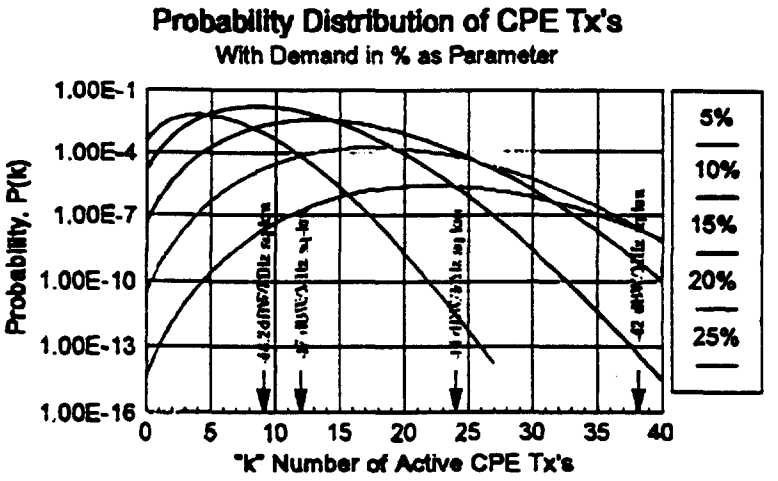
Joint Probability Distribution for Demand and Active CPE Tx's in 30 Degree Sector



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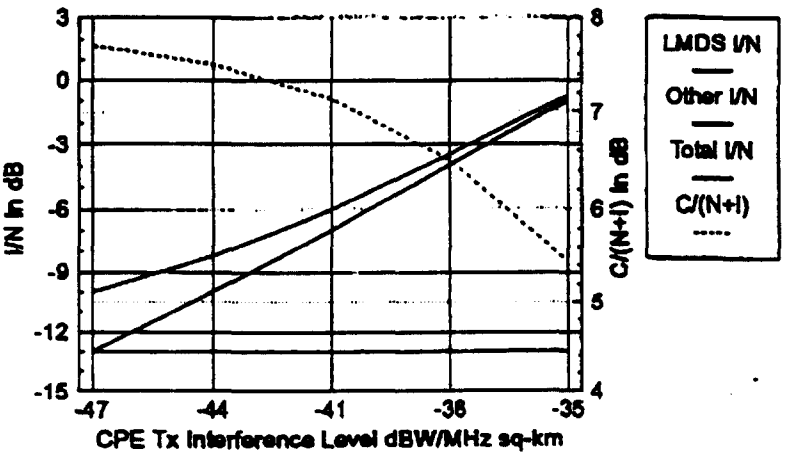
Effect of Interference Level on C/(N+I)



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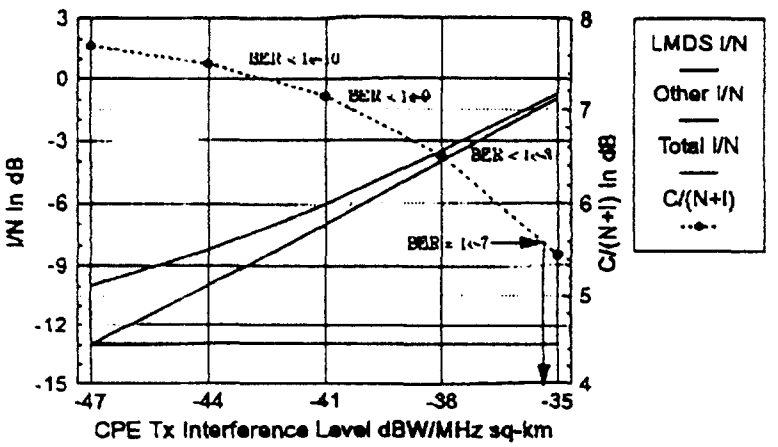
Effect of Interference Level on C/(N+I) and BER



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Summary

- In the major geographical regions in the continental U.S., assuming a uniform distribution of active CPE Tx's pointing in their intended direction, the PSAD can be expected to be:
  - At 0 degrees elevation, 17dB to 27dB below the level specified in proposed Rule 21.1021, 3rd NPRM.
  - At 6.0 to 15 degrees elevation, 2dB to 11dB below the level specified in proposed Rule 21.1021, 3rd NPRM.
  - At 15 to 90 degrees elevation, 0dB to 15dB below the level specified in proposed Rule 21.1021, 3rd NPRM.
- Statisical spread in PSAD due to demand and non-uniformly distributed active CPE Tx's will result in higher PSAD and in the Northeast could result in levels exceeding proposed Rule 21.1021, 3rd NPRM, but with very low probabilities.
  - Assuming a Poisson distribution, the probability of sufficient interference to cause BER to drop to 1e-8 is <1e-7.

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D.Gray/11/22/95

DISTRIBUTION

November 28, 1995

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LMDS AND IRIDIUM SHARING
FOR THE
29.1 TO 29.25 GHZ BAND

DECEMBER 1, 1995

SHARING SUMMARY

EXTENSIVE ANALYSES SHOW LMDS SUBSCRIBER RETURN LINKS AND IRIDIUM MSS/FSS FEEDER LINKS CAN SHARE THE 29.1-29.25 GHZ BAND.

- Acceptable bit error rates are achievable while sharing.(attachments A-D)
- Minimum elevation for the mid-CONUS gateway is 11.9 degrees resulting in a 4 dB system power control margin. (attachment E)
- Power spectral density is not dependent on LMDS cell radius. (attachment F)
- Look-up angle for CPEs are typically not greater than 5 degrees. (attachment G)
- Maximum slant range to the satellite is less at the 11 degree elevation
  - -results in 1.73 dB increase in the gateway signal, which is more than adequate to offset the 0.2 dB or 0.4 dB produced by either 5 or 10 percent interference.
  - -sufficient margin exist to offset 10 dB interference increase. (attachment H and I)
- CPE aggregate sidelobe power decreases 11.5 dB more than the satellite power control at short range, 90 degree elevation. (attachment J)
- CPE transceivers can fit the Proposed rules, 21.1020 and 21.1021 of the Third NPRM suggested for LMDS hubs. (attachment K)

ATTACHMENTS
28 November 1995

LMDS SUBSCRIBER AND IRIDIUM CO-PRIMARY SHARING OF THE 29.1-29.25 GHZ BAND

ATTACHMENTS
28 November 1995

LMDS SUBSCRIBER AND IRIDIUM CO-PRIMARY SHARING OF THE 29.1-29.25 GHZ BAND

A. INTRODUCTION
-Extensive analysis shows LMDS subscriber return links and Iridium MSS/FSS feeder links can share the 29.1-29.25 GHz band.

B. LOCAL MULTIPOINT DISTRIBUTION SERVICE CUSTOMER PREMISE EQUIPMENT TRANSMISSION AND IRIDIUM SATELLITE RECEIVER COMPATIBILITY ANALYSIS, SEPTEMBER 12, 1995.
-LMDS subscriber CPE parameters and Iridium feeder links are shown to yield acceptable C/I ratios using both the statistical analysis program that models the LMDS CPE deployment and the direct beam interaction analysis.

C. PROPOSED RULES FOR LMDS SUBSCRIBER TRANSCEIVERS IN THE 29.1-29.25 GHZ BAND.
-Proposed rules for maximum EIRP, (20 dBW/MHz, clear air with power control and 14 dBW/MHz without power control), and antenna mask allows for co-primary operation.

D. POPULATION DENSITY AND GATEWAY PARAMETERS BIT ERROR RATE ANALYSIS.
-Shows Motorola's N/I and C/I ratio levels along with acceptable bit error rates for the Iridium gateway link.

E. AN EXAMINATION OF IRIDIUM ORBITS AND GATEWAY ELEVATION ANGLE-IMPACT ON SYSTEM AVAILABILITY IN THE PRESENCE OF LMDS SUBSCRIBER TRANSMITTERS, NOVEMBER 17, 1995. Eric Barnhart, CellularVision.
-Minimum elevation angle for mid-CONUS (40 degrees North Latitude) is 11.9 degrees and produces 4 dB system power margin available to allow Motorola to maintain their desired satellite receiver operating point.

F. TOTAL POWER SPECTRAL DENSITY DEPENDENCY, OCTOBER 29, 1995. Doug Gray, Hewlett-Packard.
-Total power spectral density is dependent only on maximum EIRP at the cell periphery.

G. LOOK-UP ANGLE VERSUS HUB ANTENNA HEIGHT, OCTOBER 29, 1995. Doug Gray, Hewlett-Packard.
-Subscriber look-up angle is less than 10 degrees for ranges greater than 2 KM (300 meter hub antenna height) and less than 5 degrees for ranges greater than 100 meters, (30 meter hub antenna height).

H. SLANT RANGE TO SATELLITE AND SIGNAL LEVEL VERSUS ELEVATION ANGLE. Leland Langston, Texas Instruments.
-Elevation angle of 11 degrees, (Iridium CONUS elevation angle minimum), versus 5 degrees produces 1.73 dB increase in gateway signal level due to decreased range and space loss.

I. EFFECTS OF 5 PERCENT INTERFERENCE ALLOCATION.
Bill Myers, Texas Instruments
-An interference of -210 dBW/Hz (5 percent interference budget) only represents 0.2 dB change of the system noise temperature, an interference of -207 dBW/Hz, (10 percent interference budget) results in 0.4 dB thermal noise increase. An interference of -200 dBW/Hz (10 dB increase) results in 1.7 dB power change which can be easily compensated by the system margin due to reduced range (11 degree minimum elevation angle) or by increasing the gateway power by 1.7 dB.

J. EFFECT OF SATELLITE POWER CONTROL AT MINIMUM RANGE.
Bill Myers, Texas Instruments
-The aggregate sidelobe power from CPE return link transmissions will produce signal reductions much greater than the satellite link power control reductions. For main beam coupling at minimum range (90 degree elevation) a CPE operating at the maximum proposed rule power will result in only 0.2 dB degradation.

K. ANALYSIS OF CPE TRANSCEIVERS SHOWS FIT TO THE PROPOSED RULES 21.1020 AND 21.1021 PER THE THIRD NPRM FOR 28 GHZ, NOVEMBER 14, 1995. Doug Gray, Hewlett-Packard.
-At 7.5 degrees elevation, the aggregate of the LMDS CPEs power spectral area density (PSAD) is 2 dB to 9 dB below the required limit proposed for hubs.
-At 90 degrees elevation, the PSAD is 6 dB to 15 dB below the required limit.

RESPONSE TO MOTOROLA'S
NOVEMBER 27, 1995
LETTER TO
MR. THOMAS S. TYCX
FCC INTERNATIONAL BUREAU

- Motorola's November 27, 1995 Table 1 assumes a bit error rate of 1.0E-7 at an interference level of -207.5 dBW/Hz. However, the **received feeder link signal level** (per Motorola's Application amendment of November 15, 1994) **of -181.3 dBW/Hz results** in a **C/I ratio of 26.2 dB** which produces a **bit error rate of 1.0E-20.**

  An LMDS and noise composite level of **-189 dBW/Hz** would result in a **C/I ratio** of **7.7 dB** and produce a **bit error rate of 1.0E-8.**

- Motorola's views on sharing analysis:

Item 1.

The results of the TI analysis is valid and is not in error by an order of 20 to 27 dB. Random draw of program parameters for statistical analysis produced C/I results in the 30 dB to 35 dB range. TI does agree that multiple runs of the program and when related to I/N instead of C/I a mean I/N of -17 dB with a 3 sigma peak of -10.7 dB per Dr. Kubik's Figure 8 may be obtained. However, this does not provide the bit error rate performance of the satellite system. That assessment must be accomplished using the C/I ratio.

The simultaneous CPE transmitters used in the TI analysis is the worse case quantity with random pointing angles It is not valid for Motorola to confine these to a single 90 degree sector.

The 3 dB blocking reduction at low elevation angles (<5 degrees) is not related to power control as assumed by Dr. Kubik, but it represents a conservative estimate of the CPE transmitters that will not have line of sight to a low satellite.

The TI sharing analysis is valid and does show even with the statistical variation that results in the statistical analysis that the desired feeder link performance (bit error rate of 1.0E-7) can be maintained.

Item 2.

There is agreement with the math used to show signal levels in excess of the Motorola interference criteria of -210.5 dBW/Hz. However, TI has pointed out to Motorola at the NRMC and many other times that this criteria is not acceptable for determining system performance capability. Motorola has not been willing to accept that it is not the receiver noise floor level but the system C/I ratio which sets the satellite bit error rate performance levels.

Item 3.

TI agrees that the interference ground rules proposed by Motorola are unacceptable. Motorola was unwilling to consider link performance as a sharing criteria during the NRMC proceedings. Use of C/I and bit error rate performance is not a newly asserted interference criteria.

Item 4.

According to Motorola's November 15, 1994 Table R-A-6 (Rev1) SV-Gateway Links analysis there is sufficient margin in the link to accommodate sharing with out change to the gateway design. In addition, the analysis of Motorola's orbit parameters by Mr. Eric Barnhart shows that the minimum satellite elevation angle in the CONUS is 11.9 degrees (Attachment E of the 28 November 1995 letter from Texas Instruments to Motorola) not 5 degrees as proposed by Motorola.

Item 5.

Feeder link operation 3 dB over threshold allows the desired performance bit error rate to be achieved with I/N's of up to 0 dB, (13 dB increase in interference tolerance). This is consistent with the operation of the system as presented in the Motorola application revision dated November 15, 1994. The noise allocation used by the LMDS proponents did not use contributions from GEO systems since the proposed band plan does not include GEO systems operation in the 29.1 to 29.25 GHz spectrum. This also brings into question the applicability of the FCC Rule 25.204(c) to this issue of sharing between Motorola's Iridium feeder links and LMDS.

Item 6.

The LMDS proponents have offered to reduce the proposed rule EIRP to accommodate Motorola's concerns and have asked that Motorola increase their transmit power above threshold or operate at the levels indicated in the Motorola application since a very small increase in desired signal level results in a very large satellite margin increase. Thus, TI has not placed the entire burden of sharing on the Iridium system but has only asked that Motorola recognize the potential that exist for sharing.

The recommendation to use multiple up link receiving antennas with increased gain at the hubs to reduce subscriber transmit power is not feasible for all LMDS systems. Those systems that have omni coverage and make use of antenna polarization to prevent mutual interference between hubs and within hub coverage can not use higher gain narrow beam antennas as proposed by Endgate Technologies.

Item 7.

Motorola did not discuss sharing with all of the LMDS proponents during the NRMC and was not willing to discuss sharing criteria that would allow both hubs and subscriber terminals to share with the Iridium system. The agreement that was reached during the NRMC was in light of two LMDS operators (A & B) each of which would have 1 GHz of spectrum (27.5 to 29.5 GHz). The TI proposal at that time was to place the subscriber return links at the opposite ends of the 2 GHz for maximum separation to eliminate a costly diplexer in the subscriber transceiver. This proposal would have supported the Motorola sharing arrangement since the subscriber return links would not have been at the Iridium frequencies. However, the NRMC was not able to reach a successful conclusion since a consensus was not achieved. Thus, no agreements resulted from the NRMC to support either the LMDS interest or the satellite interest. Hence, the Third NRMC has resulted in a need to reconsider the possibility of LMDS sharing by the LMDS parties and Motorola.

Item 8.

The sharing agreement that was part of Motorola's input to the NRMC was signed by TI's representatives with the notation to recognize revisions that existed at that time. The basis of the agreement at that date was that LMDS was working to share 27.5 to 29.5 GHz, a total of two GHz of spectrum that supported the TI proposed LMDS spectrum utilization that was presented to the participants of the NRMC. The events as discussed in item 7 has resulted in the band plan which requires TI, the other LMDS proponents and Motorola to discuss sharing to maximize the use of the spectrum.

Item 9.

CellularVision has continued to participate in the analysis of LMDS and Motorola to operate as co-primary in the 29.1-29.25 GHz band. Their most recent contribution is a November 17, 1995 examination of Iridium orbits and gateway elevation angle which shows that for the CONUS the minimum elevation angle to the satellite is 11.9 degrees.

COMMENTS TO MOTOROLA'S
PROPOSED RULES
FOR 28 GHZ
DATED NOVEMBER 27,1995

21.107 Transmitter Power

The various LMDS proponents have commented in their response and reply comments to the Third NPRM on both the power level and the measurement bandwidth.

21.1020 LMDS Suscriber Transmissions

(a) Subscriber Transmitter EIRP Limit: Subscriber-to-hub

The limit of a maximum allowable EIRP per carrier of 0 dBW/MHz in any one megahertz in clear air is 20 dB below that value proposed by the LMDS participants. This level is 8 to 16 dB below that level specified for operation by the various LMDS proponents, (CV, ET, HP and TI).

It is suggested that the LMDS proposed rule power level can be reduced if Motorola will recognize the higher operating level specified in their application. If Motorola will increase their operating power level above minimum thresholds, as a minimum 1 dB for every 1 dB decrease in the LMDS proposed power level of 20 dBW/MHz, then the sharing between systems should be feasible with sufficient margin to protect the MSS/FSS feeder link integrity.

(b) Hub-to-Subscriber transmission

Hub to subscriber transmission on these frequencies should not be excluded unless they are used for subscriber transmission within a particular hub cell.

(c) Transmitter Interlocks

Some of the LMDS participants have shown that the random nature of CPE pointing angles of CPEs is not harmful to the satellite feeder link operation. This proposed rule should be imposed only if it can be shown that a particular system's operating power level and antenna characteristics can be shown to cause harmful interference.

The proposed rule amendments to 47 C.F.R. Part 25 of the Commission's Rules, (a) Special requirements for operation in the band 29.1-29.25 GHz and (b) Coordination of LMDS systems.... require further review and discussion.

Motorola Satellite Communications, Inc.
Timothy Klandrud
(602) 732-4254/ FAX (602) 732-2299

Re: 28 GHz NRM Process
December 1, 1995

Impact of Terrestrial LMDS Interference on IRIDIUM® System Performance

Summary Conclusions

As interference into the Space Vehicle (SV) uplink reciever increses there is a resulting loss of uplink performance to an IRIDIUM® Gateway. The loss in performance results from a loss of power that can be applied to overcome rain fades. As interference increases the effective noise floor of the uplink receiver will require more signal power to close the communications link with the same quality. This added power is no longer available to overcome rain fades. Hence, any increase in interference decreases the availability of the uplink.

The atmoshperic fade allowance that is currently used is a 30 dB margin at a 10 degree elevation angle. The margin is smaller for lower elevation angles and larger for higher elevation angles because of the change in the distance between the LEO (low earth orbit) satellite and the Gateway (ground station) site. This margin must cover rain fades, atmospheric attenuation, cloud attenuation, and scintillation effects. All of these sources of signal fading are statistical in nature. Several Gateways which are installed will need to use use two channels simultaneously. The fade margin allocation for these Gateway sites is about 4 dB lower than the fade allocation for a single channel Gateway. This will lower the available margin and increase the difficulty in selecting a site that provides the needed availability.

As and example we assume that we are operating a single channel Gateway in the Atlanta, GA area. The system assumptions used are given in the analysis section below. The results are plotted in Figure 1. The figure illustrates outage estimates using no diversity and using diversity. The outage level at a total Io/No of -10 dB is about 0.33% for no diversity and about 0.12% for diversity. The resulting 11 hours per year of outage for the diversity site is within the needed range for a Telecommunications system of reasonable quality. The outage using a single site is well above what is acceptable.

For total interference levels of 0 dB Io/No and 10 dB Io/No the outage increases by about 40% and 200% respectively. In general the interference is expected to be produced at a number of sites that are not co-located with the GW site. Since they are not at the same site the interference sources will not be significantly attenuated by the rain cell that is attenuating the signal from the GW uplink transmitter. The increases in outage due to increased interference would degrade system performance and represent an unacceptable situation. This impact assessment assumes that the power control loop used in the desired communications link has time to compensate for the increased interference levels. If the interference increases quickly the outage events would increase dramatically.

For a total interference level of 20 dB Io/No the system fails to operate at lower elevation angles. This will result in predictable link failures and represents highly unacceptable communications system performance.

Analysis

The analysis presented here assumes that we have a Gateway located in the Atlanta area. The general Crane rain attenuation model [Crane, 1980] is used to estimate the rain attenuation for a single site. The point rain rate distribution tables have been updated to reflect those presented in the NASA propagation handbook [Ippolito, 1989]. The combination of algorithm and tables has been called the "Global Model" in the handbook and in CCIR literature. The earth station latitude is assumed to be 33.73 degrees North and the height is assumed to be 0.3 km. The rain region taken from Ippolito's maps (or Crane's) is the "D3" region. A frequency of 29.3 GHz is used.

The current IRIDIUM® link budget allows for a 30 dB loss due to all atmospheric attenuation sources. There are several different practices in accounting for the different attenuation sources. We will assume that rain events are not correlated with scintillation events and combine rain attenuation and scintillation via a RSS combination (per CCIR Report 564-4, section 2.5.3). The cloud and attenuation due to humidity can be significant at low elevation angles. The occurrence of clouds and humidity correlate with rain events. We will assume that these add and will use an 80% humidity estimate for rain attenuation. Scintillation loss will be computed for a 0.5% outage probability using CCIR Report 564-4 [CCIR, 1990]. Atmospheric and cloud attenuation estimates are generated using CCIR Recommendations 676 and 840.

A summary of the atmospheric attenuations are listed for low elevation angles (and 40 degrees) in Table 1. A summary of the available power allocation to overcome rain fades is summarized in Table 2. The available power allocation is computed based on the available transmitter power, the change in range as a satellite comes closer to the Gateway site, and the estimated atmospheric attenuations.

As interference levels increase the available power allocation to compensate for rain losses decreases. The interference power can be considered to be a constant spectral power level across the space vehicle receiver bandwidth (of just over 3.125 MHz). We can characterize the interference power level in terms of the ratio of interference power level compared to the receiver noise level (Io/No). This ratio is logically equivalent to the ratio of the change in effective receiver noise temperature to the effective receiver noise level. This is most often referred to as the "delta-T/T" ratio. Delta-T/T is usually written in terms of percent and an allocation of 5% for one interference source (a system) and 10% for all interference sources is typical. The Io/No is usually written in terms of decibel and the corresponding levels are -13 dB and -10 dB respectively. The effective loss in power resulting from the interference is (approximately):

$$\text{Loss} = (\text{Io} + \text{No}) / \text{No}$$

or

$$\text{Loss} = 1 + \text{Io}/\text{No}$$

where Io/No is a fraction with the power spectral densities, Io and No, in any linear units (not decibel).

Using this relationship the remaining power allocation that can be used to overcome a rain attenuation event is computed. These values are given in Table 3 for the lower elevation angles and for 40 degrees. Using the Crane algorithm (the "Global Model" [Ippolito, 1989]) for the Atlanta site the availability for a Gateway using a single Earth Terminal is calculated and given in the "no diversity" columns of Table 4. The expected

outage at a Gateway site in the Atlanta area exceeds a reasonable outage for a telecommunications service. We need to use ground station site diversity to reduce the outage to acceptable levels at such sites. We assume that we have two site diversity with a baseline separation of 35 km and an average angle between the baseline and the look vector to the satellite of 45 degrees. The outage is calculated using the conservative "Hodge" model [Hodge, 1982] combined with the Global Model the availability using two site diversity is calculated and is given in Table 4 in the "diversity" columns. More liberal results in diversity gain are predicted by the Bothias model [Bothias, 1986]. The results using the Bothias model would accentuate the effect of lost signal fade allocation.

It is important to note that since the interference sources are not located at the same site as the Gateway uplink transmitter the interference sources will not be attenuated by the rain cell that is attenuating the desired uplink signal. We expect the interference sources to be distributed over a wide region. Some of the sources can be attenuated by rain but the majority of the sources will not be attenuated by the rain cells. The summed power of the interference sources will be dominated by the strong, unattenuated sources and the total interference will not be greatly reduced during rain events.

The outages shown in Table 4 are given for elevation angles between 5 and 10 degrees and for 40 degrees. The elevation angle between the satellite and the Gateway site varies continuously throughout a pass (of a satellite overhead) and the maximum elevation angle varies from pass to pass. The minimum elevation angle needed and the distribution of elevation angles vary depending on the latitude of the Gateway site and potential obstructions on the horizon of each Earth Terminal (ET) site. The Gateway must remain in continuous contact with the satellite constellation. In order to do this the incoming SV must be acquired prior to dropping the outgoing SV. An overlap in time is needed because the Gateway requires a minimum amount of time to acquire the new space vehicle. During the acquisition process the following sequential steps are needed: 1) the Earth Terminal must scan the antenna to find the SV signal; 2) the ET electronics must acquire the downlink signal; 3) the SV electronics must acquire the uplink signal; and 4) the computers must establish a logical link.

For GW sites at the latitude of the Atlanta site the outage can be approximated by using 0.25 times the outage at 8 degrees elevation angle and 0.75 times the outage at 40 degrees elevation angle. A minimum elevation angle of just below 7 degrees is needed to assure continuous contact with the constellation. The results of this weighted result are representative and are plotted in Figure 1.

The GW sites locations are carefully selected to meet several criteria including a maximum outage due to atmospheric conditions. A reasonable outage is about 0.13% of the time or about 11 hours per year. The dual diversity site meets this requirement for interference levels of -10 dB Io/No or below. As interference increases above this level the link performance is degraded. For interference levels above an Io/No of 0 dB the degradation becomes very large. At an Io/No level of 20 dB there are times when the interference alone causes link failures and the total outage is very large.

These results are based on the ability to overcome interference sources using the power control function of the IRIDIUM® Feeder link systems. This power control loop

cannot respond to a fast increase in the noise floor. A major assumption in this analysis is that the interference sources result in a distributed interference geometry where there are no quick increases in interference. For Io/No levels below 0 dB the system typically can handle quick changes in the interference level without suffering a link failure. Quick changes in the interference level above 0 dB Io/No can result in a link failure. In general quick changes should be considered those resulting in an increase in "Io+No" of more than 5-10 dB in one second.

References

[Bothias, 1986] Bothias, L., Battesti, J. and Rooryck, M, "Diversity improvement Factor - Prediction of the Improvement due to Diversity Reception on Microwave Links", Microcoll, Budapest, 1986.

[CCIR, 1990] CCIR Report 564-4, "Propagation Data and Prediction Methods Required for Earth- Space Telecommunications Systems", Section 2.2.4, "Diversity", Section 2.5.3.

[Crane, 1980] R. K. Crane, "Prediction of Attenuation by Rain," IEEE Transactions on Communications, Vol. COM-28, No. 9, September 1980.

[Hodge, 1982] D. B. Hodge, " An Improved Model for Diversity Gain on Earth-Space Propagation Paths," Radio Science, Vol. 17, No. 6, Pages 1393-1399, November-December 1982.

[Ippolito, 1989] L. J. Ippolito, "Propagation Effects Handbook for Satellite System Design," (10 GHz to 100 GHz), NASA Report No. NASA RP-1082(04), February 1989

Tables and Figures

Table 1 - Atmospheric Attenuations

Elevation (deg)	Oxygen (dB)	Water Vapor (dB)	Clouds (dB)	Total Atm. Attn. [dB]	Scintillation x(p) dB
5	1.20	4.59	4.59	10.38	5.59
6	1.00	3.83	3.83	8.66	4.45
7	0.86	3.28	3.28	7.43	3.67
8	0.75	2.87	2.87	6.50	3.10
9	0.67	2.56	2.56	5.79	2.68
10	0.60	2.30	2.30	5.21	2.34
40	0.16	0.62	0.62	1.41	0.41

Table 2 - Loss Allocation Available to Overcome Rain

Elevation [deg]	Range [km]	Avail. Loss [dB]	Total Atm. Attn. [dB]	Scintillation x(p) [dB]	Rain Margin for Uplink [dB]
5	2740.67	28.58	10.38	5.59	17.31
6	2650.35	28.87	8.66	4.45	19.71
7	2563.73	29.16	7.43	3.67	21.42
8	2480.75	29.44	6.50	3.10	22.73
9	2401.33	29.73	5.79	2.68	23.79
10	2325.37	30.00	5.21	2.34	24.68
40	1131.52	36.26	1.41	0.41	34.85

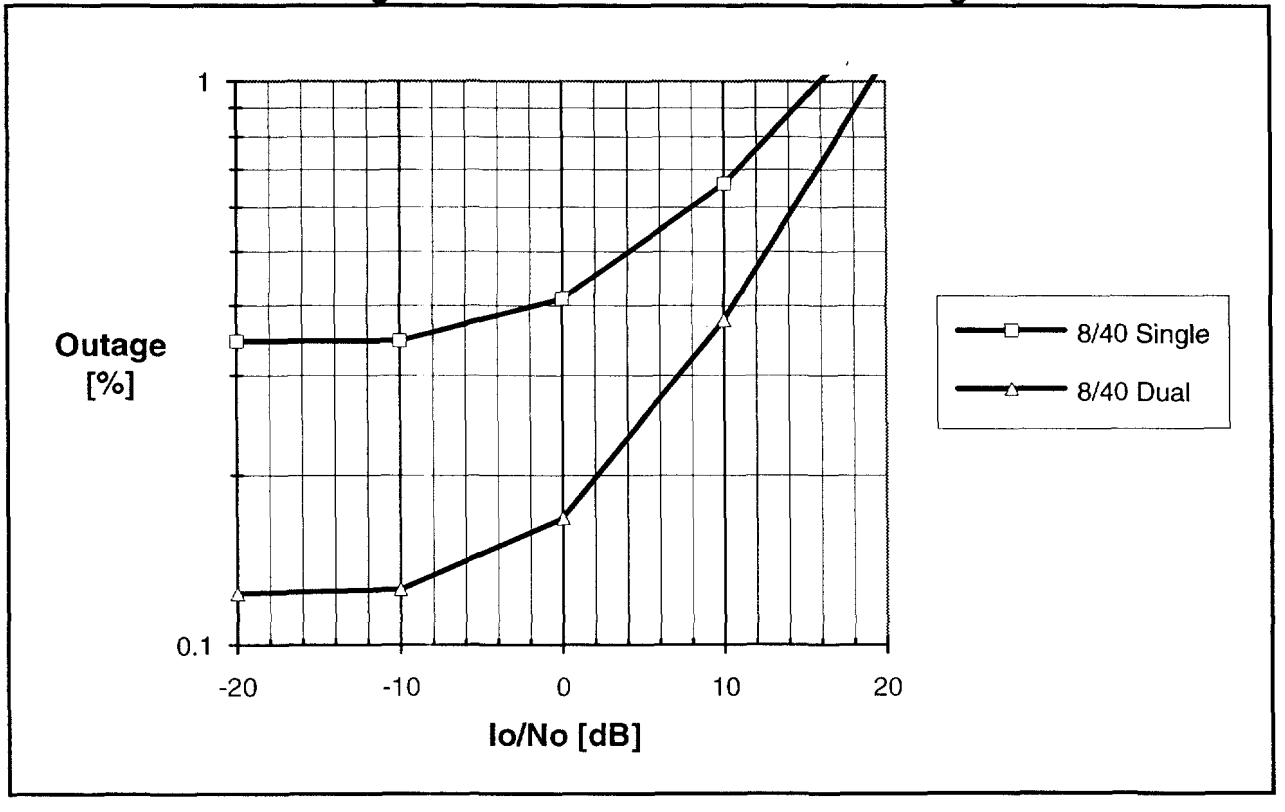
Table 3 - Loss Allocation Available with Interference

Io/No=	-20	-10	0	10	20
loss=	-0.043214	-0.41393	-3.0103	-10.4139	-20.0432
Elevation [deg]	***Remaining Rain Margin***				
5	17.27	16.90	14.30	6.90	-2.73
6	19.67	19.30	16.70	9.30	-0.33
7	21.38	21.00	18.41	11.00	1.38
8	22.69	22.32	19.72	12.32	2.69
9	23.75	23.38	20.78	13.38	3.75
10	24.64	24.27	21.67	14.27	4.64
40	34.81	34.44	31.84	24.44	14.81

Table 4 - Availability Verses Elevation Angle and Io/No

Elev. [deg]	No Diversity - Single Site					Diversity - Two Sites				
	Io/No -20	-10	0	10	20	-20	-10	0	10	20
5	2.56	2.61	3.07	4.95	100.00	1.30	1.37	1.80	3.90	100.00
6	1.86	1.92	2.22	3.63	100.00	0.81	0.85	1.19	2.56	100.00
7	1.48	1.52	1.75	2.82	4.95	0.58	0.61	0.83	1.87	4.86
8	1.18	1.18	1.41	2.27	4.51	0.45	0.46	0.62	1.40	4.11
9	0.96	0.99	1.15	1.89	3.93	0.35	0.36	0.46	1.09	3.34
10	0.77	0.79	0.97	1.60	3.43	0.28	0.29	0.37	0.85	2.75
40	0.07	0.07	0.08	0.12	0.27	0.02	0.02	0.02	0.04	0.10

Figure 1 - Effect of Interference on Outage

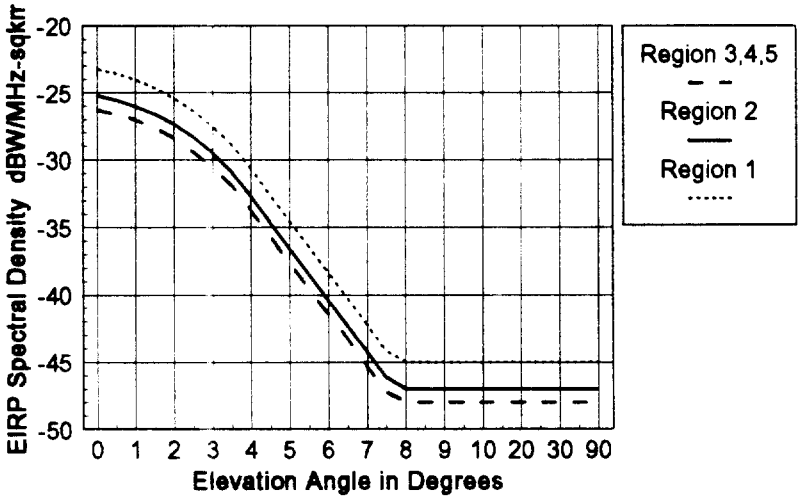


Analysis of CPE Tx's Fit to Proposed Rules, 21.1020 & 21.1021 per 3rd NPRM for 28 GHz using Proposed Rules for CPE Tx's in 150 MHz Band

Doug Gray, Hewlett-Packard Co.

HEWLETT PACKARD

Transmitter EIRP Spectral Limit as per
Proposed Rule 21.1020 & 21.1021, 3rd NPRM



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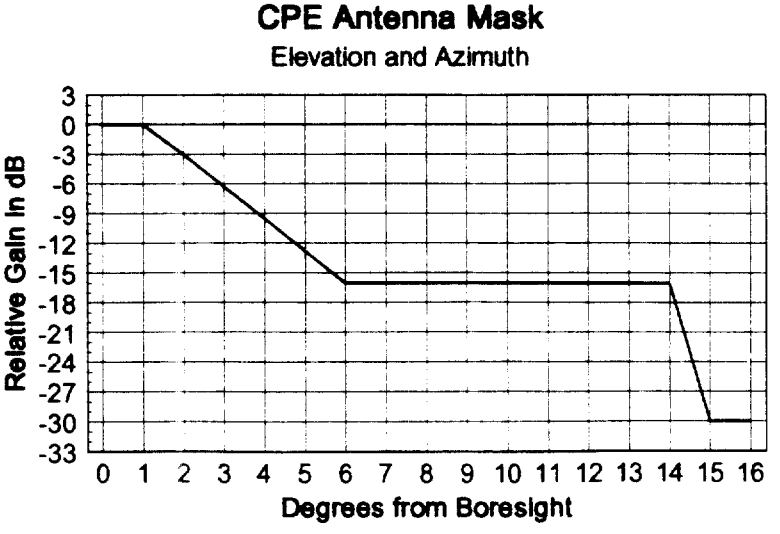
Proposed CPE Tx Antenna Mask



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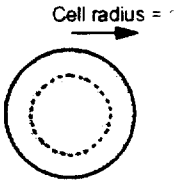
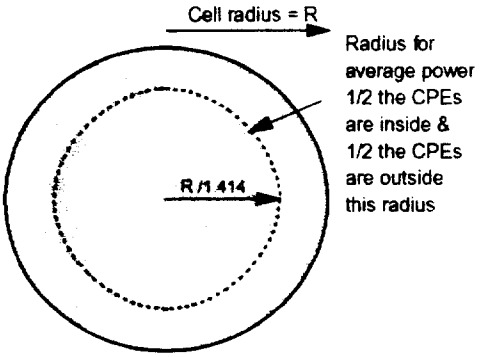
Total power spectral density is dependent only on Maximum EIRP (EIRP at the cell periphery) assuming uniform housing density

Small Cell Case



Cell Area = a = $(r/R)^2$ x A
Max EIRP = P
Avg EIRP = P/2 (assuming adaptive pwr control)
PSD/Cell = h x a x P/2
Number of cells to achieve same coverage as large cell = A/a
Total PSD = h x a x (P/2) x (A/a)
= h x (P/2) x A
where h = housing density in households/sq-km

Large Cell Case



Cell Area = a = A
Max EIRP = P
Avg EIRP = P/2 (assuming adaptive pwr control)
PSD/Cell = h x A x P/2
where h = housing density in households/sq-km

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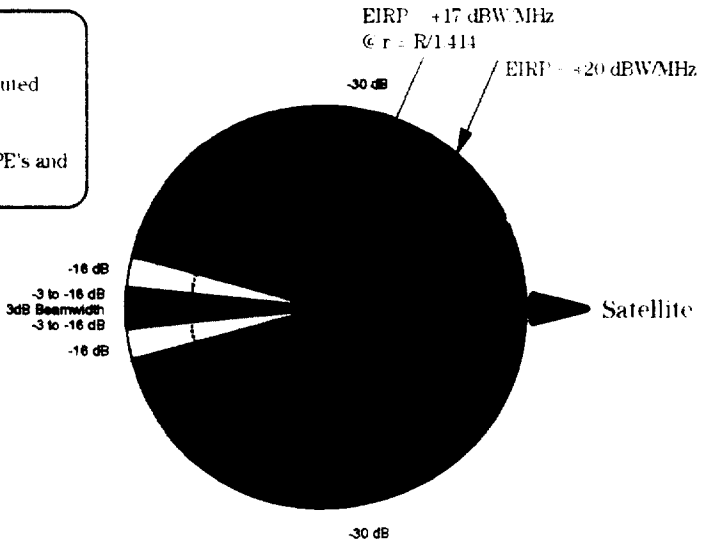
Composite CPE Tx Satellite Interference Potential at 0 Degrees Elevation

Assumptions
1. CPE Tx's pointed as intended
2. Active CPE Tx's are uniformly distributed

Statistical variation due to
1. Non-uniform distribution of active CPE's and
2. Variation in demand

- 3dB Beamwidth 1.1%, Avg EIRP/CPE = +17dBW/MHz
- -8 to -16dB relative gain 2.2%, Avg EIRP/CPE = +11dBW/MHz
- -16dB relative gain 5.0%, Avg EIRP/CPE = +1dBW/MHz
- -30dB relative gain 91.6%, Avg EIRP/CPE = -13dBW/MHz



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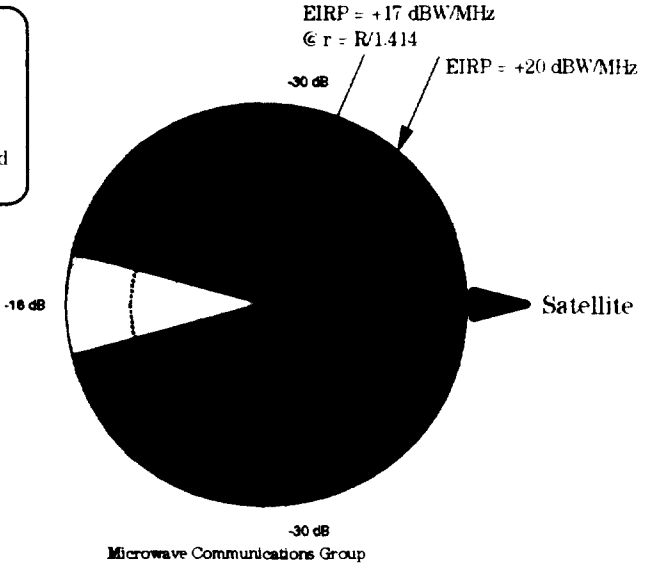
Composite CPE Tx Satellite Interference Potential at 6-15 Degrees Elevation

Assumptions:
1. CPE Tx's pointed as intended
2. Active CPE Tx's are uniformly distributed

Statistical variation due to
1. Non-uniform distribution of active CPE's and
2. Variation in demand.

- ☐ -16dB relative gain 8.3%
  Avg EIRP/CPE = -1dBW/MHz
- ■ -30dB relative gain 91.6%
  Avg EIRP/CPE = -13dBW/MHZ



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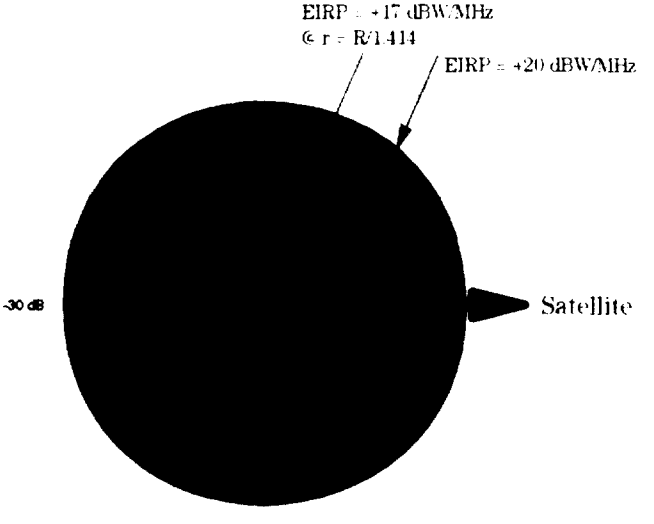
Composite CPE Tx Satellite Interference Potential at 15-90 Degrees Elevation

Assumptions
1. CPE Tx's pointed as intended

Statistical variation due to
1. Variation in demand only

- ■ -30dB relative gain 100%
  Avg EIRP/CPE = -13dBW/MHZ



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D.Gray/11/22/95

Calculation of Total EIRP Can be Done as Follows:

Equivalent Power per Antenna Sector =

10Log(S) + 10Log(Sector Beamwidth) - 10Log(360) + (Avg EIRP/CPE)

Where S = total number of active subscribers

Demographic Data — 15 Northeast/Mid-Atlantic States

			Column A	Column B	
1	Population	millions	75	75	
2	Surface Area	sq-km	825,700	825,700	
3	Households	millions	25	25	
4	Household Density	HH/sq-km	30	30	
5	Dwelling Units	millions	25	20	Note A.
6	Suitable for LMDS	%	80%	50%	Note B.
7	Take	%	25%	25%	
8	Total Subscribers		5,000,000	2,500,000	
9	Subscribers/MHz	1/150	33,333	16,667	
10	Peak Demand	%	25%		
11	Average Demand	%		10%	Note C.
12	# Active CPEs	@64kbits/s	8,333	1,667	
13	Modulation Efficiency		1	1.5	Note D.
14	Net Active CPEs		533	71	
15	Circuit Efficiency	%	60%	60%	
16	Active CPEs		**889**	**119**	
17	Active CPEs/sq-km		0.001077	0.000144	

Column "A" summarizes the numbers used in previous analysis and was generated to represent a "worse" case scenario.

Column "B" represents a more realistic scenario. It would be appropriate to apply a distribution to the final result to account for the effects of non-uniform CPE Tx densities and the effects of varying demand.

Notes:

A. Number of households include those in multiple dwelling units (MDUs), these housholds would not have 1 CPE per houshold. Individual dwelling units are a better indication of the number of possible subscribers.

B. LMDS will not be economically viable in all geographic areas due to the need for line-of-sight or near" line-of-sight conditions. The density of trees, buidings of different heights, mountains, etc. will affect the suitability of a given area. Housing density will also affect the economic viablity of LMDS as a delivery system versus other alternatives. The percent suitable for LMDS will vary from region to region.

C. Peak demand will occur for only short periods of time. Average demand is a better measure for calculating average EIRP.

D. This reflects the use of QPSK modulation which has a typical modulation efficiency of at least 1.5 bits per Hz.

Demographic Data By Region

			Northeast	South	Midwest	West		U.S. Total
1	Population	millions	58.93	78.83	59.83	53.66		251.25
2	Surface Area	sq-km	515,434	2,171,282	1,950,893	4,543,136		9,180,745
3	Households	millions	21.79	28.98	22.12	19.84		92.73
4	Household Density	HH/sq-km	42	13	11	4		10
5	Dwelling Units	millions	17.43	23.18	17.70	15.87		74.18
6	Suitable for LMDS	%	**50%**	**30%**	**70%**	**70%**	←	**53%**
7	Take	%	25%	25%	25%	25%		25%
8	Total Subscribers		2,179,000	1,738,800	3,096,800	2,777,600		9,792,200
9	Subscribers/MHz	1/150	14,527	11,592	20,645	18,517		65,281
10	Average Demand	%	10%	10%	10%	10%		10%
11	# Active CPEs	@64kbits/s	1,453	1,159	2,065	1,852		6,528
12	Modulation Efficiency		1.5	1.5	1.5	1.5		1.5
13	Net Active CPEs		62	49	88	79		279
14	Circuit Efficiency	%	60%	60%	60%	60%		60%
15	Active CPEs		**103**	**82**	**147**	**132**		**464**
16	Active CPEs/sq-km		0.0002	0.000038	0.000075	0.000029		0.000051

Source: 1992 Rand-McNally Commercial Atlas