

CHAPTER 6

TROPOSPHERIC SCATTER SYSTEM PLANNING

This chapter provides a systematic approach to the various problems involved in planning tropospheric scatter microwave communications systems. The basic concept of systems planning, as advanced in this chapter, is divided into several categories. Each category is organized in a logical fashion to describe the various tasks involved. The major tasks are presented in such a manner that each task presents information that must be considered in the development of succeeding tasks.

In the preliminary planning stages, the systems planner lays the groundwork for the proposed system. Investigations are conducted to determine the locations that must be connected by the particular system, the number and type of communications circuits required between the various locations, and the possible need for interconnecting the system with existing communications facilities. Based on the data compiled, a preliminary system plan and a channelization diagram showing the general system configuration and traffic pattern are prepared. These diagrams, although tentative in nature, show the basic system requirements and serve as a basis for the overall system plan.

The preliminary system plan indicates the geographic locations that are to be linked by the proposed microwave system. The next planning phase, that of route engineering, is concerned primarily with microwave path evaluation and site selection within the area to be served. The tasks involved comprise those required to establish suitable transmission paths between the important system locations, and to select sites for the installation of the required microwave terminal and repeater stations. Feasibility path loss calculations, together with the initiation of the BESEP (The Base Electronics System Engineering Plan) is also presented. An appendix will contain feasibility design data sheets with required equations. This chapter will provide a numerical example of the calculations.

6.1 CHARACTERISTICS OF TROPOSPHERIC SCATTER SYSTEMS

The dominant characteristic of tropospheric radio systems is the large, widely varying attenuation encountered in the propagation of microwave signals beyond the horizon. The magnitude of the attenuation is such that high system gain must be provided for successful wideband transmission; hence, the most obvious features of tropospheric radio stations - the large antennas. In addition to such outwardly apparent features, there are the transmitters capable of high power outputs at microwave frequencies and the highly sensitive and selective receiving systems. Besides the physically apparent features, there is the almost exclusive use of

frequency modulation (FM), to provide high quality performance with respect to effective noise reduction. The rapid, wide variations in attenuation necessitate a diversity of radio paths for the satisfactory reception of the desired signal; therefore, a multiplicity of similar equipment is used at most tropospheric radio stations.

Tropospheric scatter is only one of the several mechanisms of beyond-the-horizon microwave propagation. The other mechanisms result from diffraction and are classified in accordance with the terrain over which the diffraction takes place. Thus, there is knife-edged diffraction, diffraction over rounded obstacles, diffraction over rough terrain, etc. Since there is no sharp, static dividing line between tropospheric scatter and the diffraction modes - often there is a combination of mechanisms - and since the same type of equipment is required in each of the mechanisms, tropospheric radio system engineering generally encompasses all beyond-the-horizon microwave hops.

The antennas used in tropospheric radio systems consist of a feed element (usually a horn) and a parabolic reflector. The diameters of the reflectors range from 10 feet to 120 feet. The smaller antennas - up to 20 feet or so, are seldom used in strategic systems, where the installations are generally of a fixed-plant nature; they are more appropriate for tactical installations where mobility is the prime consideration. Antennas with diameters of 30 to 60 feet are used for the average tropospheric radio hop. The massive 120-foot antennas are used only on the most difficult hops. The feeder systems associated with the antennas use high quality waveguide.

The transmitters, designed specifically for tropospheric radio systems, have final power amplifiers whose average power outputs range from 500 watts to 100 kilowatts. Lower power outputs are available, but have little use in beyond-the-horizon transmission because of the high attenuations encountered. The input power requirements of the higher power amplifiers are large; consequently, high capacity primary power sources are required.

The receivers used in tropospheric radio systems are specially designed to provide high quality performance with low-level input signals. They have noise figures of only 8 to 14 dB. The receiver noise figures are often reduced to as low as 2 to 5 dB, depending upon frequency, by the use of tunnel-diode or parametric amplifiers. The pass-bands of the receivers are specially designed to produce low levels of intermodulation distortion in the complex wideband signals resulting from multichannel modulation. Diversity reception is always used in high grade tropospheric radio systems to level off the wide amplitude variations produced in the received signal by the variations in path attenuation. Successful diversity operation requires separate transmission paths, which are usually achieved through the use of multiple carrier frequencies and properly spaced multiple receiving antennas. Sophisticated combining schemes provide the maximum advantage from diversity reception.

6.2 INITIAL PLANNING

Planning functions include definition of the communication requirement, system concept, system trunking and routing, frequency considerations, support functions and manpower training requirements, project management, preliminary implementation schedule, and budgetary cost estimate. The planning functions are presented in a logical sequence for task accomplishment and to facilitate the preparation of documentation required at various stages of the system development. These activities are summarized in table 6-1.

Table 6-1. The Planner's Activities

ITEM NO.	ACTIVITY	COMMENT
1	Development of Requirements	This may be a formal procedure documented in a staff study. It may be informal and be documented in memo form. As the need crystalizes, the planner finds himself required to respond as to his solution to the problems.
2	Establishment of a Basic Concept	Early work in concept development is typically at a level indicated by Figure 4-4.
3	Detailing the Plan	Basic Information that must be Generated: Trunking and Routing Plan Map Studies Preliminary Site Survey Results Support Requirements Frequency Plan

The initial step in establishing system parameters is the interpretation and translation of the basic communication need into a realistic and feasible definition of the system requirement. This initial step is provided by a concise statement of the items developed in table 5-2 which provide an analysis and substantiation of the requirement. The analysis must necessarily consider the merits of competitive approaches. If, for example, a partially completed line-of-sight microwave system can be extended and updated more economically to do an equivalent task, the planner is required to recommend that this alternative be considered. Figure 5-1 illustrates in graphic fashion the factors considered and the courses of action to which they may lead.

During this initial phase of the project definition, broad guidance is needed to permit the planner to rapidly determine appropriate transmission means, taking into consideration, distance and the number of channels required. It is possible, for example, to use cable for carrying messages between terminals whatever the distance of separation of the two terminals involved. Further, more than one line-of-sight hop may be used in place of a single tropo hop.

When the requirements have been analyzed and defined, a system concept is developed that will meet the needs of the prospective communications users. The factors that must be considered and the steps to be followed in the establishing of the concept are shown in foldout 5-1.

The system concept in the planning stage is sufficiently simple that it may be depicted in a single line drawing on which all known information is noted. Figure 6-1 shows one possible presentation of the system concept. Large size drawings of this type are often made for planning purposes utilizing "flip-on" acetate information strips to indicate alternate concepts.

The feasibility survey which follows the development of a preliminary system concept considers such questions as whether Town A or a nearby Town E is the most appropriate choice, and whether there are reasons why any one of the major hops might be impractical. Thus, if for political or other reasons, there were no suitable radio site in City B, the alternate choice might make the link to Headquarters Location Town E, impractically long, requiring a two-hop link and the location of an additional site in the system.

6.2.1 Preliminary System Configuration

The steps in developing the preliminary system configuration and the resulting output documentation are provided in the following paragraphs.

The first step in preliminary system planning is to develop a system trunking plan based on approved user requirements. Such a system trunking plan will provide, in line diagram form, a layout of system channelization requirements and termination locations. The steps involved in developing a trunking plan are best illustrated by example. Figure 6-2 is a geographical plan of a sample system and table 6-2 presents its circuit requirements. Both voice and teletype requirements are included. The teletype requirements are also translated into equivalent voice channel requirements on the basis of multiplexing 16 teletype channels into 1 voice channel.

The system routing plan is based on the trunking plan and provides the system layout in terms of a definitive system configuration. The objective of the system layout analysis at this phase of systems planning is to determine the feasibility of installing a tropospheric radio link between two or more terminal locations and not necessarily to establish the final route of the system. Where it is apparent that

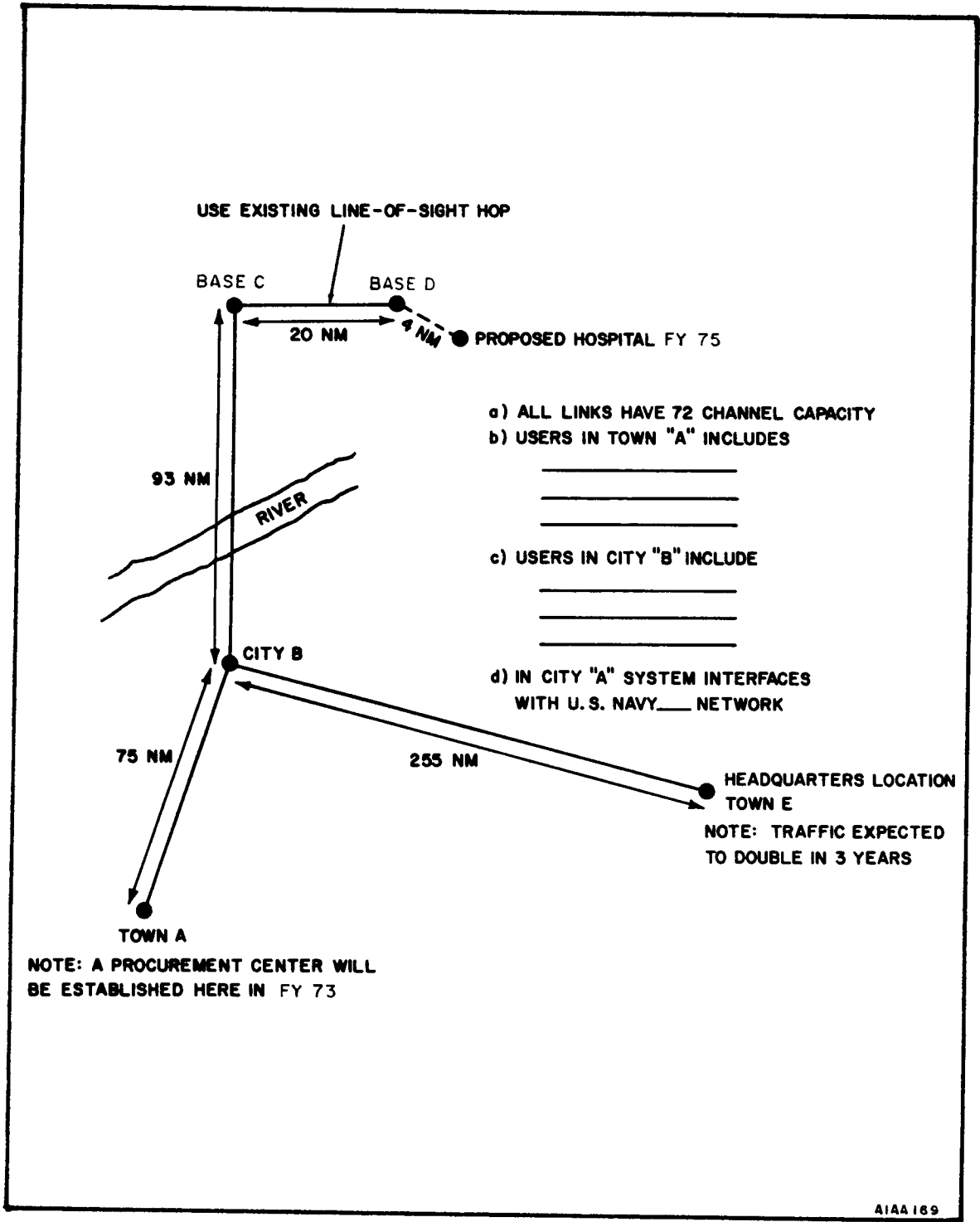


Figure 6-1. Initial System Concept, Typical

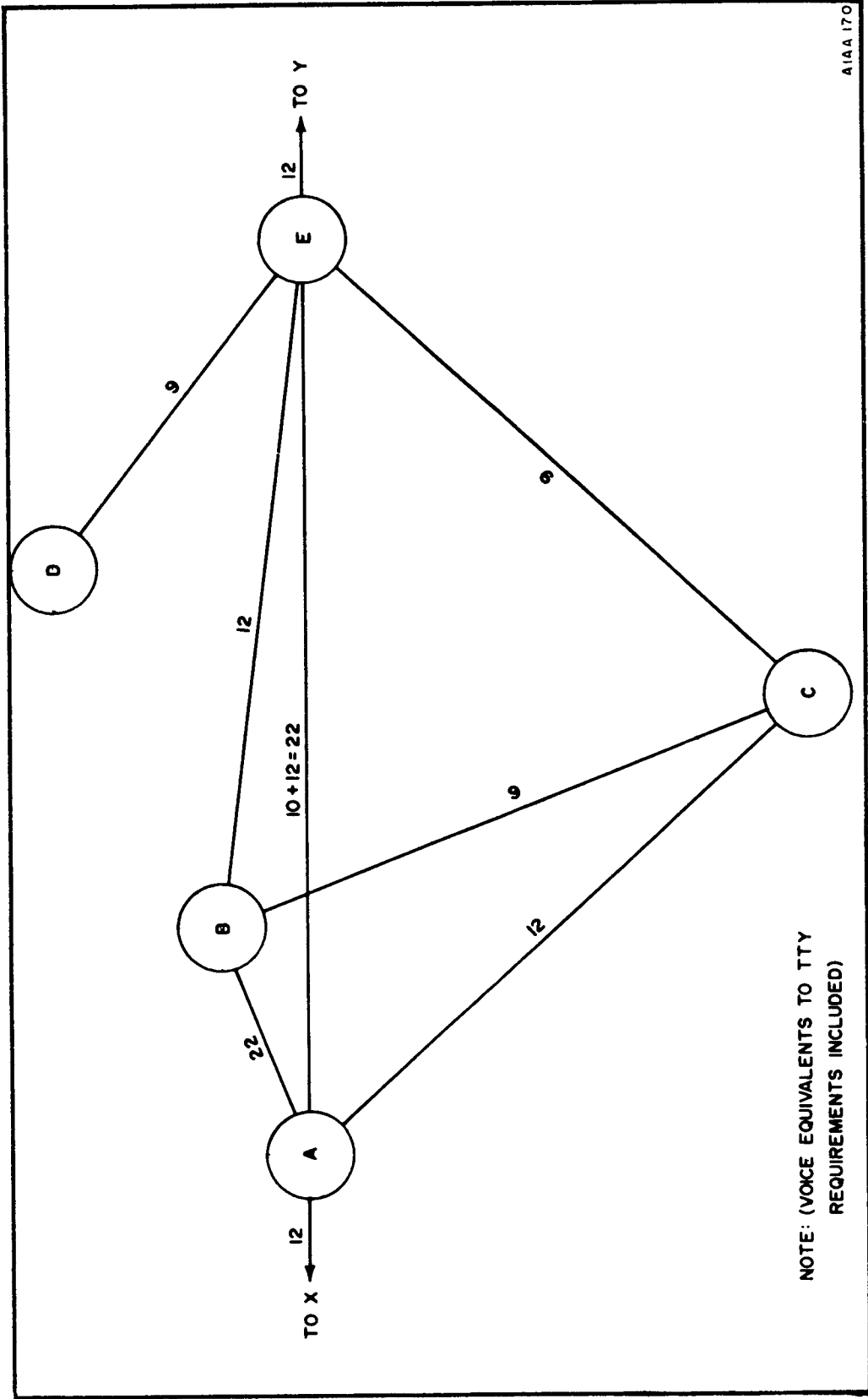


Figure 6-2. System Circuits Requirements, Sample

Table 6-2. Sample Circuit Requirements

BETWEEN STATIONS	VOICE	TELETYPE	VOICE EQUIVALENT TO TELETYPE*	TOTAL VOICE
A and B	20	30	2	22
A and C	10	24	2	12
A and E	9	12	1	10
X and Y	11	16	1	12
B and C	8	12	1	9
B and E	11	12	1	12
C and E	7	26	2	9
D and E	8	8	1	9

*1 voice channel can carry up to 16 teletype channels

certain stations will have to be located some distance from existing U. S. Military facilities the requirements for auxiliary systems and construction should be determined to a sufficient degree for approximating overall systems costs.

It is not practical at the planning level to finalize the location of all the sites of a system, because the precise site selections depend largely on the results of the definitive systems engineering described in chapter 8. For purposes of costing and other preliminary planning aspects, however, system planning groups must determine tentative terminal locations and the need for intermediate stations. Systems engineering assistance should be sought in carrying out this task. A simplified system engineering procedure is given which will enable systems engineers to make rapid determinations of the factors involved in site selection as well as other facets of system configuration.

6.2.2 Preliminary Siting of Terminals

A map survey is necessary in planning and selecting sites which offer the most promising technical and logistical possibilities. Careful analysis of maps that provide reliable topographical data will save much time and effort in the field.

From map surveys it is possible to evaluate potential sites and to determine those to be visited by the field team. One or more alternate sites will be selected for each terminal or relay facility. The criteria for map acquisition and study is outlined in chapter 2.

After obtaining the appropriate maps, the locations of the users are plotted. Insofar as practical, the terminal stations of the tropospheric radio system are located in close proximity to the ultimate users. In many instances this will not be feasible and a connecting link of wire line and/or line-of-sight radio will be required. For example, where the user is located in a city or town or where for other reasons adequate space does not exist, the tropospheric radio terminal will necessarily be removed to a different location. Furthermore, the collocation of the terminal sites with the user will frequently severely limit the site selection so as to preclude taking advantage of terrain features conducive to tropospheric radio propagation. The factors which will determine the adequacy of a tropospheric radio site are covered in the following subparagraphs. While all of the factors listed may influence the selection of a site, they cannot be considered to have equal weight; therefore, several sites should be evaluated in terms of relative merits.

a. The topography of the area surrounding the site affects several factors, such as, antenna height, the support of the site, the cost of construction of the buildings required, etc. The terrain should be fairly level to aid in location of antenna foundations and waveguide runs. However, many compromises will have to be resolved; the first being a balance between a good communications location and a good location in terms of cost of construction and logistic support.

b. The take-off angle of the radio beam from each antenna is a factor of primary importance in tropospheric radio systems. This is the angle between a horizontal line extending from the radiation center of the antenna and a line extending from the same point to the radio horizon. (See figure 6-3.) The importance of take-off angle to tropospheric radio systems stems from its geometrical relationship to the so-called scatter angle. This relationship is illustrated in figure 4-1. It can be seen that any increase in take-off angle will result in a corresponding increase in scatter angle. Since path attenuation is roughly proportional to scatter angle, it follows that high take-off angles will produce higher path attenuation than low take-off angles. In fact, an increase of only one degree in take-off angle normally results in an increase of several dB in path attenuation. For this reason it is essential that take-off angles be considered very carefully. They can be computed from topographic maps for preliminary siting but optical surveying techniques must be used during the field survey. Since take-off angles can be negative under propitious circumstances, the order of precedence in site selection is as follows: Sites with the largest negative take-off angles are the first choice, and those with the largest positive take-off angles the last choice. Objects within the beam of the antenna will cause reflections which may be detrimental to system performance. Those objects that are directly along the path within the half power antenna beam-width and cannot be removed, have to be considered in determining the take-off angle.

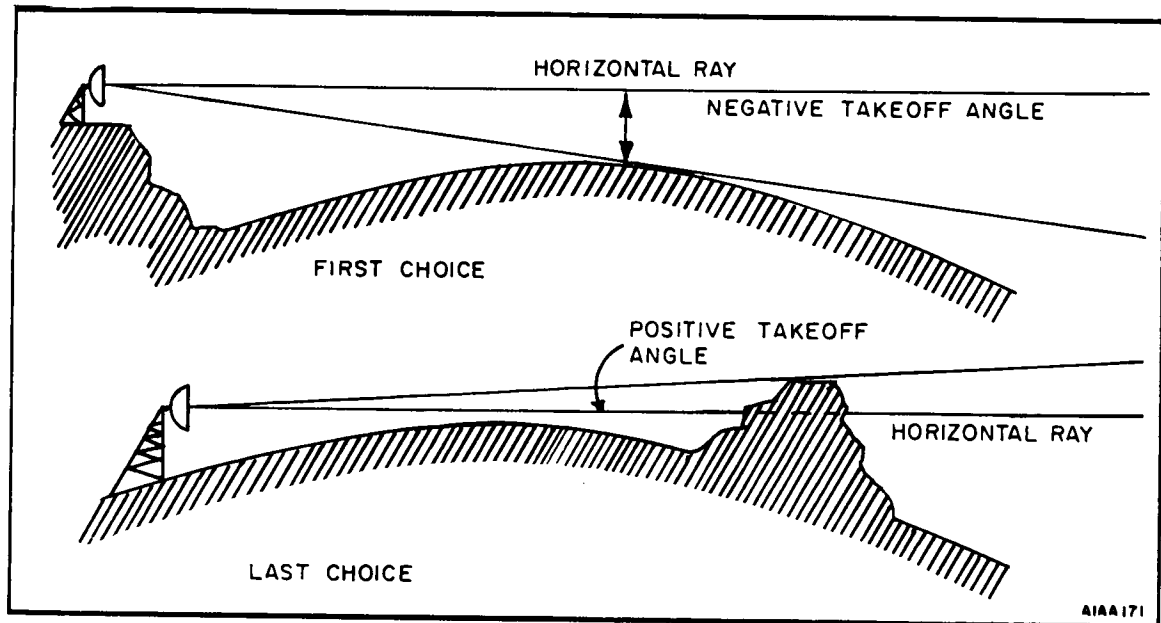


Figure 6-3. Site Choice Considering Take-off Angle

c. The effect of slight variations in path length is negligible for constant take-off angles; the transmission loss varies approximately 0.1 dB per mile. Consequently, decreasing the total path length by 10 miles only decreases the transmission loss by approximately 1 dB. The major effect of increasing or decreasing the total path distance is to change the scatter angle which does strongly affect the transmission loss.

d. Meteorology plays a very important part in tropospheric radio propagation, but its effect on siting a terminal is usually negligible because there are ordinarily no permanent sharp atmospheric boundaries in the troposphere and the general site area is presumably already established. There are exceptions to this rule, however, which require that a thorough analysis be made of the meteorological data available at each location being considered as a potential site. Ducting is a notable exception to the condition of gradual transitions between atmospheric layers, which can invalidate the most rigorous propagation analysis based on normal atmospheric physics.

e. The proximity of a tropospheric radio link to other Communication-Electronic (C-E) facilities, such as radio transmitters or receivers, radar sets, industrial areas and diathermy equipment, etc., is of extreme importance. Primary and harmonic frequencies of all these sources may produce mutual interference. If analysis of the frequencies and levels of the radiation indicates the probability of interference, it may be necessary to relocate one of the facilities.

f. In the siting of tropospheric radio communications terminals, careful consideration should be given to the harmful effects of electromagnetic radiation on the human body and on physical objects such as radio equipment, fuel storage or service areas and electrically detonated explosives. A level of 0.01 watts/cm^2 is the maximum average power which can be considered safe for personnel on a continuous exposure basis. The storage of explosive devices and fuel near the transmitting antenna presents a radiation hazard problem which requires careful observance of NAVELEX 0101, 106, Naval Shore Electronics Criteria Electromagnetic Compatibility and Electromagnetic Radiation Hazards.

g. The planner should evaluate sites with a view towards future expansion of the tropo facilities. Such expansion may require an increase in antenna sizes or possibly space for additional antennas, increased logistic areas and other facilities. Wherever possible, sites should be selected to give good take-off angles in all anticipated directions. The layouts in figures 6-4 through 6-7 depict the simplicity of illustrations adequate in the preliminary planning. Similar coding and appropriate dimensions apply to all figures. The extent of the Restricted Area is usually defined in the preliminary site sketches. Two categories of restrictions are obstruction restriction and radiation hazard restricted area.

After tentative selection of the radio terminal locations and any required intermediate repeater sites, the preliminary routing plan is prepared. Figure 6-8 is a sample routing plan, based on the circuit requirements given earlier in table 6-2. Figure 6-9 is a trunking diagram derived from the circuit requirements and the routing plan. This diagram will be used in the system engineering phase as the basis for the multiplex channelization plan.

6.2.3 Plotting the Route

The procedure used in plotting the route of a proposed system for preliminary and final path determination differs only in the order of accuracy of measurements and calculations.

When a preliminary study is made prior to the actual site survey such that alternate sites are selected, maps with a scale of at least 1 in 250,000 with contours at not more than 60 meters shall be used. The distance determinations shall be to the nearest mile and coordinates to second order accuracy.

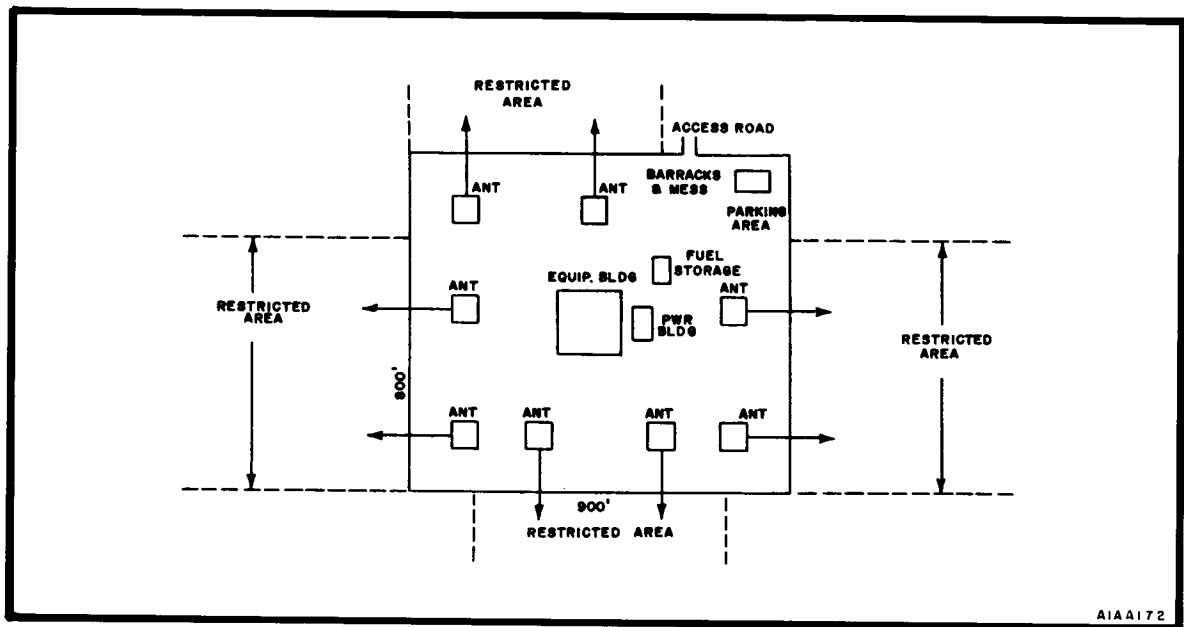


Figure 6-4. Four-Terminal Tropo Site,
60-Foot Antennas

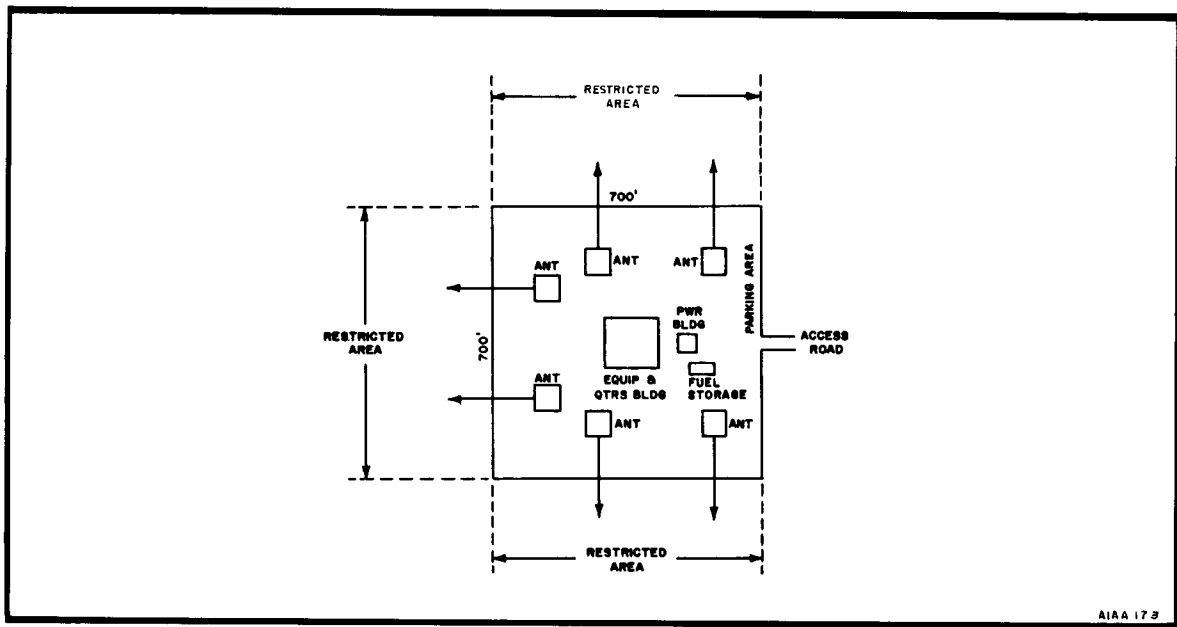


Figure 6-5. Three-Terminal Tropo
Site, 60-Foot Antennas

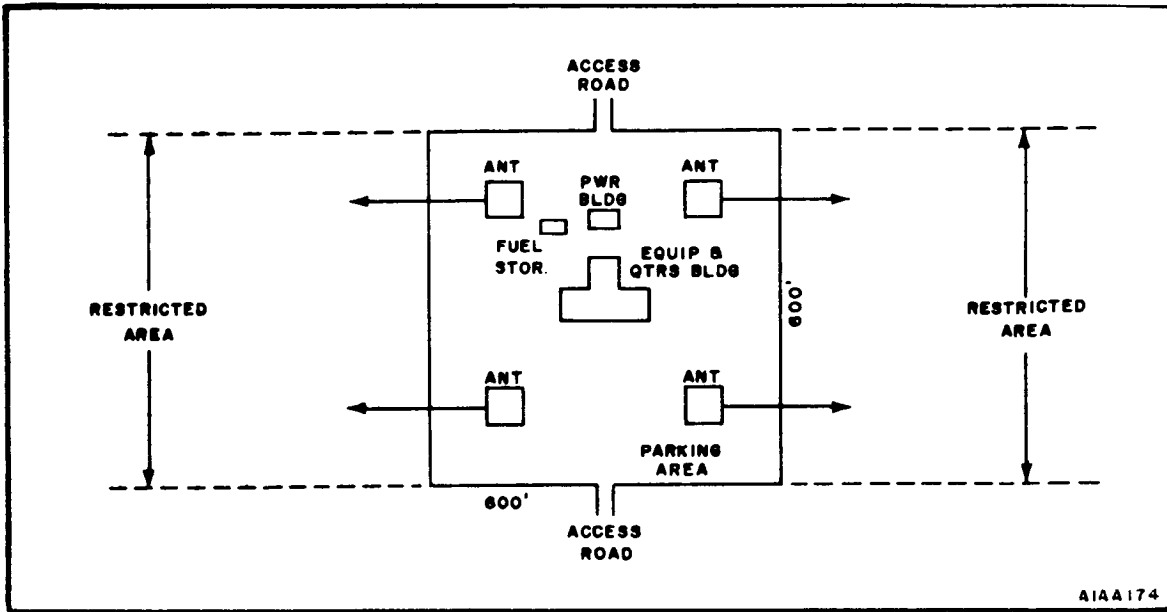


Figure 6-6. Two-Terminal Tropo Site, 60-Foot Antennas

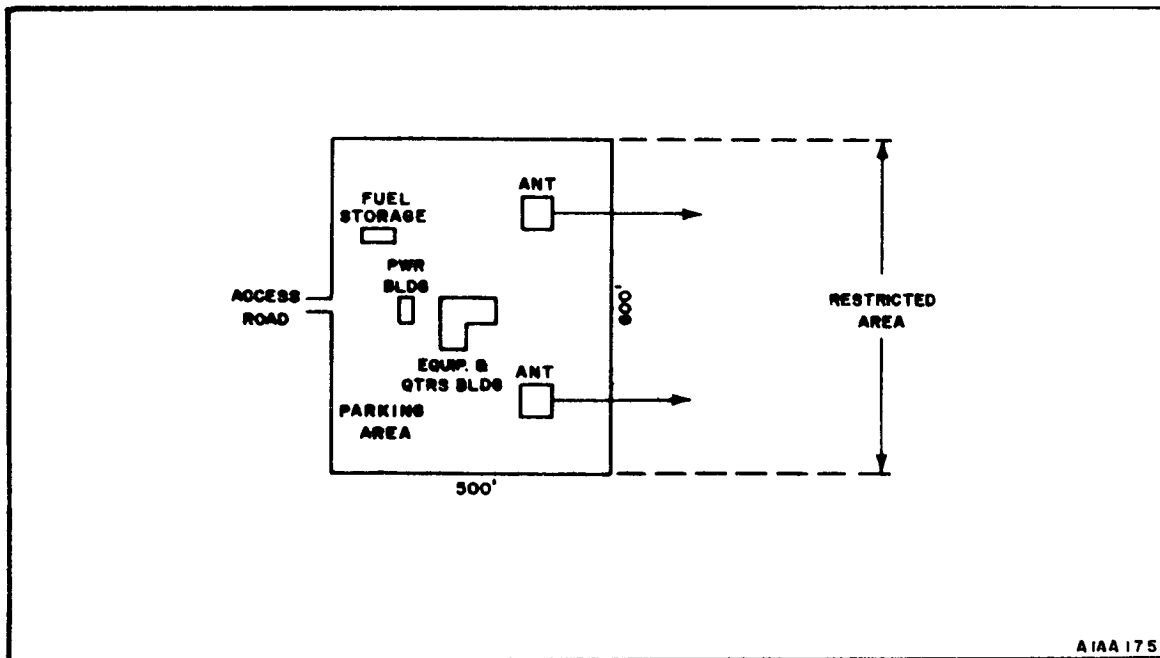


Figure 6-7. One-Terminal Tropo Site, 60-Foot Antennas

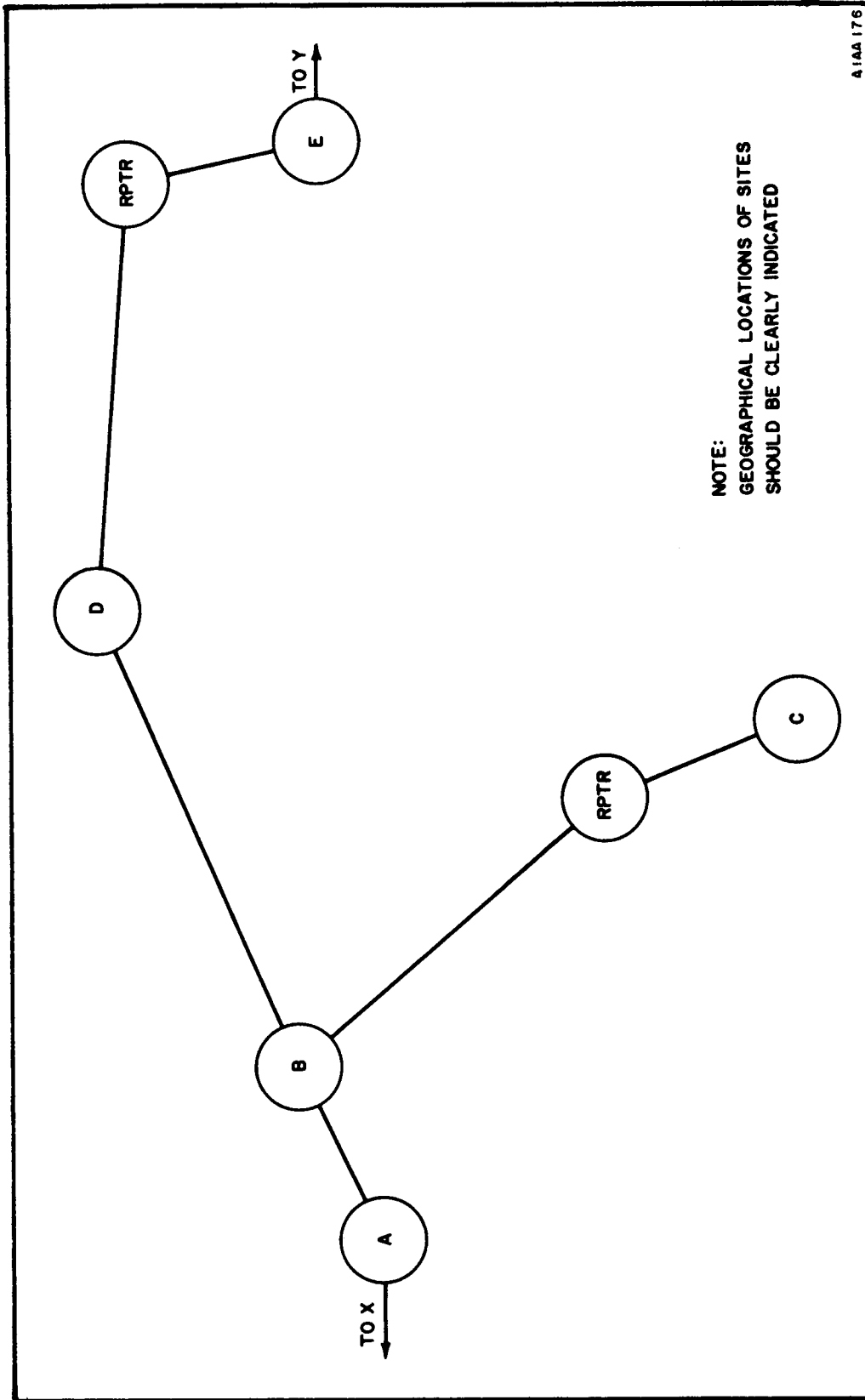


Figure 6-8. System Routing, Typical

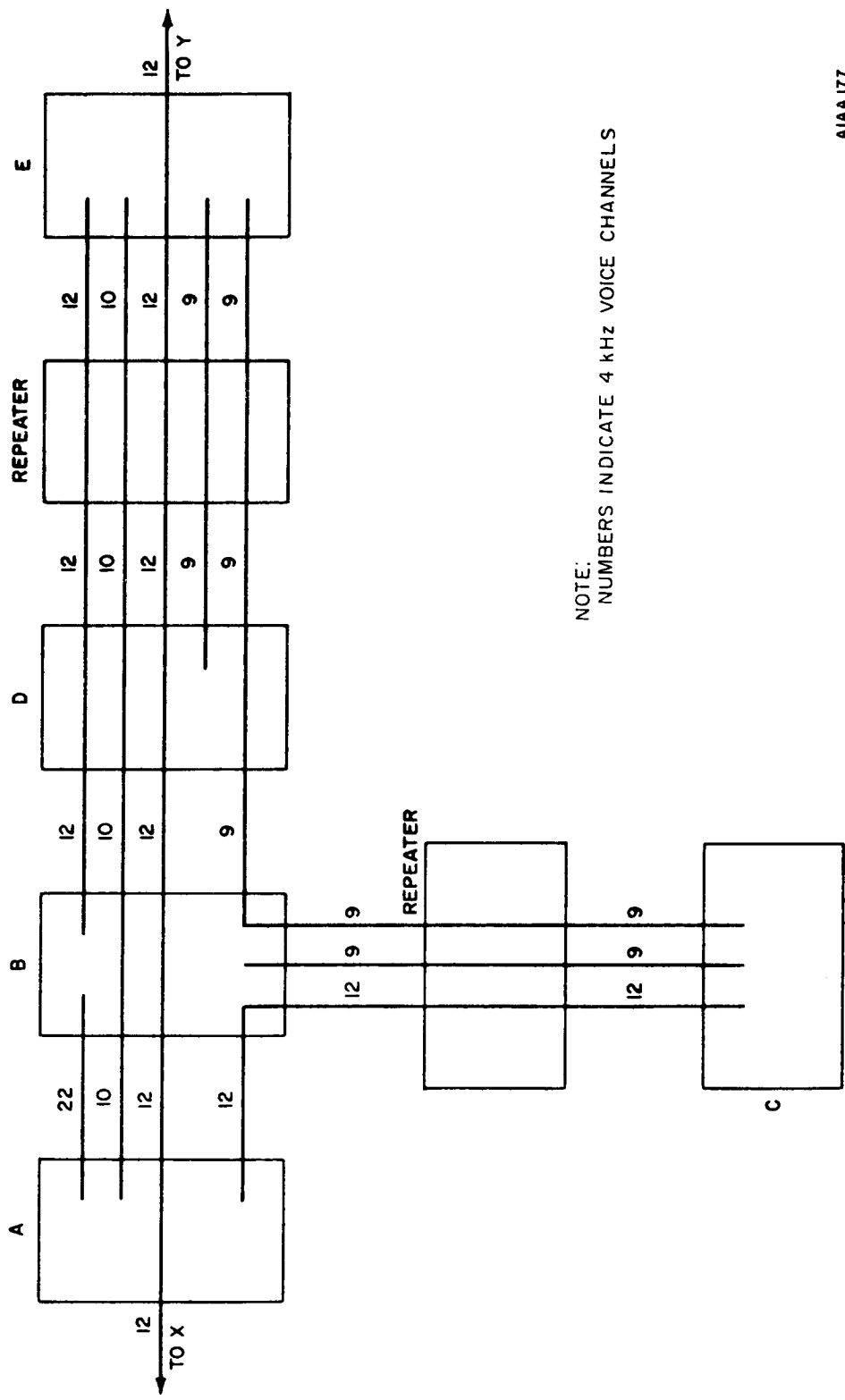


Figure 6-9. System Trunking Diagram, Typical

The selected sites shall be surveyed, so that a terrain profile may be constructed showing the distances and elevations along the path azimuth with an accuracy not less than:

- o Coordinates to third order accuracy.
- o Elevations to the nearest 5 meters.

The final path parameters (path profile) shall be determined with an accuracy not less than:

- o All distances to 0.1 mile.
- o All azimuths to 10 seconds.
- o Maps utilized shall have a scale of 1 in 25,000 with contours at 5 meter intervals.

The procedure outlined below may be used:

- o Using a small scale map such as is shown in figure 6-10, the proposed transmitter and receiver sites are plotted and a straight line (rhumb line) drawn connecting the two sites. A rhumb line is a line that intersects all meridians (degree of longitude) at the same angle. For distances less than 70 kilometers, the rhumb line approximates a great circle path. For greater distances, the true great circle path must be determined.

- o Using the rhumb line, select the detail topographic charts to be used in the path profile analysis. At the receiver site (in figure 6-10) quadrangle maps covering 7-1/2 minutes of latitude and longitude (scale 1:24,000) have been selected and at the transmitter site quadrangle maps covering 30 minutes of latitude and longitude (scale 1:125,000) have been selected for use.

- o Using the detail topographic charts, the highest suitable sites at or close to each terminal station must be located.

- o Using latitude and longitude of each site, the great circle distance, the transmit azimuth, and receive azimuth are calculated using the method in Appendix D.

- o To determine the radio horizon, the great circle path on the quadrangle charts must be plotted. The great circle path is approximated by a series of rhumb lines not exceeding 70 kilometers in length. To do this intermediate positions along the great circle path are calculated and these positions interconnected by straight lines. Normally the positions selected are on the edges of the charts.

Figure 6-11 depicts the spherical triangle for these calculations.

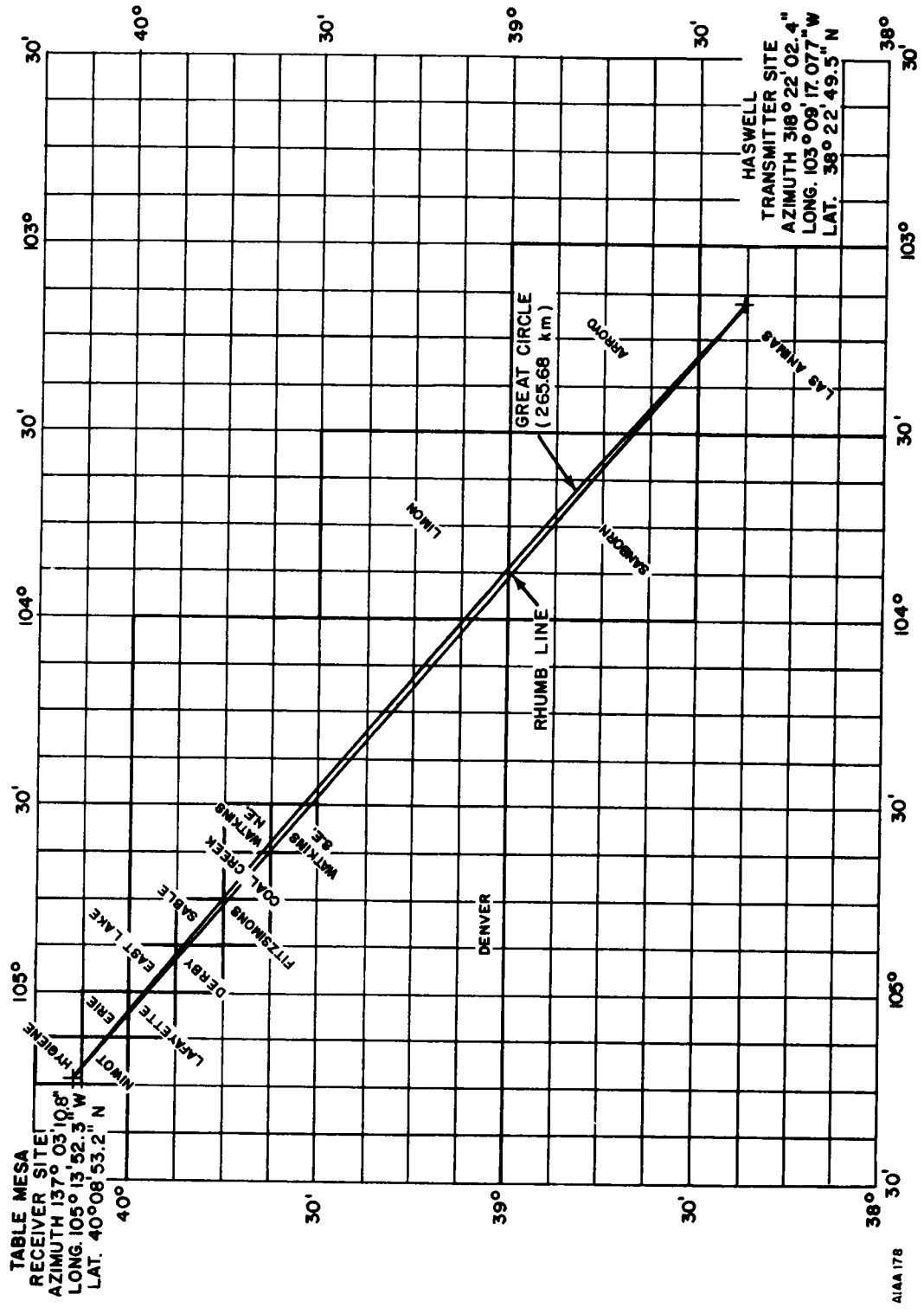


Figure 6-10. Map Study Organization

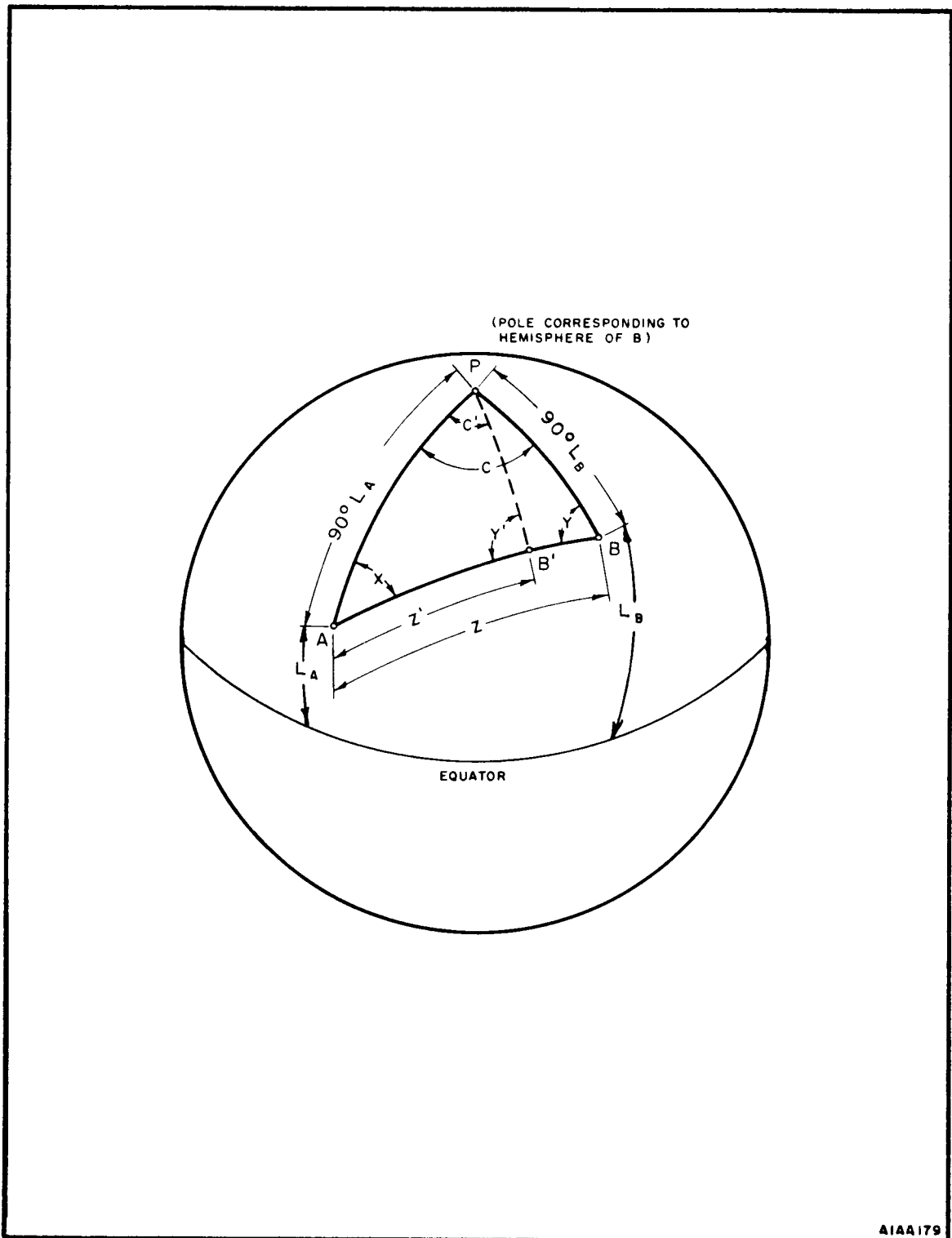


Figure 6-11. Great Circle Path Computations,
Spherical Triangle for

If the great circle path is predominately east-west a longitude is selected (longitude difference C') and latitude $L_{B'}$, is calculated from

$$\cos Y' = \sin X \sin C' \sin L_A - \cos X \cos C'$$

and

$$\cos L_{B'} = \frac{\sin X \cos L_A}{\sin Y'}$$

If the great circle path is predominately north-south, a latitude is usually selected (latitude difference L_B) and the longitude difference C^1 is then calculated from

$$\sin Y' = \frac{\sin X \cos L_A}{\cos L_{B'}}$$

and

$$\cot \frac{C'}{2} = \tan \frac{Y' - Y}{2} \left[\frac{\cos \left(\frac{L_{B'} + L_A}{2} \right)}{\sin \left(\frac{L_{B'} - L_A}{2} \right)} \right]$$

Where the path is close to 45 degrees either method may be used.

o The sea level refractivity of the atmosphere (N_0) is determined from figure 2-8 or 2-9. Using the average height of the transmitter and receiver sites above sea level and entering figure 2-10 with this height in kilometers and N_0 , the surface refractivity N_s is determined.

o The elevations h_i of the terrain on the great circle route as read on the topographic maps are tabulated with their distances x_i from the transmitting antenna. The recorded elevations should include successive high and low points along the path.

The modified elevation y_i of any point h_i at distance x_i from the transmitter along a great circle path is:

$$y_i = h_i - \frac{x_i^2}{2a}$$

where the effective earth's radius a , in kilometers, is read from figure 6-12 as a function of N_s . A plot of y_i vs x_i on linear graph paper as shown in figure 6-13 provides the desired profile. The ray from each antenna to its horizon is a straight line if the elevation above sea level of the horizon and that of its antenna differs by less than one kilometer.

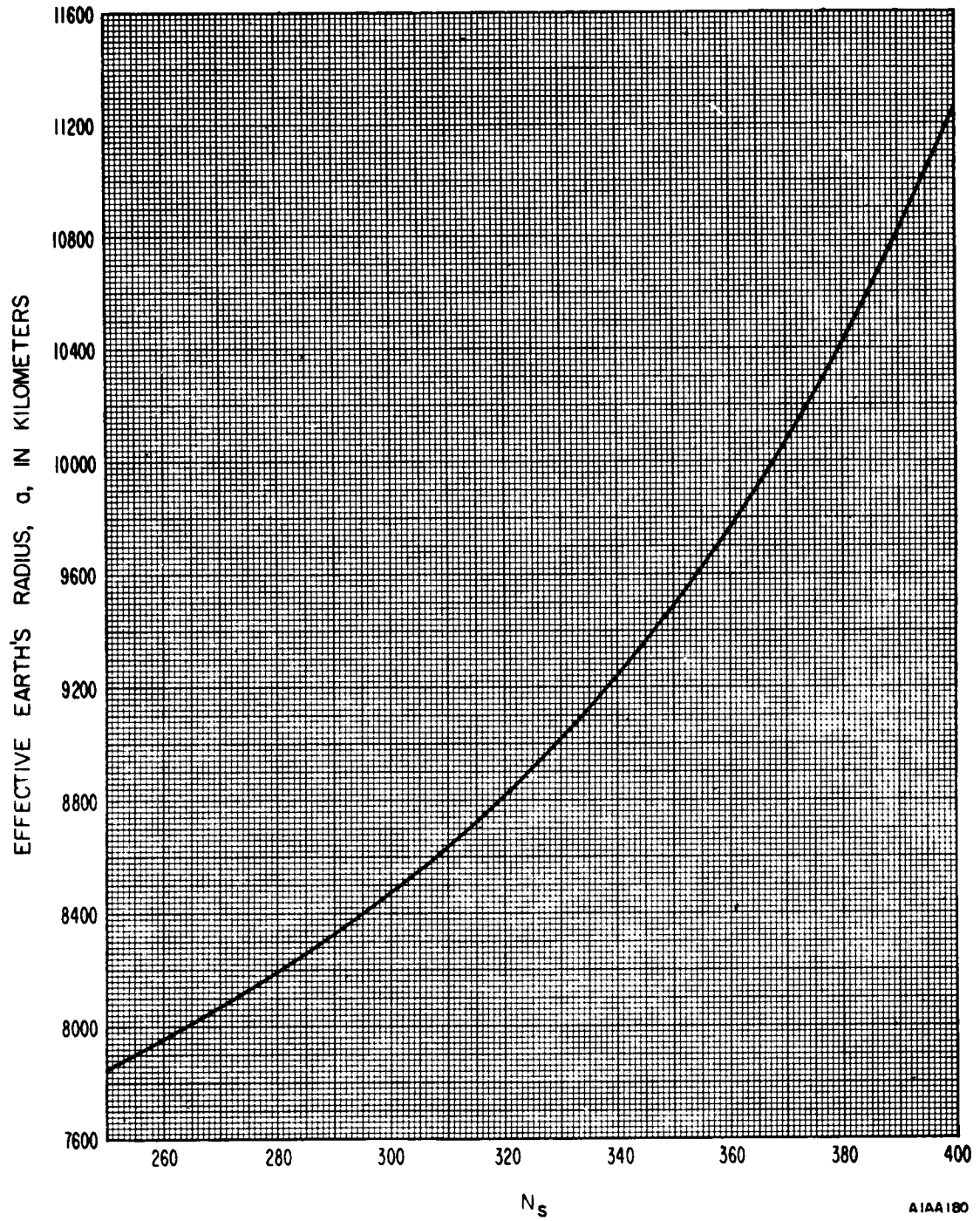


Figure 6-12. Effective Earth's Radius, a ,
Versus Surface Refractivity, N_s

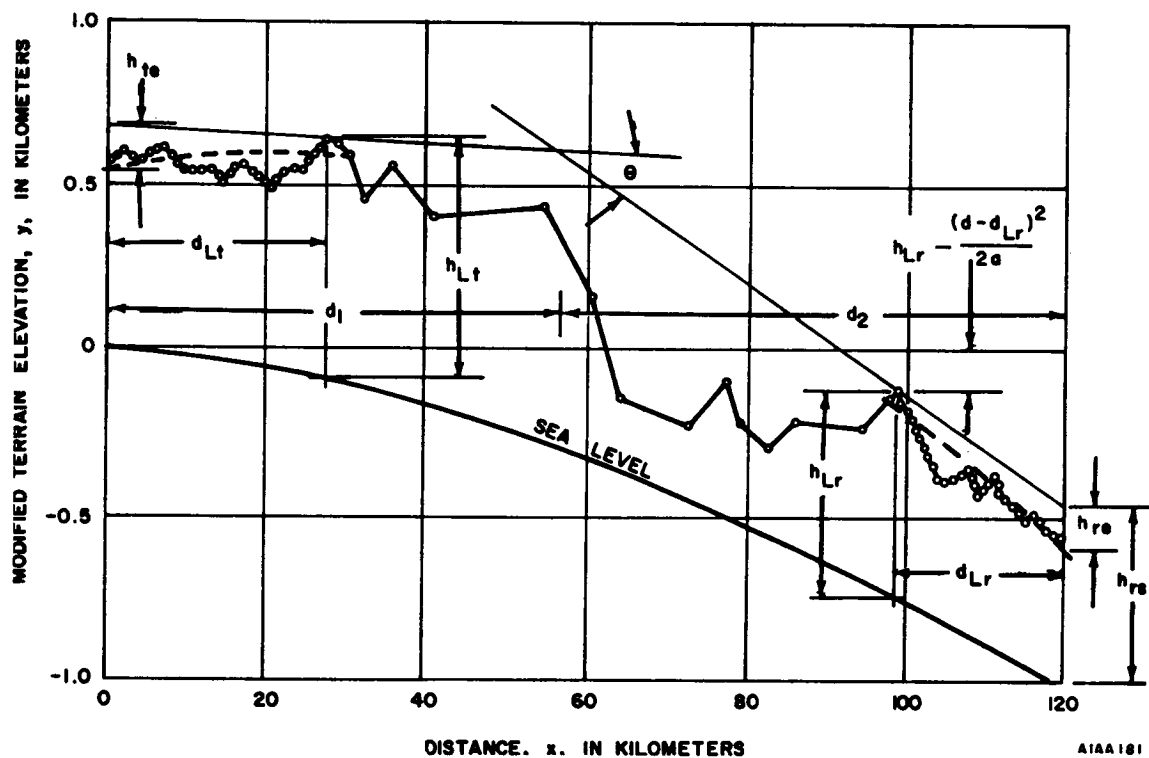


Figure 6-13. Modified Terrain Profile for a Double-Horizon Path

6.3 BASIC SYSTEM DESIGN

As a result of planning activities previously described, a basic communications requirement has been defined. The user locations, the number and type of channels needed, a tentative route and system layout have been established. The next step in the evaluation is the determination whether or not each radio frequency link is feasible. To do this:

- o The transmitter power is assumed/or selected.
- o The receiver sensitivity is assumed/or selected.
- o The frequency or frequency band is assumed/or assigned.
- o The antenna sizes and gains are assumed.
- o The antenna heights are assumed.
- o The degree of diversity is assumed.

Based upon these assumptions the RF attenuation of each path is calculated. The first result is almost always unsatisfactory requiring alteration of the propagation path, or one or more of the assumed parameters. When the preliminary calculations of path loss for each path in the proposed system show the paths are feasible, all the foregoing planning efforts are incorporated in a planning document entitled "Base Electronics System Engineering Plan" (BESEP). As the design progresses the BESEP is refined from a planning document to an implementation document.

6.4 PRELIMINARY PATH LOSS CALCULATIONS

Beyond the horizon propagation occurs by the mechanisms listed in table 6-3. The two major methods are forward scatter and diffraction over a knife edge obstacle. Paths just beyond the horizon are predominantly diffraction paths and long paths (more than $\theta = 15$ milliradians) forward scatter. The area between is a combination of the two. In preliminary or path feasibility calculations the path is considered one or the other and calculated as such.

6.4.1 Forward Scatter

A forward troposcatter microwave link is proposed between points A and B. Figure 6-14 is an example of the Path Data Calculation Sheet.

- a. The latitudes, longitudes and site elevations (items 2, 3, and 4) were determined from the map study of large scale maps (chapter 2).
- b. The antenna launch azimuths and the path length (items 7 and 8) were computed using appendix D.
- c. The frequency assigned for this path is 4.8 GHz.
- d. The following parameters are assumed:
 - o 30 foot parabolic antennas at each end (item 19).
 - o Each antenna is 26 feet (8 meters) above the ground (item 18).

Table 6-3. Basic Design Considerations

POSSIBLE PROPAGATION MECHANISMS	COMMENT
Forward Scatter	<p>Consider the following modifying factors:</p> <ul style="list-style-type: none"> Possibility of reflections enhancing or weakening the forward scatter effect. Orientation of the antennas. Height of the antennas. Frequency effects. Effect of contributions from diffraction.
Trans-Horizon Diffraction Around a Smooth Earth	<p>Distance at which diffraction and forward scatter are approximately equal is $65(100/f)^{1/3}$ km. In general, for most paths having an angular distance (θ) greater than 15 milliradians, the diffraction calculations may be omitted.</p>
Diffraction Over a Single Isolated Obstacle	<p>Obstacles may be knife edge or rounded, different design approaches apply to the two cases. The possibility of reflections on either or both sides of the obstacle should be considered.</p>
Diffraction Over Two or More Obstacles Ducting	<p>Involves an extension of the method described above.</p> <p>This is a propagation anomaly which requires the engineer to investigate the climatology of an area in detail.</p>
<ul style="list-style-type: none"> o The transmitter is 1 kW (+60 dBm) (item 26). o The receiver noise threshold is -98 dBm (item 28) and the FM improvement threshold (-49 dBa) is -88 dBm (item 30). o Items 10 through 14 are assumed based upon antenna height, diversity and experience. 	

MICROWAVE PATH DATA CALCULATIONS					
1	SITE		A		B
2	LATITUDE	N	36° 38' 23"		37° 09' 12"
3	LONGITUDE	W	6° 22' 02"		5° 35' 16"
4	ELEVATION	m	13		94.
5	TOWER HEIGHT	m			
6	TOWER TYPE				
7	AZIMUTH FROM TRUE NORTH.		50° 17'	230° 45'	
8	PATH LENGTH	km	89.75		
9	PATH ATTENUATION (L _{bsr})	dB	215.8		
10	RIGID WAVEGUIDE	Ft.	80	100	
11	FLEXIBLE WAVEGUIDE	Ft.	5	5	
12	WAVEGUIDE LOSS	dB	1.4	1.7	
13	CONNECTOR LOSS	dB	0.3	0.3	
14	CIRCULATOR OR HYBRID LOSS	dB		1.0	
15	RADOME LOSS, TYPE*	dB			
16	NEAR FIELD LOSS	dB			
17	CLOSE COUPLING LOSS (DOUBLE PASS.)	dB		10.	
18	TOTAL FIXED LOSSES	dB	1.7	13.	
19	TOTAL LOSSES	dB	230.5		
20	PARABOLA HEIGHT	C _L AGL m	8	8	
21	PARABOLA DIAMETER	Ft.	30	30	
22	REFLECTOR HEIGHT	Ft.			
23	REFLECTOR SIZE, TYPE	Ft.			
24	PARABOLA - REFLECTOR SEP.	Ft.			
25	NEAR FIELD GAIN	dB			
26	ANTENNA SYSTEM GAIN	dB	50.6	50.6	
27	TOTAL GAINS	dB	101.2		
28	NET PATH LOSS	dB	129.3		
29	TRANSMITTER POWER	dBm	+60		
30	MED. RECEIVED POWER (± 2 dB)	dBm	-69.3		
31	RECEIVER NOISE THRESHOLD	dBm	-98		
32	THEORETICAL RF C/N RATIO	dB	28.7		
33	FM IMP. THRESHOLD (4.9 dBa)	dBm	-88		
34	FADE MARGIN (To FM Imp. Thresh.)	dB	18.7		
35	RELIABILITY	SPACING† Ω			
36	POLARIZATION ‡				
37	PROFILE NUMBER				

CUSTOMER U. S. NAVY

PROJECT NO. 20631 FREQUENCY 4.8 GHz

SYSTEM _____ EQUIPMENT _____

LOADING _____ dBm0 (_____ CHANNELS OF _____)

A1A4182

DATE _____ ENGINEER _____ Sheet _____ of _____

Figure 6-14. Microwave Path Data Calculation Sheet

e. The surface radio refractivity N_O is determined from figure 2-9 and N_S for the average surface refractivity from figure 2-10 is 301.

f. Using a preprinted form with the k factor determined from table 2-2, or using the method specified in paragraph 6.2.3, the path profile is plotted as shown in figure 6-15.

g. Based upon the path geometry defined in figure 4-4, the applicable values from the profile, figure 6-15, are shown on figure 6-16.

h. Figure 6-17 shows the computations to obtain the scatter angle (or path angle) θ . $\Delta\alpha_O$ and $\Delta\beta_O$ are obtained from figure 6-18. If N_S is other than 301 the correction of figure 6-19 must be applied.

i. Using the parameters previously calculated, the long term median transmission LBSR (figure 6-20) is determined to be 215.8 dB which is entered as item 9 on figure 6-14. It must be noted that in these calculations, the scattering efficiency term F_O , the frequency gain function H_O , and the atmospheric absorption term A_a are omitted during the initial calculations.

j. The gain efficiencies of most commercial antennas with parabolic reflectors are on the order of 55 to 65 percent. With 55 percent efficiency, the gain of a parabolic antenna is:

$$G = 20 \log B + 20 \log F + 7.5$$

where

G = gain over isotropic in dB

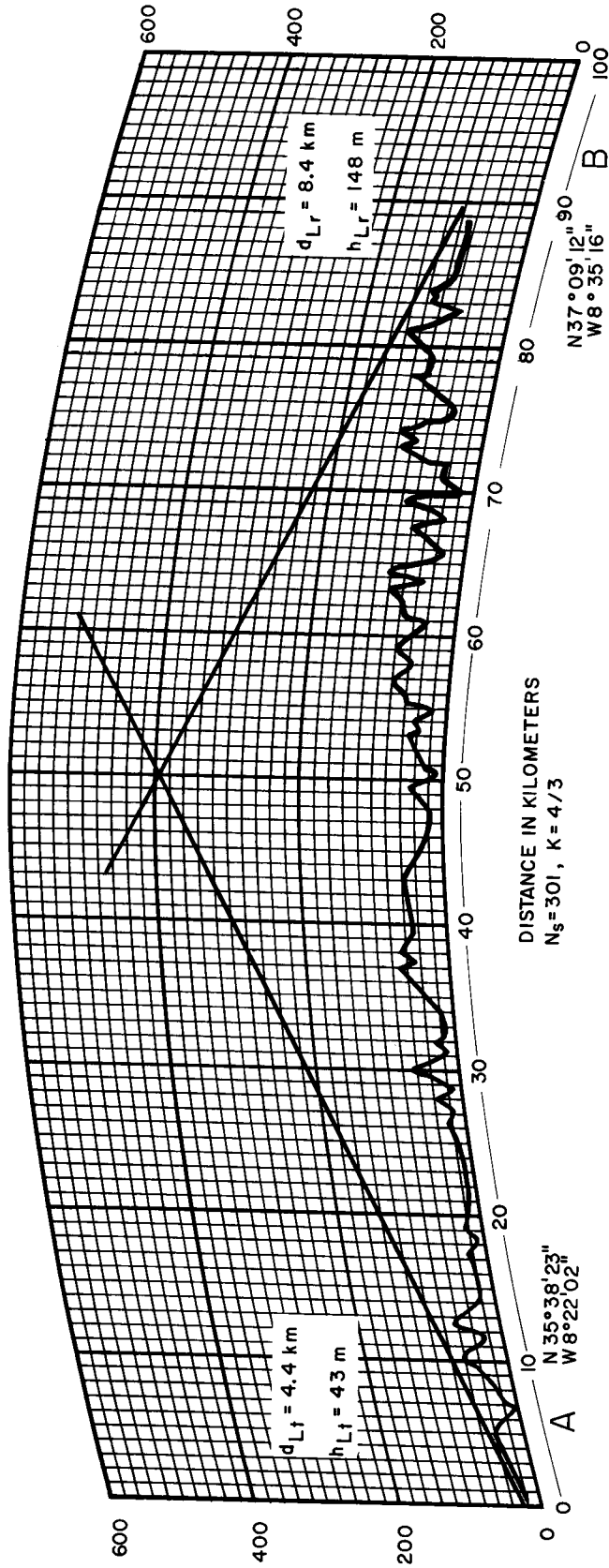
F = frequency in gigahertz

B = parabolic diameter in feet.

From this the gain of a 30 foot disk at 4.8 GHz is 50.6 dB which is entered under item 23 and totaled in item 24.

Although this formula can be used for estimating purposes, the actual gain determined from manufacturers' published specifications should be used during the final planning phases.

k. h_O and Ω are computed as shown in figure 6-21. Entering figure 6-22 with h_O and N_S determine η_S . Entering figure 6-23 with θ/Ω and η_S the antenna coupling loss L_{gp} is determined as 10 dB which is entered in figure 6-14, item 15.



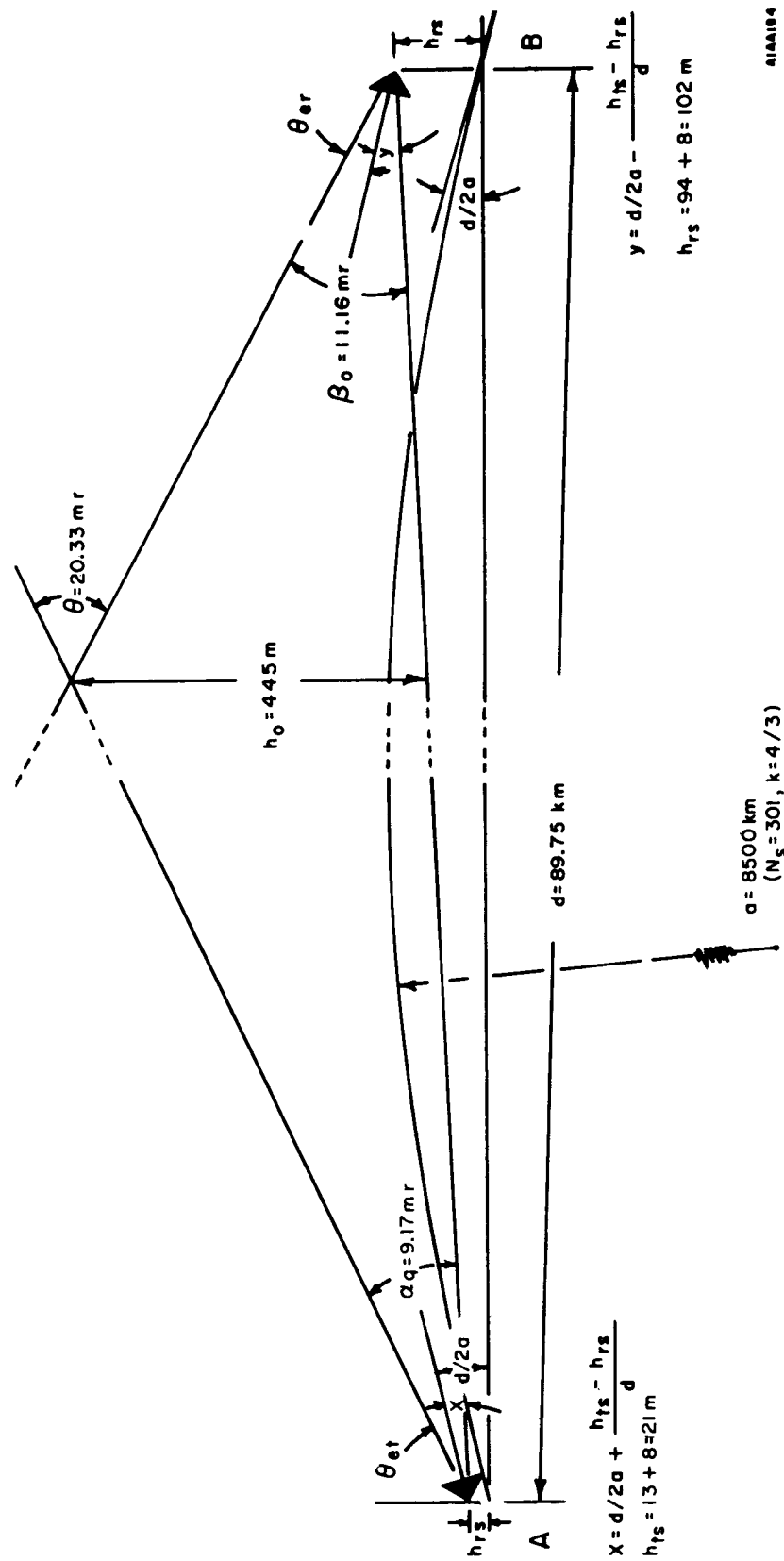


Figure 6-16. Troposcatter Path Geometry

(EXISTING TROPOSCATTER PATH)	
$d = 89.75 \text{ km}$ $a = 8500 \text{ km}$	
A	B
$h_{ts} = 21 \text{ m}$ $h_{Lt} = 43.3 \text{ m}$ $h_{te} =$ $d_{Lt} = 4.4 \text{ km}$ $d_{st} =$	$h_{rs} = 102 \text{ m}$ $h_{Lr} = 148 \text{ m}$ $h_{re} =$ $d_{Lr} = 8.4 \text{ km}$ $d_{sr} =$
$\theta_{et} = \frac{h_{Lt} - h_{ts}}{d_{Lt}} - \frac{d_{Lt}}{2a}$ $= \frac{43.3 - 21}{4400} - \frac{4.4}{2(8500)}$ $= 0.00506 - 0.00026$ $= \underline{4.80 \text{ mr}}$	$\theta_{er} = \frac{h_{Lr} - h_{rs}}{d_{Lr}} - \frac{d_{Lr}}{2a}$ $= \frac{148 - 102}{8400} - \frac{8.4}{2(8500)}$ $= 0.00546 - 0.00049$ $= \underline{4.97 \text{ mr}}$
$x = \frac{d}{2a} + \frac{h_{ts} - h_{rs}}{d}$ $= \frac{89.75}{2(8500)} + \frac{21 - 102}{89750}$ $= 0.00528 - 0.00091$ $= \underline{4.37 \text{ mr}}$	$y = \frac{d}{2a} - \frac{h_{ts} - h_{rs}}{d}$ $= \frac{89.75}{2(8500)} - \frac{21 - 102}{89750}$ $= 0.00528 + 0.00091$ $= \underline{6.19 \text{ mr}}$
$\theta_{ot} = \theta_{et} + \frac{d_{Lt}}{a}$	$\theta_{or} = \theta_{er} + \frac{d_{Lr}}{a}$
$\Delta\alpha \cong 0$ FROM FIGURES 6-18 AND 6-19	$\Delta\beta \cong 0$ FROM FIGURES 6-18 AND 6-19
$\alpha_o = \theta_{et} + x + \Delta\alpha_o$ $= 4.80 + 4.37 \text{ mr}$ $= \underline{9.17 \text{ mr}}$	$\beta_o = \theta_{er} + y + \Delta\beta_o$ $= 4.97 + 6.19 \text{ mr}$ $= \underline{11.16 \text{ mr}}$
$\theta_{oo} = \theta = \alpha_o + \beta_o = 9.17 + 11.16 = \underline{20.33 \text{ mr}}$	

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Figure 6-17. Tropospheric Path Angle Computations (Milliradians)

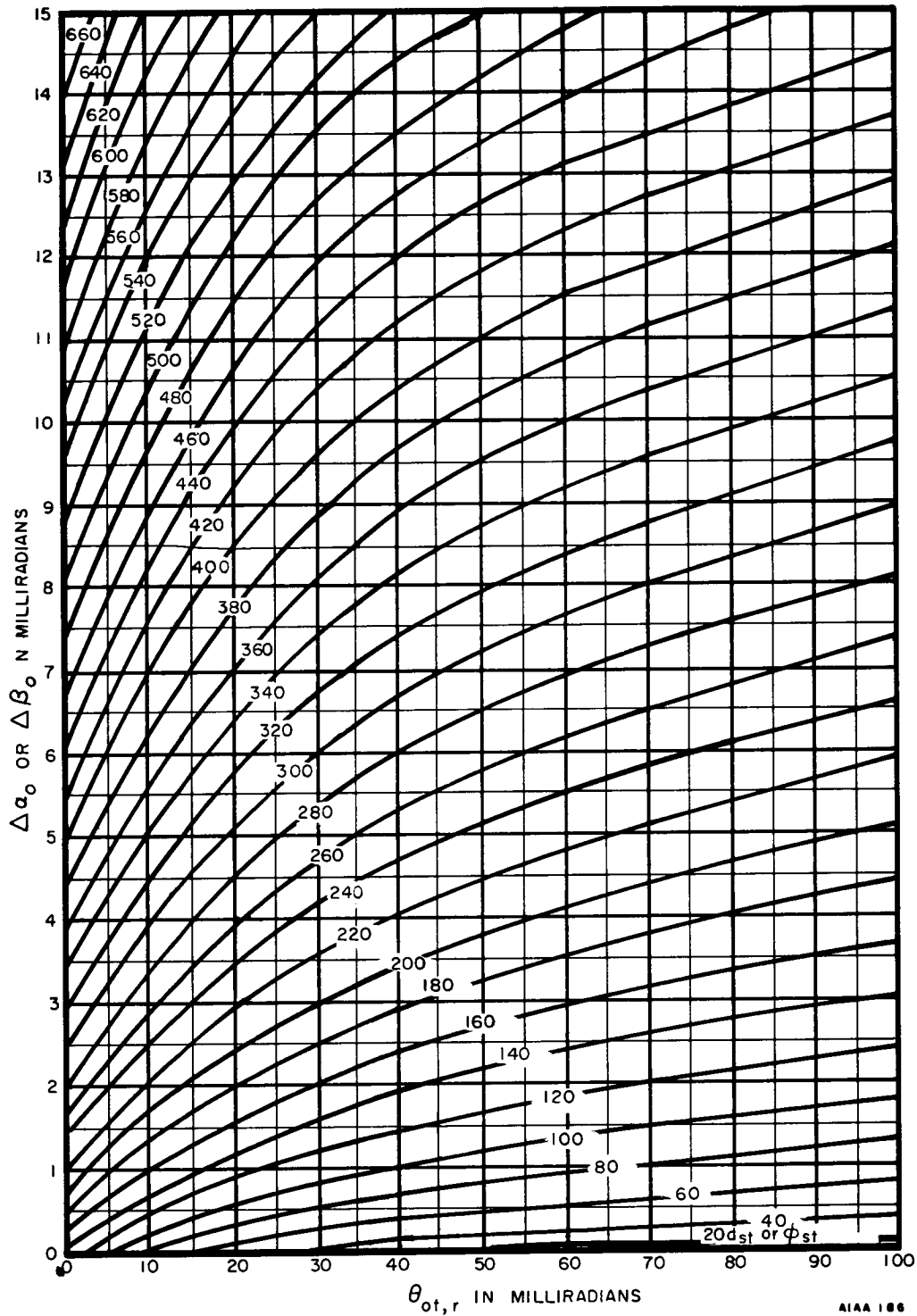
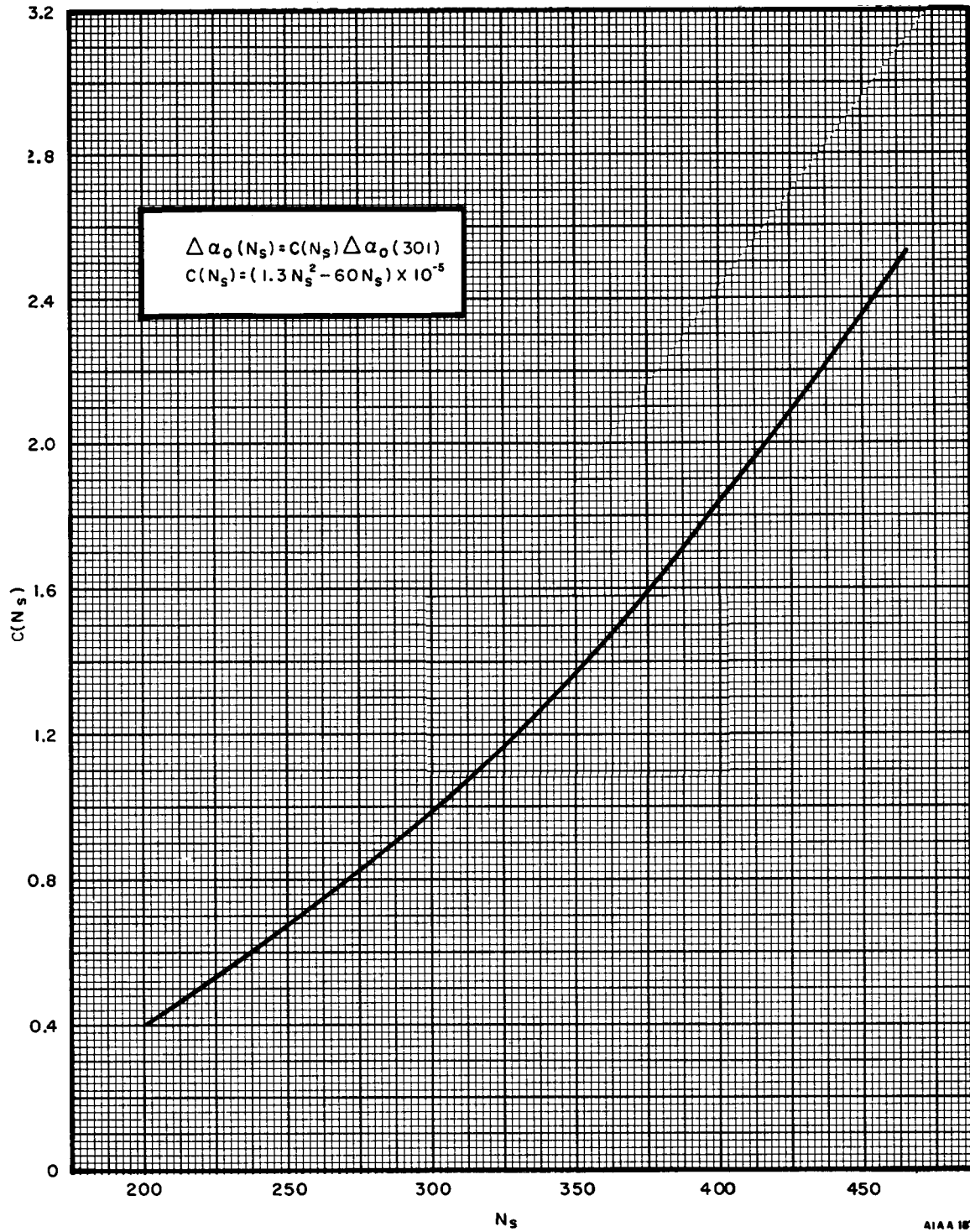


Figure 6-18. Correction Terms $\Delta\alpha_0$, $\Delta\beta_0$ for $N_S = 301$

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Figure 6-19. The Coefficient C(N_s)

PARAMETER	
DISTANCE d , km (From Figure 6-14)	89.75
SCATTER ANGLE θ , MILLIRADIANS (From Figure 6-17)	20.33
θd , RADIANS (89.75) (20.33) $\times 10^{-3}$	1.82
ATTENUATION FUNCTION $F(\theta d)$ IN dB FROM FIGURE 4-5)	144.5
30 LOG f IN dB (f is frequency in MHz) (4800)	110.4
-20 LOG d in dB (d is distance in km) (89.75)	- 39.1
F_0, H_0 , AND A_0 CONSIDERED NEGLIGIBLE	
L_{bsr} dB 144.5 + 110.4 - 39.1	215.8

$L_{bsr} = 30 \text{ LOG } f - 20 \text{ LOG } d + F(\theta d) - F_0 + H_0 + A_0 ; \text{ dB}$

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Figure 6-20. Computation of Long-Term Median Transmission Loss of Tropospheric Scatter

ANTENNA COUPLING LOSS (SCATTER LOSS)	
$S = \frac{\alpha_0}{\beta_0}$ <p>(FROM FIGURE 6-17)</p> $S = \frac{9.17}{11.16} = 0.821$	
$D_s = d - d_{LT} - d_{LR} \quad \text{km}$ <p>(FROM FIGURE 6-17)</p> $D_s = 89.75 - 4.4 - 8.4$ $= 76.95 \text{ kilometers}$	
$h_0 = \frac{S D_s \theta}{(1 + S)^2} \quad \text{km}$ $= \frac{(0.821)(76.95)(.02033)}{(1 + .821)^2}$ $= .445 \text{ km}$	
<p>THE HALF POWER BEAM WIDTH Ω OF A PARABOLIC ANTENNA IS APPROXIMATELY</p> $\Omega = \frac{1222}{FB} \text{ MILLIRADIANS} \quad \text{WHERE} \quad \begin{array}{l} F = \text{FREQUENCY IN GHz} \\ B = \text{PARABOLA DIAMETER FEET} \end{array}$ <p>(FROM FIGURE 6-14)</p> $= \frac{1222}{(4.8)(30)} = 8.5 \text{ milliradians}$	
$\frac{\theta}{\Omega} = \frac{20.33}{8.5} = 2.39$	
<p>SCATTER LOSS L_{gp}</p> <p>(FROM FIGURE 6-23)</p>	

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Figure 6-21. Antenna Coupling Loss

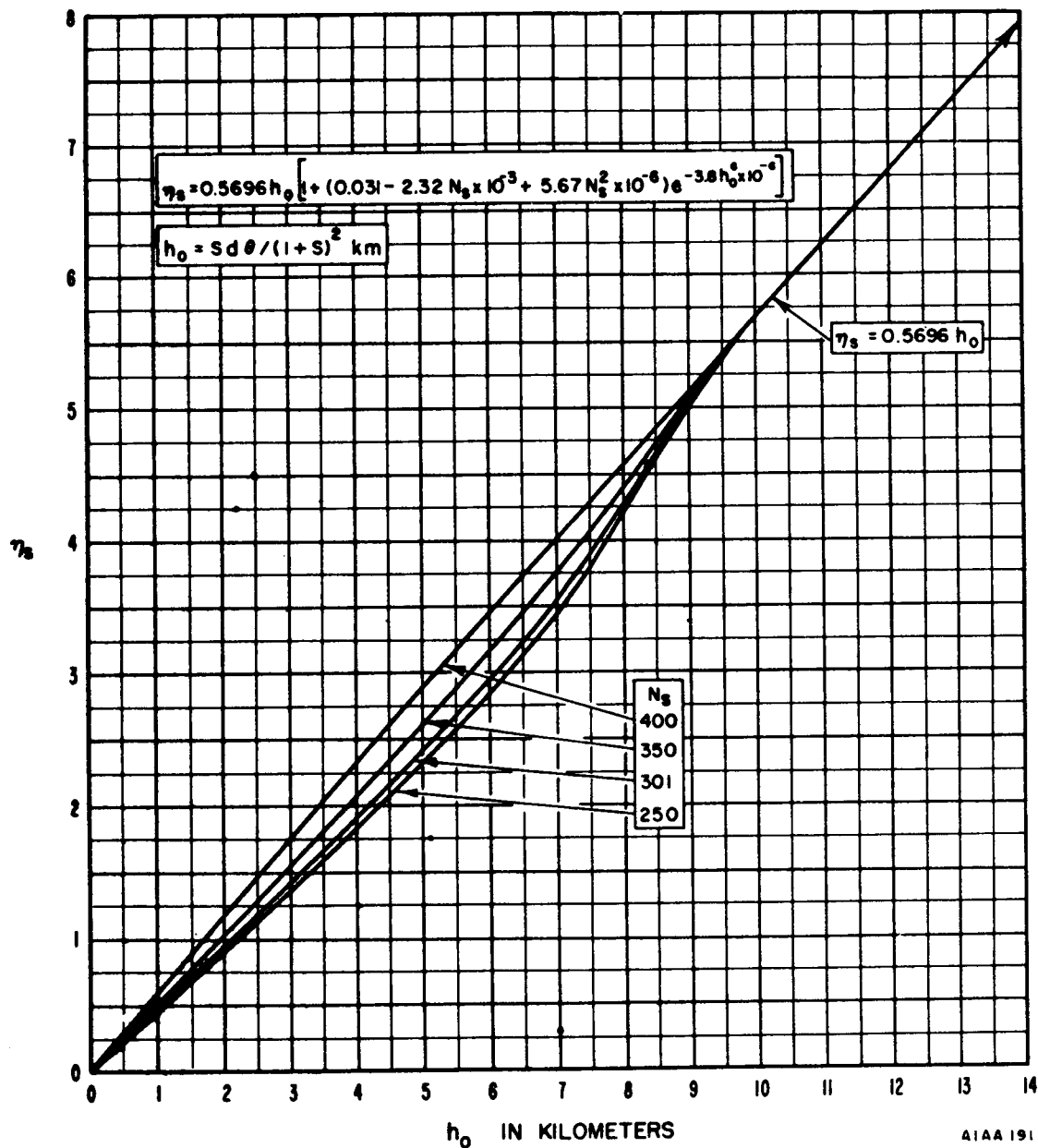
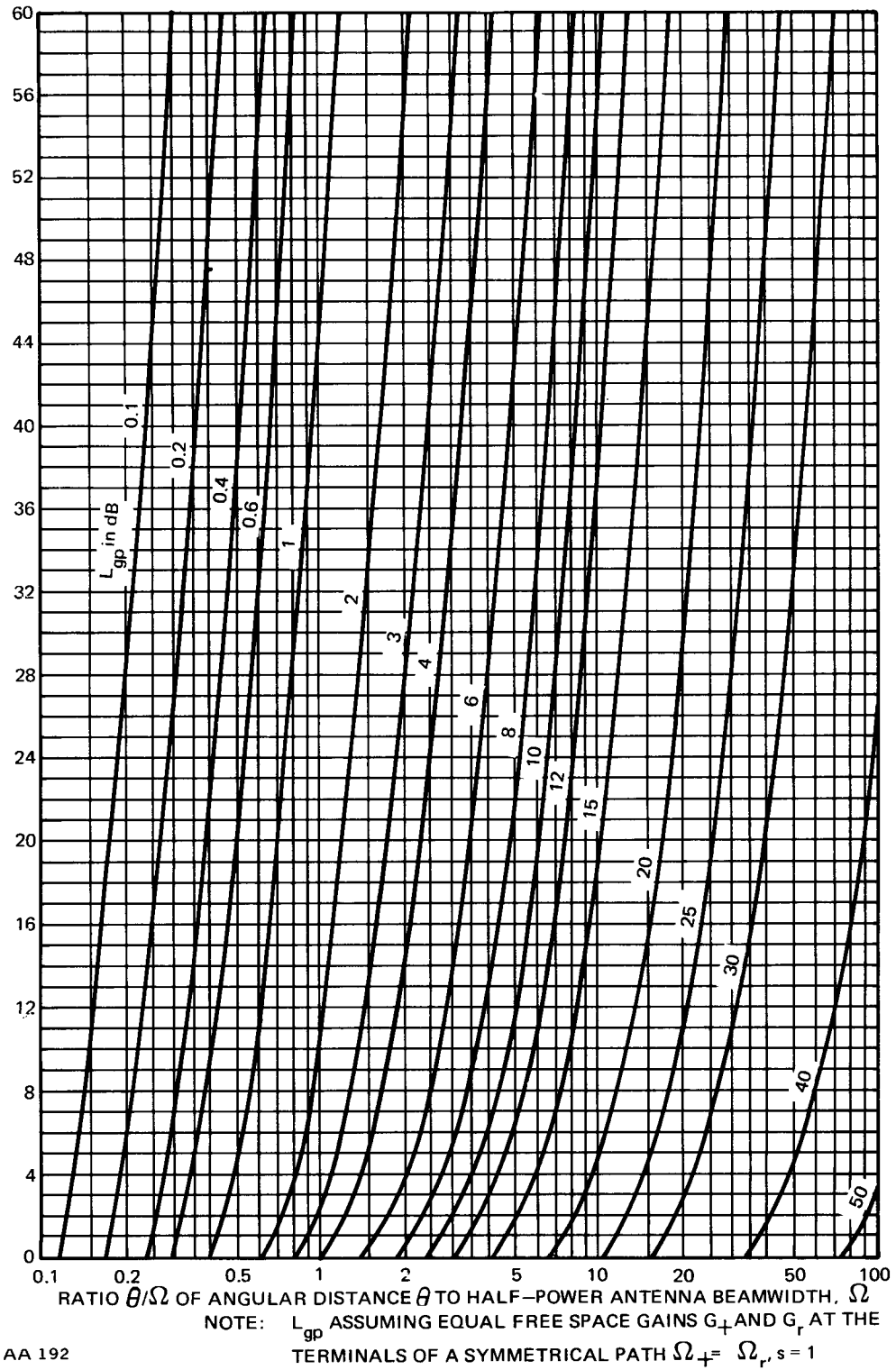


Figure 6-22. The Parameter N_s (h_0) Used to Compute H_0



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Figure 6-23. Loss in Antenna Gain, L_{gp} (Assuming Equal Free Space Gains G_t and G_r at the Terminals of a Symmetrical Path $\Omega_t = \Omega_r, s = 1$)

1. In figure 6-14:

- o Items 12, 13, 14, and 15 are totaled and entered in item 16.
- o Items 9 and 16 are totaled in item 17.
- o The difference between items 17 and 24 is entered in item 25.
- o The median received power item 27 is the difference between items 25 and 26.
- o The difference between items 27 and 28 is the theoretical signal to noise ratio, item 29.
- o The difference between items 27 and 30 is the fade margin 18.7 dB.

m. Figure 7-1 indicates that for 99.99 reliability required by DCA standards, a fade margin for quadruple diversity of 5 to 9 dB is required, depending upon the combined methods. Hence, propagation along this path is possible.

6.4.2 Diffraction Path Calculations

A propagation path with a common horizon for both terminals may be considered as having a single diffracting edge. This diffraction loss can be estimated from Figure A-7. However, the transmission loss over a practical knife-edge diffraction path depends critically on the shape of the diffracting edge. Since a natural obstacle such as a mountain ridge may depart considerably from an ideal knife edge, the diffraction loss in practice is usually up to 20 dB greater than that estimated for the ideal case.

The initial path loss calculations for this type of path should be identical to that given in chapter 5 and appendix D except that an additional diffraction loss determined from figure A-7 and an added 10 dB loss for a departure from a theoretical knife edge should be added to the free space loss.