specular direction and -30 dB at angles well removed from the specular (Prediction Models & Measurements of Microwave signals Scattered from Buildings, Al-Nuaimi & Ding, IEEE Trans. Antennas & Propagation, Vol. 42, No. 8, Aug 94).

As an illustration, consider a -30 dB reflection coefficient with total power from the hub antenna distributed over the large area of a cell. The many random scatterers will be assumed to produce an aggregate scattered power that is 30 dB below the transmitter power and radiated hemispherically. The apparent "antenna gain" for this diffuse scattering is then -30 + 3 = -27 dB(i).

For an antenna with mainbeam gain of 15 dB(i), this corresponds to virtual sidelobe whose discrimination is 15 - (-27) = 42 dB. This discrimination is in excess of those shown on Table 2 for the Suite 12 and TI hub antennas. Diffuse scattering would thus be at a lower level than sidelobe radiation for these systems and may be neglected.

For an antenna with a mainbeam gain of 29.7 dB(i) such as the Video/Phone sectored hub, the virtual sidelobe discrimination is 29.7 - (-27) = 56 dB.

Video/Phone has supplied data (computer predictions) for its 36 sector hub showing that interference at a given elevation angle is essentially that from the vertical plane pattern of one sector, contributions from the other 35 co-frequency sectors are negligible. However, if each sector is considered in the light of diffuse scattering at the above level:

For the sector whose mainbeam azimuth is toward the FSS satellite, the off-axis discrimination at 20° elevation is -51 dB from Table 2. The diffuse virtual sidelobe discrimination from above is -56 dB. The contribution of scattering is negligible for this one sector (about a 1 dB increase).

However, each of the 35 other sectors exhibits a virtual sidelobe discrimination of -56 dB due to the assumed scattering. The aggregate from 35 sectors is then -56+ 10 log(35) = -40.6 dB(i). The aggregate for all 36 sectors is then -40.2 dB. This aggregate compared to the -51 value without considering scattering is an increase in interference level of 10.8 dB.

To summarize:

If the diffuse scattering reflection coefficient were -40 dB, the resulting increase in interference level would be about 3 dB.

If the diffuse scattering reflection coefficient were -30 dB, the resulting increase in interference level would be about 11 dB.

If the diffuse scattering reflection coefficient were -20 dB, the resulting increase in interference level would be about 20 dB.

It should be noted that there is no hard evidence that such diffuse scattering actually occurs or should it occur, what level is to be expected. The above illustration serves to indicate that further investigation may be needed for high-gain sector hub antennas that claim very low sidelobe levels.

	A	B	C	D	E	F	G
1							
2	Table 2 - LMDS HUB PARAMETERS						
3		Suite 12	Video/Phone	TI	TI	TI	
4		TV/FM	TV/AM	Digital	TV/FM	TV/AM	
5	Hub EIRPo (rain)	-66	-43	-62	-57	-51	dB(W/Hz)
6	Hub EIRPo clear air	-66	-54	-74	-69	-55	dB(W/Hz)
7	Hub Po 10% rain, 90% clear air	-66	-51	-70	-65	-55	dB(W/Hz)
8	Peaking factor	10	6	3	10	6	dB
9	-Freq. Interleave	-3	-3	-3	-3	-3	dB
10	Hub interference EIRPo	-59	-48	-70	-58	-52	dB(W/Hz)
11	Gt max	12	37	15	15	15	dB(i)
12	Gt(40°)-Gmax	-29	-54	-26	-26	-26	dB
13	Gt(30°)-Gmax	-28	-54	-26	-26	-26	dB
14	Gt(20°)-Gmax	-28	-51	-26	-26	-26	dB
15	Gt(15°)-Gmax	-28	-49	-25	-25	-25	dB
16							
17	# of hubs in beam for FSS minimum elevation angle						
18	# to Teledesic (40°)	38	1,018	112	112	560	
19	# to Spaceway (30°)	450	70,496	665	665	1,557	
20	# to ACTS (30°)	365	57,102	539	539	1,262	
21	# in CONUS	5,769	330,000	3,660	3,660	8,565	
22	# of hubs in beam based approximately on:						
23	average cell radius	6.6	0.80	5	5	1	km
24	average cell area	135	2.03	78	78	3	sq. km
25	average cell density*	10%	23%	** 9%	** 9%	** 0.8%	
26	* 100% average cell density assumed for the small Teledesic beam area						
27	** 10% for CONUS						
28							
29	Table 3 - FSS SATELLITE PARAMETERS						
30							
31		ACTS	Spaceway	Teledesic	CONUS		
32				Scan Beam	coverage		
33	Gr max	46.1	46.5	32.0	32.0	dB(i)	
34	Beamwidth	0.9	1.0	4.3	3e6 sq miles	degrees	
35	Thermal Noise density	-198.0	-201.0	-200.8	-199.0	dB(W/Hz)	
36	Allowed Io/No	-13.0	-13.0	-18.0	-13.0	dB	
37	Io interference limit	-211	-214	-218.8	-212	dB(W/Hz)	
38	Min. Elev. Angle	30	30	40	30	degrees	
39	Beam area, 40° elev			2,800	7,766,000	sq. km	
40	Beam area, 30° elev	492,075	607,500	N/A	7,766,000	sq. km	
41	Beam area, 20° elev	649,520	801,876	N/A	7,766,000	sq. km	
42	Beam area, 15° elev	759,746	937,958	N/A	7,766,000	sq. km	

	A	B	C	D	E	F	G
43							
44	Table 4 - ACTS, Calculation of Interference						
45	ACTS	Suite 12	Video/Phone	TI	TI	TI	
46	Interference Received			Digital	TV/FM	TV/AM	
47	Hub interference EIRPo	-59	-48	-70	-58	-52	dB(W/Hz)
48	Gt(30°)-Gmax	-28	-54	-26	-26	-26	dB
49	# hubs in beam	365	57,102	539	539	1,262	
50	-Lbf	-213.6	-213.6	-213.6	-213.6	-213.6	dB
51	Gr	46.1	46.1	46.1	46.1	46.1	dB(i)
52	-Polarization disc	-3	-3	-3	-3	-3	dB
53	Io	-231	-224	-239	-228	-217	dB(W/Hz)
54	Io, limit	-211	-211	-211	-211	-211	dB(W/Hz)
55	Margin (30° min. elev)	20	13	28	17	6	dB
56	Margin (20° min. elev)	19	9	27	15	5	dB
57	Margin (15° min. elev)	19	7	26	14	3	dB
58							
59	Table 5 - SPACEWAY - Interference Calculations						
60	SPACEWAY	Suite 12	Video/Phone	TI	TI	TI	
61	Interference Received			Digital	TV/FM	TV/AM	
62	Hub interference EIRP	-59	-48	-70	-58	-52	dB(W/Hz)
63	Gt(30°)-Gmax	-28	-54	-26	-26	-26	dB
64	# hubs in beam	450	70,496	665	665	1,557	
65	-Lbf	-213.6	-213.6	-213.6	-213.6	-213.6	dB
66	Gr	46.5	46.5	46.5	46.5	46.5	dB(i)
67	-Polarization disc	-3	-3	-3	-3	-3	dB
68	Io	-230	-223	-238	-226	-216	dB(W/Hz)
69	Io, limit	-214	-214	-214	-214	-214	dB(W/Hz)
70	Margin (30° min. elev)	16	9	24	12	2	dB
71	Margin (20° min. elev)	15	5	23	11	1	dB
72	Margin (15° min. elev)	14	2	21	9	-1	dB
73							
74	Table 6 - TELEDESIC, Calculation of Interference						
75	TELEDESIC	Suite 12	Video/Phone	TI	TI	TI	
76	Interference received			Digital	TV/FM	TV/AM	
77	Hub interference EIRP	-59	-48	-70	-58	-52	dB(W/Hz)
78	Gt(40°)-Gmax	-29	-54	-26	-26	-26	dB
79	# hubs in beam	38	1,018	112	112	560	
80	-Lbf	-182	-182	-182	-182	-182	dB
81	Gr	32	32	32	32	32	dB(i)
82	-Polarization disc	-3	-3	-3	-3	-3	dB
83	Io	-225	-224	-229	-217	-203	dB(W/Hz)
84	Io, limit	-218.8	-218.8	-218.8	-218.8	-218.8	dB(W/Hz)
85	Margin (40° elev.)	6	6	10	-2	-16	dB
86							

	A	B	C	D	E	F	G
87	Table 7 - CONUS COVERAGE, Calculation of Interference						
88	CONUS COVERAGE	Suite 12	Video/Phone	TI	TI	TI	
89	Interference received			Digital	TV/FM	TV/AM	
90	Hub interference EIRPo	-59	-48	-70	-58	-52	dB(W/Hz)
91	Gt(30°) - Gmax	-28	-54	-26	-26	-26	dB
92	# hubs in beam	5,769	330,000	3,660	3,660	8,565	
93	-Lbf	-213.6	-213.6	-213.6	-213.6	-213.6	dB
94	Gr	32	32	32	32	32	dB(i)
95	-Polarization disc	-3	-3	-3	-3	-3	dB
96	Io	-234	-231	-245	-233	-223	dB(W/Hz)
97	Io, limit	-212	-212.0	-212.0	-212.0	-212.0	dB(W/Hz)
98	Margin (30° min. elev)	22	19	33	21	11	dB
99	Margin (20° min. elev)	22	16	33	21	11	dB
100	Margin (15° min. elev)	22	14	32	20	10	dB

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

1. Introduction

This report presents calculations of LMDS subscriber return 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 Harry Ng 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 subscriber EIRP power spectral density, duty factor, and antenna discrimination toward an FSS satellite. The EIRP density was increased by the number of simultaneously active subscribers 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° from 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 5 km digital	TI 1 km digital
ACTS, 30° elev.	18	-3	17	17
SPACEWAY, 30° elev.	13	-7	13	13
TELEDESIC, 40° elev.	2	-11	-2	-5
Typical Future GSO Satellites:				
Spot Beam, 20° elev.	12	-9	11	12
CONUS, 20° elev.	19	2	22	22

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

4. LMDS Subscriber Return Parameters

The LMDS subscriber parameters used for interference computations are listed in Table 2 and are derived from the detailed listings below supplied by each proponent. The # of cells located in each FSS beam was supplied by the LMDS proponent generally determined 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 Return Signal Parameters

	Sub TX	Sub TX	Sub TX	Sub TX
Modulation	16 kbps	64 kbps	384 kbps	1.544 mpbs
Max. range, km	4.8	4.8	4.8	4.8
Rain margin, dB	13	13	13	13
Gt max, dB(i)	31	31	31	31
EIRP, dB(W)	-10	-3.9	3.8	10
BW, MHz	0.01	0.04	0.24	1
EIRPo max range, dB(W/Hz)	-50.0	-49.9	-50.0	-50.0
-Reduction Factor	-5.4	-5.4	-5.4	-5.4
EIRPo avg, dB(W/Hz)	-55.4	-55.3	-55.4	-55.4

All return signals within a given cell are received by an 8-sector hub combined to form a single receive antenna port. Therefore, only a single subscriber return signal may occupy a given frequency channel at any one time within a given cell. Since all subscribers should provide the same received power level at the hub location regardless of their range from the hub, an "average" subscriber operates at less than the "max range" EIRP (reduced by a "reduction factor", a function of the maximum range and associated rain margin).

The maximum aggregate interfering signal to a satellite receiver may then be taken as one "average" subscriber at a random azimuthal pointing direction within each cell that is visible to the satellite. Over a number of cells visible to a satellite, an average duty factor of 15% is expected for Suite 12. Each of the four return signals exhibit essentially the same EIRP density of -62.6 dB(W/Hz), so one entry in Table 2 is sufficient for Suite 12 computations.

The antenna discrimination expected from an average subscriber was determined by:

Assigning an assumed transmitter power to each subscriber of 0 - Gt max dB(W) to each subscriber;

For a given elevation angle to a satellite, computing the aggregate EIRP for a large number of subscriber antennas whose mainbeam pointing directions were uniformly distributed in azimuth;

Dividing the result (in Watts) by the number of subscribers assumed. As the total number of subscribers in all cells is increased, the expected value of antenna discrimination approaches the constant listed below.

Suite 12 Expected Average Antenna Discrimination, dB

Elevation to Satellite, degrees	Subscriber Elevation = 0°	Subscriber Elevation = 10°	10%@10° 90%@0°
40	-29.4	-28.3	-29.3
35	-29.0	-28.4	-28.9
30	-28.8	-28.4	-28.8
25	-28.8	-28.2	-28.7
20	-28.6	-27.0	-28.4
15	-28.6	-26.0	-28.3
10	-27.3	-18.6	-25.1

Because of terrain, local building configuration, and other factors, some subscriber antenna mainbeams may point at elevation angles above the horizontal. Expected average antenna discrimination was also calculated assuming all subscriber antennas operated an elevation of 10°. Results are given above.

Assuming 10% of subscribers having an elevation angle of 10° makes little difference for satellite elevations above 15°. The expected antenna discrimination may be taken as -28.4 dB for all satellite elevation angles above 15°.

4.2 Video/Phone Return Signal Parameters

Video/phone			
Modulation	QPSK	16QAM	256QAM
Max. range, km	1.6	1.6	1.6
Rain margin, dB	5.8	5.8	5.8
Gt max	38	38	38
EIRP max range (rain)	18	28	38
-Reduction factor, rain	- 4	- 4	- 4
EIRP avg, rain	14	24	34
EIRP max range (no rain)	10	18	28
-Reduction factor, no rain	- 3	- 3	- 3
EIRP avg, no rain	7	15	25
EIRP .1/.9	8.5	17.3	27.3
BW MHz	1.544	22.5	100.0
10 log(36 sectors)	15.6	15.6	15.6
EIRPo avg, dB(W/Hz)	-37.9	-40.7	-37.2

The 3 dB reduction factor for no rain assumes that subscriber EIRP is adjusted for range to the hub to maintain a constant receiver power. The 4 dB reduction factor for rain also takes into account the 3.6 dB/km rain loss. A cell is divided into 36 sectors, each of which may contain a subscriber return link on a given frequency channel at a given time. The maximum aggregate interfering signal to a satellite receiver is taken as 36 subscribers at random azimuthal pointing directions within each cell that is visible to the satellite. Since the three signal types exhibit essentially the same EIRP density, an EIRP density of -37 dB(W/Hz) will be assumed to represent the maximum possible from a single cell.

The antenna discrimination expected of each subscriber was computed on the same basis as for Suite 12 above.

Video/Phone Expected Antenna Discrimination, dB

Elevation to Satellite, degrees	Subscriber Elevation = 0°	Subscriber Elevation = 10°	10%@10° 90%@0°
40	-50.1	-48.7	-49.9
35	-49.6	-48.1	-49.4
30	-49.1	-47.4	-48.9
25	-48.4	-46.3	-48.1
20	-47.5	-44.9	-47.2
15	-46.5	-42.4	-45.9
10	-45.0	-22.2	-32.0

The expected antenna discrimination may be taken as a nominal -47 dB for satellite elevation angles above 20°.

4.3 Texas Instrument (TI) Return Signal Parameters

TI	Sub TX	Sub TX	Sub TX
Modulation	Dig1	Dig2	Dig3
Max. range, km	5	5	1
Rain margin, dB	15	15	4
Gt max	35	35	35
EIRP max range (rain)	35	25	15
-Reduction factor, rain	-5.5	-5.5	-3.7
EIRP avg, rain	29.5	19.5	11.3
EIRP max range (no rain)	23.0	13.0	11.0
-Reduction factor, no rain	-3.0	-3.0	-3.0
EIRP avg, no rain	20.0	10.0	8.0
EIRP .1/.9	22.5	12.5	8.5
BW MHz	52.0	5.2	5.2
EIRPo avg, dB(W/Hz)	-54.6	-54.6	-58.7

From the EIRPo average values above, two cases will be considered; a 5 km digital signal with an EIRPo of -54.6 dB(W/Hz) and a 1 km digital signal with an EIRPo of -58.7 dB(W/Hz). Return transmitters operate on a TDMA basis to an omni-directional (in azimuth) receiving hub. The maximum aggregate interfering signal to a satellite receiver in a given frequency channel is taken as one subscriber at a random azimuthal pointing direction within each cell that is visible to the satellite.

The antenna discrimination expected of each subscriber was computed on the same basis as for Suite 12 above.

TI Expected Antenna Discrimination, dB

Elevation to Satellite, degrees	Subscriber Elevation = 0°	Subscriber Elevation = 10°	10% @ 10° 90% @ 0°
40	-30.0	-30.0	-30.0
35	-30.0	-30.0	-30.0
30	-30.0	-30.0	-30.0
25	-30.0	-30.0	-30.0
20	-30.0	-29.8	-30.0
15	-30.0	-29.4	-29.9
10	-30.0	-18.1	-26.1

The expected antenna discrimination may taken as -30 dB for elevation angles to the satellite above 15°.

	A	B	C	D	E	F
1						
2	Table 2 - LMDS SUBSCRIBER PARAMETERS					
3		Suite 12	Video/Phone	TI	TI	
4		Digital	Digital	5 km Digital	1 km digital	
5	Sub Po 10% rain, 90% clear air	-55	-38	-55	-59	dB(W/Hz)
6	Peaking factor	3	3	3	3	dB
7	-Freq. Interleave	-3	-3	-3	-3	dB
8	Gt(average ≥20°)-Gmax	-28.4	-47	-30	-30	dB(i)
9	EIRPo toward FSS	-84	-85	-85	-89	dB(W/Hz)
10	# of cells in beam for FSS minimum elevation angle					
11	# to Teledesic (40°)	38	1,018	112	560	
12	# to Spaceway (30°)	450	70,496	665	1,557	
13	# to ACTS (30°)	365	57,102	539	1,262	
14	# in CONUS	5,769	330,000	3,660	8,565	
15	# of cells in beam based approximately on:					
16	average cell radius	6.6	0.80	5	1	km
17	average cell area	135	2.03	78	3	sq. km
18	average cell density*	10%	23%	** 9%	** 0.8%	
19	* 100% average cell density assumed for the small Teledesic beam area					
20	** 10% for CONUS					
21						
22	Table 3 - FSS SATELLITE PARAMETERS					
23						
24		ACTS	Spaceway	Teledesic	CONUS	
25				Scan Beam	coverage	
26	Gr max	46.1	46.5	32.0	32.0	dB(i)
27	Beamwidth	0.9	1.0	4.3	3e6 sq miles	degrees
28	Thermal Noise density	-198.0	-201.0	-200.8	-199.0	dB(W/Hz)
29	Allowed Io/No	-13.0	-13.0	-18.0	-13.0	dB
30	Io interference limit	-211	-214	-218.8	-212	dB(W/Hz)
31	Min. Elev. Angle	30	30	40	30	degrees
32	Beam area, 40° elev			2,800	7,766,000	sq. km
33	Beam area, 30° elev	492,075	607,500	N/A	7,766,000	sq. km
34	Beam area, 20° elev	649,520	801,876	N/A	7,766,000	sq. km
35	Beam area, 15° elev	759,746	937,958	N/A	7,766,000	sq. km

	A	B	C	D	E	F
36						
37	Table 4 - ACTS, Calculation of Interference					
38	ACTS	Suite 12	Video/Phone	TI	TI	
39	Interference Received	Digital	Digital	5 km Digital	1 km digital	
40	Sub interference EIRPo	-84	-85	-85	-89	dB(W/Hz)
41	# cells in beam	365	57,102	539	1,262	
42	-Lbf	-213.6	-213.6	-213.6	-213.6	dB
43	Gr	46.1	46.1	46.1	46.1	dB(i)
44	-Polarization disc	-3	-3	-3	-3	dB
45	Io	-229	-208	-228	-228	dB(W/Hz)
46	Io, limit	-211	-211	-211	-211	dB(W/Hz)
47	Margin (30° min. elev)	18	-3	17	17	dB
48	Margin (20° min. elev)	16	-4	16	16	dB
49	Margin (15° min. elev)	16	-5	15	15	dB
50						
51	Table 5 - SPACEWAY - Interference Calculations					
52	SPACEWAY	Suite 12	Video/Phone	TI	TI	
53	Interference Received	Digital	Digital	5 km Digital	1 km digital	
54	Sub interference EIRPo	-84	-85	-85	-89	dB(W/Hz)
55	# cells in beam	450	70,496	665	1,557	
56	-Lbf	-213.6	-213.6	-213.6	-213.6	dB
57	Gr	46.5	46.5	46.5	46.5	dB(i)
58	-Polarization disc	-3	-3	-3	-3	dB
59	Io	-227	-207	-227	-227	dB(W/Hz)
60	Io, limit	-214	-214	-214	-214	dB(W/Hz)
61	Margin (30° min. elev)	13	-7	13	13	dB
62	Margin (20° min. elev)	12	-9	11	12	dB
63	Margin (15° min. elev)	11	-10	10	10	dB
64						
65	Table 6 - TELEDESIC, Calculation of Interference					
66	TELEDESIC	Suite 12	Video/Phone	TI	TI	
67	Interference received	Digital	Digital	5 km Digital	1 km digital	
68	Sub interference EIRPo	-84	-85	-85	-89	dB(W/Hz)
69	# hubs in beam	38	1,018	112	560	
70	-Lbf	-182	-182	-182	-182	dB
71	Gr	32	32	32	32	dB(i)
72	-Polarization disc	-3	-3	-3	-3	dB
73	Io	-221	-208	-217	-214	dB(W/Hz)
74	Io, limit	-218.8	-218.8	-218.8	-218.8	dB(W/Hz)
75	Margin (40° elev.)	2	-11	-2	-5	dB
76						

	A	B	C	D	E	F
77	Table 7 - CONUS COVERAGE, Calculation of Interference					
78	CONUS COVERAGE	Suite 12	Video/Phone	TI	TI	
79	Interference received			Digital	1 km digital	
80	Sub interference EIRPo	-84	-85	-85	-89	dB(W/Hz)
81	# hubs in beam	5,769	330,000	3,660	8,565	
82	-Lbf	-213.6	-213.6	-213.6	-213.6	dB
83	Gr	32	32	32	32	dB(i)
84	-Polarization disc	-3	-3	-3	-3	dB
85	Io	-231	-214	-234	-234	dB(W/Hz)
86	Io, limit	-212	-212.0	-212.0	-212.0	dB(W/Hz)
87	Margin (30° min. elev)	19	2	22	22	dB
88	Margin (20° min. elev)	19	2	22	22	dB
89	Margin (15° min. elev)	19	2	22	22	dB

NASA
FSS Downlink Beacons in the 27.500 - 27.501 GHz Band

The Requirement for Power Control Beacons

Use of the 20 to 30 GHz frequency band is developing on a worldwide basis, and will require the use of effective rain fading countermeasures. Due to potentially high variation of atmospheric attenuation, such countermeasures are required for Fixed Satellite Service operations in the 27.5-29.5 GHz band, and for current and future systems using the 19.7-20.2/29.5-30.0 GHz bands. The 20 to 30 GHz band represents a portion of the spectrum which is experiencing a significant increase in utilization for satellite services. Domestic satellite systems with 20/30 GHz transponders include CS-3 and Superbird (Japan), DFS-Kopernikus (Germany), and ITALSAT (Italy). 20/30 GHz technologies are included in the NASA ACTS and ESA Olympus satellites. Due to potentially high atmospheric attenuation (tens of decibels) encountered on most links for significant fractions of a year, an economic utilization of the 20 to 30 GHz band with a high service availability can only be contemplated if rain fade countermeasures, including uplink power control, are used.
Estimations of attenuation using a downlink beacon in the 20 GHz band are, in some cases, not of sufficient accuracy to closely control uplink power, due to uncertainties in frequency scaling of attenuation over the large frequency difference. The difficulty is pronounced when the uplink and downlink frequencies are separated by the water vapor line at approximately 22 GHz. This difficulty is overcome by using an open-loop scheme wherein the earth station estimates the change in the uplink attenuation based on the change in the power level of a space-to-Earth beacon signal in a frequency in or near the uplink frequency band. RR 882A provides an allocation to implement and utilize such signals, benefiting satellite services in a portion of the spectrum experiencing expanding use.

WARC-92 FSS Beacon allocation

WARC-92 adopted RR 882A and 882B which allocated the band 27.500 - 27.501 GHz for use by the Fixed-Satellite Service(space-to-Earth) for power link control beacons:

882A: Additional allocation: the bands 27.500 - 27.501 GHz and 29.999 - 30.000 GHz are also allocated to the fixed-satellite service (space-to-Earth) on a primary basis for the beacon transmissions intended for up link power control.

Such space-to-Earth transmissions shall not exceed an equivalent isotropic radiated power (e.i.r.p.) of +10 dBW in the direction of adjacent satellites on the geostationary-satellite orbit. In the band 27.500 - 27.501 GHz, such space-to-Earth transmissions shall not produce a power flux-density in excess of the values specified in No. 2578 on the Earth's surface for elevation angles of arrival (a) of:

$0° \leq a \leq 5°$	-115	dB(W/sq. meter) in a 1 MHz band
$5° \leq a \leq 25°$	-115 + 0.5(a-5)	dB(W/sq. meter) in a 1 MHz band
$25° \leq a \leq 90°$	-105	dB(W/sq. meter) in a 1 MHz band

882B: Additional allocation: the band 27.501 - 29.999 GHz is also allocated to the fixed-satellite service (space-to-Earth) on a secondary basis for beacon transmissions intended for up link power control.

NASA's ACTS Satellite Power Control Beacon

NASA's ACTS satellite provides an unmodulated downlink power control beacon at 27.505 GHz, operating in the secondary allocation provided for this purpose. The beacon power flux at the Earth's surface is approximately -142 dB(W/sq. meter). The minimum elevation angle of arrival is approximately 30° in CONUS.

Interference From FSS Power Control Beacons to LMDS

LMDS receivers exhibit an effective thermal noise temperature in the order of 1500 kelvins. This corresponds to a thermal noise power of -137 dB(W) in a 1 MHz band. Since received power:

Pr = PFD + Aeff + Gr one may then calculate the LMDS receiver antenna gain toward an FSS power control beacon for any allowed interference power level:

Gr(toward satellite) = Pr - PFD -(-50.2)

The ACTS beacon produces a PFD of -142 dB(W/sq. meter) at a minimum elevation angle of 30° in CONUS. The maximum value of LMDS receive antenna gain at an elevation angle of 30° if received power is 6 dB below the LMDS thermal noise is then:

Gr(30°) ≥ -137 - 6 -(-142) + 50.2 = 49 dB(i) greater than any expected LMDS antenna gain at an elevation angle of 30° or greater. It is thus unlikely that the ACTS beacon could cause harmful interference to LMDS in the 1 MHz band at 27.505 GHz.

Future satellites are free to employ power control beacons operating at the PFD limits listed above:

Gr(0°) ≥ -137 - 6 -(-115) + 50.2 = 22.2 dB(i), LMDS mainbeam could experience interference

Gr(25° to 90°) ≥ -137 - 6 -(-105) + 50.2 = 12.2 dB(i), LMDS would probably not experience interference.

Interference From LMDS to FSS Power Control Beacons

This section examines the free-space loss needed between LMDS transmitters and FSS Earth stations receiving a power control beacon. FSS Earth stations typically exhibit about 0 dB(i) gain in the horizontal direction and operate at noise temperature in the order of 700 kelvins. The allowed interference power density is taken to be 6 dB below the thermal noise density (-206 dB(W/Hz). The required free space path loss to afford protection from an LMDS transmission is then:

Lbf = EIRPo + 206 dB

LMDS mainbeam EIRP density values range from -60 to -42 dB(W/Hz) requiring Lbf values of 146 to 164 dB. Corresponding free-space distances at 27.5 GHz to afford protection for FSS power control beacon reception are than 17 to 138 km.

Protection should be provided to FSS power control beacon earth stations operating in accordance with RR882A (if adopted by the FCC) and for the ACTS beacon (1 MHz bands centered at 27.5005 GHz and 27.505 GHz).

ATTACHMENT L

MATLAB PROGRAM CODE USED FOR CALCULATIONS
IN 6.1 FSS EARTH STATIONS ACCESSING GSO SATELLITES
INTERFERING INTO LMDS RECEIVERS

MAINPD.M

```
initial
case  %define case
prodis  %Calcluate protection distance
plotdis  %Plot results
return
```

```
%Define global variables

global freq lambda step_size

global lmds_name lmds_file cell_radius lmds_rx_peak_gain lmds_eirp
global lmds_phi lmds_rx_gain allowed_cnir
global lmds_bw_mhz lmds_rx_noise_temp_k lmds_case rain_rate

global fss_name fss_file fss_el_angle fss_phi fss_tx_peak_gain
global fss_tx_gain fss_tx_power_per_channel fss_bw_mhz
global fss_gain_theta fss_eirp fss_case fss_power_control

%Include conversion constants
const

freq=29;
lambda=.3/freq;
step_size=1;
case_number=0;

return
```

```
%CONST provides constants and conversion coefficients

boltzmans_constant=-228.6;

M_IN=2.54/100;      %meters/in = (2.54 cm/in)(1 m/100 cm)
M_FT=M_IN*12;       %meters/ft = (meters/in)(12 in/ft)
M_MI=5280*M_FT;     %meters/mile = (5280 ft/mile)(meters/ft)
KM_FT=M_FT/1000;    %km/ft = (meters/ft)(1 km/1000 m)
KM_MI=M_MI/1000;    %km/mi = (meters/mile)(1 km/1000 m)

RAD_DEG=pi/180;  %radians/degree = pi/180

return
```

```
%LMDS parameters: name(receiver,modulation,pattern)

%suite12('subscriber','fm','supplied')
%suite12('hub','data','supplied')

%vp('subscriber','fm','supplied')
%vp('hub','45 Mbps','supplied')

%ti('subscriber','fm','supplied')  %system 3
%ti('subscriber','52 Mbps','supplied')  %system 1
%ti('hub','52 Mbps','supplied')  %system 1

%FSS parameters: name(terminal,signal,pattern,elevation angle)


%spaceway('subscriber','t1','itu',30)

%teledes('tst','t1','itu',40)
%teledes('tgt','oc24','itu',40)

%acts('usat','4.8 kbps','supplied',30)
%acts('hdrt','622 Mbps','supplied',30)

return
```

```
%Model LMDS clear sky link

lmds_rx_noise_temp=10*log10(lmds_rx_noise_temp_k);
lmds_bw=10*log10(lmds_bw_mhz*1e6);
lmds_space_loss=20*log10(lambda/(4*pi*(cell_radius*M_MI)));

lmds_carrier_power=lmds_eirp+lmds_space_loss+lmds_rx_peak_gain;
lmds_noise_power=boltzmans_constant+lmds_rx_noise_temp+lmds_bw;
lmds_cnr=lmds_carrier_power-lmds_noise_power;

%Compute protection ratio around LMDS

allowed_cir=-10*log10(1/10^(allowed_cnir/10)-1/10^(lmds_cnr/10));
allowed_interference_power=lmds_carrier_power-allowed_cir+max(0,10*l
og10(fss_bw_mhz/lmds_bw_mhz));
allowed_space_loss=allowed_interference_power-fss_eirp-lmds_rx_gain;

pro_distance_m=lambda./(4*pi*10.^(allowed_space_loss/20));
pro_distance_ft=pro_distance_m/M_FT;

return
```

```
%Display results

clf
phi1=30;
phi=phi1:step_size:180;
phi_radians=phi*pi/180;

polar(phi_radians,(pro_distance_ft(phi1/step_size+1:180/step_size+1)
),'-')

hold on
polar(-phi_radians,(pro_distance_ft(phi1/step_size+1:180/step_size+1
)),'-')
phi=lmds_phi;
phi_radians=phi*pi/180;
polar(phi_radians,(pro_distance_ft),'-')
polar(-phi_radians,(pro_distance_ft),'-')
hold off

case_number=case_number+1;
title(['Protection Distance (ft) Case: ' num2str(case_number) ' ' fs
s_name ' into ' lmds_name])

fss_text_string=str2mat(fss_name,'Terminal: ','Signal: ','Bandwidth:
 ','Pattern: ','El. angle: ');
lmds_text_string=str2mat(lmds_name,'Receiver: ','Signal: ','Bandwidt
h: ','Pattern: ');

angle1=0;
angle2=45;
angle3=180;
table_str_1=str2mat('Angle',num2str(angle1),num2str(angle2),num2str(
angle3));
table_str_2=str2mat('Distance(ft)'...
,num2str(pro_distance_ft(angle1/step_size+1))...
,num2str(pro_distance_ft(angle2/step_size+1))...
,num2str(pro_distance_ft(angle3/step_size+1))...
);

x=xx(-.42)*[1 1 1 1 1 1];
y=[yy(1) yy(.95) yy(.9) yy(.85) yy(.8) yy(.75)];
text(x,y,fss_text_string)
x=xx(-.2)*[1 1 1 1 1];
y=[yy(.95) yy(.9) yy(.85) yy(.8) yy(.75)];
text(x,y,fss_case)

x=xx(.95)*[1 1 1 1 1];
y=[yy(1) yy(.95) yy(.9) yy(.85) yy(.8)];
text(x,y,lmds_text_string)
x=xx(1.17)*[1 1 1 1];
y=[yy(.95) yy(.9) yy(.85) yy(.8)];
```

```
text(x,y,lmds_case)

x=xx(-.42)*[1 1 1 1];
y=[yy(.15) yy(.1) yy(.05) yy(0)];
text(x,y,table_str_1)
x=xx(-.2)*[1 1 1 1];
text(x,y,table_str_2)

return
```

```
function y=suite12(receiver,signal,pattern)

%receiver=subscriber
%         hub
%         repeater
%         backbone
%
%signal=am
%       fm
%       64 kbps
%
%pattern=itu
%        supplied

global freq lambda step_size

global lmds_name lmds_file cell_radius lmds_rx_peak_gain lmds_eirp
global lmds_phi lmds_rx_gain allowed_cnir
global lmds_bw_mhz lmds_rx_noise_temp_k lmds_case rain_rate

lmds_name='Suite 12';
cell_radius=3;  %miles
lmds_phi=0:step_size:180;

if strcmp(receiver,'subscriber')==1;  r='S';
  lmds_rx_peak_gain=31;
  if strcmp(pattern,'supplied')==1
    lmds_disc=min(max(-18,-3*(lmds_phi./2).^2),99.84-66.44*log10(lmd
s_phi));
    phi1=12;
    phi2=50;
    phi=phi1:step_size:phi2;
    lmds_disc(phi1/step_size+1:phi2/step_size+1)=-24*ones(size(phi))
;
    phi1=50;
    phi2=90;
    phi=phi1:step_size:phi2;
    lmds_disc(phi1/step_size+1:phi2/step_size+1)=-30*ones(size(phi))
;
    lmds_rx_gain=lmds_rx_peak_gain+lmds_disc;
  end
  if strcmp(signal,'fm')==1;  s='F';
    lmds_eirp=8;
    lmds_bw_mhz=18;
    lmds_rx_noise_temp_k=1150;
    if rain_rate==0
      allowed_cnir=26;
    else
      allowed_cnir=13;
    end
  end
```

```
end
if strcmp(receiver,'hub')==1;  r='H';
  lmds_rx_peak_gain=12;
  if strcmp(pattern,'supplied')==1
    lmds_rx_gain=12*ones(size(lmds_phi));
  end
  if strcmp(signal,'data')==1;  s='D';
    lmds_eirp=2;
    lmds_bw_mhz=.04;
    lmds_rx_noise_temp_k=586;
    if rain_rate==0
      allowed_cnir=16;
    else
      allowed_cnir=13;
    end
  end
end

if strcmp(pattern,'itu')==1
  lmds_rx_gain=gainitu(0,0,lmds_rx_peak_gain,60,lmds_phi);
end

lmds_case=str2mat(receiver,signal,num2str(lmds_bw_mhz),pattern);
lmds_file=['S' r s];

return
```

```
function y=vp(receiver,signal,pattern)

%receiver=subscriber
%         hub
%         repeater
%         backbone
%
%signal=am
%       fm
%       1.5 Mbps
%       45 Mbps
%       400 Mbps
%
%pattern=itu
%        supplied

global freq lambda step_size

global lmds_name lmds_file cell_radius lmds_rx_peak_gain lmds_eirp
global lmds_phi lmds_rx_gain allowed_cnir
global lmds_bw_mhz lmds_rx_noise_temp_k lmds_case rain_rate

lmds_name='Videophone';
cell_radius=1;  %miles
lmds_phi=0:step_size:180;

if strcmp(receiver,'subscriber')==1;  r='S';
  lmds_rx_peak_gain=38.2;
  if strcmp(pattern,'supplied')==1
    lmds_disc=max(-52,-16.82-18*log10(lmds_phi));
    phi1=3;
    phi2=5;
    phi=phi1:step_size:phi2;
    lmds_disc(phi1/step_size+1:phi2/step_size+1)=-25*ones(size(phi))
;
    phi1=0;
    phi2=3;
    phi=phi1:step_size:phi2;
    lmds_disc(phi1/step_size+1:phi2/step_size+1)=-3*(phi./1).^2;
    lmds_rx_gain=lmds_rx_peak_gain+lmds_disc;
  end
  if strcmp(signal,'fm')==1;  s='F';
    if rain_rate>0
      lmds_eirp=42;
    else
      lmds_eirp=27;
    end
    allowed_cnir=45.8;
    lmds_bw_mhz=20;
    lmds_rx_noise_temp_k=1139;
  end
```

```
end
if strcmp(receiver,'hub')==1;  r='H';
  lmds_rx_peak_gain=37;
  if strcmp(pattern,'supplied')==1
    lmds_disc=max(-3*(lmds_phi/5).^2,-10-14.5*log10(lmds_phi));
    phi1=90;
    phi2=180;
    phi=phi1:step_size:phi2;
    lmds_disc(phi1/step_size+1:phi2/step_size+1)=-38.34*ones(size(ph
i));
    lmds_disc(1)=0;
    lmds_rx_gain=lmds_rx_peak_gain+lmds_disc;
  end
  if strcmp(signal,'45 Mbps')==1;  s='D';
    if rain_rate>0
      lmds_eirp=28;
    else
      lmds_eirp=22.2;
    end
    allowed_cnir=44.2;
    lmds_bw_mhz=22.5;
    lmds_rx_noise_temp_k=937;
  end
end

if strcmp(pattern,'itu')==1
  lmds_rx_gain=gainitu(0,0,lmds_rx_peak_gain,60,lmds_phi);
end

lmds_case=str2mat(receiver,signal,num2str(lmds_bw_mhz),pattern);
lmds_file=['V' r s];

return
```