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PROPAGATION CONSIDERATIONS FOR THE ODYSSEY SYSTEM DESIGN

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ABSTRACT

This paper presents an overview of the Odyssey system with special emphasis given to the link availability for both mobile link and feeder link. The Odyssey system design provides high link availability, typically 98% in the primary service areas, and better than 95% availability in other service areas. Strategies for overcoming Ka-band feeder link rain fades are presented. Mobile link propagation study results and summary link budgets are also presented.

SYSTEM OVERVIEW

The Odyssey system, illustrated in Figure 1, provides high quality world wide personal and mobile communication services on a regional basis. The system consists of three segments: space, ground, and handset. The gateways interconnect with both public switched telephone networks (PSTN), and other gateways. The Odyssey handset is a dual mode; it can access either the Odyssey system or a terrestrial cellular network. These services include voice and data provided by a constellation of medium-altitude Earth orbiting (MEO) satellites.

Communication can be established either between mobile and fixed users or between pairs of mobile users. A fixed user is one who is connected to the terrestrial network. Mobile customers use inexpensive hand-held transceivers. These transceivers are self-powered and generally require only 0.5 watts of average transmitted power to provide quality communications. The Odyssey handset provides at least 60 minutes talk time and 24 hour standby.

Each satellite is placed in circular orbit at an altitude of 10354 Km. There are three orbit planes inclined at 52° to the equatorial plane. Deployment of the satellites permits phased introduction service. After only three launches, in which two satellites are launched in each plane, service can be provided to three major service regions. The Odyssey six satellite constellation coverage is shown in Figure 2. After three more launches for a total of 12 satellites, service can be expanded to all populated regions of the

Earth with dual coverage to most regions. Figure 3 shows 12-satellite constellation coverage.

Each satellite covers more than 14.5% of the earth surface with a multibeam antenna that divides its coverage area into thirty-seven contiguous beams. Figure 4 shows the mobile link antenna pattern. The mobile link antennas are fixed mounted to the satellite body. The attitude control system orients the satellite to ensure constant coverage of land mass and coastal areas. Pointing can be reprogrammed by ground control to ensure optimized coverage of the desired service areas.

The frequency bands for satellite-based personal mobile communications were designated at the 1992 WARC. In L-band, 1610 to 1626.5 MHz is allocated for the mobile return link from the user to satellite. The mobile forward link from satellite to user is allocated 2483.5 to 2500 MHz in S-band. However, 11.35 MHz bandwidth of L-band and 16.5 MHz bandwidth at S-band are our current baseline design. Circular polarization is used for mobile link. Part of Ka-band, 19.7 to 20.2 GHz and 29.5 to 30.0 GHz are used for the feeder return link (from the satellite to gateway) and feeder forward link (from gateway to satellite), respectively. Linear polarization is used for the feeder link.

Each beam carries an 11.35 MHz in L-band, which is fully reused in each beam. The forward link includes a Ka-band link from the gateway to the satellite and an S-band link down to the users. The return link from the user to the gateway includes an L-band link to the Odyssey satellite and a Ka-band link down to the gateway. The satellite payload functions as a simple bent pipe, frequency translating transponder. For the mobile link, each satellite has a 37-beam antenna with 38° field-of-view (40° field- of-coverage). The S-band, downlink from the satellite to users, provides a dynamic capacity distribution through the use of five matrix amplifiers. This allows each beam to support up to 20% of satellite capacity. In the feeder link, each satellite has three independent steerable antennas for both transmitting and receiving signals to/from multiple gateways. Each Ka-band antenna can support the full satellite capacity on each polarization. Each satellite weighs 1971 Kg at launch, and the solar array provides 3126 watts of power. Capacity is 2800 voice circuits per satellite. The payload block diagram is shown in Figure 5.

In order to provide the global coverage, the Odyssey system requires only seven earth stations. Each earth station is equipped with four 7 m tracking antennas. Three of the antennas are used simultaneously to communicate with three of the in-view satellites. The fourth antenna can be used to acquire an additional satellite, or used for satellite handover, or it can be used as a diversity function in the event of heavy rainfall. Separation between the antennas must be at least 10 Km to provide the diversity function. Depending on the location of the earth station, site diversity may or may not be needed.

Odyssey provides high quality voice service. Our design is based on the 4.8 kbps IMBE (Improved Multi-Band Excitation) speech codec. DVSI is the owner and developer of this codec; INMARSAT, OPTUS/ AUSSAT, and MSAT selected IMBE as their voice coding standard. The BER of 10^{-3} will provide high voice quality with 3.5 MOS (Mean Opinion Score)

Digital data from 2.4 kbps to 19.2 kbps is also accommodated in the Odyssey system. The transmitted data rate depends on the modem. The handset supports rates up to 2.4 kbps. A more powerful modem is required for the higher data rates. Digital data service quality is assured by maintaining system BER of 10^{-5} or better.

The Odyssey system uses spread spectrum CDMA techniques for forward and return links that are compatible with the service as initially authorized for these L and S-bands.

COMMUNICATION SYSTEM SIGNAL PARAMETERS

To provide high voice quality, low hand held transmitted EIRP, and minimum time delay, the following signal parameters are used in the Odyssey system:

* Digitally encoded voice data : 4800 bps
* Channel error correction encoding
  ** Convolutional code rate = 1/3, k=7
  ** Soft decision decoding
* Concatenated code is used in digital data transmission
* Modulation: filtered OQPSK
* Access method: CDMA
* Spread bandwidth: 2.5 MHz
* Voice duty cycle: 50%
* Required $\frac{Eb}{No}$: 4.0 dB, including 1.5 dB implementation loss
* Digital data rates: 2.4 kbps, 4.8 kbps, 9.6 kbps, and 19.2 kbps. Handset supports up 2.4 kbps; 4.8 kbps, 9.6 kbps and 19.2 kbps are supported by higher power modem.

SUMMARY COMMUNICATION SIGNAL REQUIREMENTS

Mobile Link

- Satellite L& S-bands
  * Received frequency: 1610 to 1621.35 MHz
  * Transmitted frequency: 2483.5 to 2500 MHz
  * Polarization: circular
  * Number of beams: 37 beams
  * Field-of-view: 38° (40° field-of-coverage)
  * Average G/T over field-of-view ≥ 1.0 dB/K

* S-band transmitted EIRP ≥ 53.4 dBW
* Satellite capacity: 2800 users
* Each beam can support up to 20% satellite capacity

- Handset transceiver
  * Received frequency: 2483.5 to 2500 MHz
  * Transmitted frequency: 1610 to 1621.35 MHz
  * Polarization: circular
  * Handset received G/T: -22.1 dB/K
  * Handset transmitted EIRP: 0.2 dBW

Feeder Link

- Satellite Ka-band
  * Received frequency: 29.5 to 29.76 GHz
  * Transmitted frequency: 19.7 to 19.96 GHz
  * Polarization: linear
  * Three independently steerable Ka-band antenna spot beams
  * Each beam can support up to 2800 users on each polarization
  * Satellite receiving G/T ≥ 6.1 dB/K
  * Satellite transmitting EIRP ≥ 48.5 dBW
- Earth station
  * Earth station receiving G/T: 32.5 dB/K
  * Earth station transmitting EIRP: 85.7 dBW
  * Polarization: linear
  * Received frequency: 19.7 to 19.96 GHz
  * Transmitted frequency: 29.5 to 29.76 GHz

LINK BUDGETS

Odyssey system uses the spread spectrum CDMA techniques, the link budgets must take into account both the receiver noise and interference noise from other users. The multiple access interference in the link budget is the total interference power including other users in the same beam and the users from other beams. We assume that power control is used for both forward and return links with 2 dB accuracy.

Return Link

The return link is a link from a mobile user to the earth station through the satellite. The return link includes an L-band link from the mobile users to the satellite and Ka-band downlink to the gateways through three independent Ka-band steerable antennas.

The data from a mobile user is transmitted according to a conventional CDMA scheme. The total noise is the sum of thermal noise and the mutual interference noise. The return link budgets are shown in Table 1

Forward Link

The forward link includes a Ka-band link from the gateway to the satellite and an S-band link down to the users. The forward link receives its signal at 30 GHz from either of the three Ka-band antennas, which provides coverage of regions of interest. The signal is bandpass filtered, fed to a low noise amplifier (LNA), and down converted to an intermediate frequency (IF).

The LNA outputs are 18 and 19 (one from vertical, and the other one from horizontal pol.) way power divided by the total of 37 separate signals for the downlink beams. The 37 separate signals are then filtered, upconverted to S-band prior to amplification by solid state amplifier for transmission to the users on the 37 beam S-band antenna.

The forward link uses orthogonal CDMA. The summary link budgets are shown in Table 2.

LINK MARGIN AND LINK AVAILABILITY

Mobile Link Margin

Return Link (User-to-satellite): The minimum return link margin for the Odyssey system is 6 dB for elevation angles above 20°. If the users are uniformly distributed over field-of-view, then the user's elevation angles are greater than 30° more than 95% of the time. Indeed, elevation angles are greater than 55° more than 50% of the time. The percent of time versus elevation angles is shown in Figure 6.

The return link margin depends on the user elevation angle, which in turn is a function of the user position within the field-of-view. The user position is measured by the angular displacement from the satellite antenna boresight. The return link margin and user elevation angle are shown as a function of user position in the field-of-view in Figure 7.

In order to provide the service down to 20° elevation angle, 40° field-of-view will need to be pointed up to 2 degrees off nadir. More than 50% of the time, the link margins are greater than or equal to 8.0 dB, which can be seen by combining the data in Figures 6 and 7.

Forward link (Satellite-to-Users): To achieve both high capacity and good voice quality, the Odyssey system employs power control for both forward and return link. Also, to account for the fact that the mobile users may be in a disadvantaged location due to antenna contours, vegetation loss, or fading, the satellite Tx S-band RF power allocated to each user can be varied depending on its need. The required forward link propagation margin is calculated as follows:

- The users are uniformly distributed in a beam and over field-of-view.
- The elevation angle distribution at several latitudes is shown in Figure 8.
- Propagation statistics representative of suburban areas were used to calculate the required propagation margin [1].
- The attenuation at S-band can be estimated as:

$$A(2.5\ GHz) \approx A(1.6\ GHz)\sqrt{\frac{2.5\ GHz}{1.6\ GHz}} \qquad \text{dB}$$

Where A(1.6 GHz) is the attenuation at 1.6 GHz

Based on all the listed conditions above, the required average down link margin is approximately 4.0, which is allocated in the forward link budgets.

Mobile Link Availability

The Odyssey system design will provide reliable, excellent quality phone service, typical 98% availability in all primary service areas, and better than 95% availability in other service areas. The Odyssey link availability is calculated by using statistics obtained from experimental data [2]& [3]. The link availability is calculated as follows:

- For each location, link availability is defined as the percentage of time that the return link margin exceeds the propagation loss.
  * Available return link margin is a function of satellite elevation angle and user location within satellite beam.
  * Probability distribution of propagation loss is a function of satellite elevation angle.
  * Link availability is determined by integrating over joint distribution of satellite elevation angle and user location.
- Satellite elevation angle histograms were developed for a number of user locations, based on the highest satellite providing directed coverage of each location.
- Propagation statistics representative of suburban areas were used to calculate the required propagation margin.

Twelve cities at different latitudes were selected from the highest demand regions to obtain a measure of Odyssey system availability. Figure 9 shows that the calculated availability for 12 satellites is typically 98% . Six Odyssey satellites provide single satellite availability between 91% and 97%.

Feeder Link Margin And Link Availability

The Odyssey system needs only seven earth stations to provide worldwide coverage. Seven potential earth stations are Los Angeles (CA - USA), Buenos Aires (Argentina), Fucino (Italy), Cape Town (South Africa), Ahmadabad (India), Yamaguchi (Japan), and Sydney (Australia).

The forward link, earth station-to-satellite operates at 30 GHz band. The return link, satellite-to-earth station operates at 20 GHz band. In our baseline design, each satellite has three transmitted and three received antennas. Dual polarization is used in the feeder link. Each antenna, and each polarization can support the full system capacity. In terms of power, each antenna (dual pol.) can support twin system capacity. 10 dB and 18 dB rain margins are allocated for the return, and the forward link, respectively. Since the Ka-band is used for the feeder link, rain attenuation is very severe in some locations depending on their rain zones.

The minimum required link availability is 99.5% (43.8 hours outage per year), with 99.9% (8.76 hours outage per year) as a goal. In order to achieve this requirement, some earth stations may need site diversity.

In our link availability calculations, we assume the following conditions:

- Global rain attenuation model is used.
  (Global Model Rain Attenuation Prediction Technique as Described in Propagation Effects Handbook for Satellite Systems Design, NASA Reference Publication 1082 (04), February 1989 by Louis J. Ippolito)
- Horizontal polarization is used.
- The Hodge model is used here for diversity gain and site separation
- Rain zone of seven potential earth stations are:
  @ Los Angeles, CA: rain zone F
  @ Buenos Aires, Argentina: rain zone D
  @ Fucino, Italy: rain zone D2
  @ Cape Town, South Africa: rain zone C
  @ Ahmadabad, India: rain zone G
  @ Yamaguchi, Japan: rain zone D
  @ Sydney, Australia: based on the map, it is very difficult to see that Sydney either belongs to rain zone D or C. In this paper, we will present the link availability of two rain zones.

The link availability calculations are based on the following:

- Percent of time versus elevation angle.
- The feeder link availability is the minimum link availability of two links namely forward and return links.
- 10 dB and 18 dB are allocated for rain attenuation in the return and forward link, respectively.

Figure 10 shows the percent of time that a given elevation angle is exceeded at the Los Angeles earth station. For example, an elevation angle of $\geq 20°$ occurs 82% of the time.

However, to compute the availability of particular location, the probability density function (pdf) of elevation angle is required. The pdf of Los Angeles earth station is shown in Figure 11. Figure 12 shows the diversity gain versus site separation. The curves of link availability versus elevation angle (with and without site diversity) are shown in Figure 13 that were computed for Los Angeles earth station based on the Global Model Rain Attenuation.

The feeder link availability for Los Angeles earth stations is founded by combining data from Figures 11 & 13 and the result is shown in Table 3. Table 3 contains the feeder link availability of the other six earth stations.

With no site diversity, the link availability for most earth stations is greater than or equal to 99.75%, which meets our requirements, except for Ahmadabad, India. With site diversity, an earth station at Ahmadabad achieves 99.6% link availability, and greater than 99.9% for the other six earth stations. There is only one earth station at Ahmadabad, India, that needs site diversity. In this analysis, horizontal polarization was assumed. If vertical polarization is used, then the rain attenuation is less, and achieved link availability is higher. Also, we assume satellite Ka-band antenna supports full satellite capacity on each polarization.

Note that, the calculated rain attenuation is based on the current available global data. The actual rain attenuation will be calculated with local rain rate data or in some cases testing may be needed.

ADVANTAGES

Odyssey, with its medium Earth orbit altitude and direct coverage of mobile link antenna patterns, has several advantages over other proposed systems as listed below:

- Time delay of Odyssey is more acceptable than the GEO satellite
- The Odyssey satellite moves only 1° per minute so that they seem almost fixed to the user.
- With medium Earth orbit altitude, the user's elevation angle is higher than LEO satellite. Indeed, the elevation angles are greater than 30° and 55° more than 95% and 50% of the time, respectively.
- With directed pointing, most users can be served by a single beam of one satellite for the duration of telephone conversation.

CONCLUSION

The Odyssey system design will provide high link availability, typical 98% link availability for mobile link, and more than 99.5% link availability for feeder link. This system will deliver an excellent voice quality, and digital data transmission.

ACKNOWLEDGMENT

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[3] Lutz, et al, " The Land Mobile Satellite Communication Channel - recording, Statistics, and Channel Model," IEEE Transactions on Vehicular Technology, May 1991.

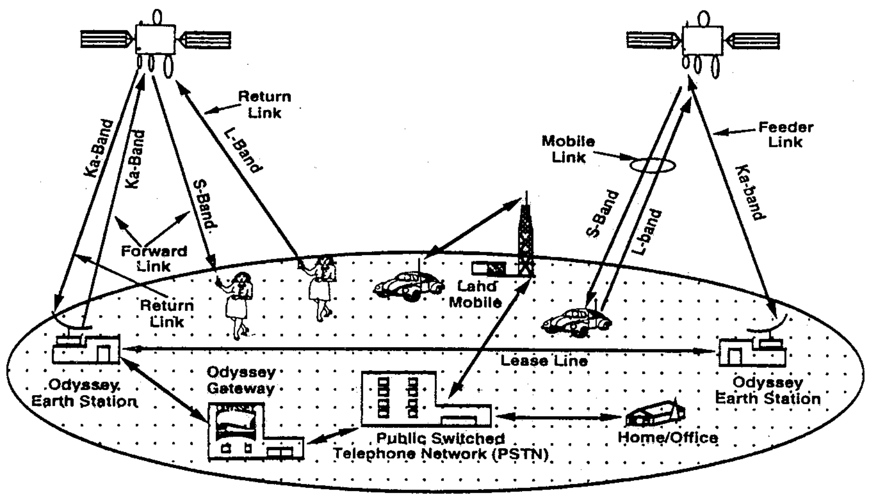


Figure 1: Odyssey Communication Concept

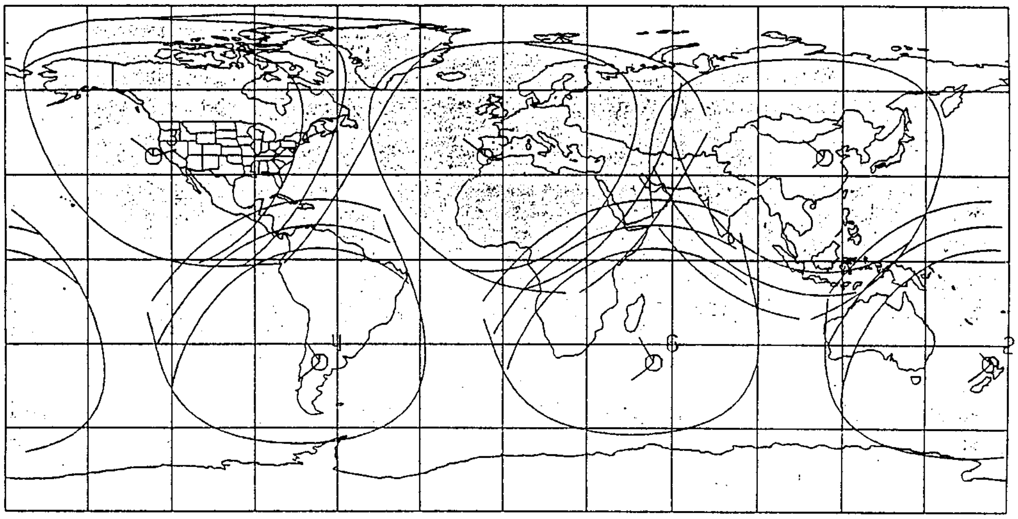


Figure 2: Example Of 6-Satellite Coverage

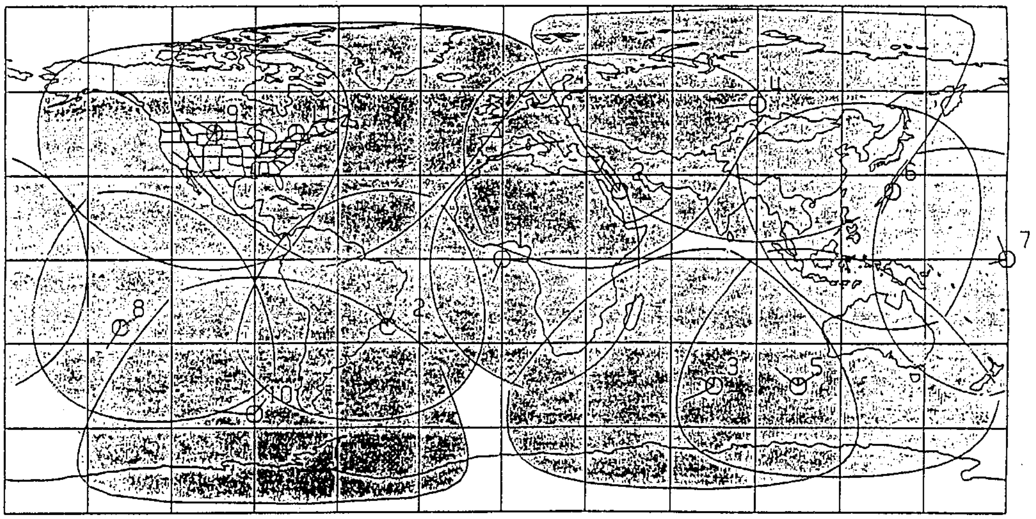


Figure 3: Example Of 12-Satellite Coverage

Table 1: Summary Return Link Budgets

ASSUMPTIONS			
USER-TO-SATELLITE LINK		SATELLITE-TO-EARTH STATION	
FREQUENCY	1.62 GHZ	FREQUENCY	19.83 GHz
HANDSET TRANSMIT EIRP	0.2 dBW	TOTAL TRANSMIT EIRP	48.5 dBW
VOICE DUTY CYCLE	50.0 %	SYSTEM CAPACITY	2800.0 Users
AVERAGE ELEVATION ANGLE	55.0 degrees	MINIMUM ELEVATION ANGLE	10.0 Degrees
NUMBER OF USERS/2.5 MHz CHANNEL	150.0 Users	EARTH STATION G/T	32.6 dB/K
ACCYRACY OF POWER CONTROL	2.0 dB	SATELLITE C/IM3	15.0 dB
SPACECRAFT G/T	1.0 dB/K		

PARAMETERS	CLEAR	RAIN	UNIT
HANDSET EIRP	0.2	0.2	dBW
PATH LOSS	177.5	177.5	dB
ATMOSPHERIC LOSS	0.2	0.2	dB
RAIN LOSS	0.0	0.0	dB
POLARIZATION LOSS	0.5	0.5	dB
REQUIRED UPLINK MARGIN	6.0	6.0	dB
RX SIGNAL	-184.1	-184.1	dBW
SPACECRAFT G/T	1.0	1.0	dB/K
BOLTZMAN'S CONSTANT, k	-228.6	-228.6	dB/K-Hz
UPLINK RECEIVED C/No	45.5	45.5	dB-Hz
UPLINK DEGRADATION DUE TO MAI (Io)	4.1	4.1	dB
UPLINK RECEIVED C/(No+Io)	41.4	41.4	dB Hz

PARAMETERS	CLEAR	RAIN	UNIT
TOTAL TRANSMIT EIRP	48.5	48.5	dBW
RETRANSMITTED NOISE LOSS	7.9	8.0	dB
NUMBER OF USER	31.5	31.5	dB
EFFECTIVE EIRP PER USER	9.1	9.1	dBW
PATH LOSS	201.6	201.6	dB
ATMOSPHERIC LOSS	0.6	0.6	dB
SCINTILLATION LOSS	0.4	0.4	dB
RAIN LOSS*	0.0	10.0	dB
POLARIZATION LOSS	0.1	0.5	dB
RX SIGNAL	-193.5	-203.9	dBW
EARTH STATION G/T	32.6	32.6	dB/K
BOLTZMAN'S CONSTANT, k	-228.6	-228.6	dB/K-Hz
DOWNLINK RECEIVED C/No	67.7	57.3	dB Hz

COMBINED UPLINK & DOWNLINK			
PARAMETERS	CLEAR	RAIN	UNIT
UPLINK RECEIVED C/(No+Io)	41.4	41.4	dBHz
DOWNLINK RECEIVED C/No	67.7	57.3	dBHz
SATELLITE C/(IM3 + SPURIOUS)	51.8	51.8	dBHz
COMBINED C/(Io + No)	41.0	40.9	dBHz
DATA RATE (4.8 Kbps)	36.8	36.8	dBHz
RECEIVED Eb/No	4.2	4.1	dB
REQUIRED Eb/No**	4.0	4.0	dB
EXCESS MARGIN (OVER 6 dB)	0.2	0.1	dB

NOTE: * INCLUDING NOISE TEMPERATURE INCREASE DUE TO RAIN

** INCLUDING 1.5 dB IMPLEMENTATION LOSS

Table 2: Summary Forward Link Budgets

ASSUMPTIONS			
EARTH STATION-TO-SATELLITE		SATELLITE-TO-USER	
FREQUENCY	29.63 GHZ	FREQUENCY	2.49 GHz
TRANSMIT EIRP (CLEAR)	67.3 dBW	TOTAL TRANSMIT EIRP	53.4 dBW
TRANSMIT EIRP (RAIN)	85.7 dBW	SYSTEM CAPACITY	2800.0 Users
SYSTEM CAPACITY	2800.0 USERS	VOICE DUTY CYCLE	50.0 %
VOICE DUTY CYCLE	50.0 %	AVERAGE USER ELEVATION ANGLE	55.0 Dg
UPLINK RAIN LOSS (ALLOWABLE)	18.0 dB	HAND SET G/T	-22.1 dB/K
SPACECRAFT G/T	6.1 dB/K	SATELLITE C/IM3	14.0 dB

PARAMETERS	CLEAR	RAIN	UNIT
TRANSMIT EIRP	67.3	85.7	dBW
NUMBER OF USERS	31.5	31.5	dB
EFFECTIVE TRANSMIT EIRP PER USER	35.9	54.3	dBW
PATH LOSS	205.1	205.1	dB
ATMOSPHERIC LOSS	0.6	0.6	dB
SCINTILLATION LOSS	0.4	0.4	dB
RAIN LOSS	0.0	18.0	dB
POLARIZATION LOSS	0.1	0.5	dB
RX SIGNAL	-170.3	-170.3	dBW
SPACECRAFT G/T	6.1	6.1	dB/K
BOLTZMAN'S CONSTANT, k	-228.6	-228.6	dB/K-Hz
UPLINK RECEIVED C/No	64.5	64.5	dB Hz

PARAMETERS	CLEAR	RAIN	UNIT
TOTAL TRANSMIT EIRP	53.4	53.4	dBW
RETRANSMITTED NOISE LOSS	0.4	0.4	dB
SIGNALLING REQUIRED POWER (10%)	0.5	0.5	dB
NUMBER OF USER	31.5	31.5	dB
EFFECTIVE EIRP PER USER	21.1	21.1	dBW
PATH LOSS	181.3	181.3	dB
ATMOSPHERIC LOSS	0.2	0.2	dB
RAIN LOSS	N/A	0.1	dB
POLARIZATION LOSS	0.5	0.5	dB
REQUIRED AVERAGE DL MARGIN	4.0	4.0	dB
RX SIGNAL	-165.0	-165.0	dBW
HANDSET G/T	-22.1	-22.1	dB/K
BOLTZMAN'S CONSTANT, k	-228.6	-228.6	dB/K-Hz
DOWNLINK DEGRADATION DUE TO MAI	0.1	0.1	dB
DOWNLINK RECEIVED C/(No+Io)	41.5	41.4	dB Hz

COMBINED UPLINK & DOWNLINK			
PARAMETERS	CLEAR	RAIN	UNIT
UPLINK RECEIVED C/No	64.5	64.5	dBHz
DOWNLINK RECEIVED C/(No+Io)	41.5	41.4	dBHz
SATELLITE C/(IM + SPURIOUS)	50.8	50.8	dB
COMBINED C/(Io + No)	41.0	40.9	dBHz
DATA RATE (4.8 Kbps)	36.8	36.8	dBHz
RECEIVED Eb/No	4.2	4.1	dB
REQUIRED Eb/No*	4.0	4.0	dB
EXCESS MARGIN (OVER 4 dB)	0.2	0.1	dB

NOTE: * INCLUDING 1.5 dB IMPLEMENTATION LOSS

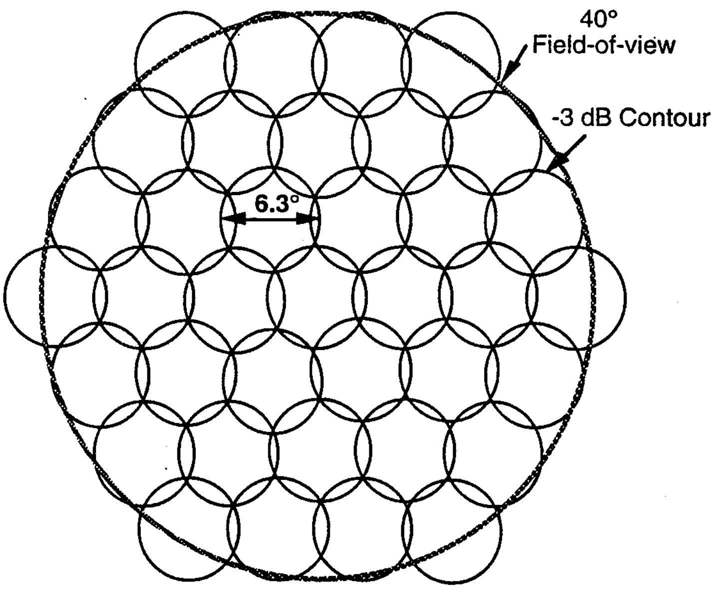


Figure 4: L And S-Band Antenna Beam Pattern

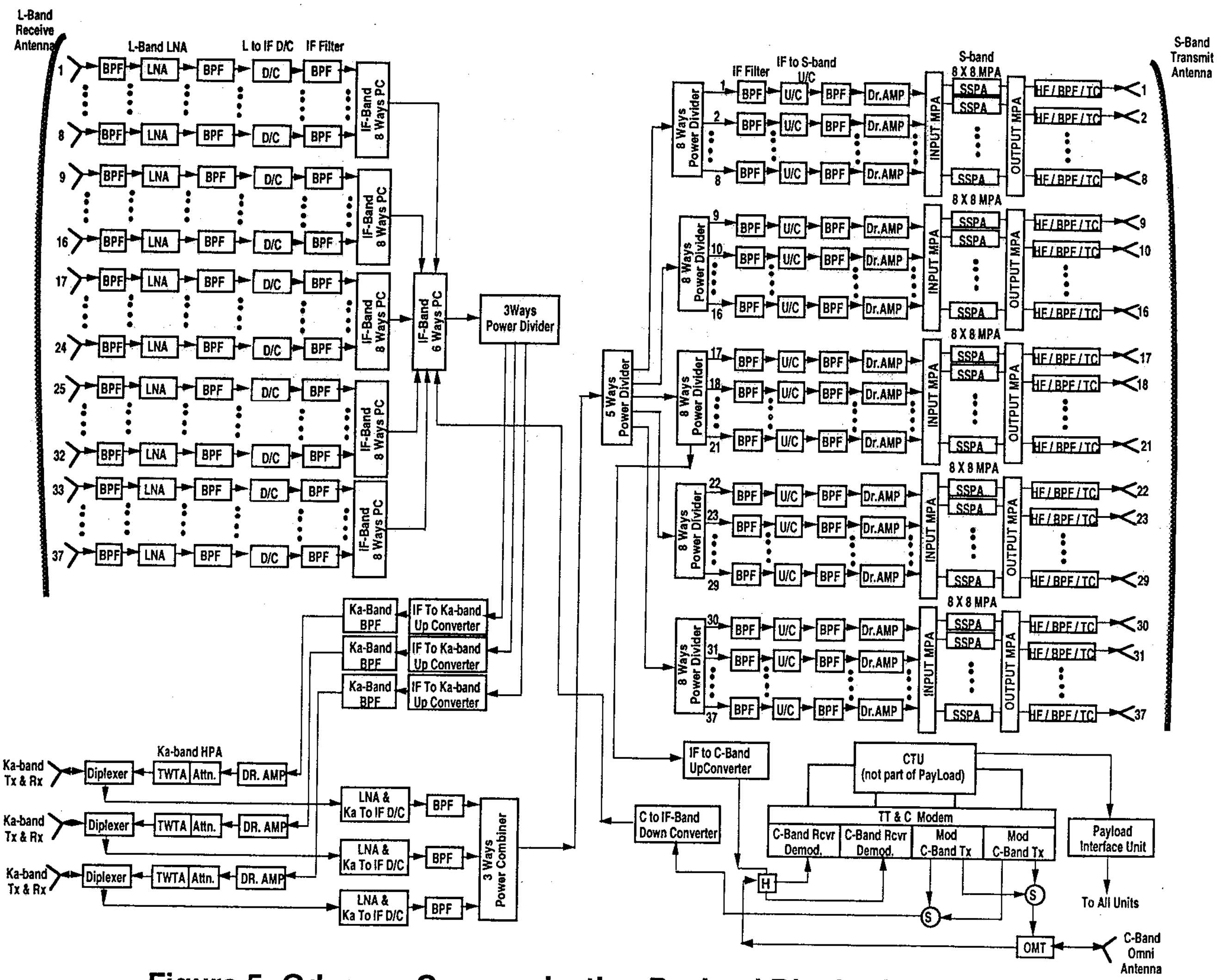


Figure 5: Odyssey Communication Payload Block Diagram

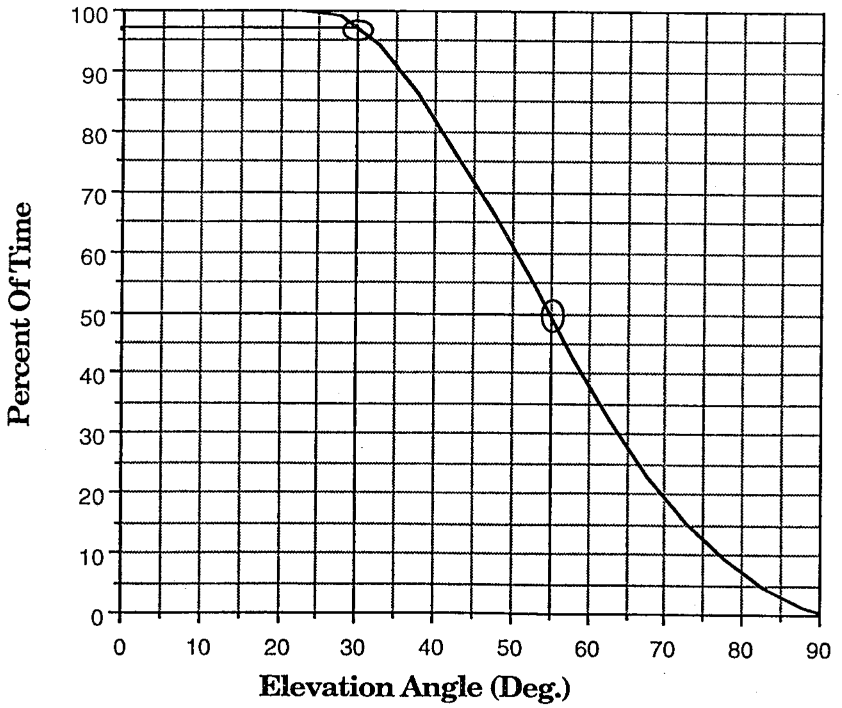
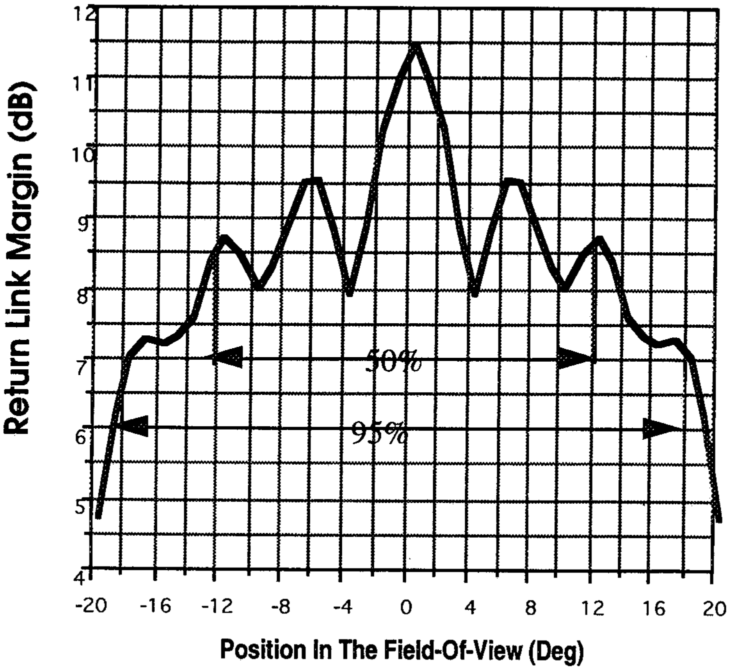


Figure 6: The Percent Of Time Elevation Angle Is Exceeded



Position In The Field-Of-View	Elevation Angle
± 0°	87°
± 2°	82°
± 4°	77°
± 6°	71°
± 8°	66°
± 10°	60°
±12°	54°
± 14°	47°
± 16°	40°
± 18°	31°
± 20°	20°

(2° Off Nadir)

Figure 7: Odyssey Uplink Margin

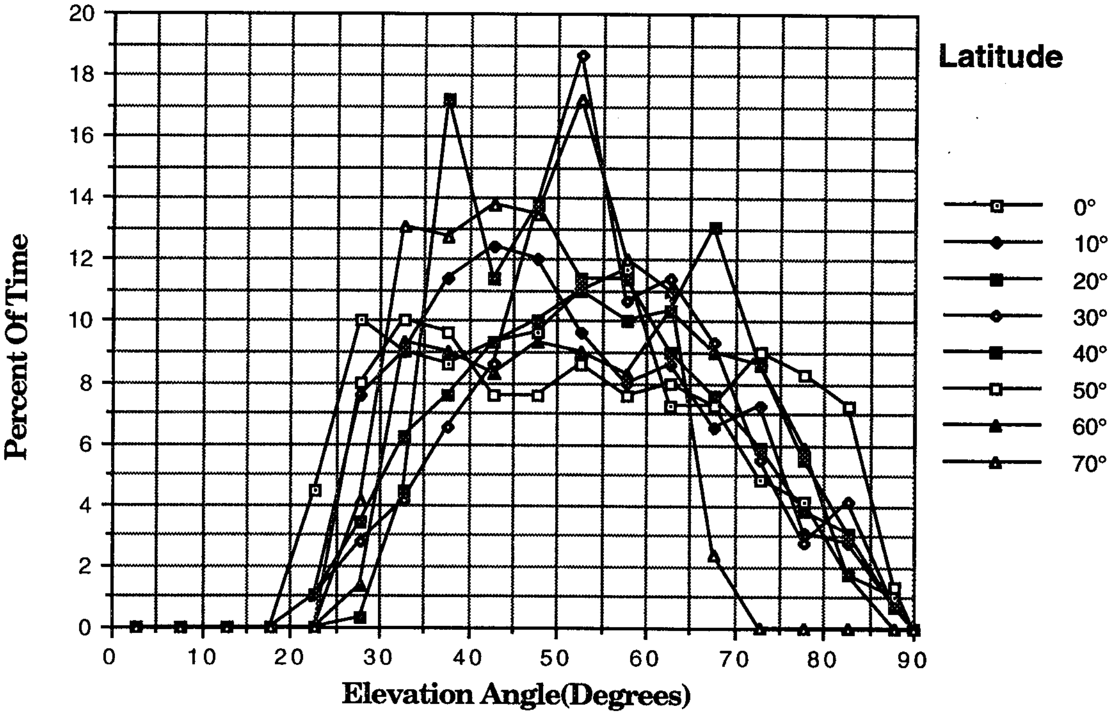


Figure 8: Users Elevation Angle Distribution

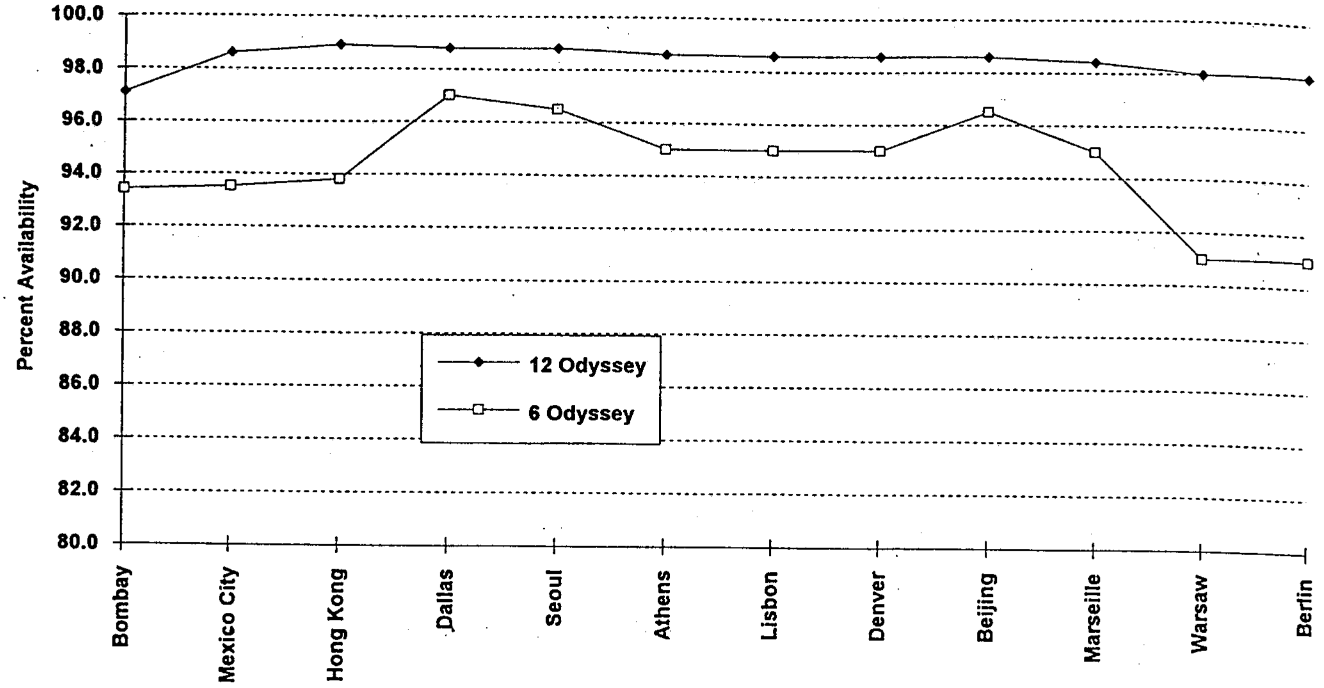


Figure 9: Calculated Availability For Odyssey Constellations

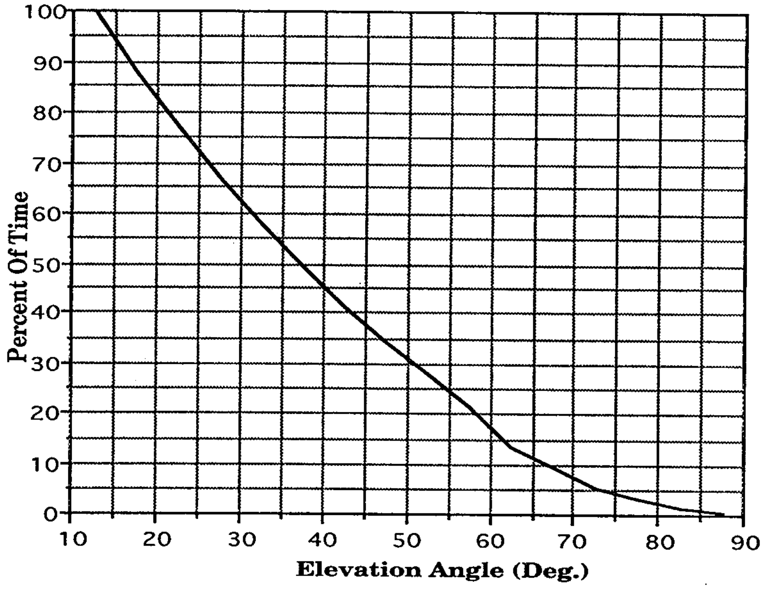


Figure 10: Percent Of Time Elevation Angle Is Exceeded (Los Angeles, CA - Earth Station)

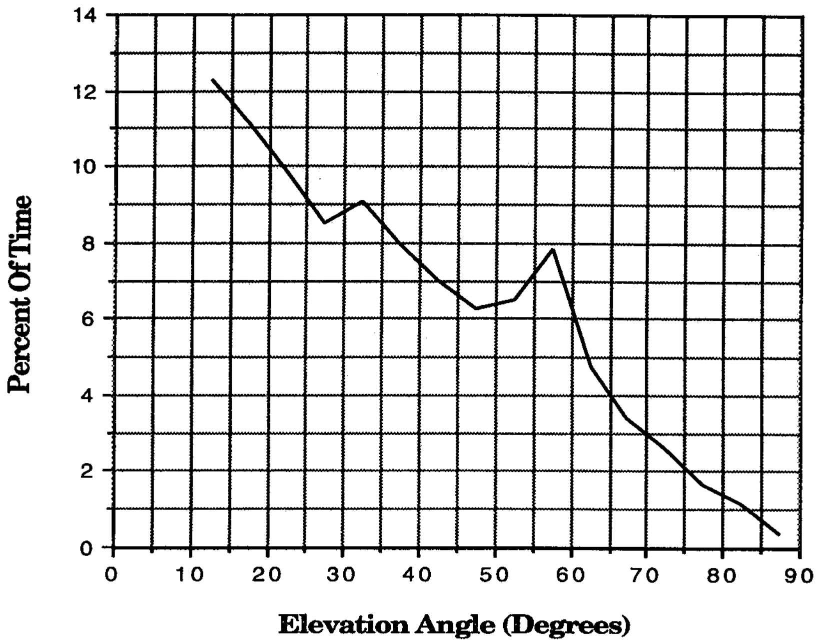


Figure 11: Elevation Angle Distribution (Los Angeles, CA - Earth Station)

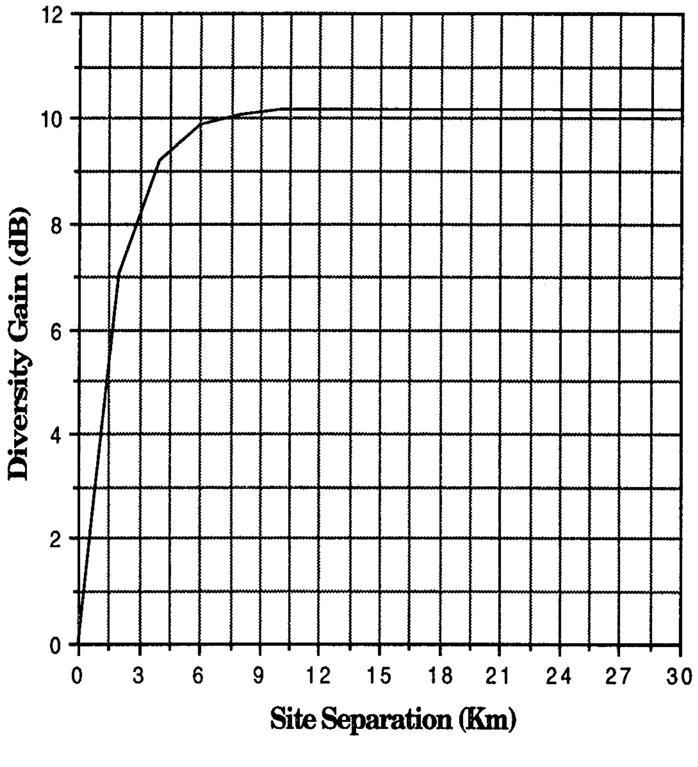


Figure 12 : Path Diversity Gain (Hodge Model) (Los Angeles, CA - Earth Station @ 30 GHz & 10° elevation Angle)

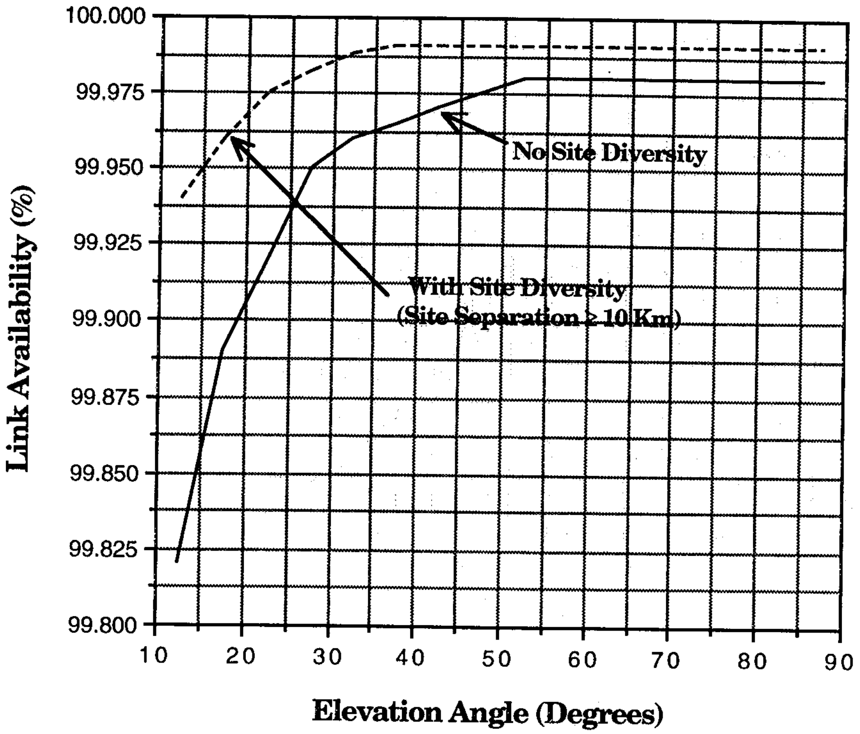


Figure 13 : Link Availability Versus Elevation Angle (Los Angeles, CA - Earth Station @ 30 GHz with18 dB Link Margin)

Table 3 : Feeder Link Availability

Feeder Link Availability		
Site	**No Site Diversity**	**With Site Diversity Site Separation≥ 10 Km**
Los Angeles, CA	99.94%	99.98%
Buenos Aires, Argentina	99.76%	99.91%
Fucino, Italy	99.86%	99.95%
Cape Town, South Africa	99.91%	99.97%
Ahmadabad, India	98.76%	99.61%
Yamaguchi, Japan	99.76%	99.92%
Sydney, Australia (Zone C)	99.89%	99.96%
Sydney, Australia (Zone D)	99.75%	99.91%