ATTACHMENT C
NRMC-25
August 5, 1994

DRAFT ADDITION TO WORK PROGRAM (FCC)

LMDS/FSS 28 GHz BAND NEGOTIATED RULEMAKING COMMITTEE

As a result of the discussions during the August 2 Committee meeting, following are two possible new Work Program (NRMC-8 (Rev. 1)) items for consideration:

"7) FSS satellite downlink beacon (see RR 882A, WARC-92), intended for up link power control and operating in the band 27.500 - 27.501 GHz, causing potential interference to LMDS hub stations and subscriber terminals.

8) LMDS hub stations and subscriber terminals causing potential interference, on an individual station basis or as an aggregate of all visible subscriber terminals and hub stations, to FSS satellite downlink beacon (see RR 882A, WARC-92) Earth station receivers."

ATTACHMENT D
NRMC- 27
WG1/29 (Rev. 1)
Aug. 3, 1994

LMDS/FSS 28 GHz BAND NEGOTIATED RULEMAKING COMMITTEE

WORK PROGRAM FOR WORKING GROUP 1 (WG/1)

Objective:

Provide recommendations for the formulation of technical regulations which should be adopted for the Local Multipoint Distribution Service (LMDS) and/or the fixed satellite service (FSS), so as to maximize the co-frequency sharing of the 27.5 - 29.5 GHz frequency band between these services. WG/1 specifically deals with sharing between terrestrial systems operating in the LMDS and satellite systems providing service links in the 27.5-29.5 GHz frequency band.

Approach:

1. Assemble data on proposed FSS and LMDS systems.

2. Perform analyses on the following sharing/compatibility cases incorporating the output of the joint technical subgroup.

   a. FSS Earth station uplinks accessing geostationary satellites causing potential interference into LMDS receivers which may be located, for example, at hub stations and subscriber terminals.

   b. FSS Earth station uplinks accessing Low-Earth Orbit satellites causing potential interference into LMDS receivers which may be located, for example, at hub stations and subscriber terminals.

   c. LMDS transmitters which may be located, for example, at hub stations and subscriber terminals, causing potential interference, on an individual station basis or as an aggregate of all visible transmitters, to FSS geostationary satellite receivers.

   d. LMDS transmitters which may be located, for example, at hub stations and subscriber terminals, causing potential interference on an individual station basis or as an aggregate of all visible transmitters, to FSS low-earth orbit satellite receivers.

   e. Other analyses as necessary to fully analyze co-frequency sharing between LMDS and FSS, for example, FSS satellite beacon transmissions to ground receivers.

3. Provide advice concerning the technical and coordination issues presented by co-frequency sharing between these two services.

4. Recommend technical rules that should be adopted which are as broad and non-system specific as possible. (All recommendations or proposed rules must comply with the International Telecommunications Union treaty obligations.)

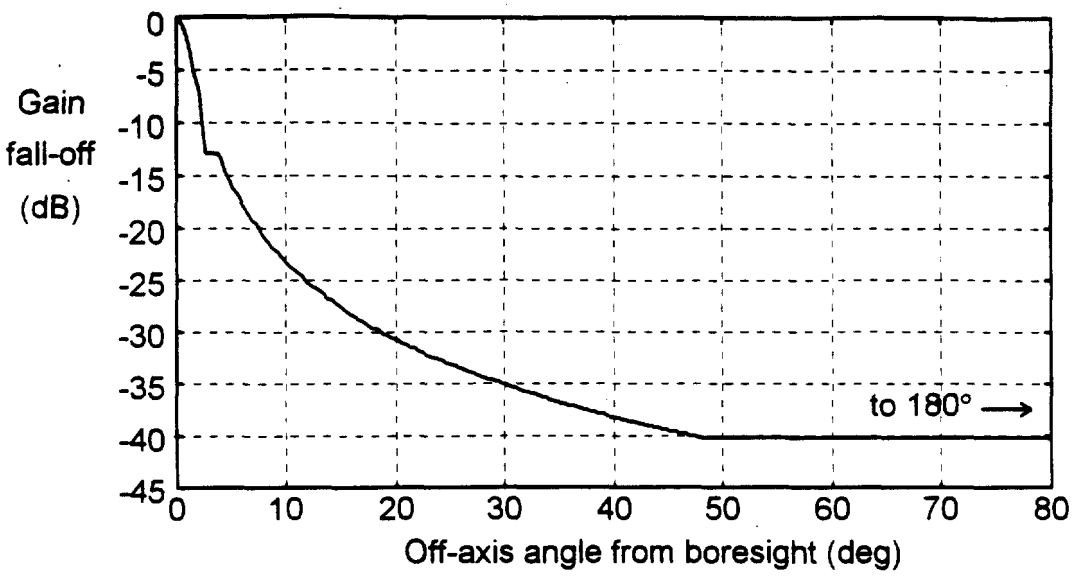
ATTACHMENT E
PARTICIPANTS IN WORKING GROUP 1 OF THE 28 GHz NEGOTIATED RULEMAKING COMMITTEE

NAME	AFFILIATION
Arnold, H. W. (Pete)	Bellcore
Barmat, Melvin	Jansky/Barmat Telecom
Bossard, Bernard (Bob)	Suite 12 Group
Brand, Charles S.	mm-Tech., Inc.
Browne, Larry	CSC
Campbell, Tim	Bell Atlantic Corporation
Chalkley, Hatcher	Texas Instruments, Inc.
Dagen, Aaron	NYNEX Science and Technology
Davidson, Tom	Akin, Gump, Strauss, Hauer & Feld, L.L.P.
Ghazvinian, Farzad	LinCom
Haddon, Perry W.	Ghz Equipment Co., Inc.
Hrycenko, George	Hughes Space & Communications Co.
James, Robert	FCC
Kiebler, John	Mitre
Krauss, Jeffrey A.	Telecommunications & Technology Policy
LaForge, Ray	FCC-OET
LeClair, Roger	Hughes Space & Communications Co.
Licqurish, Clint	M/A-COM
Lockie, Douglas, G.	Endgate Technology Corp.
Milkis, Chuck	Suite 12 Group
Miller, Edward F.	Teledesic
Nelson, Robert	GE American Communications, Inc.
Nichols, Lee	mm-Tech., Inc.
Patzan, Bruno	FCC-OET
Raish, Leonard Robert, Esq. (Larry)	Fletcher, Heald & Hildreth
Reinhart, Ed	Consultant, Hughes Space & Communications Co.
Schonoff, Thomas A.	LinCom
Serafini, Tony	FCC
Sonnenfeldt, Walter H., Esq.	Walter Sonnenfeldt & Associates
Stone, Richard	Motorola SATCOM
Sutliff, Larrie	Bellcore
Tycz, Thomas S.	FCC
Ziegler, Malcolm I.	Telesis Tech Lab

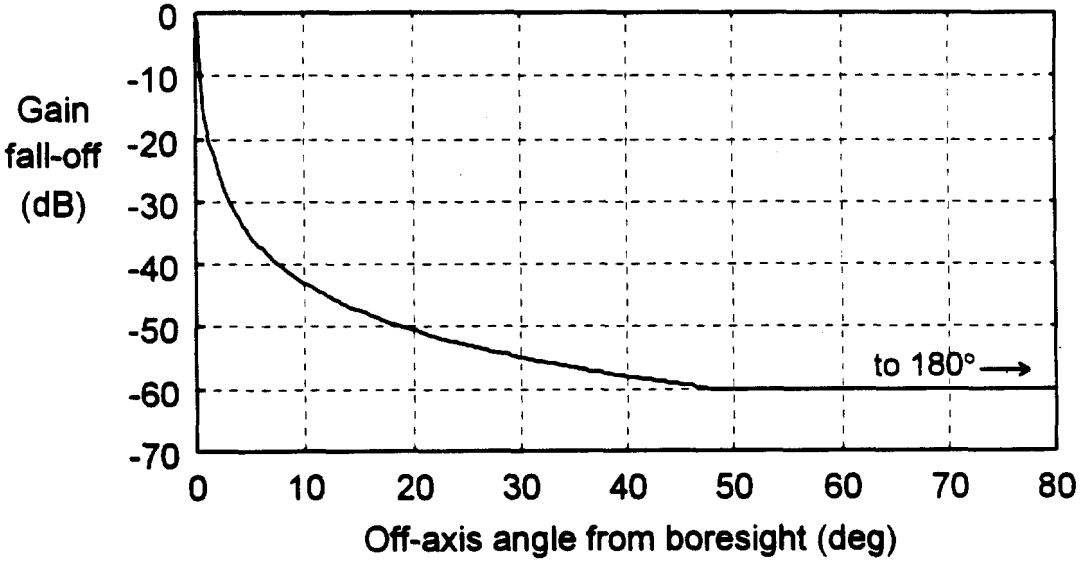
TECHNICAL CHARACTERISTICS OF TELEDESIC NETWORK	
1. Orbital Parameters	
No. of planes / No. of satellites per plane	21 / 40 - 44
Spacing of planes (deg) / Phasing of planes	9.5 / random
Inclination (deg) / Orbital period (min)	98.2 / 99
Apogee / Perigee (km)	700 / 700
Right Ascension / Argument of Perigee	9.5 spacing / N/A
2. Frequency Bands	
Uplink / Downlink (GHz)	28.6 - 29.0 / 18.8 - 19.2 (TSL) 27.6 - 28.4 / 17.8 - 18.6 (GSL)

TSL CHARACTERISTICS	
3. TSL Carrier Transmission Parameters	
Multiple Access Technique	TDMA / FDMA (up), TDMA (dn)
Modulation Type	QPSK
Data Rates (kbps)	16 (Base Line User) - 2048 (E1 User)
Burst Data Rate (kbps)	225 - 28,800 (up), 324,000 (dn)
Total Bandwidth (MHz)	400 (up), 400 (dn)
Allocated Bandwidth per Carrier (MHz)	0.275 - 35.2 (up), 400 (dn)
Maximum Uplink Transmitter Power per Carrier (dBW)	19.1
Maximum Downlink Transmitter Power per Carrier (dBW)	18.8
Satellite / Earth station Noise Temperature) (K)	652 / 375
Received Carrier to Noise Ratio in clear weather (dB)	8.6
Received Carrier to Noise Ratio in rainy weather (dB)	6.6
Required Protection Ratio, C/I dB)	25
4. Satellite Antenna Parameters	
No. of spot beams / ptg. Di. from Nadir	64 / Steerable
Xmtr. Pk. Gain (dBi) / Bmwidth (deg) / Polarization	32 / 2.9 - 6.4 / RHC & LHC
Rcvr. Pk. Gain (dBi) / Bmwidth (deg) / Polarization	32 / 2.9 - 6.4 / RHC & LHC
Sidelobe Mask	-30 dB for $\theta > 11$ deg
Satellite Footprint size (km^2)	1,636,352 (max.)
4. Earth Station Antenna Parameters	
Service Minimum Elevation angle (deg) / steerable?	40 / Yes
Xmtr Pk. Ant. Gain (dBi) / Bmwidth (deg) / Polarization	36 / 2.6 / RHC & LHC
Rcvr Pk. Ant. Gain (dBi) / Bmwidth (deg) / Polarization	33 / 3.7 / RHC & LHC
Antenna Sidelobe Mask for Beams	See Attachment 1
No. of earth stations and distribution	20 Million Worldwide (see attachment) 2

GSL CHARACTERISTICS	
3. GSL Carrier Transmission Parameters	
Multiple Access Technique	Single Channel (Uplink & Downlink)
Modulation Type	8-PSK
Data Rates (Mbps)	155.52 (OC-3) - 1244.16 (OC-24)
Burst Data Rate (Mbps)	191 - 1531
Total Bandwidth (MHz)	800 (up), 800 (dn)
Allocated Bandwidth per Carrier (MHz)	800 (up, max.), 800 (dn, max.)
Maximum Uplink Transmitter Power per Carrier (dBW)	16.9
Maximum Downlink Transmitter Power per Carrier (dBW)	6.6
Satellite / Earth station Noise Temperature (K)	652 / 375
Received Carrier to Noise Ratio in clear weather (dB)	17.3
Received Carrier to Noise Ratio in rainy weather (dB)	15.3
Required Protection Ratio , C/I (dB)	25
4. Satellite Antenna Parameters	
No. of spot beams / Ptg. Di. from Nadir	16 / Steerable
Xmtr. Pk. Gain (dBi) / Bmwidth (deg) / Polarization	41 / 1.5 / RHC & LHC
Rcvr. Pk. Gain (dBi) / Bmwidth (deg) / Polarization	41 / 1.5 / RHC & LHC
Sidelobe Mask	-30 dB for $\theta > 11$ deg
No. of Spot Coverage Areas per satellite	16
5. Earth Station Antenna Parameters	
Service Minimum Elevation Angle (deg) / Steerable?	40 / Yes
Xmtr Pk. Ant. Gain (dBi) / Bmwidth (deg) / Polarization	50 / 0.52 / RHC & LHC
Rcvr Pk. Ant. Gain (dBi) / Bmwidth (deg) / Polarization	47 / 0.73 / RHC & LHC
Antenna Sidelobe Mask for Beams	See Attachment 1
No. of earth stations and distribution	10,000 Worldwide (see attachment) 2



TST Antenna Mask



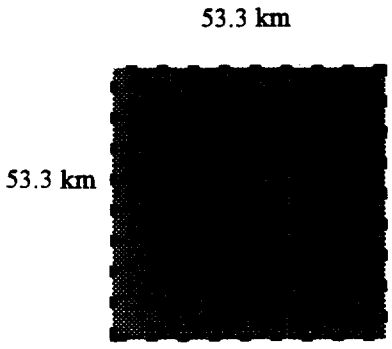
TGT Antenna Mask

ATTACHMENT 2

August 9,1994

TELEDESIC EARTH STATION DISTRIBUTIONS WITHIN COVERAGE AREAS

Number of Active Earth Stations per Cell



One Cell

- 1440 TST's at 16 kbps
- 15 TST's at T1 rate (1.544 Mbps)
- 11.25 TST's at E1 rate (2.048 Mbps)
- Or a mix of the above
- Not required to be uniformly distributed. May cluster at population centers.

Number of Active GigaLink Terminals per Satellite Footprint

Satellite Footprint
& GSL Spot Beam

- 16 GLT's at 155 - 1244 Mbps in each satellite footprint.

Page 5

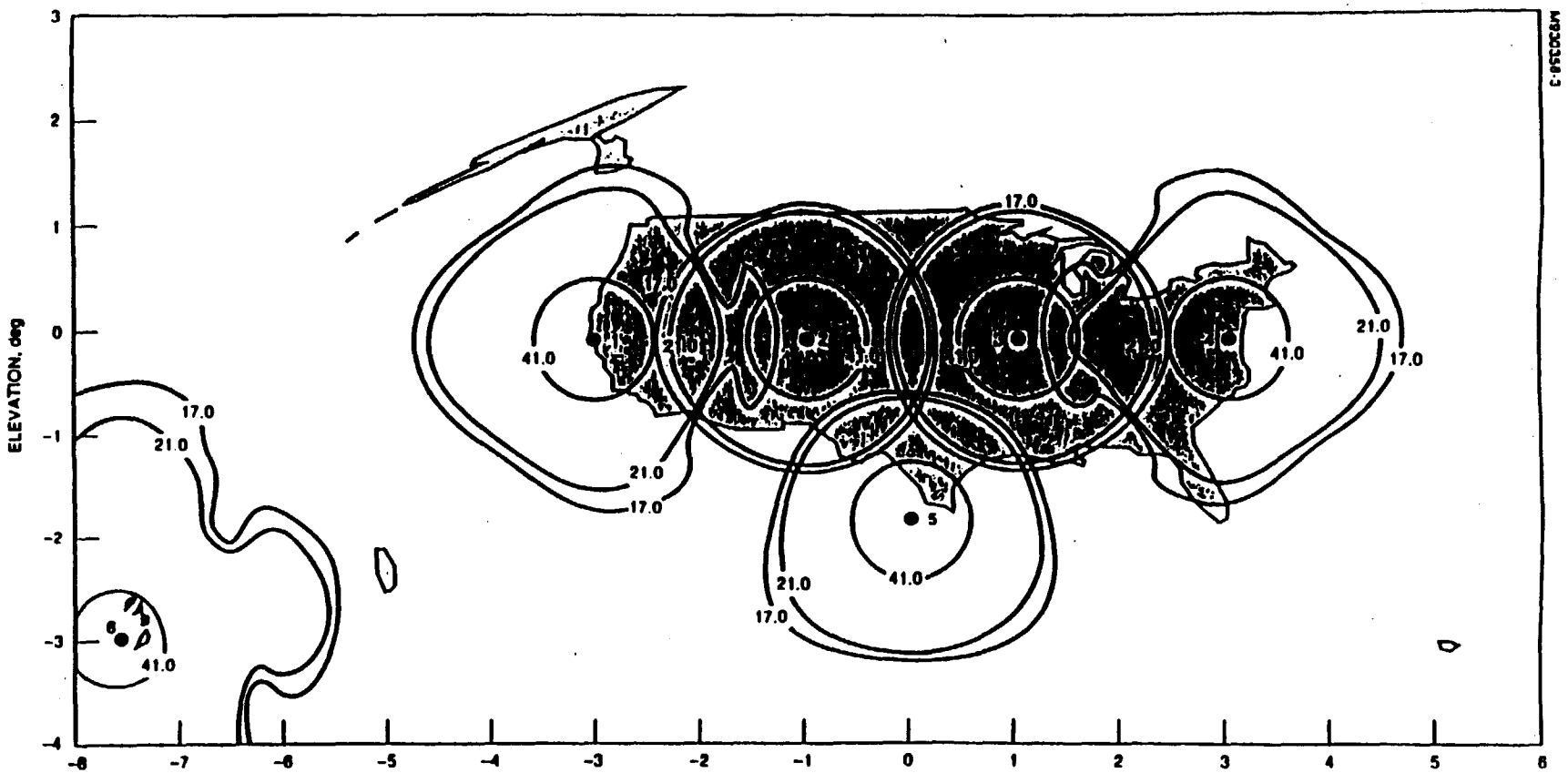
ATTACHMENT G -- TECHNICAL CHARACTERISTICS OF THE SPACEWAY NETWORK

PARAMETER	CHARACTERISTIC
1. ORBITAL PARAMETERS	
Location	Two each at 99 & 101 WL for US (See figures 2.2.2-1 and 2.2.2-2
2. FREQUENCY BANDS	
Uplink / Downlink (GHz)	29 - 30/19.2 - 20.2
3. CARRIER TRANSMISSION PARAMETERS	
Multiple Access Technique	FDMA up; TDMA down
Modulation Types / Coded Data Rate	QPSK/1544, 768, 384 kbps up; QPSK/92 Mbps down
Xmtr. Necessary BW for each carrier (MHz)	1.544, 0.768, 0.384 up; 92 down
Xmtr. Occupied BW for each carrier (MHz)	1.08, 0.54, 0.27 up; 84 down
Assigned BW for each carrier (MHz)	2, 1, 0.5 up; 120 down
Uplink Eb/No, clear & rain	11.7, 9.7
Downlink Eb/No, clear & rain	17.9, 5.7
Required Eb/(No+Io)	8.0 uplink; 5.0 downlink
Uplink Xmtr. Power per Carrier (dBW)	-3.5 for 384 kbps
Downlink Xmtr. Power per Carrier (dBW)	12.5
Satellite / Earth Station Noise Temp (°K)	575/275
4. SATELLITE ANTENNA PARAMETERS	
No. of spot beams / Pointing direction from nadir	48/vaires
Xmtr. Peak Gain (dBi) / Beamwidth (°) / Polarization	46.5/1/CP
Rcvr. Peak Gain (dBi) / Beamwidth (°) / Polarization	46.5/1/CP
Sidelobe Mask	See figure 2.2.2-3
5. EARTH STATION ANTENNA PARAMETERS	
Service min. elevation angle (°) / Steerable?	30/Not steerable
Xmtr. Peak Gain (dBi) / Beamwidth (°) / Polarization	44.3/1.1/CP
Rcvr. Peak Gain (dBi) / Beamwidth (°) / Polarization	43.1/1.6/CP
Sidelobe Mask	ITU RR Appendix 29 Annex III, d/Lambda<100
Number of Earth Stations and distribution	Several million located anywhere in US and worldwide

Transmit and receive peak gain = 46.5 dB

EIRP = gain + 12.5 dBw

Space Station G/T = 18.9 dB/k



SAMPLE SPOT BEAM TRANSMIT AND RECEIVE ANTENNA COVERAGE

ACTS TECHNICAL CHARACTERISTICS		
PARAMETER		
1. Orbital parameters		
Orbital Arc Location	100°± 0.05°W longitude	
2. Frequency Bands		
Uplink/Downlink (GHz)	29-30 GHz up / 19.2-20.2 GHz down[1]	
3. Carrier transmission parameters		
Multiple Access Technique	BBP mode of operation requires TDMA[2] MSM repeater mode of operation can use FDMA or TDMA	
Modulation Types/Symbol Rates	BBP Mode	MSM repeater Mode
	SMSK modulation Uplink Burst Rate: 110 or 27.5 Mbps Downlink Burst Rate: 110 Mbps[3]	FM,PM,SMSK,M-ary PSK or any other constant-envelope scheme Arbitrary channel data rate/bandwidth up to 900 MHz bandwidth
Allocated bandwidth for each carrier	BBP Mode[4]	MSM repeater Mode[5]

[1]For propagation studies, uplink rain fade detection, and telemetry, ACTS also transmits three beacon signals: an unmodulated uplink fade beacon at 27.505 Ghz and beacons at 20.185 and 20.195 Ghz that are modulated with telemetry information. Uplink carrier frequencies are at 29.25 Ghz and 29.63 Ghz.

[2]ACTS can operate in either a baseband processing (BBP) mode or a microwave switch matrix (MSM) mode. In the BBP mode, signals are demodulated, stored, routed, and remodulated on-board the S/C. BBP mode requires a structured TDMA format with fixed burst rates of 110 Msps or 27.5 Msps on the uplink, a fixed burst rate of 110 Msps on the downlink, and SMSK modulation. In the MSM mode, however, ACTS simply acts as a bent-pipe repeater with IF switching and each channel can essentially operate at any data rate and modulation scheme (constant envelope) up to the full transponder bandwidth which is 900 Mhz wide.

[3]These are the uncoded symbol rates under clear sky conditions. Under rain fade in BBP mode, ACTS automatically compensates by reducing the information data rate by a factor of 4 and incorporating rate 1/2 convolutional coding which together provide about 10 dB more link margin. Hence, if the clear sky rate is 110 Msps, the rain fade rate will be 55 Msps and if the clear sky rate is 27.5 Msps, the rain fade rate will be 13.75 Msps.

[4]The earth stations designed to operate with ACTS in the BBP mode are the main 5.5 meter NASA Ground Station (NGS) at Lewis which can burst at either 110 or 27.5 Mbps and the LBR (Low Burst Rate) 1.2 meter and 2.4 meter T1 VSAT stations which burst at 27.5 Mbps. Both stations will receive at 110 Mbps. The BBP works with TDMA signals that are SMSK modulated. This modulation format has a number of attractive characteristics including spectral efficiency (mainlobe BW = 1.5 times the bit rate), constant envelope, continuous phase, error rate performance equal to BPSK, easy implementation of modems for high data rates, and minimal regrowth of spectral sidebands when the signal is passed through system nonlinearities (e.g. a TWT).

[5]The unstructured MSM repeater mode requires only that an earth station transmit and receive in ACTS's Ka uplink and downlink frequency bands. NASA earth stations which will operate with ACTS in the repeater mode are the HBR-LET (High Burst Rate - Link Evaluation Terminal) which can transmit and receive at 110 Mbps and 220 Mbps burst rates, the ACTS Mobile Terminal (AMT) with data rates in the range 2.4-56 kbps, a 2.5 kbps, 35 cm USAT (Ultra-Small Aperture Terminal), aeronautical (Aero-X) terminal, high data rate terminal (HDRT) at 622 Mbps to support supercomputer and video communications, and possibly a shipboard terminal. Of course, the NGS and T1-VSAT LBR terminals can also operate in the MSM mode.

	NGS @ 110 Mbps U/L - 165 Mhz NGS or LBR @ 27.5 Mbps U/L - 41.25 MHz NGS or LBR @ 110 Mbps D/L - 165 MHz	Carrier BW up to 900 Mhz Data rate and modulation format are arbitrary. HBR-LET @ 110 Mbps SMSK -165 Mhz HBR-LET @ 220 Mbps SMSK - 330 Mhz AMT - 250 kHz HDRT @ 622 Mbps - 900 MHz
Ground Terminal Transmit EIRPs	NGS 5.5 meter terminal transmitting 27.5 Mbps burst - 74 dBW EIRP NGS 5.5 meter terminal transmitting 110 Mbps burst - 80 dBW EIRP T1-VSAT 2.4 meter LBR terminal transmitting 27.5 Mbps burst - 66 dBW EIRP (55.6 dBi peak gain and 10.5 W transmit power) T1-VSAT 1.2 meter LBR terminal transmitting 27.5 Mbps burst - 60 dBW EIRP (49.6 dBi peak gain and 10.5 W transmit power) HBR-LET 4.72 meter terminal transmitting 110/220 Mbps - 75 dBW max EIRP (59 dBi peak gain and 40 W transmit power) (The HBR-LET can vary its uplink power for uplink power control experiments) AMT has a peak EIRP of about 33.5 dBW (23.5 dBi ant gain and 10W max power) (The AMT has a min EIRP reqt of 19.6 dBW and min G/T reqt of -8.0 dB/K over a 40°-52° elevation range which accommodates vehicle pitch and roll variations) HDRT - 78.1 dBW EIRP (58.1 dBi gain and 100 W transmit power)	
Ground Terminal Receive G/Ts	NGS 5.5 meter terminal - 26.5 dB/K T1-VSAT 2.4m LBR - 22 dB/K T1-VSAT 1.2m LBR - 16 dB/K HBR-LET 4.72 m - 27 dB/K AMT - max G/T of -2.8 dB/K over required elevation range	
4. Satellite Antenna Parameters		
Number of spot beams	ACTS has a total of 6 uplink/downlink spot beams as follows: 3 fixed beams, 2 hopping beams, and 1 mechanically steerable beam Because the uplink and downlink beams each have their own reflector and BFN, the east and west U/L and D/L hopping beams can be independently scanned. In the MSM mode, any 3 uplink beams can be connected to any 3 downlink beams. In BBP mode, traffic bursts on any 2 uplink beams can be individually routed to any 2 downlink beams.	
	Uplink Spot Beams	Downlink Spot Beams

	- 3 fixed 0.3° U/L spot beams over Cleveland (Horizontal Polarization), Atlanta (VP), and Tampa (VP) -an U/L east hopping beam (0.3°) (HP) that can hop to any one of 6 discrete locations[6] or anywhere within a continuous sector in the northeast U.S. - an U/L west hopping beam (0.3°) (VP) that can hop to any one of 7 discrete locations[7] or anywhere within a continuous sector in the northeast U.S. - a mechanically steerable spot beam (from a separate 1.1 m steerable antenna) that can be moved anywhere in the hemisphere visible from 100°W. Steerable ±10° in both AZ and EL.	- 3 fixed 0.3° D/L spot beams over Cleveland (VP), Atlanta (HP), and Tampa (HP) -a D/L east hopping beam (0.3°) (VP) that can hop to any one of 6 discrete locations or anywhere within a continuous sector in the northeast U.S. - a D/L west hopping beam (0.3°) (HP) that can hop to any one of 7 discrete locations or anywhere within a continuous sector in the northeast U.S. - a mechanically steerable spot beam (from a separate 1.1 m steerable antenna) that can be moved anywhere in the hemisphere visible from 100°W. Steerable ±10° in both AZ and EL.
Beam transmit EIRPs	The downlink fixed and hopping beams at 20 Ghz are formed from a 3.3 meter offset Cassegrain antenna while the steerable spot beam is formed from the 1.1 m mechanically steerable reflector. Nominal EIRP at the edge of beam are as follows: Fixed Spot Beam - 64 dBW Isolated Spot Beam - 62 dBW Spot beam in continuous sector - 59.5 dBW Steerable Spot Beam - 55 dBW	
Beam receive G/Ts	The uplink fixed and hopping beams at 30 Ghz are formed from a 2.2 meter offset Cassegrain antenna while the steerable spot beam is formed from the same 1.1 meter reflector as used for the downlink steerable beam. Nominal G/T at edge of beam are as follows: Fixed Spot Beam - 19.5 dB/K Isolated Spot Beam - 18 dB/K Spot beam in continuous sector - 15 dB/K Steerable Spot Beam - 11 dB/K	
5. Earth Station Antenna Parameters		
Service min elevation angle	Nominally 20° minimum	
Xmtr Peak Gains	Given above under Ground Terminal Transmit EIRPs	
Recvr Peak Gains	Given above under Ground Terminal Receive G/Ts	

[6]Nominal spot beam locations are Nashville, Houston, Miami, Los Angeles, Seattle, and Kansas City

[7]Nominal spot beam locations are Dallas, Denver, Memphis, New Orleans, Phoenix, San Francisco, and White Sands

Transmit Gain Patterns	T1-VSAT 2.4 meter LBR terminal G_{max} = 55.6 dBi ; θ_{3dB} = 0.3° for 0° <= θ <= 0.35° ; $G = G_{max} - 12(\theta/\theta_{3dB})^2$ dBi for 0.35° < θ <= 1° ; G = -9.5846θ + 38.5846 dBi for 1° < θ <= 7° ; G = 29 - 25 log(θ) dBi for 7° < θ <= 9.2° ; G = 8 dBi for 9.2° < θ <= 48° ; G = 32 - 25 log(θ) dBi for 48° < θ <= 75° ; G = -10 dBi for 75° < θ <= 100° ; G = -6 dBi for 100° < θ <= 180° ; G = -15 dBi
	T1-VSAT 1.2 meter LBR terminal G_{max} = 49.6 dBi ; θ_{3dB} = 0.6° for 0° <= θ <= 0.7° ; $G = G_{max} - 12(\theta/\theta_{3dB})^2$ dBi for 0.7° < θ <= 1° ; G = 29 dBi for 1° < θ <= 7° ; G = 29 - 25 log(θ) dBi for 7° < θ <= 9.2° ; G = 8 dBi for 9.2° < θ <= 48° ; G = 32 - 25 log(θ) dBi for 48° < θ <= 75° ; G = -10 dBi for 75° < θ <= 100° ; G = -6 dBi for 100° < θ <= 180° ; G = -15 dBi
	ACTS Mobile Terminal (AMT) G_{max} = 23.5 dBi ; θ_{3dB} = 10.8° for 0° <= θ <= 15° ; $G = G_{max} - 12(\theta/\theta_{3dB})^2$ dBi for 15° < θ <= 90° ; G = 2.22 - 0.1142θ - 0.0005 θ^2 dBi for θ > 90° ; G = -15 dBi
Number of earth stations[8]	NGS (Master Control Station) - 1 (at Lewis) T1-VSAT LBR terminals - 18 (CONUS) HBR-LET - 1 (at Lewis) AMT - 4 HDRT - 5 (CONUS) USAT - 5 Aero-X terminal - 1

[8]These are the ACTS ground terminals developed (or being developed) as of March 1, 1994 for operation with the ACTS satellite.

Calculation of LMDS Hub Interference Into FSS Space Station Receivers
Report of the WG1B Ad Hoc Modeling and Analysis Group

1. Introduction

This report presents calculations of LMDS hub interference levels into FSS space station receivers and compares the calculated levels with FSS interference criteria. The calculations are applicable to Interference/Sharing Scenarios 4 and 5 as defined in NRMC/13 (Rev. 1).

2. Technical Factors Considered and Approximations Made

The technical factors included are those listed in WG1/32 (Add. 1). The power spectral density expected from each interferer was taken as the power divided by the signal bandwidth. The maximum power spectral density was then determined by adding a peaking factor (10 dB for TV/FM, 6 dB for TV/AM, and 3 dB for digital signals). A -3 dB frequency interleaving factor and a -3 dB polarization factor was also assumed. The interference power density computed on this basis represents the worst case where the victim signal bandwidth is assumed to be narrow compared with that of the interfering signal. This protects the most sensitive potential use of the victim system.

For narrow satellite beams - The beam was pointed such that its "far" edge produced the listed elevation angle. For example, for a 20° minimum elevation angle, a 1° beam boresight elevation angle is 28°, the minumum elevation angle at the "far" edge is 20°. Interference was assumed only from those LMDS transmitters contained within the satellite 3 dB beamwidth. Satellite receiving antenna gain was assumed to be constant at the peak value over the 3 dB beamwidth. Elevation angle to the satellite was assumed to be constant over the 3 dB beamwidth. Results of this simple approximation have been compared with the more exact method provided by the FCC computer program (document NRMC/21). Results agree within about 1 dB.

For a CONUS coverage satellite - Elevation angle to the satellite was assumed to be constant over all of CONUS. This yields conservative results and greatly simplifies the computation.

The computations considered the LMDS hub EIRP power spectral density and antenna discrimination toward an FSS satellite. The EIRP density was increased by the number of hubs contained in an FSS beam. The aggregate received power density at the satellite receiver was then compared with the interference limit supplied by the FSS proponent {-13 dB(thermal noise) for ACTS and Spaceway, -18 dB(thermal noise) for Teledesic}.

3. Summary of Results

A summary of the results is presented here. Values are the difference between the permissible and calculated levels of interference on a per Hertz basis. Negative values indicate that the permissible value is exceeded. Both ACTS and Spaceway Earth terminals exhibit a minimum elevation angle of 30° for CONUS locations. The LEO Teledesic system operates with a minimum 40° elevation angle.

Table 1 - Summary of LMDS Interference Margins into FSS Satellites

Limit/Io in dB	Suite 12	Video Phone	TI Digital	TI TV/FM	TI TV/AM
ACTS, 30° elev.	20	13	28	17	6
SPACEWAY, 30° elev.	16	9	24	12	2
TELEDESIC, 40° elev.	6	6	10	-2	-16
Typical Future GSO Satellites:					
Spot Beam, 20° elev.	15	5	23	11	1
CONUS, 20° elev.	22	16	33	21	11

Margins for a 20° elevation are shown to illustrate interference margins typical of future satellites occupying other GSO locations affording CONUS coverage.

4. LMDS Hub Parameters

The LMDS hub parameters used are listed in Table 2 and unless otherwise noted were supplied by the LMDS system proponent. Values supplied included the maximum hub EIRP spectral density, hub antenna discrimination at a given elevation angle toward an FSS satellite and the maximum number of hub transmitters within each FSS satellite beam.

The # of hub transmitters located in each FSS beam was supplied by the LMDS proponent. Proponents generally determined the value by dividing the area of the FSS beam intersection with the Earth by a cell area and then further reducing the number by the average cell density over a large geographical region. With the exception of Teledesic, satellite beams intersect a large geographic area. The Teledesic beam "sees" a small area (53 x 53 km), and proponents generally assumed a 100% average cell density.

4.1 Suite 12 Signal Parameters

Modulation	TV/FM
Gt max, dB(i)	12.0
EIRP, dB(W)	7.0
BW, MHz	18.0
EIRPo, dB(W/Hz)	-65.6
Ant Disc(20°), dB	-28.0
EIRPo(20°), dB(W/Hz)	-93.6

For this and the following lists of signal parameters, Ant Disc(20°) denotes the sidelobe level relative to Gt max at a 20° elevation angle; EIRPo(20°) denotes the EIRP density at a 20° elevation angle; EIRP density is computed on the basis of a flat spectrum over the signal bandwidth.

4.2 Video/Phone Signal Parameters

Modulation	TV/AM	TV/FM	256QAM
Gt max, dB(i)	29.7	29.7	29.7
EIRP (rain), dB(W)	24.9	29.8	24.9
EIRP (no rain), dB(W)	13.9	18.8	13.9
BW, MHz	6.0	20.0	6.0
EIRPo (rain), dB(W)	-42.9	-43.2	-42.9
EIRPo (no rain), dB(W)	-53.9	-54.2	-53.9
Ant Disc(20°), dB	-51.0	-51.0	-51.0
EIRPo(20°), dB(W/Hz)	-93.9	-94.2	-93.9

Video/Phone employs a unique hub that is divided into 36 sectors. Each sector exhibits the EIRP listed above. Note that power control is employed for rain.

The antenna discrimination at a given elevation angle is determined by summing contributions from one sector at a 0° azimuth and the 35 remaining sectors at their respective azimuthal pointing directions. Theoretical information supplied by Video/Phone states that the discrimination at a given elevation angle is that expected from a single sector beam whose azimuth points at the FSS satellite - the contributions from the remaining 35 co-frequency sectors are negligible. This would presume that the total contribution from 35 other sectors would be at least 6 dB below the -51 dB discrimination listed above:

$$-51 - 6 = 10 \log(35) + \text{other sector discrimination}$$

$$\text{other sector discrimination} = -72.4 \text{ dB for each sector}$$

and since the mainbeam gain of a sector is about 30 dB(i), the average sidelobe/backlobe gain of each of the remaining 35 sectors would be 30 - 72 = -42 dB(i).

4.3 Texas Instruments (TI) Signal Parameters

Modulation	QPSK	QPSK	TV/FM	TV/AM
Gt max, dB(i)	15.0	15.0	15.0	15.0
EIRP (rain), dB(W)	15.0	5.0	15.0	15.0
EIRP (no rain), dB(W)	3.0	-7.0	3.0	11.0
BW, MHz	52.0	5.2	17.0	4.2
EIRPo (rain), dB(W)	-62.2	-62.2	-57.3	-51.2
EIRPo (no rain), dB(W)	-74.2	-74.2	-69.3	-55.2
Ant Disc(20°), dB	-26.0	-26.0	-26.0	-26.0
EIRPo(20°), dB(W/Hz)	-88.2	-88.2	-83.3	-77.2

Note that power control is employed for rain.

5. FSS Satellite Parameters

The FSS satellite parameters listed in Table 2 were supplied by the FSS proponents. In addition, the area of beam intersections with the Earth have been added for reference. These are the areas that would result when the listed elevation angle is the minimum that occurs at the beam edge.

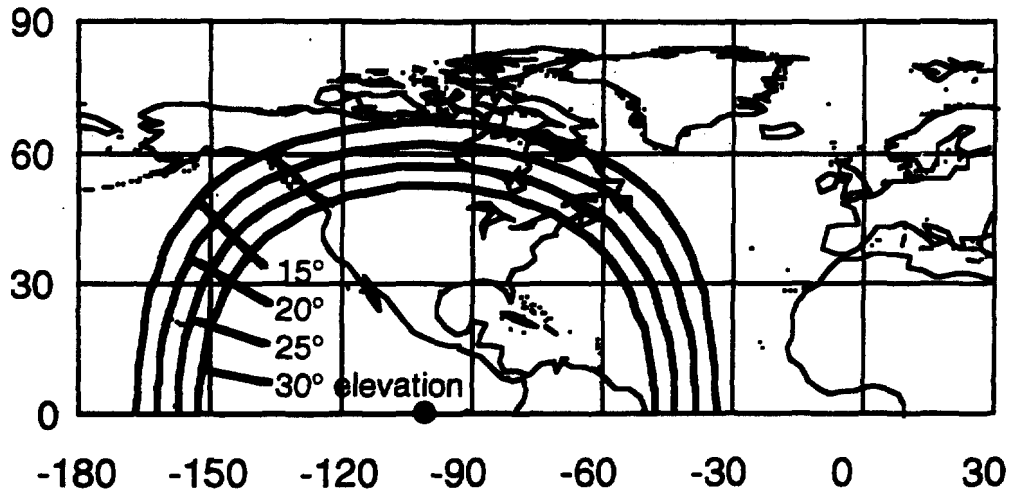
Except for Teledesic, the satellites are geosynchronous and specify an interference limit 13 dB below their thermal noise level. The Teledesic system is at a 700 km orbit altitude and "sees" a 2800 sq. km (53 x 53 km) that is constant for all elevation angles above its minimum 40° value. The difference in path length from a 40° elevation angle to the vertical represents a path loss reduction of 3.3 dB. This is expected to be more than offset by the reduced off-axis gain of LMDS hub transmitting antennas toward the vertical. Thus the 40° elevation represents the worst case. The Teledesic system specifies an interference limit 18 dB below its thermal noise level.

6. Interference Calculations (From LMDS Hub Transmissions)

Interference calculations for each FSS system against LMDS systems are listed on Tables 4 through 7. For each combination, the interference power density, Io, at the FSS satellite receiver is calculated for comparison with the interference limit; Io, limit. The calculated margin is positive for those cases where the interference limit is not exceeded.

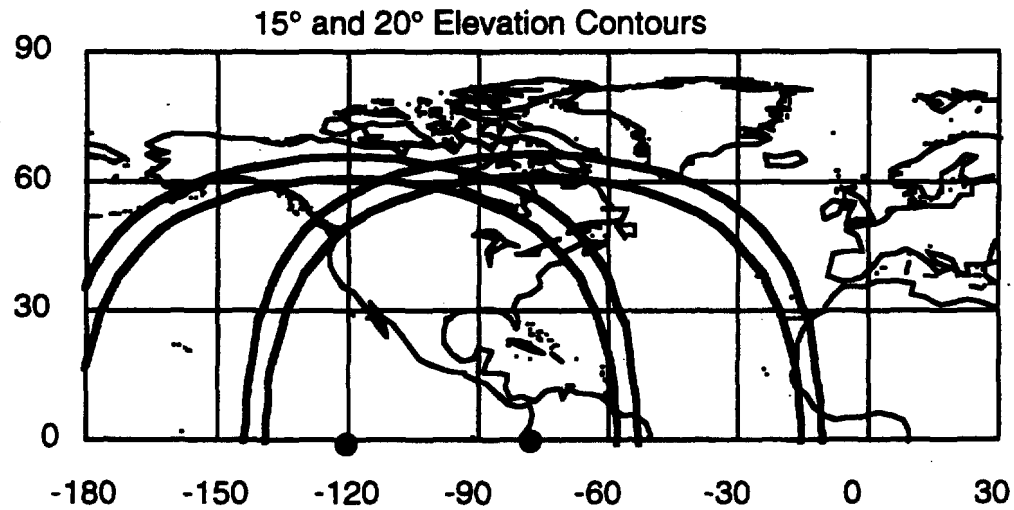
7. Effect of Elevation Angles Less Than 30°

The geosynchronous satellites for which data has been presented to the NRMC are located near 100°W. A 30° minimum elevation angle represents the worst case for these particular satellites serving CONUS. Additional calculations at lower elevation angles were made in Tables 4 through 7 to assess the range of geosynchronous satellites orbit locations capable of sharing with LMDS hub transmitters.

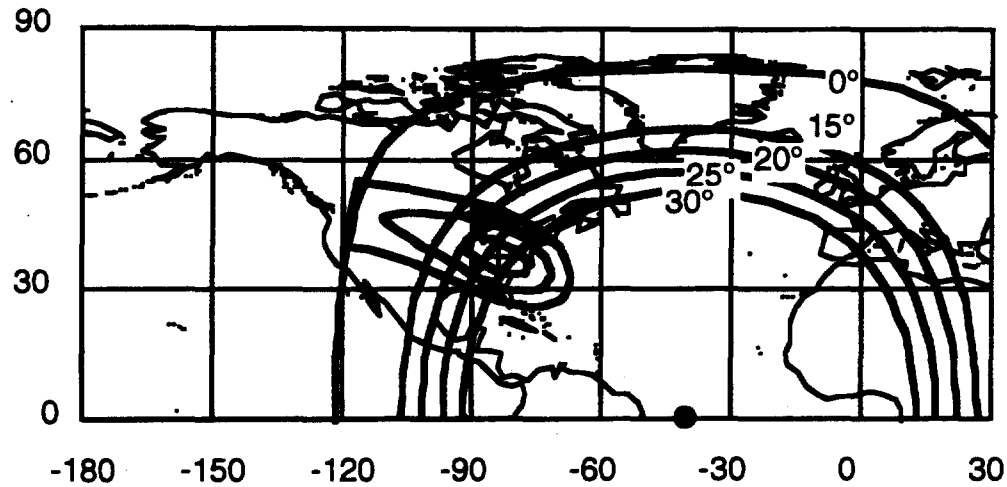


Note that the requirement for a 30° minimum elevation angle over CONUS restricts GEO satellite locations to the immediate vicinity of 100° W.

A 20° minimum elevation angle would allow GEO satellites over about a 40° arc centered about 100° W as shown below.



In addition, allowed minimum elevation angles below 30° would allow increased coverage by international satellites (Atlantic and Pacific rim) as shown below.



The figure illustrates a GEO satellite located at 40° W with a 1° 3 dB beamwidth on CONUS with a 20° minimum elevation angle footprint. Also plotted are the footprints for a 2° and 3° beamwidth (which extends to a 0° elevation angle). For this Atlantic rim satellite, LMDS transmitters over most of the width of CONUS and for elevation angles approaching 0° elevation are visible to the satellite receiving antenna sidelobes. For such a case, the approximation that all LMDS transmitters lie within the satellite 3 dB beamwidth is no longer accurate. The FCC GSO program (document NRMC/21) with the LMDS area ratio relative to the satellite antenna half-power beamwidth large enough to cover the 0° elevation region was used to evaluate results. The program was modified to include atmospheric losses at low elevation angles (rain climate zone 2).

Results for interference margins into an Atlantic rim satellite are listed below.

Summary of LMDS Interference Margins into an FSS Atlantic Rim Satellite

Limit/Io in dB	Suite 12	Video Phone	TI Digital	TI TV/FM	TI TV/AM
ACTS parameters 20° elev.	15	-16	12	0	-5
Spaceway parameters 20° elev.	11	-21	8	- 4	- 10

Note that margins have been reduced over the CONUS case listed in Table 1 by 4 dB for Suite 12, 26 dB for Video/Phone, and 7 dB for TI. The difference in values reflects the differing off-axis antenna discrimination values stated by the 3 proponents. It should be noted that the above values reflect a worst-case where the entire region enclosed by the 3° beamwidth plotted above is populated by LMDS cells.

8. Effect of Diffuse Scattering

Since the majority of power radiated from a hub antenna is incident upon the Earth's surface, the effect of diffuse scattering should not be neglected. An extensive search was undertaken and no directly applicable data was found in the literature. Scattering coefficients in the range of -5 dB to -40 dB were noted for cases of diffuse scatter in the specular direction and for backscatter. Most measured data was for lower frequencies. One study of scatter from buildings at 11.2 GHz indicated in the order of -7 dB in the