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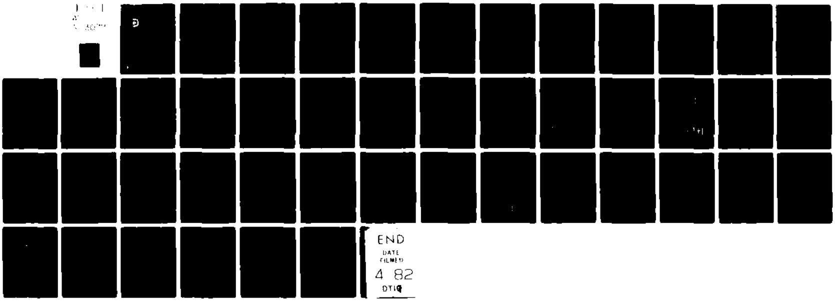

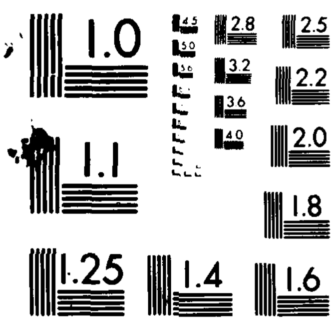

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TN 30-81

DEFENSE COMMUNICATIONS ENGINEERING CENTER

TECHNICAL NOTE NO. 30-81

PERFORMANCE ANALYSIS OF DIGITAL LOS LINK AT NAVCOMMSTA H.E. HOLT, AUSTRALIA

DECEMBER 1981

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The NAVCOMMSTA H. E. HOLT analog link M2008 is scheduled for digital operation using DRAMA equipment in FY 82. NAVSEEACT PAC asked for DCEC assistance in engineering the new digital link with special consideration requested to address the significance of multipath fading and the need for a midpath repeater to meet DCS performance criteria. This technical note contains the requested technical information.

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DECEMBER 1981

Prepared by:

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FOREWORD

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Reston, Virginia 22090

EXECUTIVE SUMMARY

This Technical Note (TN) assesses the performance of the new digital LOS link scheduled for implementation at NAVCOMMSTA H. E. HOLT, Australia in FY 82. The link performance analysis is derived from the technical information provided by NAVSEEACT PAC, existing antenna tower configuration, prevailing propagation conditions, and performance characteristics of the DRAMA radio equipment.

The TN is structured as follows:

a. The background of section II identifies previous activities related to this performance analysis.

b. In section III, the major factors controlling the performance expected for this link are identified in terms of magnitude and design configuration. Most degradation in performance is shown to be caused by multipath flat fading (35 - 40 dB), surface ducting (up to 10 dB) and superrefractive fading (8 - 9 dB). The effects of other types of fading are negligible.

c. The link configuration recommended in section IV is based on providing an optimum performance in concert with applicable DCS standards at a minimum cost. The link configuration consists of 8 foot parabolic antennae to be installed on the existing towers in a dual space diversity configuration with a 20 meter (66 foot) separation. In addition, use of low-loss circular waveguide runs is recommended for lower transmission losses.

d. Section V concludes the TN recommending a follow-up monitoring of the link performance with special emphasis during April when most of the adverse propagation conditions prevail the most.

e. A comparison between performance of the recommended parabolic antenna system and the NAVSEEAC PAC proposed periscope antenna system is included in Appendix A. The advantages in performance of the former antenna system include gain, off-beam discrimination, installation activities, and costs.

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I. INTRODUCTION

The purpose of this Technical Note (TN) is to evaluate the performance of NAVCOMMSTA H. E. HOLT LOS radio link M2008, scheduled for a digital upgrade in FY 82. The link performance analysis is based on the following considerations: prevailing fading conditions, minimum path clearance of existing antenna system, design specifications of the DRAMA radio equipment, diversity improvements, performance of a periscope vs parabolic antenna system, and design optimization vs cost effectiveness in concert with applicable DCS performance criteria.

II. BACKGROUND

A number of background activities were carried out as part of this performance analysis, these are summarized in the following paragraphs.

a. Technical Evaluation. A NAVSEEACT PAC Team performed a technical evaluation of DCS link M2008 on 27 February - 12 March 1976. The following recommendations were included in their Technical Assistance Report of 20 May 1976:

(1) Compute the refractive index and effective earth radius factor based on the most recent meteorological data collected during periods of extended deep fades in RSL (some recorded in excess of 50 dB).

(2) Continue long term stripchart recording of RSL, and of logging outage times caused by adverse propagation conditions.

(3) Program installation of solid state microwave radios followed by a complete technical evaluation as specified in DCAC 310-70-57.

b. Fading Analysis. The data measured and recorded by USN site personnel between March 1977 and February 1978 were analyzed by NAVSEEACT PAC. The results of this analysis were documented in their report of September 1978. Their recommendations were as follows:

(1) Insure operation of radio equipment at a peak efficiency through diligent maintenance for a maximum fade margin.

(2) Tilt the receive antenna slightly upward in order to diminish the chances of antenna decoupling during superrefractive conditions and to minimize ground reflections.

(3) Add an active repeater near midpath to decrease the chances of blackout fading caused by signal trapping within a superrefractive layer.

c. Request for DCEC Assistance. A letter from NAVSEEACT PAC to DCA 470 (5 March 1981) requested that DCEC perform a path analysis to determine the following:

(1) Significance of time-dispersive multipath fading.

(2) Need of an active repeater to meet DCS performance standards.

d. Meteorological Data. NAVSEEACT PAC correspondence of 16 April 1981 forwarded to DCEC included a copy of the meteorological data collected between 25 March and 25 December 1977 at Learmonth - a weather station located approximately 8 miles north of the H. E. HOLT HF receiver site. These data were analyzed to determine the seasonal distribution of the K factor pertinent to the LOS link under study.

e. DCEC Preliminary Analysis. The results of a DCEC preliminary analysis were summarized in a letter to NAVSEEACT PAC on 4 May 1981. The recommended link configuration included a standard 8 foot parabolic antenna system installed in a dual space diversity configuration with low-loss circular waveguide runs and DRAMA radio equipment. The performance of the proposed link was projected to meet DCS standards without the addition of an active repeater located at midpath.

III. LINK PERFORMANCE ANALYSIS

The performance of the future digital LOS link at NAVCOMMSTA H. E. HOLT is evaluated in this section. The analyis is conducted along the following guidelines:

- The potential problem areas characteristic to this link.
- The yearly distribution of K factor.
- Minimum path clearance.
- Degradation in link performance caused by prevailing fading conditions.
- Link design for an optimum performance.

a. Areas of Concern. A close review of the information contained in the technical material referenced in section II points to several areas of concern:

(1) Adverse effects on path clearance and link performance caused by superrefractive conditions and ground reflections.

(2) Degradation in performance induced by frequency selective fading.

(3) Comparisons in performance of a periscope antenna system vs a parabolic antenna system.

(4) Need for addition of a midpath repeater to meet DCS digital LOS performance criteria.

(5) Improvement in link performance gained by tilting the receive antenna upward.

b. Yearly Distribution of K Factor. The seasonal distributions of K values depicted in NAVSEEACT PAC report of September 1978 (refer to section II-b) and the meteorological data recorded at Learmonth (see paragraph II-d) have been statistically analyzed for a yearly distribution of the K factor characteristic to the subject LOS path. A summary of the K distribution is shown in Table I. A yearly average distribution based on 9-month data recording is derived for various relative frequencies of occurrence ranging from 50 to 99.99%. The same information is shown in Figure 1. Note the superrefractive characteristics of the K factor which range from values of 1.27 - 1.37 most of the year, to values of 1.48 - 1.64 during only 10% of the year. Part of these superrefractive values of the K factor have been confirmed by NAVSEEACT PAC in their TAR of May 1976 (see paragraph II-a). A K factor range between 1.35 - 1.58 was recorded between 28 February and 3 March 1976. The yearly distribution of the K factor ranges between 1.24 and 1.64 for most of the time (99.99% frequency of occurrence).

c. Minimum Path Clearance. The minimum path clearance provided by the existing maximum antenna tower heights is determined based on the K factor

TABLE I. YEARLY DISTRIBUTION OF K FACTOR AT H. E. HOLT LOS LINK

SEASON (MONTHS) \ Distribution OF K	RELATIVE FREQUENCY OF OCCURRENCE				
	50%	90%	99%	99.9%	99.99%
1. Fall (Mar-May)	1.27-1.37	1.25-1.53	1.25-1.63	1.23-1.67	1.23-1.71
2. Winter (Jun-Aug)	1.29-1.33	1.27-1.47	1.25-1.57	1.25-1.59	1.25-1.61
3. Spring (Sep-Nov)	1.25-1.39	1.25-1.43	1.23-1.51	1.25-1.55	1.25-1.59
4. Summer (Dec-Feb)	← DATA NOT AVAILABLE →				
Yearly Average (Based on 9 Months)	1.27-1.37	1.26-1.48	1.24-1.57	1.24-1.60	1.24-1.64

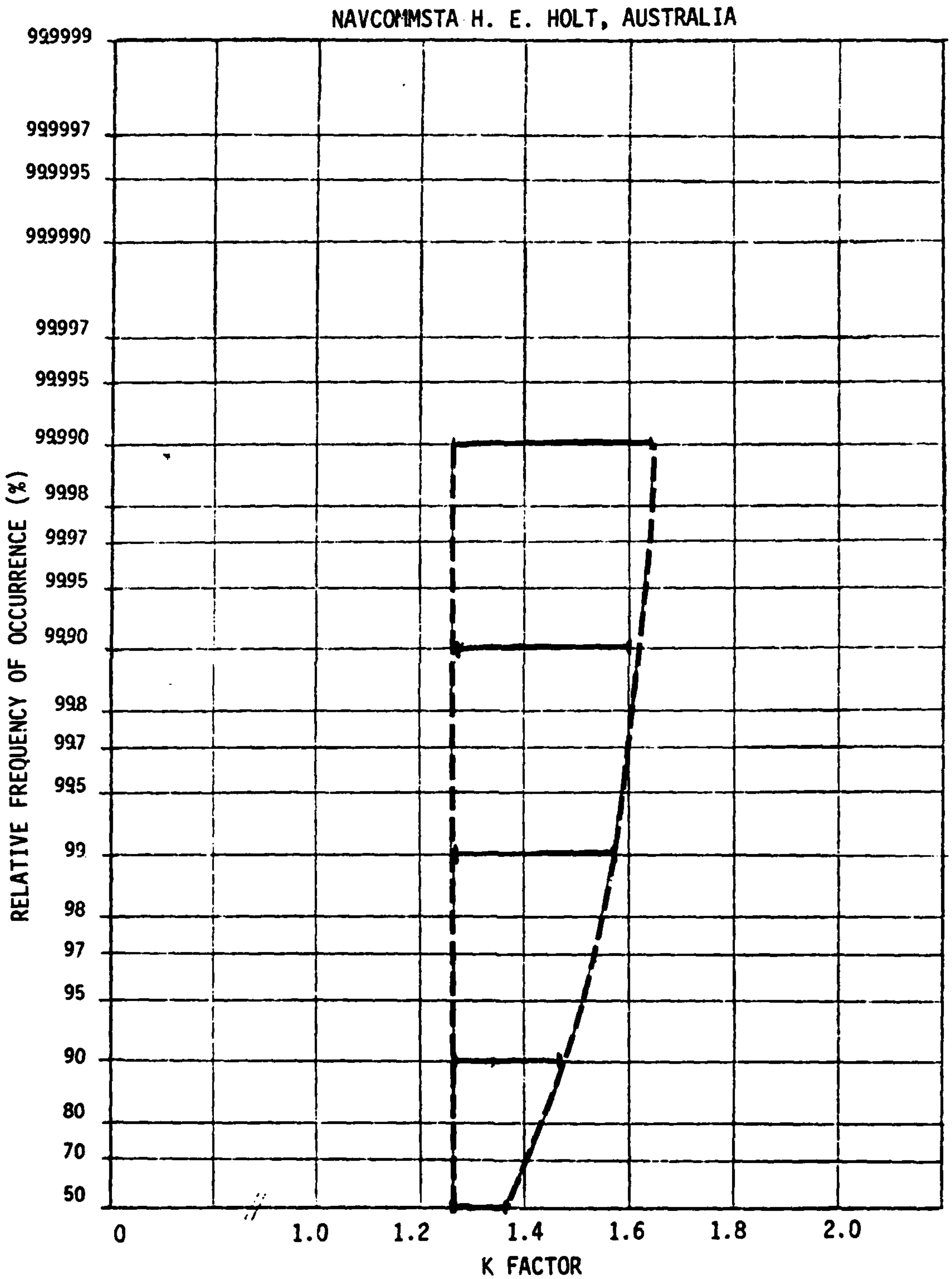


Figure 1. Yearly Distribution of K Factor Vs Relative Frequency of Occurrence

distribution derived in the previous section. A set of path profiles is derived using the DCEC PLOS program for K = 1.25, 1.45 and 1.65 and Fresnel zones of 1, 2, and 4, as shown in Figures 2, 3 and 4 respectively. A maximum height of 3 meters is allowed for tree growth in each path profile. Note that an adequate path clearance is attained at maximum antenna heights (i.e., 129 M at HFR and 98 M at CTR) of any combinations of $1.25 \leq K \leq 1.65$ and $F \leq 2$. Any other combinations out of this range would result in a partial or total path blockage. A proportionate increase in antenna height(s) would be required for an adequate path clearance of the higher Fresnel zones.

d. Normal Fading Effects. The received signal level (RSL) of any radio path is susceptible to a combination of various types of fading, categorized in two groups: normal and abnormal fading. The normal types of fading are very predictable (90-95%) in behavior and occurrence, prevailing for a large percentage of time. The normal fading includes: (1) flat (across frequency bandwidth) or frequency selective multipath fading, (2) atmospheric absorption, (3) fog, and (4) dust. Only the effects of multipath fading are considered in this section, since the other types of normal fading have a negligible effect on the link performance (i.e., 1-2 dB degradation).

(1) Multipath Flat Fading. The relation of multipath flat fading to DCS performance criteria is described in a DCEC engineering publications [1]. The DCS fade margin objective allocates ~ 33 dB for an average (climate, terrain and temperature) digital LOS link, configured in a dual space diversity mode, and about 51 km in length (i.e., link margin = 9 log 51 + 18 (dB)). The path clearance of a top-to-bottom antenna beam path is based on a 0.3 Fresnel zone clearance and a K = 2/3.

Results of previous tests performed on the existing link (documented by NAVSEEACT PAC in the test reports referenced in paragraphs II-a and II-b) indicate incidence of deep fades (in excess of 50 dB) occurring frequently on either of the diversity paths independently, but very seldom on both paths simultaneously. The monthly distributions of such deep fades on the upper 'A' and lower 'B' radio paths are shown in Figures 5a and 5b, respectively (see paragraph II-b). Note that the highest rate of deep fades occurs during April (over 26 fades on 'A', and 17 fades on 'B'), and the lowest rate occurs during November (1 fade on 'A', and 3 on 'B'); no calibrated data were reported for December-February period. Most of these deep fades were attributed to a combination of various types of fading that include multipath flat fading and ducting (Figure 11). The magnitude of multipath fading on a single radio path is estimated to be around 35-40 dB.

(2) Multipath Frequency Selective Fading (FSF). A computer program was developed by DCEC in support of the FSF analysis to calculate path length difference versus power ratio and time delay variations. A two-ray channel model accounting for the direct and the reflected/refracted (indirect) signal paths is used for this program. The performance analysis for the Santa Rita - Manila Embassy LOS link [2] described the calculations included in this program. Two major parameters were varied for assessing the FSF effects on the performance of the H. E. HOLT LOS link: (1) various antenna heights at the Communication Center location (415-315 feet in steps of 10 ft), and (2) different values of K factor (1.2 - 1.7). An example listing the input/output parameters of this program is shown in Figure 6.

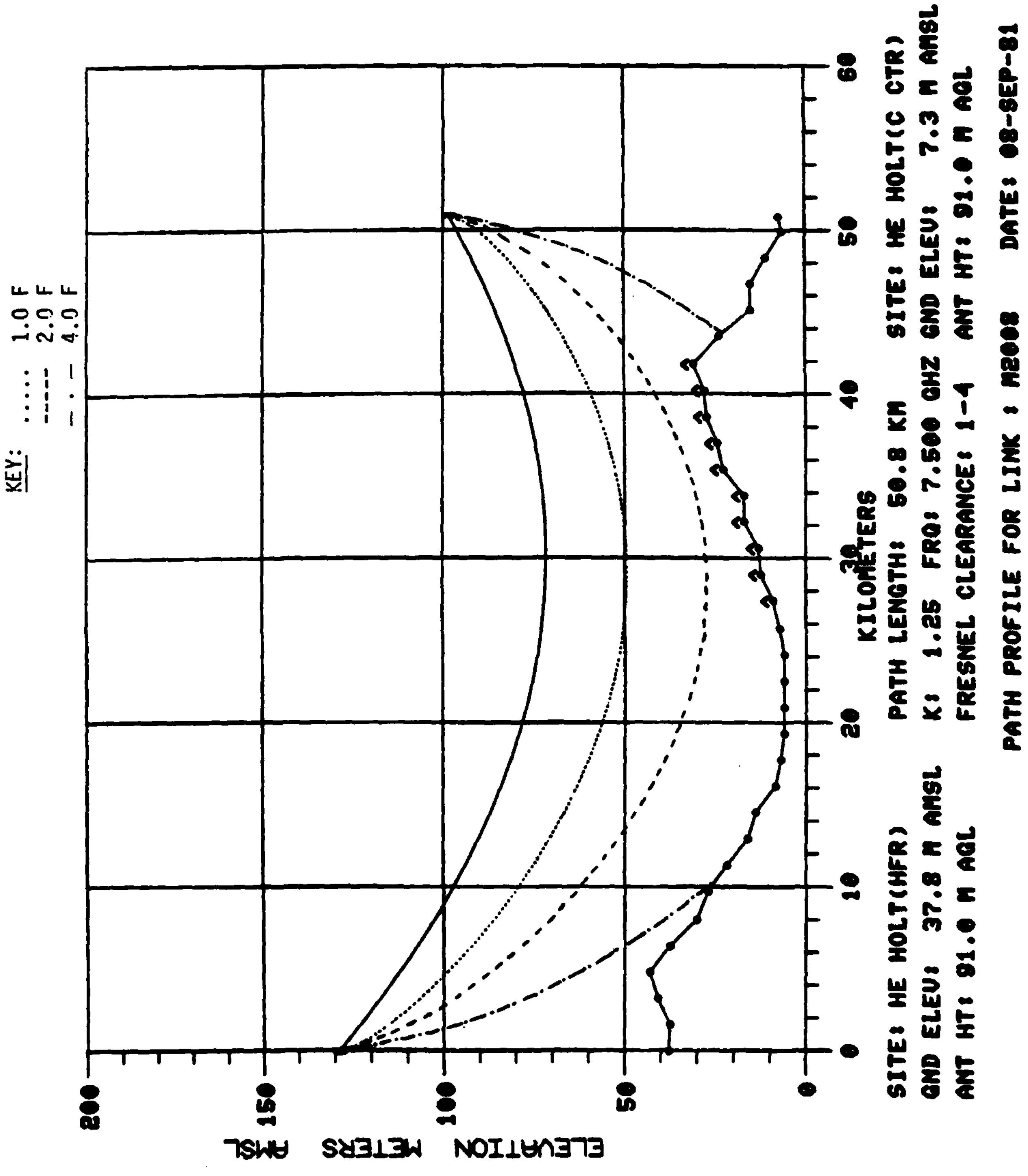


Figure 2. Path Profile for K = 1.25

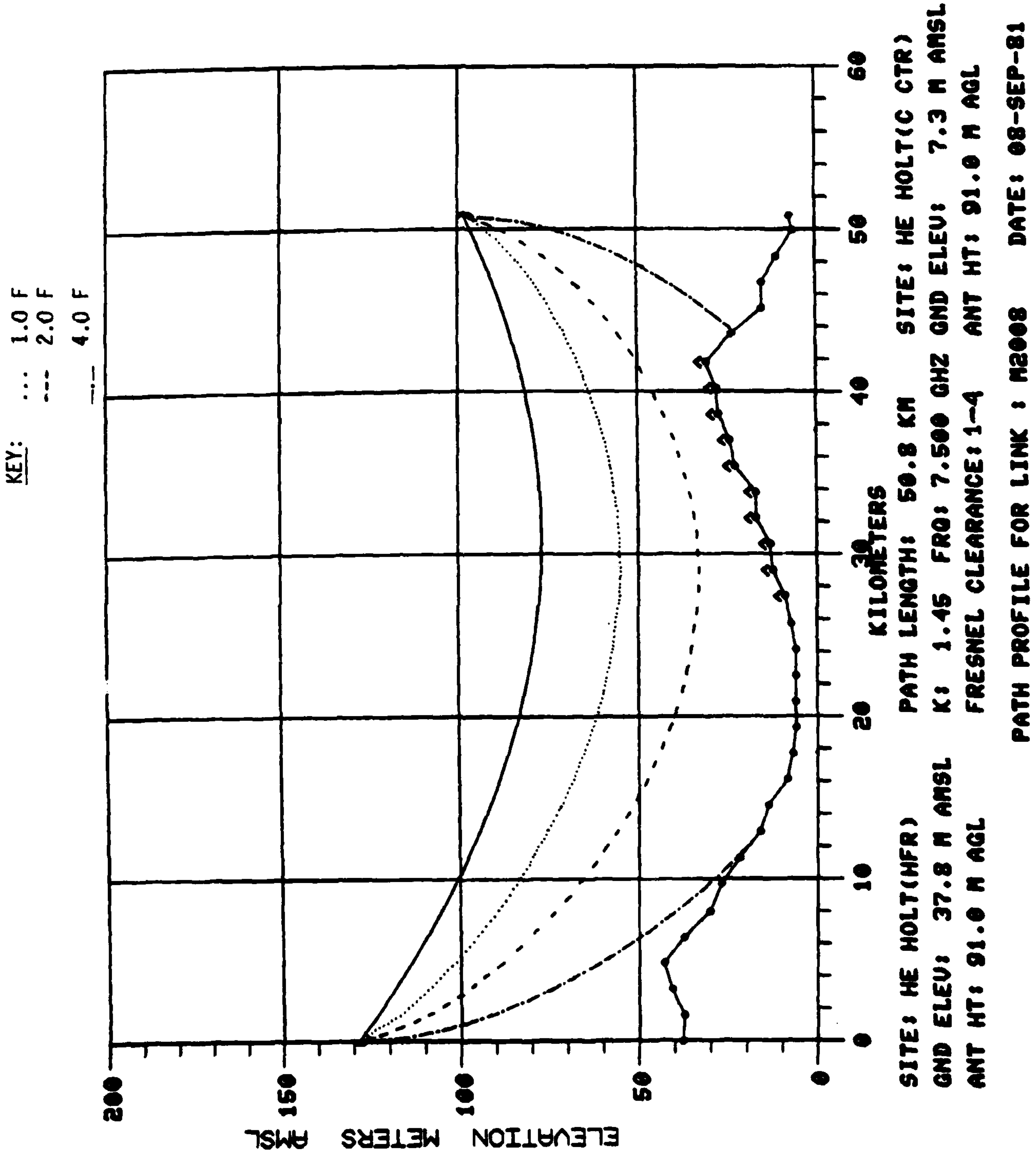


Figure 3. Path Profile for K = 1.45

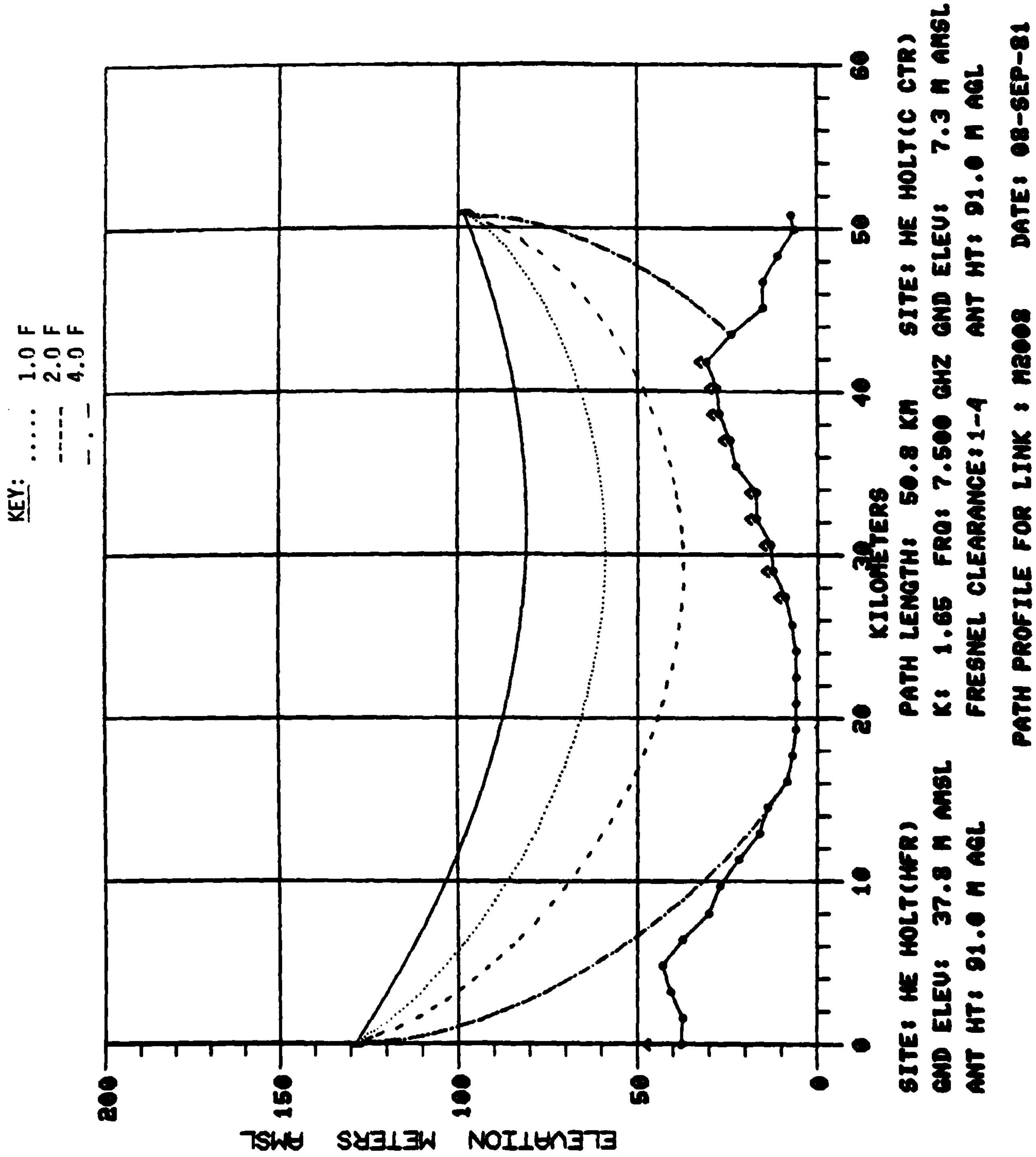


Figure 4. Path Profile for K = 1.65

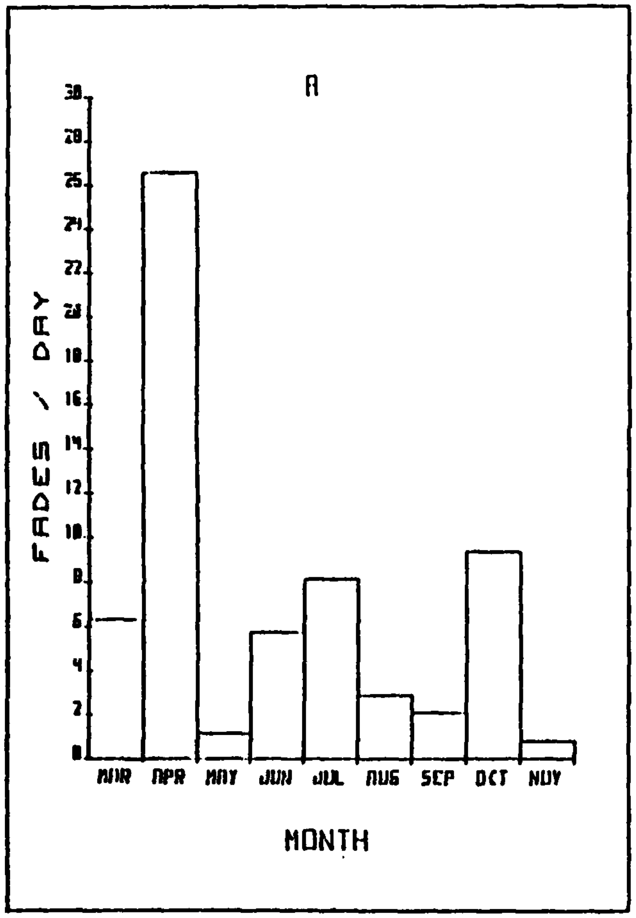


Figure 5a. Monthly Distribution of Deep Fades on the Upper "A" Path

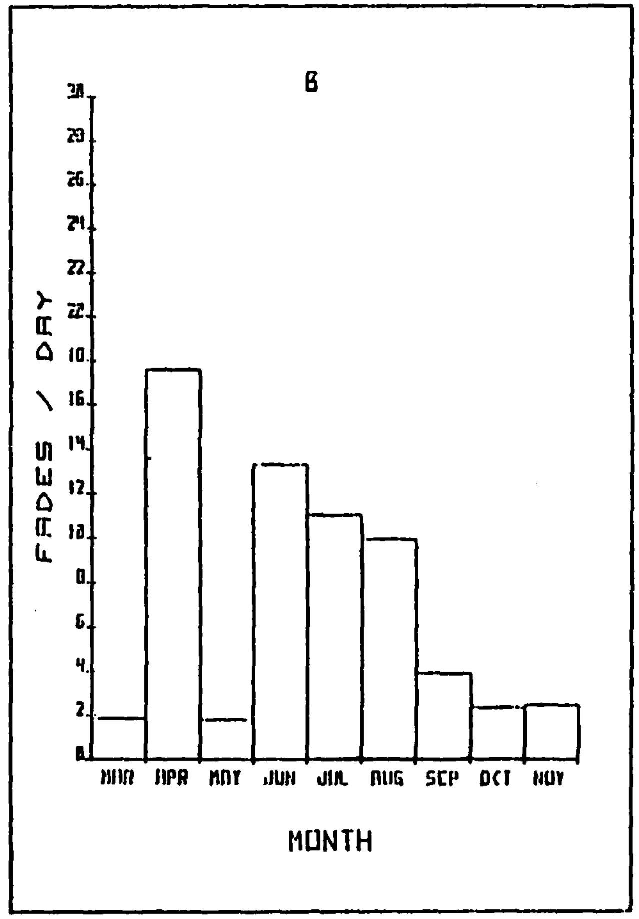


Figure 5b. Monthly Distribution of Deep Fades on the Lower "B" Path

TRANSMITTER SITE CCMM CTR
RECEIVER SITE FFR
FREQUENCY (MHZ) 7500.00
PATH LENGTH (MI) 31.52
TRANSMITTER SITE ELEVATION ABOVE MSL (FT) 24.10
TRANSMITTER ANTENNA HEIGHT ABOVE GROUND (FT) 290.40
RECEIVER SITE ELEVATION ABOVE MSL (FT) 124.70
RECEIVER ANTENNA HEIGHT ABOVE GROUND (FT) 250.40
EFFECTIVE EARTH RADIUS FACTOR 1.40
ACTUAL EARTH DIAMETER (MI) 3958.32
MAX HIGH TIDE ABOVE MSL (FT) 0.0
MAX LOW TIDE BELOW MSL (FT) 0.0
TIDE INCREMENT (FT) 0.0
RECEIVER MINIMUM HEIGHT (FT) 305.00
RECEIVER HEIGHT INCREMENT (FT) 10.00
POLARIZATION V
EPSILON 25.00
SIGMA 0.02
ANTENNA DIAMETER (FT) 0.00

RCVR ANT HT FT	TIDE HT FT	D1 S.MI	D2 S.MI	PSI DEG	RV	PHI DEG	DF DEG	M VALUE	F DB	DTH NS
415.10	0.0	14.11	17.41	0.17	1.00	82.31	2186.54	0.7179[illegible]	-5.37	0.8104E+01
405.10	0.0	14.26	17.26	0.17	1.00	82.97	2021.07	0.7134E+0[illegible]	0.22	0.7713E+01
395.10	0.0	14.42	17.10	0.16	1.00	83.65	1977.03	0.7097[illegible]	4.65	0.7327E+01
385.10	0.0	14.57	16.95	0.16	1.00	84.35	2174.37	0.703[illegible]	-9.80	0.8059E+01
375.10	0.0	14.73	16.79	0.16	1.00	85.07	2068.90	0.6965[illegible]	1.90	0.7668E+01
365.10	0.0	14.89	16.63	0.15	1.00	85.82	1746.72	0.6937[illegible]	-1.86	0.6474E+01
355.10	0.0	15.05	16.47	0.15	1.00	86.59	1719.37	0.6883[illegible]	0.97	0.6372E+01
345.10	0.0	15.22	16.30	0.15	1.00	87.39	1761.81	0.6929E+0[illegible]	-4.06	0.6530E+01
335.10	0.0	15.39	16.13	0.14	1.00	88.21	1385.50	0.6770E+0[illegible]	-1.73	0.5135E+01
325.10	0.0	15.57	15.95	0.14	1.00	89.06	1224.84	0.6711[illegible]	4.06	0.4539E+01
315.10	0.0	15.75	15.77	0.14	1.00	89.35	1268.94	0.6649[illegible]	4.40	0.4703E+01

T IS GREATER THAN ONE...ERROR...RUN TERMINATING

Figure 6. Example of Input/Output Parameters of FSF Program (K = 1.4)

The results of this program are summarized in Figures 7 and 8. The variation in the ratio of the two signal paths (reflected/direct) - defined as M (in dB) versus the path length difference - defined as DR (in feet) for a variable K factor is shown in Figure 7. Note the range of -2.2 to -4.1 dB in 'M' amplitude variation for antenna spacings less than or equal to 20 meters. Additionally, 'scattering' effects are calculated for antenna spacings in excess of 20 meters due to repetitive reflections in the indirect signal path.

The relationship of time delay - defined as DTM (in nanoseconds) versus the path length difference DR (in feet) - is depicted in Figure 8. The variation in DTM for $1.2 < K < 1.7$ ranges from 5-10 nanoseconds.

The ranges in the signal power ratio and time delay were entered in the hybrid simulation of the DRAMA radio and a LOS fading channel as described in a similar analysis [2]. Performance degradation caused by FSF was determined from the yearly distribution of K factor shown in Table I, the corresponding variation in amplitude (M) and delay (DTM) depicted in Figures 7 and 8, and other input parameters specific to DRAMA radio equipment and the subject digital LOS path.

The family of curves in Figure 9 illustrates the results of such a simulation. Degradation in SNR (in dB) required for a BER = 10^{-3} is related to the time delay (in bit times) and various power ratio values (α) ranging from 0.125 to 0.5. A summary of the FSF performance degradation of the subject LOS link as extrapolated from Figure 9, is presented in Table II. Note a gain of 1.5 to 2 dB in the signal-to-noise ratio resulting from constructive (rather than destructive) interference of the two signal rays.

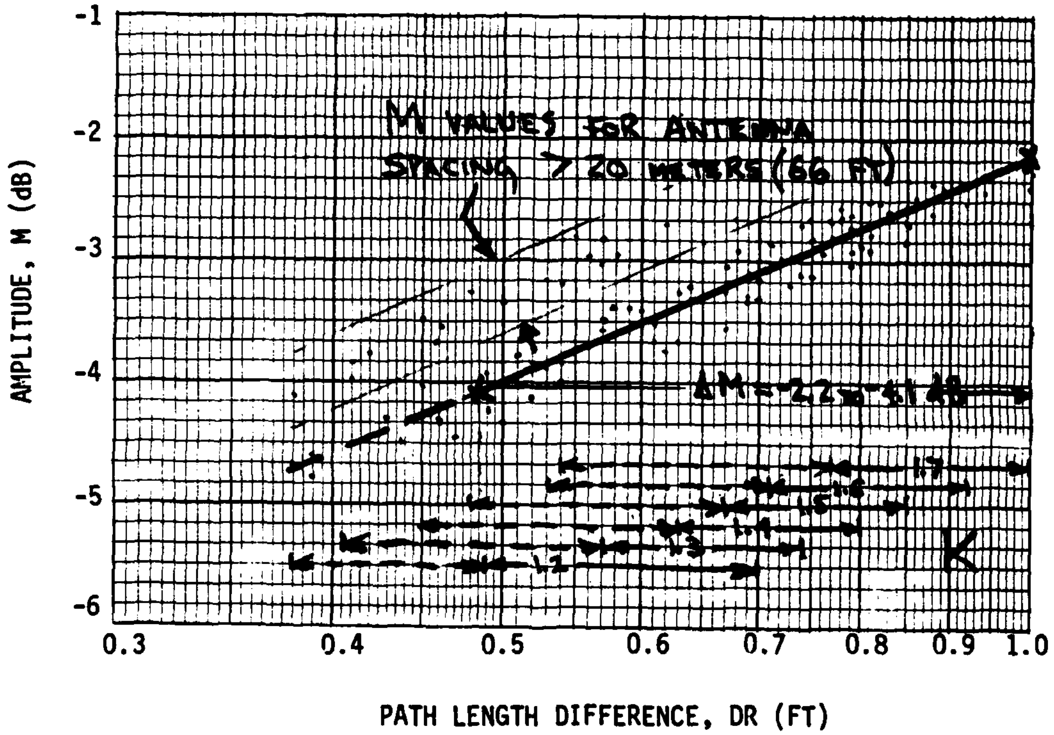
e. Abnormal Fading Effects. Abnormal fading is the fading occurring a small percentage of time in an unpredictable fashion. It includes the following types: (1) subrefractive ($K \ll 1$), (2) superrefractive ($K \gg 1$), (3) ducting, and (4) rain attenuation. The results and recommendations of the performance analysis documented by NAVSEEACT PAC (see section II) indicate that all four types of abnormal fading affect the performance of the link, with (2) and (3) being the major contributors. The following two subparagraphs assess the performance degradation caused by superrefractive fading and ducting.

(1) Superrefractive Fading. The yearly distribution of K factor shown in Table I indicates that superrefractive propagation conditions prevail most of the time. Utilizing the "two-ray model" described in reference [2], the relationship of the signal strength to a K factor ranging from 1.2 to 1.7 is derived for the subject link and shown in Figure 10. The ratio of resultant to the direct signal path (F in dB) ranges from 5 dB (odd number of Fresnel zones) to -9 dB (even number of Fresnel zones). Note that partial or total path blockage (Figures 2 to 4) results during superrefractive conditions rich in a high order of even Fresnel zones. A space diversity configuration would alleviate such degradation in performance. An example of space diversity improvement (ΔF_s = 11 dB) is shown for receive antenna heights of 120 m (upper) and 100 m (lower), and a K = 1.6.

(2) Ducting. Surface ducting caused by a combination of superrefractivity, heavy humidity layering, and sudden temperature inversions

H.E. HOLT LOS LINK
FREQUENCY: 7.5 GHz
DISTANCE: 31.22 MILES
TRANSMIT ANT. HEIGHT (MSL): 314.5 FT
RECEIVE ANT. HEIGHT (MSL): 415-315 FT
'M' VARIATION: -2.2 to -4.1 dB
where

$$'M' = 20 \log \frac{\text{REFLECTED SIGNAL PATH}}{\text{DIRECT SIGNAL PATH}}$$



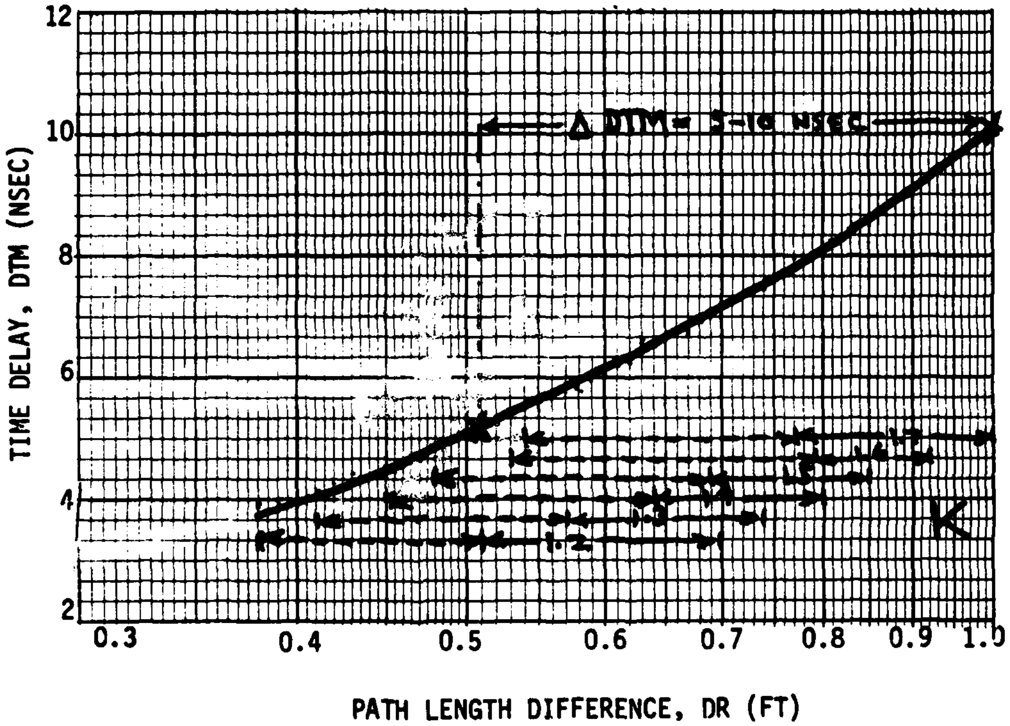
KEY:

|◄——►| ANTENNA SEPARATION LESS THAN 66 FEET.

|◄---►| ANTENNA SEPARATION OVER 66 FEET.

Figure 7. 'M' Amplitude Vs Path Length Difference for Variable K Factor

H.E. HOLT LOS LINK
FREQUENCY: 7500 MHz
DISTRIBUTION: 31.22 STAT. MILES
TRANSMIT ANTENNA HEIGHT (MSL): 314.5 FT
RECEIVE ANTENNA HEIGHT (MSL): 415-315 FT
TIME DELAY VARIATION: 5-10 NSEC



KEY:

|◄——►| ANTENNA SPACING LESS THAN 66 FEET.

|◄---►| ANTENNA SPACING OVER 66 FEET.

Figure 8. Time Delay Vs Path Length Difference for Variable K Factor

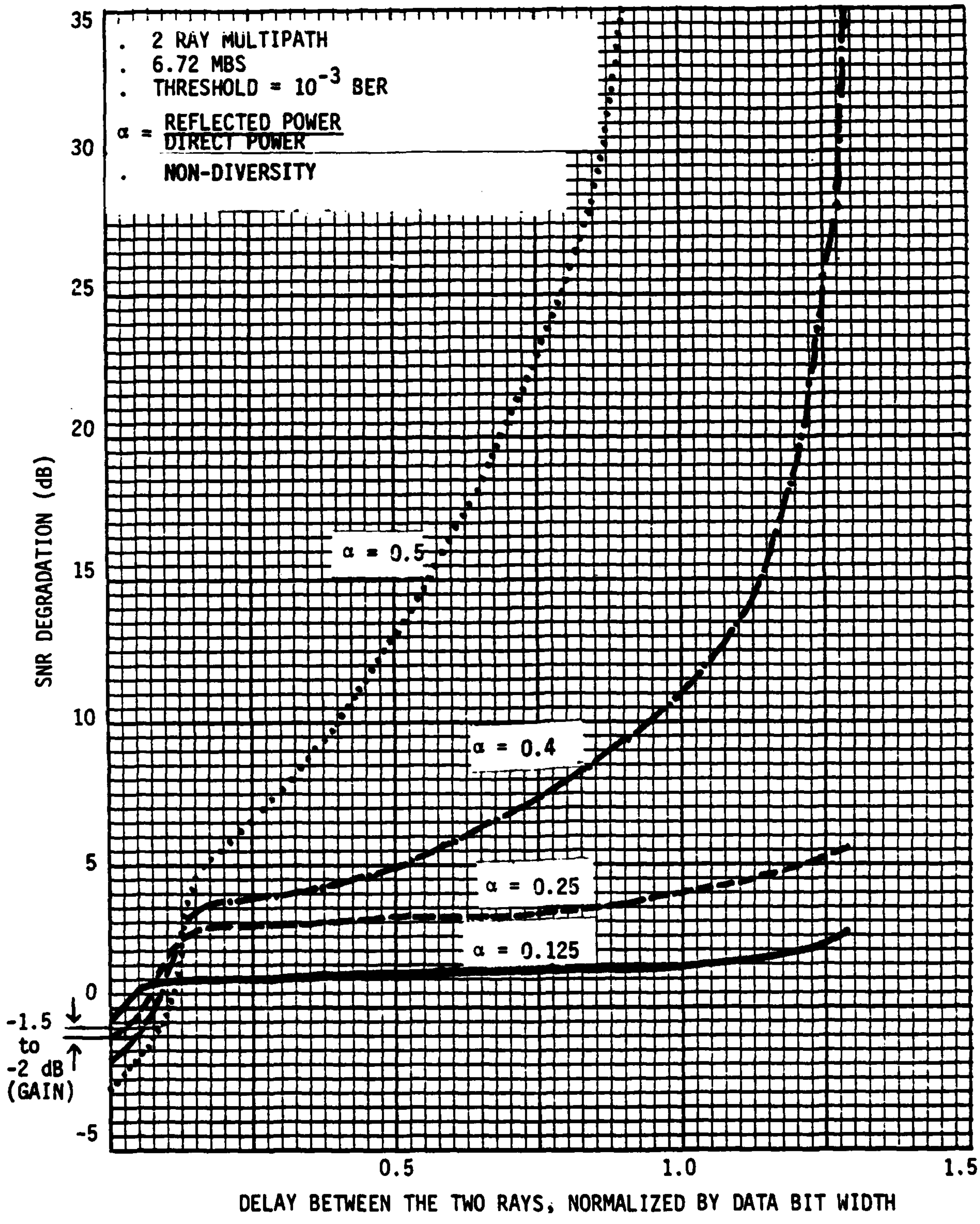


Figure 9. Degradation in SNR VS Delay for Simulation of DRAMA Radio

TABLE II. EXPECTED FREQUENCY SELECTIVE FADING OF H. E. HOLT LOS LINK

RANGE OF K-FACTOR (TABLE I)	FREQUENCY OF OCCURRENCE (TABLE I)	AMPLITUDE RATIO-M (FIG. 7)	POWER RATIO - α (NOTE 1)	TIME DELAY-DTM (FIG. 8)	DELAY IN BIT WIDTHS (NOTES 2&3)	DEGRADATION IN SNR (FIG. 9 & NOTE 4)
1.25-1.35	0.5	0.7	0.49	7.5 nsec	0.05	-1.5 dB
1.25-1.5	0.9	0.73	0.53	8.7 nsec	0.06	-1.7 dB
1.25-1.6	0.999	0.75	0.56	9.3 nsec	0.06	-2 dB
1.25-1.65	0.9999	0.75	0.56	10.0 nsec	0.07	-2 dB

NOTES:
1. $\alpha = M^2$
2. Delay = DTM x Bit Rate (QPR)
3. Bit Rate = 6.72 Mbps
4. Negative degradation equates to improvement in SNR.

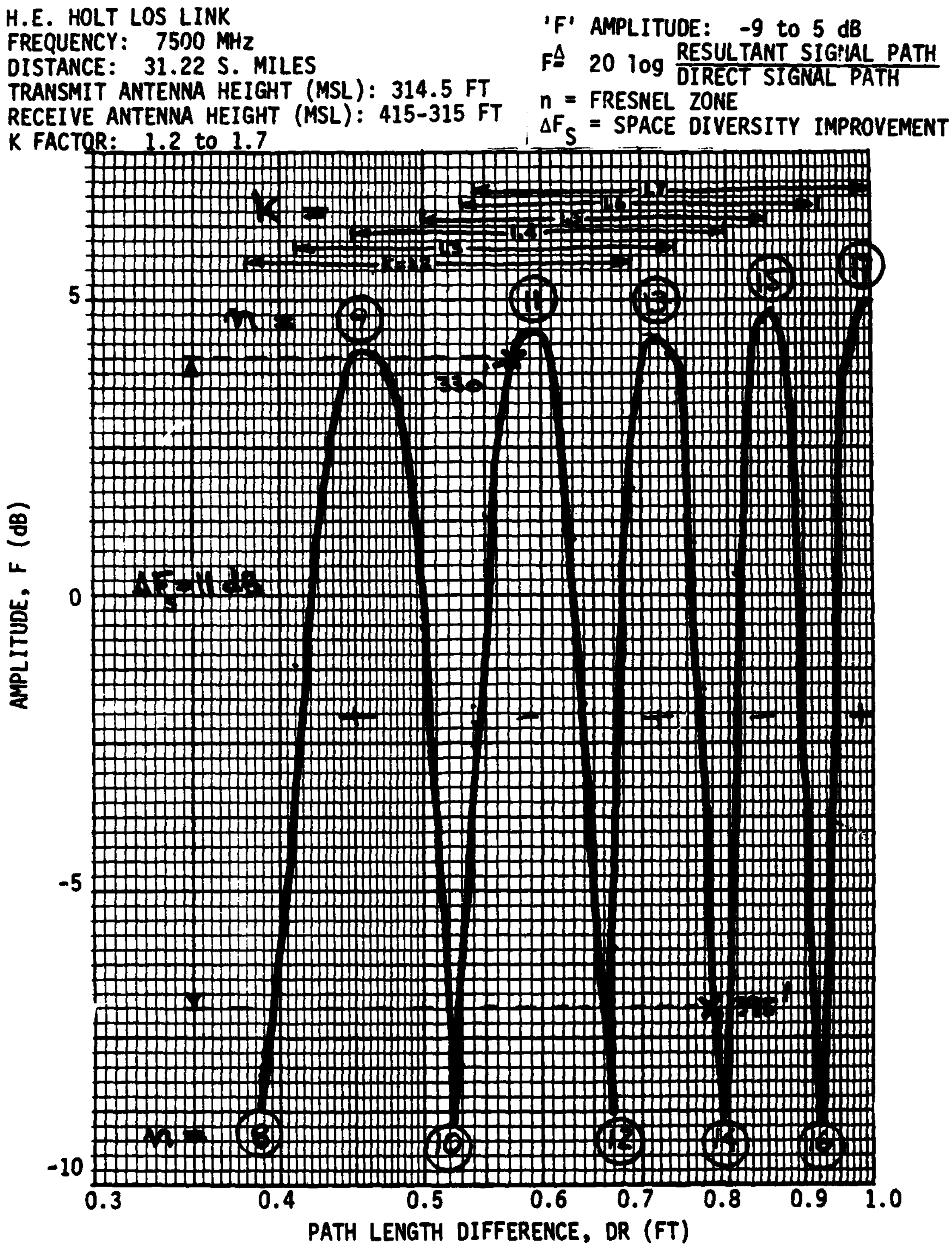


Figure 10. 'F' Amplitude Vs Path Length Difference

characteristic to this coastal area has been identified in the analyis of section II-b. According to the results of this analysis, the magnitude of fading caused by surface ducting (called "attenuation fading" in the study) varied between 5 and 10 dB as measured on either radio path. An example of ducting combined with multipath fading is shown in Figure 11.

f. Predicted Performance Degradation. A summary of the expected degradation in performance of a non-diversity (single) radio path caused by fading is depicted in Table III. The magnitude and corrective action(s) to alleviate such effects are tabulated for each of the major types of fading considered in this section. The 'REMARKS' column further defines each fading in terms of rate and nature of occurrence. Note that recurring deep fades (over 50 dB) caused by a combination of multipath flat fading and ducting have been reported by NAVSEEACT PAC (refer to Figure 11). Such major contributors are analyzed and corrective actions are recommended to combat their effects.

g. Expected Link Performance. Design trade-offs among specific link and digital radio equipment parameters affecting link performance were reviewed in order to alleviate degradation in performance caused by fading, optimize link performance in concert with applicable DCS standards, and minimize cost. Such parameters include type of diversity, antenna type and size, antenna bore angle, length and losses of transmission runs and need for a midpath repeater.

An example of link performance calculations using the DCEC computer program [1] is shown in Figure 12. It is the same as the one forwarded in DCEC preliminary analysis sent to NAVSEEACT PAC on 4 May 1981 (see paragraph II-e.). An actual fade margin of 41 dB is obtained with a dual space diversity configuration using 6 foot parabolic antennae spaced 20 meters (66 feet) apart. The performance of such a link configuration meets the DCS design criteria for digital LOS links specified with a probability that a fade outage duration greater than 5 seconds but less than or equal to 60 seconds be less or equal to 2.64×10^{-5} (i.e., 5.2×10^{-7} x path length, in km). This is representative of the link performance calculations that account for normal multipath fading, average terrain and climate, and standard DRAMA equipment specifications.

A comparison in gain of a periscope antenna (NAVSEEACT PAC proposal) versus a parabolic antenna (DCS standards) is presented in Appendix A. When using low-loss circular waveguides (i.e., WC 166) for the transmission runs, the parabolic antenna provides an additional gain of 3 dB (6 foot) to 8 dB (8 foot) over that of the proposed periscope antenna. Other advantages in utilizing the standard DCS parabolic rather than a periscope antenna include better off-beam discrimination characteristics, less weight, easier alignment, and better digital performance.

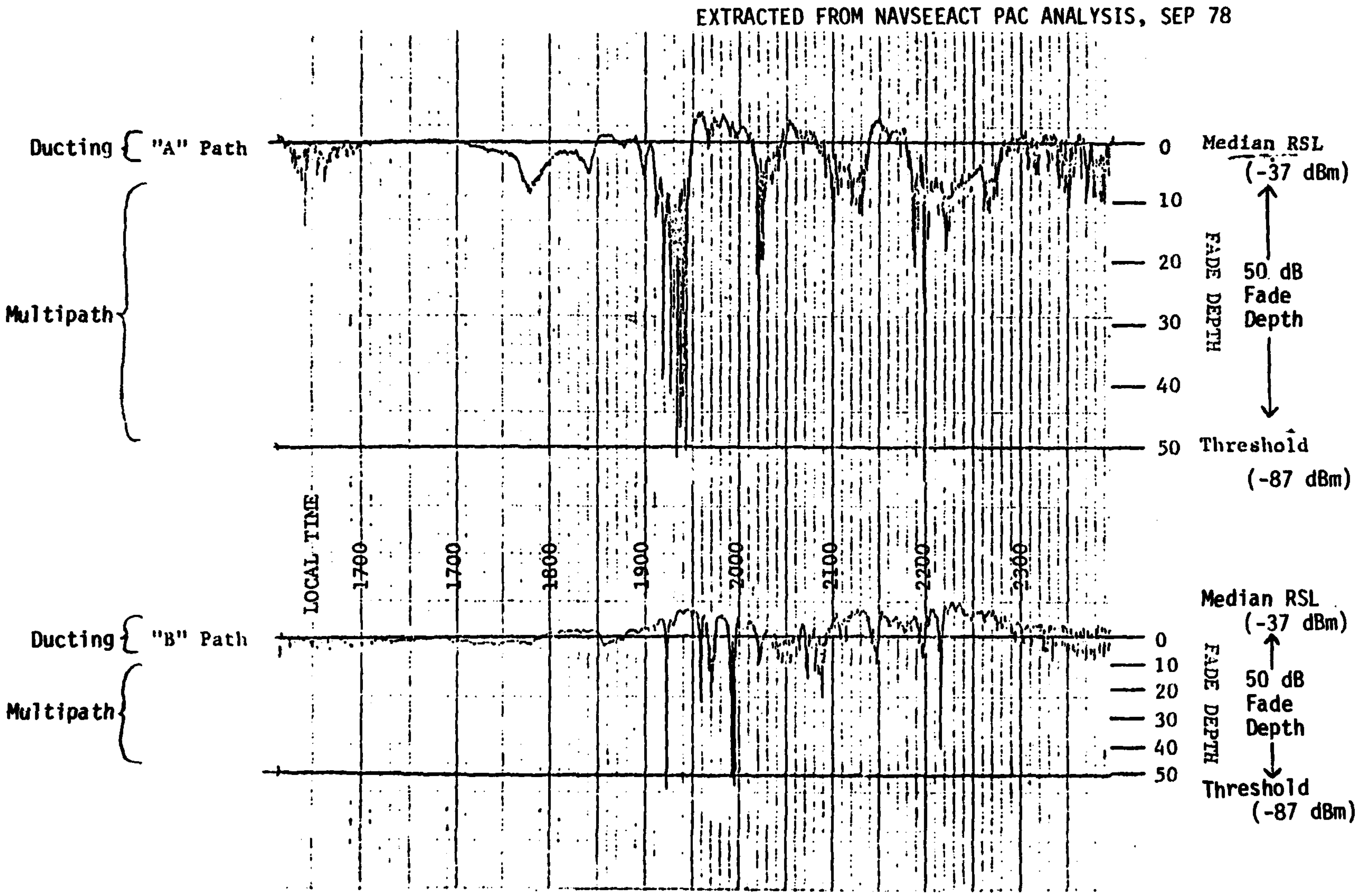


Figure 11. *Example of Multipath Fading Superimposed on Attenuation Fading Affecting Both Paths During September 19, 1977*

TABLE III. SUMMARY OF EXPECTED PERFORMANCE DEGRADATION CAUSED BY FADING NAVCOMMSTA H. E. HOLT DIGITAL LOS LINK

TYPE OF FADING (PREDICTABILITY)	MAGNITUDE[1] (SOURCE)	CORRECTIVE ACTIONS	REMARKS
A. NORMAL			Occurs Often
1. MULTIPATH o Flat (95%) o Freq. Selective (90%)	35-40 dB (NAVSEEACT PAC RPT.) 1.5-2 dB Gain (TABLE II)	Use Freq. or Space Diversity Use Space Diversity and Adaptive Equalization	Highest Rate in April Low Mission Bit Stream
2. OTHERS (90%)	Negligible: 1-2 dB		Include Atmospheric Absorption, Fog and Sand Storm
B. ABNORMAL			Occurs Seldom
1. SUPERREFRACTIVE[2] (50%)	8-9 dB (Figure 10)	Use Freq. or Space Diversity and Tilt Antenna	Multiple Fresnel Zone
2. SURFACE DUCTING (5%)	5-10 dB (Figure 11)	Use Freq. or Space Diversity	Accompanied by Mulipath Fades
3. OTHERS (50%)	Negligible: $\leq$ 1 dB		Include Subrefraction, and Rain Attenuation.

NOTES: 1. Magnitude of Degradation in Performance of a Non-Diversity (Single) Radio Path.

2. Additional losses would be caused by inadequate path clearance for a high/even number of Fresnel zones (refer to Figures 2 to 4).

HFR TO C CTR

FREQUENCY IN GHZ =	7.5000E+00
PATH LENGTH IN KILOMETERS =	5.0800E+01
XMTR ANTENNA HEIGHT ABOVE GROUND IN METERS =	8.3000E+01
XMTR HORIZONTAL XMSN LINE LENGTH IN METERS =	1.5000E+01
TOTAL XMTR XMSN LINE LENGTH IN METERS =	9.8000E+01
XMSN LINE TYPE(RECT=1,ELLIP=2,CIRC=3,COAX=4) IS	3
XMSN LINE LOSS FACTOR IN DB/METER =	2.2000E-02
TOTAL XMTR XMSN LINE LOSS IN DB =	2.1560E+00
RCVR ANTENNA HEIGHT ABOVE GROUND IN METERS =	8.3000E+01
RCVR HORIZONTAL XMSN XMSN LINE LENGTH IN METERS =	1.5000E+01
TOTAL RCVR XMSN LINE LENGTH IN METERS =	9.8000E+01
TOTAL RCVR XMSN LINE LOSS IN DB =	2.1560E+00
LOWER RCVR ANTENNA HEIGHT ABOVE GROUND IN METERS =	6.3000E+01
MEDIAN LOS FREE SPACE LOSS IN DB =	1.4412E+02
TOTAL LOSSES(XMTR & UPPER RCVR ANTENNAS) IN DB =	1.4843E+02
TRANSMITTER POWER IN DBM =	3.3000E+01
RECEIVER NOISE FIGURE IN DB =	1.0000E+01
RECEIVER NOISE DENSITY IN DBM/HZ =	-1.6400E+02
MODULATION BIT RATE IN BITS/SEC =	6.4640E+06
REQUIRED EB/NO IN DB FOR BER = 10**-4 IS	1.4000E+01
THRESHOLD FOR FADED RSL IN DBM =	-8.1895E+01
REQUIRED FADE MARGIN IN DB =	3.3353E+01
FADE MARGIN CORRECTION FACTOR IN DB =	4.9000E+00
CORRECTED FADE MARGIN IN DB =	3.8253E+01
TOTAL LINK MARGIN IN DB =	4.4253E+01
TOTAL ANTENNA GAINS(BOTH ENDS) IN DB =	7.7788E+01
CALCULATED ANTENNA DIAMETER IN METERS =	1.4122E+00
ANTENNA DIAMETER CORRECTION FACTOR =	0
PARABOLIC ANTENNA DIAMETER USED IN METERS =	1.83 ◁
SINGLE ANTENNA GAIN IN DBI =	4.0270E+01
UNFADED RSL IN DBM =	-3.4890E+01
ACTUAL FADE MARGIN IN DB =	4.1005E+01
AVERAGE YEARLY TEMPERATURE IN DEGREES F =	70.00
YEARLY FRACTION THAT IS FADING SEASON IS	3.5000E-01
TERRAIN ROUGHNESS FACTOR(SMOOTH=6,AVERAGE=15,ROUGH=42) IN METERS	IS 6.0
CLIMATE FACTOR(HUMID=2,AVG=1,DRY=0.5) IS	2.0
CLIMATE AND TERRAIN FACTOR =	6.5819E+00
DIVERSITY SWITCH FACTOR =	1.7824E+00
RCVR ANTENNA SEPARATION OR EQUIVALENT IN METERS =	2.0000E+01
DIVERSITY FACTOR IS	4.3060E+03
PROBABILITY RSL IS BELOW THRESHOLD FT =	1.3985E-07
Z(MF,D,F) FACTOR =	3.8661E+00
PROB FADE OUTAGE 5 TO 60 SEC =	5.4067E-07

Figure 12. Digital LOS Path Calculations Using 6 ft Antennas

IV. RECOMMENDED LINK CONFIGURATION

The design alternative recommended for configuration of the NAVCOMMSTA H. E. HOLT digital LOS link is based on providing an optimum link performance through a maximum fade margin, an adequate path clearance and a minimum cost. The design is constrained by existing antenna tower heights, high cost and the need to purchase real estate for the addition of a midpath repeater, by the parameters specified for DRAMA radio equipment, and expected link performance described in section III-g.

The following link configuration is recommended:

a. A dual space diversity with antenna separation of 20 meters (66 feet). For optimum path clearance and maximum space diversity improvement, place the upper antenna at a height of 120 meters (MSL) at HFR and at 90 meters (MSL) at communications center locations. Figure 13 shows the path profile for K = 1.34, a duplication from the preliminary DCEC analysis.

b. Parabolic antenna dishes of 8 feet in diameter at each end location. This will provide an additional 5 dB improvement to the fade margin calculated in Figure 12 (i.e., resultant fade margin of 46 dB).

c. Low-loss circular waveguide to diminish losses of transmission runs. A 6.7 dB (WC 166) gain will be attained by using the circular versus the customarily eliptical waveguide (refer to calculations in Appendix A).

d. Maximum transmitter power output of 2 watts.

e. If necessary, raise the bore angle of the upper antenna at one end (preferably HFR site) by $\approx 0.25^{o}$ to diminish the adverse effects of superrefractive K factor (antenna decoupling), to increase the penetration angle during periods of surface ducting, and to minimize ground reflections. A decrease in signal strength of $\approx$ 1 dB will result from offsetting the antenna bore angle by 0.25^{o}.

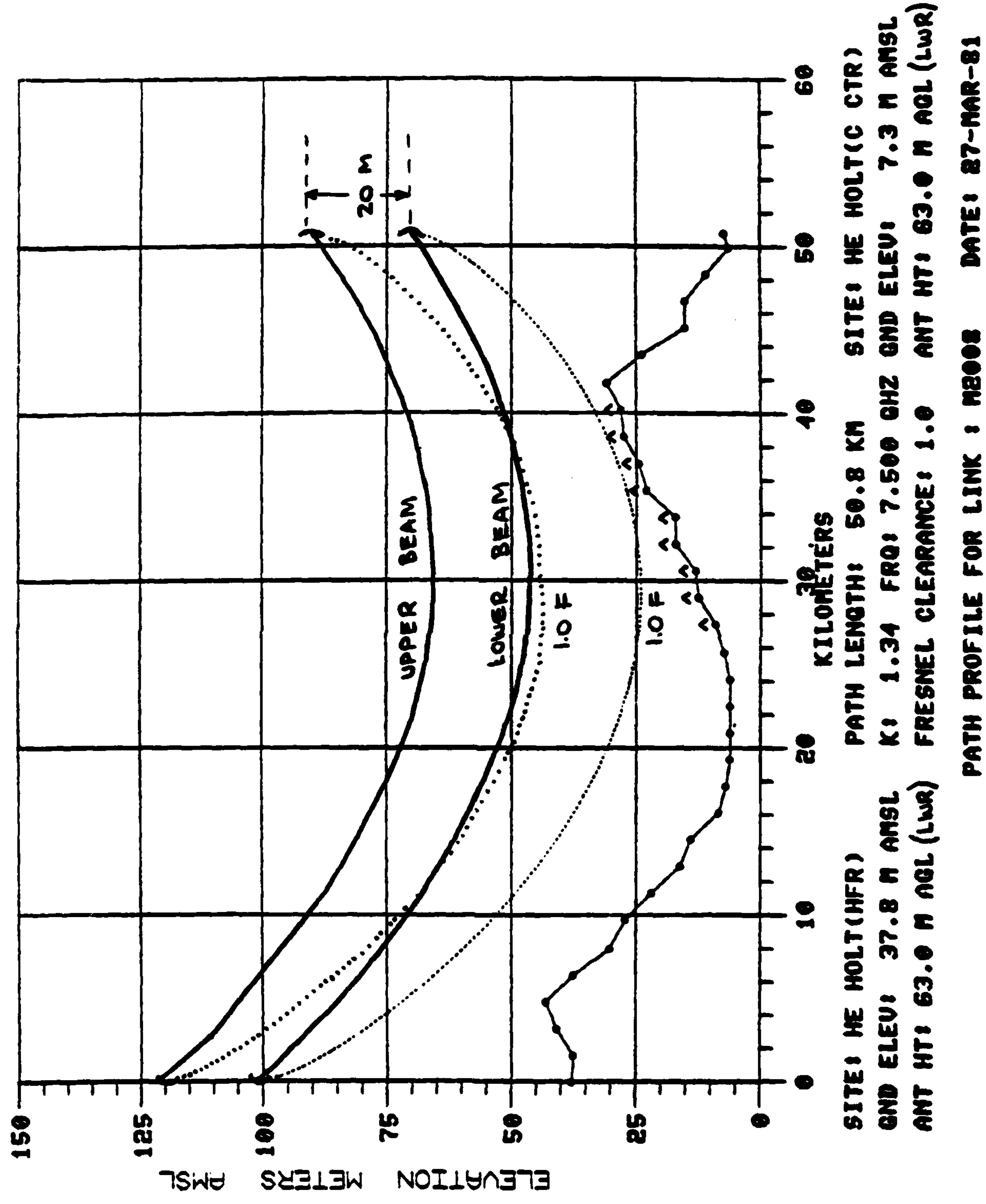


Figure 13. DCEC Proposed Link Configuration

V. CONCLUSIONS

The analysis in this report assesses the performance of the NAVCOMMSTA H. E. HOLT LOS radio link based on the information forwarded by NAVSEEACT PAC. A link configuration is recommended for an optimum performance expected to meet the DCS standards. Such a configuration is based on utilizing existing antenna towers, a parabolic antenna system configured for dual space diversity, and low-loss circular waveguides. Year-round monitoring of the link performance after cutover is indicated to further define severity of combined effects of multipath and surface ducting, particularly during the month of April when these effects are expected to be most pronounced.

REFERENCES

[1] DCEC EP 27-77, "Design Objectives for DCS LOS Digital Radio Links," December 1977.

[2] DCEC, R230, TR 26-81, "Performance Analysis of Digital LOS Link Manila Embassy - Santa Rita, Philippines," December 1981.

APPENDIX A
GAIN COMPARISON BETWEEN A PERISCOPE ANTENNA SYSTEM AND A PARABOLIC ANTENNA SYSTEM

I. INTRODUCTION

This appendix compares the performance of NAVSEEACT PAC proposed periscope antenna system with a parabolic antenna system customarily employed in the DCS. The comparison addresses primarily the gain performance of the two antenna systems, but also addresses other characteristics, such as off-beam discrimination, weight, alignment procedures and digital performance. The conclusions derived in this analysis are considered in the design of the recommended link configuration for the NAVCOMMSTA H. E. HOLT digital LOS link.

II. PERISCOPE ANTENNA SYSTEM

The antenna system configuration proposed by NAVSEEACT PAC for the subject link is shown in Figure 1. This is very similar to the present antenna configuration, where the same reflectors are utilized with two smaller, lower parabolic antennae (8 ft instead of the existing 10 ft dishes) and the addition of two new higher parabolic antennae (also 8 ft in diameter). Following is a calculation of the total antenna gain based on the configuration shown in Figure 1 and the applicable technical guidance of reference [1].

1. NEAR FIELD RADIUS

The near field radius, r, is obtained as follows:

$$r = \frac{2\,D^2}{\lambda} = \frac{2\,(8)^2}{.132} = 969.7 \text{ ft.}$$

Since both distances to the reflectors are smaller than r (i.e., d_A, d_B < r), the passive reflectors are in the "near field".

2. PROJECTED AREA OF REFLECTORS

The geometry of a typical periscope antenna system is shown in Figure 2. The projected area (a2) of a reflector (A) is given by:

$$a_i^2 = A_i \sin \frac{\theta_i}{2}.$$

At terminal A:

$$a_A^2 = A_A \sin \frac{\theta_A}{2} = 96 \sin 45^0 = 67.88$$

$$a_A = \sqrt{67.88} = 8.24 \text{ ft.}$$

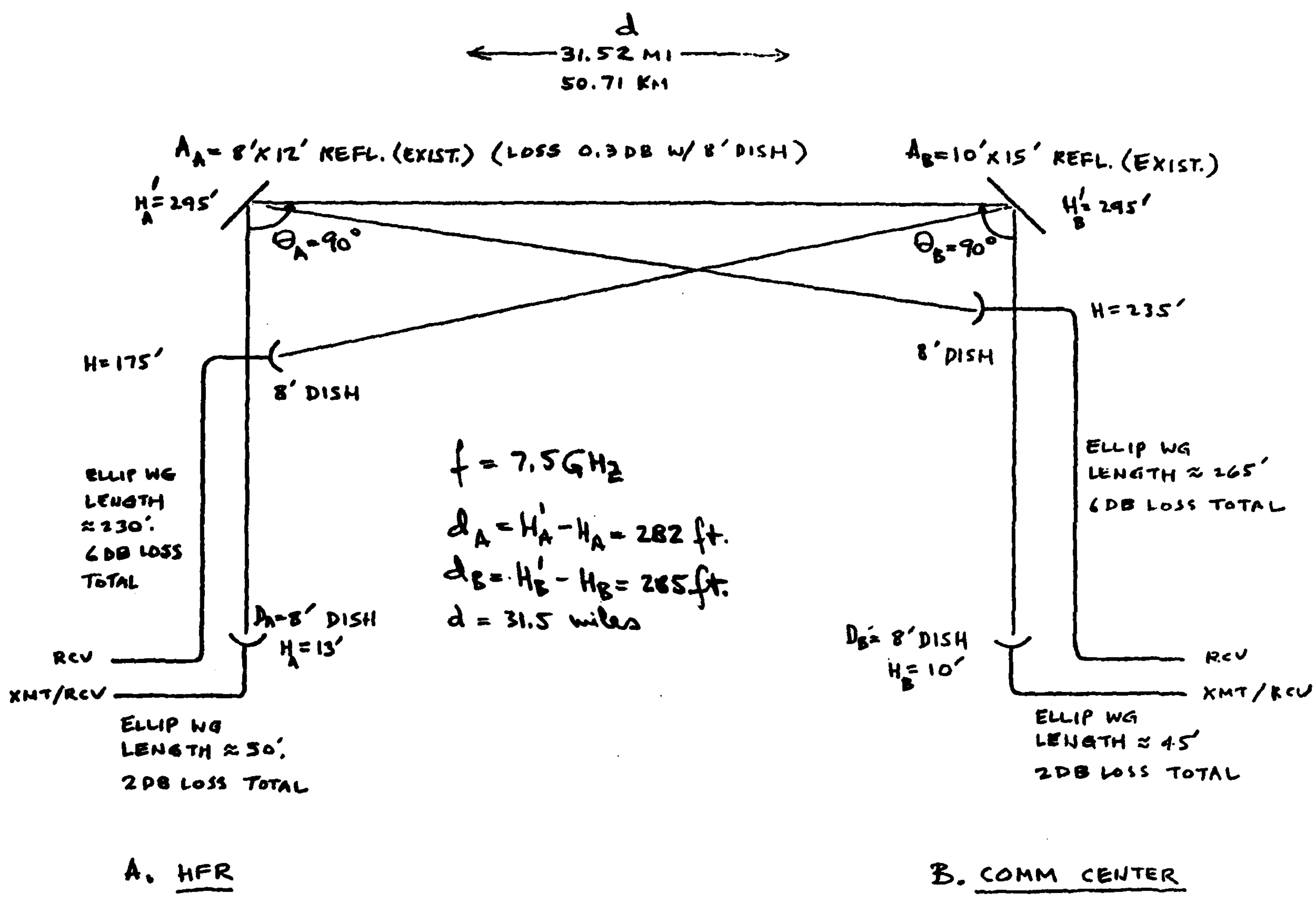


Figure 1. NAVSEEACT Proposed Configuration Without Repeater (Space Diversity)

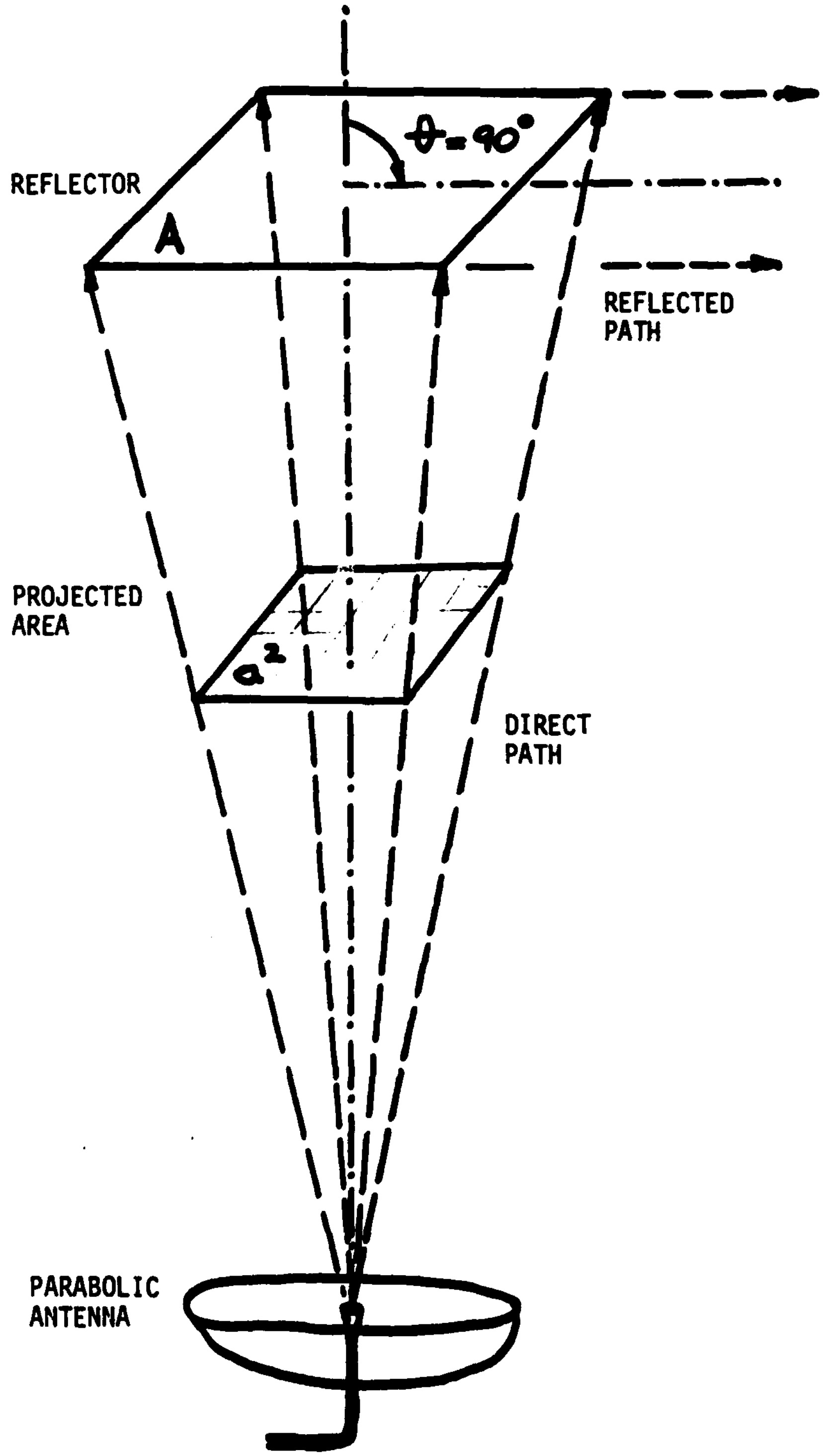


Figure 2. Geometry of a Periscope Antenna System

At B:

$$a_B^2 = A_B \sin \frac{\theta_B}{2} = 150 \sin 45^o = 106.09$$

$$a_B = \sqrt{106.09} = 10.3 \text{ ft.}$$

3. EFFICIENCY OF PASSIVE REFLECTORS

The efficiency curves of a periscope antenna is shown in Figure 3. Calculations of the parameters required at each end location is as follows:

At A:

$$\frac{1}{K_A} = \frac{\pi \lambda d_A}{4 a_A^2} = \frac{3.14 (.132) 282}{4 (67.88)} = 0.43$$

$$L_A = D_A\sqrt{\frac{\pi}{a_A^2}} = 8\sqrt{\frac{3.14}{67.88}} = 1.72$$

At B:

$$\frac{1}{K_B} = \frac{\pi \lambda d_B}{4 a_B^2} = \frac{3.14 (.132) 285}{4 (106.09)} = 0.28$$

$$L_B = D_B\sqrt{\frac{\pi}{a_B^2}} = 8 \sqrt{\frac{3.14}{106.09}} = 1.38.$$

Using these values in Figure 3, the following relative gains are extrapolated:

$$G_A' = -7 \text{ dB}$$

$$G_B' = -3.2 \text{ dB}.$$

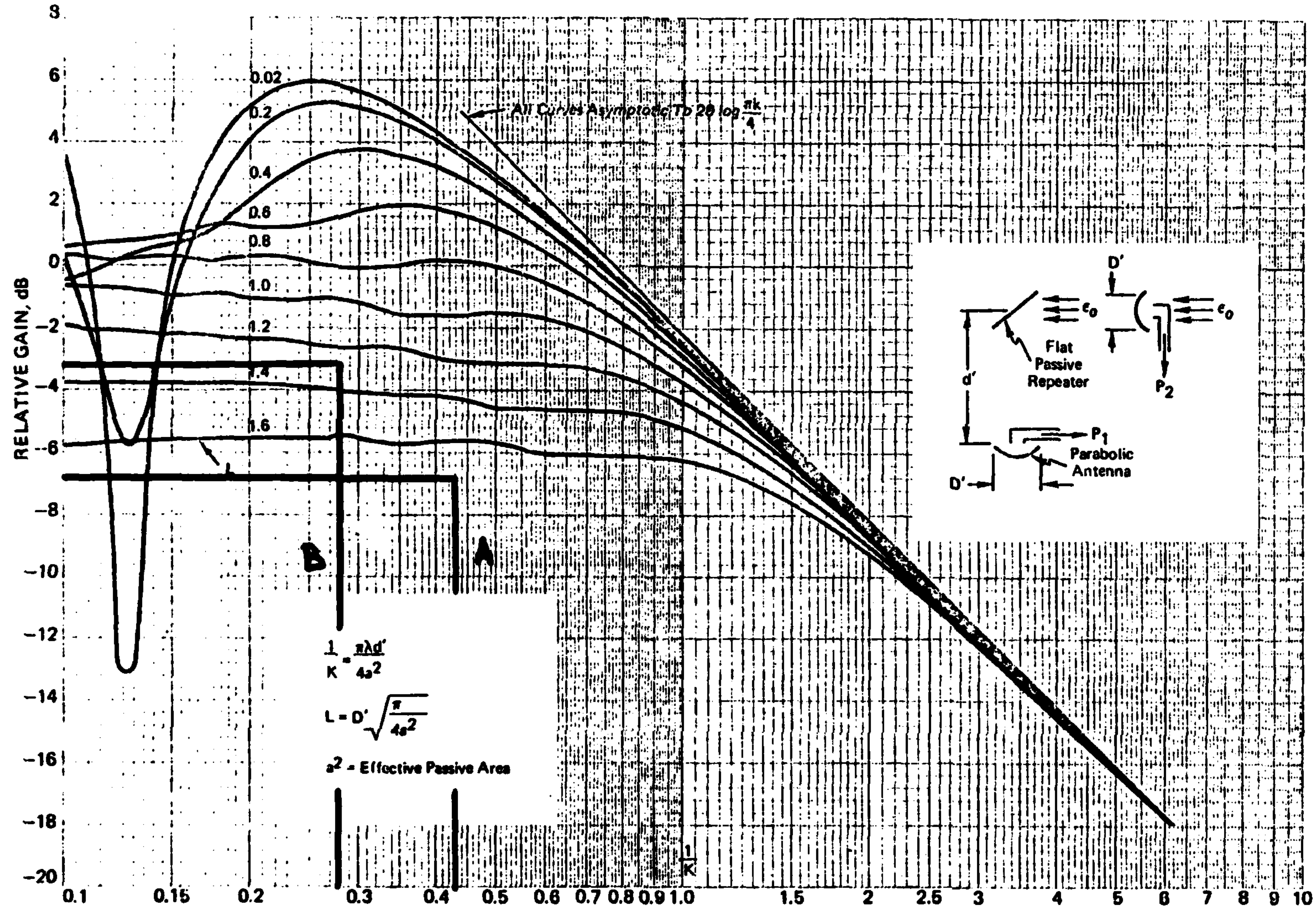


Figure 3 · Antenna-Reflector Efficiency Curves

4. GAIN OF PERISCOPE ANTENNA

Considering the effects of the "near field" from above, the following gains are calculated:

At location A, the antenna gain (G_A) is derived graphically from Figure 4 as follows:

$$G_A = 41.4 - 7 = 34.4 \text{ dBi.}$$

Similarly, at location B with reference to Figure 5:

$$G_B = 42.4 - 3.2 = 39.2 \text{ dBi.}$$

The total antenna gain is obtained by addition of the two gains for:

$$G_A + G_B = 34.4 + 39.2 = 73.6 \text{ dBi.}$$

III. PARABOLIC ANTENNA SYSTEM

The gains of DCS standard 6 and 8 foot parabolic antennae are calculated in conjunction with the additional transmission line losses required for locating a parabolic antenna at the same height as the existing reflectors (i.e., 295 feet, as shown in Figure 1).

1. ANTENNA GAIN

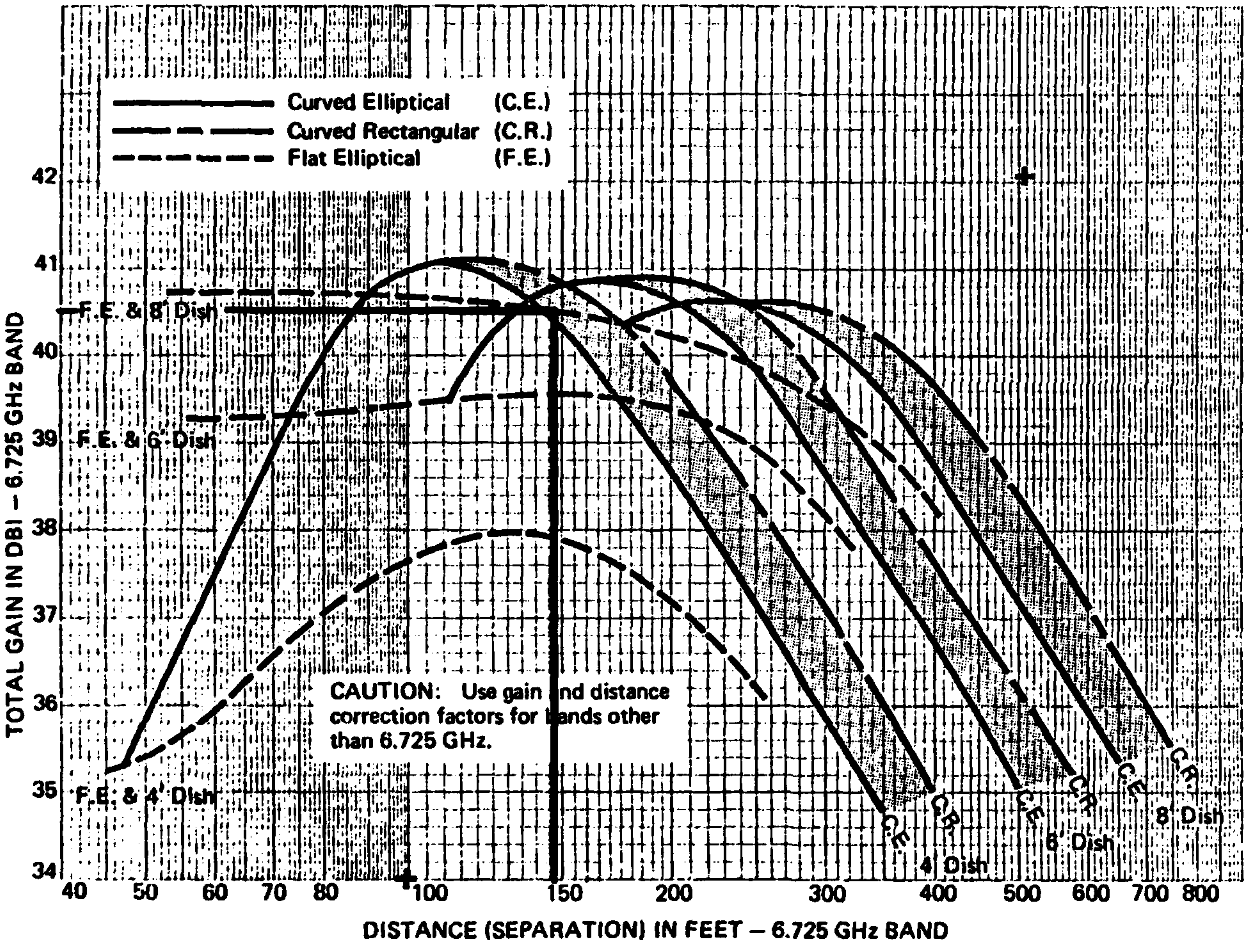
The gains of parabolic antennae with diameters of 6 feet (1.83 m) and 8 feet (2.44 m) are obtained from the family of gain curves shown in Figure 6. They are:

$$G_1 = 40.3 \text{ dBi (6 ft)}$$

$$G_2 = 42.8 \text{ dBi (8 ft).}$$

2. TRANSMISSION LINE LOSSES

The transmission line losses for an antenna configuration where the existing reflectors are replaced with parabolic antennae (reference to Figure 1) are calculated for both elliptical and circular waveguides. The waveguide attenuation is obtained from Figure 7.



Band GHz	Gain Factor	Distance Factor
1.92	−10.8	3.50
2.15	− 9.9	3.13
3.95	− 4.6	1.70
4.7	− 3.1	1.43
6.175	− 0.7	1.09
6.725	—	—
7.0	+ 0.4	.96
→7.437	+ 0.9	.91
8.0	+ 1.5	.84
11.2	+ 4.5	.60
12.45	+ 5.4	.54
14.8	+ 6.9	.46

True Gain = Chart Gain + G Factor

True Dist. = Chart Dist. / Dist. Fact.

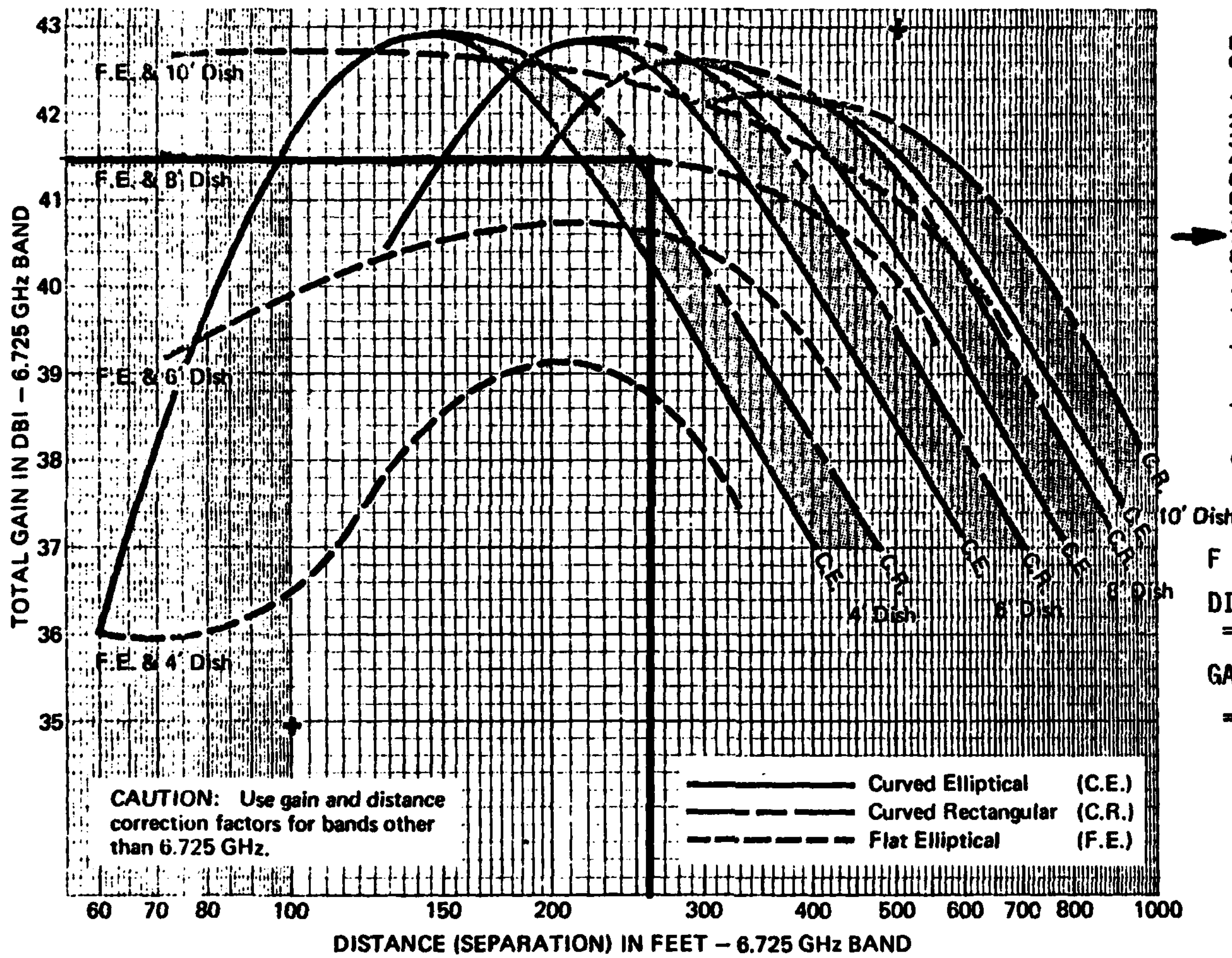
Chart Dist. = True Dist. x Dist. Factor

F = 7.5 GHz

DIST. = 162(.91)
= 147[1]

$GAIN_A$ = 40.5 + .9
= 41.4 dBi

Figure 4. Periscope Gain Curves for 8'x12' Reflectors



Band GHz	Gain Factor	Distance Factor
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8.0	+ 1.5	.84
11.2	+ 4.5	.60
12.45	+ 5.4	.54
14.8	+ 6.9	.46

True Gain = Chart Gain + G Factor

True Dist. = $\frac{\text{Chart Dist.}}{\text{Dist. Fact.}}$

Chart Dist. = True Dist. x Dist. Factor

F = 7.5 GHz

DIST. = 285(.91)
= 259[1]

$GAIN_B$ = 41.5 + 0.9
= 42.4 dBi

Figure 5. Periscope Gain Curves for 10'x15' Reflectors

D_1 = 6 ft = 1.83 m

D_2 = 8 ft = 2.44 m

f = 7500 MHz

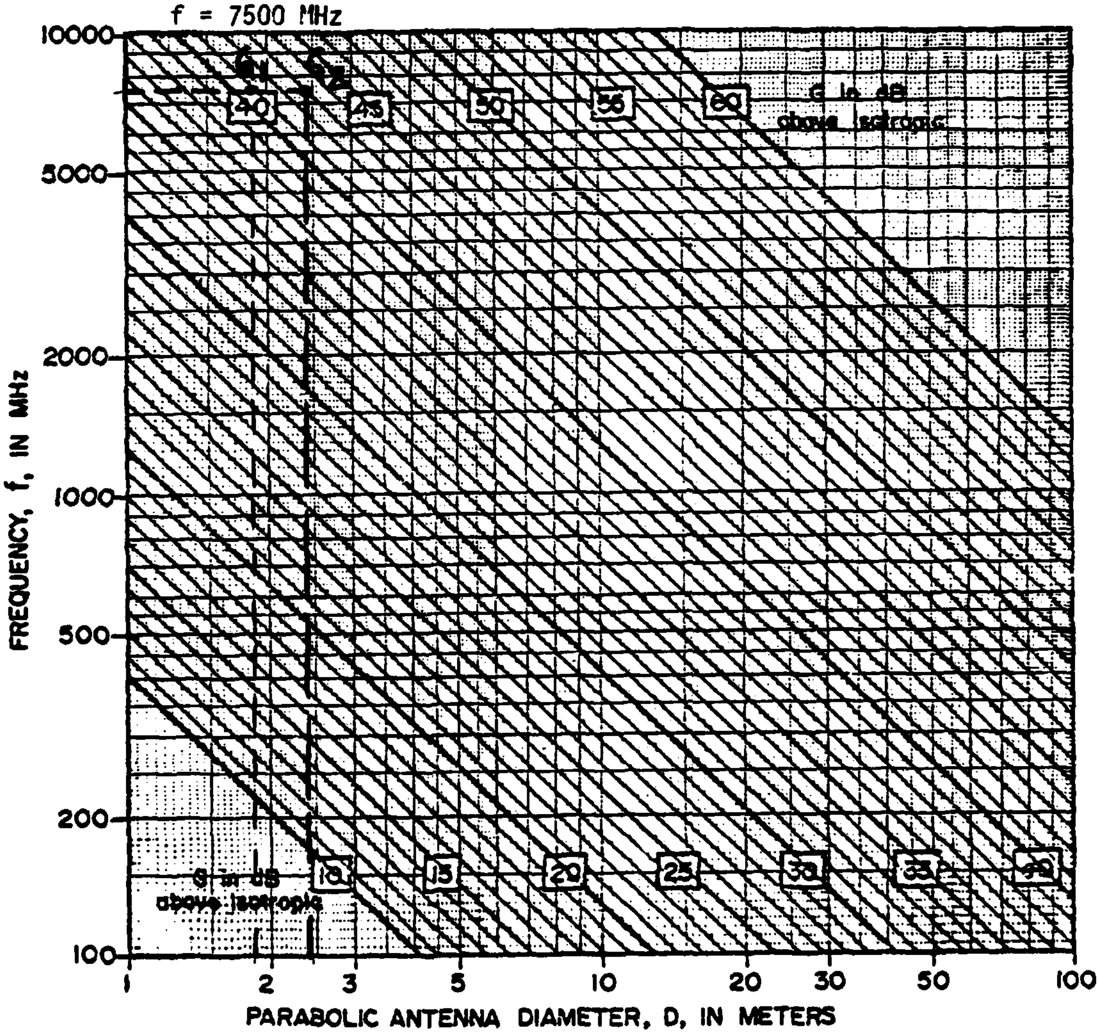

Figure 6. Free-Space Parabolic Antenna Gain, G, as a Function of Antenna Diameter and Frequency

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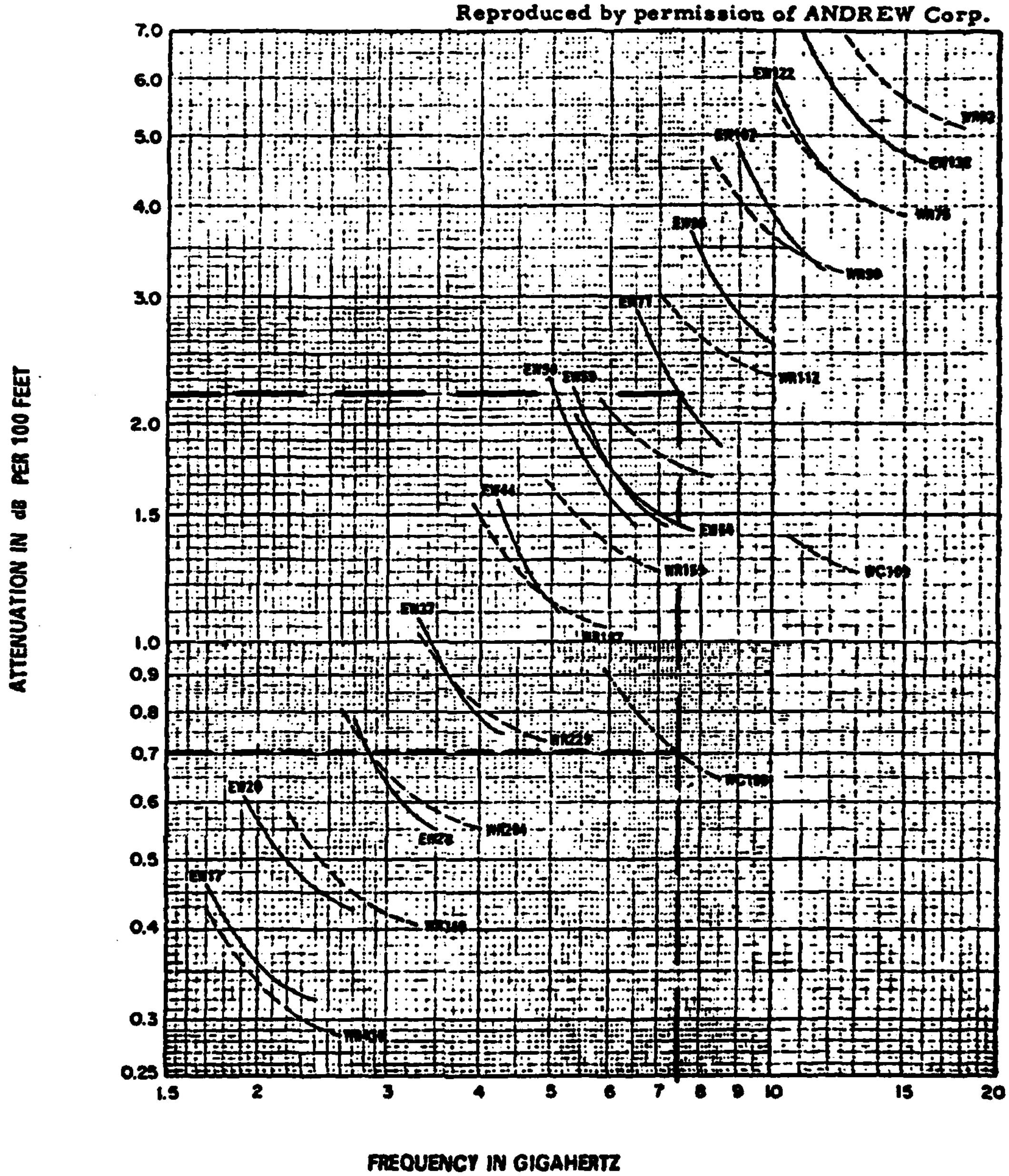

Attenuation curves based on:
VSWR 1.0
Ambient Temperature 24° C (75° F)

Conversion Data:
1 dB/100 feet = 3.28 dB/100 meters

Figure 7. Microwave Waveguide Attenuation

For elliptical waveguide (EW 71):

$$L_{A_{EW}} = (282 \text{ ft} \times 2.2 \text{ dB/ft}) \div 100 = 6.2 \text{ dB}$$

$$L_{B_{EW}} = (285 \text{ ft} \times 2.2 \text{ dB/ft}) \div 100 = 6.27 \text{ dB}$$

$$L_{EW} = L_{A_{EW}} + L_{B_{EW}} = 6.2 + 6.27 = 12.47 \text{ dB.}$$

For circular waveguide (WC 166):

$$L_{A_{CW}} = \frac{282 \times 0.7}{100} = 1.97 \text{ dB}$$

$$L_{B_{CW}} = \frac{285 \times 0.7}{100} = 2.0 \text{ dB}$$

$$L_{CW} = 1.97 + 2 = 3.97 \text{ dB.}$$

The difference between the two types of waveguides is:

$$L_{EW} - L_{CW} = 12.47 - 3.97 = 8.5 \text{ dB.}$$

3. TOTAL GAIN

The total gain of a parabolic antenna system is obtained by the addition of the antenna gain and transmission line losses at both end locations.

For a 6 ft antenna and circular waveguide the total gain is:

$$2 \times 40.3 - 1.97 - 2 = 76.63 \text{ dB.}$$

For a 8 ft antenna and circular waveguide the total gain is:

$$2 \times 42.8 - 1.97 - 2 = 81.63 \text{ dB.}$$

The difference in gain between the two sizes of antennae is 5 dB.

IV. COMPARISON IN GAIN PERFORMANCE

The advantage in gain of the parabolic antenna system in comparison with the periscope antenna system is obtained by substracting the results of section II-4 from the ones of section III-3.

For 6 ft antenna and circular waveguide, the gain advantage is:

$$\Delta_6 = 76.6 - 73.6 = 3 \text{ dB.}$$

For 8 ft antenna and circular waveguide, the gain advantage is:

$$\Delta_8 = 81.6 - 73.6 = 8 \text{ dB.}$$

V. OTHER ADVANTAGES OF PARABOLIC ANTENNA SYSTEM

In addition to the better gain performance attained with the parabolic antenna system, the following additional advantages can be realized in comparison with the periscope antenna system (explanations are provided in reference [1]:

1. Better off-beam discrimination characteristics.

2. Less weight and easier to align.

3. Better digital performance due to diminished potential for "sneak" echo during superrefractive conditions.

4. Lower acquisition and installation costs.

REFERENCES

[1] GTE Lenkurt Inc., "Engineering Considerations for Microwave Communications Systems", 1975.

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