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MODIFIED ALSEP
Maximum Antenna Pointing Error

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This document presents an analysis of the maximum antenna pointing error allowed if communication margins are to be maintained.

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1.0 INTRODUCTION AND CONCLUSIONS

This analysis determines the maximum allowable antenna pointing error for the telemetry and command links based upon a 0 db performance margin for either nominal or worst case conditions. The telemetry link considers one and two watt transmitters and selected low data rates between 200 and 1600 bps and high rates of 9,600 and 10,600 bps. The MSFN ground stations are considered to have either cooled or uncooled paramps. The command link is considered to have the current ALSEP performance parameters.

The conclusions drawn from this study indicate that at the nominal Modified ALSEP conditions, i.e., 1440 bits per second data rate and 1 watt radiated power, an antenna pointing accuracy of 5 degrees is adequate. Under nominal and worst case downlink calculations zero margin is obtained at pointing errors of 9.0 and 4.5 degrees respectively. The uplink margins are greater in all cases and impose less severe pointing accuracies. The highest accuracy constraint exists for the high data rate case. However, it is unrealistic to use this as a pointing mechanism design constraint since the high data rate is a special mode for the ASE and its use can be programmed during a portion of the monthly libration cycle where favorable margins exist.

For exact values of the maximum allowable antenna pointing error see Table 3.

2.0 MULTIPATH LOSSES

The deployment sites for Modified ALSEP have been established as possibly anywhere within the boundaries of $\pm 60^{\circ}$ in longitude and latitude. This maximum value then establishes the minimum antenna elevation angle as 30° above horizontal. Since the expected life time of Modified ALSEP is to be two to five years, the antenna would be pointed to the center of libration in order to maximize the received power throughout the duration of the mission.

Possible sources of multipath losses can occur due to the first and third side lobes of the antenna (1) as shown in Figure 1. The first side lobe occurs at an angle of 39° from the main beam and is about 10 db down in magnitude. The third side lobe occurs at an angle of 70° from the main beam and is about 15 db down in magnitude. Various combinations of antenna elevation angle and possible surface moon slopes could then cause a small amount of multipath signal cancellation.

Figure 2 shows a graph of the magnitude of a reflected signal as a function of grazing angle (2) for frequencies approximately equal to 2000 MHz or larger and for desert-like soil ($_{r}$ 3). For relative antenna side lobe gains of -10, -15, and -20 db, the maximum possible multipath loss versus grazing angle was calculated and is shown in Figure 3.

When the antenna is located on a flat surface with an elevation angle of 35^{o}, the third side lobe will reflect from the moon's surface also with a 35^{o} angle. The maximum loss from this multipath is about 0.4 db as can be determined from Figure 3.

The first side lobe can cause multipath loss when the antenna is located on or near a sloped surface. From Figure 4, it can be seen that the grazing angle necessary to cause the angle of elevation for the reflected ray to equal the angle of elevation of the antenna or direct ray must be 19.5^{o} for a 39^{o} difference between the main and first side lobe beam. This will cause a 1.05 db multipath loss. Small deviations around this grazing angle of 19.5^{o} can also produce loss depending upon how the reflected beam interfaces with the main beam at the receiving site.

It would appear that a 1 db multipath loss as a worst case value would be satisfactory and is the same value as used in the original ALSEP calculations (1, 3).

3.0 LINK MARGINS

The link margins calculated for ALSEP(3) with the antenna boresited are shown in Table 1. The telemetry link margin is the number of db of received power in excess of that required to provide a 1×10^{-4} data probability of error. For the command link, the margin is the number of db of received power in excess of that required to have an IF SNR of +12 db which is the threshold value required to have a command bit probability of error of 1×10^{-9}.

4.0 ANTENNA POINTING ERROR

The relative antenna gain versus degrees off boresight pattern is shown in Figure 5. This is the ALSEP Helical antenna pattern No. 1, Flight 2, measured 20 June 1967. It was obtained from Reference (4), and is considered to be a typical antenna pattern suitable for Modified ALSEP.

Since the antenna pointing angle with respect to a space reference system varies as a function of time due to the moon's libration and since each moon antenna deployment site and earth rotation or ground station position can produce a positional error, these variations must be considered in determining pointing error. These variations have been tabulated and are shown in Table 2.

Figure 6 shows how these variations and the antenna beamwidth corresponding to the link margin can be combined to produce the maximum "radial" antenna pointing error. The term "radial" is used to denote the RMS value of the latitude and longitude errors. Table 3 lists the maximum allowable pointing errors for 1 and 2 watt transmitters, different data rates, and for cooled and uncooled paramps. Note that the effects of libration and positional error are included so that the values presented in Table 3 are only for the antenna pointing error.

REFERENCES

1. ATM-153, "Down Link Multipath Loss", 22 Dec. 1965, Bendix Aerospace Systems Division

2. Reed and Russell, "Ultra High Frequency Propagation", Boston Technical Publishers, Inc. 1964, pg. 97

3. ICD, "Communications Performance Margins", SE-06, Rev. A., 3 Sept. 1968, Bendix Aerospace Systems Division

4. EATM-12, "PSEP Antenna Pointing Analysis", 30 Dec. 1968, Bendix Aerospace Systems Division

5. "A Compendium of the Moon's Motion and Geometry": 1966-1985, Bellcomm, Inc. NASA TR-68-310-1, Contract NASW-417

TABLE 1
LINK MARGINS
(P_t = 1 Watt, Antenna Boresited)

PARAMETER	NOMINAL VALUE (db)	WORST CASE (db)
1. TELEMETRY LINK		
1.1 UNCOOLED PARAMPS		
1.1.1 30' Antenna		
Carrier Margin	17.5	12.0
Data Margin		
R = 200 bps*	15.3	10.7
R = 530 bps	13.2	8.6
R = 800 bps	11.4	6.8
R = 1060 bps	10.2	5.6
R = 1280 bps	9.4	4.8
R = 1440 bps	9.0	4.4
R = 1600 bps	8.4	3.8
1.2 COOLED PARAMPS		
1.2.1 30' Antenna		
Carrier Margin	20.6	14.9
Data Margin		
R = 200 bps*	18.4	13.6
R = 530 bps	16.3	11.5
R = 800 bps	14.5	9.7
R = 1060 bps	13.3	8.5
R = 1280 bps	12.5	7.7
R = 1440 bps	12.1	7.3
R = 1600 bps	11.5	6.7
1.2.2 85' Antenna		
Carrier Margin	26.8	19.9
Data Margin (R = 10,600 bps)	9.5	2.9
(R = 9,600 bps)	9.9	3.3

* - A 2 db signal wipe-off was estimated and is included. This value must be varified by MSC.

TABLE 1 (Continued)

PARAMETER	NOMINAL VALUE (db)	WORST CASE (db)
2. COMMAND LINK		
2.1 30' Antenna		
IF S/N Margin (standard)	12.3	7.4
IF S/N Margin (Subcarrier format)**	11.3	5.8
2.2 85' Antenna		
IF S/N Margin (standard)	21.3	14.4
IF S/N Margin (Subcarrier format)**	20.3	12.8

** ADJUSTED LOSSES

Receiver Switch	-0.2	-0.5
Receiver Loss Improvement	+1.0	+0.7
Bandwidth (275 to 420 kHz)	-1.8	-1.8
TOTAL ADJUSTMENT	-1.0	-1.6

TABLE 2

TOTAL LIBRATION AND POSITION VARIATIONS

FUNCTION	LATITUDE	LONGITUDE
Libration	$\pm 6.8^{\circ}$	$\pm 7.8^{\circ}$
Earth Position Error	$\pm 1.0^{\circ}$	$\pm 1.0^{\circ}$
Moon Position Error	$\pm 0.2^{\circ}$	$\pm 0.2^{\circ}$
TOTAL ERROR	$\pm 8.0^{\circ}$	$\pm 9.0^{\circ}$

TABLE 3
ALLOWABLE ANTENNA POINTING ERROR*

PARAMETER	P_t = 1 W Nominal Value	P_t = 1 W Worst Case	P_t = 2 W Nominal Value	P_t = 2 W Worst Case
1. TELEMETRY LINK				
1.1 UNCOOLED PARAMPS				
Allowable Pointing Error (degrees)				
R = 200 bps	12.0	10.0	14.0	11.4
R = 530 bps	11.2	8.7	12.5	10.5
R = 800 bps	10.4	6.0	11.6	9.5
R = 1060 bps	9.7	5.8	11.2	8.7
R = 1280 bps	9.4	5.0	10.8	7.8
R = 1440 bps	9.0	4.5	10.7	7.6
R = 1600 bps	8.5	3.6	10.4	7.0
1.2 COOLED PARAMPS				
Allowable Pointing Error (degrees)				
R = 200 bps	14.0	11.4	14.3	12.6
R = 530 bps	12.5	10.5	13.0	11.7
R = 800 bps	11.6	9.5	12.7	11.0
R = 1060 bps	11.2	8.7	12.5	10.5
R = 1280 bps	10.8	7.8	12.2	10.0
R =1440 bps	10.7	7.6	12.0	9.8
R = 1600 bps	10.4	7.0	11.7	9.5
R = 10,000 bps**	9.3	2.2	10.8	6.2
R = 9,600 bps**	9.5	2.8	11.0	6.5
2. COMMAND LINK***				
Allowable Pointing Error (degrees)				
Standard Format	10.7	7.5	10.7	7.5
Subcarrier Format	10.4	5.5	10.4	5.5

* - Includes Libration Variations
** = The high data rate systems uses a cooled paramp and an 85 ft. dish antenna.
*** - Uses 30 ft. dish antenna.

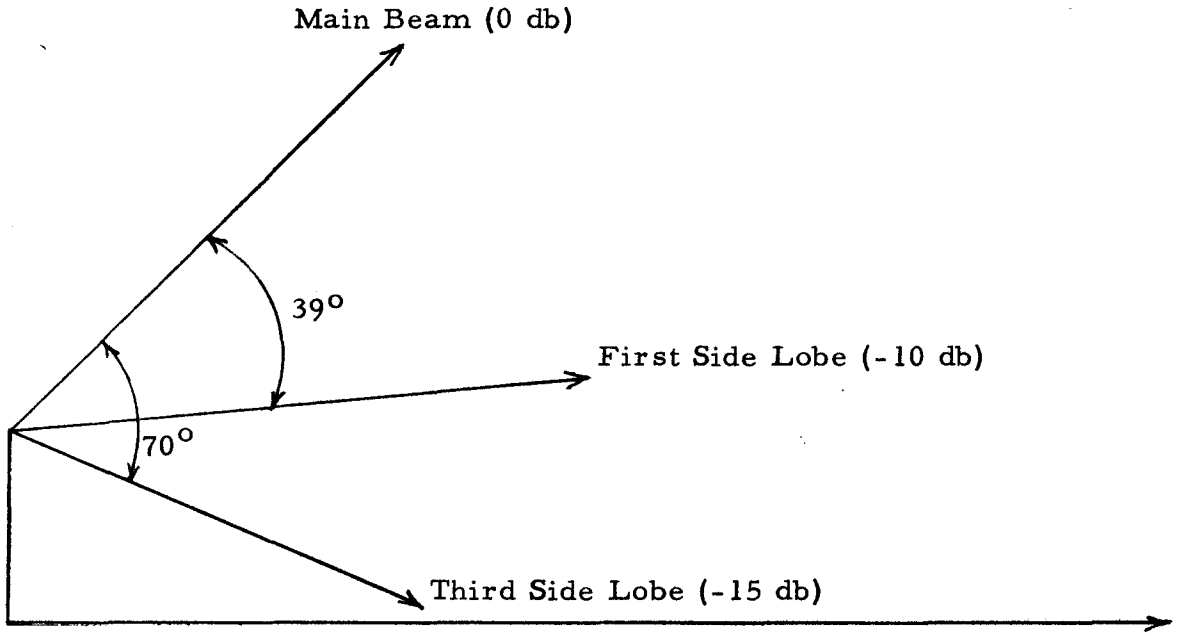
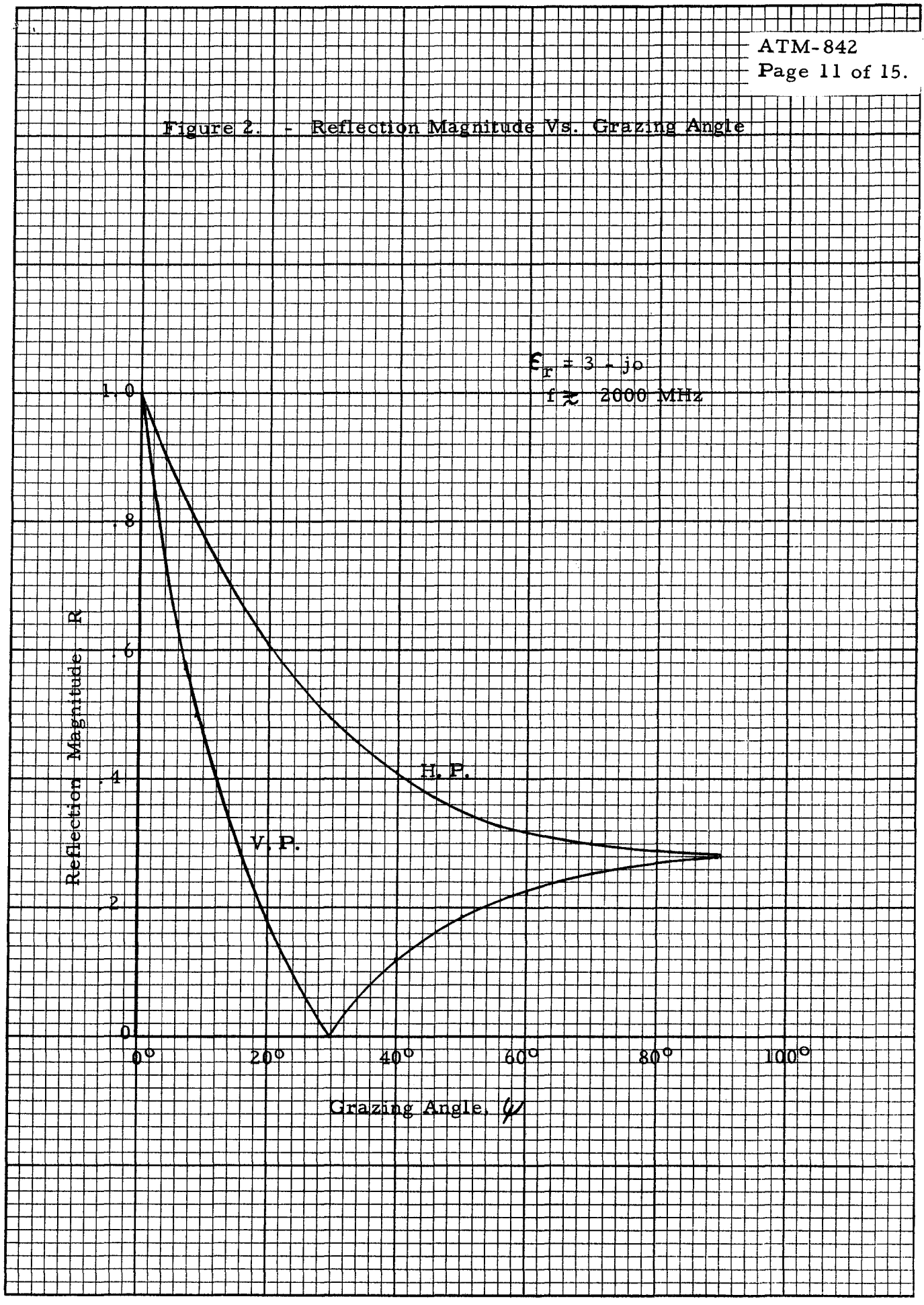


Figure 1. - Relative Position and Magnitude of Antenna Side Lobe Radiation

Figure 2. - Reflection Magnitude Vs. Grazing Angle



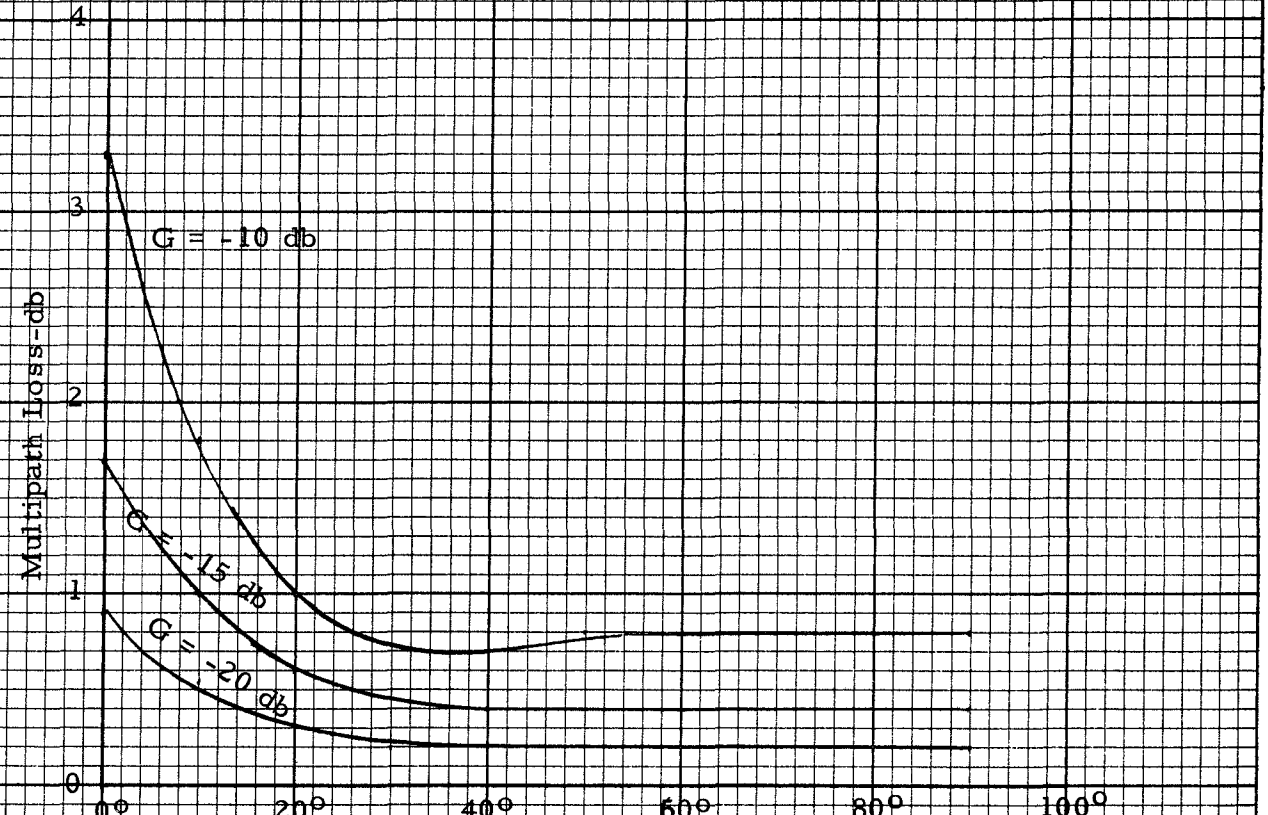
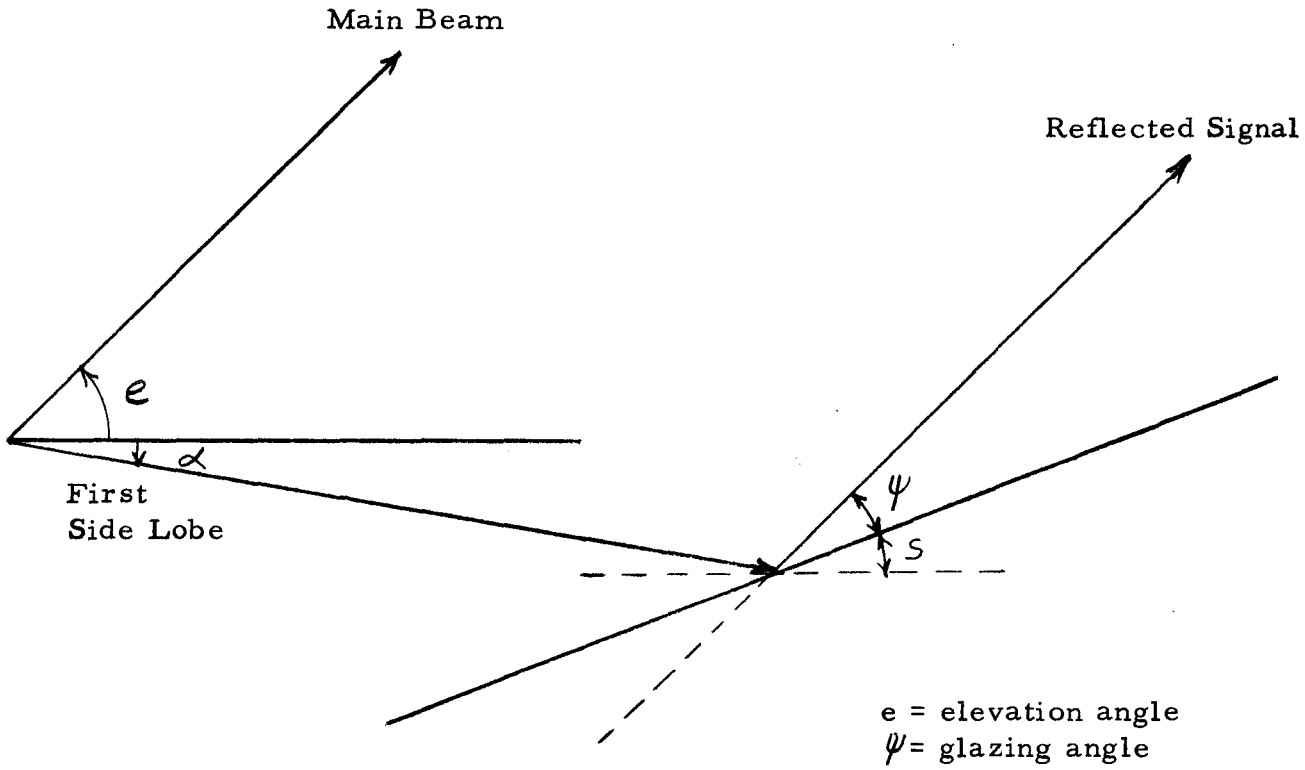


Figure 3. - Multipath Loss Vs. Grazing Angle



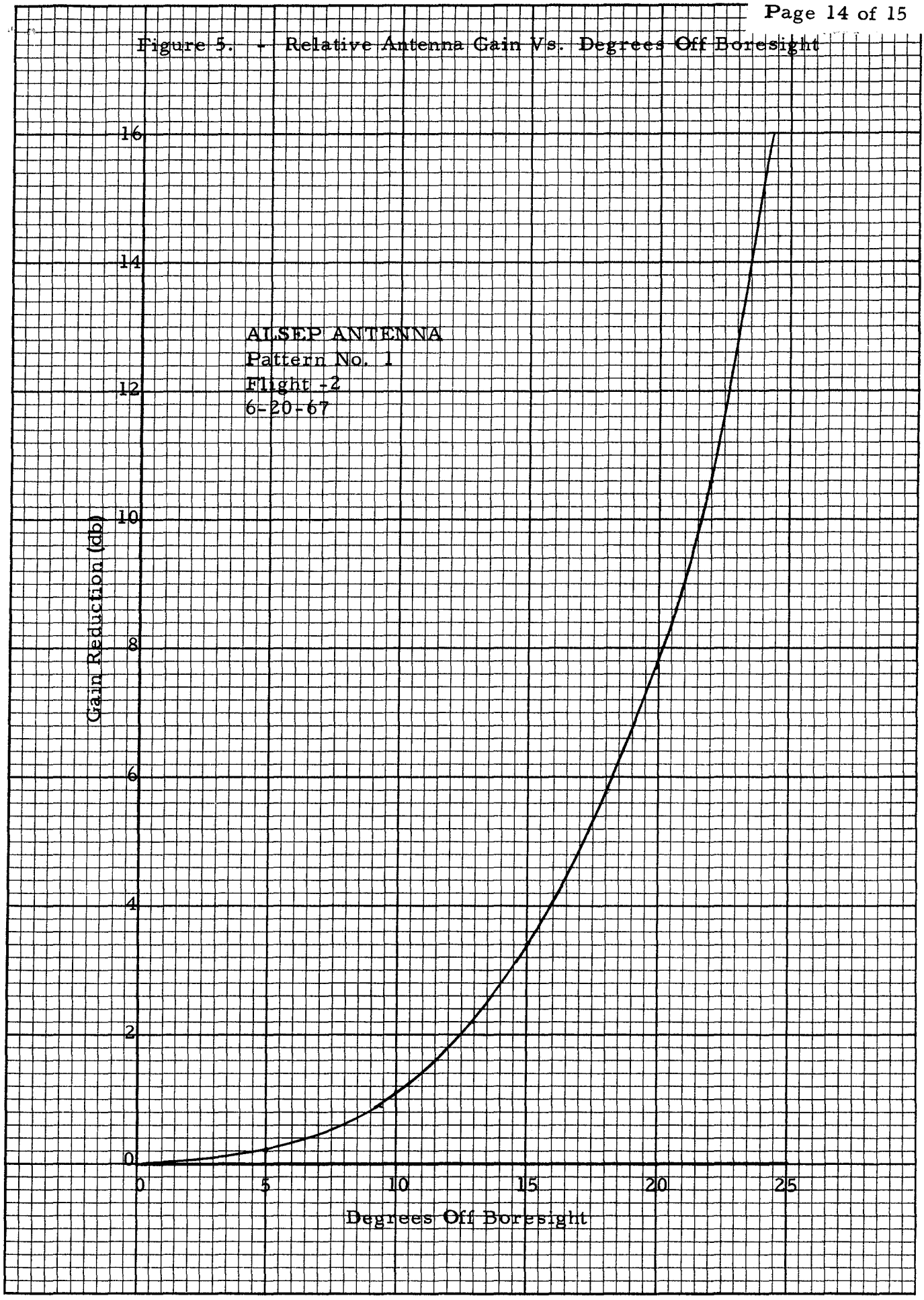
e = elevation angle
ψ = glazing angle
S = slope angle of hill
$\alpha = 39^{\circ} - e$

e°	α°	ψ°	S°
30	9	19.5	10.5
39	0	19.5	19.5
45	-6	19.5	25.5

$$S = \psi - \alpha$$
$$\psi = \frac{1}{2}(e + \alpha)$$

Figure 4. - First Side Lobe Interference

Figure 5. - Relative Antenna Gain Vs. Degrees Off Boresight



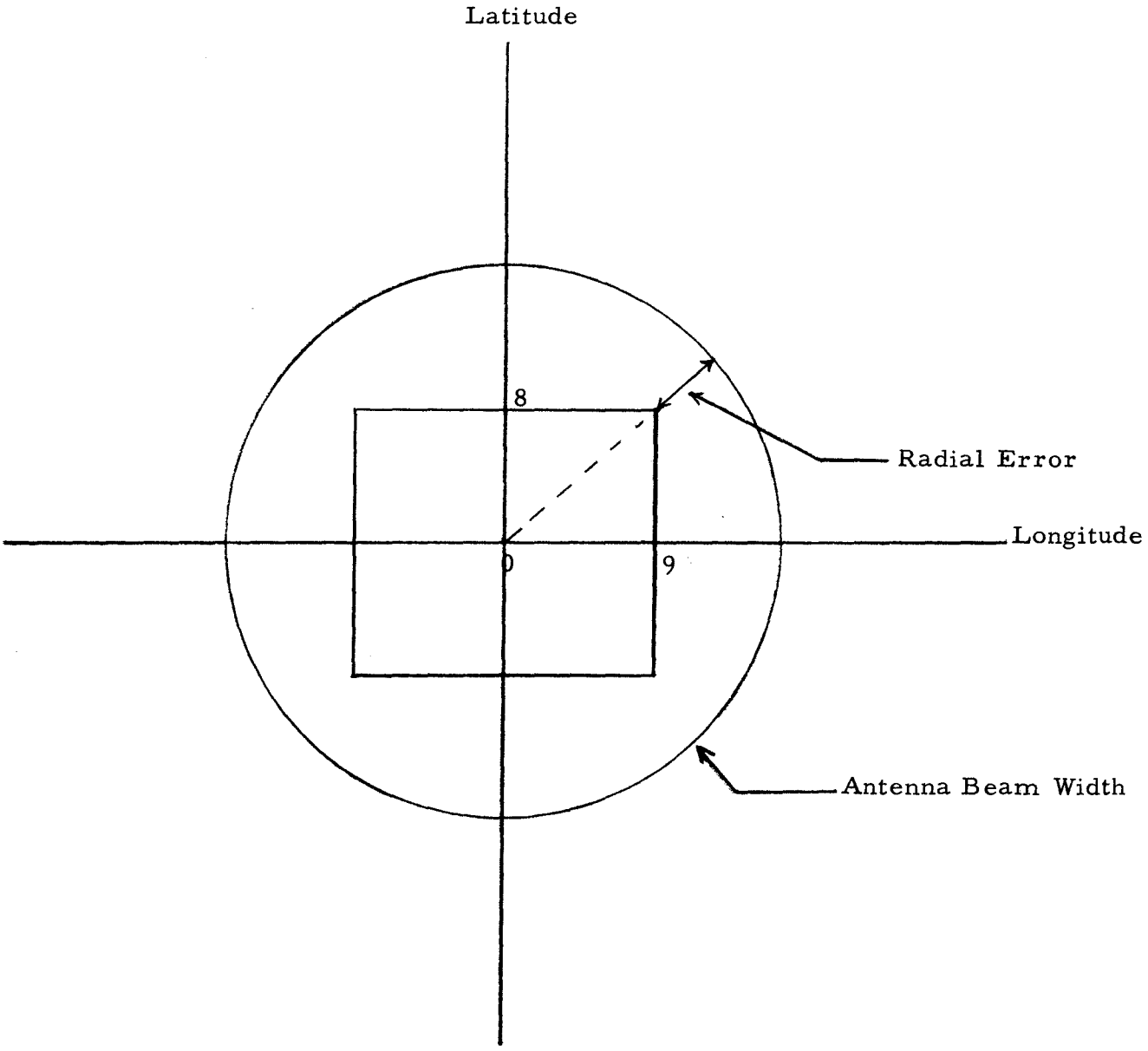


Figure 6. - The Geometry of Radial Error