station antennas are used. Significant reductions in interference levels should also be expected when improved antenna patterns are implemented on earth station antennas of other FSS systems such as SPACEWAY.

2.2 Propagation Paths and Rain Conditions

Three different radio paths are considered to include the implications of rain fading in this interference analysis. Both the LMDS and FSS uplink systems have a desired transmission path. In addition, there is an interference path between the FSS transmitter and an LMDS receiver. With rain/no rain conditions on each path, there are a maximum of eight possible rain conditions that could occur. A detailed study of the correlation of rain rates on the given paths to determine the probability of occurrence of each rain condition is not available. The maximum number of conditions has been reduced to the following four cases in order to show representative cases including the most probable and worst case interference situations:

1. LMDS desired signal in clear sky
   FSS desired signal in clear sky
   Interference path between systems in clear sky
   This case is the most probable propagation condition.
2. LMDS desired signal in clear sky
   FSS desired signal in clear sky
   Interference path between systems in 21 mm/hr rain condition (up to 4 km maximum rain cell size)
   This case illustrates how rain attenuation on the interference path affects the required separation distance.
3. LMDS desired signal in rain (amount of attenuation as specified by system proponent)
   FSS desired signal in 17.1 dB rain attenuation
   Interference path between systems in clear sky
   This case is believed to be the worst case interference scenario since many FSS systems employ power control to increase transmitter power under rain faded conditions, and LMDS systems may or may not employ power control during rain-faded conditions. In the absence of rain on the interference path, the required separation distances are largest.
4. LMDS desired signal in rain (amount of attenuation as specified by system proponent)
   FSS desired signal in 17.1 dB rain attenuation
   Interference path between systems in 21 mm/hr rain condition (up to 4 km maximum rain cell size)
   This case represents a more likely rain condition than condition 3 mentioned above.

2.3 Antenna Angles

Calculations are performed for an FSS earth station with a boresight elevation angle of 40 degrees and the azimuth pointing in the direction of the LMDS receiver. The earth station antenna is pointing directly "over the head" of the LMDS antenna. This is the worst case geometry for received interference. Three different earth station antenna masks are used in combination with the antenna mask proposed by the LMDS system proponent for four LMDS antenna azimuth angles relative to the boresight pointing directly at the earth station. Angles of 0 (boresight), 5 (just off boresight), 45 (far off sidelobe), and 180 (backlobe) degrees were used. The non-boresight angles are calculated in order to examine the impact of LMDS receiver antenna pointing on the required separation distance/margin to avoid interference.

2.4 Presentation of Results

For each combination of ES antenna discrimination at 40 degrees elevation, LMDS receiver antenna azimuth angle, and rain on the FSS and LMDS desired signal links, the results are presented in several different ways. First, the margin in decibels is calculated under clear sky interference conditions for a 1 km separation between the interference source and LMDS receiver. The required separation under clear sky is calculated based on free space path loss vs. distance plus a 0.02 dB/km atmosphere induced attenuation for climatic zones 3-5. This is the smallest rate of atmospheric attenuation, and was selected in order to provide a conservative estimate of required separation distance. The atmospheric attenuation can be as high as 0.1 dB/km in climatic zone 1. No atmospheric attenuation was considered in the NRMC Working Group 1 calculations, but is included here as a refinement. Next, the margin in decibels is calculated under a 21 mm/hr rain rate along a 1 km interference path. The rain attenuation along the interference path is calculated using the Lin model for terrestrial rain attenuation. The required separation is then calculated based on free space path loss vs. distance plus a 0.02 dB/km atmosphere induced attenuation and rain attenuation. The rain attenuation is calculated using the Lin model for a rain rate of 21 mm/hr over a maximum rain cell size of 4 km. For each minimum required separation under rain conditions, the allocation of path loss to free space, atmosphere, and rain attenuation is presented in the spreadsheet. The required separations under clear sky and rain conditions are summarized at the top of the spreadsheet with distances in miles.

3.0 Spreadsheet Organization and Calculation Assumptions

The spreadsheet describing the calculations is arranged by columns to identify the LMDS system being interfered with. For a given set of system parameters, calculations span three columns. The results in each column represent the FSS earth station antenna mask used. The first column is the ITU-699 mask as used in the NRMC calculations. The second column is for an antenna discrimination of 63 dB which is a 25 dB improvement over the ITU mask. This is labeled as the conservative improvement. A more optimistic improvement is presented in the third column for an antenna discrimination of 78 dB (40 dB improvement). The terms "conservative" and "optimistic" are used to distinguish between the relative improvements in sidelobe levels investigated, and are not intended to reflect the feasibility of implementation. Rows 1-182 are used to step through the interference calculations. Each of seven sets of calculations spans four pages.

3.1 LMDS and FSS Earth Station System Parameters

Lines 1 through 13 are used as column headings for each of the four pages for a set of calculations. These lines list the LMDS and FSS system designs considered in the interference analysis for each set of three columns. LMDS system parameters such as system proponent, link (hub-to-sub or sub-to-hub), modulation, digital data rate, channel bandwidth, antenna pattern used, and date/revision of system parameters are listed in this section on lines 4-10. Line 12 indicates the FSS system under consideration. All calculations are performed for a Teledesic Standard Terminal (TST) operating at a T1 rate.

3.2 Required Separation

Lines 14-20 summarize the clear sky separations required to reduce interference to acceptable levels for the different combinations of ES discrimination at 40 degrees and LMDS receiver antenna azimuth angle. Lines 21-27 summarize operation under rain conditions when the TST is at full power and the interference path undergoes 21 mm/hr rain along a path up to 4 km long. All separation distances are reduced to a maximum of 100 km to incorporate a conservative estimate of the radio horizon distance. Beyond the radio horizon, it is assumed that interference is reduced to acceptable levels. The calculations are based on a flat earth propagation model where the terminals are located at the same elevation above ground level. No blockage is assumed.

3.3 LMDS Signal Link Carrier Level at Cell Edge

Lines 31-40 describe the characteristics of the LMDS signal link for a subscriber located at a distance equal to the cell edge. When LMDS systems employ power control to overcome rain fades, the amount of power control used in the calculations is the minimum necessary to compensate for the rain fade. For lines 31-40, the first column in the set of three columns for a given system denotes the clear sky link budget, and the third column denotes the link budget under rain conditions.

3.4 Interference Density into LMDS

Lines 47-57 are used to calculate the interference density that can be tolerated by the LMDS system receiver. The calculation starts by computing the noise floor of the LMDS receiver. Based on the minimum required C/(N+I) and the carrier level at the cell edge (C), the maximum acceptable interference in a single channel is calculated on line 56. This value is converted to an allowable interference level based on the bandwidth correction as outlined in section 4.2 in the Working Group 1 report.

3.5 Interference Density Generated

Lines 64-78 describe the FSS uplink from the ES to the satellite as a function of antenna mask. The three columns under the calculations for each LMDS system describe how the parameters vary as a function of earth station antenna discrimination as described on line 64. The interference subtotal for clear sky conditions is given on line 72. Lines 73-77 are used to describe the link conditions under rain. Lines 73-76 are not used, and should be ignored. Line 77 indicates that the feeder link system undergoes a 17.1 dB rain fade. The power control required to overcome the rain fade is also 17.1 dB as described in line 77. The interference level subtotals on lines 72 and 78 are the transmitted interference subtotals before any propagation path loss is included.

3.6 LMDS Receiver Antenna Gain

Lines 87-91 represent the antenna gain of the victim LMDS receiver as supplied by the system proponent for antenna azimuth angles of 0, 5, 45, and 180 degrees off boresight.

3.7 Results of Calculations

The results of the calculations are provided on lines 97-182. The case of clear sky conditions on both signal paths are detailed on lines 97-138. Calculations for LMDS boresight are given on lines 99-108. These calculations are repeated for the other LMDS antenna azimuth angles on lines 109-138, and the components of the calculations are identical to the boresight antenna calculations described below.

Line 100 is the path loss required to reduce the interference to an acceptable level. Line 101 presents the margin between the actual interference and the maximum acceptable interference at the LMDS receiver for an interference source located 1 km from the victim in clear sky conditions. Line 101 shows the required separation between the terminals for clear sky conditions (free space path loss, atmospheric attenuation) for the required path loss given on line 100. No radio horizon limitations are imposed. Under 21 mm/hr rain conditions, the margin at 1 km separation is given on line 103. Line 104 shows the required separation between the terminals under 21 mm/hr rain rate conditions. A maximum rain cell size of 4 km is used to limit the amount of rain attenuation observed. Lines 105-108 demonstrate the allocation of the path loss for the required separation on line 104. Line 106 is the free space path loss, line 107 is the atmospheric attenuation, and line 108 is the rain attenuation. All path loss values in the spreadsheet represent positive loss regardless of the sign (+/-) of the number in the spreadsheet cell.

Lines 141-182 summarize the calculations for rain conditions on the FSS and LMDS desired signal paths.

4.0 Results

4.1 Comparison With NRMC Final Report

The first eight spreadsheet pages show the calculations for a T1 TST interfering into a Suite 12/CellularVision hub-to-subscriber link. The first four spreadsheet pages are used to verify correct operation of the revised spreadsheet. No atmospheric attenuation is used in the calculations, and the LMDS hub transmitter power per channel is -4 dBW. Table 1 below shows a comparison between the required separations under clear sky conditions as calculated here and in the NRMC final report. The values agree to within two tenths of a mile separation. The slight differences can

Table 1: Validation of Revised Spreadsheet

Required Separation (miles) T1 TST -> CellularVision Subscriber Receiver	NRMC Working Group 1 Final Report	Revised Spreadsheet Calculation
Boresight	23.7	23.85
5 degree Sidelobe	N/A	3.00
45 degree Sidelobe	1.50	1.50
180 degree Backlobe	0.0751	0.08

be attributed to numerical round-off or slight differences in exact carrier frequency, and are small enough to provide confidence in the calculations presented here. In addition, calculations are made for a five degree off boresight angle to show how quickly the separation distance decreases for a small angular difference from boresight. This is significant because if affects the amount of cell area where harmful interference is received.

The specific assumptions used under rain-faded conditions were not specified in the Working Group 1 final report. Hence, a direct comparison with the report is not possible. However, it is apparent that the WG 1 calculations assumed the rain cell existed over the entire length of the interference path. This can be seen in the case of interference from a T1 TST into a CellularVision subscriber antenna boresight aligned with the interferer. Under clear sky conditions, the required separation was over 23 miles. When the TST increased its output power by 17.1 dB to compensate for a rain fade, the required separation was decreased to only 8 miles. The calculations presented here under rainy conditions assume a more realistic maximum rain cell size of 4 km, and hence show larger required separations under rainy conditions than those contained in the Working Group 1 report. A contribution submitted to the Committee at the end of its negotiation period entitled, "The Teledesic System Will Interfere With LMDS," provides the CCIR formula for rain attenuation which was likely used for the Working Group 1 report. The calculations in the Working Group 1 report for systems described by Texas Instruments under clear sky conditions do not take into account the recent implementation of power control.

4.2 Impact of Improved Earth Station Antenna Discrimination

Table 2 shows the required separation under clear sky conditions for a T1 TST interfering with a Suite 12/CellularVision hub-to-subscriber link for different levels of earth station antenna discrimination. The calculations for Table 2 can be found on spreadsheet pages 5-8, and include 0.02 dB/km atmospheric attenuation and a transmitted power of -5 dBW per channel as specified by the system proponent.

Table 2: Reduction in Separation Distance Under Clear Sky Conditions

Required Separation (miles) T1 TST -> CellularVision Subscriber Receiver	ITU-699 38 dB	Conservative Improvement 63 dB	Optimistic Improvement 78 dB
Boresight	28.18	1.80	0.32
5 degree Sidelobe	3.88	0.23	0.04
45 degree Sidelobe	1.96	0.11	0.02
180 degree Backlobe	0.10	0.01	0.00

Table 2 shows the significant reduction in required separation distance when increased sidelobe suppression is employed on FSS earth station uplink antennas. Boresight separations are decreased from 23 miles to less than 2 miles under the conservative improvement, and to less than half a mile with an antenna discrimination of 78 dB. While a two mile separation between an interference source and a victim receiver still represents a major interference problem, this interference occurs only over a small area within the LMDS cell. At just five degrees away from boresight, required separations can be reduced to less than a quarter mile, and at LMDS azimuth angles further away from boresight, the interference is reduced to even lower levels. The number of LMDS subscriber receiver antennas that will be pointed at an FSS earth station is quite small. For an FSS earth station randomly located in azimuthal direction from an LMDS subscriber, there is a less than 3% chance that the earth station will be within +/- 5 degrees of the main beam of the LMDS antenna assuming a two-dimensional calculation. In three dimensions, this probability is reduced even further. As a result, the size of the geographic area where interference is caused is greatly reduced by LMDS antenna discrimination in the azimuth plane. Table 3 shows the required separation between a TST and a cell-edge located Suite 12/CellularVision subscriber under rain conditions. Note that the summary separation distances at the top of the spreadsheet are given in miles, and all other distances given throughout the spreadsheet are given in km. Under rain conditions, the reduction in required separation distance is comparable to that achieved under clear sky conditions.

Table 3: Reduction in Separation Distance Under Rain Conditions

Required Separation (miles) T1 TST -> CellularVision Subscriber Receiver	ITU-699 38 dB	Conservative Improvement 63 dB	Optimistic Improvement 78 dB
Boresight	36.72	2.46	1.09
5 degree Sidelobe	5.20	0.89	0.25
45 degree Sidelobe	2.63	0.56	0.13
180 degree Backlobe	0.50	0.04	0.01

5.0 Additional Factors Which Lead to Reduced Interference

There are several additional factors which lead to reduced interference in "real-world" situations that are not reflected in the calculations. A list of these factors is given below.

1. FSS earth station antennas are not always azimuthally pointed toward the LMDS receiver.

   Interference levels are calculated assuming the FSS earth station antenna is pointed "over the head" of the LMDS receiver. This is appropriate as this is the worst case; however, only a small number of LMDS antennas will be in the azimuth direction of the earth station at any given time. In addition, this direction is constantly changing as the satellite flies overhead.

2. FSS earth station antenna elevation angles are often greater than 30-40 degrees.

   Interference levels are calculated assuming the FSS earth station antenna is at the system-dependent minimum elevation angle of 30-40 degrees. As a non-GSO satellite flies overhead, the elevation angle will often be greater than 30-40 degrees for much of the time.

3. FSS earth stations may be located higher than the LMDS antenna, leading to increased angular discrimination.

   Since FSS earth station antennas require clearance to elevation angles of 30-40 degrees, they will often be located on the tops of tall buildings. In many cases, the LMDS receiver will be at elevations lower than the earth station installation causing an increased angular distance from the earth station antenna boresight. In these cases, the interference would be reduced due to increased antenna discrimination at larger angular distances from boresight.

4. FSS earth stations will not often be at maximum output power, and will only do so only under

heavy rain conditions.

Interference levels were calculated with the earth station at full output power. This only occurs under very heavy rain conditions. The FSS uplinks are designed for high reliability, and as such are designed to overcome *rare* rain occurrences at full output power. As the designed system reliability increases, the amount of time that the earth station would be at full power decreases. If an earth station installation does not cause interference under clear sky conditions, but only when increasing output power to overcome rain fades, then the issue becomes one of relative importance of availability between services.

5. FSS earth stations will not always be transmitting.

   Many individual earth stations will not always be transmitting information, but will be idle. In addition, peak busy hours for business users of FSS uplinks and consumer video entertainment via LMDS do not likely coincide.

6. FSS earth station transmissions may be bursty with a low (~10%) duty cycle.

   Interference from low duty cycle transmissions may either be tolerable by analog modulation systems, or may be reduced by time sharing with digital systems if inter-system synchronization can be achieved.

7. FSS earth station transmissions at T1 rates only interfere with a small number of LMDS video channels. Hence, for analog video, perceived interference may be less than actual interference statistics.

   The bandwidth of a single T1 transmission to non-GSO satellites coincide with only a few LMDS video channels. Due to the variable pointing of uplink antennas, interference may only occur over a short period of time. The specific time when interference occurs on a particular channel may not coincide with use of that channel by the subscriber of the victim receiver. Therefore, interference that occurs may not always be noticed. However, if this interference occurs on a subscriber's favorite channel during an important event, the impact could be severe.

8. FSS uplink antennas may employ higher gain antennas.

   The use of higher gain antennas would allow for a reduction of uplink power for the same EIRP. This would reduce the amount of interference power into an LMDS receiver. In addition, improvements in sidelobe discrimination are likely easier to achieve in higher gain antennas.

9. In typical operating environments, there will often be building and foliage blockage between FSS earth stations and LMDS receivers.

   NRMC interference calculations did not include the effects of building and foliage blockage due to the inability to determine suitable models. In typical operating environments, however, these natural mitigating factors will serve to decrease the likelihood of receiving harmful interference.

10. Many LMDS receivers will have received carrier levels greater than the level received at cell edge.

    NRMC interference levels were calculated with the LMDS receiver at the cell edge since this is the location where the receiver is most sensitive to interference. At locations in the cell that are closer to the hub, received carrier levels are often higher, and higher levels of interference can be tolerated.

11. LMDS subscriber receivers may also be able to employ antennas with reduced sidelobe levels.

Improved sidelobe discrimination of LMDS receiver antennas would lead to reduced interference in situations where the interference source is not in the main beam of the LMDS antenna.

6.0 Additional Factors Which May Limit Achievable Reduction in Interference

1. Building reflections may create additional interference paths.

While building reflections may create additional paths for interference to reach a LMDS receiver, the probability that this interference arrives in the main beam of a highly directional receiver antenna is quite small. In order for interference from a reflected path to be received in the main beam, the receiver must be pointed toward the reflecting surface. The desired signal from the hub must also be reflected off that same surface. For this situation to exist, the interference source must either be located at the hub or be reflected by surfaces very close to the hub antenna mount. While building reflections may cause interference to be received from directions where sidelobes are higher than the sidelobes pointed directly at the interference source, it is highly unlikely that interference will be received through the main beam of a highly directional LMDS receiver. Antennas with wider beamwidths are more susceptible to receiving interference from reflected paths. This susceptibility can likely be reduced by requiring a minimum separation distance between FSS earth stations and LMDS hubs which employ broad beamwidth antennas.

2. FSS earth stations may occasionally be located below LMDS receiver antennas leading to reduced angular discrimination (hub or subscriber on top of a building and earth station at ground level).

FSS earth station antennas require clearance down to a 30-40 degree elevation angle, and will likely be located in areas with a clear view to potential satellite locations. This reduces the probability that LMDS antennas will be located at higher elevations than FSS uplink antennas. This also serves to reduce the likelihood of building reflections.

3. Multiple earth stations may be located in an LMDS service area.

While multiple earth stations may be located in an LMDS service area, the satellite footprint is much larger than any single LMDS cell. Some form of multiplexing between any two satellite uplink signals is required in order for the satellite receiver to distinguish between the two transmissions. Possibilities include frequency and time division multiple access. Hence, there is no aggregation of interference sources on the same frequency at the same time. The effect of multiple interferers would be to increase the size of the cell area where uplink transmissions would cause unacceptable interference. For analog video LMDS systems, this interference would be spread over different subscribers and/or different channels.

7.0 Further Study

The calculations presented here provide the minimum separation distances required to avoid interference from FSS earth station uplinks for specific LMDS azimuth angles. Interference calculations presented in the Working Group 1 report show the "exclusion zone" area for all azimuth angles around an LMDS receiver where an FSS uplink cannot be located in order to avoid causing interference. The percentage of cell area excluded from FSS transmissions for multiple LMDS receivers in a coverage area was calculated. The contribution submitted to the Committee at the end of its negotiation period entitled, "The Teledesic System Will Interfere With LMDS," calculates the probability that a given percentage of an LMDS cell is interfered with. Presentation of the results calculated here in either of the above formats was not possible to allow timely submission of this paper. Future calculations could show how improved earth station antenna sidelobe performance can decrease the cell area where FSS uplink transmissions would cause interference. Additional cases of interference from a Teledesic Giga-Link (TGL) terminal or a SPACEWAY terminal can be considered. Monte Carlo simulation of the factors listed in Sections 5 and 6 above can be used to also address the impact of antenna improvements on the importance of these factors in interference calculations. Additional mitigating opportunities such as hub diversity and operational techniques can be studied.

8.0 Conclusions

This paper calculates the interference from a Teledesic Standard Terminal (TST) operating at a T1 rate into LMDS hub and subscriber receivers. The spreadsheet used to calculate interference from MSS feeder links into LMDS receivers for the NRMC Working Group 2 report was modified to calculate the interference received from FSS earth stations. Calculations were compared with the calculations presented in the Working Group 1 report to validate the revised spreadsheet under identical system parameters and model assumptions. One of the mitigation opportunities identified in Chapter 5 of the Working Group 1 report was improved antenna sidelobe discrimination. Document NRMC/104 indicated that antenna sidelobe improvements on the order of 20-45 dB over the ITU-699 antenna mask may be possible. The impact of such large potential improvements was investigated here.

Under clear sky conditions, calculations of required separation distance show a reduction from around 28 miles to just under 2 miles when a TST uplink is in the main beam of a Suite 12/CellularVision subscriber located at the edge of coverage for a 25 dB improvement in TST antenna discrimination. A 40 dB sidelobe improvement leads to required separations on the order of just a third of a mile in the main beam of the LMDS antenna. An interferer occurs in the main beam of the LMDS receiver antenna relatively infrequently (less than 3% of the locations). When the LMDS subscriber is pointed away from the interference source by at least five degrees, required separations are reduced to less than a quarter of a mile and are typically reduced to hundreds of feet (see Table 2). A reduction in required separation distance corresponds to a decrease in the size of the cell area where interference is received from an individual earth station. Similar dramatic improvements in interference levels are achieved for LMDS system descriptions provided by Video/Phone and Texas Instruments. For hub receivers, required separation distances are reduced from four miles to less than a quarter mile. Although not analyzed, interference from other FSS earth station transmitters that utilize antennas that fall under the ITU-699 mask such as SPACEWAY would also be significantly reduced. Under rain conditions, when the TST is at full output power, the required separation is slightly larger, but is still significantly reduced when improved antenna pattern sidelobes are implemented.

These calculations are *still* performed for essentially free space propagation. Additional real-world factors such as building and foliage blockage would likely serve to further reduce interference levels at LMDS receivers. Monte Carlo simulations can be performed to determine the full impact of improved sidelobe levels on the amount of area where FSS uplink transmissions would cause unacceptable interference into LMDS receivers.

When improved sidelobe levels are employed on FSS uplink antennas, interference is reduced to levels that are much closer to being acceptable by LMDS receivers. This is equivalent to reducing the amount of geographic area within an LMDS cell where interference is present. If these antenna patterns are realizable and economically viable, then the magnitude of co-frequency sharing problems is greatly reduced, and the implementation of some additional mitigating factors may reduce interference to tolerable levels. Hence, additional consideration should be given to co-frequency sharing between FSS and LMDS in the 28 GHz frequency band.

FSS Earth Station Uplink Interference into LMDS Receivers
The Impact of Improved Antenna Patterns

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Receivers 9/26/94**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		18 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	NRMC Final Report WG1 Calculations		
11					
12	**FSS System**		T1 - TST		
13					
14	**Required Separation (clear sky, incl. 100 km radio horizon)**				
15	ES angle from boresight		40 - ITU	40-conserv.	40-optimistic
16	LMDS receiver pointing angle				
17	Boresight	miles	23.85	1.38	0.25
18	5 Degree Sidelobe	miles	3.00	0.17	0.03
19	45 Degree Sidelobe	miles	1.50	0.09	0.02
20	180 Degree Backlobe	miles	0.08	0.00	0.00
21	**Required Separation (rain on all paths, incl. 100 km radio horizon)**				
22	ES angle from boresight		40 - ITU	40-conserv.	40-optimistic
23	LMDS receiver pointing angle				
24	Boresight	miles	32.08	2.22	0.93
25	5 Degree Sidelobe	miles	4.04	0.75	0.19
26	45 Degree Sidelobe	miles	2.29	0.46	0.10
27	180 Degree Backlobe	miles	0.41	0.03	0.01
28					
29	**Calculations**				
30					
31	**LMDS Signal Link Carrier Level at Cell Edge**		Clear Sky		Rain Conditions
32	Transmitted Power	dBW/channel	-4		-4
33	Transmitter Antenna Gain	dBi	12		12
34	EIRP (clear sky)	dBWi/channel	8		8
35	Power Control (rain)	dB	0		0
36	Distance to Cell Edge	km	4.83		4.83
37	Rain Attenuation (cell edge)	dB	0		-13
38	Free Space Path Loss (cell edge)	dB	-135.5		-135.5
39	Receiver Antenna Gain	dBi	31		31
40	Carrier Level at Cell Edge	dBW/channel	-96.5		-109.5
41	Notes:				
42	Rain attenuation from WG1/52 (rev. 5)		-4 dBW/channel as in NRMC final report		
43	Power control is the minimum necessary to overcome rain fade without exceeding maximum				
44					
45					
46	**Interference Density into LMDS**		Clear Sky		Rain Conditions
47	k (Boltzmann's Constant)	dBW/K/Hz	-228.6		-228.6
48	Receiver Noise Figure	dB	6		6
49	Receiver Noise Temperature	K	1155		1155
50	Channel Bandwidth	MHz	18		18
51	Receiver Noise Floor	dBW/channel	-125.4		-125.4
52	Minimum Required C/(N+I)	dB per channel	26		13
53	Cell Edge C/N	dB	28.9		15.9
54	Cell Edge C/N	linear	782		39
55	Required C/(N+I)	linear	398		20
56	Allowed Interference Power (w/o BW correction)	dBW/channel	-125.6		-125.6
57	Allowed Interference Power	dBW	-123.9		-123.9
58	Notes:				
59					
60					
61	**Interference Density Generated**				
62	Teledesic TST FSS Uplink into LMDS Receivers				
63					
64	Earth Station Angle From Boresight		40 - ITU	40-conserv.	40-optimistic

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Receivers 9/26/94**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		18 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	NRMC Final Report WG1 Calculations		
11					
12	**FSS System**		T1 - TST		
13					
65	Earth Station Output Power (no rain)	dBWi/channel	0.85	0.85	0.85
66	Maximum Antenna Gain	dBi	36.0	36.0	36.0
67	Sidelobe Discrimination	dB	38.3	63.0	78.0
68	Antenna Gain toward LMDS Receiver	dBi	-2.3	-27.0	-42.0
69	Single Channel BW	MHz	26.5	26.5	26.5
70	Number of Interfering Channels	dB	0	0	0
71	LMDS Receiver Bandwidth	MHz	18	18	18
72	Interference Subtotal (clear sky)	dBW	-1.4	-26.2	-41.2
73	Rain Rate	mm/hr	Not Used	Not Used	Not Used
74	Length of rain cell	km	Not Used	Not Used	Not Used
75	Path Length through rain	km	Not Used	Not Used	Not Used
76	Rain Attenuation	dB	Not Used	Not Used	Not Used
77	Power Control (rain)	dB	17.1	17.1	17.1
78	Interference Subtotal (rain on signal path)	dBW	15.7	-9.1	-24.1
79	Notes:				
80	Antenna Gain is the maximum elevation pattern gain in the direction of the LMDS receiver which occurs when the azimuth of				
81	the earth station is pointing in the direction of the LMDS receiver				
82	Antenna Gain is antenna mask specified in ITU Appendix 29		No atmospheric attenuation considered		
83	Lin Model used for rain attenuation on interference path				
84	0.02 dB/km of atmospheric attenuation included in new calculations (climatic zones 3-5)				
85					
86					
87	LMDS Receiver Antenna Gain				
88	Boresight	dBi	31		
89	5 Degree Sidelobe	dBi	13		
90	45 Degree Sidelobe	dBi	7		
91	180 Degree Backlobe	dBi	-19		
92	Note:				
93	Negative margin indicates C/(N+I) objective not met at 1 km separation				
94	All path loss values indicate positive loss (negative gain) regardless of sign				
95					
96					
97	**LMDS Signal: clear sky, Satellite Signal: clear sky**				
98	**ES angle from boresight**		40 - ITU	40-conserv.	40-optimistic
99	*LMDS Boresight*				
100	Required Path Loss	dB	-153.5	-128.7	-113.7
101	Margin at 1 km (clear sky)	dB	-31.7	-6.9	8.1
102	Required Separation (clear sky, no radio horizon)	km	38.4	2.2	0.4
103	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-28.0	-3.2	11.8
104	Required Separation (21 mm/hr rain on interference up to 4 km)	km	7.2	1.3	0.3
105	Path Loss Allocation:				
106	Free Space	dB	139.0	124.0	112.5
107	Atmosphere	dB	0.0	0.0	0.0
108	Rain	dB	14.5	4.7	1.3
109	*LMDS 5 degree Sidelobe*				
110	Required Path Loss	dB	-135.5	-110.7	-95.7
111	Margin at 1 km (clear sky)	dB	-13.7	11.1	26.1
112	Required Separation (clear sky, no radio horizon)	km	4.8	0.3	0.0
113	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-10.0	14.8	29.8
114	Required Separation (21 mm/hr rain on interference up to 4 km)	km	2.0	0.3	0.0
115	Path Loss Allocation:				

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Receivers 9/26/94**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		18 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	NRMC Final Report WG1 Calculations		
11					
12	**FSS System**		T1 - TST		
13					
116	Free Space	dB	128.0	109.8	95.6
117	Atmosphere	dB	0.0	0.0	0.0
118	Rain	dB	7.5	0.9	0.2
119	*LMDS 45 degree Sidelobe*				
120	Required Path Loss	dB	-129.5	-104.7	-89.7
121	Margin at 1 km (clear sky)	dB	-7.7	17.1	32.1
122	Required Separation (clear sky, no radio horizon)	km	2.4	0.1	0.0
123	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-4.0	20.8	35.8
124	Required Separation (21 mm/hr rain on interference up to 4 km)	km	1.4	0.1	0.0
125	Path Loss Allocation:				
126	Free Space	dB	124.5	104.3	89.7
127	Atmosphere	dB	0.0	0.0	0.0
128	Rain	dB	5.0	0.5	0.1
129	*LMDS 180 degree Backlobe*				
130	Required Path Loss	dB	-103.5	-78.7	-63.7
131	Margin at 1 km (clear sky)	dB	18.3	43.1	58.1
132	Required Separation (clear sky, no radio horizon)	km	0.1	0.0	0.0
133	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	22.0	46.8	61.8
134	Required Separation (21 mm/hr rain on interference up to 4 km)	km	0.1	0.0	0.0
135	Path Loss Allocation:				
136	Free Space	dB	103.1	78.7	63.7
137	Atmosphere	dB	0.0	0.0	0.0
138	Rain	dB	0.4	0.0	0.0
139					
140					
141	**LMDS Signal: rain Satellite Signal: rain**				
142	**ES angle from boresight**		40 - ITU	40-conserv.	40-optimistic
143	*LMDS Boresight*				
144	Required Path Loss	dB	-170.6	-145.8	-130.8
145	Margin at 1 km (clear sky)	dB	-48.8	-24.0	-9.0
146	Required Separation (clear sky, no radio horizon)	km	274.9	15.9	2.8
147	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-45.1	-20.3	-5.3
148	Required Separation (21 mm/hr rain on interference up to 4 km)	km	51.6	3.6	1.5
149	Path Loss Allocation:				
150	Free Space	dB	156.1	132.9	125.3
151	Atmosphere	dB	0.0	0.0	0.0
152	Rain	dB	14.5	13.0	5.5
153	*LMDS 5 degree Sidelobe*				
154	Required Path Loss	dB	-152.6	-127.8	-112.8
155	Margin at 1 km (clear sky)	dB	-30.8	-6.0	9.0
156	Required Separation (clear sky, no radio horizon)	km	34.6	2.0	0.4
157	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-27.1	-2.3	12.7
158	Required Separation (21 mm/hr rain on interference up to 4 km)	km	6.5	1.2	0.3
159	Path Loss Allocation:				
160	Free Space	dB	138.1	123.4	111.7
161	Atmosphere	dB	0.0	0.0	0.0
162	Rain	dB	14.5	4.4	1.2
163	*LMDS 45 degree Sidelobe*				
164	Required Path Loss	dB	-146.6	-121.8	-106.8
165	Margin at 1 km (clear sky)	dB	-24.8	0.0	15.0
166	Required Separation (clear sky, no radio horizon)	km	17.3	1.0	0.2

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Receivers 9/26/94**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		18 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	NRMC Final Report WG1 Calculations		
11					
12	**FSS System**		T1 - TST		
13					
167	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-21.1	3.7	18.7
168	Required Separation (21 mm/hr rain on interference up to 4 km)	km	3.7	0.7	0.2
169	Path Loss Allocation:				
170	Free Space	dB	133.2	119.1	106.2
171	Atmosphere	dB	0.0	0.0	0.0
172	Rain	dB	13.4	2.7	0.6
173	*LMDS 180 degree Backlobe*				
174	Required Path Loss	dB	-120.6	-95.8	-80.8
175	Margin at 1 km (clear sky)	dB	1.2	26.0	41.0
176	Required Separation (clear sky, no radio horizon)	km	0.9	0.1	0.0
177	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	4.9	29.7	44.7
178	Required Separation (21 mm/hr rain on interference up to 4 km)	km	0.7	0.0	0.0
179	Path Loss Allocation:				
180	Free Space	dB	118.2	95.7	80.8
181	Atmosphere	dB	0.0	0.0	0.0
182	Rain	dB	2.4	0.2	0.0

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		18 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5		
11					
12	**FSS System**		T1 - TST		
13					
14	**Required Separation (clear sky, incl. 100 km radio horizon)**				
15	ES angle from boresight		40 - ITU	40-conserv.	40-optimistic
16	LMDS receiver pointing angle				
17	Boresight	miles	28.18	1.80	0.32
18	5 Degree Sidelobe	miles	3.88	0.23	0.04
19	45 Degree Sidelobe	miles	1.96	0.11	0.02
20	180 Degree Backlobe	miles	0.10	0.01	0.00
21	**Required Separation (rain on all paths, incl. 100 km radio horizon)**				
22	ES angle from boresight		40 - ITU	40-conserv.	40-optimistic
23	LMDS receiver pointing angle				
24	Boresight	miles	36.72	2.46	1.09
25	5 Degree Sidelobe	miles	5.20	0.89	0.25
26	45 Degree Sidelobe	miles	2.63	0.56	0.13
27	180 Degree Backlobe	miles	0.50	0.04	0.01
28					
29	**Calculations**				
30					
31	**LMDS Signal Link Carrier Level at Cell Edge**		Clear Sky		Rain Conditions
32	Transmitted Power	dBW/channel	-5		-5
33	Transmitter Antenna Gain	dBi	12		12
34	EIRP (clear sky)	dBWi/channel	7		7
35	Power Control (rain)	dB	0		0
36	Distance to Cell Edge	km	4.83		4.83
37	Rain Attenuation (cell edge)	dB	0		-13
38	Free Space Path Loss (cell edge)	dB	-135.5		-135.5
39	Receiver Antenna Gain	dBi	31		31
40	Carrier Level at Cell Edge	dBW/channel	-97.5		-110.5
41	Notes:				
42	Rain attenuation from WG1/52 (rev. 5)		-5 dBW/channel as in WG1/52 (rev. 5)		
43	Power control is the minimum necessary to overcome rain fade without exceeding ma				
44					
45					
46	**Interference Density into LMDS**		Clear Sky		Rain Conditions
47	k (Boltzmann's Constant)	dBW/K/Hz	-228.6		-228.6
48	Receiver Noise Figure	dB	6		6
49	Receiver Noise Temperature	K	1155		1155
50	Channel Bandwidth	MHz	18		18
51	Receiver Noise Floor	dBW/channel	-125.4		-125.4
52	Minimum Required C/(N+I)	dB per channel	26		13
53	Cell Edge C/N	dB	27.9		14.9
54	Cell Edge C/N	linear	621		31
55	Required C/(N+I)	linear	398		20
56	Allowed Interference Power (w/o BW correction)	dBW/channel	-127.9		-127.9
57	Allowed Interference Power	dBW	-126.3		-126.3
58	Notes:				
59					
60					
61	**Interference Density Generated**				
62	Teledesic TST FSS Uplink into LMDS Receivers				
63					
64	Earth Station Angle From Boresight		40 - ITU	40-conserv.	40-optimistic

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		18 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5		
11					
12	**FSS System**		T1 - TST		
13					
65	Earth Station Output Power (no rain)	dBWi/channel	0.85	0.85	0.85
66	Maximum Antenna Gain	dBi	36.0	36.0	36.0
67	Sidelobe Discrimination	dB	38.3	63.0	78.0
68	Antenna Gain toward LMDS Receiver	dBi	-2.3	-27.0	-42.0
69	Single Channel BW	MHz	26.5	26.5	26.5
70	Number of Interfering Channels	dB	0	0	0
71	LMDS Receiver Bandwidth	MHz	18	18	18
72	Interference Subtotal (clear sky)	dBW	-1.4	-26.2	-41.2
73	Rain Rate	mm/hr	Not Used	Not Used	Not Used
74	Length of rain cell	km	Not Used	Not Used	Not Used
75	Path Length through rain	km	Not Used	Not Used	Not Used
76	Rain Attenuation	dB	Not Used	Not Used	Not Used
77	Power Control (rain)	dB	17.1	17.1	17.1
78	Interference Subtotal (rain on signal path)	dBW	15.7	-9.1	-24.1
79	Notes:				
80	Antenna Gain is the maximum elevation pattern gain in the direction of the LMDS rece				
81	the earth station is pointing in the direction of the LMDS receiver				
82	Antenna Gain is antenna mask specified in ITU Appendix 29				
83	Lin Model used for rain attenuation on interference path				
84	0.02 dB/km of atmospheric attenuation included in new calculations (climatic zones 3-				
85					
86					
87	LMDS Receiver Antenna Gain				
88	Boresight	dBi	31		
89	5 Degree Sidelobe	dBi	13		
90	45 Degree Sidelobe	dBi	7		
91	180 Degree Backlobe	dBi	-19		
92	Note:				
93	Negative margin indicates C/(N+I) objective not met at 1 km separation				
94	All path loss values indicate positive loss (negative gain) regardless of sign				
95					
96					
97	**LMDS Signal: clear sky, Satellite Signal: clear sky**				
98	**ES angle from boresight**		40 - ITU	40-conserv.	40-optimistic
99	*LMDS Boresight*				
100	Required Path Loss	dB	-155.9	-131.1	-116.1
101	Margin at 1 km (clear sky)	dB	-34.0	-9.3	5.7
102	Required Separation (clear sky, no radio horizon)	km	45.4	2.9	0.5
103	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-30.3	-5.6	9.4
104	Required Separation (21 mm/hr rain on interference up to 4 km)	km	9.3	1.5	0.4
105	Path Loss Allocation:				
106	Free Space	dB	141.1	125.5	114.5
107	Atmosphere	dB	0.2	0.0	0.0
108	Rain	dB	14.5	5.6	1.6
109	*LMDS 5 degree Sidelobe*				
110	Required Path Loss	dB	-137.9	-113.1	-98.1
111	Margin at 1 km (clear sky)	dB	-16.0	8.7	23.7
112	Required Separation (clear sky, no radio horizon)	km	6.2	0.4	0.1
113	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-12.3	12.4	27.4
114	Required Separation (21 mm/hr rain on interference up to 4 km)	km	2.3	0.3	0.1
115	Path Loss Allocation:				

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**					
2						
3	**LMDS System Parameters**					
4	System Proponent		Suite 12			
5	Link		Hub to Sub			
6	Modulation		FM			
7	Digital Data Rate		N/A			
8	Channel Bandwidth		18 MHz			
9	Antenna Pattern Used		Proponent			
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5			
11						
12	**FSS System**		T1 - TST			
13						
116	Free Space	dB	129.2	111.9	97.9	
117	Atmosphere	dB	0.0	0.0	0.0	
118	Rain	dB	8.6	1.2	0.2	
119	*LMDS 45 degree Sidelobe*					
120	Required Path Loss	dB	-131.9	-107.1	-92.1	
121	Margin at 1 km (clear sky)	dB	-10.0	14.7	29.7	
122	Required Separation (clear sky, no radio horizon)	km	3.2	0.2	0.0	
123	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-6.3	18.4	33.4	
124	Required Separation (21 mm/hr rain on interference up to 4 km)	km	1.6	0.2	0.0	
125	Path Loss Allocation:					
126	Free Space	dB	125.9	106.5	92.0	
127	Atmosphere	dB	0.0	0.0	0.0	
128	Rain	dB	5.9	0.6	0.1	
129	*LMDS 180 degree Backlobe*					
130	Required Path Loss	dB	-105.9	-81.1	-66.1	
131	Margin at 1 km (clear sky)	dB	16.0	40.7	55.7	
132	Required Separation (clear sky, no radio horizon)	km	0.2	0.0	0.0	
133	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	19.7	44.4	59.4	
134	Required Separation (21 mm/hr rain on interference up to 4 km)	km	0.1	0.0	0.0	
135	Path Loss Allocation:					
136	Free Space	dB	105.3	81.1	66.1	
137	Atmosphere	dB	0.0	0.0	0.0	
138	Rain	dB	0.6	0.0	0.0	
139						
140						
141	**LMDS Signal: rain Satellite Signal: rain**					
142	**ES angle from boresight**		40 - ITU	40-conserv.	40-optimistic	
143	*LMDS Boresight*					
144	Required Path Loss	dB	-173.0	-148.2	-133.2	
145	Margin at 1 km (clear sky)	dB	-51.1	-26.4	-11.4	
146	Required Separation (clear sky, no radio horizon)	km	218.2	19.9	3.7	
147	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-47.4	-22.7	-7.7	
148	Required Separation (21 mm/hr rain on interference up to 4 km)	km	59.1	4.0	1.8	
149	Path Loss Allocation:					
150	Free Space	dB	157.2	133.8	126.7	
151	Atmosphere	dB	1.2	0.1	0.0	
152	Rain	dB	14.5	14.4	6.5	
153	*LMDS 5 degree Sidelobe*					
154	Required Path Loss	dB	-155.0	-130.2	-115.2	
155	Margin at 1 km (clear sky)	dB	-33.1	-8.4	6.6	
156	Required Separation (clear sky, no radio horizon)	km	41.3	2.6	0.5	
157	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-29.4	-4.7	10.3	
158	Required Separation (21 mm/hr rain on interference up to 4 km)	km	8.4	1.4	0.4	
159	Path Loss Allocation:					
160	Free Space	dB	140.3	124.9	113.7	
161	Atmosphere	dB	0.2	0.0	0.0	
162	Rain	dB	14.5	5.3	1.5	
163	*LMDS 45 degree Sidelobe*					
164	Required Path Loss	dB	-149.0	-124.2	-109.2	
165	Margin at 1 km (clear sky)	dB	-27.1	-2.4	12.6	
166	Required Separation (clear sky, no radio horizon)	km	21.6	1.3	0.2	

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		18 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5		
11					
12	**FSS System**		T1 - TST		
13					
167	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-23.4	1.3	16.3
168	Required Separation (21 mm/hr rain on interference up to 4 km)	km	4.2	0.9	0.2
169	Path Loss Allocation:				
170	Free Space	dB	134.3	120.9	108.4
171	Atmosphere	dB	0.1	0.0	0.0
172	Rain	dB	14.5	3.3	0.8
173	*LMDS 180 degree Backlobe*				
174	Required Path Loss	dB	-123.0	-98.2	-83.2
175	Margin at 1 km (clear sky)	dB	-1.1	23.6	38.6
176	Required Separation (clear sky, no radio horizon)	km	1.1	0.1	0.0
177	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	2.6	27.3	42.3
178	Required Separation (21 mm/hr rain on interference up to 4 km)	km	0.8	0.1	0.0
179	Path Loss Allocation:				
180	Free Space	dB	120.0	98.0	83.2
181	Atmosphere	dB	0.0	0.0	0.0
182	Rain	dB	3.0	0.2	0.0

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Sub to Hub		
6	Modulation		QPSK or AM		
7	Digital Data Rate		64 kbps		
8	Channel Bandwidth		40 kHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5		
11					
12	**FSS System**		T1 - TST		
13					
14	**Required Separation (clear sky, incl. 100 km radio horizon)**				
15	ES angle from boresight		40 - ITU	40-conserv.	40-optimistic
16	LMDS receiver pointing angle				
17	Boresight	miles	4.14	0.24	0.04
18	5 Degree Sidelobe	miles	4.14	0.24	0.04
19	45 Degree Sidelobe	miles	4.14	0.24	0.04
20	180 Degree Backlobe	miles	4.14	0.24	0.04
21	**Required Separation (rain on all paths, incl. 100 km radio horizon)**				
22	ES angle from boresight		40 - ITU	40-conserv.	40-optimistic
23	LMDS receiver pointing angle				
24	Boresight	miles	19.84	1.86	0.72
25	5 Degree Sidelobe	miles	19.84	1.86	0.72
26	45 Degree Sidelobe	miles	19.84	1.86	0.72
27	180 Degree Backlobe	miles	19.84	1.86	0.72
28					
29	**Calculations**				
30					
31	**LMDS Signal Link Carrier Level at Cell Edge**		Clear Sky		Rain Conditions
32	Transmitted Power	dBW/channel	-34.9		-34.9
33	Transmitter Antenna Gain	dBi	31		31
34	EIRP (clear sky)	dBWi/channel	-3.9		-3.9
35	Power Control (rain)	dB	0		0
36	Distance to Cell Edge	km	4.83		4.83
37	Rain Attenuation (cell edge)	dB	0		-13
38	Free Space Path Loss (cell edge)	dB	-135.5		-135.5
39	Receiver Antenna Gain	dBi	12		12
40	Carrier Level at Cell Edge	dBW/channel	-127.4		-140.4
41	Notes:				
42	Rain attenuation from WG1/52 (rev. 5)				
43	Power control is the minimum necessary to overcome rain fade without exceeding ma				
44					
45					
46	**Interference Density into LMDS**		Clear Sky		Rain Conditions
47	k (Boltzmann's Constant)	dBW/K/Hz	-228.6		-228.6
48	Receiver Noise Figure	dB	3		3
49	Receiver Noise Temperature	K	579		579
50	Channel Bandwidth	MHz	0.04		0.04
51	Receiver Noise Floor	dBW/channel	-155.0		-155.0
52	Minimum Required C/(N+I)	dB per channel	19		13
53	Cell Edge C/N	dB	27.6		14.6
54	Cell Edge C/N	linear	571		29
55	Required C/(N+I)	linear	79		20
56	Allowed Interference Power (w/o BW correction)	dBW/channel	-147.0		-158.6
57	Allowed Interference Power	dBW	-118.8		-130.4
58	Notes:				
59					
60					
61	**Interference Density Generated**				
62	Teledesic TST FSS Uplink into LMDS Receivers				
63					
64	Earth Station Angle From Boresight		40 - ITU	40-conserv.	40-optimistic

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Sub to Hub		
6	Modulation		QPSK or AM		
7	Digital Data Rate		64 kbps		
8	Channel Bandwidth		40 kHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5		
11					
12	**FSS System**		T1 - TST		
13					
65	Earth Station Output Power (no rain)	dBWi/channel	0.85	0.85	0.85
66	Maximum Antenna Gain	dBi	36.0	36.0	36.0
67	Sidelobe Discrimination	dB	38.3	63.0	78.0
68	Antenna Gain toward LMDS Receiver	dBi	-2.3	-27.0	-42.0
69	Single Channel BW	MHz	26.5	26.5	26.5
70	Number of Interfering Channels	dB	0	0	0
71	LMDS Receiver Bandwidth	MHz	18	18	18
72	Interference Subtotal (clear sky)	dBW	-1.4	-26.2	-41.2
73	Rain Rate	mm/hr	Not Used	Not Used	Not Used
74	Length of rain cell	km	Not Used	Not Used	Not Used
75	Path Length through rain	km	Not Used	Not Used	Not Used
76	Rain Attenuation	dB	Not Used	Not Used	Not Used
77	Power Control (rain)	dB	17.1	17.1	17.1
78	Interference Subtotal (rain on signal path)	dBW	15.7	-9.1	-24.1
79	Notes:				
80	Antenna Gain is the maximum elevation pattern gain in the direction of the LMDS rece				
81	the earth station is pointing in the direction of the LMDS receiver				
82	Antenna Gain is antenna mask specified in ITU Appendix 29				
83	Lin Model used for rain attenuation on interference path				
84	0.02 dB/km of atmospheric attenuation included in new calculations (climatic zones 3-				
85					
86					
87	LMDS Receiver Antenna Gain				
88	Boresight	dBi	21		
89	5 Degree Sidelobe	dBi	21		
90	45 Degree Sidelobe	dBi	21		
91	180 Degree Backlobe	dBi	21		
92	Note:				
93	Negative margin indicates C/(N+I) objective not met at 1 km separation				
94	All path loss values indicate positive loss (negative gain) regardless of sign				
95					
96					
97	**LMDS Signal: clear sky, Satellite Signal: clear sky**				
98	**ES angle from boresight**		40 - ITU	40-conserv.	40-optimistic
99	*LMDS Boresight*				
100	Required Path Loss	dB	-138.4	-113.7	-98.7
101	Margin at 1 km (clear sky)	dB	-16.6	8.2	23.2
102	Required Separation (clear sky, no radio horizon)	km	6.7	0.4	0.1
103	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-12.9	11.9	26.9
104	Required Separation (21 mm/hr rain on interference up to 4 km)	km	2.4	0.3	0.1
105	Path Loss Allocation:				
106	Free Space	dB	129.5	112.4	98.4
107	Atmosphere	dB	0.0	0.0	0.0
108	Rain	dB	8.9	1.3	0.3
109	*LMDS 5 degree Sidelobe*				
110	Required Path Loss	dB	-138.4	-113.7	-98.7
111	Margin at 1 km (clear sky)	dB	-16.6	8.2	23.2
112	Required Separation (clear sky, no radio horizon)	km	6.7	0.4	0.1
113	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-12.9	11.9	26.9
114	Required Separation (21 mm/hr rain on interference up to 4 km)	km	2.4	0.3	0.1
115	Path Loss Allocation:				

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Suite 12		
5	Link		Sub to Hub		
6	Modulation		QPSK or AM		
7	Digital Data Rate		64 kbps		
8	Channel Bandwidth		40 kHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5		
11					
12	**FSS System**		T1 - TST		
13					
116	Free Space	dB	129.5	112.4	98.4
117	Atmosphere	dB	0.0	0.0	0.0
118	Rain	dB	8.9	1.3	0.3
119	*LMDS 45 degree Sidelobe*				
120	Required Path Loss	dB	-138.4	-113.7	-98.7
121	Margin at 1 km (clear sky)	dB	-16.6	8.2	23.2
122	Required Separation (clear sky, no radio horizon)	km	6.7	0.4	0.1
123	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-12.9	11.9	26.9
124	Required Separation (21 mm/hr rain on interference up to 4 km)	km	2.4	0.3	0.1
125	Path Loss Allocation:				
126	Free Space	dB	129.5	112.4	98.4
127	Atmosphere	dB	0.0	0.0	0.0
128	Rain	dB	8.9	1.3	0.3
129	*LMDS 180 degree Backlobe*				
130	Required Path Loss	dB	-138.4	-113.7	-98.7
131	Margin at 1 km (clear sky)	dB	-16.6	8.2	23.2
132	Required Separation (clear sky, no radio horizon)	km	6.7	0.4	0.1
133	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-12.9	11.9	26.9
134	Required Separation (21 mm/hr rain on interference up to 4 km)	km	2.4	0.3	0.1
135	Path Loss Allocation:				
136	Free Space	dB	129.5	112.4	98.4
137	Atmosphere	dB	0.0	0.0	0.0
138	Rain	dB	8.9	1.3	0.3
139					
140					
141	**LMDS Signal: rain Satellite Signal: rain**				
142	**ES angle from boresight**		40 - ITU	40-conserv.	40-optimistic
143	*LMDS Boresight*				
144	Required Path Loss	dB	-167.1	-142.3	-127.3
145	Margin at 1 km (clear sky)	dB	-45.2	-20.5	-5.5
146	Required Separation (clear sky, no radio horizon)	km	134.3	10.3	1.9
147	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-41.5	-16.8	-1.8
148	Required Separation (21 mm/hr rain on interference up to 4 km)	km	31.9	3.0	1.2
149	Path Loss Allocation:				
150	Free Space	dB	151.9	131.3	123.0
151	Atmosphere	dB	0.6	0.1	0.0
152	Rain	dB	14.5	10.9	4.3
153	*LMDS 5 degree Sidelobe*				
154	Required Path Loss	dB	-167.1	-142.3	-127.3
155	Margin at 1 km (clear sky)	dB	-45.2	-20.5	-5.5
156	Required Separation (clear sky, no radio horizon)	km	134.3	10.3	1.9
157	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-41.5	-16.8	-1.8
158	Required Separation (21 mm/hr rain on interference up to 4 km)	km	31.9	3.0	1.2
159	Path Loss Allocation:				
160	Free Space	dB	151.9	131.3	123.0
161	Atmosphere	dB	0.6	0.1	0.0
162	Rain	dB	14.5	10.9	4.3
163	*LMDS 45 degree Sidelobe*				
164	Required Path Loss	dB	-167.1	-142.3	-127.3
165	Margin at 1 km (clear sky)	dB	-45.2	-20.5	-5.5
166	Required Separation (clear sky, no radio horizon)	km	134.3	10.3	1.9

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**					
2						
3	**LMDS System Parameters**					
4	System Proponent		Suite 12			
5	Link		Sub to Hub			
6	Modulation		QPSK or AM			
7	Digital Data Rate		64 kbps			
8	Channel Bandwidth		40 kHz			
9	Antenna Pattern Used		Proponent			
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5			
11						
12	**FSS System**		T1 - TST			
13						
167	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-41.5	-16.8	-1.8	
168	Required Separation (21 mm/hr rain on interference up to 4 km)	km	31.9	3.0	1.2	
169	Path Loss Allocation:					
170	Free Space	dB	151.9	131.3	123.0	
171	Atmosphere	dB	0.6	0.1	0.0	
172	Rain	dB	14.5	10.9	4.3	
173	*LMDS 180 degree Backlobe*					
174	Required Path Loss	dB	-167.1	-142.3	-127.3	
175	Margin at 1 km (clear sky)	dB	-45.2	-20.5	-5.5	
176	Required Separation (clear sky, no radio horizon)	km	134.3	10.3	1.9	
177	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-41.5	-16.8	-1.8	
178	Required Separation (21 mm/hr rain on interference up to 4 km)	km	31.9	3.0	1.2	
179	Path Loss Allocation:					
180	Free Space	dB	151.9	131.3	123.0	
181	Atmosphere	dB	0.6	0.1	0.0	
182	Rain	dB	14.5	10.9	4.3	

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Video/Phone		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		20 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5		
11					
12	**FSS System**		T1 - TST		
13					
14	**Required Separation (clear sky, incl. 100 km radio horizon)**				
15	ES angle from boresight		40 - ITU	40-conserv.	40-optimistic
16	LMDS receiver pointing angle				
17	Boresight	miles	1.34	0.08	0.01
18	5 Degree Sidelobe	miles	0.05	0.00	0.00
19	45 Degree Sidelobe	miles	0.01	0.00	0.00
20	180 Degree Backlobe	miles	0.00	0.00	0.00
21	**Required Separation (rain on all paths, incl. 100 km radio horizon)**				
22	ES angle from boresight		40 - ITU	40-conserv.	40-optimistic
23	LMDS receiver pointing angle				
24	Boresight	miles	2.19	0.42	0.09
25	5 Degree Sidelobe	miles	0.28	0.02	0.00
26	45 Degree Sidelobe	miles	0.05	0.00	0.00
27	180 Degree Backlobe	miles	0.02	0.00	0.00
28					
29	**Calculations**				
30					
31	**LMDS Signal Link Carrier Level at Cell Edge**		Clear Sky		Rain Conditions
32	Transmitted Power	dBW/channel	-10.9		-10.9
33	Transmitter Antenna Gain	dBi	29.7		29.7
34	EIRP (clear sky)	dBWi/channel	18.8		18.8
35	Power Control (rain)	dB	0		5.8
36	Distance to Cell Edge	km	1.61		1.61
37	Rain Attenuation (cell edge)	dB	0		-5.8
38	Free Space Path Loss (cell edge)	dB	-125.9		-125.9
39	Receiver Antenna Gain	dBi	38		38
40	Carrier Level at Cell Edge	dBW/channel	-69.1		-69.1
41	Notes:				
42	Rain attenuation from WG1/52 (rev. 5)				
43	Power control is the minimum necessary to overcome rain fade without exceeding ma Video/Phone max power control: 11 dB				
44					
45					
46	**Interference Density into LMDS**		Clear Sky		Rain Conditions
47	k (Boltzmann's Constant)	dBW/K/Hz	-228.6		-228.6
48	Receiver Noise Figure	dB	7.5		7.5
49	Receiver Noise Temperature	K	1631		1631
50	Channel Bandwidth	MHz	20		20
51	Receiver Noise Floor	dBW/channel	-123.5		-123.5
52	Minimum Required C/(N+I)	dB per channel	24		24
53	Cell Edge C/N	dB	54.3		54.3
54	Cell Edge C/N	linear	270346		270346
55	Required C/(N+I)	linear	251		251
56	Allowed Interference Power (w/o BW correction)	dBW/channel	-93.2		-93.2
57	Allowed Interference Power	dBW	-91.9		-91.9
58	Notes:				
59					
60					
61	**Interference Density Generated**				
62	Teledesic TST FSS Uplink into LMDS Receivers				
63					
64	Earth Station Angle From Boresight		40 - ITU	40-conserv.	40-optimistic

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Video/Phone		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		20 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5		
11					
12	**FSS System**		T1 - TST		
13					
65	Earth Station Output Power (no rain)	dBWi/channel	0.85	0.85	0.85
66	Maximum Antenna Gain	dBi	36.0	36.0	36.0
67	Sidelobe Discrimination	dB	38.3	63.0	78.0
68	Antenna Gain toward LMDS Receiver	dBi	-2.3	-27.0	-42.0
69	Single Channel BW	MHz	26.5	26.5	26.5
70	Number of Interfering Channels	dB	0	0	0
71	LMDS Receiver Bandwidth	MHz	18	18	18
72	Interference Subtotal (clear sky)	dBW	-1.4	-26.2	-41.2
73	Rain Rate	mm/hr	Not Used	Not Used	Not Used
74	Length of rain cell	km	Not Used	Not Used	Not Used
75	Path Length through rain	km	Not Used	Not Used	Not Used
76	Rain Attenuation	dB	Not Used	Not Used	Not Used
77	Power Control (rain)	dB	17.1	17.1	17.1
78	Interference Subtotal (rain on signal path)	dBW	15.7	-9.1	-24.1
79	Notes:				
80	Antenna Gain is the maximum elevation pattern gain in the direction of the LMDS rece				
81	the earth station is pointing in the direction of the LMDS receiver				
82	Antenna Gain is antenna mask specified in ITU Appendix 29				
83	Lin Model used for rain attenuation on interference path				
84	0.02 dB/km of atmospheric attenuation included in new calculations (climatic zones 3-				
85					
86					
87	LMDS Receiver Antenna Gain				
88	Boresight	dBi	38		
89	5 Degree Sidelobe	dBi	9.1		
90	45 Degree Sidelobe	dBi	-8		
91	180 Degree Backlobe	dBi	-14		
92	Note:				
93	Negative margin indicates C/(N+I) objective not met at 1 km separation				
94	All path loss values indicate positive loss (negative gain) regardless of sign				
95					
96					
97	**LMDS Signal: clear sky, Satellite Signal: clear sky**				
98	**ES angle from boresight**		40 - ITU	40-conserv.	40-optimistic
99	*LMDS Boresight*				
100	Required Path Loss	dB	-128.5	-103.8	-88.8
101	Margin at 1 km (clear sky)	dB	-6.7	18.1	33.1
102	Required Separation (clear sky, no radio horizon)	km	2.2	0.1	0.0
103	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-3.0	21.8	36.8
104	Required Separation (21 mm/hr rain on interference up to 4 km)	km	1.3	0.1	0.0
105	Path Loss Allocation:				
106	Free Space	dB	123.8	103.3	88.7
107	Atmosphere	dB	0.0	0.0	0.0
108	Rain	dB	4.7	0.4	0.1
109	*LMDS 5 degree Sidelobe*				
110	Required Path Loss	dB	-99.6	-74.9	-59.9
111	Margin at 1 km (clear sky)	dB	22.2	47.0	62.0
112	Required Separation (clear sky, no radio horizon)	km	0.1	0.0	0.0
113	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	25.9	50.7	65.7
114	Required Separation (21 mm/hr rain on interference up to 4 km)	km	0.1	0.0	0.0
115	Path Loss Allocation:				

1	**Interference Calculations for FSS Uplinks Interfering with LMDS Rec**				
2					
3	**LMDS System Parameters**				
4	System Proponent		Video/Phone		
5	Link		Hub to Sub		
6	Modulation		FM		
7	Digital Data Rate		N/A		
8	Channel Bandwidth		20 MHz		
9	Antenna Pattern Used		Proponent		
10	Date/Revision of System Parameters	WG 1/52	9/20/94 Rev 5		
11					
12	**FSS System**		T1 - TST		
13					
116	Free Space	dB	99.3	74.9	59.9
117	Atmosphere	dB	0.0	0.0	0.0
118	Rain	dB	0.3	0.0	0.0
119	*LMDS 45 degree Sidelobe*				
120	Required Path Loss	dB	-82.5	-57.8	-42.8
121	Margin at 1 km (clear sky)	dB	39.3	64.1	79.1
122	Required Separation (clear sky, no radio horizon)	km	0.0	0.0	0.0
123	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	43.0	67.8	82.8
124	Required Separation (21 mm/hr rain on interference up to 4 km)	km	0.0	0.0	0.0
125	Path Loss Allocation:				
126	Free Space	dB	82.5	57.8	42.8
127	Atmosphere	dB	0.0	0.0	0.0
128	Rain	dB	0.0	0.0	0.0
129	*LMDS 180 degree Backlobe*				
130	Required Path Loss	dB	-76.5	-51.8	-36.8
131	Margin at 1 km (clear sky)	dB	45.3	70.1	85.1
132	Required Separation (clear sky, no radio horizon)	km	0.0	0.0	0.0
133	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	49.0	73.8	88.8
134	Required Separation (21 mm/hr rain on interference up to 4 km)	km	0.0	0.0	0.0
135	Path Loss Allocation:				
136	Free Space	dB	76.5	51.8	36.8
137	Atmosphere	dB	0.0	0.0	0.0
138	Rain	dB	0.0	0.0	0.0
139					
140					
141	**LMDS Signal: rain Satellite Signal: rain**				
142	**ES angle from boresight**		40 - ITU	40-conserv.	40-optimistic
143	*LMDS Boresight*				
144	Required Path Loss	dB	-145.6	-120.9	-105.9
145	Margin at 1 km (clear sky)	dB	-23.8	1.0	16.0
146	Required Separation (clear sky, no radio horizon)	km	15.0	0.9	0.2
147	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	-20.1	4.7	19.7
148	Required Separation (21 mm/hr rain on interference up to 4 km)	km	3.5	0.7	0.1
149	Path Loss Allocation:				
150	Free Space	dB	132.7	118.4	105.3
151	Atmosphere	dB	0.1	0.0	0.0
152	Rain	dB	12.8	2.5	0.6
153	*LMDS 5 degree Sidelobe*				
154	Required Path Loss	dB	-116.7	-92.0	-77.0
155	Margin at 1 km (clear sky)	dB	5.1	29.9	44.9
156	Required Separation (clear sky, no radio horizon)	km	0.6	0.0	0.0
157	Margin at 1 km (3.7 dB rain attenuation on interference)	dB	8.8	33.6	48.6
158	Required Separation (21 mm/hr rain on interference up to 4 km)	km	0.5	0.0	0.0
159	Path Loss Allocation:				
160	Free Space	dB	115.0	91.9	77.0
161	Atmosphere	dB	0.0	0.0	0.0
162	Rain	dB	1.7	0.1	0.0
163	*LMDS 45 degree Sidelobe*				
164	Required Path Loss	dB	-99.6	-74.9	-59.9
165	Margin at 1 km (clear sky)	dB	22.2	47.0	62.0
166	Required Separation (clear sky, no radio horizon)	km	0.1	0.0	0.0