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INTERNATIONAL BUREAU

Satellite and Radiocommunication Division
Satellite Policy Branch

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To: **William S. Caton, Acting Secretary**

Date: October 11, 1995

From: Karl A. Kensinger

Re: **CC Docket No. 92-297**

On October 10, the International Bureau's Satellite and Radiocommunication Division convened a meeting with the participants listed in attachment A to this memorandum. The participants discussed the subject matter contained in the documents in attachment B to this memorandum.

I am forwarding this material for inclusion in the record of CC Docket No. 92-297, and treatment to the extent necessary as an ex parte presentation in a non-restricted proceeding.

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List A B C D E

Attachment A

List of Participants

Name	Affiliation
Tom Tycz	FCC/IB
Mike Marcus	FCC/OET
Don Gips	FCC/OPP
Greg Rosston	FCC/OPP
Bob James	FCC/WB
Susan Magnotti	FCC/WB
Tim May	FCC/WB
Harry Ng	FCC/IB
Jennifer Gilsenan	FCC/IB
Karl Kensinger	FCC/IB
Giselle Gomez	FCC/IB
Eric Barnhart	Cellularvision
Doug Gray	Hewlett Packard
Charles Milkis	M. Gardner
Phil Malet	Motorola/Steptoe and Johnson
Barry Lamberghman	Motorola
Ken Engle	Motorola
John Knudsen	Motorola
Gene Robinson	Texas Instruments
Bill Myers	Texas Instruments
Leland Langston	Texas Instruments

Attachment B

Texas Instruments Incorporated

TEXAS INSTRUMENTS

Post Office Box 660311
Dallas, Texas 75265
7839 Churchill Way
Dallas, Texas 75251

02 October 1995

Mr. John Knudsen
Motorola
Satellite Communications
2501 S. Price Road
Chandler, Arizona 85248-2899

Re: CC Docket No. 92-297

Dear John:

Thank you for your quick review and response to our analyses of sharing between systems of the Local Multipoint Distribution Service ("LMDS") and feeder links for Motorola's Iridium MSS system. Because LMDS and MSS feeder links are co-primary services in the 28.1 - 28.5 GHz range of the FCC's proposed 28 GHz band plan, it is critical that this dialog continue as long as necessary to ensure successful sharing.

As you note, we did not propose technical constraints or rules with these analyses. Our purpose simply was to determine if sharing between the Iridium system and LMDS subscriber links from the four principal LMDS system proponents was feasible. Using the technical criteria previously identified by Motorola, the results of these analysis indicate that margin exists for each of the LMDS systems and, therefore, that sharing is possible. It appears that Motorola might not agree with this assessment. We look forward to discussing your concerns with you. In addition, as you suggest, FCC technical rules will be in order to ensure that these co-primary services can co-exist. Thus, I hope we all can get together as soon as possible to understand what sort of rules Motorola believes would be necessary for the services to share the band.

To facilitate our discussions, I understand that the Commission staff is trying to arrange a meeting among the LMDS system proponents and Motorola. I also understand that the nominal date and venue for this meeting is October 10, 1995, in Tom Tycz's conference room. Although Mr. Tycz is the first point of contact, please feel free to call Paul Misener, at 202-828-7506, if you have any questions in my absence.

Sincerely,

Gene Robinson

Gene Robinson
Senior Fellow, Texas Instruments

MOTOROLA

September 29, 1995

Mr. Gene Robinson
Texas Instruments Inc.
P.O. Box 650311
Dallas, Texas 75251

Re: CC Docket No. 92-297

Dear Gene:

In connection with sharing between the feeder links of the IRIDIUM® system and the Local Multipoint Distribution Service ("LMDS"), in the above-captioned rulemaking proceeding before the FCC, we have reviewed your detailed Compatibility Analysis attached to your letter dated September 12, 1995. The study of the possibility of compatibility between LMDS subscriber units and the up link of an IRIDIUM® satellite is doubtless complex. We appreciate what a difficult problem it is to quantify and that is why WG-2 of the NRM was only able to address the hub compatibility. Unfortunately, your original input on this matter to the NRM's full committee was made only two weeks before the conclusion and there was insufficient time for WG-2 to evaluate your contribution.

Your bringing together four LMDS proponents to assist you in this recent endeavor was certainly appropriate. It gave you an opportunity to use their latest thinking on the probable technical characteristics that best matched their various business plans. We have also reviewed the four proponents (TI, Endgate, Cellularvision , and HP) NPRM comments which helped us get additional perspective on this use of the shared band segment. Nonetheless, Motorola is quite perplexed at the final conclusions of all these contributions.

While all proponents said sharing was quite feasible, only one proposed any technical constraints and these were on the satellite. On the other hand, your compatibility studies all assumed some technical limits on terminal equipment characteristics and on terminal distribution in order for you to develop quantitative interference levels but no commensurate rules were suggested for LMDS operators.

TI is also to be commended for using three different simulation techniques to calculate the amount of aggregate wide area interference that could appear in the spacecraft's receiver as a consequence of many thousands of co-frequency subscriber units emitting some energy in the direction of the spacecraft. Intuitively, the confidence level of the analysis should improve with this type of cross checking.

Satellite Communications
2501 S. Price Road, Chandler, Arizona 85248-2899 (602) 732-2000 Fax (602) 732-3046

The three methodologies used were:

- FCC computer program by Harry Ng
- Excel spread sheet similar to Larry Browne at NRM
- Converting subscriber emissions into "equivalent" hub emissions and comparing to spectral area density limits developed during NRM

At the NRM, Motorola's concerns, were not in calculating the energy levels but the confidence level in estimating the subscriber transmitter characteristics and geographic distribution of these transmitters. These parameters had to be capable of being converted to regulatory rules that could be followed by each LMDS operator. There was not consensus by the LMDS proponents on the current proposed rules for the more definable hub emitters.

Trying to reconcile your different models and assumptions is quite challenging. Motorola started with an examination of EIRP spectral density from each subscriber unit. In your coordination meeting with other proponents, it appears you received agreement on this parameter as summarized in your Table 3 page 4. There was close agreement on a "typical" EIRP density which is reproduced in Table 1 below. In addition, we reviewed comments on the FCC proposed limit of -52 dBW/Hz in the NPRM and have added comments on this rule from each proponent to Table 1

.

Table 1 Proposed Subscriber EIRP Spectral Density

	TI	HP	EG	CV
Typical EIRP density (dBW/Hz)	-47	-44.6	-47.8	-52
Maximum EIRP from Comments (dBW/Hz)	-37	-30	-18	no limit rqd.

You will note the extremely large discrepancy between the "typical" EIRPs used in the analysis and the proposed rule limits. This fundamental assumption has a large uncertainty factor built into it and the accuracy of any subsequent interpretation must be considered very poor. Again, Motorola could comment in a quantitative manner if a rule was proposed for each operator on the EIRP density limits.

TO: Gene Robinson
FROM: Ken Engle
DATE: Sept 29, 1995

With regard to the various methods for interference estimation:

1. The FCC FORTRAN program

This program was developed to analyze the up link interference from a number of identical emitters within the field of view of the satellite. It quite accurately can estimate the interference from a number of emitters that have constant EIRP in the azimuth plane and the elevation plane is a function of the elevation angle to the satellite.

In order to use this simulation tool for analyzing the interference from subscribers, you are required to reduce an aggregate group of subscribers to a collection of identical "artificial hubs". Motorola was unable to follow this discussion and cannot comment on its accuracy. It would have been useful if TI had proposed a rule on distribution of subscriber units and their technical parameters as this would clarify your model.

It appears you used a modified FCC program as you list an input parameter as being the "satellite elevation angle at the half power beam width". The program available at the NRM used the satellite antenna elevation angle at boresight. We cannot ascertain the validity of your modification without a description of the algorithm itself.

2. Spread sheet analysis

The spread sheet analysis you employed is only useful at high elevation angles where the elevation angle to each emitter within the main beam is nearly constant. However you attempted to use it for main beam coupling by assuming the satellite boresight is at 2.5 deg. Motorola has repeatedly provided technical data on its footprint that shows some regions are at zero degree elevation for bore sight elevation angles up to 12 degrees. It is not necessary to have the satellite boresight at low elevation angles to get boresight coupling.

An equivalent "artificial hub" concept was employed which makes this analysis difficult to understand unless tied to a technical rule.

3. Equivalent hub spectral density

Without being presented a clear cut methodology for converting subscriber distributions to equivalent hub characteristics, Motorola cannot comment. It should be noted that the proposed rule §21.1020 not only has quantitative limits but it also contains the methodology by which an operator can estimate compliance. It should also be noted that §21.1020 must be applied with §21.1021 as the radiation limit above the horizon is quite important in controlling satellite interference. In your NPRM comments you failed to recognize this fact and made a 25 dB error as a consequence.

TO: Gene Robinson
FROM: Ken Engle
DATE: Sept 29, 1995

In conclusion, TI has failed to provide a technical analysis and associated rules that would permit subscriber units to transmit in the shared band without jeopardizing the up link availability of Motorolas feeder links. Also, in your Comments to the NPRM, you make frequent suggestions that "coordination" between the IRIDIUM operator and the myriad of LMDS operators can easily be accomplished. Without technical criteria it is inconceivable that coordination between these parties could be accomplished particularly if one party (LMDS) would not suffer any interference no matter the outcome. We, of course, remain interested in any progress you may be able to achieve in the direction indicated in your letter -- particulary toward formulating concrete, enforceable and broadly acceptable rules that associate aggregate energy limits with limits on the number and the geographic distribution of subscriber terminals. We look forward to commenting on any such rules.

Sincerely,

John Knudsen
Director Spectrum and Standards

cc: Mr. David Carroll, Motorola
Mr. Ken Engle, Motorola
Mr. Richard Stone, Motorola
Mr. Charles Brand, CellularVision
Mr. Eric Barnhart, CellularVision
Mr. Shant Hovnanian, CellularVision
Mr. Bernard Bossard, CellularVision
Mr. Samir Kamal, Hewlett Packard
Mr. Doug Gray, Hewett Packard
Mr. Doug Lockie, Endgate
Mr Lelland Langston, Texas Instruments
Mr. Bill Myers, Texas Instruments
Mr. Paul Misener, Texas Instruments
Mr. Greg Rosston, FCC
Mr. Don Gips, FCC
Mr. Bob James, FCC
Mr. Thomas Tycz, FCC
Mr. Bruoce Franca, FCC
Dr. Michael Marcus, FCC

cc: Donald, Karl, Jennifer, Chris (orig back to ...)

Texas Instruments Incorporated

TEXAS INSTRUMENTS

Post Office Box 650311
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7839 Churchill Way
Dallas, Texas 75251

September 12, 1995

Mr. John Knudsen
Motorola Satellite Communications
2501 South Price Road
Chandler, Arizona 85248

SEP 13 1995

Dear John:

I would like to thank you for providing me the opportunity to meet with David Carroll and Richard Stone during August to discuss the Local Multipoint Distribution Service and the Iridium system using the 29.1 to 29.25 GHz band jointly. The analysis that Texas Instruments presented during the Negotiated Rule Making Committee last year, NRMC 46, using the FCC analysis program indicated that both LMDS hubs and CPEs could operate on the same frequencies as the Iridium uplink without harmful interference. The analysis that I presented in August of this year was one of direct beam interaction which also indicated that the two systems, LMDS with transmissions from subscriber locations and the Iridium satellite receivers, could operate without harmful interference. Adjustment of satellite foot print area by a factor of ten and accommodating the increased bandwidth of the Iridium receiver still indicated that the two systems could share the same operating frequencies. The recent proposed band plan from the FCC with the limited spectrum available in the 28 GHz band makes it imperative that we work together to accommodate the co-sharing of the 29.1 to 29.25 GHz frequencies.

Mr. Stone felt that analysis of different LMDS systems would be necessary to determine if sharing of the frequencies were possible. Thus, to this end, the proponents of the different LMDS systems, (CellularVision, Endgate, Hewlett Packard and Texas Instruments), met last week in Washington to identify each of the individual system parameters associated with their CPEs that would be a factor in sharing the same operating frequencies with the Iridium satellite receiver and conduct analysis using these parameters. A statistical analysis based on the FCC analysis developed during the NRMC and a direct beam analysis with both dense and sparse area distributions were conducted during this meeting. The results of these analyses produced positive C/I margins such that sharing between the LMDS CPEs and Iridium in the 29.1 - 29.25 GHz band is shown to be possible without interference to the satellite receiver.

The results of these analyses is provided in the attached report for your review. We look forward to meeting with Motorola to further discuss the analysis and sharing of the 28 GHz band.

Regards,

Gene Robinson,
Senior Fellow,
Texas Instruments

cc: Mr. Dave Carroll, Motorola
Mr. Ken Engle, Motorola
Mr. Richard Stone, Motorola
Mr.Charles Brand, CellularVision
Mr. Eric Barnhart, CellularVision
Mr. Shant Hovnanian, CellularVision
Mr. Bernard Bossard, CellularVision
Mr. Samir Kamal, Hewlett Packard
Mr. Doug Gray, Hewlett Packard
Mr. Doug Lockie, Endgate
Mr. Leland Langston, Texas Instruments
Mr. Bill Myers, Texas Instruments
Mr. Paul Misener, Texas Instruments
Mr. Greg Rosston, FCC
Mr. Don Gips, FCC
Mr. Bob James, FCC
Mr. Thomas Tycz, FCC
Mr. Bruce Franca, FCC
Dr. Michael Marcus, FCC

LOCAL MULTIPOINT DISTRIBUTION SERVICE CUSTOMER PREMISE EQUIPMENT TRANSMISSION AND IRIDIUM SATELLITE RECEIVER COMPATIBILITY ANALYSIS

SEPTEMBER 12, 1995

INTRODUCTION

Local Multipoint Distribution Service proponents met September 6-7, 1995, to conduct analysis to determine the feasibility of the various LMDS customer premise equipment (CPE) to use the 29.1 to 29.25 GHz band as the return link frequency to the LMDS hubs and demonstrate compatibility with the Iridium satellite receiver operating in this band. The typical CPE parameters were determined for four proposed LMDS systems from CellularVision, Endgate Technology, Hewlett Packard and Texas Instruments. These systems all make use of narrow beam antennas (2.5 to 4 degree beamwidth), return link power control to adjust the transmit power for rain attenuation and/or range (0.1 km to 2.0-5 km) from the CPE to the system hub and low EIRP density at maximum range(-44.6 dBW to -52 dBW). These parameters were then used in a statistical analysis derived from the program generated by the FCC during the Negotiated Rule Making Committee for 28 GHz in 1994 and in a direct beam interaction analysis. These analyses are presented in the following sections of this report.

SUMMARY OF RESULTS

The results of the analysis using a statistical approach to CPE distribution and transmission shows that the Iridium receiver carrier to interference ratio (C/I) requirement of 20.9 dB can be met with positive margin. In addition the direct beam analysis shows that the power spectral density of -26 dBW/MHz-km^2 can be met by the various LMDS CPE return links. Thus, the LMDS CPEs are capable of using the 29.1 GHz to 29.25 GHz band for return links without harmful interference to the Iridium satellite receiver. Table one is a summary of the C/I ratios provided by each of the LMDS systems and Table two provides a summary of the power spectral density for dense and sparse populated LMDS systems.

Table One: C/I Ratio Analysis Summary

System	Total C/I	Main Beam C/I
CellularVision	36.7	37.1
Endgate Technology	27.6	28.1
Hewlett Packard	41.9	43.1
Texas Instruments	35.4	36.0

Table Two: Power Density Summary

System	200 X 400 km, dBW/MHz-km^2	2000 X 400 km, dBW/MHz-km^2
CellularVision	-42.65	-46.65
Endgate Technology	-26.2	-30.2
Hewlett Packard	-34.56	-38.56
Texas Instruments	-39.67	-43.67

STATISTICAL ANALYSIS

Overview

The aggregate power density from LMDS subscriber transmissions directed toward the Iridium satellite vehicle is calculated for four LMDS systems, Texas Instruments, Hewlett Packard, Endgate Technology and CellularVision. The aggregate power density is compared to the satellite feeder power density to provide a C/I ratio. The satellite C/I for each of 4 LMDS system ranges from 27.6 to 41.9 dB with a desired C/I of 20.9 dB.

System Parameters

The satellite parameters used as inputs to the analysis program are as follows.

SV altitude=780.0 Km.
SV half power beamwidth (HPBW) =5.0 degrees
SV elevation angle to the edge of the HPBW = 7.5 degrees
SV feeder EIRP density = -21.1 dBW/Hz
SV antenna pattern for Iridium

LMDS system parameters that were used for the four different LMDS systems in the analysis program are listed below.

Table Three: Typical LMDS System Parameters

Parameter	TI	HP	EG	CV
Transmitter Power per RF channel (dBW)	17	-19.6	-13	-23
Modulation Type	QPSK	QPSK	4FSK	QPSK
Bandwidth of RF channel (MHz)	2.5	1.0	24	1.0
Antenna Gain (dBi)	34	35	39	31
EIRP density (dBW/Hz)	-47	-44.6	-47.8	-52
Minimum hub-CPE range (Km)	0.1	0.1	0.1	0.1
Maximum hub-CPE range (Km)	5	2	2.2	5
Tower height (meters)	30	15	20	30
Hub spacing in HPBW (Km)	17	17	17	17
Hub spacing out of HPBW (Km)	68	68	68	68
Maximum look angle for 50% blocking (Deg)	5	5	5	5

CPE Antenna pattern envelope is specific for each LMDS supplier
(Frequency reuse is included in the hub spacing density for a reuse factor of 4)

As noted above, LMDS system specific parameters are included. A common hub spacing is used for each LMDS system. This is equivalent to CPE spacing for simultaneous transmissions based on a frequency reuse factor of 4. Adjustments are made in the results for variations to these parameters for each LMDS system.

Analysis Results

Outputs resulting from the program are listed below. Adjustments are made for different frequency reuse and hub densities for each LMDS system. The number of simultaneous hub receiving frequencies is equivalent to the number of CPEs transmitting simultaneously.

Table Four: Statistical Analysis Results

Data Output and Adjustments	TI	HP	EG	CV
CPEs in SV HPBW (frequency reuse 4x)	896	896	896	896
CPEs outside the SV HPBW	3940	3940	3940	3940
C/I for CPEs within the SV HPBW (dB)	36.0	41.4	35.1	37.1
C/I for all CPEs as an aggregate (dB)	35.4	40.2	34.6	36.7
Frequency reuse adjustment (dB)	-	-	-7.0 (4/20)	-
Concentration factor (dB)		1.7 (6/4)		
Resulting Total Aggregate C/I (dB)	35.4	41.9	27.6	36.7

Adjustments for frequency reuse and concentration factors effect the number of CPEs transmitting in the calculation of density and therefore are converted to a dB value. The dB value is used to adjust the program results. HP plans on a circuit concentration of 6x which would reduce the number of hubs. Endgate plans a frequency reuse factor of 20 rather than a value of 4 that was used in calculations. It should be noted that the hub spacing derived from the population density is valid for the Endgate Technology deployment which is based primarily on business applications. The resultant C/I ratio is conservative since the hub densities should be based on business distributions instead of general population distributions.

With worst case population density, worst case subscriber density area, LMDS suitability factor of 100% and fully loaded busy hour circuits, this analysis indicates the lowest LMDS supplier aggregate C/I created by subscriber transmissions is within the required Iridium C/I limit.

DIRECT BEAM INTERACTION

The statistical analysis approach presented above provides a snapshot of the total interference into the Iridium satellite by typical LMDS CPEs for four different LMDS systems. It includes interference from CPE antenna side lobes and possibly interference from main beam interaction between the CPE antennas and the satellite. However it is a statistical model and as such does not provide an indication of what the interference could be under certain worst case conditions. Therefore an analysis was performed to provide an estimate of the worst-case interference caused by LMDS CPE main beam interaction with the main beam of the Iridium satellite.

Overview

The computer model was exercised over many different geometries with different initial conditions. Although the results indicate that the expected interference from LMDS CPEs into the Iridium satellites is low, concern has been expressed that the model may not provide information about the interference under certain worst-case geometries and CPE operations. Therefore a separate model was developed to analyze the interference into the Iridium satellite by CPE transmitters when the parameters are adjusted for worst-case conditions. This model does not provide any estimate of the probability of this result, but only establishes an upper bound on the interference based on the worst-case conditions for direct main beam interaction.

The first step is to define the worst case scenario. Although a "worst-case" could be defined for all CPE antennas coupling into the Iridium satellite, this would be completely unrealistic because of the CPE distributions. Therefore we should define the worst-case scenario as one which is realistic, although highly improbable. The worst-case scenario will be defined based on the design parameters of the different LMDS systems and the expected deployment scenario. The analysis will be performed for the various LMDS

system implementations and for two satellite footprints. The worst-case earth-satellite geometry is assumed to be one which places the satellite antenna 2.5 degrees above the horizon. All CPE antennas are assumed to be pointed at the horizon. Therefore the Iridium satellite "sees" all CPE antennas pointed in the direction of the satellite. Although the CPE antenna-satellite distance varies over the satellite footprint, this distance is assumed to be equal to the distance between the Iridium gateway and the satellite in each case. The analysis calculates the total LMDS CPE power spectral area density in the satellite footprint for this worst-case scenario and shows a range of -30.2 to -46.65 dBW/MHz-km^2 for the large satellite footprint.

System Parameters

There may be numerous LMDS system implementations. Therefore the analysis was performed for four typical LMDS system implementations which represent a broad range of system parameters and distribution geometries. The analysis was also performed for different system operating parameters. The LMDS system parameters used in the analyses are shown in Table Five. The satellite parameters are shown in Table Six. The parameters are based on maximum capacity and assume the full 150 MHz return bandwidth is utilized. The satellite elevation angle and subscriber antenna elevation angles are adjusted to provide maximum interference on the horizon..

Table Five: Direct Beam LMDS System Parameters

System Parameter	(TI) Sys 1	(CV) Sys 2	(HP) Sys 3	(EG) Sys 4
1. Number of Subscriber Channels in 150 MHz BW	60	150	150	6
2. Number of Subscribers per Node in 150 MHz BW	5760	14400	3600	120
3. Subscriber Distribution	----------Uniform----------			
4. Subscriber Duty Cycle, %	4	4	4	100
5. Subscriber Antenna Elevation Angle, degrees	2.5	2.5	2.5	2.5
6. Subscriber Antenna Gain, dB	34	31	35	39
7. Antenna 3 dB Beamwidth, degrees	2.5	4.0	3.0	2.5
8. Subscriber TX bandwidth, MHz	2.5	1.0	1.0	24
9. Subscriber TX Power, Clear Air, dBW	-17	-23	-19.6	-13
10. Hub Density (Actual No. Hubs/Maximum No. Hubs)				
a. In 200 km X 400 km footprint	0.25	0.25	0.25	0.25
b. In 2000 km X 400 km footprint	0.1	0.1	0.1	0.1
11. Cell (hub) spacing, km	5	5	2	2.2

Table Six: Direct Beam Satellite Parameters

1. Satellite Footprint	
a. Small	200 km X 400 km
b. Large	2000 km X 400 km
2. Allowed Power Spectral Density	- 26 dBW/MHz-km^2
3. Receiver Bandwidth	6.25 MHz
4. Satellite Elevation angle, degrees	2.5

In addition to these parameters, a number of assumptions about the system were used in the calculations. These assumptions are:

Percent of CPE signals having same polarization as satellite	50%
Percent of CPEs having clear LOS path to satellite	50%
Percent of CPEs simultaneously active	50%

Direct Beam Interaction Analysis Results

The system parameters for the four systems were used to analyze the expected interference level radiated from within the satellite footprint. Two footprints were used: 200 X 400 km and 2000 X 400 km. The total interference was calculated in terms of dBW/MHz-km^2. The analysis procedure and equations are described in the following paragraphs and summarized at the end.

The first step is to calculate the Effective Isotropic Radiated Power (EIRP) from any CPE. This is calculated as follows:

$$P_{EIRP} = P_{TX} + G_{TX\,ANT}$$

The EIRP Power Spectral Density is then calculated, based on the channel bandwidth for the particular system:

$$PSD_{EIRP} = P_{EIRP} - 10 \log (BW)$$

Since Adaptive Power Control is used at each CPE to normalize the received power at the node or hub antenna, the average power of the CPE transmitter can be used. The average power is taken to be the power averaged over all CPE transmitters associated with a hub. Since the CPEs are uniformly distributed in area about the hub, the average power is the power radiated by a CPE located on the boundary of a circle which equally divides the

coverage area of a hub. This distance is 0.707 R, where R is the cell radius. (The area of the hub coverage is πR^2 and the area within the circle bounded by 0.707 R is $(0.707)^2 \pi R^2 = 0.5 \pi R^2$.) Hence the average CPE TX power is 3 dB less than the power at maximum range; hence the PSD is also 3 dB less:

$$\overline{PSD_{EIRP}} = PSD_{EIRP} - 3 \text{ dB}$$

The next step is to determine the average area associated with each subscriber which causes interference into the satellite so as to determine the PSD area density. The first step toward this objective is to determine the average number of subscribers associated with a hub which can be transmitting on the same frequency. This is simply the total number of subscribers supported by a hub divided by the number of unique frequency channels.

N = (Total No. Subscribers/hub)/(Number of frequency channels)

The average number of subscriber or CPE antennas which couple with the satellite antenna is simply the ratio of the CPE antenna beamwidth, θ, to 360 degrees multiplied by N:

$$n = N\theta/360$$

Now the average area associated with an interfering subscriber can be computed. It is the total area, A, served by a hub (with cell radius R), divided by n:

$$A = \pi R^2$$
$$A' = A/n = \pi R^2/n$$

Now the desired Power Spectral Area Density, ψ, can be calculated:

$$\psi = \overline{PSD_{EIRP}} - 10 \log(\pi R^2/n)$$

The units of ψ are dBW/MHz-km^2. This value assumes that all subscribers transmit with a 100% duty factor. This is the case for some systems (e.g., Endgate Technology). However others are able to serve the stated number of subscribers based on a duty factor. In those cases, the Power Spectral Area Density value must be adjusted for the duty factor:

$$\psi' = \psi + 10 \log(\text{duty factor})$$

This is the average value associated with a single hub. The next step is to adjust the value for the wide area covered by the satellite footprint. Since the value is per unit area, it is

only necessary to adjust the value based on ratio of coverage. The following factors are applied:

P_1	Percent of CPE signals having same polarization as satellite	50%	- 3 dB
P_2	Percent of CPEs having clear LOS path to satellite	50%	- 3 dB
P_3	Percent of CPEs simultaneously active	50%	- 3 dB
P_4	Percent of Hub coverage		
	For 200 X 400 km footprint	25%	- 6 dB
	For 2000 X 400 km footprint	10%	-10 dB

$$\Psi = \psi' + P_1 + P_2 + P_3 + P_4$$

The final Power Spectral Area Density, Ψ, is the effective value for the LMDS CPEs located within a specific satellite footprint (either 200 X 400 km, or 2000 X 400 km). It represents the worst case (realistic) power spectral area density seen by a satellite located at an elevation angle of 2.5 degrees and "seeing" the CPEs located within a CPE antenna beamwidth. This does not include any CPE sidelobe radiation, but only the radiation from the CPE main beam.

The analysis was implemented using a spread sheet to perform the calculations. The results are tabulated in Table Seven.

Table Seven. Typical CPE/Iridium Satellite Direct Beam Interaction Analysis

	TI Sys 1	CV Sys 2	HP Sys 3	EG Sys 4
No Sub Ch in 150 MHz BW	60	150	150	6
No Sub/Node in 150 MHz BW	5760	14400	3600	120
Subscriber Duty Cycle	0.04	0.04	0.04	1
Sub Ant Gain, dB	34	31	35	39
Sub Ant Beam Width, Deg	2.5	4	3	2.5
Sub TX Bandwidth, MHz	2.5	1	1	24
Sub TX Power, dBW	-17	-23	-19.6	-13
Hub Spacing, km	5	5	2	2.2
Avg PSD/MHz	10.02	5.00	12.40	9.20
Psi, dBW/MHz-sq km	-10.69	-13.67	-5.58	-11.2
Psi with duty factor applied	-24.67	-27.65	-19.56	-11.2
PSAD, Small Footprint	-39.67	-42.65	-34.56	-26.2
PSAD, Large Footprint	-43.67	-46.65	-38.56	-30.2

The analysis was completed for the four types of systems and for two footprint areas. The results are summarized in Table Eight.

Table Eight: Typical LMDS CPE/Iridium Main Beam Interaction Analysis

System	Power Spectral Area Density, dBW/MHz-km^2 For 200 km X 400 km Area	For 2000 km X 400 km Area
Texas Instruments (Sys 1)	-39.67	-43.67
CellularVision (Sys 2)	-42.65	-46.65
Hewlett Packard (Sys 3)	-34.56	-38.56
Endgate Technology (Sys 4)	-26.2	-30.2

The results indicate that the Power Spectral Area Densities are below the levels necessary to provide the required C/I ratios at the satellite for the large foot print case, even under the worst case scenario. Even when combined with the interference caused by CPE antenna sidelobes, the levels are well below the tolerable levels (-26 dBW/MHz-km^2) for the satellite. When the satellite is well above the horizon, the main beam coupling will be significantly reduced. Therefore it is concluded that LMDS CPEs will not cause sufficient interference into the satellite to degrade performance of the satellite even under worst case conditions. This is achieved without any system constraints other than antenna sidelobe control, EIRP control and PSD control.

CONCLUSIONS

The C/I ratio results using the statistical approach for CPE distribution and return link operation, and the direct beam interaction analysis shows that the Iridium satellite receiver is not affected by the CPE return link transmission. In addition, the direct beam interaction analysis yielded power spectral densities lower than the specified -26 dBW/MHz -km^2. Thus, one can conclude that LMDS systems designed for the terrestrial applications can co-exist with the Iridium system and not cause harmful interference to the Iridium satellite receivers when the 29.1 to 29.25 GHz spectrum is used as return links from the LMDS CPEs to the hubs.

Appendix A. Statistical Program Description

For analysis of the aggregate power emanating from a large area, the program written by FCC engineer Harry Ng was used with modifications to accommodate subscriber (CPE) transmissions. Modifications include the addition of subscriber antenna patterns, random subscriber-to-hub distance, power control, and a random azimuth for CPE transmission. The subscriber-to-hub distance is based on a maximum and minimum hub range. Subscriber antenna elevation angle is calculated from hub tower height and distance from the hub. Following is a description of the program calculations.

Inputs to the program are as follows.

- satellite altitude
- satellite half power beam width and antenna pattern
- satellite elevation angle at the edge of the half power beam width
- satellite earth station feeder link radiated power density
- CPE radiated power density at maximum range to the hub
- hub or CPE spacing within the footprint
- hub or CPE spacing outside the footprint
- hub tower height
- maximum CPE range to hub
- angle where CPE path blocking is expected

The program loops through latitude swaths equal to the CPE spacing. For each swath, the power as seen by the satellite antenna, is computed for each simultaneous CPE transmission. A matrix of latitude and longitude calculations is performed and the power is accumulated to obtain the aggregate power into the satellite. Each latitude swath is summarized in the output with the angle from the CPE to the satellite in 5 degree bins.

To accurately model the subscriber radiated power directed toward the satellite, the pointing angle of each subscriber antenna is randomly selected over 360 degrees with a uniform distribution. The azimuth and elevation angle of the subscriber antenna is used to calculate antenna pattern gain and the look-angle to the hub.

Look-angle to the hub is determined from the tower height and subscriber to hub distance. Based on the maximum range to the hub, the distance to the hub is randomly selected using square root of uniform distribution. The square root applies because subscriber density varies by area and the area varies by the square of the distance from the hub. Once the look-angle is calculated, the angle to the satellite is calculated from the satellite geometry and the subscriber antenna pattern is interpolated to find the radiated power density directed toward the satellite.

Subscriber power is based on the distance from the hub. Radiated power is reduced by the 20*log the ratio of the randomly selected distance to the hub and the maximum range.

Blocking is expected for low elevation angles of subscriber transmission such that line of sight to the satellite is blocked for 50% of the subscribers.

The aggregate power at the satellite is computed for locations in the half power beamwidth and outside the half power beam width. The total from both inside and outside the beamwidth is compared to the feeder power density to determine the C/I ratio.

The number of hubs in the footprint is geometrically computed from the SV antenna beamwidth, SV altitude and elevation angle to satellite and is provided as an output. The number of hubs outside the half power beamwidth is also an output.

Appendix B. Population/Subscriber Density Calculations

The number of simultaneously transmitting subscribers is based on the hub circuit capacity. To determine the number of subscribers (CPEs) transmitting simultaneously within the SV footprint, high density areas of the United States were used to calculate the number of hubs required. Footprint orientations of North-South along the Northeastern seaboard and East-West from the Northeast seaboard are summarized by state in the table below.

Table B.1 Population and Area for North-South and East-West Footprints

State	North-South	Population (millions)	Area x1000 (Sq Km)	East-West	Population (millions)	Area (K Sq Km)
NH	X	1.1	24.2			
VT	X	0.6	24.9			
MA	X	6.0	27.3	X	6.0	27.3
RI	X	1.0	4.0	X	1.0	4.0
CT	X	3.3	14.4	X	3.3	14.4
NY	X	18.2	139.8	X	18.2	139.8
NJ	X	7.8	22.6	X	7.8	22.6
PA	X	12.0	119.3	X	12.0	119.3
DC	X	0.6	.2			
DE	X	0.7	6.4			
MD	X	5.0	32.1			
VA	X	6.4	110.8			
WV	X	1.8	62.8			
SC	X	3.6	82.9			
GA	X	6.9	154			
OH				X	11.1	116.1
MI				X	9.5	250.7
IL				X	11.7	150.0
IN				X	5.7	94.3
WI				X	5.0	169.0
Totals		75	825.7		43	780.1

From the table above, the worst case footprint density would be North to South covering the Northeast and Mid-Atlantic coast. The area approximates a footprint of 400x2000 km^2 and contains a population of 75 million people. Using an average 3 people per household, the number of households would be 25 million.

Based on the upstream circuit capacity of the hub, the number of hubs required to serve the densely populated Northeastern area is described above. The number of subscribers transmitting is determined by the hub capacity. Worst case busy hour maximum loading is

assumed such that all frequencies of all hubs are 100% active. The worksheet table below provides the calculation for average hub spacing for the satellite footprint. This table, for example, is for the TI system which uses the following system parameters.

a) Take rate factor = 0.25. This factor is a conservative estimate of the number of subscribers (CPEs) that would desire 2-way service.

b) Concentration = 4. This is the system circuit concentration (inverse of Erlang).

c) Frequency reuse = 4. The hub frequency is reused 4 times by providing 4 sectors with alternating polarization. In order to account for all CPE frequencies active at one time the spacing is based on 4 times the number of hubs.

d) Capacity of each hub is the worst case if the entire 150 MHz were loaded with RF channels.

e) Active CPE refers to the number of reused frequencies at the hub.

Table B.2 Calculation Worksheet for Determining Hub Spacing

1	B	C	D	E	F
2	ITEM INPUT	CALC	INPUT	RESULT	UNITS
3	Total Households		2.50E+07		Households
4	Take Rate Factor	D3*D4	0.25	6250000	Subscribers
5	Circuit concentration	E4/D5	4	1562500	Circuits required
6	Capacity of each Hub	D5/E6	5760	271	Hubs required
7	Frequency reuse factor	E6/D7	4	1085	CPEs
8	** For 400x2000 Sq. Km. footprint: **				
9	Area of population		800000		Sq. Km.
10	Average area per active CPE	D9/E7		737	Sq. Km./CPE
11	Average spacing (400x2000)	E10^0.5		27	Km.
12	** For original 200x1400 Sq. Km. footprint: **				
13	Original footprint area		280000		Sq. Km.
14	Average area per active CPE	D13/E7		258	Sq. Km./CPE
15	Average spacing (200x1400)	E14^0.5		16	Km.

Table note: The original spacing for 200x1400 footprint did not include ME, SC and GA due to the smaller footprint and was based on a CPE spacing of 17 Km.. The aggregate power calculations use 17 Km. spacing and was not changed to reflect the 27 Km. spacing now being predicted for the larger footprint.

Hub and CPE density outside the footprint is based on similar calculations for the continental US.