., on the order of 1/2.4 ksps, or 41.7 milliseconds). This is necessary in order to ensure that even if interference from Iridium were to cause only one errored symbol per Iridium transmission frame, the effects of that interference would be reflected in the BER. The same geostationary MSS symbol interval assumed for the uplinks to geostationary satellites is examined for the downlinks from geostationary MSS satellites. Thus, the uplink and downlink interference is additive.

Note 3: The non-co-channel case addresses the least affected channel of a geostationary MSS satellite operating in a band used by Iridium. The desired signal is not faded.

i. <u>Motorola's use of average interference</u>

Average levels of interference as used by Motorola simply are irrelevant in cases such as this, where the levels of interference are highly variable and where digital modulations are used in the victim system. Moreover, in this case the victim MSS systems will be providing safety communications.

Among the reasons that interference from Iridium will be highly variable is the fact that Iridium would use a burst transmission format that periodically results in multiple Iridium uplink and downlink bursts from several time slots being received simultaneously at a geostationary satellite.[19] Even if these burst overlaps or other interference enhancements were to occur only once per Iridium transmission frame (i.e., once per 60 ms)

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[19] The Iridium transmission frame is 60 msec long and contains 14 uplink bursts interleaved with 14 downlink bursts. The difference between the minimum and maximum distances between Iridium mobile earth stations and a geostationary satellite is 5,876 km, which results in a geostationary satellite simultaneously receiving Iridium uplink bursts occurring over 32% of the Iridium transmission frame (i.e., 100% x 5,876 km / [3 x 10E5 km/sec x 0.060 sec]). Likewise, Iridium downlink transmission bursts occurring over a somewhat larger percentage of the Iridium transmission frame could arrive simultaneously at the geostationary satellite orbit. Because each Iridium uplink and downlink burst time slot occupies 2.2% and 4.8% of the transmission frame, respectively, and because the uplink and downlink bursts are interleaved and repeated across the frame, uplink and downlink bursts can be received simultaneously. The number of overlapping received bursts and their individual power levels vary over time, such that the instantaneous received interference power will vary by large amounts (e.g., by more than 10 dB) when considering the interference power occurring in the transmitted bit or symbol intervals of an uplink to a geostationary satellite).

and cause only one bit error per occurrence, the bit error ratio ("BER") in a 4.8 kbps uplink to a geostationary MSS satellite would be 3.47×10^{-3} (i.e., 1 error/[4800 bps x 0.060 sec]), which would render voice or data communications unintelligible. Motorola assumes, however, that its transmission bursts would be essentially uniformly distributed over time when received by a geostationary satellite, such that transmission bursts from only one-seventh of the Iridium antenna beams need be considered. Even if the "average" level of interference were unobtrusive, the short-term instantaneous interference levels under the same sharing scenario could result in an unacceptably high BER.

ii. Motorola's incorporation of system loading factors

Motorola states that its system loading would be no higher than 65% (i.e., system access protocols and trunking factors enable only 65% efficiency in channel utilization). On this basis, Motorola assumes that any given Iridium channel is in use (i.e., assigned to a user) in no more than 65% of the cells that could use the same frequency at the same time. System loading and occupancy of a particular channel, however, are not related in this manner. The Iridium application includes no mention of any channel assignment strategy that would evenly disperse frequency assignments across the spectrum used by Iridium, nor could Iridium perform in this manner because of the numerous frequency sharing constraints with which it must operate.[20] In other words, even in the absence of sharing constraints, it is equally likely that Iridium would assign the same frequency channel to users in every beam, as it would uniformly spread the channel assignments across the entire band (even at system loading less than 5%). Because there are numerous sharing constraints, Iridium would have less than 10 MHz in which to concentrate its channel assignments. Thus, Motorola errs grossly in applying its 65% maximum system loading as an interference reduction factor.

iii. <u>Motorola's use of low Iridium power levels</u>

Motorola's application explains that Iridium uplinks and downlinks would provide power control in response to the level of fading occurring on the signal path between Iridium satellites and user terminals. The Iridium link power budgets show the nominal performance when the minimum transmission power levels are used ("no shadowing," fixed fade allowance of 0.3 dB for atmospheric losses) and when the maximum transmission power

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[20] If interference is to be avoided to the Radio Astronomy and Radionavigation-Satellite services, Iridium would be required to use only those channels that are above at least 1616.5 MHz (plus the required frequency separation between Iridium downlinks and Radionavigation-Satellite downlinks). See Section I. Of this spectrum (approximately 1616.85-1626.5 MHz), several frequency segments will be unusable to in order to prevent Iridium interference to the allocated terrestrial services. Further, additional segments of the 1616.85-1626.5 MHz band would be unusable by Iridium because of potential interference to AMS(R)S or other MSS systems.

levels are used ("shadowing," with mean vegetation losses between 6.2 dB and 12.0 dB).[21] Motorola commits two errors in characterizing these Iridium transmission power levels (EIRP levels) in its interference analysis: (1) Motorola uses as its minimum EIRP levels values that are 2 dB to 6.1 dB less than the minimum power levels specified in its application, as amended, and (2) Motorola assumes that 80% of its uplinks and 80% of its downlinks are at below-minimum power levels.[22] Obviously, the EIRP of all Iridium satellites and user terminals must be greater than or equal to the minimum specified EIRP level, and far less than 80% of the satellite and user terminal transmissions often would be near the minimum power levels. The net effect of both errors is that Motorola ultimately has assumed uplink and downlink interfering EIRP levels that are too low to be representative of even average interference conditions, let alone the short-term interference conditions that are determinant of whether Iridium can share the same band as a geostationary MSS system.

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[21] See "Supplemental Information to Iridium System Application," Appendix A, p 1 and tables A-2 through A-5. (The Iridium power levels listed in this citation are higher than those listed in Motorola's original application of 3 December 1990).

[22] See Supplemental Reply Comments to the Supplemental Notice of Inquiry (10 May 1991), Gen. Docket 89-554, Appendix B, at Tables B-1 and B-2. The EIRP levels assumed for interfering Iridium uplinks and downlinks are 2 dB to 6.1 dB less than the minimum values stated in Motorola's application, as amended. As will be discussed in Section II.A, Iridium signal paths to user terminals will experience fading for substantial percentages of time, such that power control often would boost the Iridium uplink and downlink power significantly above the minimum levels.

iv. Motorola's omission of significant uplink interference

Yet another major error in Motorola's analysis is the complete disregard of interference from Iridium uplinks occurring through the sidelobes of the geostationary satellite antenna. Far more interfering Iridium user terminals are located outside of the MSS satellite mainbeam than inside the mainbeam coverage contour. It is axiomatic that while the sidelobe gain of the geostationary satellite toward these interfering Iridium user terminals is substantially lower than the mainbeam gain of the geostationary satellite, the relatively high numbers of Iridium user terminals in the sidelobe regions results in significant interference. Even under Motorola's "average" interference approach, the Iridium user terminals located outside AMSC's spot beam coverage contour would cause even more interference than the interferers located inside the spot beam contour. Thus, Motorola has overlooked a significant interference coupling mechanism.

v. Motorola's omission of interference arising from oceanic areas

Motorola's interference analysis assumes that Iridium provides service only to land areas; thus, Motorola assumes that no interference would arise from Iridium user terminals on boats, ships, and aircraft operating over ocean areas. This is inconsistent with the maritime and aeronautical services proposed by Motorola and with the significant levels of MSS traffic that will arise in ocean areas, particularly in coastal areas. Based on numerous MSS traffic projections, the levels of oceanic traffic would contribute significantly to the interference caused by Iridium.

vi. Motorola's omission of interference from the most significant Iridium downlinks

Motorola's analysis also disregards the most onerous set of Iridium interference sources. Specifically, Motorola has not addressed interference from its satellite downlink beams that do not happen to cover cells located in AMSC's spot beam contour. While an AMSC spot beam would provide discrimination towards Iridium satellites located outside the spot beam, the benefit of that discrimination is more than offset by the cumulative interference power generated by large numbers of visible Iridium satellites and the relatively low antenna discrimination levels of many of those Iridium satellites towards AMSC's satellite. These Iridium downlink beams constitute the most onerous set of Iridium interference sources because of the high power levels used in Iridium downlinks.

vii. Motorola's neglect of Earth reflections and backscatter

Yet another major error in Motorola's analysis is its complete disregard of the potential interference resulting from

Earth reflections and backscatter of Iridium satellite mainbeam emissions. This omission occurs in defiance of the Commission's request that such interference be considered.[23] The Earth backscatter and reflection path for Iridium interfering signals can be treated like a multipath propagation problem. Using this analysis approach, it is shown in AMSC's analysis that the scattered and reflected signal are less onerous than the interfering signals arriving on direct line-of-sight interfering signal paths. Nevertheless, the scattered and reflected interfering signals are significant because the direct line-of-sight interfering signals are so powerful.

viii. <u>Two Iridium's Cannot Coexist</u>

Iridium could not share frequencies with another MSS system of similar design unless the peak capacity levels of both systems were essentially halved and both systems used precisely synchronized, identical TDMA reference frames and time slots. If these systems were not precisely synchronized, mobile earth stations of one system would be transmitting in the vicinity of receiving mobile earth stations of the other system and the satellites of the two systems also would interfere with one another. Assuming that two Iridium-type systems could be

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[23] See Supplementary NOI for WARC-92, para. 21 and n. 25. On the basis of comments made by the FAA at the U.S. JIWP preparatory meeting held early in 1991, AMSC addressed the potential Earth backscatter contributions to the interference caused by Iridium in its interference analysis. See Exhibit 2-4.

precisely synchronized, the systems would require separate frequencies in order to avoid generating C/I levels that, by definition, could be no higher than 0 dB in the most affected system (i.e., a 0 dB C/I would occur if both systems used identically overlaid cellular beam coverage patterns and sequencing among beams and the power levels in all links of both systems were identical). Thus, in a given service area such as the United States, the number of users that can be supported by one Iridium system decreases in direct proportion to the number of other Iridium type systems. In other words, there really can be no frequency reuse among systems of Motorola's design.

5. Iridium Will Cause Harmful Interference to Systems in the Fixed- and Mobile-Satellite Services at 20/30 GHz

Motorola proposes to operate its feeder links in the bands allocated to the Fixed-Satellite service ("FSS") at 20/30 GHz, in this case in the same directions of transmission as other systems. Motorola further proposes to share the frequencies with geostationary FSS systems by applying the provisions of RR No. 2613, which would require Iridium to cease or reduce its uplink emissions at 30 GHz and its downlink emissions at 20 GHz in order to avoid causing unacceptable levels of interference to geostationary FSS systems. Specifically, Motorola states that it would avoid causing interference to 20/30 GHz geostationary FSS systems through three methods: (1) retuning Iridium frequencies on a case-by-case basis to avoid frequencies used by geostationary FSS systems; (2) operation at reduced power levels; and (3) shutting off the Iridium feeder links at times they would cause interference. Supplemental Information to Application, at Appendix C, Doc. No. U.S. JIWP-27. However, Motorola's design does not accommodate these provisions.

The efficacy of any of the three interference mitigations proposed by Motorola can be evaluated only on the basis of interference analyses; Motorola has not provided any such analyses. The interference analysis presented in Table 12, however, indicates that only the "shut off" method will effectively prevent interference once FSS usage of frequencies across the 20 GHz and 30 GHz bands commences.

If it were simply a matter of shutting off the feeder links when the earth station antenna mainbeam passes within a few tenths of degrees of an FSS satellite, then the concern would be simply that shut-offs would be needed more and more frequently as use of the 20/30 GHz bands by FSS systems increases. However, the interference situation is much worse. As shown in Table 12, several degrees of off-pointing are required between an Iridium satellite and the mainbeam of an FSS earth station at 20 GHz. Analyses of Iridium interference to other 20/30 GHz FSS systems likely would yield similar results. Thus, while FSS operators may choose to accept interference greater than the 6% delta T/T level, it is apparent that under Motorola's proposed sharing approach Iridium's feeder links often will have to be terminated for significant time intervals. Motorola presents no plan for rerouting feeder link traffic, signaling users of temporary interruptions of service, or other means for contending with the problems endemic to the sharing approach it proposes.

Table 12 - Iridium interference to 20/30 GHz FSS systems

Victim FSS System:	ACTS		Superbird		
Frequency Band:	20 GHz	30 GHz	20 GHz	30 GHz	
Iridium EIRP Density:	-41.3	-17.8	-41.3	-17.8	dBW/Hz
Victim Noise Temperature:	912	1080	300	1330	K
Victim Mainbeam Gain:	51.5/55.1	52.3	49.4	44.5	dBi
Received Interference Power Density (Note 1):	-171.5	-179.1	-177.7	-186.9	
Delta T/T (Note 2):	56,250	8,225	12,306	1,112%	
Discrimination required to obtain delta T/T < 6%:	40	31	33	23	dB
Required off-axis angle at earth station (Note 3):	5°	2°	4°	1°	

Note 1: It is assumed for 20 GHz downlink interference that the Iridium satellite is in the mainbeam of the FSS earth station at an elevation angle of 10 degrees. For the 30 GHz uplink cases, it is assumed that the Iridium earth station mainbeam is pointed at the FSS satellite. The interference levels so obtained indicates the amount of discrimination required from an FSS earth station antenna at 20 GHz and from an Iridium earth station at 30 GHz and, hence, the required off-axis angles.

Note 2: The delta T/T calculations conform with the method of RR Appendix 29.

Note 3: The antenna patterns of RR Appendix 29 are assumed for the FSS earth station antenna (20 GHz) and the Iridium earth station (30 GHz).

II. ELLIPSO AND IRIDIUM HAVE A NUMBER OF APPARENT RELIABILITY PROBLEMS

A number of parameters must be known in order to evaluate the reliability and performance of the proposed MSS systems and, hence, whether an applicant's claims are realistic. Complete descriptions of these parameters are particularly critical in the cases of Ellipso and Iridium because the information provided raises serious doubts about the levels of performance and reliability that will be achieved.

This section discusses several areas where the applicants omitted information on reliability that is required by the Commission. Among the most significant omissions, the applications of Ellipsat and Motorola have not sufficiently described (1) satellite visibility and coverage; (2) spacecraft electrical power systems; (3) gateway earth station deployment; (4) service restoration plans; (4) effects and mitigations of interference from other systems; and (5) spacecraft antenna pointing tolerances and methods for meeting those tolerances.

A. Satellite Visibility and Coverage

Three basic parameters of non-geostationary satellite systems are a vital part of an assessment of their reliability: (1) data regarding elevation and azimuth angles between user terminals and their host satellite(s) (i.e., visibility); (2) parameters depicting the handovers of user communications between spacecraft; and (3) the coverage density of the satellite constellation. These parameters should be established by applicants at an early stage of system development.

Satellite visibility statistics are needed in order to evaluate the potential gaps or disruptions in service that are associated with signal fading caused by shadowing (i.e., attenuation of the desired signal by terrain, buildings, foliage, the body of the user terminal operator, and by other obstacles) and by multipath (e.g., signal reflections from the same objects that at other times cause shadowing or signal refraction in atmospheric strata). The users of Ellipso or Iridium would have absolutely no control over the occurrence of these disruptive propagation mechanisms because of the continual motion of the satellites relative to the user. For example, a user next to a building or tree may initially have an adequate signal path to an Ellipso or Iridium satellite, but the signal may then fade to inadequate levels as the satellite transits the sky and the building or tree shadows the signal path. The user simply would not know in which direction he or she should move in order to sustain communications. This type of problem would render Ellipso and Iridium unsuitable for many MSS applications. The fact is, the motion of non-geostationary satellites virtually assures that communications that require sustained virtual or physical circuits (i.e., voice and many data communications) would be impossible at many locations.[24] In contrast, with geostationary MSS systems, a user located such that propagation is initially adverse need move only slightly in virtually any direction to obtain a steady, reliable signal. In this respect, geostationary MSS systems perform like high quality terrestrial mobile systems that have base stations at fixed locations, whereas Ellipso or Iridium signals would be comparable to vagarious shortwave broadcasts.

The requisite information on handovers is based on the mutual visibility statistics of two or more satellites in the constellation and convey the ranges of elevation angles over which handovers would be initiated and completed as well as the probability of unavailable handovers. The elevation angles at

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[24] The elevation angles to Ellipso and Iridium satellites will be relatively low for substantial percentages of the time and, therefore, debilitating propagation conditions will exist in Ellipso and Iridium uplinks and downlinks for substantial percentages of the time. Thus, it should be obvious that for purposes of interference analyses, Iridium's power levels should be assumed to be among the highest levels that its power control system can command. Ellipsat has not provided even basic parameters of its planned elliptical orbits such as the latitude and longitude of apogee, nor has it indicated over what portions of each orbital ellipse it would attempt to operate the satellites. In any case, with only 6 satellites in its constellation, and on the basis of the limited information provided, Ellipso users in the U.S. would have to operate at elevation angles of less than 25 degrees for over 50% of the time that any Ellipso satellite is visible; oftentimes, however, there will be no visible Ellipso satellite. Iridium users located at 37 degrees latitude would operate with elevation angles between 10 degrees and 20 degrees for 48% of the time. To put this in perspective, a 36 foot tree or building located 100 feet from an Iridium user would intervene on uplinks and downlinks to an Iridium satellite located at an elevation angle of 20 degrees or less.

which handovers are expected to be initiated and completed indicate the degree to which the Ellipso or Iridium handover scheduling is stressed or overstressed, and the extent to which satellite station keeping problems or failures may lead to dropped calls. Unavailable handovers occur when a handover would be required to sustain communications but other operational apssatellites are not appropriately located to receive the handover. This should not be confused with blocked handovers, which would occur in Ellipso or Iridium when handovers are required and the other visible satellite(s) have no available channels on which to accommodate the handover. In the proposed Ellipso and Iridium systems, unavailable and blocked handovers would occur regardless of the priority of the communications involved.

Other missing parameters relating to satellite visibility are the breadth and locations of "seams" between adjacent satellite orbital planes in which the satellites revolve about the Earth in opposite directions. The problems associated with seam width and location include the precession of large seams that may result in multiple successive handovers and discontinuities in transmission delays, which in turn can result in significant communications disturbances. In the case of Iridium, the transmission difficulties associated with the lack of inter-satellite links spanning the seam also need to be explored insofar as Motorola has not explained how it would sustain communications when the seam intervenes between the termini of the communications channel.

B. Spacecraft Electrical Power Systems

The efficacy of the spacecraft electrical power systems proposed by Ellipsat and Iridium cannot be adequately evaluated on the basis of the information supplied. Specifically, because the Ellipso and Iridium spacecraft would experience solar eclipses in over 90% of their orbital revolutions (often for more than 20% of their orbital period of revolution), and because the sun aspect angles of the Ellipso and Iridium solar arrays vary considerably throughout each orbit, detailed spacecraft battery charging and discharging budgets and complete descriptions of the underlying considerations are needed to verify that electrical power equilibrium can be maintained at the system capacity levels claimed by Ellipsat and Motorola. Indeed, it appears on the basis of the scant information supplied that neither Ellipso nor Iridium can deliver the high radio frequency ("RF") power levels that are claimed. For example, Motorola states that "the battery system will be sized to provide all housekeeping loads during eclipse plus some capability for communications." Application, p. 79. (Emphasis added.)

Among the apparent power system problems with Ellipso, the solar array is located on the gravity-gradient stabilization boom in a manner that apparently results in fixed-pointing of the array along the spacecraft yaw axis. Ellipsat Application, at 15. However, the sun will be located in the yaw axis only infrequently and briefly, such that the operational solar array efficiencies would be far less than the maximum achievable efficiency. Thus, it is doubtful that Ellipso can build and sustain ample charge of its battery, and it is also doubtful that Ellipso could produce the claimed power levels even when it is not operating under eclipse conditions. Iridium appears to suffer similar problems.

C. <u>Gateway Earth Station Deployment</u>

The handovers that occur in both the Ellipso and Iridium systems will include handovers of communications between different gateway earth station facilities in cases where the satellite in use moves out of coverage of either the mobile user terminal or the gateway (i.e., feeder link) earth station. If the gateway and mobile user happen to be co-located, and if another satellite is suitably positioned to accept a handover, there never would be a need to reroute the communication through alternate gateway and terrestrial facilities. However, this is not the case; there usually will be a large distance between the gateway and the mobile user that ultimately may require gateway handovers. One consequential problem is that in making these handovers, the total transmition delay over the channel may change significantly such that there is a gap or overlap in the communication.

Ellipso does not employ inter-satellite links; thus, a communication initiated through one satellite and gateway eventually would have to be handed over to another satellite and rerouted through another gateway facility that is within coverage of the satellite receiving the handover. Ellipsat did not address this problem. Motorola apparently attempts to remedy this problem at the expense of tremendous added complexity by using inter-satellite links; however, failures and blocking in Iridium inter-satellite links as well as the absence of cross-seam links means that Iridium will encounter rerouting requirements that Motorola does not address. The extent and disruptive effects of these problems can be ascertained only by Ellipsat and Motorola providing a complete description of the spatial deployment of gateway earth stations as well as the control system measures that would accomplish ground segment rerouting.

D. Service Restoration Plans

Service restoration plans are a critical element of applications for satellite systems, yet neither Ellipsat nor Motorola address this issue adequately, if at all. The problem is that in constellations of non-geostationary satellites, a failed satellite is not backed up by the other operational satellites. Instead, those ground stations that would normally operate via the failed satellite would experience interruptions in service as the failed satellite transits the sky. This problem is exacerbated by the short lifetimes of the proposed Ellipso and Iridium satellites (three and five years, respectively). Thus, beyond some point after initial deployment of the system, satellite failures and service interruptions will be routine occurrences. In order to better define the extent of this unreliability, Ellipsat and Motorola should provide the requisite service restoration information, including the anticipated durations and periods of service interruptions under various expected failure scenarios (e.g., two simultaneous satellite failures, three simultaneous satellite failures, etc.).

E. Interference from Other Systems

In Section I, it was demonstrated that Ellipso and Iridium would present severe interference problems to other systems. There also are complementary interactions where Ellipso and Iridium would receive extremely high levels of interference that would disrupt their own systems. Neither Ellipsat nor Motorola have described in their applications the expected levels and durations of disabling interference, nor have they described any potential mitigations that enable their systems to provide effective MSS in the interference environments that are present in the requested bands. Furthermore, insofar as Motorola's plan is to provide service to areas outside the U.S., extensive interference problems should be expected to arise in conjunction with the non-domestic services that have been proposed.

F. Spacecraft Antenna Pointing

The Ellipso and Iridium systems each would rely on precise interleaving and positioning of their respective satellite antenna beam coverage areas. However, neither Ellipsat nor Motorola have provided adequate information on satellite antenna pointing tolerances that would enable assessment of the consequential coverage gaps and self-interference problems. It is apparent from Ellipsat's application that antenna pointing accuracy is reliant on the spacecraft attitude control accuracy since the antenna is affixed to the gravity-gradient boom. However, Ellipsat has omitted information on the accuracy of its attitude control system, and so, it is not possible to evaluate fully the extent of Ellipso's antenna pointing problems.

It would appear that Iridium antenna pointing tolerances could severely curtail Iridium's frequency reuse capabilities. This is because adjacent Iridium satellites must generate precisely abutted beams in order to produce a composite "cellular" coverage pattern that resembles the ideal pattern that has been portrayed. Specifically, if the antennas on either of two adjacent Iridium satellites were mispointed by only a small amount, beams whose coverage areas are supposed to abut one another would, instead, overlap or fail to cover the service area in contiguous fashion. The unwanted-overlap problem reduces Iridium's potential for reusing frequencies in a regular cellular pattern and, in fact, may destroy the ability of Iridium's closely synchronized time division multiple access slots to provide isolation sufficient to enable any frequency reuse over expansive areas. The coverage gap problem caused by antenna mispointing may result in communications gaps that, at best, would be annoying in the personal communications context. Such gaps are yet another reason why Iridium would be unsuitable for safety communications and other critical MSS needs.

III. THE CAPACITIES OF THE APPLICANT'S SYSTEMS ARE SUBSTANTIALLY LESS THAN THOSE CLAIMED BY MOTOROLA AND ELLIPSAT

Ellipsat and Motorola claim that their systems would provide extremely high capacities. In fact, these claims are based on assumptions that are totally incorrect. Neither applicant has considered limitations on system capacity attributable to the interference environment in which they would operate, the technical standards with which they must comply, inadequate spacecraft power supplies, or practical limits on the ability of their respective network management systems to deliver available capacity where it is needed and when it is needed. When these factors are properly considered, the capacity levels of Ellipso and Iridium are seen to be far less than the applicants' estimates. Ellipsat would have no more than one channel in one direction of transmission. Iridium would have no more than 10 channels for service to CONUS. These results indicate that the technologies proposed by Ellipsat and Iridium cannot cope with the standards and sharing constraints incumbent in the 1610-1626.5 MHz and 2483.5-2500 MHz bands.

A. The Capacity Achievable by Ellipso is Less Than Three Percent of Its Estimate

Ellipsat claims that its satellites can support 200 CDMA carriers, depending on the interpretation of the information supplied.[25] However, Ellipsat's capacity is based on several unrealistic assumptions, including (1) that there are no power limits with which it must comply; (2) that Ellipso would have unconstrained access to the full 16.5 MHz of spectrum in both the uplink and downlink bands; and (3) that its spacecraft can deliver an average power of 170 watts.[26] As discussed in Section I, there are uplink and downlink power limits that Ellipso violates substantially. It was also shown in Section I that Ellipso simply cannot operate in the 1610-1618.1 MHz segment without causing harmful interference to radio astronomy and radionavigation-satellite systems. In addition, sharing with other services may impose further constraints on frequency usage. Prevention of this interference would necessitate capacity reductions over and above those needed for conformance with the power limits. As stated in Section II, it is doubtful that an

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[25] Ellipsat application addresses both and Ellipso I (first generation) and Ellipso II (2nd generation) space segment. Several ambiguities exist throughout the application as to which space segment is being discussed. In the section titled "Transponder Capacity Estimates," it is stated that each satellite can support 200 carriers. Ellipsat Application, at 28.

[26] Id.

Ellipso satellite can deliver an average power level of 170 watts. (However, it is conceivable that Ellipso satellites could supply power commensurate with the other foregoing capacity limitations.)

The requisite reductions in Ellipso power levels and elimination of Ellipso channels below 1618.1 MHz will reduce Ellipso's system capacity by 95%, as shown in Table 13. In other words, Ellipso could operate only one channel modified to meet the power limit. Thus, Ellipso could operate in only one direction of transmission since it requires two channels for two-way communications.

Table 13 - Calculation of Ellipso capacity

Amount By Which Ellipso Violates The PFD Limit (Note 1):	7 dB
Percent of Stated System Capacity Available With PFD Conformance (Note 2):	20%
Number of Channels Unusable Due To Sharing With Radio Astronomy And Radionavigation-Satellite:	5 out of 10 channels
Number of Usable Channels (Note 3):	1

Note 1: See Table 3. The actual amount by which Ellipso would exceed the PFD limit could exceed 7 dB. This would occur with a distribution of power among the 10 Ellipso channels in a less balanced manner than was assumed in Table 3.

Note 2: Depending on the approach taken to redesign Ellipso to conform with the PFD limit in the 2483.5-2500 MHz band, the reduction in capacity would be approximated by the requisite reduction in satellite EIRP density.

Note 3: Ellipso could use one channel in only one direction of transmission, provided that the chip rate on that channel is increased by a factor of at least five. The requisite modification would enable only five users to be served simultaneously.

B. The Capacity Achievable by Iridium is Less Than One Percent of Its Estimate

Motorola claims its system can provide 6,960 channels for service to the contiguous United States ("CONUS") on the basis of (1) a theoretical frequency reuse factor, (2) no limit on PFD, (3) use of 16.5 MHz without any frequency sharing constraints, and assumptions that (4) the Iridium spacecraft power system can deliver power sufficient to sustain communications on all channels and (5) that feeder link and inter-satellite sub-systems impose no capacity limits. In other words, Motorola's stated capacity is not based on practical considerations.

As shown in the calculations in Table 14, the deliverable amount of capacity for service to CONUS would be less than 10 channels if Iridium must comply with existing PFD limits and if the system capacity were also limited in order to avoid interference to radio astronomy and radionaviagation-satellite systems. This capacity represents 0.14% of the capacity claimed by Motorola. The capacity of Iridium could be further limited by sharing constraints (e.g., from the Fixed service or from splitting the band with another MSS system); spacecraft power limitations (i.e., there are limits on the amount of time during which maximum capacity can be delivered); and capacity limits of feeder links and inter-satellite links. (With regard to Motorola's claimed capacity, feeder link and inter-satellite link blocking could be substantial in light of the amount of system and network control data that also must be carried on the feeder and inter-satellite links during full loading).[27]

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[27] Motorola is vague as to the allocation of network and system control functions among system elements, such that it is difficult to estimate the extent of system overhead communications in the Iridium feeder and inter-satellite links. It is quite possible that these links ultimately may limit Iridium's capacity for service to a large contiguous are such as CONUS.

Table 14 - Calculation of Iridium's capacity

Claimed number of virtual channels per cell (Note 1):	174 (uniformly distributed)
Number of cells in CONUS:	40
Number of CONUS virtual channel time and frequency slots:	6,960 (claimed)
Power-limited virtual channel capacity factor (Note 2):	1/399
Spectrum limitation factor (Note 3):	0.6
Effective number of Iridium channels for service to CONUS (Note 4):	10 channels
Percent of claimed capacity actually available:	0.14% powered ch.s/ claimed ch.s

Note 1: The power system problems in Iridium satellites may limit capacity to 110 channel/cell assuming two time slots are used per cell. Application, at 57. However, Motorola claims its capacity in the 16.5 MHz bandwidth is 6,960 channels. Application, at 60.

Note 2: As shown in Table 2, Iridium exceeds the applicable PFD limit by 26 dB; thus, compliance with the PFD limit would nominally reduce Iridium system capacity by 26 dB (factor of 1/399) depending on how Motorola would redesign its system for conformance.

Note 3: Iridium cannot operate below 1616.5 MHz because of the attendant interference problems. See Section I.B.

Note 4: The equivalent 10 channels are for CONUS-wide service.

IV. THE MERITS OF THE SYSTEMS PROPOSED BY MOTOROLA AND ELLIPSAT ARE OVERSTATED OR COMPLETELY ERRONEOUS

A. Ellipsat's Mobile Terminal Design Based on Adaptors for Existing CDMA Cellular Terminals is Not Practical

Ellipsat claims that its mobile user terminal ground segment would be largely comprised of existing CDMA cellular terminals to which a $300 adapter would be added. Application, at 11-14. The proposed adaptors would accomplish frequency conversion between 800 MHz cellular transmit and receive frequencies and the frequencies used by Ellipso, amplification of signals to the requisite power levels, and automatic switching of the adapter unit into and out of the RF cabling of the cellular unit according to whether terrestrial cellular or Ellipso-based service is to be used. As an initial matter, Ellipsat does not identify a particular existing, experimental or conceptual cellular terminal or provide a description of the cellular terminal that would enable so simple an adaptation to be made for operation with Ellipso. In addition, there are a number of apparent design and operational problems with Ellipsat's proposed terrestrial cellular adapter that indicate that its cost would be higher than the cost of a conventional user terminal and the adaptor cannot properly be characterized as providing "seamless" interoperability between terrestrial cellular systems and Ellipso.

Through consideration of the major sub-systems of CDMA cellular user terminals, it is easy to see that Ellipsat's adaptor simply cannot work as described.[28] Specifically, it is highly unlikely that any existing or future cellular terminal does or will use the same spread spectrum chip rate, voice source coding algorithm, signaling method, multiplexing method, and error correction algorithm as Ellipso. This is because optimal selections of these major design elements for the 800 MHz cellular signal propagation scenario, frequency reuse environment, and frequency allocation constraints, are unlikely to be similar to, let alone identical to, the selections made by Ellipsat. Thus, the adaptor would, therefore, essentially consist of separate Ellipso and cellular terminals. In short, it would be cheaper to have two separate radios.

B. Motorola's Claimed Superior Transmission Delay Properties are Overstated

Motorola claims that Iridium's transmission delay properties inherently provide advantages. Motorola Application, at 14. However, no quantitative or qualitative delay information is provided. In any case, it is obvious that a cross-country call over the Iridium "virtual" circuits would encounter several

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[28] The RF switches that would insert and remove the Ellipso adaptor from the RF cabling would be controlled by some processor that Ellipsat has not described. The balance of the adapted terminal would consist of highly integrated cellular CDMA user terminal sub-systems that are not likely to be consistent with Ellipsat's design.

delays that could exceed the delay over an MSS system using geostationary satellites. Table 15 lists estimates of the various transmission delays that may contribute to the overall delay in an Iridium cross-country circuit between a mobile user and a telephone user. In this estimate, it is assumed that Motorola will wish to bypass other transmission systems to the extent possible. The 215-225 millisecond delay estimated for the cross-country link is comparable to the delay encountered in a geostationary MSS system (about 260 milliseconds). In the event that the call over Iridium is between mobile users, the delay may be on the order of 280 milliseconds as a result of time differences between the time of arrival of a packet over an inter-satellite link and the time at which it may be transmitted in the appropriate TDMA time slot.

Table 15 - Estimated transmission delay in an Iridium virtual circuit between users located in the Pacific Ocean and East Coast areas

Mobile terminal source coding and packet assembly (Note 1):	80 msec
Packet propagation delay, mobile-to-satellite:	2.5 to 7.7 msec
Delay Over N-Hop Inter-satellite Path:	
- Packet demodulation, error correction, routing, insertion in serial TDM stream, and retransmission:	(5 msec)
- Inter-satellite propagation delay:	(N x 13 msec)
- Cross-link demodulation, packet routing, reinsertion in serial TDM stream, and retransmission:	(N x 4 ms)
- Total Delay Over N=3 Inter-Satellite Hops To Terminating Satellite (Note 2):	56 msec
TDM demodulation and decommutation, routing,and TDM retransmission:	4 msec
Propagation delay, Satellite-to-Gateway:	2.5 to 7.7 msec
Gateway TDM demodulation, error correction, packet routing, decoding:	70 msec
Total Delay:	215 to 225 msec

Note 1: Iridium terminals must encode the real-time voice signal and insert the voice symbols into packets for burst transmission. Because the transmission frame is 60 ms in duration, 60 ms of real time voice signals must be captured before its associated packet can be sent. The packet must be ready for transmission slightly ahead of the assigned transmission time slot. No additional, variable delay buffering is assumed for the purposes of maintaining continuous communications during handovers.

Note 2: Three inter-satellite hops often would be needed on calls between Hawaii and the East coast of the U.S. It is assumed that no orbital seam intervenes between these user locations. In the event that a seam is intervening, Iridium apparently would not utilize its inter-satellite links to complete the transmission path.

C. Neither Ellipsat Nor Iridium Provide True RDSS

Ellipsat and Motorola claim their systems will provide RDSS.[29] Neither system, however, can autonomously determine the position of remote users in real time. In the position location techniques proposed by Ellipsat, a pair of satellites is capable of determining a line of position and two such lines of position are needed to determine a user location. The visibility statistics for Ellipso satellites, however, indicate that over one-half hour may be needed to determine a user location. (See Section II.A herein). The Iridium system does not determine accurate positions, in that it is able to resolve user locations to within only one mile of the actual user location. Instead, for the accurate position determination normally associated with RDSS, it communicates positions that have been determined by other systems (e.g., GPS).

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[29] See Ellipsat application, at 18-21, and Motorola application, at 22-23.

TECHNICAL APPENDIX

EXHIBIT 1

Supplemental Comments of AMSC
in Gen. Docket No. 89-554
(February 21, 1991) Exhibit 1

Exhibit 1-1. Computation of the number of simultaneous, co-channel Iridium uplink signal bursts interfering with a geostationary MSS satellite receiver

1. A satellite in the geostationary satellite orbit (GSO) would have geometric line-of-sight visibility to Iridium transmitting mobile earth stations located on a spherical sector of the Earth's surface that has an Earth-central angle of 81.3°. Iridium transmitting aircraft earth stations would similarly be visible when located over a spherical sector having an Earth-central angle of 85.6°. Because of atmospheric refraction of radio signals (i.e., earthward bending of the radio path), emissions from Iridium earth stations located beyond these geometric horizons also can be received by GSO satellites. In order to simplify the analysis of Iridium uplink interference to GSO MSS satellites, and in the interest of forcing errors from simplifications to yield conservatively low estimates of interfering signal levels, the following assumptions are made:

1a. Atmospheric refraction effects are disregarded;

1b. All Iridium mobile earth stations located outside a spherical segment having an 81.3° Earth-central angle are disregarded.

2. Iridium uplink interference entries into a spot beam generated by a North American MSS satellite will be considered. The projection of the assumed GSO satellite beam on the "cells" generated by Iridium satellite antenna spot beams is illustrated in the adjoining figure. The number of co-channel, uplink bursts received simultaneously by the example GSO satellite beam is well approximated by the number of Iridium cells within the subject beam divided by seven. This is because Iridium employs a seven-cell frequency reuse pattern and because co-channel uplink bursts are generated in one cell in each cluster of seven cells during the same TDMA time slot. (_See_ Motorola application, at 54-56a.) Portions of 48 Iridium cells are contained within the GSO satellite beam; however, only 35 of these 48 cells are assumed to be in use (i.e., Iridium is operating at less than peak capacity). Five (i.e., 35/7) co-channel, uplink bursts are assumed to be received simultaneously from Iridium mobile earth stations located within the GSO satellite beam.

Exhibit 1-1 (Cont.). Computation of the number of simultaneous, co-channel Iridium uplink signal bursts interfering with a geostationary MSS satellite receiver

PROJECTION OF EXAMPLE GSO SATELLITE
SPOT BEAM ON THE IRIDIUM CELLS

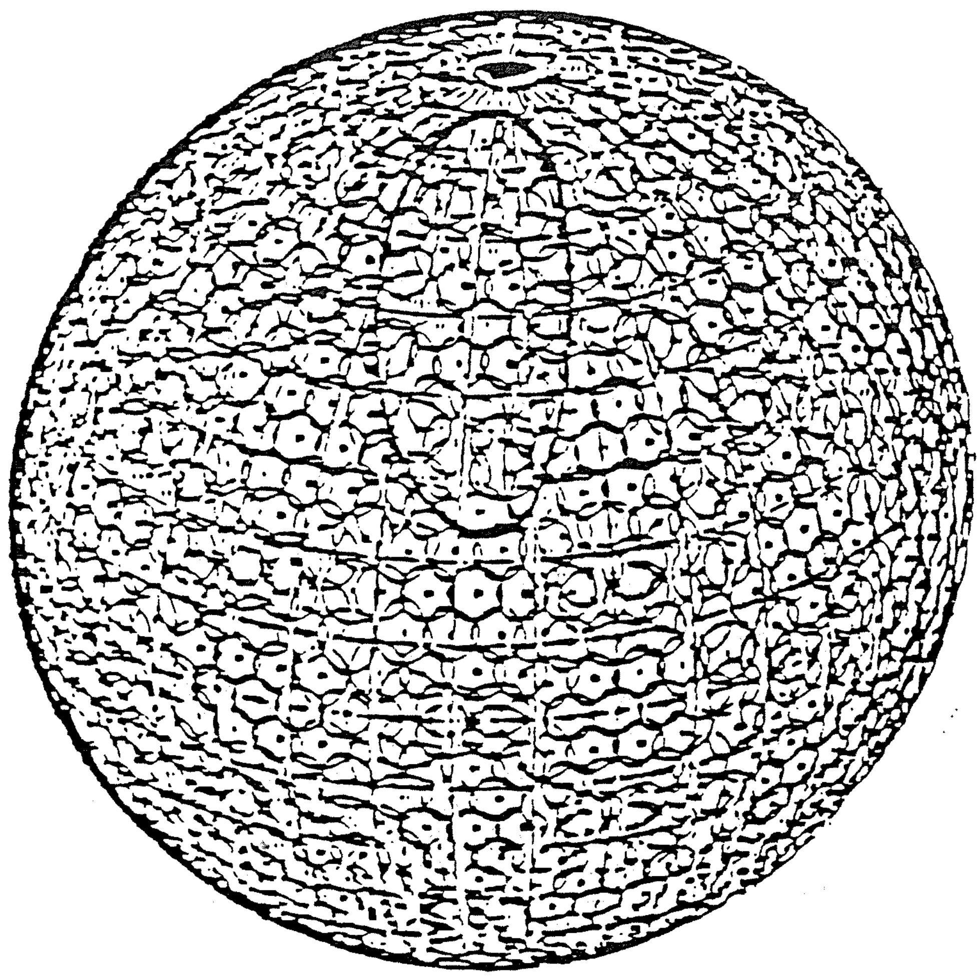


Exhibit 1-1 (Cont.). Computation of the number of simultaneous, co-channel Iridium uplink signal bursts interfering with a geostationary MSS satellite receiver

3. In addition to the Iridium interferers located in the GSO satellite beam, it is necessary to consider the other simultaneous, co-channel interferers that would be dispersed over the entire area visible to the GSO satellite. While the GSO satellite antenna gain towards these additional interferers is much lower than its peak gain, the lower gain is offset by higher numbers of interferers. Based on area calculations, over 690 Iridium cells are visible from a GSO satellite. However, as noted in Item 2 above, it is not assumed that Iridium is operating at peak capacity (i.e., this is not a worst-case analysis). We assume that only 580 of the 690 visible Iridium cells are in use on a co-channel basis. Thus, it is assumed that 83 (i.e., 580/7) co-channel Iridium uplink bursts are received simultaneously. The following table shows the distribution of simultaneous, co-channel traffic among the types of beams associated with the 580 cells that are under consideration. The "beam type" is important insofar as the equivalent isotopically radiated power (EIRP) of Iridium earth stations is dependent on the gain of the Iridium satellite beam that will receive the signal (i.e., uplink power control is used).

DISTRIBUTION OF CO-CHANNEL UPLINK TRAFFIC AMONG IRIDIUM BEAMS (580 visible cells)

PARAMETER	BEAM TYPE							Σ
	1	2	3	4	5	6	7	
Distribution of Beam Types In That Are Active Simultaneously (Averaged over 7 Mid-Latitude Iridium Satellites)	3	4	4	6	6	6	1	30
Number of Bursts Received by the GSO Satellite Simultaneously	9	9	12	16	16	17	4	83

Exhibit 1-1 (Cont.). Computation of the number of simultaneous, co-channel Iridium uplink signal bursts interfering with a geostationary MSS satellite receiver

4. In determining the above distribution of uplink transmissions among satellite beam-types, it was necessary to consider the deactivation of Iridium satellite antenna beams in satellites located at mid- and high-latitudes that occurs in order to avoid overlaps among beams from adjacent Iridium satellites. At mid-latitudes, approximately seven beams are deactivated in each Iridium satellite (e.g., three type 1 beams, two type 2 beams, and two type 3 beams). At lower latitudes, all 37 satellite antenna beam are activated to maintain full-Earth coverage but the demand for service may be relatively low (i.e., intensive frequency reuse is not needed).1/ Likewise, at higher latitudes, less than 30 satellite beams are activated and the service demand may be relatively low. Thus, for the purposes of defining the distribution of uplink traffic among Iridium satellite antenna beam-types, it is reasonable to assume that an average of 30 satellite antenna beams are active in all Iridium satellites involved in the uplink interference situation.

5. Bursts in Iridium uplinks using the same TDMA time slot (i.e., those associated with a set of cells that are exercising frequency reuse) are synchronized to arrive simultaneously at the associated Iridium satellites. Thus, because the uplink desired signal paths vary in length from 765 km to about 2300 km, the leading edges of the bursts span an interval of 5.2 milliseconds (msec). These bursts are further dispersed in time over an interval of 19.6 msec as a result of different path lengths to the GSO. Because the uplink bursts are only 2.9 msec in duration, and because the interval between uplink bursts is 4.2857 msec (from different mobile earth stations), the average number of simultaneously received uplink bursts is approximately 0.68 (2.9/4.2857) times the number of uplink bursts per time slot. In order to simplify the analysis and to arrive at conservatively low levels of interference, this time averaging is incorporated in the analysis by reducing the received interference level by a "burst overlap factor" of 1.7 dB (i.e., 10 log 0.68).

1/ According to Doc. US JIWP-26 "LEO and GEO Sharing of 1-3 GHz Satellite Allocations," (dated January 28, 1991), which was prepared by Motorola for consideration by the U.S. CCIR National Committee, Iridium satellite antenna beams will be deactivated when their half-power beamwidth illuminates the GSO. Thus, all 37 Iridium beams would not be used at certain times while the satellite is at low latitudes. This proposal was made by Motorola in an attempt to reduce the level of Iridium downlink interference that would be caused to receiving GSO satellites. Regardless, as will be shown in Exhibit 2, the interference caused to receiving GSO MSS satellites from Iridium downlinks is onerous.

Exhibit 1-1 (Cont.). Computation of the number of simultaneous, co-channel Iridium uplink signal bursts interfering with a geostationary MSS satellite receiver

6. The frequency dispersion of co-channel Iridium uplink bursts as a result of Doppler shift is not sufficient to reduce the number of bursts that interfere with the same channel in a GSO MSS system. Specifically, because the Iridium mobile earth stations adjust their uplink frequencies to offset Doppler shifts with respect to their associated satellites, and because the Iridium satellites have velocities as high as 6.6 km/sec with respect to a mobile earth station, the uplink signal burst may be transmitted at frequencies spanning a +/-35.9 kHz range about the nominal assigned frequency (disregarding frequency instability, which is relatively small). Given that the occupied bandwidth of an Iridium uplink burst is 126 kHz (Motorola application, at 57), the "co-channel" Iridium uplink bursts will overlap one another over a bandwidth of at least 54 kHz (i.e., 126 kHz - 2x35.9 kHz).

Exhibit 1-2 (Cont.). Computation of Iridium interfering uplink signal power at the antenna port of the receiving GSO satellite

3. According to Motorola's application (at Appendix A), the EIRP levels associated with each of the seven types of satellite antenna beams are as follows (both the minimum and maximum power levels will be considered):

Beam Type "i":	1	2	3	4	5	6	7
Minimum EIRP (watts):	1.36	1.33	1.33	1.53	2.23	3.71	5.0
Maximum EIRP (watts):	7.50	7.50	7.50	5.92	7.31	8.93	10.54

4. The areas "j" are defined as follows for the purposes of determining quantized average values for the parameters d_j and g_j.

Area "j" Index No.	Definition of Area "j"	d_j (dB)	g_j (dBi)
1	The area within the half-power coverage contour of the GSO beam	0	30
2	The sector outside area 1 but within a contour located 0.5 minor-axis beamwidths from the GSO beam	0	24
3	The sector outside areas 1 and 2 but within a contour located 1.0 minor-axis beamwidths from the GSO beam 4	0	18
4	The sector outside areas 1-3 but within a contour located 1.5 minor-axis beamwidths from the GSO beam	0	12
5	The sector outside a contour located more than 1.5 beamwidths from the GSO beam	+1	8

The Iridium earth station antenna discrimination levels ("d_j") presented above optimistically assume that, when all transmitting mobile earth stations are considered, on the order of 1 dB of discrimination is available in area j=5 relative to the gain towards the Iridium satellite (i.e., relative to the antenna gain encompassed in the Iridium earth station EIRP levels).

Exhibit 1-2. Computation of Iridium uplink interfering signal power at the antenna port of the receiving GSO satellite

1. The RF interfering signal power level at the GSO satellite receiver antenna port is computed as the sum of the co-channel interfering signal power levels generated by Iridium uplink signals that are simultaneously present. The interfering signal power level is calculated as follows:

$$I_{RF} = 10 \log \sum [n_{ij}(EIRP_i)(g_j)/(d_j)] - D_u - VA - 189 \text{ dB}$$

where:

I_{RF} = interfering signal power (dBW) at the GSO satellite antenna port from co-channel Iridium signal bursts;

"i" is the type of Iridium beam associated with an uplink burst (i = 1, 2, 3, ...7);

"j" is the area associated with an Iridium earth station antenna discrimination level and a GSO satellite antenna gain level (j = 1, 2, 3, 4, or 5);

n_{ij} = number of Iridium uplink bursts associated with "i" and "j";

$EIRP_i$ = the equivalent isotropically radiated power (watts) of an Iridium mobile earth station transmitting to beam type "i";

g_j = the antenna gain (numerical power ratio) of the GSO satellite towards area "j";

d_j = the gain (numerical power ratio) of the Iridium mobile earth stations in area "j" in the direction of the GSO satellite relative to their gain towards the associated Iridium satellites;

D_u = time dispersion factor (1.7 dB) for averaging the number of Iridium co-channel uplink bursts received simultaneously at the GSO satellite (see Exhibit 1-1, Item 5);

VA = Iridium packet transmission probability factor for active uplinks (assumed to be 4 dB, consonant with typical baseband speech activity);

189 dB is the nominal basic transmission loss on all interfering signal paths.

2. It should be noted that a 40% voice activity factor "VA" is assumed in the interference equation presented in Item 1, above. This 4 dB reduction in uplink interference may be over optimistic because Iridium voice packet assembly may not reflect the 40% average baseband voice activity, and because Iridium is intended to provide RDSS, data and facsimile services that do not yield 40% average loading of channels.

Exhibit 1-2 (Cont.). Computation of Iridium interfering uplink signal power at the antenna port of the receiving GSO satellite

4. (Cont.) The fact is, at times, the Iridium earth station EIRP towards a GSO satellite will exceed its EIRP towards the Iridium satellite by as much as 2 dB (i.e., "d_j" would equal -2dB). The quantized GSO satellite antenna discrimination levels are based on the gain pattern of AMSC's and TMI's MSS satellites. The minor-axis beamwidth used as a reference for the above area definitions is the smallest beamwidth as measured through the beam axis in a cross-section of the GSO spot beam.

5. For the above uplink interference model, the values of n_{ij} presented below are used for the summation in the interference equation defined in Item 1.

NUMBER OF SIMULTANEOUS, CO-CHANNEL INTERFERENCE ENTRIES BY BEAM TYPE AND AREA OF ORIGIN

Beam Type i	1	2	3	4	5	6	7
Area							
j=1	1	0	1	1	1	1	0
j=2	1	1	1	1	1	1	1
j=3	1	1	2	3	2	3	1
j=4	2	2	3	3	4	4	1
j=5	4	5	5	8	8	8	1
$\sum n_i$	9	9	12	16	16	17	4

6. <u>Results</u>. Application of the equation in Item 1 yields:

I_{RF} = -152.3 dBW for Iridium mobile earth stations operating at their minimum power levels;

I_{RF} = -146.8 dBW for Iridium mobile earth stations operating at their maximum power levels.

Exhibit 1-3. Computation of the C/I levels caused by Iridium uplink interference in a representative uplink channel used in the GSO system

1. The equation below is used for the purpose of computing the interfering Iridium uplink signal power falling within a representative channel in the GSO system (assuming that C/I at the GSO satellite equals the C/I at its receiving feeder link earth station). The interfering signal level computed here is the average instantaneous signal level (over time) and should not be confused with "worst case" interference levels. No attempt has been made in this analysis to model the worst-case interference situation.

$$I = I_{RF} - OTR + n_i - n_o$$

where:

OTR is the on-tune rejection, as described in CCIR Reports 654 and 972:

$$OTR \quad 10 \log \left[\frac{(\text{Iridium signal bandwidth})}{(\text{GSO system receiver noise bandwidth "B"})} \right]$$

$$10 \log [126 \text{ kHz}/B \text{ kHz}]$$

n_i is the average-to-peak power ratio (dB) for Iridium uplink bursts;

n_o is the duty cycle of the GSO MSS channel response waveform (in dB); from CCIR Report 972;

$$n_o = 10 \log \left[\frac{(t_s, \text{ Iridium burst width (milliseconds)})}{(T_s, \text{ time between bursts (milliseconds)})} \right]$$

$n_o = n_i$ for the Iridium signal burst parameters;

thus:

$$I = I_{RF} - OTR$$

2. Desired signal carrier power levels at the GSO satellite receiver are as given for representative channels in AMSC's system ("Request for Modification and Supplemental Information of AMSC," at Attachments 5 and 7). An ICAO-standard type of GSO MSS channel will be considered:

Exhibit 1-3 (Cont.). Computation of the C/I levels caused by Iridium uplink interference in a representative uplink channel used in the GSO system

2. (Cont.)

"Configuration AERO 2" - an ICAO-standard C-channel for aeronautical safety applications operating at a 10.5 kbps information rate.

3. <u>Results</u>: Intermediate parameters for use with the equation given in Item 1 and the resulting C/I levels are as follows:

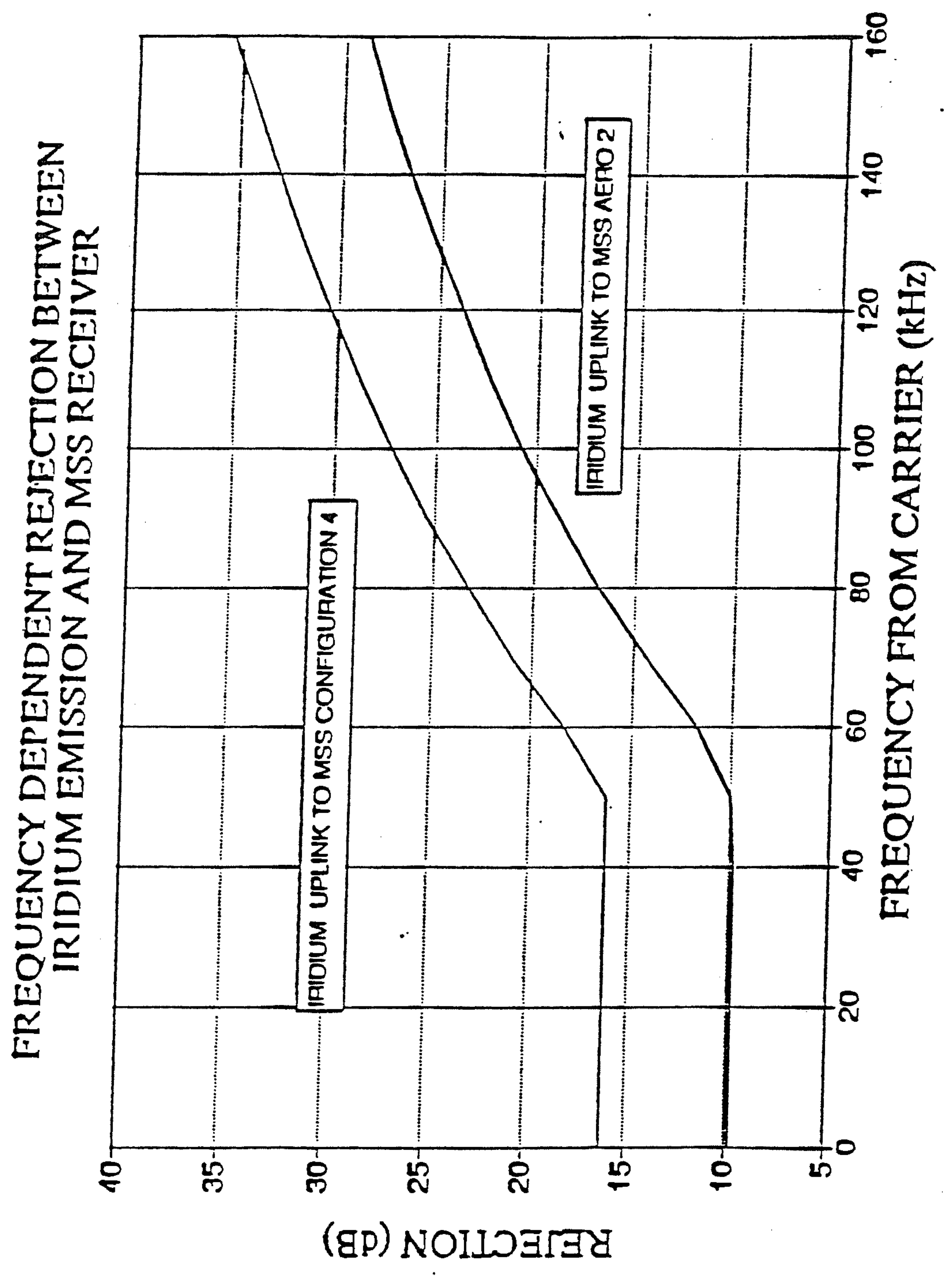
Iridium Power Levels	Minimum	Maximum
GSO MSS Symbol Rate (ksps)	10.5	10.5
Noise Bandwidth B (kHz)	13.1	13.1
I_{RF} (dBW)	-152.3	-146.8
OTR (dB)	9.8	9.8
I (dBW)	-162.1	-156.6
C (dBW) (NOMINAL)	-152.0	-152.0
C (dBW) (THRESHOLD)	-154.8	-154.8
C/I (dB) (NOMINAL)	10.1	4.6
C/I (dB) (THRESHOLD)	7.3	1.8

The above nominal and threshold C/I calculations assume that the desired signal (C) is at unfaded levels and at levels corresponding to the minimum performance objective, respectively. Under realistic conditions of desired signal fading, even lower C/I levels would occur. Because the Iridium uplink transmission bursts will elicit noise-like burst responses in GSO MSS channels, and because the above C/I levels would substantially increase receiver noise power levels, the link bit error rate will increase significantly even under ideal conditions of desired signal propagation and optimistic interference assumptions.

Exhibit 1-3 (Cont.). Computation of the C/I levels caused by Iridium uplink interference in a representative uplink channel used in the GSO system

As a consequence, GSO MSS communications would be disrupted by Iridium uplink emissions alone, and the interference would be considered harmful. These results do not include the interference that would occur simultaneously from Iridium downlinks.

The adjoining figure depicts the frequency dependent rejection (FDR) of the assumed ICAO-standard GSO MSS channel with respect to the Iridium uplink bursts, assuming that the bursts are all tuned to the same frequency. However, as was noted in Item 6 of Exhibit 1-1, the bursts received at a GSO satellite are dispersed in frequency such that they all overlap only within a 54 kHz band centered on the nominal burst channel frequency. Doppler dispersion of the bursts increases the aggregate uplink interference because of the concave shape of the FDR curve.


FREQUENCY DEPENDENT REJECTION BETWEEN
IRIDIUM EMISSION AND MSS RECEIVER
IRIDIUM UPLINK TO MSS CONFIGURATION 4
IRIDIUM UPLINK TO MSS AERO 2
REJECTION (dB)
40
35
30
25
20
15
10
5
0
20
40
60
80
100
120
140
160
FREQUENCY FROM CARRIER (kHz)

<u>TECHNICAL APPENDIX</u>

<u>EXHIBIT 2</u>

Supplemental Comments of AMSC
in Gen. Docket No. 89-554
(February 21, 1991) Exhibit 2

Exhibit 2-1. Number and categorization of transmitting Iridium satellites that can cause interference to GSO MSS satellite uplinks

1. The total number of Iridium satellites that are visible from a satellite in the geostationary satellite orbit is (approximately):

N = N, x A,   A,

where:

N = number of Iridium satellites visible from a GSO satellite;

N, is the total number of Iridium satellites (77);

A, is the area of the Iridium orbital sphere;

$A = 4\pi(R + a)^2$

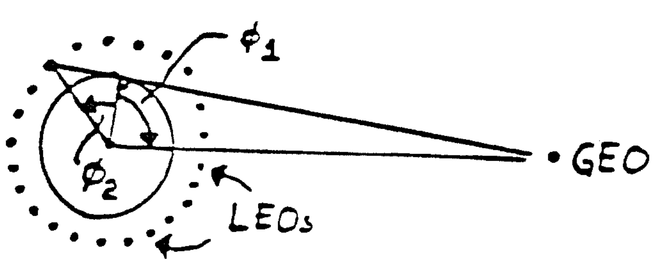
and R = Earth radius = 6368 km,

a = Iridium orbital altitude = 765 km:

thus A, = 639,373,029 km^2;

A, is the area of the visible region of the Iridium orbital sphere;

A, = (area of orbital sphere) - (area of orbital sphere not in view from GSO)



$\emptyset_1$ = 81.31°
$\emptyset_2$ = 26.78°
$\emptyset_3 = 180° - \emptyset_1 - \emptyset_2$
h = height of non-visible sphere segment
$h = (R+a) - (R+a) \times \cos\emptyset_3$
= 4918 km

$A, = A, - 2\pi(R+a) \times h$

= 418,958,298 km^2

and, thus:

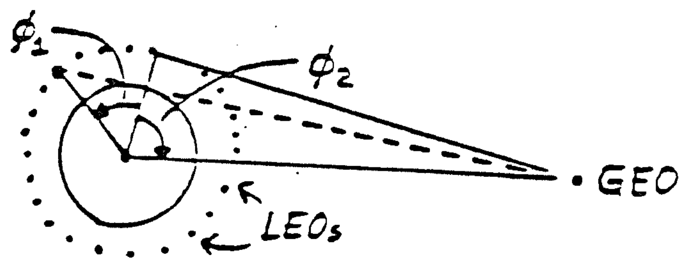
N = 50.5 (49 Iridium satellites are assumed to be visible to a GSO satellite to obtain conservatively low interference estimates, even though 51 or more satellites could be visible for upwards of 50% of the time).

Exhibit 2-1 (Cont.). Number and categorization of transmitting Iridium satellites that can cause interference to GSO MSS satellite uplinks

2. Two angular regions of the Iridium orbital sphere are significant in terms of the interference caused to a GSO MSS satellite. These are defined as follows:

* "Angular region 1" is the annulus of the Iridium orbital sphere located near the rim of the Earth as seen by the GSO satellite. In this angular region, the underside of Iridium satellites is visible to the GSO satellite (i.e., the nadir-looking type 7 Iridium beams may be significant) and small off-axis angles occur for certain of the Iridium beams of type 1-6 in the direction of the GSO satellite (i.e., little Iridium satellite antenna discrimination is available in some cases).

* "Angular region 2" is the visible segment of the Iridium orbital sphere bounded by the edge of the above Earth-rim annulus. Iridium satellites in this region generally will have greater discrimination towards the GSO satellite than that which occurs in angular region 1.



$\emptyset_1 = 27.83^\circ$
$\emptyset_2 = 80.26^\circ$

$h_1 = (R+a) - (R+a) \times \cos\emptyset_1$
$h_2 = (R+a) - (R+a) \times \cos\emptyset_2$

3. From the geometry of the above defined angular regions of concern, the equations used in Item 1 (for 49 visible Iridium satellites) yields:

Number of Iridium Satellites in Angular Region 1 = 16

Number of Iridium Satellites in Angular Region 2 = 33

Exhibit 2-2. Computation of the number of co-channel Iridium downlink bursts that would simultaneously interfere with a GSO MSS satellite uplink

1. In Exhibit 1-1, an uplink beam activity distribution was developed for Iridium satellites located at mid-latitudes; this distribution is equally applicable to the Iridium downlink situation. However, in angular region 1, some satellites will be in polar regions where few of the 37 satellite beams would be activated (in order to avoid overlap with beams from adjacent satellites). Accordingly, the following downlink beam activity is assumed.

DOWNLINK BEAM ACTIVITY OF INTERFERING IRIDIUM SATELLITES

ANGULAR REGION "k"	TOTAL NUMBER OF SATELLITES	ASSUMED ACTIVITY MODEL
1	16	14 sat.s as in Exhibit 1-1, and 2 sat.s using only one beam type 7
2	33	As given in Exhibit 1-1

2. From the above general downlink beam activity, the table below indicates the distribution of simultaneously transmitted downlink bursts among the various beam-types.

DISTRIBUTION OF SIMULTANEOUS DOWNLINK BURSTS AMONG BEAMS

PARAMETER	BEAM TYPE							Σ
	1	2	3	4	5	6	7	
Number of Simultaneous Transmissions From Angular Region 1	6	8	8	12	12	12	4	62
Number of Simultaneous Transmissions From Angular Region 2	14	19	19	28	28	28	5	141

Exhibit 2-2 (Cont). Computation of the number of co-channel Iridium downlink bursts that would simultaneously interfere with a GSO MSS satellite uplink

3. Bursts in Iridium downlinks using the same TDMA time slot (i.e., those associated with a set of cells that are exercising frequency reuse) are transmitted simultaneously. Thus, because the downlink interfering signal paths to the GSO vary in length from about 35,000 km to 41,600 km, the leading edges of the received bursts span an interval of 19.6 msec. Because the downlink bursts are only 1.3 msec in duration, and because the interval between bursts in the TDMA frame (from different antenna beams) is 4.2857 msec, the average number of simultaneously received uplink bursts is approximately 0.30 (1.3/4.2857) times the number of downlink bursts per time slot. In order to simplify the analysis and to arrive at conservatively low levels of interference, this time averaging is incorporated in the analysis by reducing the received interference level by 5.2 dB (i.e., 10 log 0.30).

4. The frequency dispersion of co-channel Iridium downlink bursts as a result of Doppler shift is not sufficient to reduce the number of bursts that interfere with the same channel in a GSO MSS system. Specifically, because the Iridium satellites have velocities as high as 7.4 km/sec with respect to a GSO satellite, the downlink signal burst may be transmitted at frequencies spanning a +/-40.2 kHz range about the nominal assigned frequency (disregarding frequency instability, which is relatively small). Given that the occupied bandwidth of an Iridium downlink burst is 280 kHz (Motorola application, at 57), the "co-channel" Iridium uplink bursts will overlap one another over a bandwidth of at least 199 kHz (i.e., 280 kHz - 2x40.2 kHz).

Exhibit 2-3. Computation of Iridium downlink interfering signal power arriving at the antenna port of the receiving GSO satellite via line-of-sight paths

1. The interfering signal power level at the GSO satellite receiver antenna port is computed as the sum of the interfering signal power levels generated by Iridium downlink signals that are simultaneously present. Line-of-sight (LOS) and Earth-backscatter interfering signal paths exist. The interfering signal power level propagated over LOS paths is calculated as follows:

$$I_{RFLOS} = 10 \log \sum [n_{ijk}(EIRP_i)(g_{jk})/(d_{ik})] - D_d - 189 \text{ dB}$$

where:

I_{RF} = interfering signal power (dBW) at the GSO satellite antenna port;

"i" is the type of Iridium beam associated with a downlink burst (i = 1, 2, 3, ...7);

"j" is the angular area associated with the GSO satellite antenna discrimination level as described in Exhibit 1-2 (j = 1, 2, 3, 4, 5);

"k" is a portion of the Iridium satellite orbital sphere as described in Exhibit 2-1 (k = 1, 2).

n_{ijk} = number of Iridium downlink bursts associated with i, j, k;

$EIRP_i$ = the equivalent isotropically radiated power (watts) of an Iridium satellite transmitting through beam type "i";

d_{ik} = the antenna discrimination (numerical power ratio) of the Iridium satellite antenna beam type "i" in the portion of the Iridium orbital sphere "k" in the direction of the GSO satellite;

g_{jk} = the antenna gain (numerical power ratio) of the GSO satellite towards angular areas "j" and "k";

D_d = time dispersion factor (5.2 dB) for averaging the number of Iridium co-channel downlink bursts received simultaneously at the GSO satellite.

Exhibit 2-3 (Cont). Computation of Iridium downlink interfering signal power arriving at the antenna port of the receiving GSO satellite via line-of-sight paths

2. According to Motorola's application (at Appendix A), the EIRP levels associated with each of the seven types of satellite antenna beams are as follows:

Beam Type "i":	1	2	3	4	5	6	7
Minimum EIRP (watts):	205.6	179.9	179.9	121.1	101.2	44.1	17.6
Maximum EIRP (watts):	1,321	1,169	1,169	428	330	100	30

3. The discrimination levels of the Iridium satellite antennas towards the GSO satellite (d_{ik}) as well as the gain of the GSO satellite antenna towards the Iridium satellites (g_{jk}) are determined from the positions of the visible Iridium satellites. These discrimination and gain levels are presented below with the associated values of n_{ijk} in the form of two distributions corresponding with the two angular regions defined for the visible portions of the Iridium orbital sphere (k=1, an Earth-rim annulus; k=2, a sector of the sphere). The angular areas "j" and the associated antenna gain levels "g_j" are as defined in Item 4 of Exhibit 1-2. Iridium satellite antenna discrimination levels were estimated from the antenna patterns in Motorola's application (at 55a-55g). In angular region k=1 of the Iridium orbital sphere, no more than one beam of types (i=1, 2, or 3) will have small off-axis angles towards the GSO satellite; no beams in angular region k=2 will have small off-axis angles.

Exhibit 2-3 (Cont). Computation of Iridium downlink interfering signal power arriving at the antenna port of the receiving GSO satellite via line-of-sight paths

DISTRIBUTION OF IRIDIUM SATELLITE ANTENNA DISCRIMINATION LEVELS (dB) AMONG BEAMS (n_{ijk})

(Iridium Angular Area k = 1)

GSO MSS ANGULAR AREA j	DISCRIMINATION LEVEL d_{jk} (dB)	BEAM TYPE i: 1	2	3	4	5	6	7
2 (1 LEO, g=24 dBi)	4	0	0	0	0	0	0	0
	14	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	1
	30	0	0	0	0	0	1	0
3 (2 LEOs, g=18 dBi)	4	0	1	1	0	0	0	0
	9	1	0	1	0	0	0	0
	14	0	0	0	0	0	0	0
	20	0	0	0	1	1	0	0
	30	0	0	0	1	1	2	0
5 (14 LEOs, g=8 dBi)	4	1	2	1	0	0	0	0
	9	1	1	2	0	0	0	0
	14	1	0	0	2	0	0	0
	20	1	2	2	5	5	0	3
	30	1	2	1	3	5	9	0

Exhibit 2-3 (Cont). Computation of Iridium downlink interfering signal power arriving at the antenna port of the receiving GSO satellite via line-of-sight paths

(Iridium Angular Area k = 2)

GSO MSS ANGULAR AREA j	DISCRIMINATION LEVEL d_{jk} (dB)	BEAM TYPE i						
		1	2	3	4	5	6	7
1 (2 LEOs, g=30 dBi)	6	1	0	0	0	0	0	0
	9	0	1	0	0	0	0	0
	14	0	0	0	1	0	0	0
	20	0	0	1	0	1	1	0
	30	0	0	0	1	1	1	0
2 (3 LEOs, g=24 dBi)	6	1	1	0	0	0	0	0
	9	0	0	1	0	0	0	0
	14	0	0	0	1	0	0	0
	20	0	1	0	1	2	1	1
	30	1	0	1	1	1	2	0
3 (5 LEOs, g=18 dBi)	6	0	0	1	0	0	0	0
	9	0	0	1	0	0	0	0
	14	1	1	0	1	0	0	0
	20	0	1	1	1	1	2	0
	30	1	1	0	1	2	1	1
4 (8 LEOs, g=12 dBi)	6	1	1	0	0	0	0	0
	9	0	1	1	0	0	0	0
	14	1	1	2	1	0	0	0
	20	1	1	1	2	2	3	0
	30	1	1	1	2	3	2	1
5 (15 LEOs, g=8 dBi)	6	1	1	2	0	0	0	0
	9	1	2	1	0	0	0	0
	14	1	1	1	3	0	0	0
	20	1	2	2	6	5	7	2
	30	1	2	2	6	10	8	0

Exhibit 2-3 (Cont). Computation of Iridium downlink interfering signal power arriving at the antenna port of the receiving GSO satellite via line-of-sight paths

4. It should be noted that no voice activity factor is assumed in the interference equation presented in Item 1, above. This is because 2.2:1 DSI voice compression is applied. In addition, in the 2.2:1 DSI downlink packet assembly process, it is likely that many partially filled packets must be transmitted in order to avoid excessive transmission delay. Accordingly, because Motorola claims that Iridium has low transmission delay (application, at 14), the equation presented in Item 1 allows that Iridium downlinks may be loaded less than 50% (1/2.2 x 100% = 45%).

5. The equation presented in Item 1, when executed for k=1 and k=2 using the distributions and EIRP levels discussed in Item 2 yields the following levels of interfering signal power arriving via LOS paths:

* For the minimum levels of Iridium downlink EIRP:

$I_{RFLOS} = 10 \log [10^{(0.1)(-153.1\ dBW)} + 10^{(0.1)(-143.1\ dBW)}]$

$I_{RFLOS} = -142.7$ dBW

* For the maximum levels of Iridium downlink EIRP:

$I_{RFLOS} = 10 \log [10^{(0.1)(-143.9\ dBW)} + 10^{(0.1)(-135.2\ dBW)}]$

$I_{RFLOS} = -134.7$ dBW

Exhibit 2-4. Computation of Iridium downlink interference to a receiving GSO satellite via Earth backscatter

1. The analysis of interference from Earth backscatter of Iridium downlink bursts into a receiving GSO satellite can use the same Iridium deployment and beam activity assumptions as were presented in Exhibits 2-1 and 2-2. For purposes of simplifying the analysis and ensuring conservatively low estimates of interference from this coupling mode, the 16 visible Iridium satellites that are located at Earth-central angles greater than 81.3° from the GSO satellite (i.e., area k=1) are disregarded; however, it should be noted that the scattering from these neglected satellites would be highly variable over time (i.e., as in multipath propagation) such that the interference estimates made here would be greatly exceeded at times. Further, less conservative, evaluation of this interference mechanism should be conducted.

2. The approach used in CCIR Report 850 for Earth backscatter interference can be adapted for analysis of the subject Iridium frequency sharing situation using the following equation:

$$I_m = 10 \log \sum ([pfd_i][\sigma_k A/4\pi R_{mk}^2][g_{ij} \lambda^2 \; 2/4\pi]) - D_d$$

where:

I_m = received backscatter interfering signal power level (dBW);

i = type of Iridium beam associated with a downlink burst ($i = 1, 2, \ldots 7$);

j = angular area associated with the GSO satellite antenna discrimination level ($j = 1, 2, \ldots 5$);

k = annulus of Earth associated with an Iridium downlink angle of incidence and area from which signal backscatter occurs towards the GSO satellite ($k = 1, 2, \ldots 5$);

pfd_i = power flux density (w/m^2)

σ_k = scattering coefficient of Earth (numerical power ratio) in the area k;

A = effective area of scattering surface (m^2);

R_{mk} = range (m) between the GSO satellite and the scattering area k;

λ = wavelength (m);

Exhibit 2-4 (Cont). Computation of Iridium downlink interference to a receiving GSO satellite via Earth backscatter

$g_{i,j}$ = receiving gain of the GSO satellite antenna towards the area j (numerical power ratio);

D_d = time averaging factor (5.2 dB), as defined in Item 3 of Exhibit 2-2.

Simplification of the above equation by removing constants from the summation yields:

$$I_b = -77.8 + 10 \log \sum \{[pfd_i][\sigma_i][g_{i,j}]\}$$

The constant in the above simplified equation was determined as follows:

$$10 \log \{[1/4\pi R_{max}^2][\lambda^2/4\pi][A]\} - D_d$$

and with A corresponding with an Iridium cell (372 nmi diameter)

$$10 \log \{[5.2\times10^{-17}][2.8\times10^{-3}][\pi(3.4\times10^{5}m)^2]\} - 5.2 \text{ dB}$$

-77.8 dBm^2

Note that by defining the area "A" as the Iridium cell area, we are considering Iridium signal scattering only within the mainbeam area (i.e., a cell). Scattering of Iridium emissions radiated by antenna sidelobes is disregarded, but could contribute significant interference.

3. The pfd_i values are given in the Iridium link budgets in Appendix A of the Motorola application, but they are expressed per 4 kHz and appear to include fading. Thus, the following per-carrier pfd values were calculated using the slant range and EIRP values (Item 2 of Exhibit 2-3):

Beam Type	1	2	3	4	5	6	7
Minimum pfd (dBW/m^2)	-109.1	-109.1	-109.1	-109.8	-109.2	-110.3	-111.1
Maximum pfd (dBW/m^2)	-101.0	-100.9	-100.9	-103.6	-104.1	-106.7	-108.7

Exhibit 2-4 (Cont). Computation of Iridium downlink interference to a receiving GSO satellite via Earth backscatter

4. CCIR Report 1008 gives values for σ as a function of the angle of incidence for cases where signal scattering is from land and from the Ocean for direct specular reflection. The angle of incidence relates to areas "k" that are defined in the adjoining figure (k=1 & 2 were used already in the LOS analysis, so we start with k=3). The following table shows the parameter values associated with the areas "k", including quantized values of σ and applicable Iridium beam types for the direct specular reflection component of the backscattered signals.

Area k	Angle of Incidence	Applicable Beam Types "i"	σ Ocean	σ Dry Ground
3	0-5°	7	0.6	0.7
4	5-10°	7	0.4	0.3
5	10-20°	7	0.5	0.2
6	20-50°	5,6	0.6	0.3
7	>50°	1,2,3,4	0.7	0.4

5. The GSO satellite antenna gains g_{rj} are the same as were used in Exhibit 2-3, Item 3. The following table shows the assumed distribution of Iridium satellite antenna beam types "i" and the associated scattering surfaces (Ocean/land), angle of incidence areas "k" and GSO satellite antenna discrimination areas "j".

Exhibit 2-4 (Cont). Computation of Iridium downlink interference to a receiving GSO satellite via Earth backscatter

ILLUSTRATION OF SCATTERING AREAS "k"

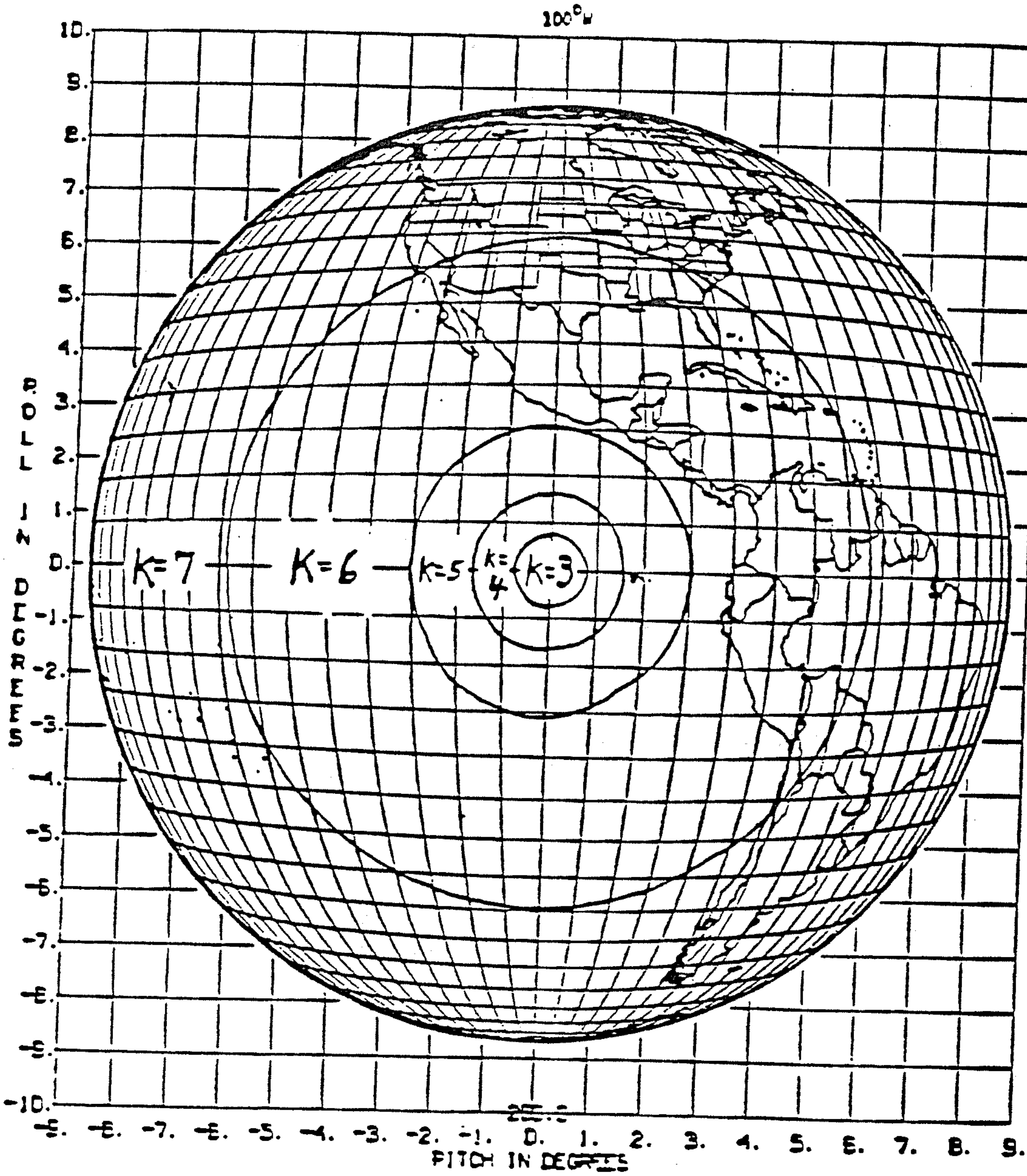


Exhibit 2-4 (Cont). Computation of Iridium downlink interference to a receiving GSO satellite via Earth backscatter

AREA "k"	AREA "j"	$g_{r,j}$ (dB)	Iridium Beam Type "i"	Number of Backscattered Bursts Scatter by Ocean	Scatter by Land
3	4	12	7	1	0
4	3	18	7	1	0
5	2	24	7	1	0
5	5	8	7	2	0
6	1	30	6	0	1
6	2	24	5	1	0
6	3	18	6	1	0
6	4	12	5	1	0
6	4	12	6	0	1
6	5	8	5	2	0
6	5	8	6	2	1
7	1	30	1	1	0
7	1	30	2	0	1
7	2	24	3	1	1
7	3	18	2	1	0
7	3	18	3	1	0
7	4	12	1	1	0
7	4	12	2	1	0
7	4	12	4	1	0
7	5	8	1	1	0
7	5	8	2	1	1
7	5	8	3	1	0
7	5	8	4	1	0
Total Number of Backscatters Bursts:				23	6

Only 29 out of the 141 significant Iridium beams (about 20%) are included in the above table as a result of simplifications that were made. These beams (29) are geometrically aligned to produce direct specular scattering (i.e., scattering at the angle corresponding with Earth reflections). The downlink bursts from the other 112 active beams would be diffusely scattered and are conservatively estimated to produce 6 dB less interference than the 29 specularly scattered bursts (i.e., the interference level calculated for specular scattering is increased by 1 dB to account for diffuse scattering).

Exhibit 2-4 (Cont). Computation of Iridium downlink interference to a receiving GSO satellite via Earth backscatter

6. Using the above parameters, the values of I_{bs} for the Iridium minimum and maximum downlink power levels are as follows:

* For minimum Iridium downlink power: I_{bs} = -152.8 dBW

* For maximum Iridium downlink power: I_{bs} = -145.4 dBW

These interference levels are about 10 dB less than the levels estimated for LOS paths; however, several conservative assumptions have been made that should be revisited in a more rigorous evaluation of the Earth backscatter interference. Specifically, the 16 visible satellites located at Earth central angles greater than 81.3° and certain diffuse scattering interference contributions have been disregarded. In any case, the total estimated interference power (LOS and backscatter) caused by Iridium downlinks is:

$$I_{RF} = 10 \log [10^{(0.1)(I_{LOS})} + 10^{(0.1)(I_{bs})}]$$

* For the minimum levels of Iridium downlink EIRP:

$$I_{RF} = 10 \log [10^{(0.1)(-142.7\ dBW)} + 10^{(0.1)(-152.8\ dBW)}]$$

I_{RF} = -142.3 dBW

* For the maximum levels of Iridium downlink EIRP:

$$I_{RF} = 10 \log [10^{(0.1)(-134.7\ dBW)} + 10^{(0.1)(-145.4\ dBW)}]$$

I_{RF} = -134.3 dBW

Exhibit 2-5. Computation of the C/I levels in a representative GSO MSS uplink channel caused by Iridium downlinks.

1. The following equation is used for the purpose of computing the Iridium downlink interfering signal power falling within a 10.5 krps ICAO-standard GSO MSS uplink channel (assuming that the C/I at the GSO satellite equals the C/I at the receiving feeder link earth station):

$$I = I_{RF} - OTR + n_i - n_o$$

where:

OTR is the on-tune rejection, as described in CCIR Report 654.

OTR = 10 log [(Iridium signal bandwidth) + (GSO MSS receiver noise bandwidth)]

= 10 log [280 kHz/13.1 kHz]

= 13.3 dB

$n_i = n_o$ as in Exhibit 1-3;

thus:

$$I = I_{RF} - OTR \text{ dBW}$$

* For minimum Iridium downlink power levels:
  I = -142.3 - 13.3 = -155.6 dBW

* For maximum Iridium downlink power levels:
  I = -134.3 - 13.3 = -147.6 dBW

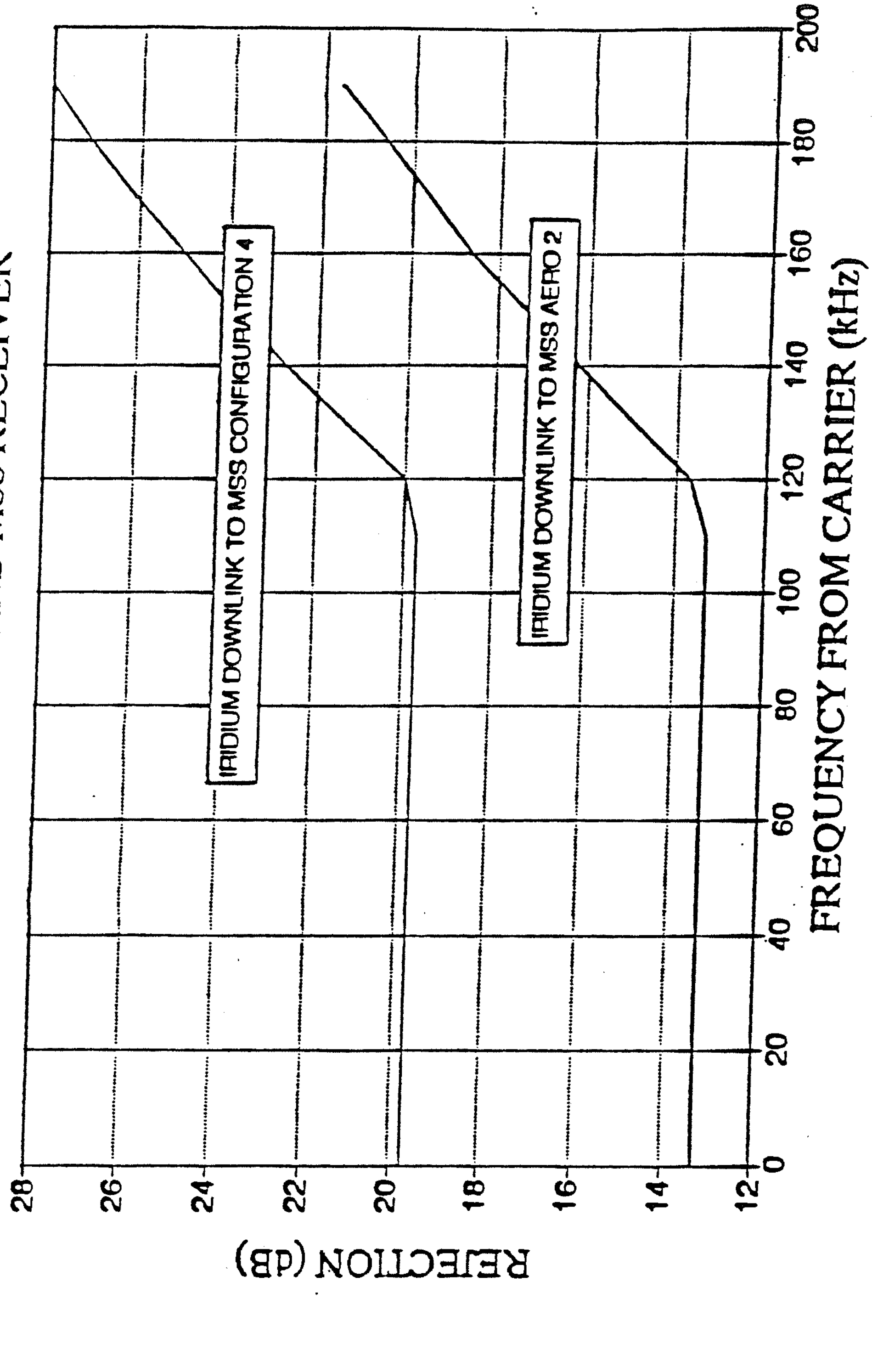
2. The nominal and threshold carrier power levels at the GSO satellite receiver are -152 dBW -154.8 dBW, respectively (as in Exhibit 1-3).

3. Assuming the minimum Iridium power levels, the C/I in the satellite receiver resulting from Iridium downlinks are 3.6 dB and 0.8 dB when the desired signal is at its nominal and threshold levels. The C/I levels are -4.4 dB and -7.2 dB when maximum Iridium power levels are used and the desired signal is at its nominal and threshold levels. Thus, no communications could occur over the GSO MSS uplink.

Exhibit 2-5 (Cont). Computation of the C/I levels in a representative GSO MSS uplink channel caused by Iridium downlinks.

4. The adjoining figure depicts the frequency dependent rejection (FDR) of the assumed ICAO-standard GSO MSS channel with respect to the Iridium downlink bursts, assuming that the bursts are all tuned to the same frequency. However, the bursts received at a GSO satellite are dispersed in frequency such that they all overlap only within a 199 kHz band centered on the nominal burst channel frequency. Doppler dispersion of the bursts reduces the FDR applicable to the aggregate uplink interference because of the concave shape of the FDR curve.

FREQUENCY DEPENDENT REJECTION BETWEEN IRIDIUM EMISSION AND MSS RECEIVER



TELEPHONE 202-331-5856

FACSIMILE 202-331-5851

AMERICAN MOBILE SATELLITE CORPORATION

TECHNICAL CERTIFICATE

I hereby certify that I am the technically qualified person responsible for the preparation of this application; that I am familiar with Part 25 of the Commission Rules and Regulations; that I have either prepared or reviewed the technical information contained in this Petition; and, that it is complete and accurate to the best of my knowledge and belief.

____
Michael Ward

Date: ____________________

CERTIFICATE OF SERVICE

I, Ruth E. Davis, a secretary in the law offices of Gurman, Kurtis, Blask & Freedman, Chartered, do hereby certify that on this 3rd day of June, 1991, a copy of the foregoing "Petition to Deny" of American Mobile Satellite Corporation was sent by U.S. first class mail, postage prepaid to:

Mr. Robert G. Perry
President and Chief Operating Officer
Ellipsat Corporation
2420 K Street, N.W.
Washington, D.C. 20037

Jill Abeshouse Stern, Esq.
Miller & Holbrooke
1225 19th Street, N.W.
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Leonard Kolsky
Vice President and Director
Regulatory Affairs
Motorola, Inc.
1350 I Street, N.W.
Washington, D.C. 20005

Philip L. Malet
Alfred M. Mamlet
Steptoe & Johnson
1330 Connecticut Avenue, N.W.
Washington, D.C. 20036

Ruth E. Davis

DECLARATION

I, Thomas M. Sullivan, do hereby declare as follows:

1. I have a Bachelor of Science degree in Electrical Engineering and have taken numerous post-graduate courses in Physics and Electrical Engineering.

2. I am presently employed by Atlantic Research Corporation and was formerly employed by the IIT Research Institute, DoD Electromagnetic Compatibility Analysis Center.

3. I am qualified to evaluate the technical information in the Petition of American Mobile Satellite Corporation. I am familiar with Part 25 and other relevant parts of the Commission's Rules and Regulations.

4. I received, in 1982, an official commendation from the Department of the Army for the establishment of international provisions for the worldwide operation of mobile earth stations.

5. I have served in the CCIR as Vice-Chairman of IWP-8/14, and chaired Working Groups in IWP-8/14 (Melbourne) and IWP-8/15 (Helsinki), that addressed detailed MSS frequency sharing matters in the CCIR preparations for WARC-92.

6. I am familiar with the design and operation of non-geostationary spacecraft, and I am participating in the design of advanced data handling and transmission sub-systems for the NOAA-O,P,Q satellites and ground systems and the European Polar Orbiting Platform;

7. I am the engineer principally responsible for the current CCIR methods for coordinating frequency assignments and predicting actual levels of interference for systems using non-geostationary spacecraft;

8. I have first-hand experience in the international coordination of frequency assignments for mobile satellite systems.

9. I have been involved in the preparation of and have reviewed the Petition of American Mobile Satellite Corporation including the specific proposals, the system performance analyses, and the sharing analyses, and concur with the technical contents. The technical facts contained therein are accurate to the best of my knowledge and belief.

Under the penalties of perjury, the foregoing is true and correct.

June 3, 1991
Date

Thomas M. Sullivan
Thomas M. Sullivan

TELEPHONE 202-331-5858 FACSIMILE 202-331-5861

AMERICAN MOBILE SATELLITE CORPORATION

TECHNICAL CERTIFICATE

I hereby certify that I am the technically qualified person responsible for the preparation of this application; that I am familiar with Part 25 of the Commission Rules and Regulations; that I have either prepared or reviewed the technical information contained in this Petition; and, that it is complete and accurate to the best of my knowledge and belief.

Michael Ward

Michael Ward

Date: 3 - June - 91

1150 Connecticut Avenue, N.W., Fourth Floor, Washington, D.C. 20036

CERTIFICATE OF SERVICE

I, Ruth E. Davis, a secretary in the law offices of Gurman, Kurtis, Blask & Freedman, Chartered, do hereby certify that on this 3rd day of June, 1991, a copy of the foregoing "Petition" of American Mobile Satellite Corporation was sent by U.S. first class mail, postage prepaid to:

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Ruth Davis

Ruth E. Davis