5.2.5. Required Regulatory Support and Coordination Parameters. Certain regulatory action would facilitate CDMA/TDMA frequency sharing and maximize achievable MSS capacity to serve the U.S. public. For example, LEO MSS should be allowed to operate at higher PFD than the existing coordination trigger point of -142 dBW/m^2/4 KHz. This PFD regulation is a co-ordination trigger point, not an absolute limit. MSS systems, especially a TDMA system, may occasionally exceed the PFD limitation, but those systems should be able to coordinate with FS in S-band when the PFD is interpreted on a averaging basis. It is assumed that in other parts of the world, the MSS traffic loading may not be as heavy as the anticipated traffic loading in the U.S.; therefore, LEO MSS systems should be able to co-ordinate with FS over the world.

The above-mentioned CDMA/TDMA scheme would allow MSS systems (CDMA, TDMA, FDMA, LEO and GSO) to co-ordinate with each other with manageable FCC administrative efforts. The major co-ordination parameters are:

(1) Downlink PFDs in S-band for each system in each polarization;

(2) Aggregate mobile user EIRP density per area in each polarization;

(3) Required minimum cross-polarization isolation for satellite and user antennas;

(4) Average propagation margin;

These system parameters are very much similar to the system parameters used in the full-band CDMA/CDMA interference sharing described in Section 2.

5.2.6. Required Modifications For the Iridium System Under this Scheme. By using a high static margin of 16 dB and bi-directional operation, Motorola's Iridium system, as presently designed, cannot share co-frequency, co-coverage with any other MSS systems. As discussed in previous sections, the requirement for 16 dB link margin and large dynamic range make the Motorola system vulnerable to interference from other CDMA systems. In addition, the present Motorola link design only allocates a portion of the noise budget, if any, for interference from other MSS systems sharing the same band. For example, Motorola allocated 6.3% noise (with Eb/Io=18 dB) for interference.

Motorola's system would have to make the following modifications to its system under this analysis:

	Present	Modified for Sharing
Frequency Bandwidth	10.5 MHz L-band	2.75 MHz L-band and 2.75 MHz S-band
Data Rate	50 Kbps (TDD)	20 Kbps (FDD)
User Antenna Gain	1.0 dB	3.0 dB
X-pol Isolation	N/A	6-8 dB
User burst power	0.4 W	0.5-0.66 W
TDMA Frame	90 ms	90 ms
Voice Circuit/Carrier	4	4
Uplink Margin	15.7 dB	15.7 dB
Downlink Margin	15.7 dB	12.5 dB
Achievable Conus Capacity	3854 channels	3640 channels

5.2.7. Motorola's Response to IWG1-73 Proposal. While Motorola agrees with the general intent of IWG1-73 (LQSS), there are several technical flaws, and it is not as simple as portrayed in that paper. Motorola believes that the band segmentation approach presented by Motorola in several presentations, IWG-1 papers, and within the workings of the drafting groups serves to fulfill the intent of IWG1-73. The approach described above, however, does not achieve those goals.

5.2.7.1. Polarization. Motorola disagrees that polarization provides sufficient margin to allow it to be used as a discriminator. The environment of the mobile subscriber, be it from a vehicle-mounted unit, a portable handset, or a transportable unit, is commonly viewed (e.g., IWG1-8) as an environment that exhibits fading and shadowing. Wherever fading or shadowing occurs, the polarization is altered. Furthermore, testing conducted by Motorola in the L-band showed that reflections on the order of 100 nS or less are received by the subscriber units, while longer delays are not detected. These "short bounces" also result in altered polarizations.

In short, the polarization discriminator is not available when offering MSS. Just as important, the antenna requirements needed to achieve this level of polarization isolation cannot be implemented in hand-held portable units. See Section 5.3.

5.2.7.2. S-Band. In IWG1-28, Motorola explained why S-Band is unusable for the Iridium system. In the time since the presentation of that paper, IWG-2 has verified many issues raised in that paper and found additional impediments to the use of that band. The Iridium business plan includes the operation of portable handsets that will be operated in all areas (cities, suburbs, rural areas, etc.) and the limitations in S-band do not allow the quality of service Motorola intends to provide.

5.2.7.3. Link Margin. To provide the quality of service Motorola will provide its users, 16 dB of link margin is required. Motorola went through the expense of totally designing its system because its link margin tests showed that the previous 350 Kg satellite, 77-satellite design with a 9 dB average link margin was insufficient to execute its business plan. The current 700 Kg satellite, 66-satellite design operates with large phased array antennas designed to meet the user demand.

5.2.8. Motorola's Statement About FDMA/TDMA vs. CDMA Sharing. It is undisputed that the Iridium system, as currently designed, cannot viably operate on a co-frequency, co-coverage basis with any of the CDMA applicants' contemplated systems under the full band interference sharing rules proposed in this report. The other CDMA applicants' proposed systems would cause unacceptable levels of interference into Motorola's uplinks.

Motorola has been requested to consider whether it could modify its system design in such manner as to maintain its vision of the market and live within the proposed sharing rules. In fact, before settling upon the current Iridium system design, Motorola considered various system designs, including different modulation/access techniques, lower link margins, and unidirectional operations in the L- and S-bands. None of these options, however, proved to be feasible considering the service requirements that Motorola expects the market will demand; i.e., global, high-quality, ubiquitous service primarily to pocket-sized personal terminals operating in obstructed as well as line-of-site conditions.

Motorola firmly believes the FDMA/TDMA is the best communications architecture for a large power density satellite system, such as Iridium, because it will allow for robust links capable of operating with handsets when they are obstructed by fading, shadowing and ground clutter. Motorola's propagation tests have confirmed that a 16 dB link margin is required to serve uses with pocket-sized handsets in virtually all conditions. Motorola simply cannot obtain the required link margins in the S-band, even with CDMA techniques, primarily because of the PFD levels established in the international Radio Regulations to protect the many terrestrial systems operating in the band. In addition, the S-band is not conducive to MSS downlinks because of in-band and out-of-band emissions from other sources (such as ISM devices and radio communication users). Dual band operations would also add significantly to the overall cost of the Iridium system satellites.

5.3. FDMA/TDMA v. FDMA/TDMA.

In narrow-band TDMA and FDMA systems, polarization alone typically cannot be used to isolate systems unless antennas with very good performance (8-10 dB or 18 dB of polarization isolation depending upon one's assumptions) can be guaranteed. This is difficult in a mobile environment with low cost handheld mobile antennas. However, the 8-10 dB cross-polarization isolation could be achieved with more expensive, vehicle-mounted antennas.

5.4. LEO vs. GEO MSS/RDSS.

5.4.0. Summary and Conclusions. The Commission has questioned the feasibility of LEO and geostationary systems sharing the 1610-1626.5/2483.5-2500 MHz band. NPRM, ¶ 17. It was stated that ... "sharing of the RDSS bands by LEO and geostationary systems may require severe limits on power and frequency that render both systems unworkable." The purpose of this section is to address the issues that are associated with LEO and geostationary system sharing and assess the impact of sharing between LEO and geostationary system's operations and capacity.

The conclusion is that LEO and geostationary satellite systems can share the band. Geostationary satellite systems can operate within the EIRP density thresholds of RR 2548A and 731E associated with the 1610-1626.5 MHz band and the PFD limits of RR 2566 in the 2483.5-2500 MHz band. It is anticipated that future geostationary satellite systems will be able to support service to handheld terminals.

In an interference sharing approach, all geostationary and non-geostationary applicants will have full access to the entire band. Geostationary and LEO CDMA systems can share equitably as long as all systems operate under mutually agreed upon uplink EIRP areal spectral density and downlink PFD spectral density thresholds. Section 5 of this report contains capacity estimates for two types of geostationary satellite systems designed to operate in the band.

5.4.1. Geometric Considerations. Sharing between a variety of geostationary and nongeostationary systems in the subject bands is no more difficult than sharing between different geostationary satellite systems or different non-geostationary satellite systems. All the MSS applicants are proposing service to low-powered mobile satellite terminals that have antennas with little or no angular discrimination in either the azimuth or elevation angles of transmission. Terminals will receive transmissions from all MSS satellites (whether non-geostationary or geostationary) that are operating on the same frequency and serving the same area. Similarly, transmissions from the terminals will emanate in all directions so that any non-geostationary or geostationary satellite that is serving the area will receive the terminal's transmission. Since the direction of transmission is not a factor with these types of mobile terminals when calculating the potential interference, the intersystem interference environment does not substantially change in considering a geostationary or a non-geostationary satellite or any combination of the two types of systems.

5.4.2. Sharing in the space-to-Earth Direction. The presence of non-geostationary and geostationary satellites has no direct bearing on the ability to share the 2483.5-2500 MHz band among multiple networks. Specifically, non-geostationary and geostationary MSS networks can be designed to operate within the same power flux density limitations to bound the potential level of intersystem interference. The individual carriers of the proposed CDMA systems will operate well below the PFD threshold of RR 2566. System operators will have to limit the number of simultaneous channels that are supported on a system basis to insure that any selected PFD limit is not being exceeded in the coverage area.

In the space-to-Earth direction of transmission the angle of arrival of the interference is not an issue for MSS terminals, since the majority will use omni-directional antennas. Thus, the terminals can receive a signal from any angle of arrival, which is a requirement when communicating from a mobile terminal. From the point of view of sharing the band, the use of omni-directional antennas on terminals does not disadvantage a LEO or geostationary satellite system, if all the systems agree to operate within a common PFD limit.

> *Thus, the interfering, ground incident PFD spectral density conveys* all the *information necessary to characterize the* interfering potential of *any downlink signal, indifferent* to satellite altitude *or orbit selection.*

5.4.3. Sharing in the Earth-to-space Direction. As described below, there is no fundamental difference in the terminal uplink EIRP requirements for non-geostationary and geostationary the other CDMA applicants by using additional signal spreading. Moreover, because the total EIRP density reaching the satellite is of concern, the geostationary and LEO networks should operate within an aggregate limit of EIRP areal spectral density. Given that the EIRP areal spectral densities of the systems can be harmonized, then the overriding issue in sharing on the uplink is

5.5. Motorola Band Segmentation Plan.

The LEO FDMA/TDMA system parameters depicted in this section are for the IRIDIUM[*] system as presented by Motorola. Estimates of FDMA or FDMA/TDMA capacities are relatively straightforward and require knowledge of only a limited number of parameters for a particular system design. For such systems, the downlink and uplink capacities will be identical.

Calculations are provided both for channel capacity and "channels per megahertz". Channel capacity is defined as the number of full duplex voice band channels that can be supported in an allocated bandwidth and may depend upon available power. Channels per megahertz is defined as the number of full duplex voice band channels that can be supported per megahertz of spectrum used. The derivations are general and apply to both FDMA/TDMA (channelized TDMA) systems and systems that are FDMA only.

For the purposes of this analysis, 8.25 MHz of bandwidth is assumed to have been allocated to FDMA/TDMA systems. The channel capacities and channels per megahertz are calculated for one through four FDMA/TDMA IRIDIUM-type systems utilizing this 8.25 MHz allocated band. The FDMA capacity of larger or smaller band segments can be determined by calculating the ratio of the bandwidth of the alternative segment to 8.25 MHz and multiplying this ratio by the channel capacities shown for 8.25 MHz.

5.5.1. System Data Required for the Analysis. The following system parameters are required to perform the analysis.

(A) Available RF Bandwidth: The total bandwidth available for use by a specific FDMA/TDMA system.

(B) Number of Beams in the Coverage Area: The number of satellite antenna spot beams that cover the area of analysis, the continental United States.

(C) Cell Cluster Size (Reuse Factor): Cell cluster size is an indication of how often the frequencies may be reused by the satellite antenna beams in a coverage area. The reciprocal of the cell cluster size indicates how often the frequencies may be reused in the beam pattern. For example, a cell cluster size of six indicates that the frequencies may be reused in every sixth beam.

(D) Required Doppler Guard Band: The guard band that is required at each edge of the available RF bandwidth to accommodate the Doppler on the communication link.

(S) <u>FDMA Channel Spacing:</u> Spacing of the FDMA channels in the available RF Bandwidth (generally measured from center to center of the occupied bandwidth of adjacent channels).

(T) <u>TDMA Time Slots:</u> The number of duplex timeslots that may be accommodated in a single TDMA timeframe.

5.5.2. <u>Uplink and Downlink Capacity Formula</u>. The capacity of a system where the available RF bandwidth is continuous may be derived as follows:

$$\text{Capacity} = f[(A - 2D)/S] \times T \times B/ C,$$

where f[(A-2D)/S] is the value of (A - 2D)/S rounded down to its

The channels per megahertz of these systems may be determined by dividing the number of channels by the number of megahertz of occupied spectrum. Table 5.5.B. shows this figure for 1 to 4 IRIDIUM type systems.

Table 5.5.B.

Channels Per Megahertz of Multiple FDMA/TDMA

IRIDIUM-Type Systems

Number of MSS Systems	Spectral Efficiency Channels per MHz
1	467
2	462
3	457
4	453

5.6. Capacity of Other Band Segmentation Plans.

Several other methods have been proposed to segment the MSS bands. Rather than provide a separate capacity analysis for each, it is possible to derive the resulting capacity using the data in Sections 5.1 - 5.5. Each of these sections reported that the results shown there could be scaled according to the available bandwidth.

5.6.1. Band Segmentation by Number of Applicants. If the band were divided evenly among the MSS applicants, it can be assumed that the five CDMA systems would consolidate their segments and use full-band interference sharing within them. This would result in a capacity of approximately five sixths of that given in Section 5.1. The sole TDMA applicant has indicated that the remaining amount of spectrum would not allow it to fulfill its business plan, so it would likely not add to the total capacity.

5.6.2. Band Segmentation by Channelization. The same reasoning given in Section 5.6.1. applies. The final capacity will be somewhere between that given in Section 5.1. (CDMA sharing) and 5.5 (TDMA sharing) depending on how many segments are devoted to each technology.

Annex 5.5: Revised Capacity Analysis of TDMA MSS Systems

1. Introduction

In Section 5.5, Motorola provided an analysis of the capacity of TDMA and FDMA satellite systems such as Iridium. The basis of that analysis is that TDMA systems can be analyzed simply by counting the available timeslots. This simplified view ignores several important constraints that systems such as Iridium will face in a realistic operating environment. The following annex revises the basic capacity equation provided by Motorola, explains the changes, and concludes with the realizable capacity of Iridium or similar TDMA/FDMA systems.

The basic TDMA capacity equation given by Motorola in section 5.5 is repeated below with the one required additional factor. Other necessary corrections to account for realistic operation can be made within the framework of this equation by modifying the parameters used.

$$\text{Capacity} = \frac{(A-2D)}{S} \times \frac{T \times B \times F}{C}$$

where A = Available RF bandwidth (i.e., 16.5MHz, 10MHz, 8.25MHz, 2.75MHz, 1.25MHz)

B = Number of beams over CONUS = 59

C = Cell Cluster size (Frequency Reuse Factor) = 12 (Motorola uses 6)

D = Required Doppler Guard Band = 37.5 kHz

S = FDMA Channel Spacing = 41.67 kHz

T = TDMA time slots per frame = 4 (for 4.8 kb/s vocoder)

F = Power Availability Factor = 67% (Motorola has omitted this factor)

2. Frequency Reuse

The most obvious error in Motorola's calculations is the assumption of a frequency reuse factor (which it calls a "cell cluster size") of 6. This factor accounts for the fact that adjacent beams must be assigned different frequencies to avoid interfering with each other.

The science of minimizing the frequency reuse factor has been well studied in communications systems, particularly in terrestrial cellular telephone systems, which must deal with the same issue when arranging cells within a given area. In these cellular systems, the problem is much simpler than the one Motorola faces with its Iridium system. Terrestrial cells are fixed and unmoving. The locations of new cells can be chosen to carefully tailor coverage, and even such parameters as antenna height can be optimized. Terrestrial cellular engineers have been able to do no better than a frequency reuse factor of seven.

Even a frequency reuse factor of seven would be optimistic for the Iridium system because of its dynamic nature. As the satellites move, the 48 beams on each satellite are constantly being turned on and off. Beams at the edge of one satellite's footprint are brushing against beams from an adjacent satellite. As they move away from the equator, these "edge beams" overlap more and more, until a decision is made to shut some down. At this moment, frequency assignments must be changed. The frequency reuse assignments must guarantee non-interference both immediately before and after this change.

In addition, Motorola has said they plan to mitigate the interference their secondary downlinks may cause to primary operators by dynamically switching users to frequencies with less of an interference problem. This requirement will make optimum frequency reuse even more difficult, since some frequencies may occasionally need to be shut off completely.

It has also been pointed out that the Iridium system may need frequency isolation not only between adjacent beams, but also between any beam and those one removed from it. This is due to the difficulty of generating small beams with rapid rolloff characteristics with an antenna aperture of reasonable size. Again, this problem is especially acute at the boundary between satellites, where beams aren't aligned as well, and may spill over into other beams.

An appreciation for the complexity of this problem can best be understood with a picture of the Iridium beam patterns, which is given in figure 1. Although it shows four satellites, for clarity, this figure depicts the outer ring of beams for only one satellite (at the top of the figure). Each of the other three satellites also have these elongated beams around their edges. As described above, many of the beams overlap not only their immediate neighbor, but also those one concentric ring away. In addition, the elongated outer ring beams stretch all the way past directly under the adjacent satellite. Choosing one of these in the left center of the figure, for example, it is easy to see that it overlaps nine other beams (allowing a minimum frequency reuse of 10) even with the edge beams of its neighbor satellite turned off.

The combination of these constraints makes it very difficult to attain high frequency reuse in a TDMA system. Indeed, the system must err on the side of conservatism, since beams that interfere even briefly would completely jam each other. This is in contrast to CDMA systems, where a small amount of interference merely results in a small decrease in capacity. For this reason, the value of twelve which appeared in Motorola's initial application[1] is probably reasonable, and so is used here. When asked to explain its switch to more optimistic values, Motorola has declined, saying it is proprietary information.

3. Number of Beams over CONUS

In section 5, Motorola analyzed the Iridium capacity on the assumption that there were 59 satellite beams over CONUS. Counting the beams shown in figure 1 shows this to be incorrect. The actual number at any given time of the day will vary slightly as the constellation of satellites moves. At some times, one satellite might be directly over the center of the continental US. Given the overall area of the satellite footprint, however, adjacent satellites would not be in view at that time. Another scenario (that shown in figure 1) is when several satellites each are partly in view of CONUS. Due to the low altitude of the satellites, they move very quickly; these scenarios and the number of beams over CONUS can change on the order of minutes. At some optimal time, it may be possible that Iridium has 59 beams over CONUS, but the average and minimum values are clearly smaller than this. At the time depicted in figure 1, about 49 beams can be counted. Whether capacity should be calculated with minimum values (so that user calls aren't dropped as the satellites move and capacity decreases) or the average value is debatable. But clearly, a value as high as 59 gives a misleading capacity. If it were corrected to 49 beams, the capacity would decrease by 15%. For the purposes of this analysis, however, we will use Motorola's value of 59 beams.

4. Inadequate Preamble for Reliable Demodulation

Motorola also claims that it can fit four simplex time slots in each frame. It is well known (and acknowledged by Motorola) that in TDMA systems such as Iridium an adequate length preamble is needed for each frame. In its application, Motorola has a frame structure that includes almost 25 msec of time at the beginning which was described as "framing." Although other applicants originally thought this was their preamble, Motorola has said that this "framing" time is actually guard time during which the of symbols available in each frame for a preamble. Motorola has

Based on these revised parameters, the capacity results for the Iridium system are as follows:

RF Bandwidth (MHz)	Capacity (Channels)	Capacity per MHz
16.5	2572	156
10.5	2458	234
8.25	1927	233
2.75	629	229
1.25	275	220

The Iridium system claims to put 59 antenna beams over CONUS. The decision to use this many antenna beams is an economic one, which can, and may, be made by some of the other applicants. In order to compare the spectral efficiency (capacity per MHz) of various systems on an equal technical basis, the number of beams must be normalized. If, for example, the Iridium capacity is calculated [illegible]

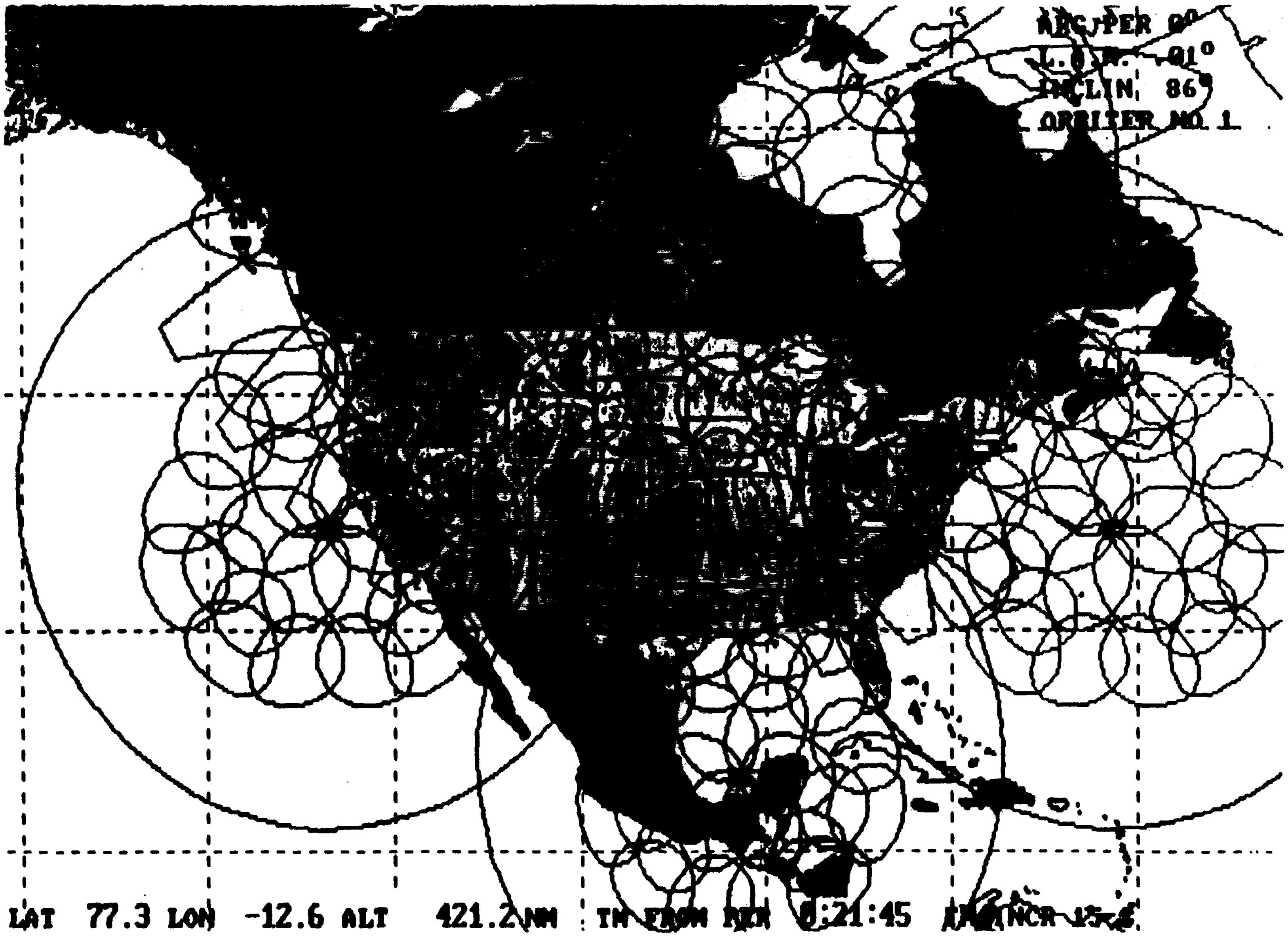

Figure 1: Motorola Iridium Antenna Beam Pattern

6. SYSTEM DESCRIPTIONS FOR SHARING ANALYSIS.

Section 6.1 describes for each participating system the suggested refinements in its system design used in Section 5. Section 6.2 addresses parameters which could be adjusted at later stages in order to improve system performance beyond that described in 6.1.

6.1. Differences between System Parameters in Section 5 and Initial System Descriptions.

6.1.1. AMSC. AMSC initially applied to extend its existing planned FDMA services into the RDSS band by matching the 1610-1626.5 MHz uplink with an L- or S-band downlink that would permit it to operate its FDMA carriers without modification. When the FCC rejected the suggestion to match the uplink with another downlink band, AMSC recognized that the use of the 2483.5-2500 MHz band would require the use of some form of spectrum spreading to operate below the PFD threshold of RR 2566. In addition to this, it was recognized that operating in an interference sharing environment would require further modifications to operate compatibly and generate sufficient capacity to rationalize the construction of a geostationary satellite. Thus, AMSC is considering the following modifications to its satellite system for operation in an interference sharing environment.

An increase in the spacecraft antenna reflector to 8.3M to generate 6 CONUS coverage beams;

A 3 x 5.5 MHz spacecraft channelization plan to operate compatibly with other CDMA systems operating in the band;

The use of coherent demodulation in the forward and reverse links; and,

The use of individual link power control in the forward and reverse links.

Thus, AMSC will primarily provide service to vehicular terminals. AMSC terminal EIRP capabilities will not be restricted by the EIRP limitations associated with handheld terminals, since it is vehicle mounted.

6.1.2. Celsat. Celsat feels that no design changes are necessary to its planned system to accommodate sharing.

6.1.3. Constellation. Constellation has indicated that several changes are currently planned to its system to improve its ability to share spectrum and increase capacity. The two most significant changes are the reconfiguration of its satellite antennas from a single-beam to a multiple-beam (e.g. 7 beam) design, and the modification of its uplink mobile earth station transmission format to include spreading over a 1 to 5 MHz bandwidth.

6.1.4. Ellipsat. Ellipsat Corporation has made several changes to the Ellipso system design in order to improve performance. These changes reflect best current thinking, but remain subject to change. These changes include:

- The Ellipso satellite will now use a 37-beam array on the service uplinks and downlinks in order to permit more accurate placement of PFD.
- Ellipso will spread user signals over the full 16.5 MHz band, or as much of it as is available for use.
- The feeder link formats will be changed to accommodate service link changes.

6.1.5. LQSS.

(a) Antenna patterns. In reviewing its system parameters for the analysis in Section 5.1, LQSS has used 12 beams per satellite to enhance its system design in the proposed sharing environment with other CDMA systems. The increased number of beams increases the antenna gain and the link budgets change accordingly. This represents an increase from the application value of 6. Analysis of the optimum number of beams for each satellite will continue as the sharing criteria is developed further and the technical requirements imposed upon MSS licensees are established.

(b) Satellite/gateway links. The satellite to gateway links contribute to overall Eb/No values. On the return link the satellite to gateway link was a major contributor to the overall Eb/No values in the application. Accordingly, for the analysis in Section 5.1, LQSS has assumed that its system will be designed such that the C-band link from the satellite to the gateway is not a capacity limiting factor in the system.

(c) Orbital altitude. In its application, LQSS stated a value of 1389 km. The design to facilitate the simulation of the sharing depicted in Section 5.1 uses 1414 km.

6.1.6. Motorola. The Iridium system was analyzed with the following changes in parameters to its current system design:

(1) an increase in reuse of spatial separation (6 vs. 12 beam reuse cluster); and

(2) additional antenna isolation to mitigate interference as may be required by the rules.

[redacted]

6.2. Further Improvements Achievable.

Section 5 of this report contains an analysis of the operation of the MSS systems as currently designed, with some enhancements to facilitate efficient operation in a sharing environment. Each of the proposed systems was originally conceived without a knowledge of the sharing environment (i.e. how many systems might be sharing the spectrum, and what coordination rules might be adopted). The following section describes some improvements which may be used to enable the systems to share the spectrum more efficiently in order to increase system capacity.

6.2.1. First Generation Improvements.

6.2.1.1. Satellite Antenna Design. As is clear from the equations developed in Section 5, the capacity of MSS systems in a sharing environment is directly related to the size and number of antenna beams a system employs on its satellites. This is due to a more efficient frequency reuse factor. If a system doubles the number of beams that cover a given region on the ground, there is a nearly proportional increase in capacity, since all frequency channels can be used again in all the new beams. This holds true for both the uplink and downlink.

In developing the analysis for Section 5, several applicants have indicated that they would use more beams to increase capacity in the proposed sharing environment; some applicants have indicated that this could occur during a coordination process. At present, all of the applicants which have proposed CDMA techniques have based their capacity analysis on 37 or fewer beams per satellite. Other applicants, however, have said that as many as 48 beams are feasible on a LEO satellite, or up to 150 on a geostationary satellite.

This design parameter must be left flexible to respond to market forces since there is a tradeoff between system cost and capacity.

6.2.1.2. Use of Polarization Isolation. Overall, given the polarization isolation levels reflected in Section 5, a reasonable improvement in shared system capacity is possible. All of the CDMA system proponents have said they intend to use polarization isolation to maximize shared system capacity.

6.2.1.3. Sharing with Smaller Systems. For the interference sharing analysis of Section 5, it was assumed that all systems used approximately the same operating point for both downlink PFD spectral density and uplink aggregate EIRP areal spectral density.

Some applicants may decide to introduce smaller, lower capacity, less expensive systems that would operate at lower interfering power levels than is assumed for the cases analyzed in Section 5. This reduced interference contribution would enable the other systems to operate with more channels.

6.2.1.4. <u>Improvement of Simplified Sharing Models in Section 5</u>. The system capacities derived in Section 5 were based on simplified models which, in several cases, used overly conservative assumptions relative to what would actually be done during an actual coordination process. In operation, the "degraders" and the interference will not be as severe as shown in the analysis in Section 5.

For example, an improvement in downlink capacity will be realized when the statistical nature of the interference is taken account of. The simplified analysis assumed that the interference was at the maximum PFD value at all times and in all places in the coverage area. In practice, the interference will, on average, be below this value, and this statistical average will result in less average interfering PFD and hence greater system capacity. Considering that the main contributor to this effect is "orbit and beam effects," which has a typical average value of 2 to 3 dB, this is likely to result in an average reduction in interference of 1 to 2 dB.

6.2.2. <u>Future System Enhancements</u>. There are several other system improvements that have been proposed for future implementation in a sharing environment.

6.2.2.1. <u>Improved Vocoders</u>. It is reasonable to expect that vocoder technology will continue to improve. As a result, quality

7. EFFECTS OF SHARING WITH SERVICES OTHER THAN MSS/RDSS.

7.1. Introduction.

IWG2 was tasked with considering spectrum sharing solutions with services other than MSS/RDSS. The sharing solutions recommended by IWG2 and the interference from other services reported by IWG2 may restrict MSS system capacity, performance and service areas.

7.2. Sharing with Radio Astronomy.

The Radio Astronomy Service (RAS) operates 14 observatories in the United States in the 1610.6-1613.8 MHz band. In addition, there are 16 other RAS sites outside of the United States operating in this band. In any given year, Radio Astronomy (RA) observations occur approximately 25% of the time in the 1610.6-1613.8 MHz band.

7.2.1. Protection Zones for MSS Operators in the 1610.6-1613.8 MHz Band. IWG2 proposes protection zones as the principal means for MSS operators in the 1610.6-1613.8 MHz band to share with the RAS. Co-frequency operation within the protection zones during periods of radio astronomy operation would be prohibited. The RA community has agreed to provide MSS operators with an advance schedule of their observations.

IWG2 proposes protection zones of 100 mile radius around five RA sites: Arecibo, Puerto Rico; Green Bank, West Virginia; VLA (San Augustin, New Mexico); Owens Valley, California; and Ohio State University, Ohio.

IWG2 also recommends protection zones of 30 mile radius around ten Very Large Baseline Array (VLBA) RA sites in the United States listed in Section 3, Table 1 of the IWG2A report service in immediately adjacent frequencies would be subject to significantly smaller protection zones.

MSS transmitters operating in these portions of the band will be forced to operate in higher frequencies when within a radio astronomy site protection zone during periods of observation. This will reduce the available spectrum near the sites by about 23% (3.8/16.5) under any band sharing approach. If less than 16.5 MHz is available, the overall number of channels available would be further reduced for the systems operating on an interference sharing basis.

IWG1 encourages further work on implementation of the beacon concept to increase the spectrum sharing efficiency of the MSS systems.

7.3. Sharing with Aeronautical Radionavigation.

The Global Positioning Service (GPS) and GLONASS systems operate under the radionavigation-satellite (space-to-Earth) service allocation in the 1559-1610 MHz band. The band 1610-1626.5 MHz is also allocated to the Aeronautical Radionavigation Service on a primary basis. RR 732 indicates that the 1610-1626 MHz band is also reserved for the use and deployment of airborne electronic aids including satellite-borne facilities subject to