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COMPUTER PROGRAMS FOR AIR/GROUND PROPAGATION AND INTERFERENCE ANALYSIS
0.1 to 20 GHz

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E R R A T A

DOT REPORT FAA-RD-73-103 (Sept. 1973)

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by

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All errata for the above report known to the authors as of January 14, 1974, are listed below. Readers finding additional errata are urged to contact an author at the Office of Telecommunications, Institute for Telecommunication Sciences, Boulder, Colorado 80302, (telephone, area code 303-499-1000).

Page	Errata
41	Change "...if lobing..." in (16) to "... or if lobing..." and delete", or path is beyond line of sight".
57	Change the second " = " in (81) to " + ".
78	Change "...$F_{\sigma h}$ from (66)" in line 5 to "...$\sigma_h \sin(\psi)/\lambda = \delta$". Change all $F_{\sigma h}$'s in (194) to δ's. Change "$\sqrt{0.000893} - (F_{\sigma h} - 0.1026)^2$ in (194) to "$\sqrt{0.000843 - (\delta - 0.1026)^2}$."
108	Change the "I2" in statement 8 to "2I2".
111	Change "Read 8...IA" in line 5 to "Read 8...IA, JJ".

Page	Errata
114	Change KE's in the two statements preceding statement 73 (near page bottom) to JE's.
124 (line 6	Replace "IF (LV. EQ. 1) GO TO 148" with "IF (DZR. LT. 0.) GO TO 145".
131 (line 4 from bottom)	
138 (line 24 from bottom)	
125	Insert "DZR = 0. " just before statement 148.
133	
140	

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF TABLES

COMPUTER PROGRAMS FOR AIR/GROUND PROPAGATION AND INTERFERENCE ANALYSIS (0.1 to 20 GHz)

G. D. Gierhart and M.E. Johnson

This report describes three computer programs for use in predicting the service coverage associated with air/ground radio systems operating in the frequency band from 0.1 to 20 GHz. Power density, station separation, and service volume programs are used to obtain computer-generated microfilm plots. These are: (1) power density available at a particular altitude versus distance from a ground-based transmitting facility; (2) the desired-to-undesired signal ratio, D/U, available at an isotropic receiving antenna versus the distance separating desired and undesired facilities; and (3) constant D/U contours in the altitude versus distance space between the desired and undesired facilities. A detailed discussion of the propagation model involved and program listings are included in the appendices.

KEY WORDS: air/ground, computer program, DME, frequency sharing, ILS, interference, navigation aids, propagation model, TACAN, transmission loss, VOR.

1. INTRODUCTION

Assignments for aeronautical radio in the radio frequency spectrum must provide reliable services for an increasing air traffic density [25]*. Potential interference between facilities operating on the same or on adjacent channels must be considered in expanding present services to meet future demands. Service quality depends on many factors including the desired-to-undesired signal ratio at the receiver. This ratio varies with receiver location and time even when other parameters, such as antenna gain and radiated powers, are fixed.

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*References are listed alphabetically by author at the end of the report so that reference numbers do not appear sequentially in the text.

The computer programs described in this report were developed by the Institute for Telecommunication Sciences (ITS) of the Office of Telecommunications (OT) under the sponsorship of the Federal Aviation Administration (FAA). Although these programs were intended for use in predicting the service coverage associated with ground-based VHF/UHF/SHF air navigation aids, they can be used for other services.

The three computer programs discussed are for use in predicting the service coverage associated with air/ground radio systems in the frequency band from 0.1 to 20 GHz. Power density, station separation, and service volume programs are used to obtain computer-generated microfilm plots. These are, respectively, (1) power density available at a particular altitude versus distance from a ground-based transmitting facility; (2) the desired-to-undesired signal ratio, D/U, available at an isotropic receiving antenna versus the distance separating desired and undesired facilities; and (3) constant D/U contours in the altitude versus distance space between the desired and undesired facilities.

This type of information is very similar to that previously developed by ITS for the FAA [17,19]. However, many more operations are automated via these computer programs. The new service volume program performs operations that previously involved (a) the use of separate programs for each propagation region (line-of-sight, diffraction, and scatter), (b) manual blending between regions to obtain continuous transmission loss curves, (c) using this transmission loss data with another program to obtain D/U versus distance curves for various aircraft altitudes and station separations, and (d) using these curves to construct service volume displays. In addition, the propagation model incorporated into the programs is more general than those used previously; e.g., smooth earth conditions were emphasized in previous models, whereas the current model may also be used for irregular terrain.

The use of such information in spectrum engineering has been discussed by Hawthorne and Daugherty [23] and Frisbie et al. [16]; information on spectrum engineering for air navigation aids is available [11, 12, 14, 15, 24, 28].

The brief description of the propagation model given in section 2 is supplemented by a detailed technical discussion in appendix A. Section 3 includes a description of the computer programs in terms of input parameters and output generated. A summary and recommendations are given in sections 4 and 5, respectively. Program listings are given in appendix B, and a list of abbreviations, acronyms, and symbols is provided in appendix C along with an index to equations in appendix D.

2. PROPAGATION MODEL

The propagation model used in the programs is applicable to ground/air telecommunication links operating at radio frequencies from about 0.1 to 20 GHz at aircraft altitudes less than 300,000 ft. Ground station antenna heights must be (1) greater than 1.5 ft, (2) less than 9,000 ft, and (3) at an altitude below the aircraft. In addition, the elevation of the radio horizon must be less than the aircraft altitude. Ranges for other parameters associated with the model will be given later (table 1).

At these frequencies, propagation of radio energy is affected by the lower, non-ionized atmosphere (troposphere), specifically by variations in the refractive index of the atmosphere. Atmospheric absorption and attenuation or scattering due to rain become important at SHF [18, sec. A.3; 30, ch. 7; 40, ch. 3; 41]. The terrain, along and in the vicinity of the great circle path between transmitter and receiver, also plays an important part. In this frequency range, time and space variations of received signal and interference ratios are best described statistically.

Conceptually, the model is very similar to the Longley-Rice [32] propagation model for propagation over irregular terrain, particularly in that attenuation versus distance curves calculated for the (a) line-of-sight (b) diffraction, and (c) scatter regions are blended together to obtain values in transitions regions. In addition, the Longley-Rice relationships involving the terrain parameter, Δh, are used to estimate radio horizon parameters when such information is not available from facility siting data. The model includes allowance for (a) average ray bending, (b) horizon effects, (c) long-term fading, (d) ground facility antenna pattern, (e) surface reflection multipath, (f) tropospheric multipath, and

and (g) atmospheric absorption. However, special allowances are <u>not</u> included for the less common effects of (a) ducting, (b) rain attenuation, (c) rain scatter, (d) ionospheric scintillations, or (e) the aircraft antenna pattern.

A detailed discussion of the propagation model is provided in appendix A.

3. COMPUTER PROGRAM

The propagation model described in section 2 has been incorporated into three computer programs. These programs are written in FORTRAN for a digital computer (CDC 3800) at the Department of Commerce, Boulder, Colorado, Laboratories. Since they utilize the cathode ray tube microfilm plotting capability at the Boulder facility, substantial modification would have to be made for operation at any other facility. Average running time for the power density and station separation programs is a few seconds for each graph produced, whereas calculations for service volumes may take a minute or so. Information on input parameter requirements and output produced is provided in sections 3.1 and 3.2, respectively. Program listings are given in appendix B.

3.1 Input Parameters

The programs may be operated with 20 or more separate parameters specified. Most parameters not specifically provided as input will be set to initial conditions incorporated into the programs or will be estimated from parameters that are specified. However, three primary parameters must be provided by the user. These are facility antenna height, frequency, and aircraft altitude. Most input parameters are common to all three programs and are discussed in section 3.1.1. Section 3.1.2 is devoted to those additional parameters needed for each program.

3.1.1 Common Parameters

Parameters that may be specified as input common to all three programs are summarized in table 1, along with the acceptable value range (or options available) and the value (or option) selected in lieu of a specified parameter. For convenience, parameters are listed in table 1 in the same order as in the parameter sheet produced by the computer for the power density program (fig. 3).

Blank spaces are provided in table 1 so that copies of it can be used to specify input requirements for program runs. The units of measure following each blank are the units that will be assumed for values placed in the blanks if other units are not provided. Blanks are not provided where fixed sets of options are available, and the option desired should be circled to indicate preference. Where values (or options) are not specified, the values (or options) marked by asterisks will be used. Each parameter listed in the table is discussed below.

Aircraft Altitude Above Mean Sea Level (msl)

As shown in figure 1, this altitude is measured above msl. The propagation model is not valid for facility antennas located below the surface, and radio horizons may not be treated correctly if the aircraft altitude is less than the facility antenna elevation above msl. Use of such aircraft altitudes will result in an aborted run after an appropriate note has been printed on the computer-generated parameter sheet (fig. 5). Notes are printed, but the run is not aborted if the altitude is (a) less than 1.5 ft where surface wave contributions that are not included in the model could become important, (b) less than the effective reflecting surface elevation plus 500 ft where the model may fail to give proper consideration to the aircraft radio horizon, or (c) greater than 300,000 ft, where ionospheric effects not included in the model may become important.

Table 1. Model Parameter Specification$^{(a)}$

Parameter$^{(b)}$	Range	Value
	Primary Parameters, Specification Required	
Aircraft altitude above mean sea level (msl)	Elevation > facility antenna and < 300,000 ft-msl.	________ ft-msl
Facility antenna height above site surface (ss)	> 1.5 ft and < 9,000 ft-ss.	________ ft-ss
Frequency	100 to 20,000 MHz	________ MHz
	Secondary Parameters, Specified, Computed, Estimated, or Assumed.	
Absorption (at surface): Oxygen options	Calculated* or specified	________ dB/km
Water vapor options	Calculated* or specified	________ dB/km
Effective altitude correction factor options	Via ray tracing* or specified	________ ft
Effective reflection surface elevation above msl	At ss* or specified < facility antenna elevation	________ ft-msl
Equivalent isotropically radiated power	0.0 dBW* or specified	________ dBW
Facility antenna type options	Cosine, DME, isotropic*, JTAC, TACAN or specified	
Counterpoise diameter	0* to 500 ft	________ ft
(c) Height above ss	0* to 500 ft < facility antenna height by at least 3 ft but no more than 2000 ft	________ ft-ss
Surface options	Poor, average, or good ground, or fresh or sea water, concrete, or metal*	
Polarization options	Horizontal* or vertical	

Horizon obstacle distance from facility	From 0.1 to 3 times smooth earth horizon distance (calculated)*	__________	n mi
Elevation angle above horizontal at facility	< 12 deg (calculated)* ____deg ___min ___ sec		
Height above msl	0* to 15,000 ft-msl (calculated)*	__________	ft-msl
Type options	Irregular terrain or smooth earth*		
Minimum monthly mean surface refractivity (msl)	250 to 400 N-units (301 N-units)*	__________	N-units
Surface reflection lobing options	Contributes to variability* or determines median level		
Terrain elevation above msl at site	0* to 15,000 ft-msl	__________	ft-msl
Parameter, Δh	0* or greater	__________	ft
Type options	Poor, average* or good ground, or fresh or sea water or concrete		
Time availability options	For instantaneous levels exceeded* or for hourly median levels exceeded		

(a) Copies of this table may be used to provide data for computer runs by utilizing the blanks provided in the value column and circling desired options. The units of measure following each blank will be assumed for the values placed in the blanks if other units are not provided. These parameters are common to all three programs. However, additional information is needed for each program (tables 4, 5, and 6) and more than one "model parameter specification" is required if the desired and undesired facilities are not identical.

(b) Parameters are listed in the same order as on the parameter sheet produced by the power density computer program. Parameter sheets produced by the other programs are very similar, but not identical.

(c) These parameters are not reproduced on the computer-generated parameter sheet when a counterpoise is not present, i.e., zero counterpoise diameter.

(*) Values or options that would be assumed when specific designations are not made are flagged by asterisks.

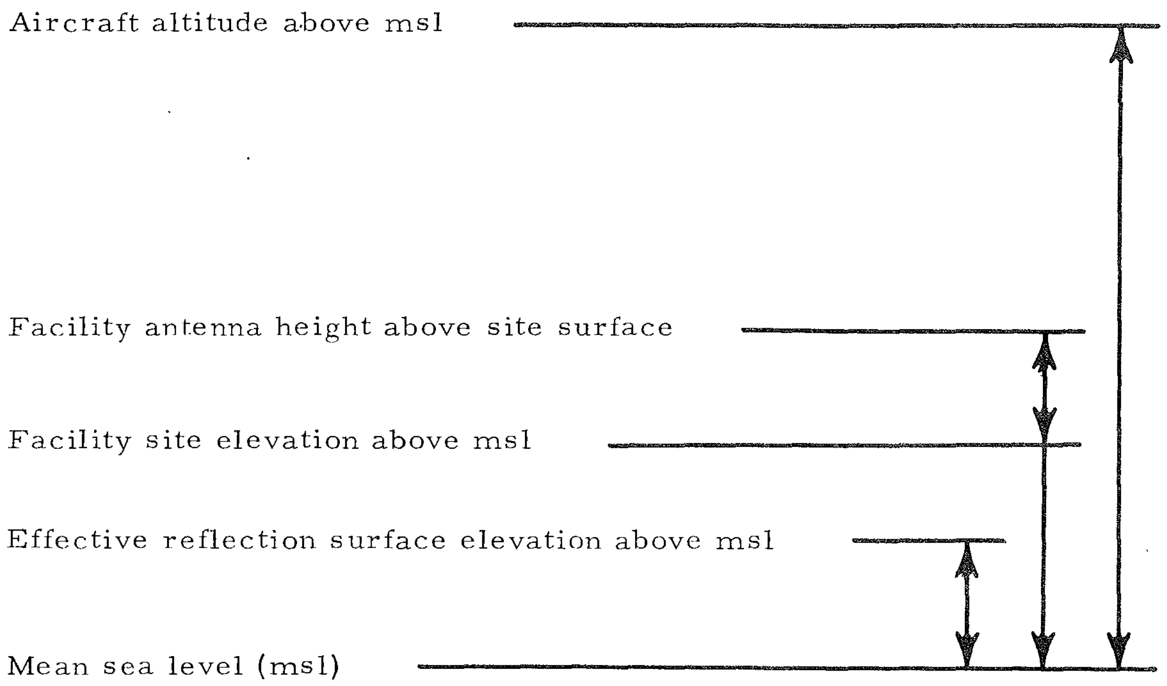

Figure 1. Antenna heights and surface elevations.

Facility Antenna Height Above Site Surface (ss)

As shown in figure 1, this height is measured above the facility site surface (ss), not msl. The propagation model is not valid for antennas below the surface, and such a facility antenna height will result in an aborted run, after an appropriate note has been printed on the computer-generated parameter sheet (fig. 5). Notes are printed, but the run is not aborted if the height is (a) less than 1.5 ft, for which surface wave contributions not included in the model could become important, or (b) greater than 9,000 ft, for which the model may include too much ray bending.

Frequency

Notes are printed if the frequency is (a) less than 100 MHz, when neglected ionospheric effects may become important; (b) greater than 5 GHz, when neglected attenuation and/or scattering from hydrometeors (rain, etc.) may become important; and (c) greater than 17 GHz, when the estimates made for atmospheric absorption may be inaccurate. For frequencies less than 20 MHz or greater than 100 GHz, the run is aborted.

Absorption (at surface) Oxygen and Water Vapor Options

The program will calculate surface oxygen and water vapor absorption rates if values are not specified. These calculations involve interpolation between values taken from Rice et al. [40, fig. 3.1]. Metric units (dB/km) are used for these parameters since this allows values printed on the parameter sheet to be checked directly against sources of such information [40, fig. 3.1; 3, sec. 7.3; 30, ch 8].

Effective Altitude Correction Factors Options

If not specified, these factors are calculated by ray tracing through an exponential atmosphere [3, sec. 3.8;4]. These factors are used in correcting for the excessive bending associated with the effective earth radius model when high (> 9,000 ft) antennas are used [40, fig. 6.7]. However, values provided by Rice et al. [40, fig. 6.7] are based on ray tracing through a three part atmosphere [3, sec. 3.7].

Effective Reflection Surface Elevation Above msl

As shown in figure 1, this elevation is measured above msl. If not specified it will be taken as the "terrain elevation above msl at site." This factor is used when the terrain from which reflection is expected is not at the same elevation as the facility site, e.g., a facility located on a hill top or cliff edge. When the elevation of the facility antenna is below the spherical reflection surface level, a note will be printed and the run aborted.

Equivalent Isotropically Radiated Power

Equivalent isotropically radiated power (EIRP) is the power radiated from the facility transmitting antenna increased by the antenna's main lobe directive gain (expressed in decibels above an isotropic antenna). For example, a radiated power of 10 dBW and an antenna gain of 10 dB would result in 20 dBW EIRP. Effective radiated power (ERP) is similar to EIRP but is calculated with an antenna measured relative to a half-wave dipole; therefore, EIRP values are 2.15 dB greater than ERP values when the same radiated power is involved.

Facility Antenna Type Options

These options involve the antenna gain pattern of the facility antenna in the vertical plane. Patterns currently built into the program are shown in figure 2 where antenna gain, normalized to the maximum gain, is plotted against elevation angle (measured above the horizontal). The "cosine" pattern is used for a vertically polarized electric dipole or a horizontally polarized magnetic dipole such as the antenna associated with the VHF Omni Range (VOR) or Instrument Landing System (ILS). FAA specifications [13, sec. 3.5] were used to define the Distance Measuring Equipment (DME) pattern. Measured gain data on the RTA-2 antenna, supplied to ITS by FAA, were used in obtaining the pattern for this Tactical Air Navigation (TACAN) antenna. The JTAC [29, p. 51] pattern is for an antenna with a 40° half-power beamwidth and a beam that is tilted up to 20°. Program modifications can easily be made to accommodate other patterns that are specified in terms of gain versus elevation angle.

Antenna pattern data is used to provide information on gain relative to the main beam <u>only</u>. The extent to which the facility's main beam antenna gain exceeds that of an isotropic antenna is included in the specification of equivalent isotropically radiated power, EIRP, since

$$\mathrm{EIRP} = P_{TR} + G_M \ \mathrm{dBW} \qquad (1)$$

where P_{TR}(dBW) is the total power radiated from the facility antenna and G_M (dB greater than isotropic) is the main beam gain of the facility antenna.

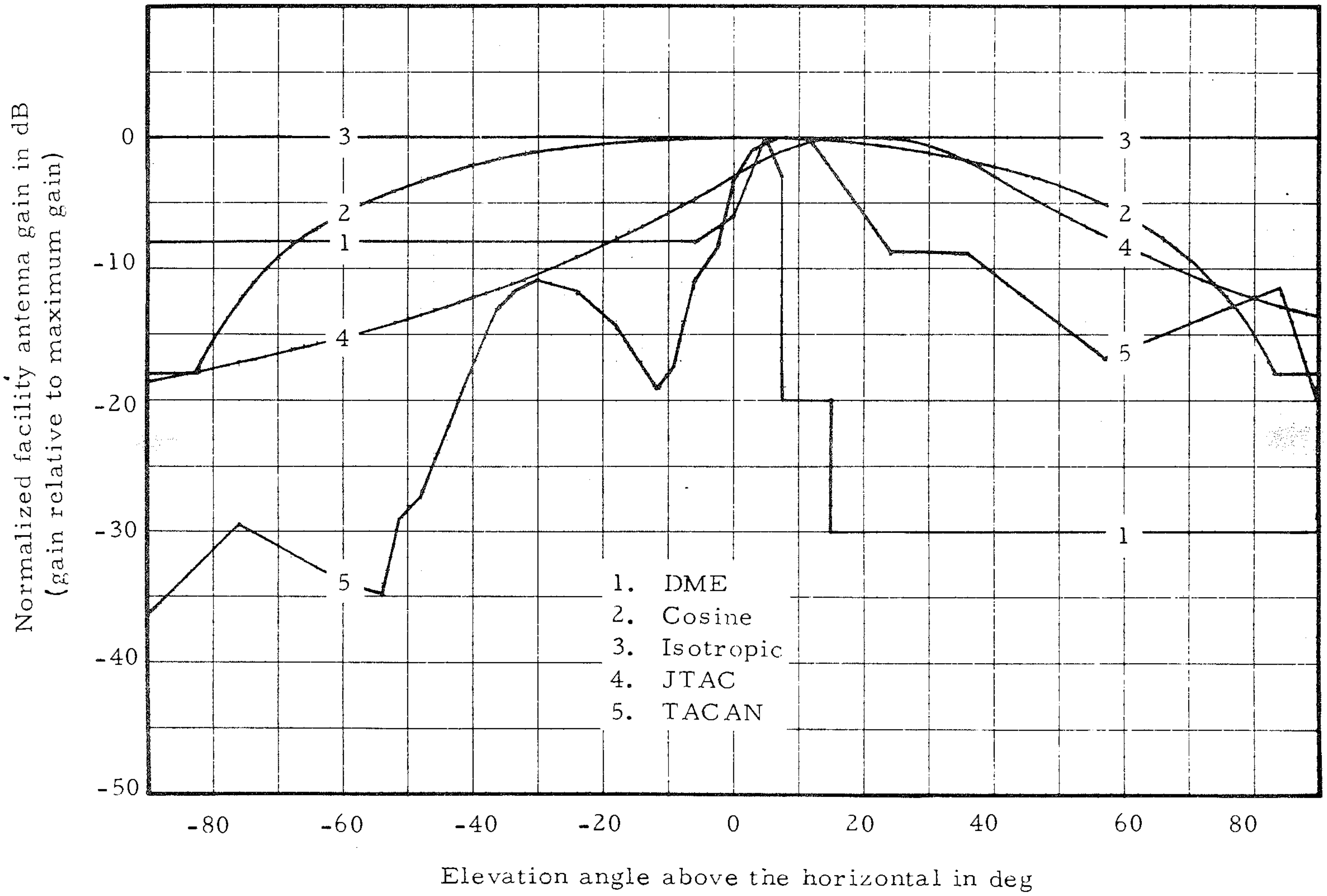

Figure 2. Normalized antenna gain vs. elevation angle.

Facility Antenna Counterpoise Diameter

The counterpoise was incorporated into the model for the VOR. It will not be included in the calculations if its diameter is specified as zero, and the parameters associated with it will not be printed. A diameter greater than 500 ft will cause a warning note to be printed, but will not abort the run.

Facility Antenna Counterpoise Height Above ss

If the height above the site surface is less than zero, it will be set equal to zero. An appropriate note will be printed and the run aborted if the height is (a) greater than 500 ft or (b) greater than the "facility antenna height."

Facility Antenna Counterpoise Surface Options

These options fix the conductivity and dielectric constant associated with the counterpoise surface. Values estimated for each option are given in table 2 [32, table 2].

Table 2. Surface Types and Constants

Type	Conductivity (mhos/m)	Dielectric Constant
Poor ground	0.001	4
Average ground	0.005	15
Good ground	0.02	25
Sea water	5	81
Fresh Water	0.01	81
Concrete	0.01	5
Metal	10^7	1

Facility Antenna Polarization

The option selected for polarization (horizontal) when a specific option is not selected will frequently result in poorer propagation conditions for typical line-of-sight air/ground links.

Horizon Obstacle Distance from Facility

If not specified, this distance will be calculated from horizon parameters that are specified and/or by using the terrain parameter Δh. When the distance is not within 0.1 to 3 times the smooth earth horizon distance, a warning note will be printed, but the run will not be aborted.

Horizon Obstacle Elevation Angle Above Horizontal at Facility

If not specified, this angle will be calculated from horizon parameters that are specified and/or by using the terrain parameter Δh. When the angle exceeds 12°, a warning note will be printed but the run will not be aborted.

Horizon Obstacle Height Above msl

If not specified, this height will be calculated from horizon parameters that are specified and/or by using the terrain parameter Δh. When the height is not within the 0 to 15,000 ft-msl* range, a warning note will be printed but the run will not be aborted.

Horizon Obstacle Type Options

When the smooth earth option is used, all horizon parameters, effective reflection surface elevation, and the terrain parameter Δh are set to their smooth earth values.

Minimum Monthly Mean Surface Refractivity

Values for the minimum monthly mean surface refractivity referred to mean sea level, N_0, may be obtained from figure 3. Specification of

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*This notation is used to indicate the units of measure and the base from which it is measured so that ft-msl implies feet above mean sea level.

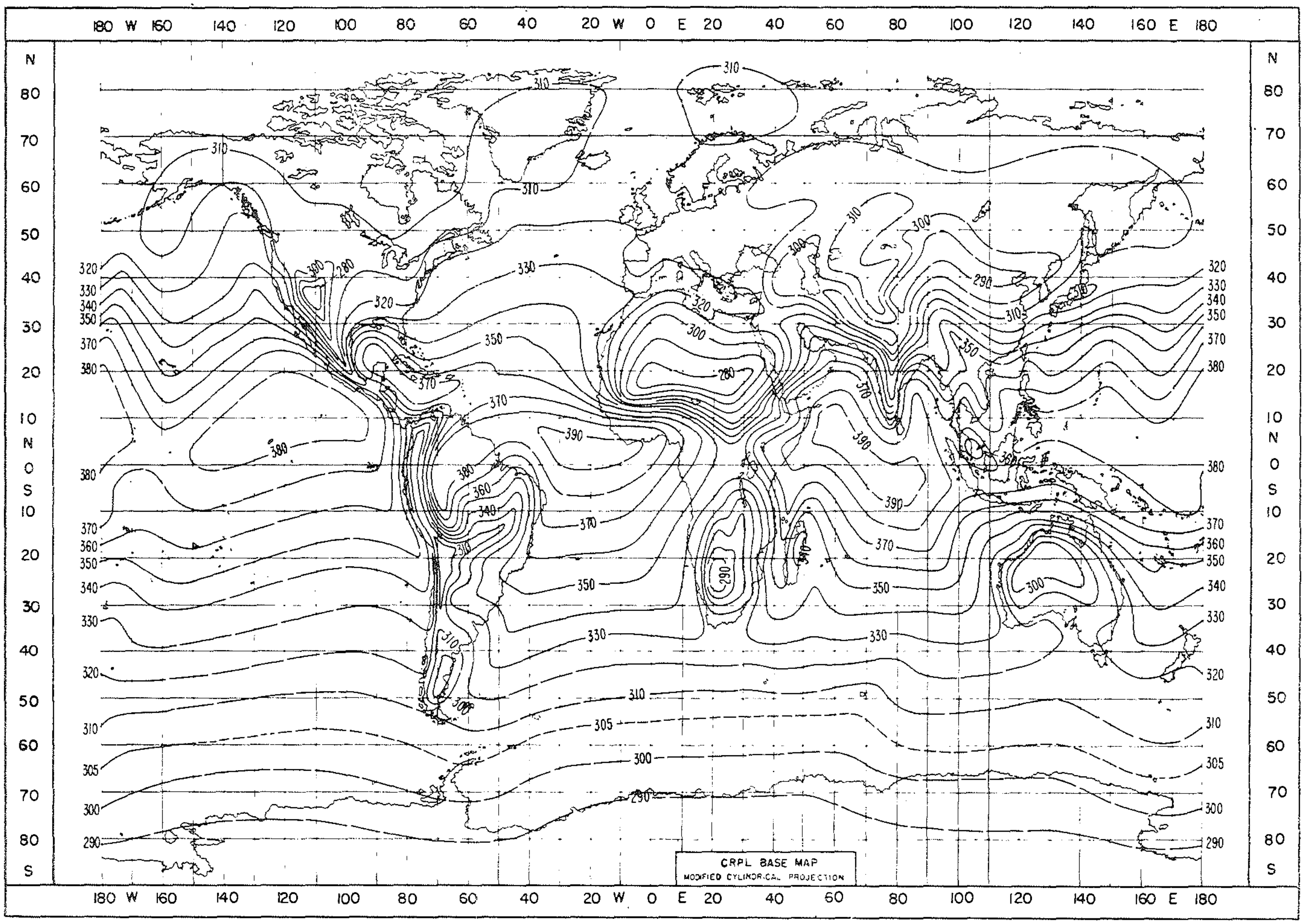

Figure 3. *Surface refractivity map [40, fig. 4.1]. Minimum monthly mean surface refractivity values are referred to mean sea level,* N_o *N-units.*

N_o outside the 250-to-400 N-unit range will result in N_o being set to 301. If the surface refractivity, Ns, calculated from N_o is less than 250 N-units, N_s will be set to 250 N-units and an appropriate note printed. An N_s of 301 N-units corresponds to an effective earth radius factor of 4/3 [40, fig. 4.2].

Surface Reflection Lobing Options

Lobing associated with interference between direct and reflected rays in the line-of-sight region contributes to the short-term variability (within-the-hour fading) or is used to define the median level in the line-of-sight region. These options can result in predictions that are very different. The variability option provides a more reliable estimate of propagation statistics in most cases. However, the pattern option is useful when selecting antenna heights to avoid low signal levels (nulls) in particular portions of air space. With the first option, lobing is treated as part of the short-term (within-the-hour) variability when the reflected ray path length exceeds the direct ray path length by more than half a wavelength (inside horizon lobe); i.e., the lobing pattern is not plotted. The other option allows the median level to be determined by such lobing for several (~10) lobes just inside the radio horizon; i.e., the lobing pattern will be plotted. Regardless of the option selected, lobing caused by reflection from the counterpoise (if present) is used in median level determination for about 10 lobes and does not contribute to the short-term fading, i.e., if present, counterpoise lobing is plotted with either option.

Terrain Elevation Above msl at Site

This is the elevation of the facility site above msl. It is used to calculate the height of the facility antenna above msl from "facility antenna height above site surface" as implied by figure 1. Values less than zero are set to zero, and a note will be printed if the 15,000 ft-msl limit is exceeded, but the run will not abort.

Table 3. Estimates of Δh [32, table 1]

Type of Terrain	Δh (feet)	Δh (meters)
Water or very smooth plains	0 - 20	0 - 5
Smooth plains	20 - 70	5 - 20
Slightly rolling plains	70 - 130	20 - 40
Rolling plains	130 - 260	40 - 80
Hills	260 - 490	80 - 150
Mountains	490 - 980	150 - 300
Extremely rugged mountains	>2,000	>700

Terrain Parameter Δh

This parameter is used to characterize irregular terrain. Values for it may be calculated from path profile data [32, annex 2], or estimated using table 3.

Terrain Type Options

These options fix the conductivity and dielectric constants associated with the effective reflecting surface. Values associated with each option are given in table 2.

Time Availability Options

If the first option is selected short-term (within-the-hour) fading will contribute to the variability, and time availability is applicable to instantaneous levels that are available for specific percentages of the time. With the second option only long-term (hourly median) variations are included in the variability, and time availability is applicable to the hourly median levels that are available for a specific percentage of hours.

3.1.2 Additional Parameters

Table 1 may be used to provide most of the information needed to run any of the three programs, and the additional information required may be specified by using tables 4, 5, and 6 for the power density, station separation, and service volume programs, respectively. Two facilities (desired and undesired) are involved in station separation and service volume calculations so that data via table 1 are required for each facility. The "Graph Format" sections of these tables are similar except for items related to the specific parameters used as abscissa and ordinate in the different programs. When scales are not specified, appropriate ones will be estimated so that the "Graph Format" items should be specified only when definite requirements exist. A title of 35 characters or spaces may be specified; it will appear on the computer-generated plots and parameter sheets (samples given in sec. 3.2).

Additional parameters for the power density program (table 4) involve only "Graph Format" parameters so that the above discussion is sufficient. However, parameters other than "Graph Format" are included in tables 5 and 6. These are described in the text below.

Distance from Desired Facility to Aircraft (Table 5)

A sketch showing the relative positions of the desired facility, undesired facility, and aircraft is given in figure 4. The great circle distance from the desired facility to the aircraft, d_D, and the great circle distance from the undesired facility, d_U, are shown.

D/U Signal Ratios (Table 6)

The desired-to-undesired signal ratio, D/U, expressed in decibels, is measured at the terminals of an ideal (lossless) isotropic receiving aircraft antenna. If the desired and undesired facilities transmit at the same frequency, D/U would be identical with the power density (dB-W/sq m) available from the desired facility at the aircraft minus that available from the undesired station. This occurs because the effective receiving area of an isotropic antenna varies with frequency

Table 4. Additional Parameters for Power Density Program.(a)

Parameter	Range	Value
	Graph Format (b), Estimated if not Specified	
Abscissa grid intervals (Facility-to-aircraft distance)	< difference between limits	_____ n mi
Left-hand limit	≥ 0, right-hand limit	_____ n mi
Right-hand limit	≤ 1,000 n mi	_____ n mi
Ordinate grid intervals (Power density)	< difference between limits	_____ dB
Lower Limit	< upper limit	_____ dB-W/sq m
Upper Limit	Usually < 0 dB-W/sq m	_____ dB-W/sq m
Title	< 35 characters or spaces	

(a) Copies of this table may be used to provide data for computer runs by utilizing the blanks provided in the value column. The units of measure following each blank will be assumed for values placed in the blanks if other units are not provided. Other parameter values may be specified using table 1.

(b) Except for the title, graph format parameters are not given on the computer generated parameter sheet (fig. 5).

Table 5. Additional Parameters for Station Separation Program.[a]

Parameter	Range	Value
Additional Primary Model Parameter, Specification Required		
Distance from desired facility to aircraft	0.1 to 1,000 n mi	_____ n mi
Graph Format[b], Estimated if not specified		
Abscissa grid intervals (Station separation)	< difference between limits	_____ n mi
Left-hand limit	≥ 0, < right-hand limit	_____ n mi
Right-hand limit	≤ 1,000 n mi	_____ n mi
Ordinate grid intervals (D/U signal ratio)	< difference between limits	_____ dB
Lower limit	< Upper limit	_____ dB
Upper limit	Usually < 100 dB	_____ dB
Title	< 35 characters or spaces	

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[a] Copies of this table may be used to provide data for computer runs by utilizing the blanks provided in the value column. The units of measure following each blank will be assumed for values placed in the blanks if other units are not provided. Other parameter values may be specified using Table 1.

[b] Except for the title, graph format parameters are not given on the computer-generated parameter sheet (fig. 4).

Table 6. Additional Parameters for Service Volume Program.[a]

Parameter	Range	Value
Primary Model Parameters, Specification Required		
D/U signal ratios (dB)	Up to 30 values may be specified in space below for a particular program run.	
Station separation	0.1 to 1,000 n mi	____ n mi
Secondary Model Parameter, Estimated if not specified		
Aircraft altitudes (ft above msl) up to 25 may be specified in space below to cover extent of the service volume required. Values for effective altitude correction factors may be paired with altitude values if desired. See Table 1 and discussion following it for additional information.		
Graph Format[b], Estimated if not specified		
Abscissa grid intervals	< difference between limits	____ n mi
Left-hand limit	≥ 0, < right-hand limit	____ n mi
Right-hand limit	< 1,000 n mi	____ n mi
Ordinate grid intervals (Aircraft altitude)	< difference between limits	____ ft
Lower Limit	< Upper limit	____ ft
Upper Limit	≤ 300,000 ft	____ ft
Title	< 35 characters or spaces	____ ft

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[a] Copies of this table may be used to provide data for computer runs by utilizing the spaces provided. The units indicated will be assumed for values provided if other units are not provided. Other parameter values may be specified using Table 1.

[b] Except for the title, graph format parameters are not given on the computer-generated parameter sheet (fig. 5).

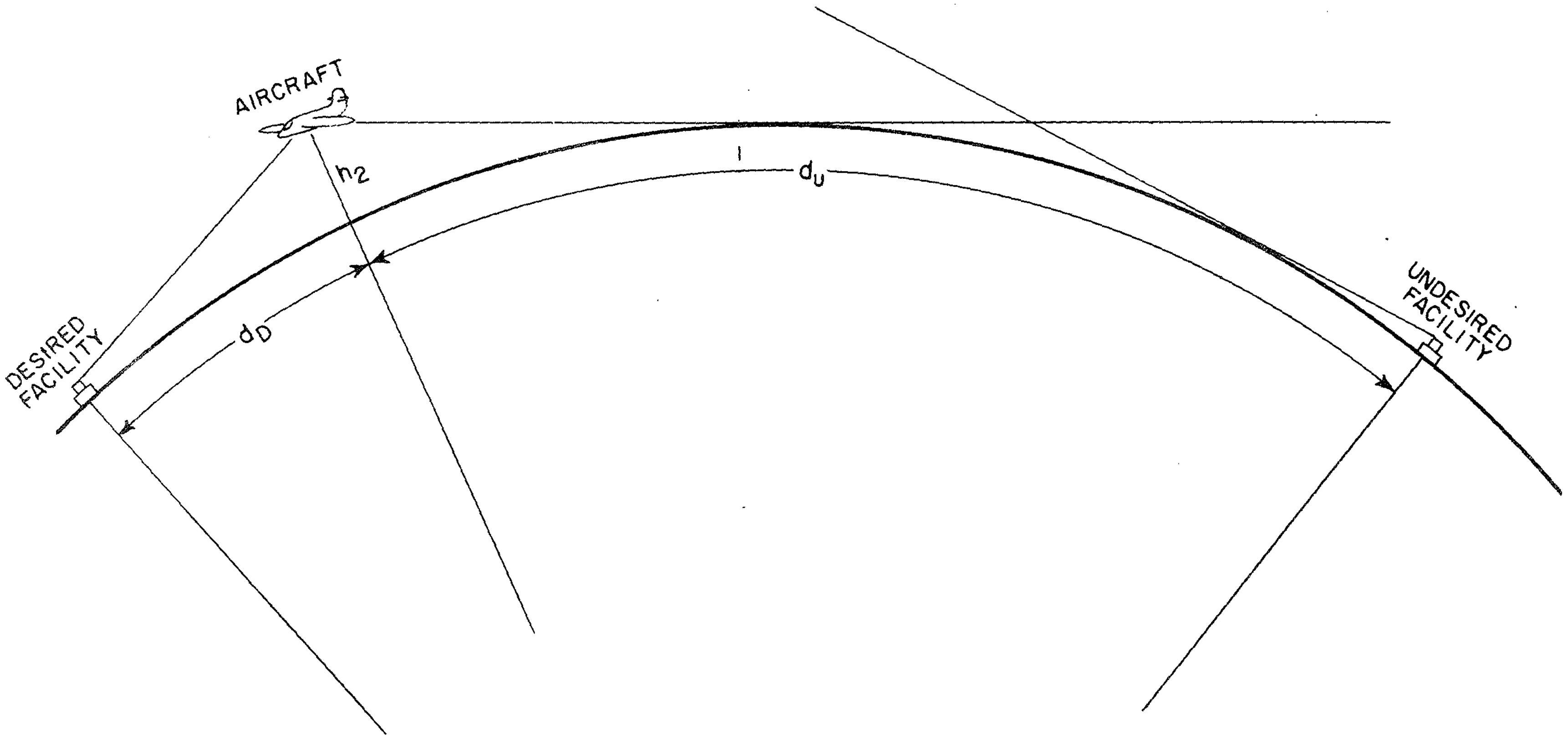

Figure 4. Sketch illustrating interference configuration.

(see eq. 3 of sec. 3.2). When the antenna gain and transmission line losses associated with the aircraft are common to both desired and undesired signals, D/U at the receiver is identical with D/U at the antenna.

Service volume calculations are done by (a) calculating D/U values at a large number of aircraft locations and (b) interpolating between these values to obtain locations where other D/U levels are available. Each service volume plot is applicable to one specified D/U value, but up to 30 service volume curves may be obtained without repeating the initial calculations when the D/U requirement is the only parameter allowed to change.

Station Separation (Table 6)

The great circle station separation, S, between desired and undesired facilities is

$$S = d_D + d_U \text{ n mi} \tag{2}$$

where the desired and undesired distances, d_D and d_U, are measured in nautical miles. This relationship is illustrated in figure 4. Note that the 30 service volume curves mentioned in the previous paragraph would correspond to 30 D/U values, all for a single station separation.

Aircraft Altitudes

Up to 25 altitudes may be used in calculating D/U values from which service volumes will be developed (see previous paragraph on D/U signal ratios). These would normally be selected to (a) provide coverage of the air space of interest and (b) specifically include any altitudes that have special significance.

3.2 Output Generated

Each program causes the computer to produce (a) a listing of parameters associated with a particular run and (b) a microfilm plot. These outputs are provided for each parameter set used as input to the computer and are tied to each other by a run code consisting of the date and time at which calculations for a particular parameter set started. Sample outputs for the power density, station separation, and service volume programs are provided in sections 3.2.1, 3.2.2, and 3.2.3, respectively.

3.2.1 Power Density

A sample parameter sheet for the power density program is shown in figure 5. Parameters are given in the same order as they were in table 1 (sec. 3.1). They were selected so that a comparison with the reference [18, fig. 1] can be made. The term*, A_e dB-sq m, required to convert power density*, S_a dB-W/sq m, to power available at the terminals of an isotropic antenna P_I dBW, is given at the bottom of the parameter sheet; i.e.,

$$P_I = S_a + A_e \text{ dBW}. \tag{3}$$

Figure 6 shows the power density versus distance curves that go with the parameter sheet provided in figure 5. The curves show the power density levels expected to be exceeded for 5%, 50%, and 95% of the time along with the power density that would be present under free-space propagation conditions. Lobing is not shown in figure 6 curves since the option to consider lobing as part of the variability was used. Figure 7 shows the lobing that results when the other option is taken.

3.2.2 Station Separation

Sample parameter sheets for the station separation program are shown in figures 8 and 9. A parameter sheet was produced for each facility (desired, fig. 8; undesired, fig. 9), since they do not share common parameters. The format of the parameter sheets is similar to

---

*The notation used for the units of these quantities is intended to imply that they are decibel-type quantities obtained by taking 10 log of a quantity with the units indicated after dB-; e.g., A_e=10 log a_e (effective area expressed in square meters).

```
         PARAMETERS FOR ITS PROPAGATION MODEL  AUG 73
                  09/05/73  16:01:23 RUN

              POWER DENSITY FOR ISOTROPIC ANT.
                   REQUIRED OR FIXED
                   -----------------
AIRCRAFT ALTITUDE:   40000 FT ABOVE MSL
FACILITY ANTENNA HEIGHT:   50.0 FT ABOVE SITE SURFACE
FREQUENCY:   125 MHZ

                SPECIFICATION OPTIONAL
                ----------------------
ABSORPTION: OXYGEN  0.00029 DB/KM*
            WATER VAPOR  0.00000 DB/KM*
EFFECTIVE ALTITUDE CORRECTION FACTOR:   2107 FT*
EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL:      0 FT
EQUIVALENT ISOTROPICALLY RADIATED POWER:    0.0 DBW
FACILITY ANTENNA TYPE:  ISOTROPIC
     POLARIZATION: HORIZONTAL
HORIZON OBSTACLE DISTANCE:   8.69 N MI FROM FACILITY*
     ELEVATION ANGLE:   -0/ 6/30 DEG/MIN/SEC ABOVE HORIZONTAL*
     HEIGHT:     0 FT ABOVE MSL
     TYPE: SMOOTH EARTH
MINIMUM MONTHLY MEAN SURFACE REFRACTIVITY:
     301 N-UNITS     AT SEA LEVEL: 301 N-UNITS
SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
TERRAIN ELEVATION AT SITE:     0 FT ABOVE MSL
     PARAMETER:    0 FT
     TYPE:  AVERAGE GROUND
TIME AVAILABILITY:  FOR INSTANTANEOUS LEVELS EXCEEDED


POWER DENSITY (DB-W/SQ M) VALUES MAY BE CONVERTED TO POWER
     AVAILABLE AT THE TERMINALS OF A PROPERLY POLARIZED
     ISOTROPIC ANTENNA (DBW) BY ADDING   -3.4 DB-SQ M.

* COMPUTED VALUE
```

Figure 5. Sample parameter sheet, power density program.

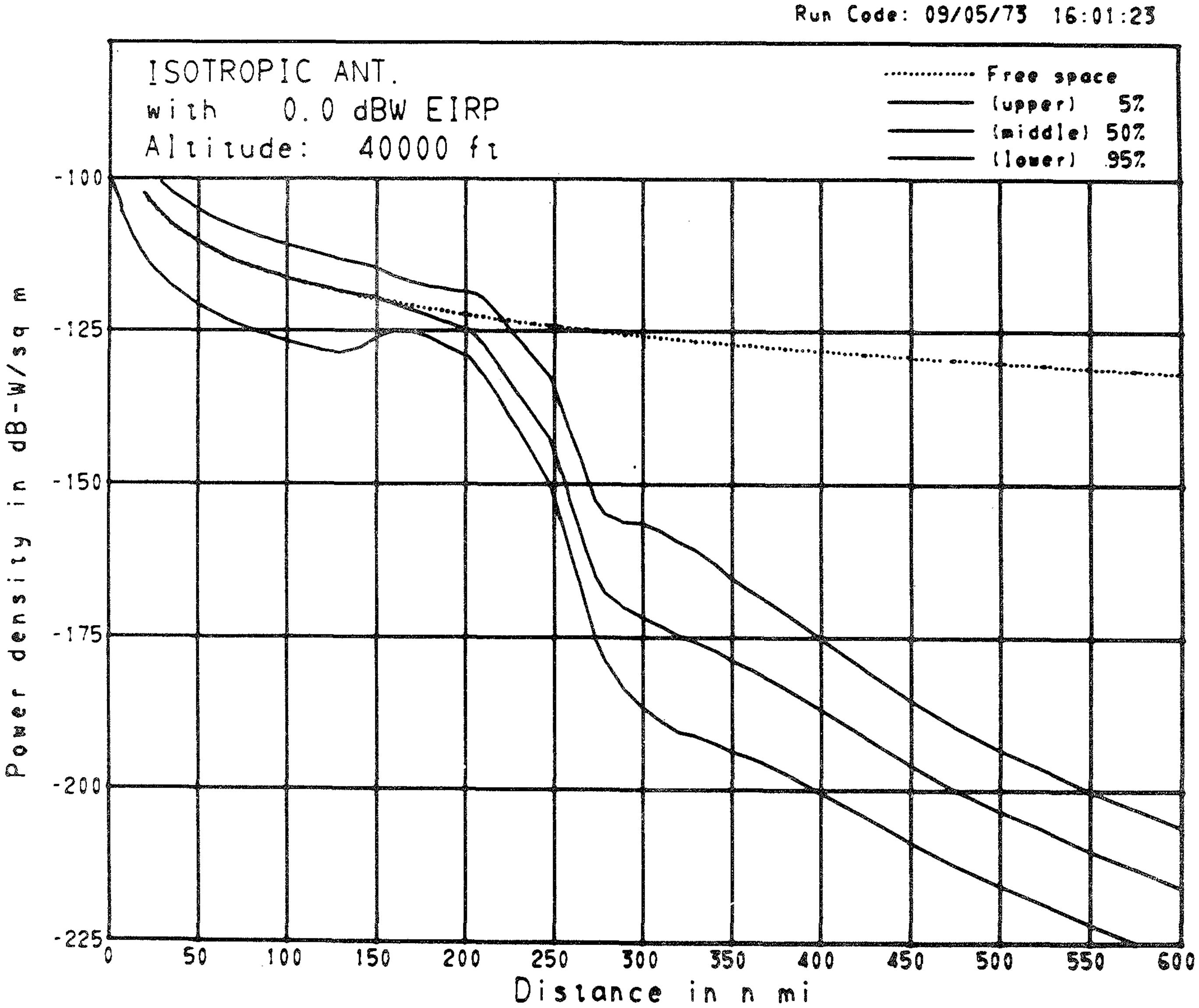

Figure 6. Sample power density versus distance plot.

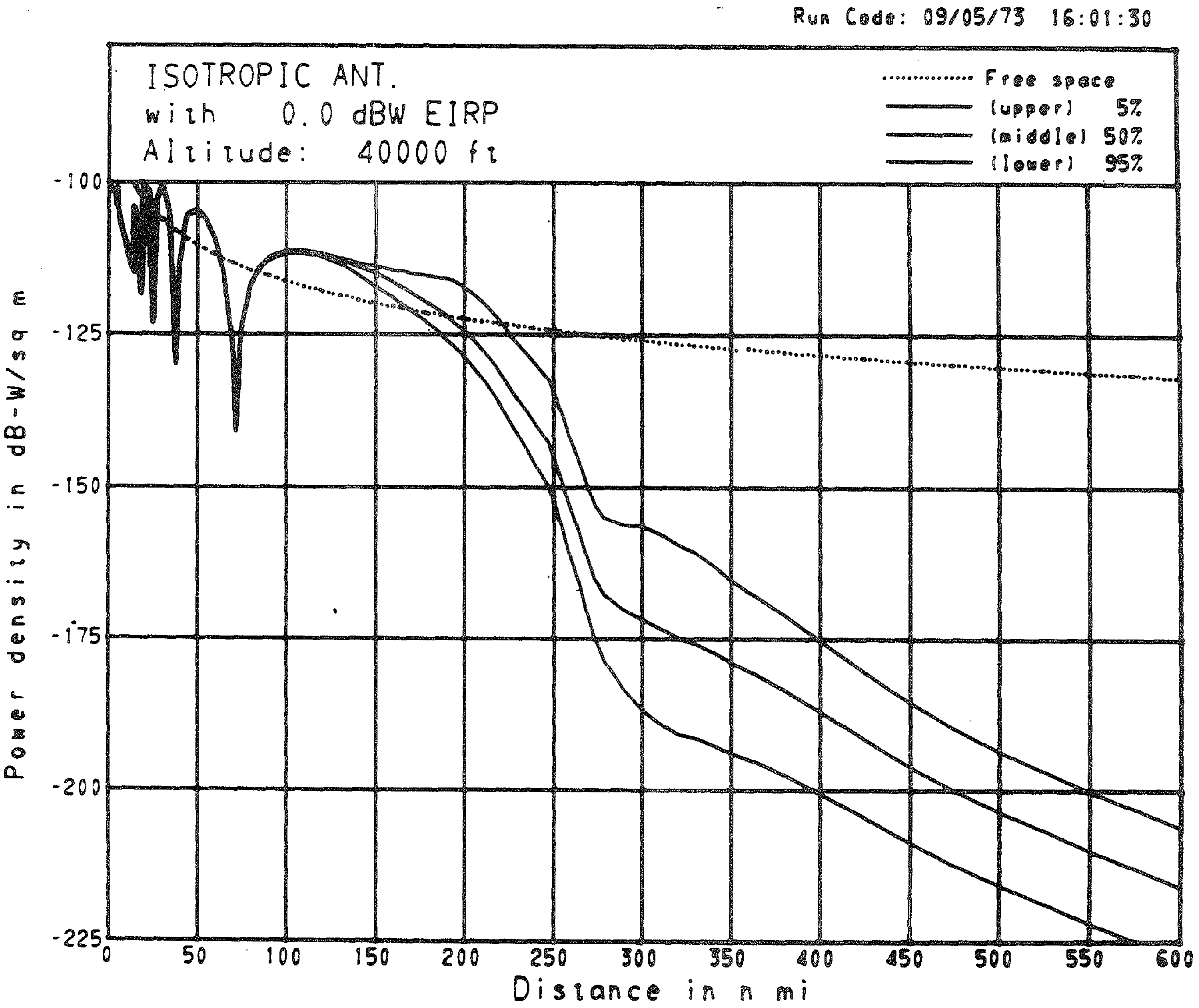

Figure 7. Sample power density versus distance plot, with lobing.

```
        PARAMETERS FOR ITS PROPAGATION MODEL  AUG 73
                 09/05/73  16 56:49 RUN


        DESIRED STATION IS ILS LOCALIZER (8-LOOP)
                 REQUIRED OR FIXED
                 -----------------
AIRCRAFT ALTITUDE:    6250 FT ABOVE MSL
FACILITY ANTENNA HEIGHT:    5.5 FT ABOVE SITE SURFACE
FREQUENCY:   110 MHZ

              SPECIFICATION OPTIONAL
              ----------------------
ABSORPTION: OXYGEN  0.00023 DB/KM*
            WATER VAPOR  0.00000 DB/KM*
EFFECTIVE ALTITUDE CORRECTION FACTOR:      0 FT*
EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL:      0 FT
EQUIVALENT ISOTROPICALLY RADIATED POWER:   22.1 DBW
FACILITY ANTENNA TYPE:  8-LOOP ARRAY (COSINE VERTICAL PATTERN)
     POLARIZATION: HORIZONTAL
HORIZON OBSTACLE DISTANCE:   2.88 N MI FROM FACILITY*
     ELEVATION ANGLE:   -0/ 2/ 9 DEG/MIN/SEC ABOVE HORIZONTAL*
     HEIGHT:    0 FT ABOVE MSL
     TYPE: SMOOTH EARTH
MINIMUM MONTHLY MEAN SURFACE REFRACTIVITY
     301 N-UNITS     AT SEA LEVEL; 301 N-UNITS
SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
TERRAIN ELEVATION AT SITE:    0 FT ABOVE MSL
     PARAMETER:   0 FT
     TYPE:  AVERAGE GROUND
TIME AVAILABILITY:  FOR INSTANTANEOUS LEVELS EXCEEDED


* COMPUTED VALUE
```

Figure 8. Sample parameter sheet, station separation program, desired facility.

```
        PARAMETERS FOR ITS PROPAGATION MODEL  AUG 73
                 09/05/73  16:56:49 RUN


             UNDESIRED STATION IS STANDARD VOR
                  REQUIRED OR FIXED
                  -----------------
AIRCRAFT ALTITUDE:     6250 FT ABOVE MSL
FACILITY ANTENNA HEIGHT:   16.0 FT ABOVE SITE SURFACE
FREQUENCY:   110 MHZ

                SPECIFICATION OPTIONAL
                ----------------------
ABSORPTION: OXYGEN  0.00023 DB/KM*
            WATER VAPOR  0.00000 DB/KM*
EFFECTIVE ALTITUDE CORRECTION FACTOR:      0 FT*
EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL:      0 FT
EQUIVALENT ISOTROPICALLY RADIATED POWER:   22.1 DBW
FACILITY ANTENNA TYPE:  4-LOOP ARRAY (COSINE VERTICAL PATTERN)
     COUNTERPOISE DIAMETER:   52 FT
          HEIGHT:   12 FT ABOVE SITE SURFACE
          SURFACE:   METALLIC
     POLARIZATION: HORIZONTAL
HORIZON OBSTACLE DISTANCE:   4.91 N MI FROM FACILITY*
     ELEVATION ANGLE:   -0/ 3/41 DEG/MIN/SEC ABOVE HORIZONTAL*
     HEIGHT:      0 FT ABOVE MSL
     TYPE: SMOOTH EARTH
MINIMUM MONTHLY MEAN SURFACE REFRACTIVITY
     301 N-UNITS      AT SEA LEVEL: 301 N-UNITS
SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
TERRAIN ELEVATION AT SITE:     0 FT ABOVE MSL
     PARAMETER:    0 FT
     TYPE:  AVERAGE GROUND
TIME AVAILABILITY:  FOR INSTANTANEOUS LEVELS EXCEEDED


* COMPUTED VALUE
```

Figure 9. Sample parameter sheet, station separation program, undesired facility.

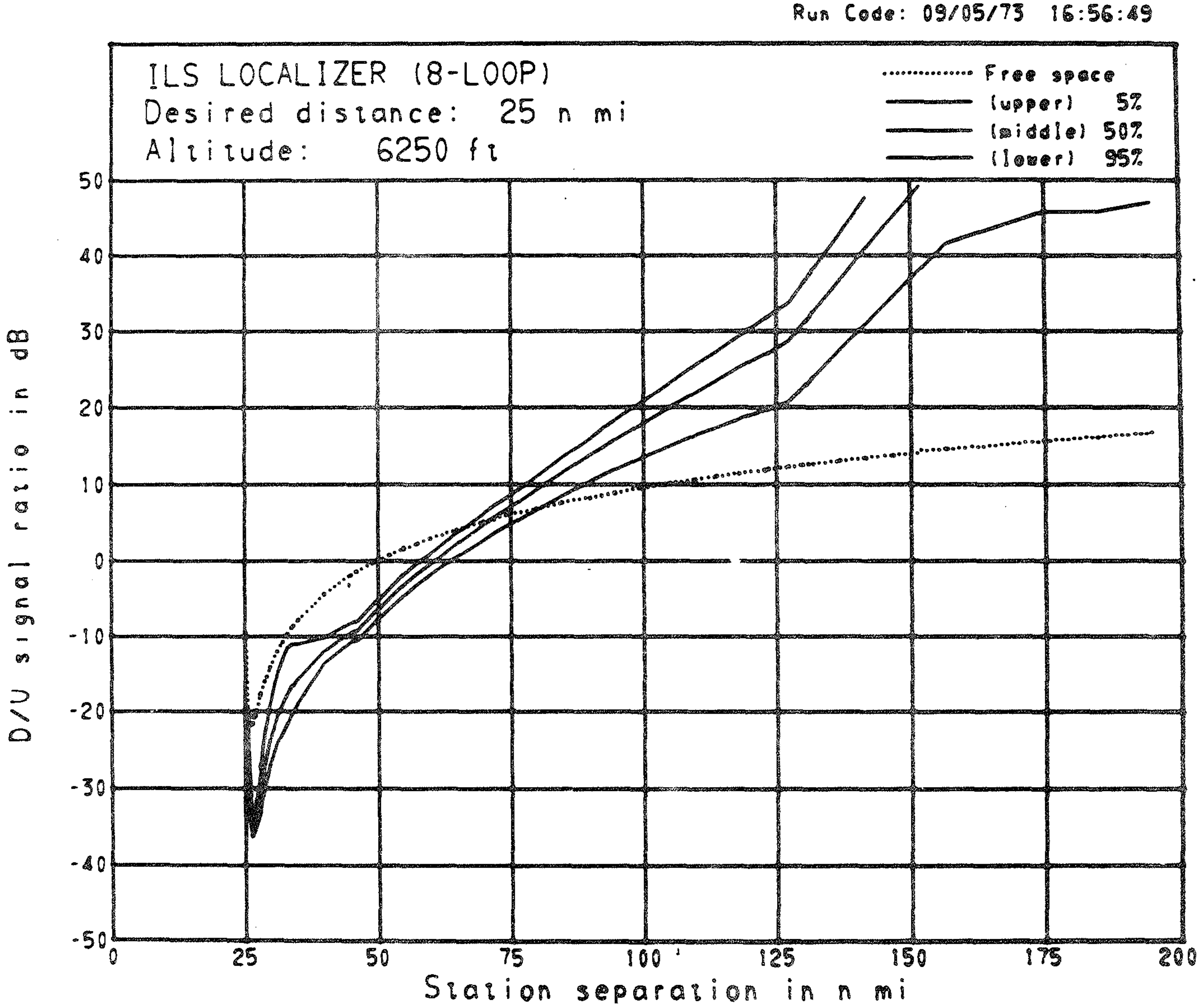

Figure 10. Sample D/U signal ratio versus station separation plot.

that produced with the power density program (fig. 5) except for the additional primary parameter of "Distance from desired facility to aircraft." In accordance with footnote c of table 1, counterpoise data is included on the desired station parameter sheet (fig. 8) only.

The station separation plot generated for the parameters given in figures 8 and 9 is shown in figure 10. Desired-to-undesired, D/U, signal ratios (see D/U Signal Ratio paragraph in sec. 3.1.2) are plotted against station separation (see Station Separation paragraph of sec. 3.1.2) for three time availabilities (5%, 50%, and 95%) and free-space propagation conditions. These curves are calculated for a fixed desired facility to aircraft distance so that the undesired facility to aircraft distance varies in accordance with (2). A time availability of 95% implies that the D/U corresponding to it for a specific configuration will be available at least 95% of the time (see Time Availability Options paragraph of sec. 3.1.1).

3.2.3 Service Volume

Figure 11 is a sample parameter sheet for the service volume program. Only one parameter sheet was produced since the desired and undesired facilities were given identical parameters. Except for data associated with D/U ratios, station separations, and aircraft altitudes (see paragraphs on D/U Signal Ratios, Station Separation, and Aircraft Altitudes in sec. 3.1), the format is similar to that produced by the power density program (fig. 5).

The service volume plot generated for the parameters given in figure 11 is shown in figure 12. Contours of constant D/U (see D/U Signal Ratio paragraph in sec. 3.1.2) are plotted in the altitude versus distance between facilities plane. These are shown for free-space propagation conditions and three time availabilities (5%, 50%, and 95%). Inside the volume formed by rotating the contours about the ordinate axis, the time availability will almost always equal or exceed that associated with the contours used to form it. A fixed station separation is used in producing all curves shown on a particular service volume plot (see Station Separation paragraph of sec. 3.1.2).

```
              PARAMETERS FOR SERVICE VOLUME CURVES
                        ITS MODEL AUG 73
                    09/05/73  20:02:25 RUN

     DESIRED/UNDESIRED STATIONS ARE VOR WITH COUNTERPOISE

                        REQUIRED OR FIXED
                        -----------------
AIRCRAFT ALTITUDES IN FT ABOVE MSL:     500,    1000,    5000,
       10000,  20000,  30000,  40000,  50000,  60000,  70000,
       80000,  90000, 100000
D/U RATIOS IN DB:  20
FACILITY ANTENNA HEIGHT:   16.0 FT ABOVE SITE SURFACE
FREQUENCY:   113 MHZ
STATION SEPARATION:  390 N MI

                     SPECIFICATION OPTIONAL
                     ----------------------
ABSORPTION: OXYGEN  0.00025 DB/KM*
            WATER VAPOR  0.00000 DB/KM*
EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL:      0 FT
EQUIVALENT ISOTROPICALLY RADIATED POWER:   22.1 DBW
FACILITY ANTENNA TYPE: 4-LOOP ARRAY (COSINE VERTICAL PATTERN)
     COUNTERPOISE DIAMETER:   52 FT
          HEIGHT:   12 FT ABOVE SITE SURFACE
          SURFACE:   METALLIC
     POLARIZATION: HORIZONTAL
HORIZON OBSTACLE DISTANCE:   4.91 N MI FROM FACILITY*
     ELEVATION ANGLE:   -0/ 3/41 DEG/MIN/SEC ABOVE HORIZONTAL*
     HEIGHT:      0 FT ABOVE MSL
     TYPE: SMOOTH EARTH
MINIMUM MONTHLY MEAN SURFACE REFRACTIVITY
     301 N-UNITS      AT SEA LEVEL: 301 N-UNITS
SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
TERRAIN ELEVATION AT SITE:     0 FT ABOVE MSL
     PARAMETER:    0 FT
     TYPE:  AVERAGE GROUND
TIME AVAILABILITY:  FOR INSTANTANEOUS LEVELS EXCEEDED

* COMPUTED VALUE
```

Figure 11. Sample parameter sheet, service volume program.

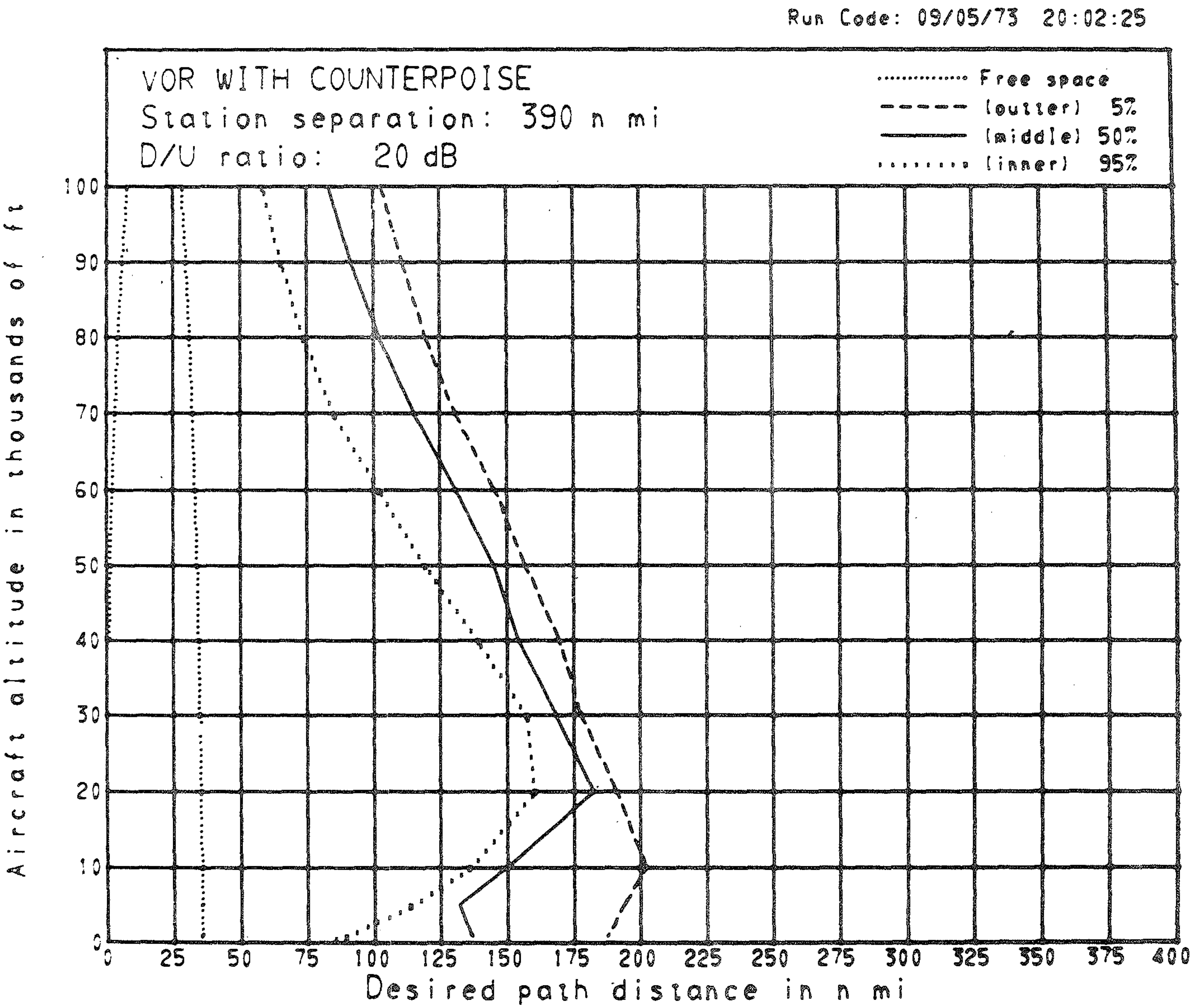

Figure 12. Sample service volume plot.

4. SUMMARY

A brief description of a computerized propagation model for air/ground telecommunications developed by ITS for FAA was given in section 2, and a detailed discussion is provided in appendix A. The model is very similar to the Longley-Rice [32] propagation model for propagation over irregular terrain. It uses the Longley-Rice relationships involving the terrain parameter, Δh, to estimate radio horizon parameters when such information is not available [32, sec. 2.4]. Allowances are included in the model for (a) average ray bending, (b) horizon effects, (c) long-term power fading, (d) ground facility antenna pattern and counterpoise, (e) surface reflection multipath, (f) tropospheric multipath, and (g) atmospheric absorption. However, special allowances are not included for the less common effects of (a) ducting, (b) rain attenuation, (c) rain scatter, (d) ionospheric scintillations, or (e) the aircraft antenna pattern.

Three computer programs that utilize the propagation model are discussed in section 3, and program listings are provided in appendix B. These programs are for use in predicting the service coverage associated with air/ground radio systems in the frequency band from 0.1 to 20 GHz. Power density, station separation, and service volume programs are used to obtain computer-generated microfilm plots. These are, respectively, (1) power density available at a particular altitude versus distance from a ground-based transmitting facility, (2) the desired-to-undesired signal ratios versus the distance separating desired and undesired facilities, and (3) constant D/U contours in the altitude versus distance space between the desired and undesired facilities. Sample parameter sheets (figs. 5, 8, 9, and 11) and graphs produced using the programs (figs. 6, 7, 10, and 12) are given in section 3.2. Tables 1, 4, 5, and 6 of section 3.1 summarize input data requirements for the programs and have spaces provided on them so that they may be used to record values for input data.

5. RECOMMENDATIONS

The current ITS propagation model for air/ground propagation can be used for a wide range of input parameters (see table 1 of sec. 3.1). Further development work on the model should include (a) testing the model within its current parameter ranges by utilizing it to provide predictions for particular applications, (b) comparing predictions made using it with experimental data and/or theoretical results, and (c) revisions to improve prediction accuracy and ranges.

An atlas of predictions should be prepared to show the effect of various parameter changes on transmission-loss predictions. Parameters of primary interest would be (a) facility antenna height, (b) frequency, (c) facility antenna counterpoise configuration and pattern, (d) horizon elevation angle, (e) minimum monthly mean surface refractivity, (f) terrain parameter, and (g) terrain type.

Although some comparisons with data are available [20, sec. 2.4; 21], more should be made. The effort to locate data with which useful comparisons can be made should be continued.

Methods could be developed and appropriate model modifications made to predicted propagation characteristics for (a) ducting [44], (b) rain attenuation [41], (c) rain scatter [8], (d) ionospheric scintillations [45], and (e) aircraft antenna patterns [17, eq. 36]. In addition, it might be desirable to include capabilities in the model for (a) circular polarization [39, ch. 8], (b) long-term fading models for different climates and time blocks [40, sec. III.7], (c) reflection from water where sea-state temperature and salinity [5] would be used in calculating the reflection coefficient, (d) absorption where water-vapor absorption is determined using relative humidity, and (e) reflection from a non-spherical surface such as a tilted plane.

Computer programs similar to those described here should be developed for (a) air-to-air, (b) ground-to-satellite, and (c) air-to-satellite. Work on these programs has been initiated by ITS [19, 20], and is expected to continue, but will be limited by available resources.

Other versions of the programs may also be desirable such as a program to produce contours of constant power density in the altitude versus distance space above a great circle radial from a facility, i.e., service volume without interference [17, fig. 9].

APPENDIX A. PROPAGATION MODEL

The propagation model used in the programs is applicable to ground/air telecommunications links operating at radio frequencies from about 0.1 to 20 GHz with aircraft altitudes less than 300,000 ft. Ground-station antenna heights must be (1) greater than 1.5 ft, (2) less than 9,000 ft, and (3) at an altitude below the aircraft. In addition, the elevation of the radio horizon must be less than the aircraft altitude. Ranges for other parameters associated with the model are given in table 1 (sec. 3.1.1).

Units of measure associated with input parameters are also given in table 1, and those associated with computer-generated output are provided in section 3.2. However, almost all of the calculations within the programs are made with distances and heights expressed in kilometers, and the equations given in this appendix follow this procedure, i.e., unless specifically stated otherwise, all distances and heights are measured in kilometers. Frequency is always measured in megahertz.

Conceptually the model is very similar to the Longley-Rice [32] propagation model for propagation over irregular terrain; i.e., attenuation versus distance curves calculated for the (a) line-of-sight (sec. A.4.2), (b) diffraction (sec. A.4.3), and (c) scatter (sec. A.4.4) regions are blended together to obtain values in transition regions. In addition, the Longley-Rice relationships involving the terrain parameter, Δh, are used to estimate radio horizon parameters when such information is not available from facility siting data (sec. A.4.1). The model includes allowance for (a) average ray bending (sec. A.4.1), (b) horizon effects (sec. A.4.1), (c) long-term power fading (sec. A.5), (d) ground facility antenna pattern and counterpoise (sec. A.4.2), (e) surface reflection multipath (sec. A.6), (f) tropospheric multipath (sec. A.7), and (g) atmospheric absorption (sec. A.4.5). However, special allowances are not included for (a) ducting [44], (b) rain attenuation [41], (c) rain scatter [8], (d) ionospheric scintillations [45], or (e) the aircraft antenna pattern [17, eq. 36].

A discussion of the computer programs in terms of input requirements and the output generated is given in section 3. Computer program listings are provided in appendix B along with some annotation. The formulation used in this appendix was devised to describe the propagation model, and some of the variables and equations used here are not specifically used in the programs.

A.1 Transmission Loss

Methods and procedures have been developed for calculating field strength and its variability at VHF/UHF/SHF. The work discussed here follows procedures that have been used by ITS to predict statistically the effects of terrain and atmosphere on the variability of field strength, and on the performance of radio systems [7, 17, 18, 20, 21, 22, 27, 32, 33, 40]. It is also convenient to use the concept of transmission loss [36, 37], which is the ratio (usually expressed in decibels) of power radiated to the power that would be available at the receiving antenna terminals if there were no circuit losses other than those associated with the radiation resistance of the receiving antenna.

Transmission-loss levels, L(q), that are not exceeded during a fraction of the time q are calculated from

$$L(q) = L_b\ (0.5) + L_{gp} - G_F - G_A - Y_\Sigma(q) \quad \mathrm{dB} \qquad (4)$$

where $L_b(0.5)$ is the median basic transmission loss [40, sec.2], L_{gp} is the path antenna gain loss, G_F and G_A are free-space antenna gains for the ground facility and aircraft, respectively, and $Y_\Sigma(q)$ is the total variability.

The calculation of $L_b(0.5)$ is described in section A.4. Free-space loss and atmospheric absorption are included in $L_b(0.5)$ along with lobing, diffraction, and/or scatter attenuation.

Values for L_{gp} and G_A are taken as 0 dB in the model. The former is valid when (a) transmitting and receiving antennas have the same polarization and (b) the maximum gain of the facility antenna is less than 50 dB [32, sec. 1-3]. The latter results from assuming that the aircraft antenna is isotropic (0 dB gain in all directions). Values for G_F are not explicitly used in the model since the maximum facility antenna gain is included in the specification of equivalent isotropically radiated power (secs. A.2 and A.3) and gain normalized to the maximum is used in antenna pattern specification (secs. 3.1.1 and A.4.2).

Total variability, $Y_\Sigma(q)$ is calculated from

$$Y_\Sigma(q) = \pm\sqrt{Y_e^2\,(q) + Y_\pi^2\,(q)} \quad \text{dB} \qquad (5)$$

$$\begin{pmatrix} + \text{ for } q \leq 0.5 \\ - \text{ otherwise} \end{pmatrix}$$

where $Y_e(q)$ is the variability associated with long-term power fading (sec. A.5) and $Y_\pi(q)$ is the variability associated with multipath. This method of combining variabilities is similar to the method suggested by Rice et al. [40, eq. V.5] and is the same as that previously used by Tary et al. [42, eq. 25]. The Nakagami-Rice distribution [40, sec. V.2] is used for $Y_\pi(q)$. Values are determined using K*, the ratio in decibels between the steady component of the received power and the Rayleigh fading component, where

$$K = -10 \log(W_R + W_a) \;\; \text{dB} . \qquad (6)$$

Here, W_R and W_a are the relative power levels of Rayleigh fading components associated with surface reflection multipath (sec. A.6) and tropospheric multipath (sec. A.7).

---

*The K defined by Rice et al. [40, sec. V.2] and used here differs in sign from the K defined by Norton et al. [38]. Some of the subroutines using K were written before 1967 so that K in the computer program has a sign opposite to that of the K used in this text.

A.2 Power Density

Power density $S_a(q)$ available for a fraction of the time > q is determined using

$$S_a(q) = \text{EIRP} - L_b(q) + G_N - A_e \text{ dB-W/sq m} \qquad (7)$$

where EIRP is the equivalent isotropically radiated power defined in (1) of section 3.1.1, $L_b(q)$ is the basic (isotropic antennas) transmission loss <u>not</u> exceeded during a fraction of time q, G_N is the normalized gain of the facility antenna (fig. 2) that is directed toward the aircraft (line-of-sight) or toward the facility radio horizon (beyond line-of-sight), and A_e is the effective area of an isotropic antenna [39, sec. 4.11]. The formulation used to determine G_N is a slight extension of that used for g_D which follows (80); i.e., $G_N = 20 \log g_D$. Values of $L_b(q)$ and A_e are determined from

$$L_b(q) = L_b(50) - Y_\Sigma(q) \quad \text{dB} \qquad (8)$$

and

$$A_e = 10 \log(\lambda_m^2/4\pi) \quad \text{dB-sq m} \qquad (9)$$

where the total variability $Y_\Sigma(q)$ is given by (5), and λ_m is the wavelength in meters. For a frequency of f MHz,

$$\lambda_m = 299.7925/f \quad \text{m} \quad . \qquad (10)$$

A.3 Desired-to-Undesired Signal Ratio

Desired-to-undesired signal ratios that are available for a fraction of time q, D/U(q) dB, at the terminals of a lossless isotropic airborne receiving antenna are calculated using [18, sec. 3]

$$D/U(q) = D/U(0.5) + Y_{DU}(q) \quad \text{dB} \ . \qquad (11)$$

The median value of D/U(0.5) and the variability $Y_{DU}(q)$ of D/U are calculated as

$$D/U(0.5) = [EIRP-L_b(0.5)+G_N]_{Desired} - [EIRP-L_b(0.5)+G_N]_{Undesired} \tag{12}$$

and

$$Y_{DU}(q) = \pm\sqrt{[Y_\Sigma(q)]^2_{Desired} + [Y_\Sigma(1-q)]^2_{Undesired}} \text{ dB} \tag{13}$$

$$\left(\begin{array}{l} -\text{ for } q \geq 0.5 \\ +\text{ otherwise} \end{array}\right)$$

where EIRP is defined by (1) of section 3.1.1, the calculation of $L_b(0.5)$ is discussed in section A.4, G_N values for antenna options currently available are given in figure 2, and $Y_\Sigma(q)$ values are obtained using (5).

A.4 Median Basic Transmission Loss

Median basic transmission loss, $L_b(0.5)$, is calculated from

$$L_b(0.5) = L_{br} + A_Y + A_a \quad \text{dB} \tag{14}$$

where L_{br} is a calculated reference level of basic transmission loss, A_Y is a conditional adjustment factor, and A_a is atmospheric absorption (sec. A.4.5). The factor, A_Y, [18, sec. 3] is used to prevent available signal powers from exceeding levels expected for free-space propagation by an unrealistic amount when the variability about $L_b(0.5)$ is large, and $L_b(0.5)$ is near its free-space level, L_{bf}. That is,

$$L_{bf} = 32.45 + 20 \log f + 20 \log r \quad \text{dB} \tag{15}$$

where f MHz is frequency and r km is the shortest facility-to-aircraft ray length,

$$A_Y = \left\{ \begin{array}{ll} 0 \text{ if } (L_{bf}-3) \leq [L_{br}-Y_e(0.1)] & \text{if lobing option (sec. 3.1.1)} \\ & \text{is used and the aircraft is} \\ & \text{within 10 lobes of its radio} \\ & \text{horizon, or path is beyond} \\ & \text{line of sight} \\ (L_{bf}-3) - [L_{br}-Y_e(0.1)] & \text{otherwise} \end{array} \right\} \text{dB} \quad (16)$$

where $Y_e(0.1)$ is the long-term variability $Y_e(q)$ described in section A.5 with q = 0.1 and is calculated from (180). Note that A_Y adjusts $L_b(0.5)$ so that $L_b(0.1) \geq (L_{bf}-3)$ when $Y_\pi = 0$ in (3).

Terrain attenuation, A_T, and a variability adjustment term, $V_e(0.5, d_e)$, are used along with L_{bf} to determine L_{br}; i.e.,

$$L_{br} = L_{bf} + A_T - V_e(0.5, d_e) \quad \text{dB} \quad . \tag{17}$$

Methods used to calculate $V_e(0.5, d_e)$ are described in section A.5. Since the effect of terrain depends on the propagation mechanisms involved, the discussion of terrain attenuation, A_T, is spread through three sections dealing with propagation in the line-of-sight (sec. A.4.2), diffraction (sec. A.4.3), and scatter regions (sec. A.4.4).

A.4.1 Horizon Geometry

Almost all calculations within the programs are made with distances and heights expressed in kilometers, and the equations given in the appendix follow this pattern, unless specifically stated otherwise. Frequency is always measured in megahertz, and angles are usually measured in radians.

Geometry for the facility radio horizon is shown in figure 13. An effective earth radius [3, sec. 3.6], a, is used to compensate for ray bending so that the ray is shown as a straight line from facility to horizon, and as a curved line from horizon to aircraft. A straight line extension from horizon-to-aircraft ray is shown dotted to indicate that the effective earth radius model predicts too much bending for high antennas, which would result in a maximum great circle line-of-sight

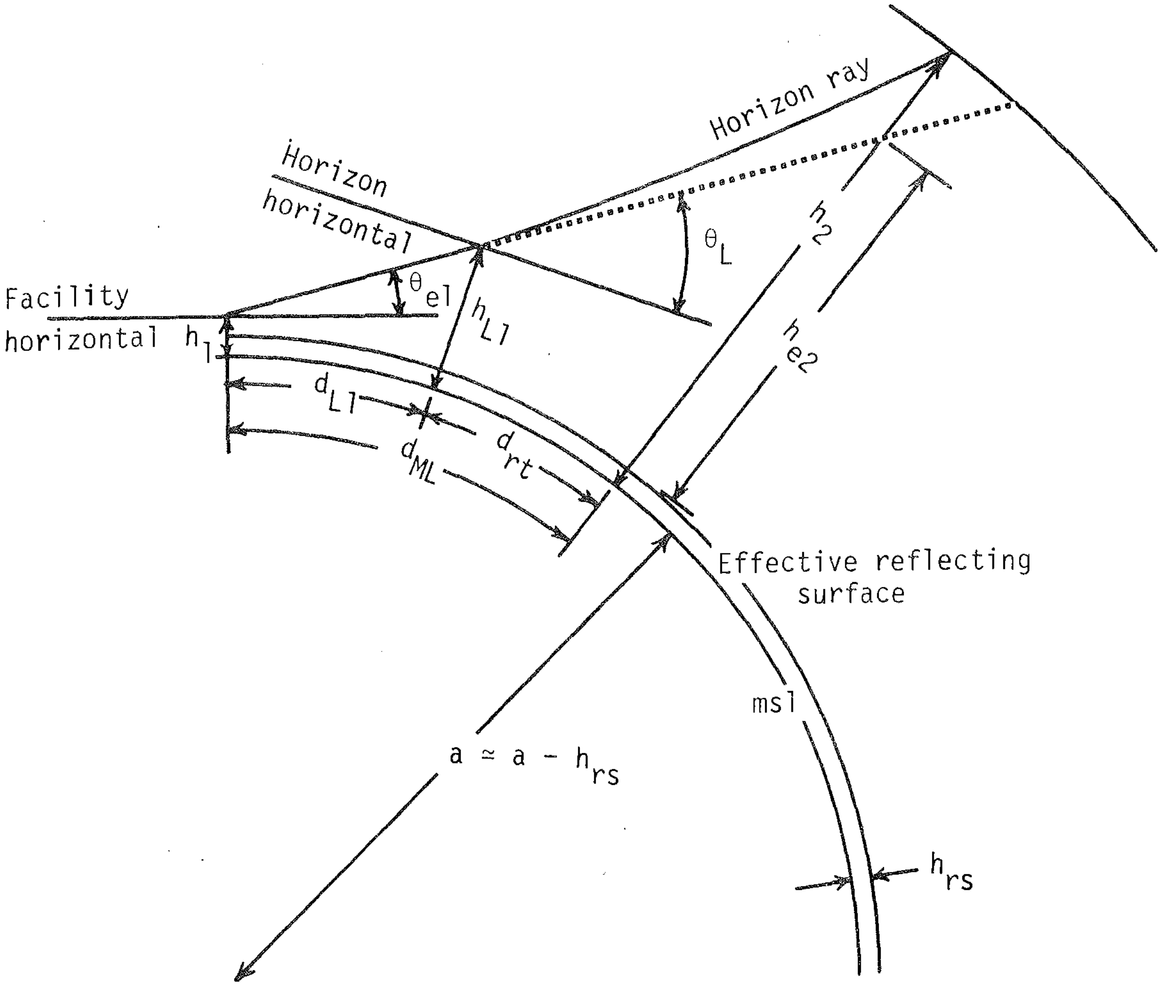

Figure 13. Geometry for facility radio horizon (not drawn to scale).

distance, d_{ML}, that is excessive [40, fig. 6.7]. Facility antenna height, facility horizon elevation, and aircraft altitude above msl are h_1, h_{L1}, and h_2, respectively. Facility ray horizon elevation angles measured above the horizontal at the facility and its horizon are θ_{e1} and θ_L, respectively. The great circle facility-to-horizon distance is d_{L1}.

Effective earth radius, a, is calculated using the minimum monthly mean surface refractivity referred to mean sea level, N_0 (fig. 3), and the height of the effective reflection surface above mean sea level, h_{rs}km [40, sec. 4]; i.e.,

$$N_s = N_o \exp(-0.1057\ h_{rs}) \quad \text{N-units} \tag{18}$$

$$a_o = 6370 \text{ km} \tag{19}$$

and

$$a = a_o[1-0.04665\ \exp(0.005577\ N_s)]^{-1} \text{ km.} \tag{20}$$

Here N_s is the surface refractivity at the effective reflecting surface, and a_o is the actual earth radius to about three significant figures. Since relationships involving a are approximate, greater precision is usually not justified or appropriate.

Facility horizon parameters d_{L1}, h_{L1}, and θ_{e1} are related to each other by the following

$$\theta_{e1} = \mathrm{Tan}^{-1} \left\{ \frac{h_{L1}-h_1}{d_{L1}} - \frac{d_{L1}}{2a} \right\} \text{ rad} \tag{21}$$

$$h_{L1} = h_1 + \frac{d^2_{L1}}{2a} + d_{L1} \tan \theta_{e1} \quad \text{km} \tag{22}$$

and

$$d_{L1} = \pm \sqrt{2a(h_{L1}-h_1) + a^2 \tan^2 \theta_{e1}} - a \tan \theta_{e1} \quad \text{km} \tag{23}$$

where the ± choice is made such that (23) yields its smallest positive value. If d_{L1} and/or θ_{e1} are not specified, they may be estimated [32, sec. 2.4] using the terrain parameter, Δh km, and the effective height of the facility antenna above the reflecting surface, h_{e1} km. The h_{e1} is calculated from specified elevations (fig. 1) or is taken as the facility antenna height above the facility site surface when the effective reflecting surface elevation is not specified. That is,

$$d_{Ls1} = \sqrt{2a\ h_{e1}} \quad \text{km} \tag{24}$$

$$h_e = \text{larger of } \left\{ h_{e1} \text{ or } 0.005 \right\} \quad \text{km} \tag{25}$$

$$d_{L1} = \text{larger of} \left\{ \begin{matrix} 0.1\ d_{Ls1} \text{ or} \\ d_{Ls1} \exp(-0.07 \sqrt{\Delta h/h_e}) \end{matrix} \right\} \quad \text{km} \tag{26}$$

and

$$\theta_{el} = \text{lesser of} \left\{ \begin{array}{l} \dfrac{0.5}{d_{Ls1}} \left[1.3 \left(\dfrac{d_{Ls1}}{d_{L1}} - 1 \right) \Delta h - 4\, h_{el} \right] \\ \text{or} \\ 0.2094\ (12°) \end{array} \right\} \text{rad.} \qquad (27)$$

The programs allow any two of h_{L1}, d_{L1}, or θ_{el} to be specified or estimated via Δh, and the remaining parameter to be calculated. When a smooth earth is specified, Δh is set to zero, h_{L1} is set to h_{rs}, d_{L1} set to d_{Ls1}, and θ_{el} calculated via (21). This logic is summarized in figure 14.

Ray tracing is used in the determination of effective aircraft altitude, maximum line-of-sight distance, and effective distance only when the effective altitude correcting factor is not specified. Then it is performed through an exponential atmosphere [3, eqs. 3.44, 3.43, 3.40] in which the refractivity, N, varies with height above msl, h km, as

$$N = N_s \exp\left[- C_e\, (h - h_{rs}) \right] \quad \text{N-units} \qquad (28)$$

where

$$C_e = \ln \frac{N_s}{N_s + \Delta N} \qquad (29)$$

and

$$\Delta N = -7.32 \exp(0.005577\, N_s) \quad \text{N-units/km .} \qquad (30)$$

Thayer's algorithm [43] for ray tracing through a horizontally stratified atmosphere is used with layer heights (above h_{rs}) taken as 0.01, 0.02, 0.05, 0.1, 0.2, 0.305, 0.5, 0.7, 1, 1.524, 2, 3.048, 5, 7, 10, 20, 30.48, 50, 70, 90, 110, 225, 350, and 475 km. Above 475 km raybending is neglected; i.e., rays are assumed to be straight relative to a true earth radius, a_o. The computer subroutine used for ray tracing (sec. B.4.1, RAYTRAC) was written so that: (a) the initial ray elevation angle may be negative; (b) if the initial angle is too negative it will be set to a value that corresponds to grazing for a smooth earth; and (c) the antenna heights may be very large, e.g., satellites.

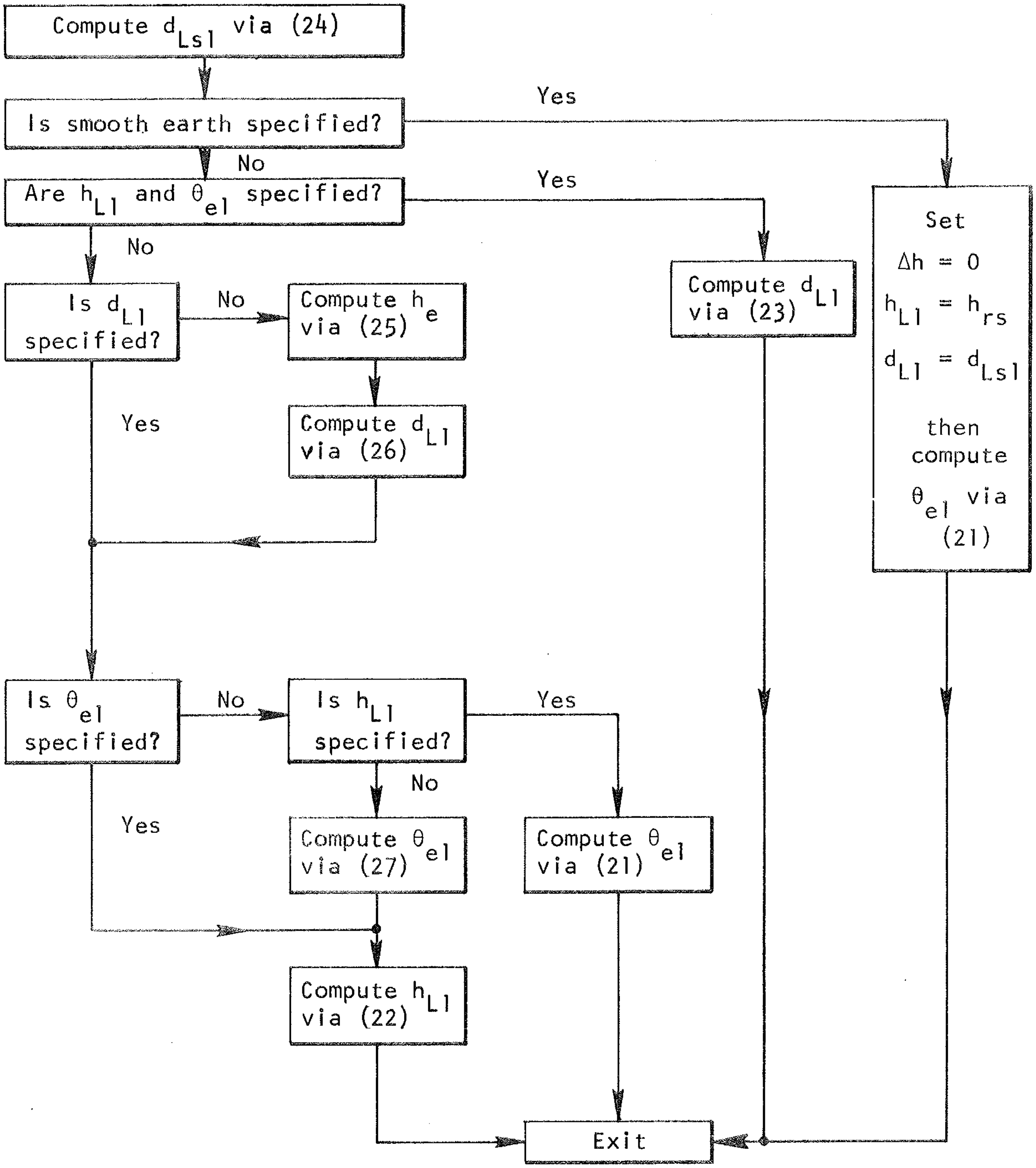

Figure 14. Logic for facility horizon determination.

Effective aircraft altitude, h_{e2} km in figure 13, may be calculated from

$$h_{a2} = h_2 - h_{rs} \quad \text{km} \tag{31}$$

and

$$h_{e2} = h_{a2} - \Delta h_e \quad \text{km} . \tag{32}$$

However, Δh_e specification is neither required or recommended. When Δh_e is not specified, h_{e2} is defined as the lesser of h_{a2} or the aircraft altitude above the effective reflecting surface which will yield the proper aircraft smooth-earth horizon distance d_{Ls2} when used with

$$d_{Ls2} = \left\{ \begin{array}{ll} \sqrt{2a\ h_{e2}} & \text{if } h_{e2} \leq 50 \text{ km} \\ a \operatorname{Cos}^{-1}[a/(a+h_{e2})] & \text{otherwise} \end{array} \right\} \text{km.} \tag{33}$$

The upper expression in (33) is based on a parabolic approximation to the earth's surface and is good when d_{Ls2}'s resulting from its use do not exceed about a/10 km. Whereas the lower expression is for a spherical earth and may not yield sufficient precision when d_{Ls2}'s resulting from its use do not exceed a/10 km, it is useful when altitudes greater than about 50 km are encountered. Based on the above, h_{e2} calculations are made using

$$h_{e2} = \left\{ \begin{array}{ll} h_{a2} - \Delta h_e \text{ if } \Delta h_e \text{ is specified} & \\ \text{lesser of} \left[\begin{array}{l} h_{a2} \\ \text{or} \\ \left\{ \begin{array}{l} d_{Ls2}^2/(2a) \text{ if } \theta_{s2} \leq 0.1 \text{ rad} \\ a[\sec\ (\theta_{s2})-1] \text{ otherwise} \end{array} \right\} \end{array} \right] & \text{otherwise} \end{array} \right\} \text{km} \tag{34}$$

where

$$\theta_{s2} = \frac{d_{Ls2}}{a} \text{ rad} . \tag{35}$$

The d_{Ls2} is determined by tracing a ray that leaves the effective reflection surface at a 0 rad take-off angle out until h_{a2} is reached. If h_{e2} is set equal to h_{a2} or is determined from Δh_e, d_{Ls2} is calculated using (33). Values obtained for h_{e2} by using ray tracing do not always agree with those [40, fig. 6.7] based on a modified effective earth's radius model [3, sec. 3.7], since the ray tracing described here is based on the later exponential model [3, sec. 3.8]. Actually this effective earth radius model predicts smooth earth radio horizon distances that are too short (insufficient ray bending) for antenna heights less than a few kilometers [3, sec. 3.8], but the propagation models [32, 40] on which much of air/ground model is based use the effective earth radius model. Therefore, h_{a2} is selected in (34) when such antenna heights are encountered, and Δh_e is not specified.

Aircraft horizon parameters are determined using either (a) case 1, where the facility horizon obstacle is assumed to provide the aircraft radio horizon, or (b) case 2, where the effective reflection surface is assumed to provide the aircraft radio horizon. The great circle horizon distance for the aircraft, d_{L2}, is calculated using the parameters shown in figure 15 along with the great circle distance, d km, between the facility and the aircraft; i.e.,

$$h_{eL} = h_{L1} - h_{rs} \text{ km} \tag{36}$$

$$d_{sL} = \sqrt{2a\, h_{eL}} \quad \text{km} \tag{37}$$

and

$$d_{L2} = \left\{ \begin{array}{ll} d-d_{L1} & \text{if } d - d_{L1} \leq d_{sL} + d_{Ls2} \\ d_{Ls2} & \text{otherwise} \end{array} \right\} \text{ km} \tag{38}$$

Here h_{eL} km is the height of the facility horizon obstacle above the effective reflection surface, d_{sL} is the smooth earth horizon distance for the obstacle, and the other parameters were previously discussed. The horizon ray elevation angle at the aircraft is measured relative to

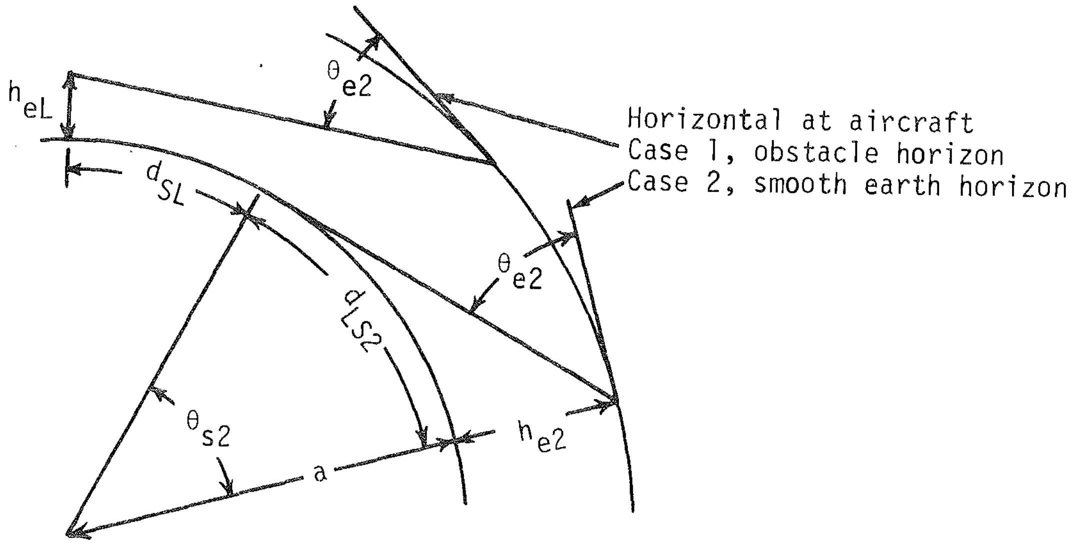

Figure 15. Geometry for aircraft radio horizon (not drawn to scale).

the horizontal at the aircraft, with positive values assigned to values above the horizontal, and is calculated from

$$\theta_{e2} = \begin{cases} \operatorname{Tan}^{-1}\left[\dfrac{h_{eL}-h_{e2}}{d_{L2}} - \dfrac{d_{L2}}{2\,a}\right] & \text{if } d_{L2}=d-d_{L1} \\ \text{or} & \\ \operatorname{Tan}^{-1}\left[-\dfrac{h_{e2}}{d_{L2}} - \dfrac{d_{L2}}{2\,a}\right] & \text{otherwise} \end{cases} \text{ rad.} \qquad (39)$$

<u>Maximum Line-of-Sight Distance</u>, d_{ML} km, is calculated using effective earth radius geometry or d_{rt} (fig. 13), i.e.,

$$d_{ML} = \begin{cases} a\left(\operatorname{Cos}^{-1}\left[\dfrac{(a+h_{e1})\cos\theta_{e1}}{(a+h_{e2})}\right] - \theta_{e1}\right) & \text{if } \Delta h_e \text{ is specified} \\ d_{L1} + d_{rt} \quad \text{otherwise} & \end{cases} \text{ km.} \quad (40)$$

The great circle ray-tracing distance, d_{rt} km, is determined by tracing a ray from the horizon obstacle to the aircraft location where the ray leaves the obstacle at the angle θ_L (fig. 13). This angle is related to θ_{e1} by

$$\theta_L = \theta_{e1} + \frac{d_{L1}}{a} \text{ rad.} \tag{41}$$

A.4.2 Line-of-Sight Region

Calculation of $L_b(0.5)$ in the line-of-sight region via (14) and (17) involves L_{bf} from (15), A_Y from (16), A_a of section A.4.5, $V_e(0.5, d_e)$ of section A.5, and A_T.

A detailed discussion of the methods used in calculating the terrain attenuation term, A_T, in the line-of-sight region is provided in this section. Values of A_T obtained by these methods are used only when the path distance does not exceed the maximum line-of-sight distance, i.e., only when $d \leq d_{ML}$, where the determination of d_{ML} is described in section A.4.1. Allowances are included for (a) lobing caused by surface reflection, (b) lobing caused by counterpoise reflection, and (c) diffraction near the radio horizon. Methods used to combine these allowances will be described in detail; then a block diagram of the procedure used to calculate A_T within the line-of-sight will be provided.

Path length difference, Δr km, is the extent by which the length of the reflected ray path, $r_1 + r_2 = r_{12}$ km, exceeds that of the direct ray, r_o km. It is used in calculations involving lobing in the line-of-sight region, and the geometry involved is shown in figure 16. Given: (a) the effective earth radius, a km from (20), and a_o from (19); (b) grazing angle, ψ rad; (c) h_{a2} km from (31), and h_{e2} from (32); (d) counterpoise height above facility site surface, h_{cg} km; (e) effective facility antenna height above reflection surface, h_{e1} km; and (f) facility antenna height above its counterpoise, h_{fc} km. The Δr and the corresponding great circle path distance, d km, are calculated for both surface and counterpoise reflection lobing as follows:

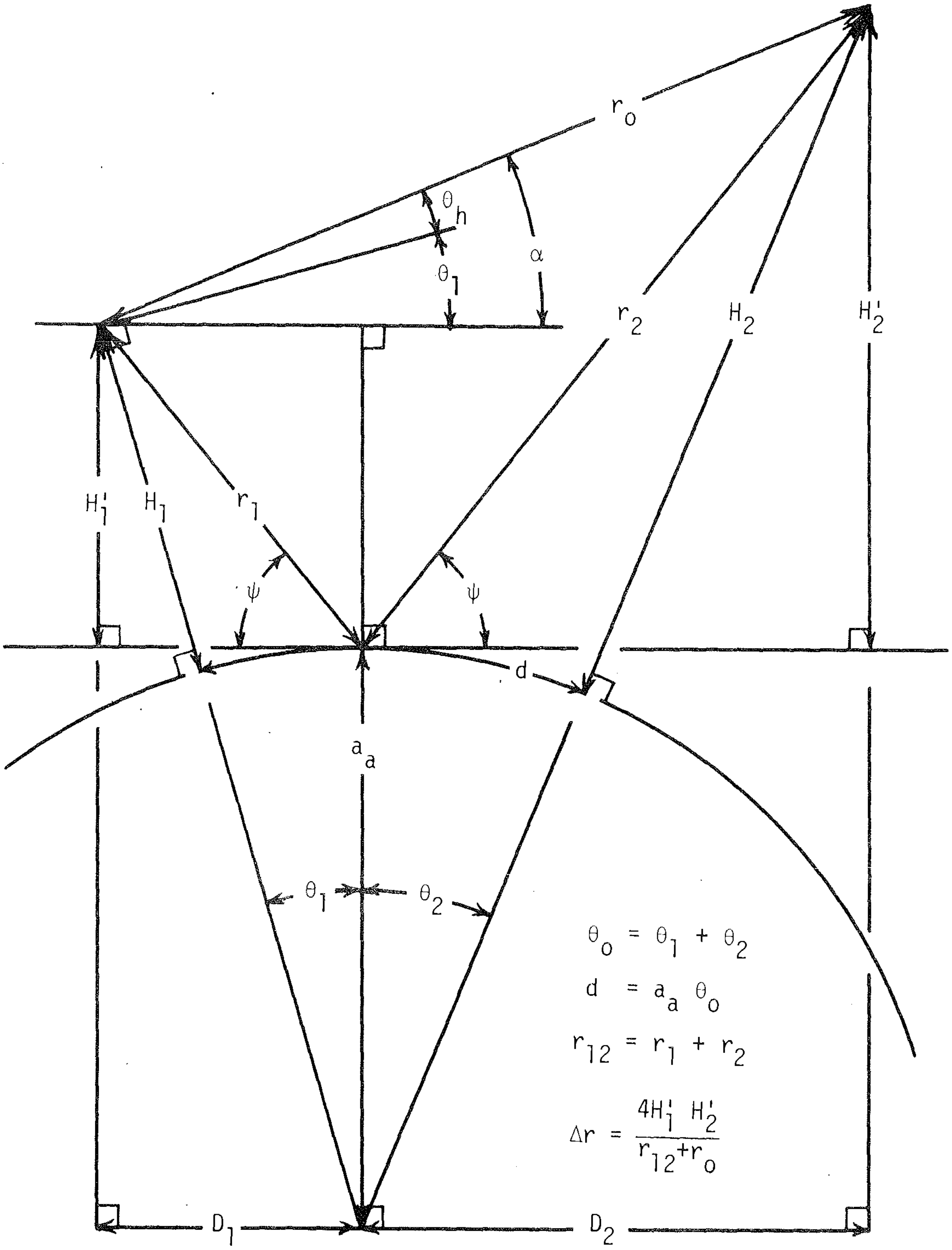

Figure 16. Geometry for path length difference, Δr, calculations (not drawn to scale).

$$z = (a_o/a) - 1 \ , \tag{42}$$

$$k_a = 1/(1+z \cos \psi) \tag{43}$$

$$a_a = a_o \, k_a \quad \text{km} \tag{44}$$

$$\Delta h_a = h_{a2} - h_{e2} \ \text{km} \tag{45}$$

$$\Delta h_a = \Delta h_e \, (a_a - a_o)/(a - a_o) \quad \text{km} \tag{46}$$

$$H_2 = \left\{ \begin{matrix} h_{a2} - \Delta h_a & \text{for earth} \\ h_{a2} - \Delta h_a - h_{cg} & \text{for counterpoise} \end{matrix} \right\} \text{km} \tag{47}$$

$$H_1 = \left\{ \begin{matrix} h_{e1} & \text{for earth} \\ h_{fc} & \text{for counterpoise} \end{matrix} \right\} \quad \text{km} \tag{48}$$

$$z_{1,2} = a_a + H_{1,2} \quad \text{km} \tag{49}$$

$$\theta_{1,2} = \text{Cos}^{-1} \, [a_a \cos (\psi)/z_{1,2}] - \psi \quad \text{rad} \tag{50}$$

$$D_{1,2} = z_{1,2} \sin \theta_{1,} \quad \text{km} \tag{51}$$

$$H'_{1,2} = \left\{ \begin{matrix} D_{1,2} \tan \psi \text{ for } \psi < 1.56 \text{ rad} \\ H_{1,2} \text{ otherwise} \end{matrix} \right\} \text{km} \tag{52}$$

$$\alpha = \left\{ \begin{matrix} \text{Tan}^{-1}[(H'_2 - H'_1)/(D_1 + D_2) \text{ for } \psi < 1.56 \quad \text{rad} \\ \\ \psi \quad \text{otherwise} \end{matrix} \right\} \text{km} \tag{53}$$

$$r_o = \left\{ \begin{matrix} (D_1 + D_2)/\cos \alpha \text{ for } \psi < 1.56 \text{ rad} \\ H_2 - H_1 \quad \text{otherwise} \end{matrix} \right\} \quad \text{km} \tag{54}$$

$$r_{12} = \left\{ \begin{matrix} (D_1 + D_2)/\cos \psi \text{ for } \psi < 1.56 \text{ rad} \\ H_1 + H_2 \quad \text{otherwise} \end{matrix} \right\} \quad \text{km} \tag{55}$$

$$\Delta r = 4\ H_1'\ H_2'/(r_o + r_{12}) \quad \text{km} \tag{56}$$

$$\theta_h = \alpha - \theta_1 \quad \text{rad} \tag{57}$$

$$\theta_{er} = \psi + \theta_1 \quad \text{rad} \tag{58}$$

$$\theta_o = \theta_1 + \theta_2 \quad \text{rad} \tag{59}$$

and

$$d = a_a\ \theta_o \quad \text{km}\ . \tag{60}$$

An effective earth radius, a_a, and an effective aircraft altitude, H_2, that varies with ψ are used in these expressions since the values of a and h_{e2} determined in section A.4.1 are not appropriate for large ray take-off angles when cos ψ is not ~ 1 [3, eq. 3.23].

Effective specular reflection coefficient for reflection from the earth, $R_g \exp(-j\phi_g)$, has a magnitude R_g and a phase lag of $-\phi_g$. Allowances are included for the effect on reflection coefficient of (a) reflecting area illumination (antenna gain), (b) surface dielectric constant ε and conductivity σ mho/m from table 2, (c) polarization, (d) surface roughness, and (e) wavelength λ_m m from (10), but not allowances for divergence [6, sec. 11.2] or shadowing by the counterpoise (included later). It is calculated using the complex plane earth reflection coefficient $R \exp(-j\phi)$ [6, sec. 11.1] and the reflection reduction factor $F_{\sigma h}$ [32, eqs. 3, 3.5, 3.6]. That is

$$\varepsilon_c = \varepsilon - j\ 60\lambda_m\ \sigma \tag{61}$$

ψ = grazing angle (fig. 17)

$$Y_c = \sqrt{\varepsilon_c - \cos^2 \psi} \tag{62}$$

and

$$R \exp(-j\phi) = \left\{ \begin{array}{ll} \dfrac{\sin(\psi) - Y_c}{\sin(\psi) + Y_c} & \text{for horizontal polarization} \\ & \\ \dfrac{\varepsilon_c \sin(\psi) - Y_c}{\varepsilon_c \sin(\psi) + Y_c} & \text{for vertical polarization} \end{array} \right\} . \tag{63}$$

With Δh_m as the terrain parameter (m) from table 3 and d as the great circle path distance (km) as shown in figure 16,

$$\Delta h_d = \Delta h_m[1-0.8\ \exp(-0.02d)]\ \text{m} \tag{64}$$

$$\sigma_h = \left\{ \begin{array}{l} 0.39\ \Delta h_d\ \text{for}\ \Delta h_d \leq 4\ \text{m} \\ \\ 0.78\ \Delta h_d\ \exp(-0.5\ \Delta h_d{}^{1/4})\ \text{otherwise} \end{array} \right\}\ \text{m} \tag{65}$$

and

$$F_{\sigma h} = \exp(-2\pi\sigma_h\ \sin(\psi)/\lambda_m)\ . \tag{66}$$

Further,

$$g = \left\{ \begin{array}{l} \left. \begin{array}{l} \cos\ \theta_{er}\ \text{if}\ |\theta_{er}| \leq 83° \\ 0.12589\ \ \text{otherwise} \end{array} \right\} \begin{array}{l} \text{for cosine option where} \\ \theta_{er}\ \text{is from (58)} \end{array} \\ 10^{G_N/20}\ \text{with}\ G_N\ \text{from fig. 2 for DME and TACAN options} \\ 1\ \text{for isotropic option} \\ [1+(2|\theta_{er}-\theta_t|/\theta_{HP})^{2.5}]^{-0.5}\ \text{for JTAC option where} \\ \quad \text{the beam tilt above horizontal is}\ \theta_t\ \text{and the} \\ \quad \text{half-power beamwidth is}\ \theta_{HP}\ \text{degree, both in} \\ \quad \text{the same units as}\ \theta_{er} \end{array} \right\} \tag{67}$$

and

$$R_g\ \exp(-j\phi_g) = F_{\sigma h}\ g\ R\ \exp(-j\phi_{h,v})\ \ . \tag{68}$$

Similarly, the effective reflection coefficient for the counterpoise, R_c $\exp(-j\phi_c)$; is calculated from

$$R_c\ \exp(-j\phi_c) = g\ R\ \exp(-j\phi_{h,v}) \tag{69}$$

where parameters appropriate for the counterpoise are used to determine R $\exp(-j\phi)$ via (63), and g via (67).

Counterpoise shadowing of earth reflecting surfaces and the limited reflection surface available to support reflection from the counterpoise are accounted for by using knife-edge diffraction factors in the process of combining direct and reflected rays. Geometry associated with this diffraction is shown in figures 17 and 18 for earth and counterpoise reflections, respectively. The "v" parameters used in the diffraction calculations are calculated as follows:

h_{fc} = height (km) of facility antenna above counterpoise

d_c = counterpoise diameter (km),

$$\theta_{ce} = \mathrm{Tan}^{-1}(2\, h_{fc}/d_c) \quad \text{rad} \tag{70}$$

$$r_c = 0.5\, d_c/\cos \theta_{ce} \quad \text{km} \tag{71}$$

ψ = grazing angle (fig. 17)

$$\theta_{kg} = |\, \theta_{ce} + \theta_{er} \,| \quad \text{rad} \tag{72}$$

where θ_{er} is determined from (58)

$$\lambda = \lambda_m/1000 \quad \text{km} \tag{73}$$

where λ_m is from (10)

$$Y_v = \sqrt{2r_c/\lambda} \tag{74}$$

$$v_g = \pm\, 2\, Y_v \sin(\theta_{kg}/2) \begin{pmatrix} - \text{ for } \theta_{er} < \theta_{ce} \\ + \text{ otherwise} \end{pmatrix} \tag{75}$$

$$\theta_{kc} = |\theta_{ce} - \theta_h| \quad \text{rad} \tag{76}$$

where θ_h rad, determined from (57) for reflection from the earth, is used as the grazing angle ψ_c for counterpoise reflection and

$$v_g = \pm\, 2\, Y_v \sin(\theta_{kc}/2) \begin{pmatrix} - \text{ for } \theta_h > \theta_{ce} \\ + \text{ otherwise} \end{pmatrix} \tag{77}$$

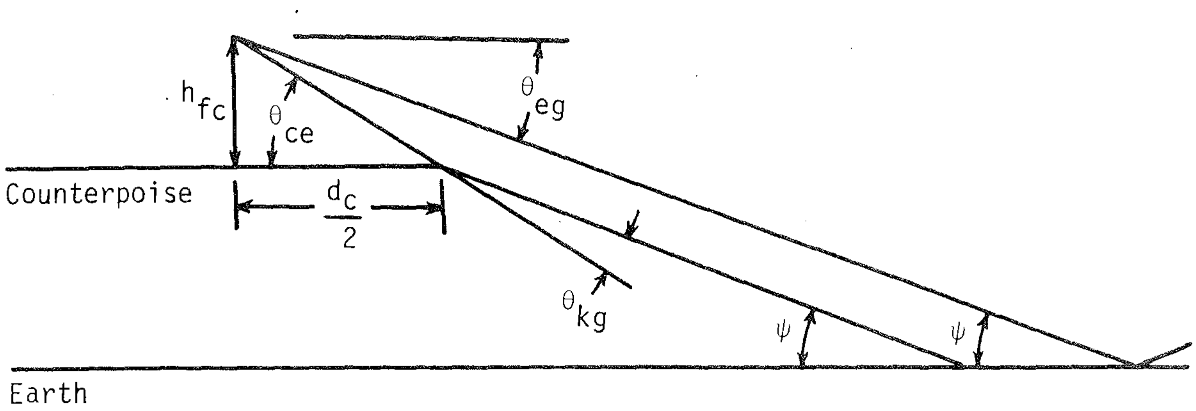

Figure 17. *Geometry for determination of earth reflection diffraction parameter, v_g, associated with counterpoise shadowing.*

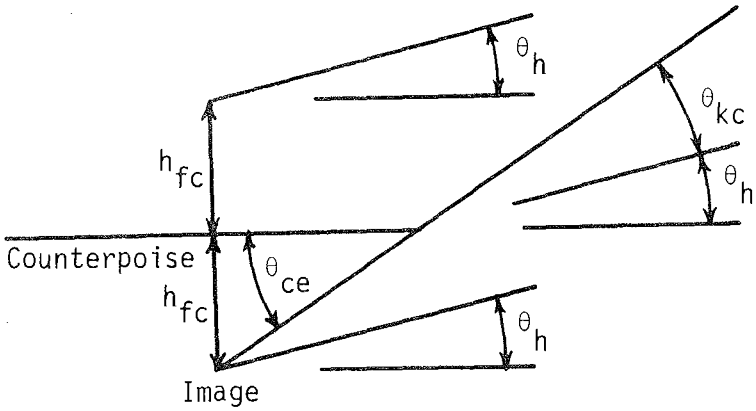

Figure 18. *Geometry for determination of counterpoise reflection diffraction parameter, v_c, associated with the limited reflecting surface of the counterpoise.*

A subroutine, FRENEL (sec. B.4.1), written for the Fresnel integrals [40. sec. III.3] is used to determine the loss, $f_{g,c}$ (dimensionless voltage ratio), and phase shift, $\phi_{\kappa g,c}$ rad, factors from $v_{g,c}$.

Ray combining is performed as follows:

$\Delta r_{g,c}$ = path length difference (km) earth or counterpoise reflection from (56)

$R_{g,c} \exp(-j\phi_{g,c})$ = complex effective reflection coefficient for earth or counterpoise reflection from (68) and (69)

$f_{g,c}$ and $\phi_{kg,c}$ are the knife-edge loss and phase shift factors for earth or counterpoise reflection that are discussed in the preceding paragraph

d_c = counterpoise diameter (km),

λ = wavelength (km) from (73)

$$R_{Tg} = \begin{cases} \left.\begin{cases} R_g \text{ if } d_c \leq 0 \\ f_g\ R_g \text{ otherwise} \end{cases}\right\} \text{ if lobing option (sec. 3.1) used} \\ \\ \left.\begin{cases} 0 \text{ if } \Delta r_g > \lambda/6 \\ R_g \text{ if } d_c \leq 0 \\ f_g\ R_g \text{ otherwise} \end{cases}\right\} \text{ otherwise} \end{cases} \tag{78}$$

$$R_{Tc} = \begin{cases} 0 \text{ if } d_c \leq 0 \\ f_c\ R_c \text{ otherwise} \end{cases} \tag{79}$$

$$\phi_{Tg,c} = (2\pi\ \Delta r_{g,c}/\lambda) + \phi_{g,c} + \phi_{kg,c} + \pi v^2_{g,c}/2 \text{ rad} \tag{80}$$

g_D = value of g for direct ray from (67) with θ_{er} set to θ_h from (57).

$$W_{RO} = |g_D = R_{Tg} \exp(-j\phi_{Tg}) + R_{Tc} \exp(-j\phi_{Tc})|^2 + 0.0001 \qquad (81)$$

and

$$P_{RO} = 10 \log(W_{RO}/g_D^2) \quad \text{dB.*} \qquad (82)$$

Diffraction is included in the line-of-sight calculations near the radio horizon by using (a) the largest within-the-horizon distance, d_o km, from (140), at which diffraction effects are considered negligible (sec. A.4.3); (b) the value of $-P_{RO}$ from (82) at d_o, A_o dB; (c) the maximum line-of-sight distance, d_{ML} km; and (d) the attenuation greater than free space at d_{ML}, A_{ML} dB from (137). Hence the terrain attenuation factor A_T is calculated for the line-of-sight region ($d \leq d_{ML}$) from

$$M_L = \frac{A_{ML} + P_{RO}}{d_{ML} - d_o} \quad \text{dB/km} \qquad (83)$$

and

$$A_T = \left\{ \begin{matrix} -P_{RO} \text{ if } d < d_o \\ M_L(d - d_o) - P_{RO} \text{ if } d_o \leq d \leq d_{ML} \end{matrix} \right\} \text{dB} \quad . \qquad (84)$$

A block diagram for the procedure used for A_T calculations in the line-of-sight region is provided in figure 19.

A.4.3 Diffraction Region

Calculations based on diffraction mechanisms are used both in the line-of-sight (see eq. 84) and diffraction regions. Diffraction attenuation, A_d, is assumed to vary linearly with distance in the diffraction region when other parameters (heights, etc.) are fixed. Most of the equations given in this section are related to the determination of two points needed to define this diffraction line. Since irregular terrain may be involved, rounded earth diffraction is combined with knife-edge

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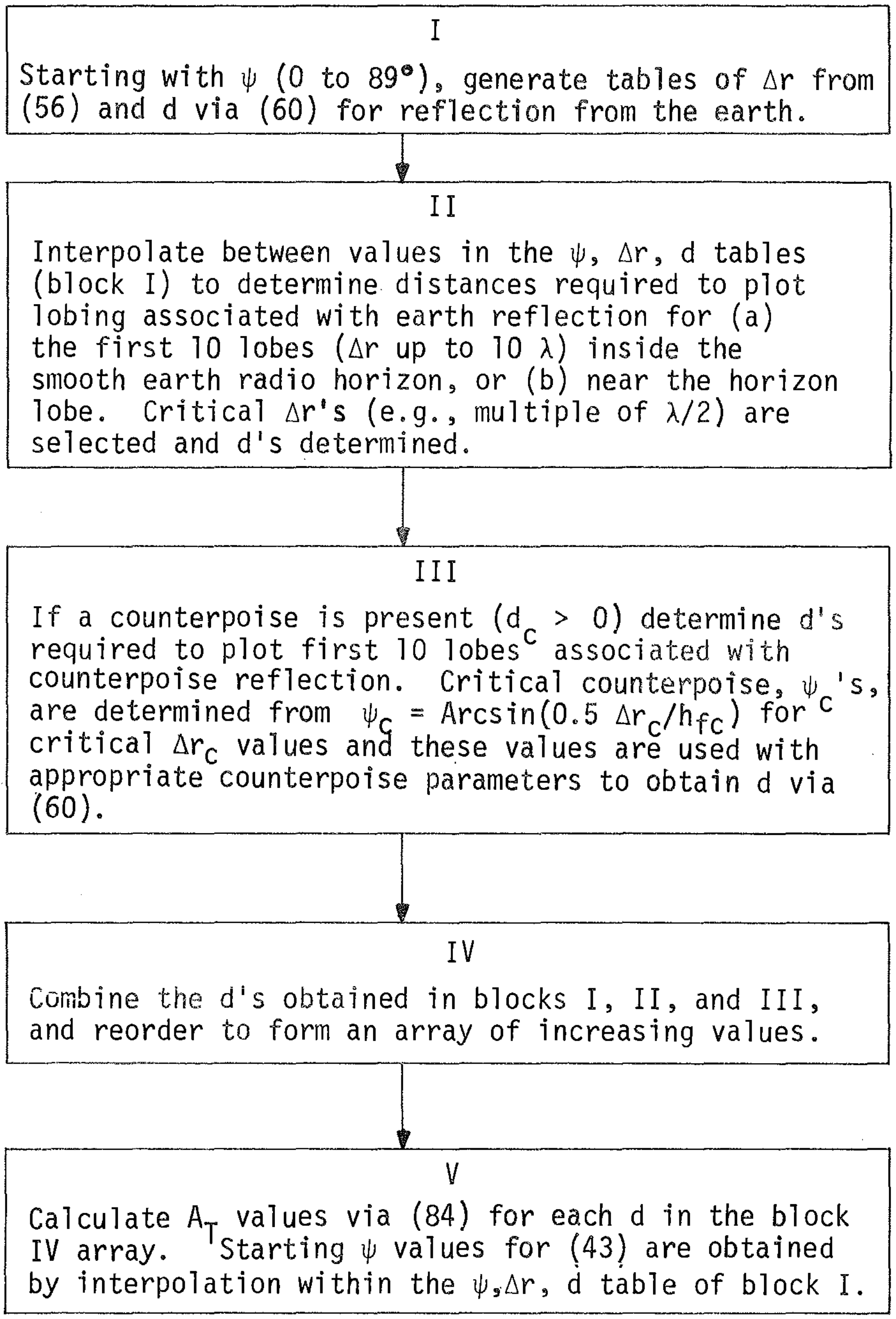
*Decibels greater than the free-space power level.



I

Starting with ψ (0 to 89°), generate tables of Δr from (56) and d via (60) for reflection from the earth.

II

Interpolate between values in the ψ, Δr, d tables (block I) to determine distances required to plot lobing associated with earth reflection for (a) the first 10 lobes (Δr up to 10 λ) inside the smooth earth radio horizon, or (b) near the horizon lobe. Critical Δr's (e.g., multiple of $\lambda/2$) are selected and d's determined.

III

If a counterpoise is present ($d_c > 0$) determine d's required to plot first 10 lobes associated with counterpoise reflection. Critical counterpoise, ψ_c's, are determined from $\psi_c = \text{Arcsin}(0.5\ \Delta r_c/h_{fc})$ for critical Δr_c values and these values are used with appropriate counterpoise parameters to obtain d via (60).

IV

Combine the d's obtained in blocks I, II, and III, and reorder to form an array of increasing values.

V

Calculate A_T values via (84) for each d in the block IV array. Starting ψ values for (43) are obtained by interpolation within the ψ,Δr, d table of block I.

Figure 19. Block diagram of procedure used in line-of-sight calculations.

diffraction considerations. In this section details are given concerning (a) rounded earth diffraction calculations, (b) knife-edge calculations, (c) the determination of the distance, d_o, in the line-of-sight region at which diffraction effects are considered negligible, and (d) the calculation of A_T for beyond the horizon paths ($d \geq d_{ML}$).

Rounded earth diffraction is treated using referenced methods [32, eq. 3.28, etc.; 40, sec. 8.2]. Rounded earth diffraction attenuation, A_{Pr}, for path "p" is calculated as follows:

$d_{pL1,2}$ = radio horizon distance (km) for terminal 1 or 2 of path p

$h_{pe1,2}$ = effective height (km) for terminal 1 or 2 of path p

$$d_{pL} = d_{pL1} + d_{pL2} \quad \text{km} \tag{85}$$

a = effective earth radius from (20)

f = frequency (MHz)

d_{pLs} = smooth earth horizon distance for path p

$$d_3 = \text{larger of} \left\{ \begin{array}{l} d_{pL} + 0.5(a^2/f)^{1/3} \\ \text{or} \\ d_{pLs} \end{array} \right\} \quad \text{km} \tag{86}$$

$$d_4 = d_3 + (a^2/f)^{1/3} \quad \text{km} \tag{87}$$

$$a_{1,2} = d^2_{pL1,2}/(2\, h_{pe1,2}) \quad \text{km} \tag{88}$$

$\theta_{pe1,2}$ = horizon elevation angle (rad) for terminal 1, or 2 of path p

$$\theta_{pe} = \theta_{pe1} + \theta_{pe2} \quad \text{rad} \tag{89}$$

$$\theta_{3,4} = \theta_{pe} + d_{3,4}/a \quad \text{rad} \tag{90}$$

$$a_{3,4} = (d_{3,4}-d_{pL})/\theta_{3,4} \quad \text{rad} \tag{91}$$

σ = conductivity (mho/m) from table 2

$$x = 18000\ \sigma/f \tag{92}$$

ε = dielectric constant from table 2

$$K_d = 0.36278 f^{-1/3}\ [(\varepsilon-1)^2+x^2]^{-1/4} \tag{93}$$

$$K_{1,2,3,4} = \left\{ \begin{array}{ll} K_d\ a^{-1/3}_{1,2,3,4} & \text{for horizontal polarization} \\ \text{or} & \\ K_d\ a^{-1/3}_{1,2,3,4}\ [\varepsilon^2+x^2]^{1/2} & \text{for vertical polarization} \end{array} \right\} \tag{94}$$

$$B_{1,2,3,4} = 416.4 f^{1/3}\ (1.607-K_{1,2,3,4}) \tag{95}$$

$$x_{1,2} = B_{1,2}\ a^{-2/3}_{1,2}\ \ d_{pL1,2} \quad \text{km} \tag{96}$$

$$W_{1,2} = 0.0134\ x_{1,2}\ \exp(-0.005\ x_{1,2}) \tag{97}$$

$$y_{1,2} = 40 \log(x_{1,2}) - 117 \text{ dB} \tag{98}$$

$$x_{3,4} = B_{3,4}\ a^{-2/3}_{3,4}\ (d_{3,4}-d_{pL}) + x_1 + x_2 \tag{99}$$

$$G_{1,2,3,4} = 0.05751\ x_{1,2,3,4} - 10 \log x_{1,2,3,4} \tag{100}$$

$$F_{1,2} = \left\{ \begin{array}{l} \text{When } 0 < x_{1,2} \le 200 \\ \quad \left\{ \begin{array}{l} y_{1,2} \text{ if } |y_{1,2}| < 117 \\ -117 \text{ otherwise} \end{array} \right\} \text{ if } 0 \le K_{1,2} \le 10^{-5} \\ \quad \text{or} \\ \quad y_{1,2} \text{ if } 10^{-5} \le K_{1,2} < 1 \\ \qquad \underline{\text{and}}\ x_{1,2} \ge -450/[\log K_{1,2}]^{3} \\ \quad \text{or} \\ \quad 20 \log(K_{1,2}) - 15 + 2.5(10)^{-5} x_{1,2}^{2}/K_{1,2} \\ \qquad\qquad\qquad\qquad\qquad\qquad \text{otherwise} \\ \text{When } 200 < x_{1,2} \le 2000 \\ \quad W_{1,2}\, y_{1,2} + (1-W_{1,2})\, G_{1,2} \\ \text{When } x_{1,2} > 2000 \\ \quad G_{1,2} \end{array} \right\} \text{ dB} \tag{101}$$

$$A_{3,4} = G_{3,4} - F_1 - F_2 - 20 \quad \text{dB} \tag{102}$$

$$M_{pr} = (A_4 - A_3)/(d_4 - d_3) \quad \text{dB/km} \tag{103}$$

$$A_{pro} = A_4 - M_{pr}\, d_4 \quad \text{dB} \tag{104}$$

$$A_{pr} = A_{pro} + M_{pr}\, d_p \tag{105}$$

$$h_{m1,2} = 1000\, h_{pe1,2} \quad \text{m} \tag{106}$$

and

$$B_{N1,2} = 1.607 - K_{1,2} \tag{107}$$

Then $G_{p\overline{h}1,2}$ are obtained with subroutine GHBAR [sec. B.4.1] by using value of $a_{1,2}$, f, $B_{N1,2}$, $K_{1,2}$, $d_{pL1,2}$, and $h_{m1,2}$ where GHBAR [7, eq. 64, fig.31; 40, eq. 7.6, fig. 7.2] includes a weighting function [20, eq. 17].

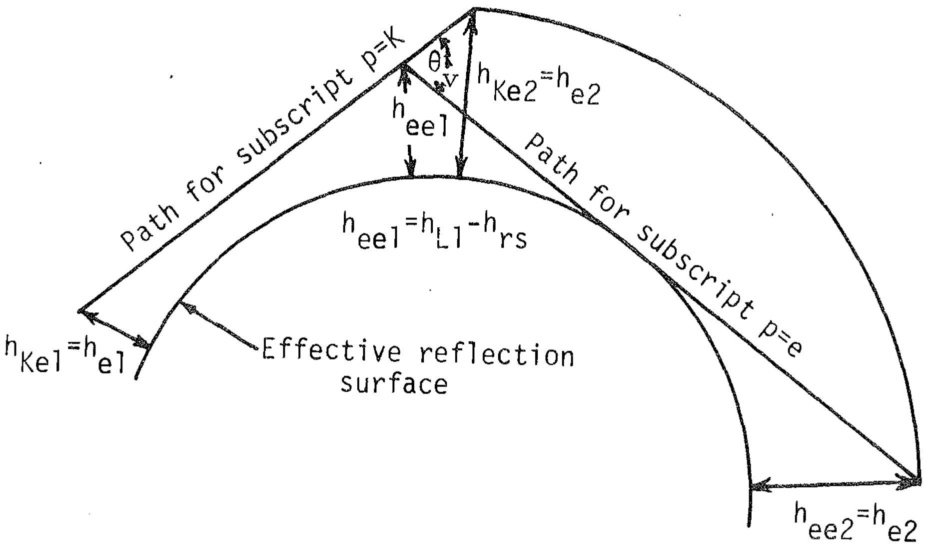


Figure 20. Paths used to determine diffraction loss (not drawn to scale). Rounded earth diffraction is calculated for the h_{Ke1} *to* h_{Ke2} *and* h_{ee1} *to* h_{ee2} *paths. Knife-edge diffraction is calculated for the* h_{e1} *to* h_{Ke2} *and* h_{e1} *to* h_{ee1} *paths.*

This formulation is used to determine rounded earth diffraction lines, (105) and $G_{p\overline{h1},2}$ (discussed under knife-edge diffraction in the next paragraph) values for two paths illustrated in figure 20. The first path involves diffraction over the facility horizon obstacle only where the subscript p is replaced by K so that:

(a)
$$d_{K1} = d_{L1} \quad \text{km} \tag{108}$$

with dL1 from figure 14 and

$$d_{KL2} = d_{ML} - d_{KL1} \quad \text{km} \tag{109}$$

where d_{ML} is from (40),

(b)
$$h_{Ke1,2} = h_{e1,2} \quad \text{km} \tag{110}$$

where

$$h_{e1} = h_1 - h_{rs} \quad \text{km} \tag{111}$$

(fig. 13) and h_{e2} is from (34),

(c) $$d_{KLs} = d_{Ls1} + d_{Ls2} \quad \text{km} \tag{112}$$

where d_{Ls1} is from (24) and d_{Ls2} is from (33), and

(d) $$\theta_{Ke1,2} = \theta_{e1,2} \quad \text{rad} \tag{113}$$

from figure 14 and (39). The second path involves diffraction over smooth earth from the facility horizon obstacle to the aircraft where the subscript p is replaced by e, so that:

(a) $$h_{ee1} = h_{L1} - h_{rs} \quad \text{km} \tag{114}$$

where h_{L1} km is from figure 14, h_{rs} is the reflection surface elevation above msl (fig. 13), and

$$h_{ee2} = h_{e2} \quad \text{km} \tag{115}$$

from (34),

(b) $$d_{eL1,2} = \sqrt{2a\ h_{ee1,2}} \quad \text{km} \tag{116}$$

where a is from (20),

(c) $$d_{eLS} = d_{eL1} + d_{eL2} \quad \text{km} \tag{117}$$

and

(d) $$\theta_{ee1,2} = \text{Tan}^{-1}\left(\frac{h_{ee1,2}}{d_{eL1,2}} - \frac{d_{eL1,2}}{2a}\right) \quad \text{rad .} \tag{118}$$

Knife-edge diffraction is used to define another diffraction line for diffraction by an isolated obstacle with ground reflections [33, sec. 3.5; 34, sec. 2.1; 40, sec. 7.2]. This line is based on linear interpolation between knife-edge attenuation values, $A_{KK,e}$, calculated for two knife-edge diffraction paths illustrated in figure 20; i.e., paths from h_{e1} to h_{Ke2} and from h_{e1} to h_{ee2}. Parameters discussed in the previous paragraph are used in these calculations. That is, $G_{K\bar{h}1,2}$ and $G_{e\bar{h}1,2}$ are determined as per discussion following (107) where calculations are based on parameters for subscript K and e paths (fig. 20). Further:

$$A_{KK} = 6 - G_{K\bar{h}1} - G_{K\bar{h}2} \quad \text{dB} \tag{119}$$

$$\theta_v = \theta_{e1} + \theta_{ee2} + (d_{eLs} + d_{L1})/a \quad \text{rad} \tag{120}$$

where θ_{e1} is from figure 14, θ_{ee2} is from (118), d_{eLs} is from (117), d_{L1} is from figure 14, and a is from (20)

$$v_h = 2.583 \sin(\theta_v) \sqrt{f d_{L1} d_{eLs}/(d_{L1} + d_{eLs})} \tag{121}$$

where f MHz is frequency and d_{L1} is from figure 14.

Subroutine FRENEL (sec. B.4.1) written for the Fresnel integrals [40, sec. III.3] is used to determine the knife-edge loss factor, f_h (dimensionless voltage ratio), associated with v_h. Then

$$A_{eK} = A_h - G_{e\bar{h}1} - G_{K\bar{h}1} - 20 \log f_h \quad \text{dB} \tag{122}$$

where A_h is obtained from (105) with path parameters for the subscript e path (fig. 20) and $d_p = d_{eLs}$,

$$M_K = (A_{eK} - A_{KK})/(d_{L1} + d_{eLs} - d_{ML}) \quad \text{dB/km} \tag{123}$$

where d_{ML} is from (40)

$$A_{Ko} = A_{KK} - M_K d_{ML} \quad \text{dB} \tag{124}$$

and

$$A_K = M_K\, d + A_{Ko} \quad \text{dB} \tag{125}$$

where d km is the great circle path distance.

The distance d_o km in the line-of-sight region at which diffraction is considered negligible is required for line-of-sight calculations via (84). It is determined from diffraction considerations as follows:

$$\theta_h = \text{Sin}^{-1}[(\frac{0.5}{2.853})]\ \sqrt{d_{ML}/fd_{L1}\ d_{KL2}} \quad \text{rad} \tag{126}$$

where d_{ML} is from (40), f Mhz is frequency, d_{L1} is from figure 14, and d_{KL2} is from (109)

$$\theta_5 = \theta_h - \theta_{e1} \quad \text{rad} \tag{127}$$

where θ_{e1} is from figure 14,

$$d_{L5} = -a\theta_5 + \sqrt{(a \tan \theta_5)^2 - [(h_1 - h_{L1})/(2a)]} \quad \text{km} \tag{128}$$

where a is from (20), h_1 km is facility antenna elevation above msl, and h_{L1} is from figure 14

$$d_5 = d_{L5} + d_{L1} \quad \text{km} \tag{129}$$

$$h_{s2} = h_2 - \Delta h_e \quad \text{km} \tag{130}$$

where h_2 is aircraft altitude above msl and Δh_e is from (45)

$$\theta_{e5} = \text{Tan}^{-1} \left(\frac{h_{L1} - h_{s2}}{d_{L5}} - \frac{d_{L5}}{2a} \right) \quad \text{rad} \tag{131}$$

$$\theta_6 = \theta_{e1} + \theta_{e5} + (d_5/a) \quad \text{rad} \tag{132}$$

$$v_5 = 2.583 \sin(\theta_6)\ \sqrt{fd_{L1}\ d_{L5}/d_5}\ . \tag{133}$$

Subroutine FRENEL (sec. B.4.1), written for Fresnel integrals [40, sec. III.3], is used to determine the knife-edge loss factor, f_5 (dimensionless voltage ratio) associated with v_5. Then

$$A_{K5} = 20 \log f_5 \quad \text{dB} \tag{134}$$

and

$$W = \left\{ \begin{array}{l} 1 \quad \text{when } d_{ML} \geq d_{KLs} \\ 0 \quad \text{when } d_{ML} \leq 0.9\, d_{KLs} \\ 0.5 \left\{ \quad + \cos \left[\dfrac{\pi(d_{KLs} - d_{ML})}{0.1\, d_{KLs}} \right] \right\} \text{ otherwise} \end{array} \right\} \tag{135}$$

where d_{KLs} is from (112), rounded earth attenuations A_{rML} and A_{r5} are obtained from (105) with parameters for the subscript e path (fig. 20), and d_p set to d_{ML} and d_o, respectively,

$$A_5 = \left\{ \begin{array}{l} A_{r5} \text{ if } W > 0.999 \\ A_{K5} \text{ if } W < 0.001 \\ (1-W)\, A_{K5} + W\, A_{r5} \text{ otherwise} \end{array} \right\} \quad \text{dB} \tag{136}$$

$$A_{ML} = \left\{ \begin{array}{l} A_{rML} \text{ if } W > 0.999 \\ A_{KK} \text{ if } W < 0.001 \\ (1-W)\, A_{KK} = W\, A_{rML} \quad \text{otherwise} \end{array} \right\} \quad \text{dB} \tag{137}$$

$$M_o = (A_{ML} - A_5)/(d_{ML} - d_o) \quad \text{dB/km} \tag{138}$$

$$A_o = A_{ML} - M_o\, d_{ML} \quad \text{dB} \tag{139}$$

and

$$d_o = - A_o/M_o \quad \text{km} . \tag{140}$$

This procedure involves (a) combining knife-edge diffraction values (A_{K5}, A_{KK}) and rounded earth diffraction values (A_{r5}, A_{rML}) at the distance where the knife-edge v parameter is about -0.5, d_o, and the maximum line-of-sight distance, d_{ML}, (b) using these points to define a linear diffraction line with slope M_o and intercept A_o, and (c) using this line to define the distance d_o at which the attenuation resulting from it would be zero. It is very similar to a referenced method [20, sec. 2.1].

Terrain attenuation A_T for beyond-the-horizon paths ($d \geq d_{ML}$) is determined using attenuations for diffraction and scatter. Attenuation for scatter, A_s, is discussed in section A.4.4 whereas diffraction attenuation, A_d, is calculated using the rounded earth and knife-edge diffraction formulations previously discussed in this section. That is rounded earth attenuation A_{rK} is obtained from (105) with parameters for the subscript K path (fig. 20) and d_p set to $d_{L1} + d_{eLs}$ where d_{L1} is the facility horizon distance and d_{eLs} is obtained from (118).

$$A_6 = \left\{ \begin{array}{l} A_{rK} \text{ if } W > 0.999 \\ A_{Ke} \text{ if } W < 0.001 \\ (1-W)\ A_{Ke} + W\ A_{rK} \text{ otherwise} \end{array} \right\} \quad \text{dB} \qquad (141)$$

where W and A_{Ke} are obtained from (135) and (122),

$$M_d = (A_{ML} - A_6)/(d_{ML} - d_{L1} - d_{eLs}) \quad \text{dB/km} \qquad (142)$$

where A_{ML} is obtained from (137),

$$A_{do} = A_{ML} - M_d\ d_{ML} \quad \text{dB} \qquad (143)$$

and

$$A_d = M_d\ d + A_{do} \quad \text{dB} \qquad (144)$$

where d km is the great circle path distance. The distance, d_x km, is the shortest distance just beyond the radio horizon at which scatter attenuation, A_s, is $\geq$ 20 dB and the slope of the A_s versus d curve, M_s, is $\leq M_d$ where M_s is determined using successive A_s calculations (sec. A.4.4) for distances greater than d_{ML}. Then

$$A_T = \left\{ \begin{array}{l} \left.\begin{cases} A_d \text{ if } A_{sx} \geq A_{dx} \\ A_s + \left(\dfrac{A_{sx}-A_{ML}}{d_x-d_{ML}}\right)(d-d_x) \text{ otherwise} \end{cases}\right\} \text{for } d_{ML} \leq d \leq d_x \\ \left.\begin{cases} \text{lesser of } A_d \text{ or } A_s \text{ if } A_T \neq A_s \\ \text{for all shorter distances previously considered} \\ A_s \text{ otherwise} \end{cases}\right\} \text{for } d_x<d \end{array} \right\} \text{dB} \quad (145)$$

where A_{dx} and A_{sx} are values of A_d and A_s that correspond to $d = d_x$. For within-the-horizon paths, $d < d_{ML}$, A_T is determined using (84).

A.4.4 Scatter Region

For beyond-the-horizon paths, the terrain attenuation is equal to that associated with forward scatter, $A_t=A_s$ dB, when contributions from diffraction, A_d, are neglected. Use of A_s and A_d to obtain A_T was discussed in the previous section (145) so that this section is only concerned with the calculation of A_s. Portions of the programs that deal with scatter are nearly identical with Johnson's earlier scatter program [27, sec. 7], which is based on the model described by Rice et al. [40, secs. 9, III.5], but includes certain CCIR information [7, sec. 11]. Readers interested in details concerning the scatter model should refer to these documents. However, A_s calculations may be summarized as follows:

d = great circle path distance (km)

a = effective earth radius from (20)

θ_{e1} = facility horizon elevation angle (rad) via figure 14

θ_{e2} = aircraft horizon elevation angle (rad) from (39)

h_1 = elevation of facility antenna (km) above msl

h_{es2} = effective altitude of aircraft (nm) above msl

$$h_{es2} = h_2 - \Delta h_e \quad \text{km} \tag{146}$$

where h_2 is the aircraft altitude above mean sea level and Δh_e is obtained from (45) ,

$$\alpha_{oo} = \frac{d}{2a} + \theta_{e1} + \frac{h_1 - h_{es2}}{d} \quad \text{rad} \tag{147}$$

$$\beta_{oo} = \frac{d}{2a} + \theta_{e2} - \frac{h_1 - h_{es2}}{d} \quad \text{rad} \tag{148}$$

$$\theta_{oo} = \alpha_{oo} + \beta_{oo} \quad \text{rad} \tag{149}$$

d_{L1} = facility horizon distance (km) via figure 14

d_{L2} = aircraft horizon distance (km) from (38)

$$\theta_{o1,2} \left\{ \begin{array}{ll} 0 \text{ for smooth earth} & \\ \theta_{e1,2} + \frac{d_{L1,2}}{a} & \text{otherwise} \end{array} \right\} \quad \text{rad} \tag{150}$$

$$Y_{s1} = \frac{d\, \beta_{oo}}{\theta_{oo}} - d_{L1} \quad \text{km} \tag{151}$$

$$Y_{s2} = \frac{d\, \alpha_{oo}}{\theta_{oo}} - d_{L2} \tag{152}$$

$$d_{s1,2} = \left\{ \begin{array}{ll} Y_{s1,2} \text{ if } \theta_{o1,2} \geq 0 & \\ Y_{s1,2} - \left|\frac{a}{\theta_{o1,2}}\right| & \text{otherwise} \end{array} \right\} \quad \text{km} \tag{153}$$

Values for $\Delta\alpha_o$ and $\Delta\beta_o$ [7, fig. 18] are obtained with subroutine DELTA (sec. B.4.1) by using values of $\theta_{o1,2}$ and N_s from (18). Then

$$\alpha_o = \alpha_{oo} + \Delta\alpha_o \quad \text{rad} \tag{154}$$

$$\beta_o + \beta_{oo} + \Delta\beta_o \quad \text{rad} \tag{155}$$

$$\theta = \alpha_o + \beta_o \quad \text{rad} \tag{156}$$

$$S_I = \alpha_o/\beta_o \tag{157}$$

$$s = \left\{ \begin{array}{l} S_I \text{ if } S_I \leq 1 \\ 1/S_I \text{ otherwise} \end{array} \right\} \tag{158}$$

$$D_s = d - d_{L1} - d_{L2} \quad \text{km} \tag{159}$$

$$h_v = D_s \; s \; \theta/(1 + s)^2 \quad \text{km} \tag{160}$$

$$h_o = ds \; \theta(1 + s)^2 \quad \text{km} \tag{161}$$

$$\eta = 0.031 - (2.32 \; N_s/10^3) + (5.67 \; N_s^2/10^6) \tag{162}$$

$$\eta_s = 0.5696 \; h_o[1 + \eta] \exp[-3.8 \; (\frac{h_o}{10})^6] \tag{163}$$

$$F_o = 1.086 \; (\eta_s/h_o) \; (h_o - h_v - h_{L1} - h_{L2}) \quad \text{dB} \tag{164}$$

λ = wavelength (km) from (73)

$$v_\alpha = 4\pi \; h_1 \; \alpha_o/\lambda \tag{165}$$

$$v_\beta = 4\pi \; h_{es2} \; \beta_o/\lambda \tag{166}$$

$$v_1 = \left\{ \begin{array}{l} v_\alpha \text{ if } S_I \leq 1 \\ v_\beta \text{ otherwise} \end{array} \right\} \tag{167}$$

and

$$v_2 = \begin{Bmatrix} v_\beta \text{ if } S_I \leq 1 \\ v_\alpha \text{ otherwise} \end{Bmatrix} \quad . \tag{168}$$

A value for H_o is obtained with subroutine HCHNOT (sec. B.4.1) by using values of s, η_s, and $v_{1,2}$ where HCHNOT is based on a referenced [7, sec. 11.4]. Subroutine FDTETA (sec. B.4.1) is used to obtain $F_{d\theta}$ from values for d, θ, N_s, and s where FDTETA is based on a referenced method [7, sec. 11.1]. Then

$$A_s = 10 \log f - 40 \log d + F_{d\theta} + H_o - F_o - 32.45 \text{ dB} \tag{169}$$

where f MHz is frequency.

A.4.5 Atmospheric Absorption

The formulation used to estimate median values for atmospheric absorption is similar to a described method [18, sec. A.3]. Allowances are made for absorption due to oxygen and water vapor by using surface absorption rates and effective ray lengths where these ray lengths are lengths contained within atmospheric layers with appropriate effective thicknesses. The geometry associated with this formulation is shown in figure 21 along with key equations relating geometric parameters.

For line-of-sight paths, ($d \leq d_{ML}$) where d_{ML} is from (40), the figure 21 expressions are used to calculate effective ray lengths $r_{eo,w}$ where $H_{\gamma 1} = h_{e1}$ from (111), $H_{\gamma 2} = H_2$ from (47), for earth, $a_\gamma = a_a$ from (44), and $\beta = \theta_h$ from (57).

For single horizon paths ($d_{ML} < d \leq d_{L1} + d_{eL1}$) where d_{L1} is from figure 14 and d_{eL1} is from (116), the figure 21 expressions are used with two sets of starting parameters and the $r_{eo,w}$'s obtained with these are called $r_{1eo,w}$ and $r_{2eo,w}$. In the first calculations, $H_{\gamma 1} = h_{e1}$, Parameter values for $H_{\gamma 1}$ km, $H_{\gamma 2}$ km, and a_γ km and β are defined in the text for line-of-sight, single horizon, and two horizon paths.

$$A_t = \beta + 0.5\,\pi$$

$$H_t = T_{eo,w} + a_\gamma$$

$$H_q = H_{\gamma 1} + a_\gamma$$

$$H_z = \text{lesser of } \{H_t \text{ or } H_{\gamma 2} + a_\gamma\}$$

When $H_{\gamma 1} < T_{eo,w}$

$$A_q = \mathrm{Sin}^{-1}(H_q \sin A_t / H_z)$$

$$A_e = \pi - (A_t + A_q)$$

$$r_{eo,w} = \left\{\begin{array}{l} H_t - H_q \text{ if } A_q < 0.02 \text{ rad} \\ H_q \sin A_e / \sin A_q \text{ otherwise} \end{array}\right\} \text{km}$$

When $T_{eo,w} < H_{\gamma 1}$

$$H_c = H_q \sin A_t$$

$$r_{eo,w} = \left\{\begin{array}{l} 0 \text{ if } H_t \leq H_c \text{ or } A_t \leq \frac{\pi}{2} \\ 2\, H_t \sin[\cos^{-1}(H_c/H_t)] \text{ otherwise} \end{array}\right\} \text{km}$$

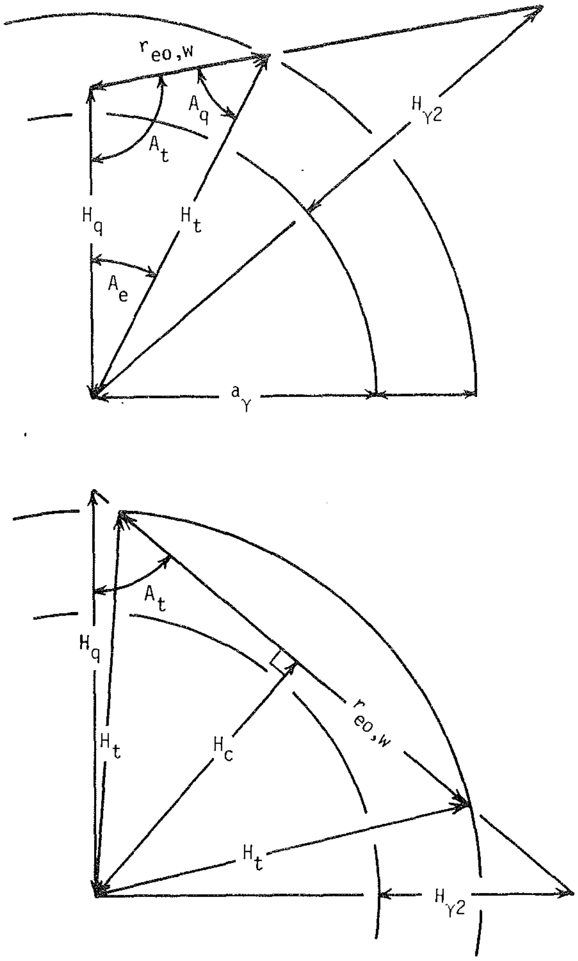


Figure 21. Geometry associated with atmospheric absorption calculations. Values of $T_{eo,w}$ for oxygen and water vapor are taken as 3.25 and 1.36 km [18, table A.2], respectively (not drawn to scale).

$H_{\gamma 2} = h_{ee1}$ from (114), $a_\gamma = a$ from (20), and $\beta = \theta_{e1}$ from figure 14. For the second set $H_1 = H_{L1}$, $H_{\gamma 2} = h_{e2}$ from (34), $a_\gamma = a$, and $\beta = -\theta_{e2} - (d - d_{L1})/a$ where θ_{e2} is from (36). Values for $r_{eo,w}$ are then obtained using

$$r_{eo,w} = r_{1eo,w} + r_{2eo,w} \quad \text{km} . \tag{170}$$

For two horizon paths ($d_{L1} + d_{eL1} < d$), the figure 21 expressions are also used with two sets of input parameters, and the results obtained are called $r_{1eo,w}$ and $r_{2eo,w}$, where (170) is used to determine $r_{eo,w}$ values. Height of the scattering volume above the effective reflection surface, H_V, is used as an input parameter and it is calculated using h_{ee2} km at distance d_{s1} km from (153), θ_{o1} rad from (150), and a km; i.e.,

$$H_V = h_{ee2} + d_{s1} \tan \theta_{o1} + d_{s1}^2/(2a) \quad \text{km} . \tag{171}$$

In the first set of calculations, $H_{\gamma 1} = h_{e1}$, $H_{\gamma 2} = H_V$, $a_\gamma = a$, and $\beta = \theta_{e1}$. For the second set, $H_{\gamma 1}$ = lesser of $\{H_V$ or $H_{e2}\}$, $H_{\gamma 2}$ = greater of $\{H_V$ or $H_{e2}\}$, $a_\gamma = a$, and β = greater of $\{-\theta_{e2}$ or $-\theta_{e2} - (d - d_{L1} - d_{s1})/a\}$.

Surface absorption rates for oxygen and water vapor, $\gamma_{oo,w}$ dB/km are used with effective ray lengths, $r_{eo,w}$ km, to obtain an estimate for atmospheric absorption, A_a dB; i.e.,

$$A_a = \gamma_{oo} r_{eo} + \gamma_{ow} r_{ew} \quad \text{dB} . \tag{172}$$

Values for $\gamma_{oo,w}$ may be provided as input (sec. 3.1.1). When values are not provided as input, estimates are made within subroutine ASORP (sec. B.4.1) by interpolating between values taken from referenced curves [40, fig. 3.1].

A.5 Long-Term Power Fading

The formulation used for the variability associated with long-term (hourly median) power fading that is required for (5) is designated $Y_e(q)$

dB where q is the time availability parameter of section A.1 and the sign associated with $Y_e(q)$ values is such that the positive values associated with $q \leq 0.5$ will decrease transmission loss or increase received power levels. It is (a) based on a recommended model [22, sec. 3.1] that was tested against air/ground data [21, sec. 4.3], (b) almost identical with a previous model [20, sec. 2.2], and (c) a modified version of a power fading model [40, secs. 10, III.6, III.7]. These modifications consist of: (a) the conditional use of ray tracing to determine effective distance, d_e; (b) replacing θ_h in their elevation angle correction function [40, fig. III.24] by 8 θ_h, where θ_h is the elevation angle of the facility-to-aircraft direct ray from (57); and (c) conditional limiting of $Y_e(q)$ values for $q < 0.1$. The 8 θ_h modification in (b) comes from a comparison [20, fig. 2] with satellite data [35, fig. 8]. In the calculation of $Y_e(q)$, ray tracing from the earth surface to the aircraft is used to determine the smooth earth horizon distance d_{LoR} when Δh_e is not specified as an input parameter (sec. 3.1.1) where the surface refractivity used in the ray tracing (sec. A.4.1) is determined via (20) for a 9000-km effective earth radius. Then

$$d_{Lo1} = \sqrt{18000\ h_{e1}} \quad \text{km} \tag{173}$$

where h_{e1} is from (111)

$$d_{Lo2} = \left\{ \begin{array}{l} d_{LoR} \text{ if } \Delta h_e \text{ not specified} \\ \sqrt{18000\ h_{a2}} \text{ otherwise} \end{array} \right\} \text{km} \tag{174}$$

where h_{a2} km is the actual aircraft altitude above the reflecting surface

$$d_{ds} = 65(100/f)^{1/3} \quad \text{km} \tag{175}$$

where f MHz is frequency

$$d_M = d_{Lo1} + d_{Lo2} + d_{ds} \quad \text{km} \tag{176}$$

$$d_e = \left\{ \begin{array}{l} 130d/d_M \text{ for } d \leq d_M \\ \\ 130 + d - d_M \text{ otherwise} \end{array} \right\} \text{km} \tag{177}$$

where d km is great circle path distance and

$$\left. \begin{array}{r} V(0.5) \\ Y(0.1) \\ -Y(0.9) \end{array} \right\} = \left[C_1 d_e^{\,n_1} - f_2 \right] \exp(-C_3\, d_e^{\,n_3}) + f_2 \quad \text{dB} \tag{178}$$

where $f_2 = f_\infty + (f_m - f_\infty) \exp(-C_2 d_e^{\,n_2})$ and the values used for the parameters C_1, C_2, C_3, n_1, n_2, n_3, f_m, and f_∞ depend on whether V(0.5) [40, table III.5, climate 1], Y(0.1) [40, table III.3, all hours all year], or Y(0.9) [40, table III.4, all hours all year] is being calculated. Then

$$f_{\theta h} = 0.5 - \pi^{-1} \operatorname{Tan}^{-1} [20 \log(32\, \theta_h)] \tag{179}$$

$$Y_e(0.1) = f_{\theta h}\, Y(0.1) \quad \text{dB} \tag{180}$$

$$Y_e(0.9) = f_{\theta h}\, Y(0.9) \quad \text{dB} \qquad (181$$

$$Y_T = L_b(0.5) - [\, L_{bf} - 20 \log(g_D + R_{Tg} + R_{Tc})] \quad \text{dB} \tag{182}$$

where $L_b(0.5)$ is from (14), L_{bf} is from (15), and g_D, R_{Tg}, and R_{Tc} have the same values as they would in (81).

$$Y_e(0.0001) = \left\{ \begin{array}{l} \text{lesser of} \left\{ \begin{array}{c} 3.33\ Y_e(0.1) \\ \text{or} \\ Y_T \end{array} \right\} \text{for lobing} \\ \\ \text{lesser of} \left\{ \begin{array}{c} 3.33\ Y_e(0.1) \\ \text{or} \\ L_{br} + A_Y - (L_{bf} - 6) \end{array} \right\} \text{otherwise} \end{array} \right\} \text{dB} \tag{183}$$

where the lobing option is discussed in sec. 3.1.1, L_{br} is from (17) and A_Y is from (15),

$$Y_e(0.001) = \left\{\begin{array}{ll} \text{lesser of } \left\{\begin{array}{l} 2.73\ Y_e(0.1) \\ \quad \text{or} \\ Y_T \end{array}\right\} & \text{for lobing} \\ \\ \text{lesser of } \left\{\begin{array}{l} 2.73\ Y_e(0.1) \\ \quad \text{or} \\ L_b(0.5)-(L_{bf}-5,8) \end{array}\right\} & \text{otherwise} \end{array}\right\} \text{dB} \quad (184)$$

$$Y_e(0.01) = \left\{\begin{array}{ll} \text{lesser of } \left\{\begin{array}{l} 1.95\ Y_e(0.1) \\ \quad \text{or} \\ Y_T \end{array}\right\} & \text{for lobing} \\ \\ \text{lesser of } \left\{\begin{array}{l} 1.95\ Y_e(0.1) \\ \quad \text{or} \\ L_{br}+A_Y-(L_{bf}-5) \end{array}\right\} & \text{otherwise} \end{array}\right\} \text{dB} \quad (185)$$

$$Y_B = L_b(0.5) - (L_{bf} + 80) \ \ \text{dB} \quad (186)$$

$$Y_e(0.99) = \left\{\begin{array}{ll} \text{greater of } \left\{\begin{array}{l} 1.82\ Y_e(0.9) \\ \quad \text{or} \\ Y_B \end{array}\right\} & \text{for lobing} \\ \\ 1.82\ Y_e(0.9) \text{ otherwise} & \end{array}\right\} \text{dB} \quad (187)$$

$$Y_e(0.999) = \left\{\begin{array}{ll} \text{greater of } \left\{\begin{array}{l} 2.41\ Y_e(0.9) \\ \quad \text{or} \\ Y_B \end{array}\right\} & \text{for lobing} \\ \\ 2.41\ Y_e(0.9) \text{ otherwise} & \end{array}\right\} \text{dB} \quad (188)$$

and

$$Y_e(0.9999) = \left\{\begin{array}{ll} \text{greater of } \left\{\begin{array}{l} 2.90\ Y_e(0.9) \\ \quad \text{or} \\ Y_B \end{array}\right\} & \text{for lobing} \\ 2.90\ Y_e(0.9) \text{ otherwise} & \end{array}\right\} \text{dB}. \quad (189)$$

The median adjustment factor $V_e(0.5, d_e)$ required for (17) is obtained using the results of (178 and 179), i.e.,

$$V_e(0.5, d_e) = f_{\theta h} \, V(0.5) \;\; \text{dB} . \tag{190}$$

A.6 Surface Reflection Multipath

Multipath associated with reflections from the earth's surface is considered as part of the short-term (within-the-hour) variability for line-of-sight paths, and is used only when the time availability option for "instantaneous levels exceeded" is selected (table 1). Contributions associated with both specular and diffuse reflection components may be included though the specular component is not allowed to make a full contribution when it is also used in determining the median levels (e.g., when lobing option is selected, table 1). These contributions are incorporated into the variability part of the model via the relative power level, W_R, in (6). Formulas used to calculate W_R may be summarized as follows:

F_{AY} = reflection reduction factor [42, eq. 21 modified] associated with the conditional adjustment factor A_Y from (16)

$$F_{AY} \quad \left\{ \begin{array}{l} 1 \text{ if } A_Y \leq 0 \\ 0.1 \text{ if } A_Y \geq 6 \\ 0.5[1.1 + 0.9 \cos(\pi A_Y/6)] \text{ otherwise} \end{array} \right\} \tag{191}$$

$F_{\Delta r}$ = reflection reduction factor [42, eq. 22] associated with path length difference, Δr km, from (56) wavelength, λ km, from (73)

$$F_{\Delta r} = \left\{ \begin{array}{l} 0 \text{ for lobing (table 1)} \\ \left\{ \begin{array}{l} 1 \text{ for } \Delta r \geq \lambda/2 \\ 0.1 \text{ for } \Delta r \leq \Delta r_0 = \lambda/6 \\ \dfrac{1.1 - 0.9 \cos\,[3\pi(\Delta r - \Delta r_0)/\lambda]}{2} \text{ otherwise} \end{array} \right\} \text{ otherwise} \end{array} \right\} \tag{192}$$

$$R_s = R_{Tg}\ F_{AY}\ F_{\Delta r} \tag{193}$$

where R_s^2 is the specular contribution to relative multipath power, and R_{Tg} is from (78). $F_{d\sigma h}$ is the reflection reduction factor associated with diffuse reflection that is based on curves fit to data [5, fig. 4] and expressed in terms of $F_{\sigma h}$ from (66)

$$F_{d\sigma h} = \begin{cases} 0.01 + 9.46\ F_{\sigma h}^2 \text{ if } F_{\sigma h} < 0.00325 \\ 6.15\ F_{\sigma h} \text{ if } 0.00325 \leq F_{\sigma h} \leq 0.0739 \\ 0.45 + \sqrt{0.000893 - (F_{\sigma h} - 0.1026)^2} \text{ if } 0.0739 < F_{\sigma h} < 0.1237 \\ 0.601 - 1.06\ F_{\sigma h} \text{ if } 0.1237 \leq F_{\sigma h} \leq 0.3 \\ 0.01 + 0.875 \exp(-3.88\ F_{\sigma h}) \text{ otherwise} \end{cases} \tag{194}$$

$$R_d = R_{Tg}\ F_{d\sigma h}/F_{\sigma h} \tag{195}$$

where R_d^2 is the diffuse contribution to relative multipath power and

$$W_R = \begin{cases} R_s^2 + R_d^2 \text{ for line-of-sight } (d \leq d_{ML}) \\ 0 \text{ otherwise} \end{cases} \tag{196}$$

where d_{ML} is from (40) and d is path distance.

The R_{Tg} in (193) is an effective reflection coefficient for reflection from the earth. It is calculated using (78) and (68), and includes allowances for: (a) surface constants and frequency via the plane earth reflection coefficient, R, of (63); (b) antenna illumination of the reflecting area via the relative antenna gain, g, of (67), (c) shadowing of the reflecting area by the counterpoise with f_g of (78), and (d) surface roughness via $F_{\sigma h}$ of (66). This formulation for $F_{\sigma h}$ [32, eq. 3.5] has been previously used [20, p. 17; 42, eq. 18]. Although it differs from some formulations [6, p. 246] and [40, eq. 5.1], it does agree well with data [6, p. 318; and Montgomery, 1969, "A note on selected definitions of effective antenna heights", ESSA Tech. Memo. ERLTM-ITS 158, pp. 7-9; limited distribution, contact author at ITS for more information].

A.7 Tropospheric Multipath

Tropospheric multipath is caused by reflections from atmospheric sheets or elevated layers, or additional direct (nonreflected) wave paths [2; 9, sec. 3.1] and may be present when antenna directivity is sufficient to make surface reflections negligible. It is considered as part of the short-term (within-the-hour) variability for line-of-sight path, is used only when the time availability option for "instantaneous levels exceeded" is selected (table 1), and is incorporated into the variability part of the model via the relative power level, W_a, in (6).

The formulation for W_a within the line-of-sight region [$d_{ML} < d$ where d_{ML} is the maximum line-of-sight distance from (40) and d is the great circle path distance] involves: frequency, f MHz; effective water vapor ray length, r_{ew}, from figure 21;

$$F = \left\{ \begin{array}{l} 10 \log (f\, r_{ew}^3) - 84.26 \text{ if } d \leq d_{ML} \\ \text{and is not calculated otherwise} \end{array} \right\} \text{dB} \tag{197}$$

$$K_t = \left\{ \begin{array}{l} \text{obtained via (201) if } d > d_{ML} \\ 40 \text{ dB if } F \leq 0.14 \\ -20 \text{ dB if } F \geq 18.4 \\ \text{or is obtained from curves [40, fig. V.1]} \end{array} \right\} \text{dB} \tag{198}$$

and

$$W_a = 10^{-K_t/10} \quad . \tag{199}$$

The expression for fade margin, F, given in (197) is identical with the one used in [20, eq. 42], and was derived from the outage time formulation provided in [31, pp. 60, B-2, 119] by: replacing the path distance with r_{ew}; expressing frequency in megahertz; setting both "climate" and "terrain" factors to 0.25; setting the "actual fade probability" to 0.01 (100-0.99); and solving the resulting equation for F. Values for F are used in (198) by selecting the K_t that corresponds to $Y_\pi(0.99) = -F$ in [40, fig. V.1]. This operation is performed in the programs by a function called FDASP (sec. B.4.1) which interpolates between predetermined values [40, fig. V.1].

For beyond-the-horizon paths ($d_{ML} < d$), values for W_a may be determined from K_t values with (201), where K_t is calculated using (a) the scattering angle θ rad from (156), and (b) the value K_{ML} of K obtained from (6) at $d = d_{ML}$ with W_R from (196) and W_a from (199); i.e.,

$$M_{Ka} = (-20-K_{ML})/0.02618 \quad \text{dB/rad} \tag{200}$$

and

$$K_t = \left\{ \begin{array}{l} \text{obtained via (198) if } d \leq d_{ML} \\ -20 \text{ if } \theta > 0.02618 \text{ rad} \\ K_{ML} + M_{Ka}\,\theta \text{ otherwise} \end{array} \right\} \text{dB} . \tag{201}$$

However, the calculation of W_a for such paths can be bypassed since the K of (6) is equal to the K_t of (201) because W_R in (6) from (196) is zero. Data [26] was used to determine the values of θ at which short-term fading for beyond-the-horizon paths can be characterized as Rayleigh fading ($K \leq -20$ dB), and (201) includes a linear interpolation between the horizon ($\theta = 0$, $K_t = K_{ML}$) and Rayleigh fading ($\theta = 0.02618$ rad, $K_t = -20$ dB) points.

APPENDIX B. PROGRAM LISTINGS

Program listings are given in this appendix for the power density (POWAV, sec. B.1), station separation (DOVERU, sec. B.2), and service volume (SRVVOLM, sec. B.3) programs. Most subprograms (functions and subroutines) are common to all three programs and are listed in section B.4. All listings are in FORTRAN and have some annotation to assist readers.

Data tables, which are read into the computer prior to any system configuration data, are listed in section B.4.2. Initial (first 5) READ statements of all three programs concern these tables. Remaining READ statements concern model parameter data where the cards used to provide such data for each program are indicated in figure 22 (POWAV), figure 23 (DOVERU), and figure 24 (SRVVOLM). FORTRAN variable names used in the programs and in these figures are described in table 7. Additional information concerning most of these parameters is given in section 3.1.1. Format requirements are given in the program listings.

B.1 POWER DENSITY PROGRAM

Input parameters for the power density program (POWAV) and the output generated by it are discussed in sections 3.1.1 and 3.2.1, respectively. Information concerning input parameter cards and FORTRAN variables is given in figure 22 and described further in table 7. Subprograms (sec. B.4.1) and data tables (sec. B.4.2) required by POWAV are ALOS, ASORP, CONLUT, DEFRAC, DELTA, FDASP, FDTETA, FRENEL, GAIN, GHBAR, HCHNOT, LINE, PAGE, PLTGRPH, RADEMS, RAYTRAC, RECC, RTATAN, SCATTER, SORB, TABLE, TERP, TRMESH, TSMESH, VZD, and YIKK. A block diagram of the operations performed by POWAV is given in figure 25. Text references and major subprograms that are relevant to specific blocks are included there. A listing of POWAV is provided at the end of this section.

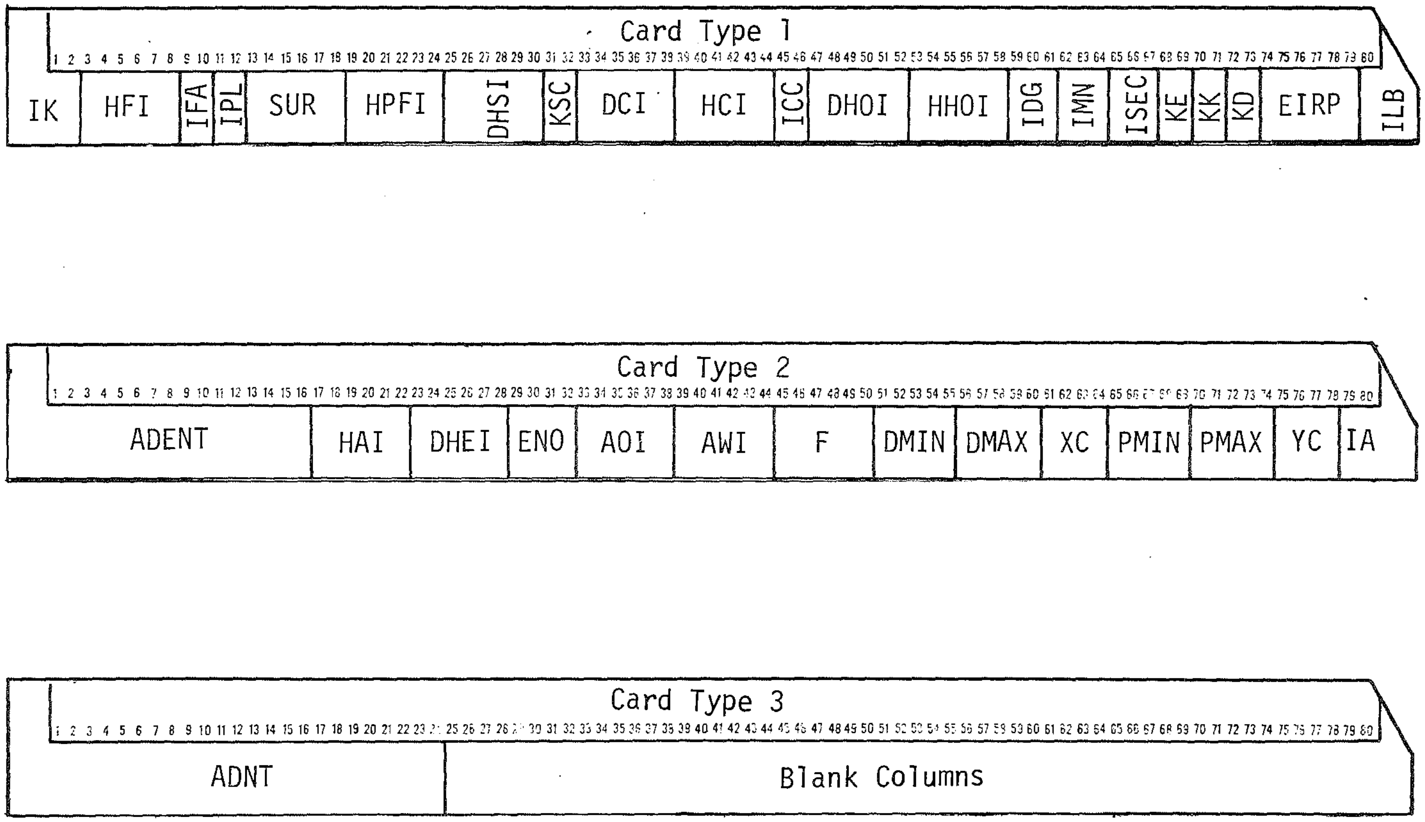


Figure 22. Parameter card types for the power density program, POWAV. The card types are in the order required for computer input.

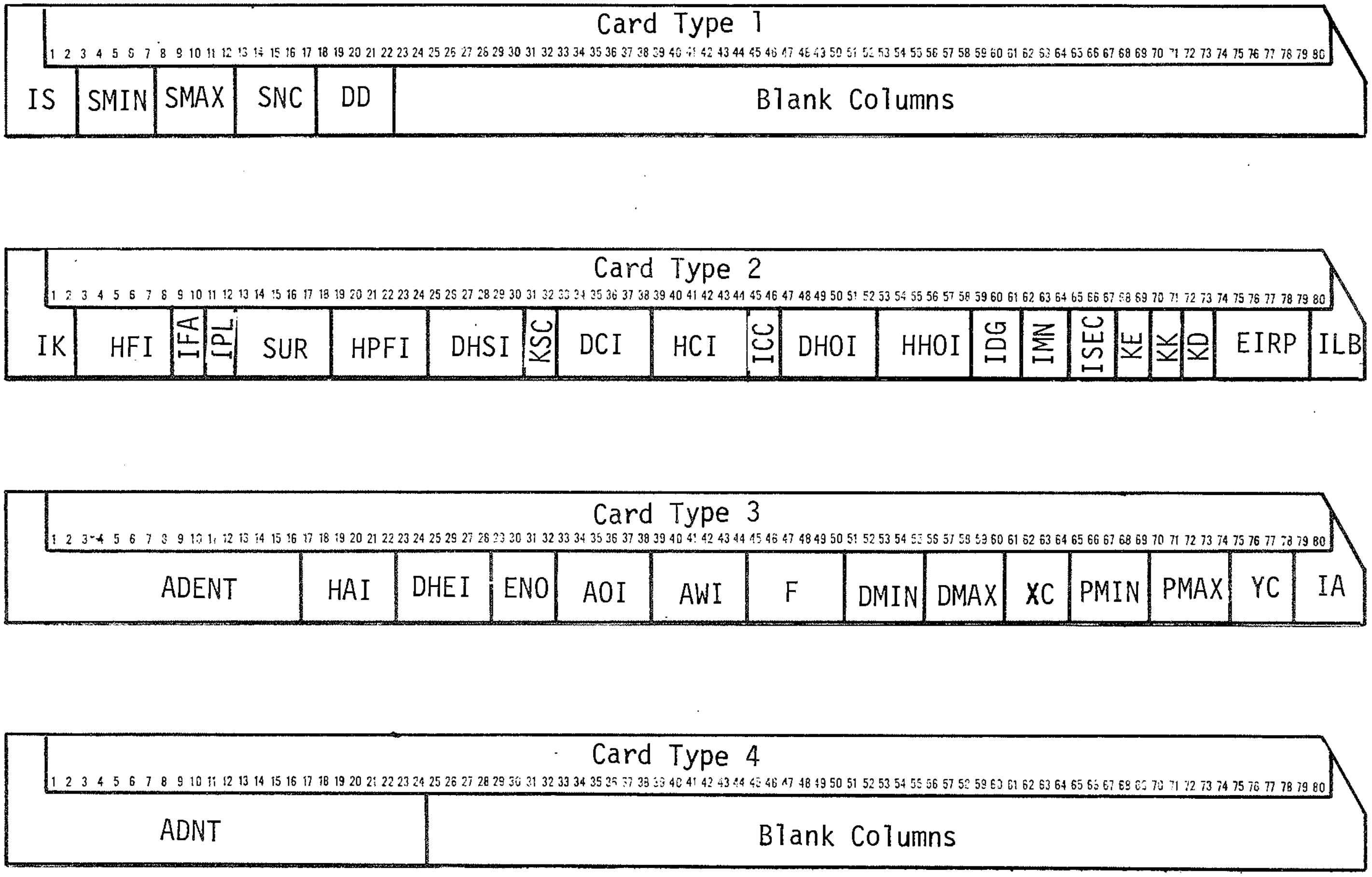


Figure 23. Parameter card types for the station separation program, DOVERU. The card types are in the order required for computer input. Card type 2, 3, and 4 are identical with card type 1, 2, and 3 for POWAV (fig. 22). If the undesired facility has parameters different from those of the desired facility, IS = 2 is used and a second set of card types 2, 3, and 4 for the undesired facility is required. When the facilities have identical parameters, IS = 1 is used and the second set of card is not used.

Card Type 1

IS	DMAX	S	LH	LE	SX(1)	SX(2)	XC	SY(1)	SY(2)	YC	Blank Columns

Card Type 2

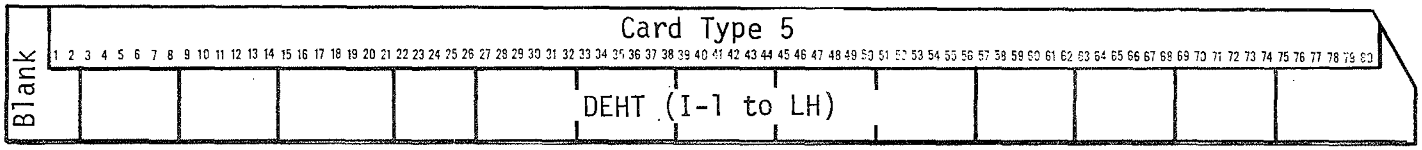
IK	HFI	IFA	IPL	SUR	HPFI	DHSI	KSC	DCI	HCI	ICC	DHOI	HHOI	IDG	IMN	ISEC	KE	KK	KD	EIRP	ILB

Card Type 3

ADENT	ADNT	ENO	AOI	AWI	F	IA	JJ	Blank Columns

Card Type 4

Blank	ACHT(I=1 to LH)



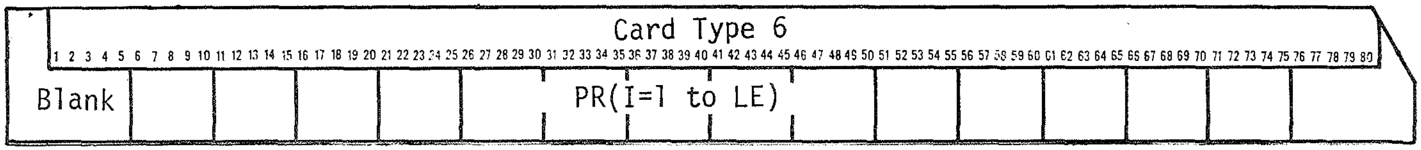


Figure 24. Parameter card types for the service volume program, SRVVLOM. The card types are in the order required for computer input. Card type 2 is identical with cards used for other programs (POWAV, type 1, fig. 22; DOVERU, type 2, fig. 23). Card types 2 and 3 are the facility cards, and if the undesired facility has different parameters than the desired facility (IS = 2), then another set of cards, types 2 and 3, with the parameters for the undesired facility must follow after the last card (type 6). Card type 4 has aircraft altitudes on it. If LH on card type 1 is greater than 13, then the remaining altitudes are on a second card type 4 following immediately after the first card type 4. If JJ = - 1 on card type 3, there will be no card type 5. Otherwise there must be a one-to-one correspondence between the aircraft altitudes (type-4 cards) and the altitude correction factors (type-5 cards) so that two type-4 cards would require two type-5 cards. Card type 6 contains the D/U ratios to be graphed, and if LE>15 on card type 1, there must be a second card with the remaining D/U ratios.

Table 7. FORTRAN input variables for parameter cards

Fortran Input Variables	Parameter Card Type Number For			Description
	POWAV	DOVERU	SRVVOLM	
IK	1	2	2	Code for units to be used with input. The units given for variables in this table are correct only when <u>IK=3</u> is used. NOTE: IK=0 terminates a POWAV run.
HFI	1	2	2	Height of facility antenna (feet above site surface).
IFA	1	2	2	Code for facility antenna pattern: (1) isotropic, (2) DME, (3) TACAN (RTA-2), (4) 4-loop array (cosine vertical pattern), (5) 8-loop array (cosine vertical pattern), (6) I or II (cosine vertical pattern), (7) JTAC tilted 20 degrees with 40 half-pow B.W., and (8) JTAC tilted 8 degrees. NOTES: (a) these phrases will appear on the parameter sheet, (b) representative vertical patterns are given by (63) and are shown in figure 2 where options 4, 5, and 6 all use the "cosine pattern".
IPL	1	2	2	Code for polarization: (1) horizontal, (2) vertical, and (3) circular. NOTE: provisions for option 3 are <u>not</u> complete.
SUR	1	2	2	Elevation of facility site surface (feet above msl).
HPFI	1	2	2	Elevation of effective reflection surface (feet above msl).
DHSI	1	2	2	Terrain parameter Δh (ft) from table 3.
KSC	1	2	2	Code for earth reflection material type (table 2): (1) sea water, (2) good ground, (3) average ground, (4) poor ground, (5) fresh water, (6) concrete, and (7) metallic.
DCI	1	2	2	Diameter of facility counterpoise (ft). NOTE: Zero or negative values will cause the program to assume that no counterpoise is present.
HCI	1	2	2	Height of facility counterpoise above facility site surface (ft).
ICC	1	2	2	Code for counterpoise reflection material type (same as for KSC above).
DHOI	1	2	2	Distance to facility radio horizon (n mi). NOTE: Zero or negative values will result in calculation of this parameter from others (fig. 14).
HHOI	1	2	2	Elevation of facility radio horizon (feet above msl). NOTE: negative values will result in the calculation of these parameters from others (fig. 14).
IDG	1	2	2	Facility radio horizon angle in degrees,
IMN	1	2	2	minutes,
ISEC	1	2	2	and seconds.
KE	1	2	2	Code for horizon options: (0) no specified complete; (1) angle specified by IDG, IMN, and SEC; (2) height specified by HHOI; (3) neither the angle nor the elevation is specified.
KK	1	2	2	Code for time availability options: (1) hourly median levels, (2) instantaneous levels.

KD	1	2	2	Code for terrain type options: (1) smooth earth, (2) irregular terrain.
EIRP	1	2	2	Equivalent isotropically radiated power (dBW)
ILB	1	2	2	Code for lobing options: (0) No lobing, (2) lobing.
ADENT	2	3	3	First 16 characters of spaces of label for graph and parameter sheet.
HAI	2	3	-	Aircraft altitude (feet above msl).
DHEI	2	3	-	Effective aircraft altitude correction factor (ft). Note: values less than zero will cause this factor to be calculated using ray tracing.
ENO	2	3	3	Surface refractivity referred to sea level (N-units) from figure 3. NOTE: 301 N-units will be used if value is not specified or is <250 or >400 N-units.
AOI	2	3	3	Surface absorption rate for oxygen (dB/km). NOTE: negative values will cause the program to determine a value via ASORP (sec. B.4).
AWI	2	3	3	Surface absorption for water vapor (dB/km). NOTE: negative value in AOI will cause the program to determine a value via ASORP (sec. B.4).
F	2	3	3	Frequency (MHz).
DMIN	2	3	-	Abscissa value for left-hand limit of graph (n mi).
DMAX	2	3	1	Abscissa value for right-hand limit of graph (n mi).
XC	2	3	1	Abscissa increment for graph grid lines (n mi).
PMIN	2	3	-	Ordinate value for bottom limit of graph (dB-W/sq. mi for POWAV, dB for DOVERU).
PMAX	2	3	-	Ordinate value for top limit of graph (dB-W/sq. mi for POWAV, dB for DOVERU).
YC	2	3	1	Ordinate increment for graph grid lines (dB-W/sq. mi for POWAV, dB for DOVERU, feet for SRVVOLM).
IA	2	3	3	Number of characters and spaces in label.
ADNT	3	4	3	Additional (up to 18 more than ADENT) characters or spaces for label. NOTE: If IA $\leq$ 16, this card will not be read in.
IS	-	1	1	Number of parameter sets required to describe both desired and undesired facilities: (0) will terminate DOVERU or SRVVOLM runs, (1) when facilities are identical, (2) otherwise.
SMIN	-	1	-	Minimum value for station separation used in calculations (n mi).
SMAX	-	1	-	Maximum value for station separation used in calculations (n mi).
SNC	-	1	-	Increment for station separation used in calculations (n mi).
DD	-	1	-	Desired facility to aircraft distance (n mi).
S	-	-	1	Station separation (n mi).
LH	-	-	1	Number of aircraft altitudes (1 to 25).
LE	-	-	1	Number of desired-to-undesired signal ratios (1 to 30).
SX(1)	-	-	1	Abscissa value for right-hand limit of service volume graph (n mi).

Table 7. FORTRAN input variables for parameter cards (Cont'd)

Fortran Input Variables	Parameter Card Type Number For			Description
	POWAV	DOVERU	SRVVOLM	
SX(2)	-	-	1	Abscissa value for left-hand limit of service volume graph (n mi).
SY(1)	-	-	1	Ordinate value for top limit of service volume graph (feet).
SY(2)	-	-	1	Ordinate value for bottom limit of service volume graph (feet).
JJ	-	-	3	Code for service volume program to determine effective aircraft altitude correction factors: (-1) will cause these factors, DEHT, to be calculated by using ray tracing and <u>not</u> read in.
ACHT	-	-	4	Sequence of aircraft altitudes (see LH). NOTE: only 13 are allowed on a card and if LH is greater than 13, the remaining heights are on a card immediately following the first.
DEHT	-	-	5	Sequence of aircraft altitude correction factors corresponding to the altitudes of ACHT. Note: If JJ is (-1), these correction factors will not be read in. If the number of heights (LH) is greater than 13, the remaining correction factors are on a second card immediately following.
PR	-	-	6	Desired-to-undesired signal ratios for which service volumes will be graphed (see LE). Note: Only 15 are allowed on a card, and if LE is greater than 15, the remainder are on a second card immediately following.

---

* If the undesired facility has different parameters in the DOVERU and SRVVOLM programs, a second set of cards 2,3 (and if necessary, 4) follow the first set in DOVERU and in the SRVVOLM program, another set 2 and 3 follow the last PR or signal ratio card (6).

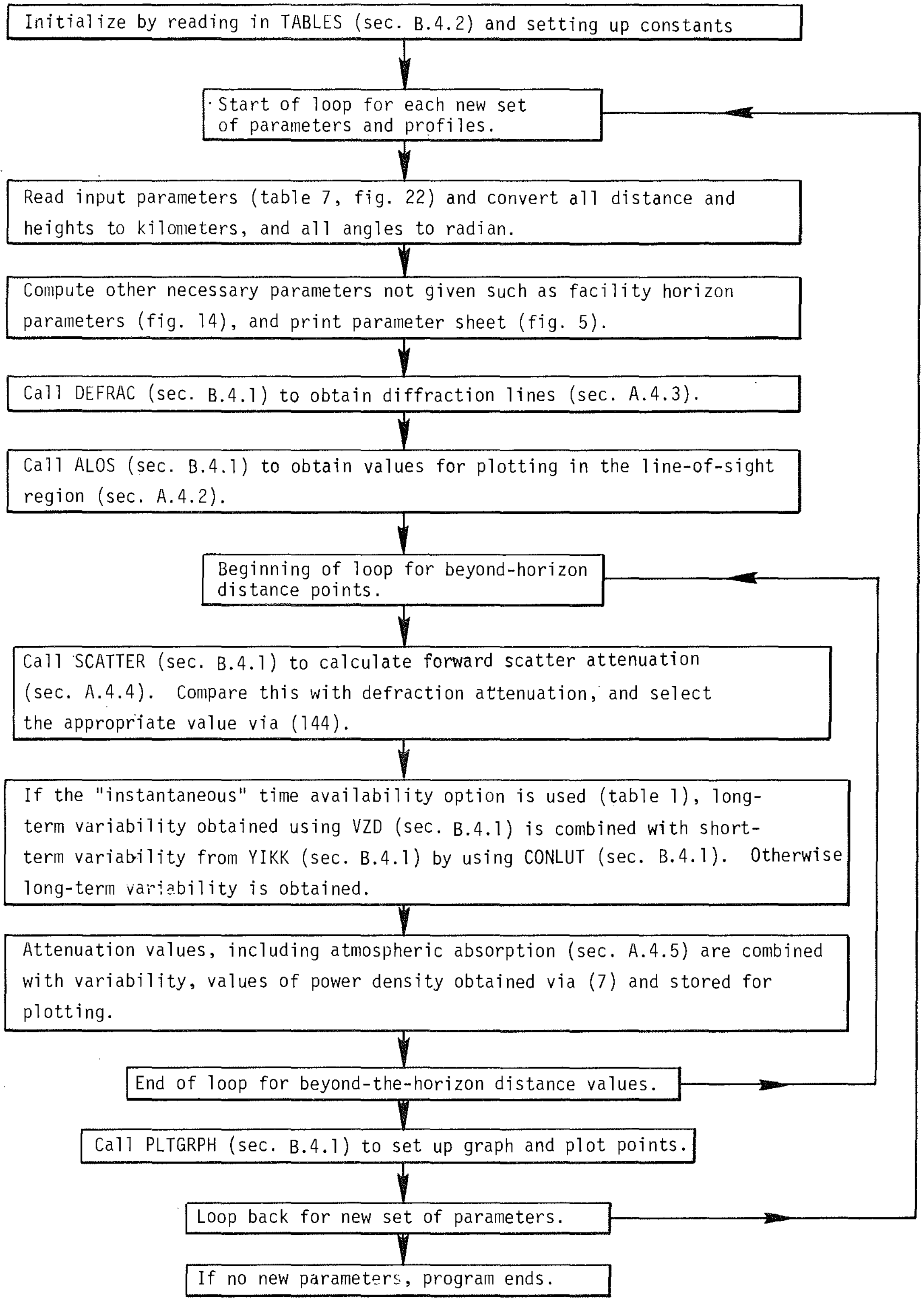


Figure 25. Block diagram for power density program, POWAV.

```
      PROGRAM POWAV
C     ROUTINE FOR MODEL AUG 73
    2 FORMAT(*   PROGRAM IS FINISHED. *)
    4 FORMAT(1H1)
    5 FORMAT(1H )
    6 FORMAT(20X,*INPUT*,21X,*WORKING VALUE*)
    7 FORMAT(I2,F6.0,2I2,3F6.0,I2,2F6.0,I2,2F6.0,3I3,3I2,F6.0,I1)
    8 FORMAT(2A8,2F6.0,F4.0,3F6.0,2(2F5.0,F4.0),I2)
   32 FORMAT(3X,F5.1)
   50 FORMAT(F7.0,1X)
   71 FORMAT(F5.0,14F5.1)
  106 FORMAT(5X,* DML IS LESS THAN ZERO.   ABORTING RUN *)
  108 FORMAT(2(F5.3,7F5.2))
  110 FORMAT(3A8)
  505 FORMAT(11F7.4)
C             FORMAT STATEMENTS FOR PARAMETER SHEET AND WORK SHEET
  700 FORMAT(23X,*PARAMETERS FOR ITS PROPAGATION MODEL *,A8,/32X,A8,2X,A
     X8,* RUN*,//)
  701 FORMAT(32X,*REQUIRED OR FIXED*,/32X,*----------------- *,/15X,*AIR
     1CRAFT ALTITUDE:*,F8.0,* FT ABOVE MSL*)
  702 FORMAT(15X,*FACILITY ANTENNA HEIGHT:*,F7.1,* FT ABOVE SITE SURFACE
     X*)
  703 FORMAT(15X,*FREQUENCY:*,F6.0,* MHZ*)
  704 FORMAT(29X,*SPECIFICATION OPTIONAL*,/29X,*----------------------*,
     4/15X,*ABSORPTION: OXYGEN*,F9.5,* DB/KM*,A2,/27X,*WATER VAPOR*,F9.5
     4,*DB/KM*,A2)
  705  FORMAT(15X,*EFFECTIVE ALTITUDE CORRECTION FACTOR: *,F6.0,* FT*,A2
     5,/15X,*EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL:*,F7.0,* F
     5T*,/15X,*EQUIVALENT ISOTROPICALLY RADIATED POWER: *,F6.1,* DBW*,/1
     55X,*FACILITY ANTENNA TYPE: *,5A8)
  706 FORMAT(20X,*COUNTERPOISE DIAMETER:*,F5.0,* FT*,/25X,*HEIGHT:*,F5.0
     6,* FT ABOVE SITE SURFACE *,/25X,*SURFACE:*,2A8)
  707 FORMAT(20X,*POLARIZATION:*,2A8)
  708 FORMAT(15X,*HORIZON OBSTACLE DISTANCE:*,F7.2,* N MI FROM FACILITY*
     8,A2,/20X,*ELEVATION ANGLE:  *,I3,*/*,I2,*/*,I2,* DEG/MIN/SEC ABOVE
     8 HORIZONTAL*,A2,/20X,*HEIGHT:*,F6.0,* FT ABOVE MSL*,A2)
  709 FORMAT(15X,*MINIMUM MONTHLY MEAN SURFACE REFRACTIVITY:*,/20X,F3.0,
     9* N-UNITS     AT SEA LEVEL: *,F3.0,* N-UNITS*)
  710 FORMAT(15X,*TERRAIN ELEVATION AT SITE:*,F6.0,* FT ABOVE MSL*,/20X,
     A*PARAMETER:*,F5.0,* FT*,/20X,*TYPE: *,2A8)
  711 FORMAT(25X,*PLOT LIMITS*,/25X,*------------*,/15X,*AVAILABLE POWER:
     B*,F5.0,*, *,F5.0,* DBW*,/17X,*DISTANCE:*,F5.0,*, *,F5.0,* N MI*)
  712 FORMAT(20X*ANTENNA HEIGHT TOO HIGH, IONOSPHERIC EFFECTS*,/25X,*MAY
     2 BE IMPORTANT*)
  713 FORMAT(20X,*AIRCRAFT TOO LOW, TERRAIN BEYOND FACILITY *,/25X,*HORI
     3ZON MAY BE IMPORTANT*)
  714 FORMAT(20X,*IN ADDITION, SURFACE WAVE CONTRIBUTIONS SHOULD*,/15X,*
     4BE CONSIDERED*)
  715 FORMAT(20X,*ANTENNA TOO HIGH, RAY BENDING OVERESTIMATED*,/)
  716 FORMAT(20X,*ANTENNNA TOO LOW, SURFACE WAVE SHOULD BE*,/25X,*CONSID
     6ERED*)
  717 FORMAT(20X,*FREQUENCY TOO LOW, IONOSPHERIC EFFECTS MAY BE*,/25X,*I
     7MPORTANT*,//)
  718 FORMAT(20X,*ATTENUATION AND/OR SCATTERING FROM HYDROMETEORS*,/25X,
     8*(RAIN, ETC) MAY BE IMPORTANT*)
  719 FORMAT(20X,*ATMOSPHERIC ABSORPTION ESTIMATES MAY BE*,/25X,*UNRELIA
     9BLE*)
  724 FORMAT(/15X,A2,*COMPUTED VALUE*)
  725 FORMAT(20X,*TYPE: *,2A8,A1)
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726 FORMAT(12X,*EARTH*,F9.0 ,* N MI                  *,F8.0,* KM*)
728 FORMAT(12X,*HRE= *,F8.4,*-*,F8.4,*-*,F8.4,* = *,F8.4,* KM*)
729 FORMAT(15X,*TIME AVAILABILITY:  *,4A8,A1,//)
731 FORMAT(12X,* H(A) *,F8.0,* FT MSL               *,F8.4,* KM MSL*)
732 FORMAT(12X,* H(F) *,F8.1,* FT TO SURFACE        *,F8.4,* KM *)
733 FORMAT(12X,*FREQUENCY*, F5.0,* MHZ              *,F8.0,*  MHZ *)
734 FORMAT(12X,* A(O)*, F9.5,* DB/KM                *,F8.5,* DB/KM*,A2)
735 FORMAT(12X,* A(W)*,F9.5 ,* DB/KM                *,F8.5,* DB/KM*,A2)
736 FORMAT(12X,*D(HE) *,F8.0,*                      *,F8.4,* KM*,A2)
737 FORMAT(12X,*EIRP *,F9.1 ,* DBW            P CON*,F8.1,*  DBW *)
738 FORMAT(12X,*F ANT *,6X,I2, 2X,5A8)
739 FORMAT(12X,* D(C) *,F8.0,* FT                   *,F8.4,* KM*)
740 FORMAT(12X,* H(C) *,F8.1,* FT ABOVE SURFACE     *,F8.4,* KM*)
741 FORMAT(12X,*COUNTERPOISE*,I2,10X,2A8)
742 FORMAT(12X,*H(FR) *,F8.1,* FT ABOVE REFLECTION*,F8.4,* KM*)
743 FORMAT(12X,*POLARIZATION*,I2,10X,2A8)
745 FORMAT(10X,A2,*D(HO) *,F8.2,* N MI FROM HORIZON  *,F8.2,* KM*)
746 FORMAT(10X,A2,*E(HO) *,I2,*/*,I2,*/*,I2,* DEG/MIN/SEC*,7X,F8.5,* R
   6ADIANS*)
747 FORMAT(10X,A2,*H(HO) *,F8.0,* FT MSL               *,F8.4,* KM*)
748 FORMAT(12X,* N(O)*,F9.0 ,* N-UNITS        N(S) *,F8.0,* N-UNITS*)
749 FORMAT(12X,*H(SUR)*,F8.0,* FT MSL               *,F8.4,* KM*)
750 FORMAT(12X,*DH(SUR)*,F7.0,* FT                  *,F8.4,* KM*)
751 FORMAT(12X,*TERRAIN*,5X,I2,10X,2A8)
757 FORMAT(12X*INPUT PARAMETERS FOR *,A8,2X,A8,* RUN*,/12X*OF *,A8,* A
   1IR/GROUND MODEL*,//)
760 FORMAT(1X,F7.2,12F8.1,F6.1,2F5.1,F6.1,A5)
761 FORMAT(5X,*HORIZON POW=*,F7.1,* AWD=*,F8.2,* SLOPE=*,F8.2,*  Z=*,
   XE13.5)
767 FORMAT(2F7.3,3F7.2,F4.0,F6.0,F5.0,F7.3,2F8.5)
768 FORMAT(3F7.3,2F7.1,2F7.2, 5X,4F7.1,E13.5)
769 FORMAT(2F7.3,3F7.1,2F7.3)
772 FORMAT(*   HTE    HRE     D      DLT    DLR  ENS  ERTH FREK LAMDA
   X    TET      TER*)
773 FORMAT(*  HFS    HRS     DH     AED    SLP   DLST   DLSR
   X DD NM  LBF     AT      DO          WRH*)
775 FORMAT(/12X,*POWER DENSITY INTO POWER AVAILABLE ADD     *,F6.1,/)
776 FORMAT(15X,*POWER DENSITY (DB-W/SQ M) VALUES MAY BE CONVERTED TO P
   XOWER*,/20X,*AVAILABLE AT THE TERMINALS OF A PROPERLY POLARIZED*,/2
   XOX,*ISOTROPIC ANTENNA (DBW) BY ADDING *,F6.1,* DB-SQ M.*)
777 FORMAT(1H(I2,25HX*POWER DENSITY FOR *5A8))
778 FORMAT(15X,*SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
   X*)
779 FORMAT(15X,*SURFACE REFLECTION LOBING:  DETERMINES MEDIAN*)
785 FORMAT(12X,*SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
   X*)
786 FORMAT(12X,*SURFACE REFLECTION LOBING:  DETERMINES MEDIAN*)
800 FORMAT(//10X,*SOME PARAMETERS ARE OUT OF RANGE*)
809 FORMAT(20X,*DLT IS LESS THAN .1XDLST OR GREATER THAN 3XDLST*)
810 FORMAT(20X,*INITIAL TAKE-OFF ANGLE GREATER THAN 12 DEG.*)

    DIMENSION CFK(3),CMK(3),CFM(3),CKM(3),CKN(3)
    DIMENSION ACD(101),AND(101),SCT(101),AAD(101),RW(101)
    DIMENSION FAT(5,8),CCI(2,7),POL(2,3),TSC(2,7)
    DIMENSION ADNT(3), VARFOR(4)
    DIMENSION ADENT(2),PAS(2)
    DIMENSION MTM(5),YCON(5)
    DIMENSION YV(10),SV(10)
    DIMENSION P(35),QC(50),QA(50),PQA(50),PQK(50),QK(50),PQC(50)
    DIMENSION TYD(3,2),VYD(5,2)
    DIMENSION RE(2),AD(35),BD(35),ALM(12)
    COMMON/RYTC/QNS,QHC,QHA,QHS,QQD
    COMMON/EGAP/IP,LN,IDT,IXT
    COMMON/PARAM/HTE,HRE,D,DLT,DLR,ENS,EFRTH,FREK,ALAM,TET,TER,KD,GAO,
   XGAW
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       COMMON/PLTD/LUD,LL,NU(8),NS(8),SX(2),SY(2),TT(6),XC,YC,BX(200,8),B
      XY(200,8),LYD,AAT,TG
       COMMON/SIGHT/DCW,HCW,DMAX,DML,DZR,IK,EAC,H2,ICC,HFC,PRH,DSL1,PIRP,
      XQG1,QG9,PFY(200,4),KK,ZH,RDHK,ILB
       COMMON/SCATPR/HT,HR,ALSC,TWEND,THRFK,HLT,HLR,THETA,HTP,AA,REW
       COMMON/DIFPR/HTD,HRD,DH,AED,SLP,DLST,DLSR,IPL,KSC,HLD,HRP,AWD,SWP
       COMMON/VAT/TAV(175),TAH1(7,175)
       COMMON/DLAT/TALD(20),TAFL(4,7,20)
       COMMON/VV/VF(36,17)
       COMMON/GAT/IFA
       DATA (CFK=.001,.0003048,.0003048)
       DATA (CMK=1.,1.609344,1.852)
       DATA (CFM=1.,.3048,.3048)
       DATA (CKM=1000.,3280.839895,3280.839895)
       DATA (CKN=1.,.6213711922,.5399568034)
       DATA (POL=8H HORIZON,3HTAL,8H VERTICA,1HL,8H CIRCULA,1HR)
       DATA (FAT=10H ISOTROPIC,3(1H ),4H DME,4(1H ),14H TACAN (RTA-2),3(1
      XH ),39H 4-LOOP ARRAY (COSINE VERTICAL PATTERN),39H 8-LOOP ARRAY (C
      XOSINE VERTICAL PATTERN),34H I OR II (COSINE VERTICAL PATTERN),1H ,
      X40HJTAC TILTED 20 DEG WITH 40 HALF-POW B.W.,17HJTAC TILTED 8 DEG,2
      X(1H ))
       DATA(ALM=-6.2,-6.15,-6.08,-6.0,-5.95,-5.88,-5.8,-5.65,-5.35,-5.0,-
      X4.5,-3.7)
       DATA (QMD=8H AUG 73 )
       DATA(TSC=16H SEA WATER        ,16H GOOD GROUND     ,16H AVERAGE GROUN
      XD ,16H POOR GROUND      ,16H FRESH WATER      ,16H  CONCRETE        ,16H
      X   METALLIC       )
       DATA (PAS=2H  ,2H* )
       DATA  ((P(I),I=1,35)=.00001,.00002,.00005,.0001,.0002,.0005,.001,.
      X002,.005,.01,.02,.05,.10,.15,.20,.30,.40,.50,.60,.70,.80,.85,.90,.
      X95,.98,.99,.995,.998,.999,.9995,.9998,.9999,.99995,.99998,.99999)
       DATA(VYD=33HFOR HOURLY MEDIAN LEVELS EXCEEDED,33HFOR INSTANTANEOUS
      X LEVELS EXCEEDED)
       DATA(TYD=17HSMOOTH EARTH      ,17HIRREGULAR TERRAIN)
       DATA (MTM=20,10,30,0,0)
       DATA (YCON=5.,10.,25.,0.,0.)
       DATA(CCI=16H SEA WATER        ,16H GOOD GROUND     ,16H AVERAGE GROUN
      XD ,16H POOR GROUND      ,16H FRESH WATER      ,16H  CONCRETE        ,16H
      X   METALLIC       )
       DATA (DMOD=5H DIFR)   $   DATA (SMOD=5H SCAT)
       DATA  (CMOD=5H COMB)
       FNA(FX,FA,FB,FC,FD)=((FX-FB)*(FC-FD)/(FA-FB))+FD
       IDT=IDATE(IDX)
       IG=0
       TPTH=2.617993878E-2   $   TLTH=0.      $   TPK=20.
       CALL Q9EXUN
       ASPA=0.25    $    ASPB=0.25
       ZO=.00000001
       RAD=.01745329252   $   DEG=57.29577951   $   TWDG=12.*RAD
       ERTH =6370.

C                    PRE-PROGRAM INPUT OF TABLES

       READ 108,(TAV(I),(TAH1(J,I),J=1,7),I=1,175)
       READ 71,(TALD(K),((TAFL(I,J,K),J=1,7),I=1,2),K=1,20)
       READ 71,(DUMB,((TAFL(I,J,K),J=1,7),I=3,4),K=1,20)
       READ 505,((VF(I,J),I=1,36),J=1,3)
       READ 505,((VF(I,J),I=1,36),J=4,17)

C      -------------PROGRAM START WITH CARD 1---------------------
  100  READ 7,IK,HFI,IFA,IPL,SUR,HPFI,DHSI,KSC,DCI,HCI,ICC,DHOI,HHOI,IDG,
      XIMN,ISEC,KE,KK,KD,EIRP,ILB
       PRINT 4
       PI=3.141592654   $     ICAR=0     $     NOC=0  $  IXT=ITIMEDAY(ITX)
       IF(IK.LE.0) GO TO 451
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```
C     ------------------INPUT OF CARD 2---------------------------
      READ 8,ADENT,HAI,DHEI,ENO,AOI,AWI,F,DMIN,DMAX,XC,PMIN,PMAX,YC,IA

C     ------------------START OF PARAMETER SHEET-----------------
      PRINT 700,QMD,IDT,IXT
      H2=HAI*CFK(IK)   $   HFS=HFI*CFK(IK)   $   FREK=F
      ENCODE(8,32,TG) EIRP
      TT(1)=ADENT(1)   $   TT(2)=ADENT(2)
      TT(3)=TT(4)=TT(5)=ADNT(1)=ADNT(2)=ADNT(3)=TT(6)=PAS(1)
C     ----------------INPUT OF CARD 3 IF NECESSARY----------------
      IF(IA.GT.16) READ 110,ADNT
      TT(3)=ADNT(1)   $   TT(4)=ADNT(2)   $   TT(5)=ADNT(3)
      NK=43-((18+IA)/2)
      ENCODE(32,777,VARFOR)NK
      PRINT VARFOR,ADENT,ADNT
      PRINT 701,HAI
      ENCODE(8,50,AAT) HAI
      IF(HAI.GT.300000.) ICAR=1
      IF(HAI.GT.150000.) PRINT 712
      IF(HAI.LT.500.) PRINT 713
      IF(HAI.LT.1.5) PRINT 714
      IF(HAI.LT.0.) GO TO 825
      PRINT 702,HFI
      IF(HFI.LT.0.) GO TO 825
      IF(HFI.GT.9000.) PRINT 715
      IF(HFI.LT.1.5) PRINT 716
      PRINT 703,FREK
      IF(F.LT.100.)GO TO 805
  806 IF(F.LT.20.) GO TO 100
      IF(F.GT.5000.) PRINT 718
      IF(F.GT.17000.) GO TO 807
  808 IF(F.GT.100000.) GO TO 100
      PRINT 5
      IF(AOI.LT.0.) GO TO 56
      PXH=PAS(1)
   57 GAO=AOI   $   GAW=AWI
      PRINT 704,GAO,PXH,GAW,PXH
      IF(SUR.GT.15000.) ICAR=1
      IF(SUR.LT.0.) GO TO 830
  831 ASPC=ASPA*ASPB*(6.E-8)*F
      PDCON=38.544-20.*ALOG10(F)   $   PIRP=EIRP-PDCON
      HRP=HPFI*CFK(IK)
      IF(HAI.LT.(HPFI+500.)) ICAR=1
      ETS=SUR*CFK(IK)   $   HAS=H2-ETS
      IF(ETS.LT.0.) ETS=0.
      IF(SUR.GT.15000.) ICAR=1
      IF(HAS.LT.HFS) GO TO 770
      IF(DHSI.LT.0.) DHSI=0.
      DH=DHSI*CFK(IK)
      IF(ENO.LT.250..OR.ENO.GT.400.) GO TO 801
  802 ENS=ENO*EXPF(-0.1057*HRP)
      IF(ENS.LE.250.) GO TO 803
  804 EFRTH=ERTH/(1.-.04665*EXPF(.005577*ENS))
      EART=EFRTH*CKN(IK)
      HT=HFS+ETS          $     H1=HT
      IF(HRP.GT.H1) GO TO 825
      HTE=HT-HRP          $   DLST=SQRTF(2.*EFRTH*HTE)
      HFRI=HTE*CKM(IK)
      IF(DHEI.LT.0.) GO TO 50
      EAC=DHEI*CFK(IK)
      PDH=PAS(1)
      HR=H2-EAC    $   HRS=HR-ETS
      HRE=HR-HRP    $    DLSR=SQRTF(2.*HRE*EFRTH)
      IF(HRE.GE.50.) DLSR=EFRTH*ACOSF(EFRTH/(EFRTH+HRE))
      DS0=3.*SQRTF(2000.*HTE)+3.*SQRTF(2000.*HRE)
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      JK=1
   55 PRINT 705,DHEI,PDH,HPFI,EIRP,(FAT(I,IFA),I=1,5)
      IF(DCI.LE.ZO) GO TO 789
      IF(ICC.LE.0) GO TO 789
C     -------------COUNTERPOISE PARAMETERS CONVERTED------------
      NOC=1
      DCW=DCI*CFK(IK)    $    HCW=HCI*CFK(IK)
      PRINT 706,DCI,HCI,(CCI(I,ICC),I=1,2)
      IF(HCI.LT.0.) GO TO 828
  829 IF(HCI.GT.500.) ICAR=1
      IF (DCW.GT..1524) ICAR=1
      IF(HCW.GT.HFS) GO TO 825
      HFC=HT-ETS-HCW
  788 CONTINUE
      PRINT 707,(POL(I,IPL),I=1,2)
C     ------HORIZON AND INITIAL TAKE-OFF ANGLE COMPUTATIONS------
      PDS=PTS=PHS=PAS(1)
      IF(KD.LE.1) GO TO 755
      HLT=HHOI*CFK(IK)    $    DLT=DHOI*CMK(IK)
      HLTS=HLT-HT
      DG=IDG   $   AMN=IMN   $   SEC=ISEC
      TET=RAD*(DG+(((SEC/60.)+AMN)/60.))    $    ATET=ABSF(TET)
      TATET=TANF(TET)
      IF(KE.EQ.3) GO TO 782
      IF(DLT.LE.ZO) GO TO 781
  759 IF(KE-1)730,758,780
  758 IF(TET.LT.0.) GO TO 752
      HLTS=DLT*TATET+(DLT*DLT/(2.*EFRTH))
  753 HLT=HLTS+HFS+ETS    $    HHOI=HLT*CKM(IK)
      PHS=PAS(2)
  783 CONTINUE
      IF(DLT.LT.(.1*DLST).OR.DLT.GT.(3.*DLST)) PRINT 809
      IF(TET.GT..20943951) PRINT 810
      IF(HHOI.GT.15000.) ICAR=1
      PRINT 708,DHOI,PDS,IDG,IMN,ISEC,PTS,HHOI,PHS
C     ----------------------------------------------------------
      PRINT 725,(TYD(I,KD),I=1,3)
      PRINT 709,ENS,ENO
      IF(ILB) GO TO 762
      PRINT 778
  763 PRINT 710,SUR,DHSI,(TSC(I,KSC),I=1,2)
      PRINT 729,(VYD(I,KK),I=1,5)
      PRINT 776,PDCON
      PRINT 724,PAS(2)
      IF(DMAX.GT.1000.) DMAX=1000.
      IF(ICAR.GT.0) PRINT 800

C     ------------------START OF WORK SHEET--------------------
      PRINT 4
      PRINT 757,IDT,IXT,QMD
      PRINT 5   $   PRINT 6
      PRINT VARFOR,ADENT,ADNT
      PRINT 731,HAI,H2
      PRINT 732,HFI,HFS
      PRINT 733,F,FREK
      PRINT 734,AOI,GAO,PXH
      PRINT 735,AWI,GAW,PXH
      PRINT 736,DHEI,EAC,PDH
      PRINT 737,EIRP,PIRP
      PRINT 738,IFA,(FAT(I,IFA),I=1,5)
      IF(NOC.LT.1) GO TO 754
      PRINT 739,DCI,DCW
      PRINT 740,HCI,HCW
      PRINT 741,ICC,(CCI(I,ICC),I=1,2)
  754 CONTINUE
      PRINT 5
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      PRINT 742,HFRI,HTE
      IF(F.GT.1600.) GO TO 304
      QG1=(.21*SINF(5.22*ALOG10(F/200.)))+1.28
      QG9=(.18*SINF(5.22*ALOG10(F/200.)))+1.23
  306 CONTINUE
      PRINT 728,H2,EAC,HRP,HRE
      PRINT 743,IPL,(POL(I,IPL),I=1,2)
      PRINT 745,PDS,DHOI,DLT
      PRINT 746,PTS,IDG,IMN,ISEC,TET
      PRINT 747,PHS,HHOI,HLT
      PRINT 748,ENO,ENS
      PRINT 726,EART,EFRTH
      PRINT 749,SUR,ETS
      PRINT 750,DHSI,DH
      PRINT 751,KSC,(TSC(I,KSC),I=1,2)
      IF(ILB) GO TO 764
      PRINT 785
  765 PRINT 775,PDCON
      PRINT 729,(VYD(I,KK),I=1,5)
      PRINT 724,PAS(2)
      PRINT 5   $   PRINT 5
      PRINT 711,PMIN,PMAX,DMIN,DMAX
      IF(ICAR.GT.0) PRINT 800
C     --------------END OF PRELIMINARY PRINTING-----------------

      CUBTR=100./F
      DSD=65.*CUBERTF(CUBTR)
      DSL1=DS0+DSD
      ALAM=.2997925/F
      PRINT 4   $   CALL PAGE(0)
      THRFK=30.*ALOG10(FREK)
      ICPT=0
      DLS=DLST+DLSR
      AFP=32.45+20.*ALOG10(FREK)
      DKAX=DMAX*CMK(IK)
C     ----HORIZON POINT DISTANCE AND PARAMETER CALCULATION-------
      IF(JK.LT.0) GO TO 58
      TRM=((HTE+EFRTH)*COSF(TET))/(HRE+EFRTH)
      DML=EFRTH*(ACOSF(TRM)-TET)
      DLR=DML-DLT
   59 DNM=DML*CKN(IK)
      IF(DML.LE.0.) GO TO 107
      D=DML   $   TWEND=20.*ALOG10(D)   $   ALFS=AFP+TWEND
      HTP=HRP
      DRP=DLSR
      TATER=((HLT-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
      TATES=((HRP-HR)/DRP)-(DRP/(2.*EFRTH))
      TES=ATANF(TATES)
      IF((HLT-HRP).LE.0.) 15,14
   15 DHRP=DLSR+DLT      $   GO TO 13
   14 DHRP=DLT+DLSR+SQRTF(2.*EFRTH*(HLT-HRP))
   13 CONTINUE

      HTD=HT   $   HRD=HR   $   HLD=HLT
      CALL DEFRAC
      GVD=GAIN(TET)   $   GDD=20.*ALOG10(GVD)
      SMD=((INTF(DNM/1.))*1.)+1.    $   AMD=AWD+(SWP*D)
      ATD=ARD=AMD
      DZR=-(AWD/SWP)
      PRH=-(AMD-GDD)       $   WRH=10.**(PRH*.1)
      ZH=ALOG10(WRH)-2.
C     ----------------------PRINT STATEMENTS-------------------
      PRINT 772
      PRINT 767,HTE,HRE,D,DLT,DLR,ENS,EFRTH,FREK,ALAM,TET,TER
      PRINT 773
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      PRINT 768, HT,HR ,DH,AED,SLP,DLST,DLSR,DNM,ALFS,AMD,DZR,WRH
      PRINT 761,PRH,AWD,SWP,ZH
      PRINT 5   $   CALL PAGE(6)
C     ------------------------------------------------------------

C     ------------------LINE-OF-SIGHT----------------------------
      CALL ALOS
      NCT=NU(1)
      SPD=SMD+2.

C     -------------BEYOND THE HORIZON CALCULATIONS--------------
      KFD=0
      DO 900 NSP=1,5
      MZS=MTM(NSP)
      IF(MZS.LE.0) GO TO 907
      DO 901 MXS=1,MZS
      D=SPD*CMK(IK)     $     DNM=SPD
      IF(D.GT.DHRP) GO TO 17
      DLR=D-DLT
      HLR=HLT
      TATER=((HLR-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
   19 CONTINUE
      IF(KFD-1)40,41,42
   40 KS=0              $         KR=0
      KS=1   $    ACD(KS)=ARD    $    AND(KS)=DML
      AMOD=DMOD
      EC1=HTE+EFRTH    $    EC2=HRE+EFRTH    $    EC3=HLT-HRP+EFRTH
      CALL SORB(EC1,EC3,EFRTH,DLT,TET,RO1,RW1)
      CALL SORB(EC2,EC3,EFRTH,DLR,TER,RO2,RW2)
      REO=RO1+RO2    $    REW=RW1+RW2    $    AA=GAO*REO+GAW*REW
                    RW(1)=REW
                    AAD(1)=AA
      DO 30 KC=1,100
      KS=KS+1
      D=DNM*CMK(IK)
      SPD=DNM
      ACD(KS)=AED+(SLP*D)
      AND(KS)=D
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      IF(D.GT.DHRP) GO TO 44
      HLR=HLT

      DLR=D-DLT    $    TATER=((HLT-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
   45 CONTINUE
      CALL SCATTER
      SCT(KS)=ALSC-ALFS
      AAD(KS)=AA    $    RW(KS)=REW
      IF(SCT(KS).LT.20.) GO TO 31
      KR=KR+1
      IF(KR.LE.1) GO TO 31
      KP=KS-1
      SSP= (SCT(KS)-SCT(KP))/(AND(KS)-AND(KP))
      PRINT 499,DNM,SCT(KS),ACD(KS),SLP,SSP
  499 FORMAT(3F7.1,2F7.2)
      IF(SSP.LE.(-.01)) GO TO 49
      IF(SSP.LE.SLP) GO TO 48
   31 DNM=DNM+1.
   30 CONTINUE
      PRINT 14      $      KFD=1     $    GO TO 33
   49 KR=0    $    GO TO 31
   14 FORMAT(5X,*BEYOND THE 50 MILE LIMIT  DOING DIFFRACTION*)
   33 DO 43 KG=1,KP
      D=AND(KG)
```

```
      DNM=D*CKN(IK)   $     SPD=DNM
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      ATTS=ACD(KG)
      AA=AAD(KG)    $    REW=RW(KG)$    THETA=TET+TER+(D/EFRTH)
      ASSIGN 36 TO KT
      GO TO 200
   36 CONTINUE
   43 CONTINUE
      SPD=DNM     $     MZS=6     $     KFD=1     $    GO TO 37
   48 IF(SCT(KP).GE.ACD(KP)) GO TO 33
      ACD(KP)=SCT(KP)
      SLP=(ACD(KP)-ARD)/(AND(KP)-DML)
      AED=ACD(KP)-(AND(KP)*SLP)
      ASSIGN 35 TO KT
      DO 34 KG=1,KP
      D=AND(KG)
      DNM=D*CKN(IK)    $     SPD=DNM
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      ATD=AED+(SLP*D)
      ATTS=ATD
      AMOD=CMOD
      AA=AAD(KG)    $    REW=RW(KG)$    THETA=TET+TER+(D/EFRTH)
      GO TO 200
   35 CONTINUE
   34 CONTINUE
      SPD=DNM     $     MZS=6     $     KFD=2     $    GO TO 37
   41 CONTINUE
      AMOD=DMOD
      ASSIGN 37 TO KT
      ATD=AED+(SLP*D)
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      IF(D.GT.DHRP) GO TO 24
      HLR=HLT
      DLR=D-DLT    $    TATER=((HLT-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
   25 CONTINUE
      CALL SCATTER
      ATS=ALSC-ALFS
      IF(ATS.LE.ATD) GO TO 46
      ATTS=ATD    $    THETA=TET+TER+(D/EFRTH)       $    GO TO 200
   46 ATTS=ATS  $  KFD=2    $    AMOD=SMOD    $    GO TO 200
   42 CONTINUE
      AMOD=SMOD
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      CALL SCATTER
      ATS=ALSC-ALFS    $    ATTS=ATS    $    ASSIGN 37 TO KT
  200 CONTINUE
C     ----------------LONG-TERM POWER FADING--------------------
      IF(D.LE.DSL1) 311,312
  311 DEE=(130.*D)/DSL1    $    GO TO 313
  312 DEE=130.+D-DSL1    $    GO TO 313
  313 CALL VZD(DEE,QG1,QG9,AD)
      NCT=NCT+1
      PFS=PIRP-ALFS
      PL=-ATTS
      ALIM=3.
      AL10=PL+AD(13)            $    AY=AL10-ALIM
      IF(AY.LT.0.) AY=0.
      DO 11 K=1,35
      BD(K)=PL+AD(K)-AY
   11 CONTINUE
```

```
      DO 12 K=1,12
      ALLM=-ALM(K)
      IF(BD(K).GT.ALLM) BD(K)=ALLM
   12 CONTINUE
C     --------------VALUES PUT INTO PLOTTING ARRAY----------------
      BX(NCT,5)=BX(NCT,6)=BX(NCT,7)=BX(NCT,8)=DNM
      BX(NCT,1)=BX(NCT,2)=BX(NCT,3)=BX(NCT,4)=DNM
      IF(KK.GT.1) GO TO 20
   23 PGS=PFS+GDD
      BY(NCT,1)=PGS                $     BY(NCT,2)=PGS+BD(18)-AA
      BY(NCT,3)=PGS+BD(12)-AA      $     BY(NCT,4)=PGS+BD(24)-AA
      BY(NCT,5)=PGS+BD(23)-AA      $     BY(NCT,6)=PGS+BD(26)-AA
      BY(NCT,7)=PGS+BD(29)-AA      $     BY(NCT,8)=PGS+BD(32)-AA
      PFY(NCT,1)=PGS+BD(4)-AA      $      PFY(NCT,2)=PGS+BD(7)-AA
      PFY(NCT,3)=PGS+BD(10)-AA     $      PFY(NCT,4)=PGS+BD(13)-AA
C     ------------------------PRINT STATEMENTS-------------------
      PRINT 760,DNM,(BY(NCT,LZ),LZ=1,8),(PFY(NCT,MW),MW=1,4),PL,AA,AY,BK
     X,AMOD
      CALL PAGE(1)
C     ---------------------- ------------------------------------
      IF(SPD.GT.DMAX) GO TO 907
      GO TO KT,(35,36,37)
   37 CONTINUE
  903 SPD=SPD+YCON(NSP)
  901 CONTINUE
      SPD=SPD+YCON(NSP)
      NPP=NSP+1
      IF(NPP.GT.5) GO TO 907
      IF(YCON(NPP).EQ.0.) GO TO 907
      IF(NPP.EQ.0) GO TO 907
      IXD=INTF(SPD/YCON(NPP))
      SPD=(YCON(NPP)*FLOATF(IXD))+YCON(NPP)
  900 CONTINUE
  907 CONTINUE

C     ------------------PLOTTING OF GRAPH-----------------------

      SX(1)=DMAX    $    SX(2)=DMIN     $    SY(1)=PMAX    $    SY(2)=PMIN
      DO 904 K=1,8
  904 NU(K)=NCT
      NS(1)=9    $    NS(2)=NS(3)=NS(4)=1
      LYD=0    $    LUD=+1    $    LL=4
      NS(5)=NS(6)=1
      IG=IG+1
      CALL PLTGRPH                                                      †
      GO TO 100                                                         †
C     ---LOOPING BACK TO START FOR NEW SET OF PARAMETERS----------------†

   17 TER=TES    $    DLR=DRP    $    HLR=HRP    $  TATER=TATES    $  GO TO 19
C     ------------------TROPOSPHERIC MULTIPATH------------------
   20 DO 21 I=1,35
      QA(I)=BD(I)-PL
      PQA(I)=P(I)
   21 CONTINUE
      IF(THETA.GE.TPTH) GO TO 26
      IF(THETA.LE.0.)  GO TO 27
      BK=FNA(THETA,TPTH,TLTH,TPK,RDHK)
   28 CONTINUE
      CALL YIKK(BK,PQK,QK)
      CALL CONLUT(QA,QK,PQA,35,+1.,0.,PQC,QC)
      DO 22 I=1,35
   22 BD(I)=QC(I)+PL
      GO TO 23
```

```
   24 TER=TES    $    DLR=DRP    $    HLR=HRP    $    TATER=TATES    $    GO TO 25
   26 BK=TPK    $    GO TO 28
   27 BK=RDHK    $    GO TO 28
   44 TER=TES    $    DLR=DRP    $    HLR=HRP    $    TATER=TATES    $    GO TO 45
C     -------------------CALCULATION OF RAY BENDING---------------
   50 PDH=PAS(2)
      HP2=H2-HRP    $    HP1=H1-HRP
      DUM=0.0    $    ZER=0.0    $    QLIM=-1.56
      QNS=329.    $    QHC=HP1    $    QHA=HP2    $    QHS=HRP
      CALL RAYTRAC(DUM)
      RY=TRACRAY(QLIM)
      DS0=QQD
      QNS=ENS    $    QHC=ZER    $    QHA=HP2    $    QHS=HRP
      CALL RAYTRAC(DUM)
      RY=TRACRAY(ZER)
      DLSR=QQD    $    TSL2=DLSR/EFRTH
      IF(TSL2.LE..1)  GO TO 53
      R2E=EFRTH/COSF(TSL2)
      HRE=R2E-EFRTH
   54 IF(HRE.GT.HP2) HRE=HP2
      HR=HRE+HRP    $    EAC=H2-HRP-HRE
      DHEI=EAC*CKM(IK)
      JK=-1
      GO TO 55
   53 HRE=(DLSR*DLSR)/(2.*EFRTH)              $      GO TO 54

   56 CALL ASORP(F,AOI,AWI)
      PXH=PAS(2)      $      GO TO 57
   58 TEH=TET+(DLT/EFRTH)
      IF(KD.LE.1) TEH=0.0
      QNS=ENS    $    QHC=HLT-HRP    $    QHA=HP2    $    QHS=HRP
      RY=TRACRAY(TEH)    $    DLR=QQD    $    DML=DLT+DLR    $    GO TO 59
  107 PRINT 106      $     GO TO 100
  304 QG1=QG9=1.05    $    GO TO 306
  762 PRINT 779    $    GO TO 763
  752 HLTS=DLT*TET  +(DLT*DLT/(2.*EFRTH))      $           GO TO 753
  764 PRINT 786    $    GO TO 765
  770 PRINT 800    $    GO TO 100
C     --------------HORIZON PARAMETER CALCULATIONS--------------
  781 HE=MAX1F(HTE,.005)
      DLT=DLST*EXPF(-.07*SQRTF(DH/HE))
      PDS=PAS(2)
      IF(DLT.LT.(.1*DLST)) DLT=.1*DLST
      IF(DLT.GT.(3.*DLST)) DLT=3.*DLST
      DHOI=DLT*CKN(IK)
      GO TO 759
  730 TRM=1.3*DH*((DLST/DLT)-1.)
      TET=(.5/DLST)*(TRM-(4.*HTE))
      IF(TET.GT.TWDG) TET=TWDG
      CALL RADEMS(TET,IDG,IMN,SEC)
      ISEC=XINTF(SEC)
      PTS=PAS(2)
      TATET=TANF(TET)
      GO TO 758
  782 XTRM=SQRTF((EFRTH*EFRTH*TATET*TATET)+(2.*EFRTH*HLTS))
      YTRM=-EFRTH*TATET       $    DLT=YTRM-XTRM
      IF(DLT.LE.0.) DLT=YTRM+XTRM
      PDS=PAS(2)
      DHOI=DLT*CKN(IK)     $    GO TO 783
  780 TATET=(HLTS/DLT)-(DLT/(2.*EFRTH))    $    TET=ATANF(TATET)
      PTS=PAS(2)
  784 CALL RADEMS(TET,IDG,IMN,SEC)'
```

```
      ISEC=XINTF(SEC)   $   GO TO 783
C     -------------------SMOOTH EARTH PARAMETERS----------------
  755 PTS=PDS=PAS(2)
      DLT=DLST   $   DHOI=DLT*CKN(IK)
      TATET=(-HTE/DLT)-(DLT/(2.*EFRTH))   $   TET=ATANF(TATET)
      HLT=HRP   $   HHOI=HLT*CKM(IK)     $    DH=0.
      GO TO 784

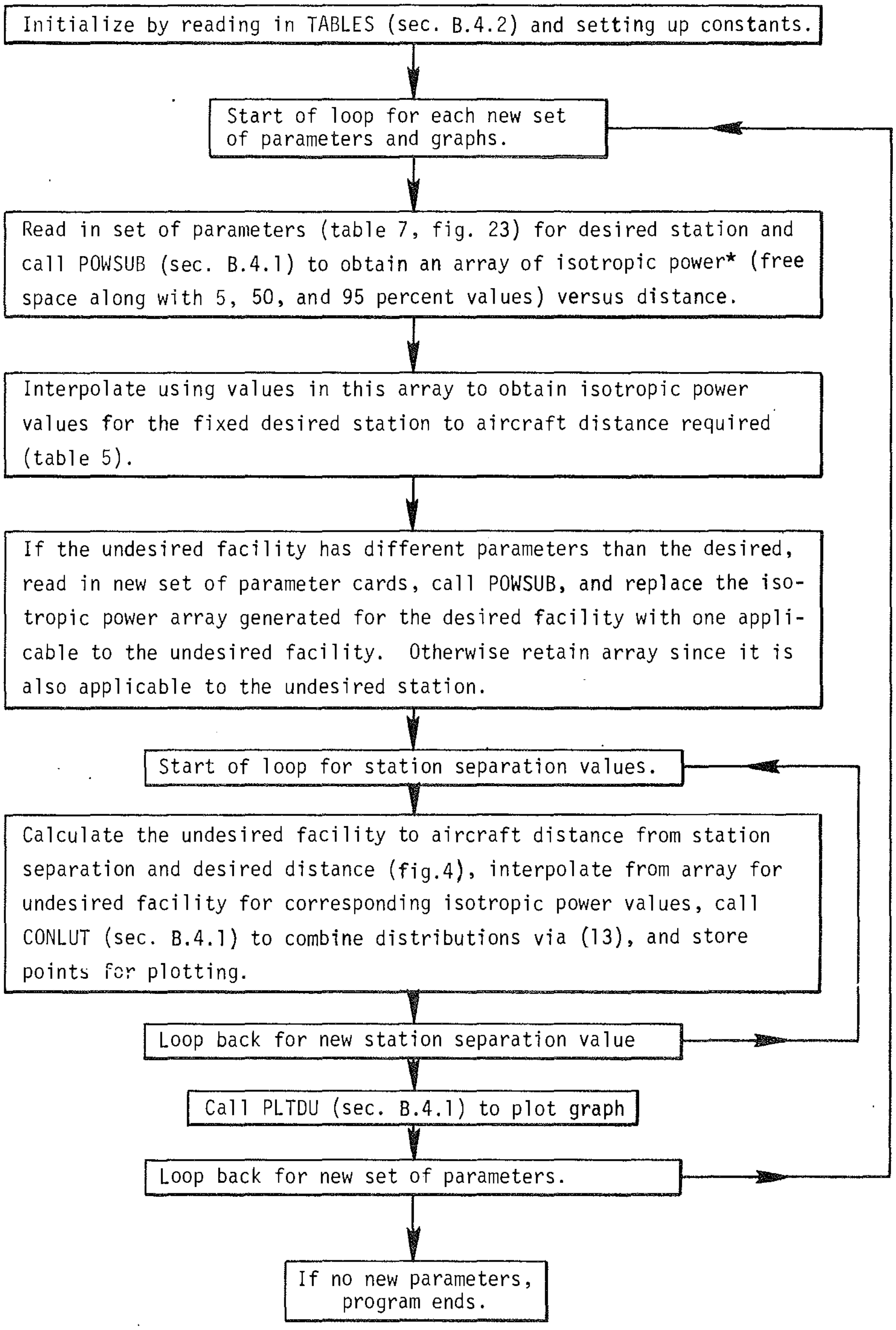
  789 HFC=0.         $   GO TO 788
  801 ICAR=1    $    ENO=301.    $    GO TO 802
  805 ICAR=1    $    PRINT 717    $    GO TO 806
  803 ENS=250. $     ICAR=1    $    GO TO 804
  807 ICAR=1    $    PRINT 719    $    GO TO 808
  825 PRINT 800     $    GO TO 100
  828 ICAR=1            $    HCI=0.    $    GO TO 829
  830 ICAR=1          $     SUR=0.    $    GO TO 831

C     -------------------TERMINATION OF PROGRAM----------------

  451 CONTINUE
      CALL CRTPLT(0,0,0,0,20)
      PRINT 4
      PRINT 2
      CALL EXIT
      END
```

B.2 STATION SEPARATION PROGRAM

Input parameters for, and the output generated by, the station separation program (DOVERU) are discussed in sections 3.1.1 and 3.2.2, respectively. Information concerning input parameter cards and FORTRAN variables is given in figure 23 and described further in table 7. Subprograms for all programs are listed in section B.4.1. Of these DOVERU, requires (app. B) ASORP, BLOS, CONLUT, DEFRAC, DELTA, FDASP, FDTETA, FRENEL, GAIN, GHBAR, HCHNOT, LINE, PAGE, PLTDU, POWSUB, RADEMS, RAYTRAC, RECC, RTATAN, SCATTER, SORB, TABLE, TERP, TRMESH, TSMESH, VZD, and YIKK (sec. B.4.1) and the data tables (sec. B.4.2). A block diagram of the operations performed by DOVERU is given in figure 26. Text references and major subprograms that are relevant to specific blocks are included there. A listing of DOVERU is provided at the end of this section.



Initialize by reading in TABLES (sec. B.4.2) and setting up constants.

Start of loop for each new set of parameters and graphs.

Read in set of parameters (table 7, fig. 23) for desired station and call POWSUB (sec. B.4.1) to obtain an array of isotropic power* (free space along with 5, 50, and 95 percent values) versus distance.

Interpolate using values in this array to obtain isotropic power values for the fixed desired station to aircraft distance required (table 5).

If the undesired facility has different parameters than the desired, read in new set of parameter cards, call POWSUB, and replace the isotropic power array generated for the desired facility with one applicable to the undesired facility. Otherwise retain array since it is also applicable to the undesired station.

Start of loop for station separation values.

Calculate the undesired facility to aircraft distance from station separation and desired distance (fig.4), interpolate from array for undesired facility for corresponding isotropic power values, call CONLUT (sec. B.4.1) to combine distributions via (13), and store points for plotting.

Loop back for new station separation value

Call PLTDU (sec. B.4.1) to plot graph

Loop back for new set of parameters.

If no new parameters, program ends.

*"Isotropic power" is the power that would be available at the terminals of an ideal (lossless) isotropic aircraft antenna.

Figure 26. Block diagram for station separation program, DOVERU.

```
      PROGRAM DOVERU
C     ROUTINE FOR MODEL AUG 73
    2 FORMAT(*   PROGRAM IS FINISHED. *)
    4 FORMAT(1H1)
    5 FORMAT(1H )
    6 FORMAT(2A8,2F6.0,F4.0,3F6.0,28X,I2)
    7 FORMAT(I2,F6.0,2I2,3F6.0,I2,2F6.0,I2,2F6.0,3I3,3I2,F6.0,I1)
    8 FORMAT(2A8,2F6.0,F4.0,3F6.0,2(2F5.0,F4.0),I2)
    9 FORMAT(I2,4F5.0)
   32 FORMAT(F4.0,4X)
   50 FORMAT(F7.0,1X)
   71 FORMAT(F5.0,14F5.1)
  108 FORMAT(2(F5.3,7F5.2))
  110 FORMAT(3A8)
  505 FORMAT(11F7.4)
  777 FORMAT(1H(I2,26HX*DESIRED STATION IS *5A8))
  778 FORMAT(1H(I2,28HX*UNDESIRED STATION IS *5A8))
  779 FORMAT(1H(I2,38HX*DESIRED/UNDESIRED STATIONS ARE *5A8))
  790 FORMAT(5X,3F7.1,2(2X,2F7.1),3X,4F7.1)
  791 FORMAT(11X,*NAUTICAL MILES      FREE SPACE         MEDIAN
     X -------D/U-------*)
  792 FORMAT(10X,*S      DD      DU         DD      DU         DD      DU    F.SP
     XACE    5%      50%      95%*)
  900 FORMAT(2(3X,6F7.1))
  901 FORMAT(5X,F8.3,5F7.1,2I2)
      DIMENSION DA(3),DB(3),DP(3),PC(3),DC(3)
      COMMON/EGAP/IP,LN,IDT,IXT
      COMMON/PAINP/IK,HFI,IPL,SUR,HPFI,DHSI,KSC,DCI,HCI,ICC,DHOI,HHOI,ID
     XG,IMN,ISEC, KE,KK,KD,EIRP,ILB,HAI,DHEI,ENO,AOI,AWI,F,IA,ADENT(2),A
     XDNT(3),VARFOR(6),CMAX
      COMMON/PAOUT/NCT,PFY(200,6)
      COMMON/VAT/TAV(175),TAH1(7,175)
      COMMON/DLAT/TALD(20),TAFL(4,7,20)
      COMMON/VV/VF(36,17)
      COMMON/GAT/IFA
      COMMON/PLTD/LUD,LL,NU(8),NS(8),SX(2),SY(2),TT(5),XC,YC,BX(200,8),B
     XY(200,8),LYD,AAT,TG
      DATA (PAS=1H )
      FNA(FX,FA,FB,FC,FD)=((FX-FB)*(FC-FD)/(FA-FB))+FD
      FNB(FRX,FRA,FRB)=(FRX-FRB)/(FRA-FRB)
      FNC(FFX,FFC,FFD)=(FFX*(FFC-FFD))+FFD
      IDT=IDATE(IDX)
      DP(1)=.01    $    DP(2)=.50    $    DP(3)=.95
      IG=0
C                    PRE-PROGRAM INPUT OF TABLES
      READ 108,(TAV(I),(TAH1(J,I),J=1,7),I=1,175)
      READ 71,(TALD(K),((TAFL(I,J,K),J=1,7),I=1,2),K=1,20)
      READ 71,(DUMB,((TAFL(I,J,K),J=1,7),I=3,4),K=1,20)
      READ 505,((VF(I,J),I=1,36),J=1,3)
      READ 505,((VF(I,J),I=1,36),J=4,17)
C     -------------PROGRAM START WITH CARD 1--------------------
  100 READ 9,IS,SMIN,SMAX,SNC,DD
      IF(IS.LE.0) GO TO 451
C     ----------------INPUT OF CARD 2---------------------------
      READ 7,IK,HFI,IFA,IPL,SUR,HPFI,DHSI,KSC,DCI,HCI,ICC,DHOI,HHOI,IDG,
     XIMN,ISEC, KE,KK,KD,EIRP,ILB
C     -----------------INPUT OF CARD 3--------------------------
      READ 8,ADENT,HAI,DHEI,ENO,AOI,AWI,F,DMIN,DMAX,XC,PMIN,PMAX,YC,IA
```

```
      IXT=ITIMEDAY(ITX)
      TT(1)=ADENT(1)    $    TT(2)=ADENT(2)     $     CMAX=SMAX
      TT(3)=TT(4)=TT(5)=ADNT(1)=ADNT(2)=ADNT(3)=PAS
C     ---------------INPUT OF CARD 4 IF NECESSARY----------------
      IF(IA.GT.16) READ 110,ADNT
      TT(3)=ADNT(1)    $    TT(4)=ADNT(2)    $    TT(5)=ADNT(3)
      ENCODE(8,50,AAT) HAI
      ENCODE(8,32,TG)DD
      IF(IS.GT.1) GO TO 15
      NK=43-((31+IA)/2)
      ENCODE(48,779,VARFOR)NK

C     ----OBTAINING ISOTROPIC POWER ARRAY FOR DESIRED STATION----

   16 CALL POWSUB
C     ------------------------PRINT STATEMENTS--------------------
      PRINT 900,((PFY(LA,LB),LB=1,6),LA=1,NCT)
      PRINT 5
      MCK=NCT/2        $      CALL PAGE(MCK)
C     ------------------------ ------------------------------------
      DO 20 I=1,NCT
      IF(DD-PFY(I,1))22,21,20
   20 CONTINUE
      I=NCT
   22 IF(I.LE.1) I=2
      L=I-1
      DRAT=FNB(DD,PFY(I,1),PFY(L,1))
      DFS=FNC(DRAT,PFY(I,2),PFY(L,2))  $ DPW=FNC(DRAT,PFY(I,3),PFY(L,3))
      DV5=FNC(DRAT,PFY(I,4),PFY(L,4))  $ U50=FNC(DRAT,PFY(I,5),PFY(L,5))
      D95=FNC(DRAT,PFY(I,6),PFY(L,6))      $    GO TO 25
   21 DFS=PFY(I,2)    $    DPW=PFY(I,3)    $    DV5=PFY(I,4)
      D50=PFY(I,5)    $    D95=PFY(I,6)
   25 IF(IS.LE.1) GO TO 28

C     --------------IF NECESSARY FOR UNDESIRED FACILITY----------

C     -------------------INPUT OF CARD TYPE 2--------------------
      READ 7,IK,HFI,IFA,IPL,SUR,HPRI,DHSI,KSC,DCI,HCI,ICC,DHOI,HHOI,IDG,
     XIMN,ISEC,ISC,KK,KD,EIRP,ILB
C     -------------------INPUT OF CARD TYPE 3--------------------
      READ 6,ADENT,HAI,DHEI,ENO,AOI,AWI,F,IA
      ADNT(1)=ADNT(2)=ADNT(3)=PAS
C     ---------IF IA GREATER THAN 16 INPUT OF CARD TYPE 4--------
      IF(IA.GT.16) READ 110,ADNT
      NK=43-((21+IA)/2)
      ENCODE(48,778,VARFOR)NK
C     ---OBTAINING ISOTROPIC POWER ARRAY FOR UNDESIRED STATION---
      CALL POWSUB
C     ------------------------PRINT STATEMENTS--------------------
      PRINT 900,((PFY(LA,LB),LB=1,6),LA=1,NCT)
      PRINT 5
      MCK=NCT/2        $      CALL PAGE(MCK)
C     ------------------------------------------------------------

C     -----------------CALCULATION OF D/U RATIOS-----------------

   28 S=SMIN
      DA(1)=DV5    $    DA(2)=D50    $    DA(3)=D95
      JCT=0
C     ------------------------PRINT STATEMENTS--------------------
      PRINT 791    $    PRINT 792    $    CALL PAGE(2)
C     ----------------------- ------------------------------------
      DO 26 KLB=1,NCT
      I=KLB     $     DU=PFY(I,1)    $     S=DU+DD
      IF(S.GT.SMAX) GO TO 27
```

```
      JCT=JCT+1
      BX(JCT,1)=BX(JCT,2)=BX(JCT,3)=BX(JCT,4)=S
   31 UFS=PFY(I,2)    $    UPW=PFY(I,3)    $    UV5=PFY(I,4)
      U50=PFY(I,5)    $    U95=PFY(I,6)
   23 BY(JCT,1)=DFS-UFS    $    REFV=DPW-UPW
      DB(1)=UV5    $    DB(2)=U50    $    DB(3)=U95
      CALL CONLUT(DA,DB,DP,3,-1.,0.,PC,DC)
C     ---------------VALUES PUT INTO PLOTTING ARRAY------------------
      BY(JCT,2)=REFV+DC(1)    $    BY(JCT,3)=REFV+DC(2)
      BY(JCT,4)=REFV+DC(3)
C     ---------------------------PRINT STATEMENTS-----------------------
      PRINT 790,S,DD,DU,DFS,UFS,DPW,UPW,(BY(JCT,K),K=1,4)
      CALL PAGE(1)
C     --------------------------------------------------------------------
   26 CONTINUE
   27 CONTINUE

C     ---------------------PLOTTING OF GRAPH----------------------------

      SX(1)=DMAX    $    SX(2)=DMIN    $    SY(1)=PMAX    $    SY(2)=PMIN
      DO 904 K=1,4
  904 NU(K)=JCT
      NS(1)=9    $    NS(2)=NS(3)=NS(4)=1
      LYD=0    $    LUD=+1    $    LL=4
      IG=IG+1
      CALL PLTDU
      GO TO 100                                                      ↑
                                                                     ↑
C---------LOOPING BACK TO START FOR NEW SET OF PARAMETERS--------------------↑

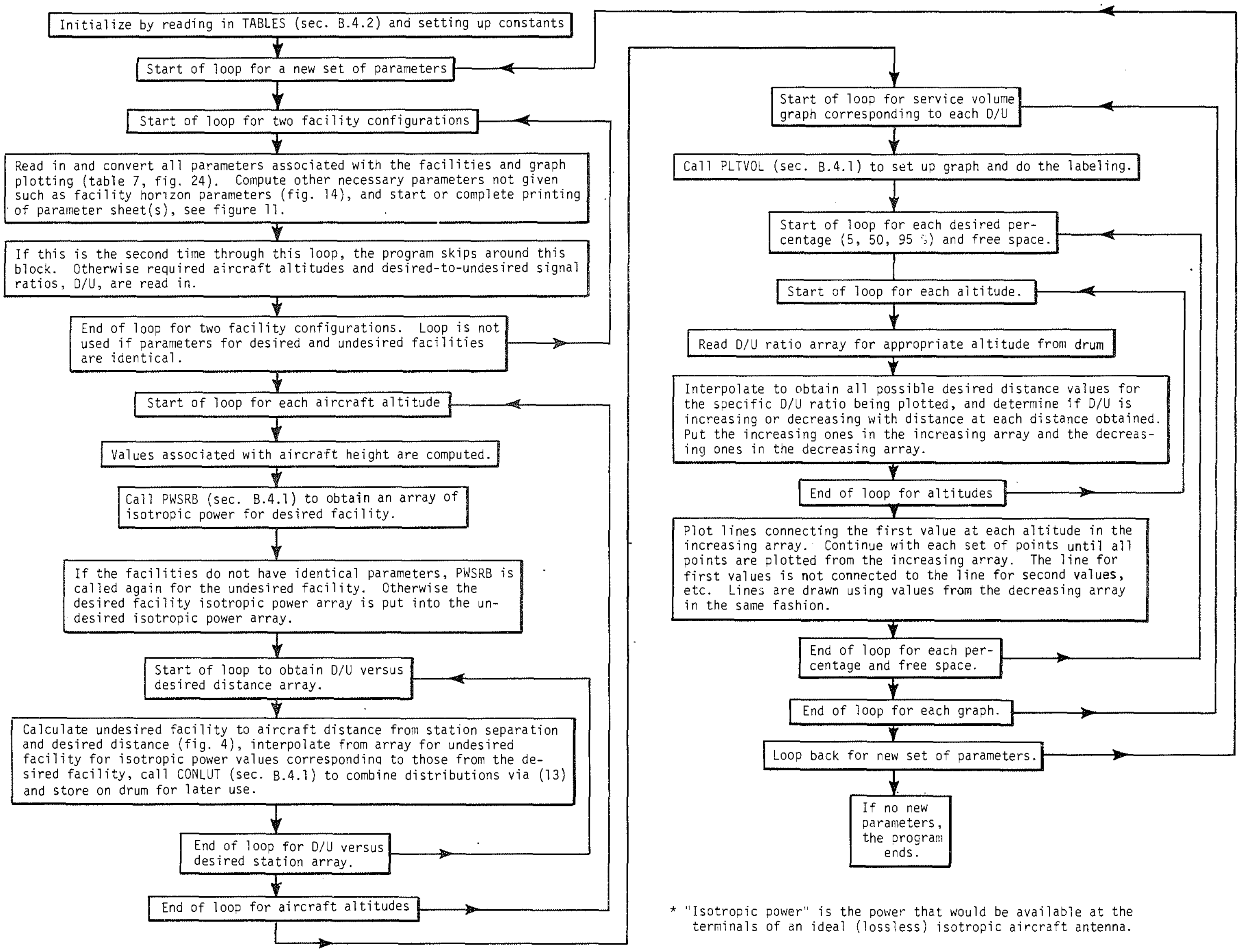
   15 NK=43-((19+IA)/2)
      ENCODE(48,777,VARFOR)NK
      GO TO 16


C     ----------------------TERMINATION OF PROGRAM---------------------

  451 CONTINUE
      CALL CRTPLT(0,0,0,0,20)
      PRINT 4
      PRINT 2
      CALL EXIT
      END
```

B.3 SERVICE VOLUME PROGRAM

Input parameters for, and output generated by, the service volume program (SRVVOLM) are discussed in sections 3.1.1 and 3.2.3, respectively. Information concerning input parameter cards and FORTRAN variables are given in figure 24 and further described in table 7 (app. B). Subprograms (sec. B.4.1) and data tables (sec. B.4.2) required by SRVVOLM are ASORP, CLOS, CONLUT, DEFRAC, DELTA, FDASP, FDTETA, FRENEL, GAIN, GHBAR, HCHNOT, LINE, PAGE, PLTVOL, PWSRB, RADEMS, RAYTRAC, RECC, RTATAN, SCATTER, SORB, TABLE, TERP, TRMESH, TSMESH, VZD, and YIKK. A block diagram of the operations performed by SRVVOLM is given in figure 27. Text references and major subprograms that are relevant to specific blocks are included there. A listing of SRVVOLM is provided at the end of this section.



* "Isotropic power" is the power that would be available at the terminals of an ideal (lossless) isotropic aircraft antenna.

Figure 27. Block diagram for service volume program, SRVVOLM.

```
      PROGRAM SRVVOLM
C     ROUTINE FOR MODEL AUG 73
    2 FORMAT(*   PROGRAM IS FINISHED. *)
    4 FORMAT(1H1)
    5 FORMAT(1H )
    6 FORMAT(2A8,2F6.0,F4.0,3F6.0,28X,I2)
    7 FORMAT(I2,F6.0,2I2,3F6.0,I2,2F6.0,I2,2F6.0,3I3,3I2,F6.0,I1)
    8 FORMAT(5A8,F4.0,2F6.0,F5.0,I2)
    9 FORMAT(I2,2F4.0,2I2,3F4.0,F6.0,2F5.0)
   32 FORMAT(F4.0,4X)
   50 FORMAT(F7.0,1X)
   71 FORMAT(F5.0,14F5.1)
  106 FORMAT(5X,* DML IS LESS THAN ZERO.   ABORTING RUN *)
  108 FORMAT(2(F5.3,7F5.2))
  505 FORMAT(11F7.4)
C            FORMAT STATEMENTS FOR PARAMETER SHEET AND WORK SHEET
  700 FORMAT(23X*PARAMETERS FOR SERVICE VOLUME CURVES*,/34X,*ITS MODEL*,
     XA8,/30X,A8,2X,A8,* RUN*,//)
  701 FORMAT(32X,*REQUIRED OR FIXED*,/32X,*----------------- *)
  702 FORMAT(15X,*FACILITY ANTENNA HEIGHT:*,F7.1,* FT ABOVE SITE SURFACE
     X*)
  703 FORMAT(15X,*FREQUENCY:*,F6.0,* MHZ*)
  704 FORMAT(29X,*SPECIFICATION OPTIONAL*,/29X,*----------------------*,
     4/15X,*ABSORPTION: OXYGEN*,F9.5,* DB/KM*,A2,/27X,*WATER VAPOR*,F9.5
     4,*DB/KM*,A2)
  705 FORMAT(15X,*EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL:*,F7.
     50,* FT*,/15X,*EQUIVALENT ISOTROPICALLY RADIATED POWER: *,F6.1,* DB
     5W*,/15X,*FACILITY ANTENNA TYPE: *,5A8)
  706 FORMAT(20X,*COUNTERPOISE DIAMETER:*,F5.0,* FT*,/25X,*HEIGHT:*,F5.0
     6,* FT ABOVE SITE SURFACE *,/25X,*SURFACE:*,2A8)
  707 FORMAT(20X,*POLARIZATION:*,2A8)
  708 FORMAT(15X,*HORIZON OBSTACLE DISTANCE:*,F7.2,* N MI FROM FACILITY*
     8,A2,/20X,*ELEVATION ANGLE:  *,I3,*/*,I2,*/*,I2,* DEG/MIN/SEC ABOVE
     8 HORIZONTAL*,A2,/20X,*HEIGHT:*,F6.0,* FT ABOVE MSL*,A2)
  709 FORMAT(15X,*MINIMUM MONTHLY MEAN SURFACE REFRACTIVITY:*,/20X,F3.0,
     9* N-UNITS     AT SEA LEVEL: *,F3.0,* N-UNITS*)
  710 FORMAT(15X,*TERRAIN ELEVATION AT SITE:*,F6.0,* FT ABOVE MSL*,/20X,
     A*PARAMETER:*,F5.0,* FT*,/20X,*TYPE: *,2A8)
  711 FORMAT(2X,13F6.0)
  712 FORMAT(5X,15F5.0)
  713 FORMAT(F8.0,2X,A8,6(F8.1,F8.0)/(18X,6(F8.1,F8.0)))
  714 FORMAT(15X*AIRCRAFT ALTITUDES IN FT ABOVE MSL: *,3(F7.0,A1))
  715 FORMAT(20X,*ANTENNA TOO HIGH, RAY BENDING OVERESTIMATED*,/)
  716 FORMAT(20X,*ANTENNNA TOO LOW, SURFACE WAVE SHOULD BE*,/25X,*CONSID
     6ERED*)
  717 FORMAT(20X,*FREQUENCY TOO LOW, IONOSPHERIC EFFECTS MAY BE*,/25X,*I
     7MPORTANT*,//)
  718 FORMAT(20X,*ATTENUATION AND/OR SCATTERING FROM HYDROMETEORS*,/25X,
     8*(RAIN, ETC) MAY BE IMPORTANT*)
  719 FORMAT(20X,*ATMOSPHERIC ABSORPTION ESTIMATES MAY BE*,/25X,*UNRELIA
     9BLE*)
  724 FORMAT(/15X,A2,*COMPUTED VALUE*)
  725 FORMAT(20X,*TYPE: *,2A8,A1)
  726 FORMAT(12X,*EARTH*,F9.0 ,* N MI           *,F8.0,* KM*)
  728 FORMAT(15X*D/U RATIOS IN DB: *,10(F3.0,A1),/20X,13(F3.0,A1))
  729 FORMAT(15X,*TIME AVAILABILITY:  *,4A8,A1)
  731 FORMAT(15X*D/U RATIOS IN DB: *,10(F3.0,A1),/20X,13(F3.0,A1),/20X,1
     X3(F3.0,A1))
  732 FORMAT(12X,* H(F) *,F8.1,* FT TO SURFACE      *,F8.4,* KM *)
```

```
733 FORMAT(12X,*FREQUENCY*, F5.0,* MHZ             *,F8.0,*  MHZ *)
734 FORMAT(12X,* A(O)*, F9.5,* DB/KM               *,F8.5,* DB/KM*,A2)
735 FORMAT(12X,* A(W)*,F9.5 ,* DB/KM               *,F8.5,* DB/KM*,A2)
736 FORMAT(15X*D/U RATIOS IN DB: *,10(F3.0,A1))
737 FORMAT(12X,*EIRP *,F9.1 ,* DBW                 *,F8.1,*  DBW *)
738 FORMAT(12X,*F ANT *,6X,I2, 2X,5A8)
739 FORMAT(12X,* D(C) *,F8.0,* FT                  *,F8.4,* KM*)
740 FORMAT(12X,* H(C) *,F8.0,* FT ABOVE SURFACE    *,F8.4,* KM*)
741 FORMAT(12X,*COUNTERPOISE*,I2,10X,2A8)
742 FORMAT(12X,*H(FR) *,F8.0,* FT ABOVE REFLECTION*,F8.4,* KM*)
743 FORMAT(12X,*POLARIZATION*,I2,10X,2A8)
745 FORMAT(10X,A2,*D(HO) *,F8.2,* N MI FROM HORIZON  *,F8.2,* KM*)
746 FORMAT(10X,A2,*E(HO) *,I2,*/*,I2,*/*,I2,* DEG/MIN/SEC*,7X,F8.5,* R
   6ADIANS*)
747 FORMAT(10X,A2,*H(HO) *,F8.0,* FT MSL             *,F8.4,* KM*)
748 FORMAT(12X,* N(O)*,F9.0 ,* N-UNITS        N(S) *,F8.0,* N-UNITS*)
749 FORMAT(12X,*H(SUR)*,F8.0,* FT MSL              *,F8.4,* KM*)
750 FORMAT(12X,*DH(SUR)*,F7.0,* FT                  *,F8.4,* KM*)
751 FORMAT(12X,*TERRAIN*,5X,I2,10X,2A8)
752 FORMAT(15X*STATION SEPARATION:*,F5.0,* N MI*)
756 FORMAT(25X,2A8)
757 FORMAT(12X*INPUT PARAMETERS FOR *,A8,2X,A8,* RUN*,/12X*OF *,A8,* A
   1IR/GROUND MODEL*,//)
772 FORMAT(15X*AIRCRAFT ALTITUDES IN FT ABOVE MSL: *,3(F7.0,A1),/20X,7
   2(F7.0,A1))
773 FORMAT(15X*AIRCRAFT ALTITUDES IN FT ABOVE MSL: *,3(F7.0,A1),/20X,7
   3(F7.0,A1),/20X,7(F7.0,A1))
774 FORMAT(15X*AIRCRAFT ALTITUDES IN FT ABOVE MSL: *,3(F7.0,A1),/20X,7
   4(F7.0,A1),/20X,7(F7.0,A1),/20X,7(F7.0,A1))
776 FORMAT(15X*AIRCRAFT ALTITUDES IN FT ABOVE MSL: *,3(F7.0,A1),/20X,7
   6(F7.0,A1),/20X,7(F7.0,A1),/20X,7(F7.0,A1),/20X,F7.0)
778 FORMAT(15X,*SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
   X*)
779 FORMAT(15X,*SURFACE REFLECTION LOBING:  DETERMINES MEDIAN*)
785 FORMAT(12X,*SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
   X*)
786 FORMAT(12X,*SURFACE REFLECTION LOBING:  DETERMINES MEDIAN*)
790 FORMAT(5X,3F7.1,2(2X,2F7.1),3X,4F7.1)
791 FORMAT(11X,*NAUTICAL MILES      FREE SPACE         MEDIAN
   X -------D/U--------*)
792 FORMAT(10X,*S        DD       DU         DD      DU         DD      DU    F.SP
   XACE    5%     50%     95%*)
796 FORMAT(5X,*AIRCRAFT HEIGHT IS*,F8.0,*  CORRECTIVE HEIGHT IS*,F8.0,
   6A2)
797 FORMAT(1H(I2,26HX*DESIRED STATION IS *5A8))
798 FORMAT(1H(I2,28HX*UNDESIRED STATION IS *5A8))
799 FORMAT(1H(I2,38HX*DESIRED/UNDESIRED STATIONS ARE *5A8))
800 FORMAT(//10X,*SOME PARAMETERS ARE OUT OF RANGE*)
809 FORMAT(20X,*DLT IS LESS THAN .1XDLST OR GREATER THAN 3XDLST*)
810 FORMAT(20X,*INITIAL TAKE-OFF ANGLE GREATER THAN 12 DEG.*)

900 FORMAT(2(3X,6F7.1))
901 FORMAT(5X,F8.3,5F7.1,2I2)
    DIMENSION DA(3),DB(3),DP(3),PC(3),DC(3)
    DIMENSION CFK(3),CMK(3),CFM(3),CKM(3),CKN(3)
    DIMENSION FAT(5,8),CCI(2,7),POL(2,3),TSC(2,7)
    DIMENSION PAS(2)
    DIMENSION ACHT(25),DEHT(25)
    DIMENSION APCT(4),LP(4)
    DIMENSION TYD(3,4),VYD(5,2)
    DIMENSION PR(30),ADENT(2),ADNT(3),VARFOR(6)
    DIMENSION QHTE(2),QDLT(2),QENS(2),QEFT(2),QFK(2),QTET(2),JKD(2),QA
   XO(2),QAW(2),QCW(2),QHW(2),JIC(2),QHRP(2),QERP(2),JKK(2),JLB(2),QHT
   X(2),QHLT(2),QHFS(2),QDH(2),QDLST(2),JPL(2),JKSC(2),JFA(2)
    COMMON/EGAP/IP,LN,IDT,IXT
```

```
      COMMON PDY(125,5),DE(125),DRU(125,4),DED(125),MU(25),MD(25),PY(25)
     X,PXU(25,4),PXD(25,4),A(25),B(25),MCT(25)
      COMMON/PLVD/LUD,LYD,SHX,SHY,TG,SX(2),SY(2),TT(6),XC,YC,AAT
      COMMON/RYTC/QNS,QHC,QHA,QHS,QQD
      COMMON/PAOUT/NCT,PFY(125,6),JJ,HP1,HP2
      COMMON/VAT/TAV(175),TAH1(7,175)
      COMMON/DLAT/TALD(20),TAFL(4,7,20)
      COMMON/VV/VF(36,17)
      COMMON/PARAM/HTE,HRE,D,DLT,DLR,ENS,EFRTH,FREK,ALAM,TET,TER,KD,GAO,
     XGAW
      COMMON/SIGHT/DCW,HCW,DMAX,DML,DZR,IK,EAC,H2,ICC,HFC,PRH,DSL1,EIRP,
     XQG1,QG9,KK,ZH,RDHK,ILB
      COMMON/SCATPR/HT,HR,ALSC,TWEND,THRFK,HLT,HLR,THETA,HTP,AA,REW
      COMMON/DIFPR/HTD,HRD,DH,AED,SLP,DLST,DLSR,IPL,KSC,HLD,HRP,AWD,SWP
      COMMON/GAT/IFA
      DATA (QMD=8H AUG 73 )
      DATA (CFK=.001,.0003048,.0003048)
      DATA (CMK=1.,1.609344,1.852)
      DATA (CFM=1.,.3048,.3048)
      DATA (CKM=1000.,3280.839895,3280.839895)
      DATA (CKN=1.,.6213711922,.5399568034)
      DATA (POL=8H HORIZON,3HTAL,8H VERTICA,1HL,8H CIRCULA,1HR)
      DATA (FAT=10H ISOTROPIC,3(1H ),4H DME,4(1H ),14H TACAN (RTA-2),3(1
     XH ),39H 4-LOOP ARRAY (COSINE VERTICAL PATTERN),39H 8-LOOP ARRAY (C
     XOSINE VERTICAL PATTERN),34H I OR II (COSINE VERTICAL PATTERN),1H ,
     X40HJTAC TILTED 20 DEG WITH 40 HALF-POW B.W.,17HJTAC TILTED 8 DEG,2
     X(1H ))
      DATA(TSC=16H SEA WATER       ,16H GOOD GROUND    ,16H AVERAGE GROUN
     XD ,16H POOR GROUND    ,16H FRESH WATER    ,16H  CONCRETE       ,16H
     X   METALLIC      )
      DATA (PAS=2H  ,2H* )
      DATA(VYD=33HFOR HOURLY MEDIAN LEVELS EXCEEDED,33HFOR INSTANTANEOUS
     X LEVELS EXCEEDED)
      DATA(TYD=17HSMOOTH EARTH     ,17HIRREGULAR TERRAIN)
      DATA(CCI=16H SEA WATER       ,16H GOOD GROUND    ,16H AVERAGE GROUN
     XD ,16H POOR GROUND    ,16H FRESH WATER    ,16H  CONCRETE       ,16H
     X   METALLIC      )
      DATA (PAS=1H )
      DATA (CM=1H,)
      DATA (LP=9,2,1,3)
      DATA(APCT=8H FREE SP,8H   5 =  ,8H  50 =  ,8H  95 =  )
      FNA(FX,FA,FB,FC,FD)=((FX-FB)*(FC-FD)/(FA-FB))+FD
      FNB(FRX,FRA,FRB)=(FRX-FRB)/(FRA-FRB)
      FNC(FFX,FFC,FFD)=(FFX*(FFC-FFD))+FFD
      IDT=IDATE(IDX)
      DP(1)=.01     $     DP(2)=.50    $     DP(3)=.95
      IG=0    $    JJ=0    $    ZO=.00000001    $    ERTH=6370.
      RAD=.01745329252    $    DEG=57.29577951    $    TWDG=12.*RAD
C                     PRE-PROGRAM INPUT OF TABLES

      READ 108,(TAV(I),(TAH1(J,I),J=1,7),I=1,175)
      READ 71,(TALD(K),((TAFL(I,J,K),J=1,7),I=1,2),K=1,20)
      READ 71,(DUMB,((TAFL(I,J,K),J=1,7),I=3,4),K=1,20)
      READ 505,((VF(I,J),I=1,36),J=1,3)
      READ 505,((VF(I,J),I=1,36),J=4,17)

C     -------------PROGRAM START WITH CARD 1--------------------
  100 READ 9,IS,DMAX,S,LH,LE,SX,XC,SY,YC
      IF(IS.LE.0) GO TO 451
      IXT=ITIMEDAY(ITX)
      DO 200 J=1,IS
C     --------------START OF LOOP FOR TWO FACILITIES------------
      ICAR=0
```

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C     ------------------INPUT OF CARD 2---------------------------
      READ 7,IK,HFI,IFA,IPL,SUR,HPFI,DHSI,KSC,DCI,HCI,ICC,DHOI,HHOI,IDG,
     XIMN,ISEC,KE,KK,KD,EIRP,ILB
C     ------------------INPUT OF CARD 3---------------------------
      READ 8,ADENT,ADNT,ENO,AOI,AWI,F,IA
      TT(1)=ADENT(1)    $    TT(2)=ADENT(2)        $    TT(6)=PAS(1)
      TT(3)=ADNT(1)    $    TT(4)=ADNT(2)    $    TT(5)=ADNT(3)
      CMAX=DMAX
      IF(IS.GT.1) GO TO 15
      NK=43-((31+IA)/2)
      ENCODE(48,799,VARFOR)NK
   14 PRINT 4
C     ------------------START OF PARAMETER SHEET-----------------
                          HFS=HFI*CFK(IK)    $    FREK=F
      PRINT 700,QMD,IDT,IXT
      PRINT VARFOR,ADENT,ADNT
      PRINT 5
      PRINT 701
      IF(J.GT.1) GO TO 820

C     --------------INPUT OF CARDS OF AIRCRAFT ALTITUDES---------
      READ 711,(ACHT(I),I=1,LH)

C     ----INPUT OF ALTITUDE CORRECTION FACTORS IF SPECIFIED------
      IF(JJ.GT.0)      READ 711,(DEHT(I),I=1,LH)

C     ------------------INPUT OF CARDS OF D/U RATIOS-------------
      READ 712,(PR(I),I=1,LE)
  820 LL=LH-1
      IF(LH.GT.24) GO TO 769
      IF(LH.GT.17) GO TO 768
      IF(LH.GT.10) GO TO 767
      IF(LH.GT. 3) GO TO 766
      PRINT 714,((ACHT(I),CM),I=1,LL),ACHT(LH)
  770 LL=LE-1
      IF(LE.GT.23) GO TO 721
      IF(LE.GT.10) GO TO 720
      PRINT 736,((PR(I),CM),I=1,LL),PR(LE)
  777 PRINT 702,HFI
      IF(HFI.LT.0.) GO TO 825
      IF(HFI.GT.9000.) PRINT 715
      IF(HFI.LT.1.5) PRINT 716
      PRINT 703,FREK
      IF(F.LT.100.)GO TO 805
  806 IF(F.LT.20.) GO TO 100
      IF(F.GT.5000.) PRINT 718
      IF(F.GT.17000.) GO TO 807
  808 IF(F.GT.100000.) GO TO 100
      ALAM=.2997925/F
      PRINT 752,S
      PRINT 5
      IF(AOI.LT.0.) GO TO 56
      PXH=PAS(1)
   57 GAO=AOI    $    GAW=AWI
      PRINT 704,GAO,PXH,GAW,PXH
      IF(SUR.GT.15000.) ICAR=1
      IF(SUR.LT.0.) GO TO 830
  831 PIRP=EIRP
      ETS=SUR*CFK(IK)
      HRP=HPFI*CFK(IK)
      IF(ETS.LT.0.) ETS=0.
      IF(DHSI.LT.0.) DHSI=0.
      DH=DHSI*CFK(IK)
      IF(ENO.LT.250..OR.ENO.GT.400.) GO TO 801
  802 ENS=ENO*EXPF(-0.1057*HRP)
```

```
      IF(ENS.LE.250.) GO TO 803
  804 EFRTH=ERTH/(1.-.04665*EXPF(.005577*ENS))
      EART=EFRTH*CKN(IK)
      HT=HFS+ETS                $     H1=HT
      IF(HRP.GT.H1) GO TO 825
      HTE=HT-HRP               $    DLST=SQRTF(2.*EFRTH*HTE)
      HFRI=HTE*CKM(IK)
      PRINT 705,HPFI,EIRP,(FAT(I,IFA),I=1,5)
      IF(DCI.LE.ZO) GO TO 789
      IF(ICC.LE.0) GO TO 789
C     -------------COUNTERPOISE PARAMETERS CONVERTED-------------
      NOC=1
      DCW=DCI*CFK(IK)    $    HCW=HCI*CFK(IK)
      PRINT 706,DCI,HCI,(CCI(I,ICC),I=1,2)
      IF(HCI.LT.0.) GO TO 828
  829 IF(HCI.GT.500.) ICAR=1
      IF (DCW.GT..1524) ICAR=1
      IF(HCW.GT.HFS) GO TO 825
      HFC=HT-ETS-HCW
  788 CONTINUE
      PRINT 707,(POL(I,IPL),I=1,2)

C     ------HORIZON AND INITIAL TAKE-OFF ANGLE COMPUTATIONS------
      PDS=PTS=PHS=PAS(1)
      IF(KD.LE.1) GO TO 755
      HLT=HHOI*CFK(IK)    $    DLT=DHOI*CMK(IK)
      HLTS=HLT-HT
      DG=IDG  $  AMN=IMN  $  SEC=ISEC
      TET=RAD*(DG+(((SEC/60.)+AMN)/60.))    $    ATET=ABSF(TET)
      TATET=TANF(TET)
      IF(KE.EQ.3) GO TO 782
      IF(DLT.LE.ZO) GO TO 781
  759 IF(KE-1)730,758,780
  758 IF(TET.LT.0.) GO TO 752
      HLTS=DLT*TATET+(DLT*DLT/(2.*EFRTH))
  753 HLT=HLTS+HFS+ETS    $    HHOI=HLT*CKM(IK)
      PHS=PAS(2)
  783 CONTINUE
      IF(DLT.LT.(.1*DLST).OR.DLT.GT.(3.*DLST)) PRINT 809
      IF(TET.GT..20943951) PRINT 810
      IF(HHOI.GT.15000.) ICAR=1
      PRINT 708,DHOI,PDS,IDG,IMN,ISEC,PTS,HHOI,PHS
C     ---------------------- ------------------------------------

      PRINT 725,(TYD(I,KD),I=1,3)
      PRINT 709,ENS,ENO
      IF(ILB.GT.0) GO TO 762
      PRINT 778
  763 PRINT 710,SUR,DHSI,(TSC(I,KSC),I=1,2)
      PRINT 729,(VYD(I,KK),I=1,5)
      PRINT 724,PAS(2)
      IF(ICAR.GT.0) PRINT 800

C     ------------------START OF WORK SHEET--------------------
      PRINT 4
      PRINT 757,IDT,IXT,QMD
      PRINT 5    $    PRINT 6
      PRINT VARFOR,ADENT,ADNT
      PRINT 701,S
      PRINT 732,HFI,HFS
      PRINT 733,F,FREK
      PRINT 734,AOI,GAO,PXH
      PRINT 735,AWI,GAW,PXH
      PRINT 737,EIRP,EIRP
      PRINT 738,IFA,(FAT(I,IFA),I=1,5)
```

```
      IF(NOC.LT.1) GO TO 754
      PRINT 739,DCI,DCW
      PRINT 740,HCI,HCW
      PRINT 741,ICC,(CCI(I,ICC),I=1,2)
  754 CONTINUE
      PRINT 5
      PRINT 742,HFRI,HTF
      PRINT 743,IPL,(POL(I,IPL),I=1,2)
  771 PRINT 745,PDS,DHOI,DLT
      PRINT 746,PTS,IDG,IMN,ISEC,TET
      PRINT 747,PHS,HHOI,HLT
      PRINT 748,ENO,ENS
      PRINT 726,EART,EFRTH
      PRINT 749,SUR,ETS
      PRINT 750,DHSI,DH
      PRINT 751,KSC,(TSC(I,KSC),I=1,2)
      IF(ILB.GT.0) GO TO 764
      PRINT 785
  765 PRINT 729,(VYD(I,KK),I=1,3)
      PRINT 724,PAS(2)
      IF(ICAR.GT.0) PRINT 800
C     --------------END OF PRELIMINARY PRINTING------------------

      IF(IS.LE.1) GO TO 201
      QAW(J)=GAW    $    QCW(J)=DCW    $    QHW(J)=HCW    $    JIC(J)=ICC
      QHRP(J)=HRP    $    QERP(J)=EIRP    $    JKK(J)=KK    $    JLB(J)=ILB
      QHT(J)=HT    $    QHLT(J)=HLT    $    QHFS(J)=HFS    $    QDH(J)=DH
      QHTE(J)=HTE    $    QDLT(J)=DLT    $    QENS(J)=ENS    $    QFK(J)=F
      QEFT(J)=EFRTH    $    QTET(J)=TET    $    JKD(J)=KD    $    QAO(J)=GAO
      QDLST(J)=DLST    $    JPL(J)=IPL    $    JKSC(J)=KSC    $    JFA(J)=IFA
      QHFC=HFC
  200 CONTINUE
C     --------------END OF LOOP FOR TWO FACILITIES--------------

  201 PRINT 4
      CALL PAGE(-1)
      ENCODE(8,32,TG) S
      IFILE=0
      MH=0
      DO 60 LD=1,LH
      HAI=ACHT(LD)
      H2=HAI*CFK(IK)
      IFILE=IFILE+1
      IF(IS.GT.1) GO TO 202
  206 CONTINUE
      IF(JJ.LT.1) GO TO 63
      ALAM=.2997925/F
      PDH=PAS(1)
      EAC=DEHT(LD)*CFK(IK)
      HR=H2-EAC
      HRE=HR-HRP     $     DLSR=SQRTF(2.*HRE*EFRTH)
      HAS=H2-ETS   $   HRS=HR-ETS     $   HRE=HR-HRP
      IF(HRE.GE.50.) DLSR=EFRTH*ACOSF(EFRTH/(EFRTH+HRE))
      DSO=3.*SQRTF(2000.*HTE)+3.*SQRTF(2000.*HRE)
   64 CONTINUE
C     -----------------------PRINT STATEMENTS--------------------

      PRINT 796, HAI,DEHT(LD),PDH     $     CALL PAGE(1)
C     ----------------------- ---------------------------------

C     --------------OBTAINING ISOTROPIC POWER ARRAY--------------
      CALL PWSRB
C     -----------------------PRINT STATEMENTS--------------------
      PRINT 900,((PFY(LA,LB),LB=1,6),LA=1,NCT)
      PRINT 5
```

```
      MCK=NCT/2        $      CALL PAGE(MCK)
C     ----------------------- --------------------------------------
      IF(IS.GT.1) GO TO JC
  203 NCD=NCT
      DO 24 LA=1,NCD
      DE(LA)=PFY(LA,1)
      DO 29 LB=2,6
      LC=LB-1
      PDY(LA,LC)=PFY(LA,LB)
   29 CONTINUE
   24 CONTINUE
      IF(IS.LE.1) GO TO 27
      J=2    $   ASSIGN 27  TO JC    $    GO TO 205
   27 CONTINUE

C     -----------------------PRINT STATEMENTS-------------------
      PRINT 791    $    PRINT 792    $    CALL PAGE(2)
C     ----------------------------------------------------------

C     -----------------CALCULATION OF D/U RATIOS----------------
      JCT=0
      DO 26 N=1,NCD
      DD=DE(N)
      DA(1)=PDY(N,3)    $    DA(2)=PDY(N,4)    $    DA(3)=PDY(N,5)
      DU=S-DE(N)    $    IF(DU.LT.0.)   GO TO 25
      DO 20 I=1,NCT
      IF(DU-PFY(I,1))22,21,20
   20 CONTINUE
      I=NCT
   22 IF(I.LE.1) I=2
      L=I-1
      DRAT=FNB(DU,PFY(I,1),PFY(L,1))
      UFS=FNC(DRAT,PFY(I,2),PFY(L,2))   $ UPW=FNC(DRAT,PFY(I,3),PFY(L,3))
      UV5=FNC(DRAT,PFY(I,4),PFY(L,4))   $ U50=FNC(DRAT,PFY(I,5),PFY(L,5))
      U95=FNC(DRAT,PFY(I,6),PFY(L,6))       $    GO TO    28
   21 UFS=PFY(I,2)    $    UPW=PFY(I,3)    $    UV5=PFY(I,4)
      U50=PFY(I,5)    $    U95=PFY(I,6)
   28 CONTINUE
      JCT=JCT+1
      DRU(JCT,1)    =PDY(N,1)-UFS   $ REFV=PDY(N,2)-UPW
      DB(1)=UV5    $    DB(2)=U50    $    DB(3)=U95
      CALL CONLUT(DA,DB,DP,3,-1.,0.,PC,DC)
      DRU(JCT,2)    =REFV+DC(1)    $    DRU(JCT,3)    =REFV+DC(2)
      DRU(JCT,4)    =REFV+DC(3)
C     -----------------------PRINT STATEMENTS-------------------
      PRINT 790,S,DD,DU,PDY(N,1),UFS,PDY(N,2),UPW,(DRU(JCT,K),   K=1,4)
      DED(JCT)=DD
      CALL PAGE(1)
C     ----------------------------------------------------------
   26 CONTINUE
   25 CONTINUE
C     -------------------WRITING FILES ON DISK------------------
      MCT(LD)=JCT
      WRITE(2) IFILE,ACHT(LD),MCT(LD)
      KCT=MCT(LD)
      DO 73 KE=1,KCT
      WRITE (2) DED(KE),((DRU(KE,JL)),JL=1,4)
   73 CONTINUE
      END FILE 2
      MH=MH+1
      PRINT 5      $      CALL PAGE(1)
   60 CONTINUE
C     ---------------END OF AIRCRAFT ALTITUDE LOOP---------------
```

```
      DO 40 M=1,LE
      LYD=0   $   LUD=+1
      IG=IG+1
      ENCODE(8,32,AAT) PR(M)
C     ------------------PLOTTING OF GRAPH------------------------

      CALL PLTVOL
C     -------------VALUES PUT INTO PLOTTING ARRAY----------------
      DO 41 JL=1,4
      DO 65 I=1,LH
      MU(I)=MD(I)=0
   65 CONTINUE
      IFILE=0
      REWIND 2
      DO 62 I=1,LH
      IFILE=IFILE+1
      READ (2) KFILE,BCHT,LCT
      IF(KFILE.NE.IFILE) GO TO 100
      DO 74 JE=1,LCT
      READ (2) DED(JE),((DRU(JE,JG)),JG=1,4)
   74 CONTINUE
      SKIPFILE 2
      JCT=LCT
      DO 42 JK=3,JCT
      JM=JK-1
      IF(PR(M).GE.DRU(JK,JL)  .AND.PR(M).LE.DRU(JM,JL))   GO TO 43
      IF(PR(M).LE.DRU(JK,JL)  .AND.PR(M).GE.DRU(JM,JL))   GO TO 44
   42 CONTINUE
   62 CONTINUE
   61 LS=LP(JL)
      DO 66 KC=1,4
      J=0
      DO 67 I=1,LH
      IF(MD(I).LT.KC) GO TO 67
      IF(PY(I).GT.SY(1).OR.PXD(I,KC).LT.SX(2)) GO TO 67
      IF(PY(I).LT.SY(2).OR.PXD(I,KC).GT.SX(1)) GO TO 67
      J=J+1    $    B(J)=PY(I)    $    A(J)=PXD(I,KC)
   67 CONTINUE
      IF(J) 68,66
C     -----------------------PRINT STATEMENTS--------------------
   68 PRINT 713,PR(M),APCT(JL),((A(NN),B(NN)),NN=1,J)
      PRINT 5
      NPG=(J/6)+2     $     CALL PAGE(NPG)
C     -----------------------------------------------------------
      IF(J.LT.2) GO TO 66
      CALL LINE(LS,A,B,J,SHX,SHY)
   66 CONTINUE
      DO 69 KC=1,4
      J=0
      DO 70 I=1,LH
      IF(MU(I).LT.KC) GO TO 70
      IF(PY(I).GT.SY(1).OR.PXU(I,KC).LT.SX(2)) GO TO 70
      IF(PY(I).LT.SY(2).OR.PXU(I,KC).GT.SX(1)) GO TO 70
      J=J+1    $    B(J)=PY(I)    $    A(J)=PXU(I,KC)
   70 CONTINUE
      IF(J) 72,69
C     -----------------------PRINT STATEMENTS--------------------
   72 PRINT 713,PR(M),APCT(JL),((A(NN),B(NN)),NN=1,J)
      PRINT 5
      NPG=(J/6)+2     $     CALL PAGE(NPG)
      IF(J.LT.2) GO TO 69
      CALL LINE(LS,A,B,J,SHX,SHY)
   69 CONTINUE
   41 CONTINUE
C     -------------------END OF GRAPH----------------------------
```

```
      PRINT 5    $    PRINT 5    $    CALL PAGE(2)
   40 CONTINUE
      REWIND 2
      GO TO 100
C--------LOOPING BACK TO START FOR NEW SET OF PARAMETERS-----------------

   43 MU(I)=MU(I)+1
      KC=MU(I)
      IF(KC.GT.4) GO TO 61
      XRD=FNA(PR(M),DRU(JM,JL),DRU(JK,JL),DED(JM),DED(JK))
      PY(I)=ACHT(I)    $    PXU(I,KC)=XRD
      GO TO 42
   44 MD(I)=MD(I)+1
      KC=MD(I)
      IF(KC.GT.4) GO TO 61
      XRD=FNA(PR(M),DRU(JM,JL),DRU(JK,JL),DED(JM),DED(JK))
      PY(I)=ACHT(I)    $    PXD(I,KC)=XRD
      GO TO 42
   15 IF(J.GT.1) GO TO 16
      NK=43-((19+IA)/2)
      ENCODE(48,797,VARFOR)NK
      GO TO 14
   16 NK=43-((20+IA)/2)
      ENCODE(48,798,VARFOR)NK
      GO TO 14
   53 HRE=(DLSR*DLSR)/(2.*EFRTH)      $     GO TO 54    -
   56 CALL ASORP(F,AOI,AWI)
      PXH=PAS(2)      $      GO TO 57

C     ------------------CALCULATION OF RAY BENDING---------------
   63 HP2=H2-HRP                $        HP1=HTE
      DUM=0.0      $      ZER=0.0      $     QLIM=-1.56
      QNS=329.    $    QHC=HP1     $    QHA=HP2    $    QHS=HRP
      CALL RAYTRAC(DUM)
      RY=TRACRAY(QLIM)
      DSO=QQD
      QNS=ENS      $    QHC=ZER     $    QHA=HP2    $    QHS=HRP
      CALL RAYTRAC(DUM)
      RY=TRACRAY(ZER)
      DLSR=QQD    $    TSL2=DLSR/EFRTH
      IF(TSL2.LE..1)  GO TO 53
      R2E=EFRTH/COSF(TSL2)
      HRE=R2E-EFRTH
   54 IF(HRE.GT.HP2) HRE=HP2
      HR=HRE+HRP
      EAC=H2-HRP-HRE
      HAS=H2-ETS  $    HRS=HR-ETS
      DEHT(LD)=EAC*CKM(IK)    $    PDH=PAS(2)      $     GO TO 64

  107 PRINT 106      $      GO TO 100

C     -------------------TWO FACILITY CALCULATIONS--------------
  202 J=1    $    ASSIGN 203 TO JC
  205 HTE=QHTE(J)    $    DLT=QDLT(J)    $    ENS=QENS(J)    $    F=QFK(J)
      EFRTH=QEFT(J)    $    TET=QTET(J)    $    KD=JKD(J)    $    GAO=QAO(J)
      GAW=QAW(J)    $    DCW=QCW(J)    $    HCW=QHW(J)    $    ICC=JIC(J)
      HRP=QHRP(J)    $    EIRP=QERP(J)    $    KK=JKK(J)    $    ILB=JLB(J)
      HT=QHT(J)    $    HLT=QHLT(J)    $    HFS=QHFS(J)    $    DH=QDH(J)
      DLST=QDLST(J)    $    IPL=JPL(J)    $    KSC=JKSC(J)    $    IFA=JFA(J)
      FREK=F
      GO TO 206
```

```
C     --------------PART OF PARAMETER SHEET PRINTING------------
  720 PRINT 728,((PR(I),CM),I=1,LL),PR(LE)     $    GO TO 777
  721 PRINT 731,((PR(I),CM),I=1,LL),PR(LE)     $    GO TO 777
  762 PRINT 779    $    GO TO 763
  764 PRINT 786    $    GO TO 765
  766 PRINT 772,((ACHT(I),CM),I=1,LL),ACHT(LH)     $    GO TO 770
  767 PRINT 773,((ACHT(I),CM),I=1,LL),ACHT(LH)     $    GO TO 770
  768 PRINT 774,((ACHT(I),CM),I=1,LL),ACHT(LH)     $    GO TO 770
  769 PRINT 776,((ACHT(I),CM),I=1,LL),ACHT(LH)     $    GO TO 770

C     --------------HORIZON PARAMETER CALCULATIONS--------------
  781 HE=MAX1F(HTE,.005)
      DLT=DLST*EXPF(-.07*SQRTF(DH/HE))
      PDS=PAS(2)
      IF(DLT.LT.(.1*DLST)) DLT=.1*DLST
      IF(DLT.GT.(3.*DLST)) DLT=3.*DLST
      DHOI=DLT*CKN(IK)
      GO TO 759
  730 TRM=1.3*DH*((DLST/DLT)-1.)
      TET=(.5/DLST)*(TRM-(4.*HTE))
      IF(TET.GT.TWDG) TET=TWDG
      CALL RADEMS(TET,IDG,IMN,SEC)
      ISEC=XINTF(SEC)
      PTS=PAS(2)
      TATET=TANF(TET)
      GO TO 758
  782 XTRM=SQRTF((EFRTH*EFRTH*TATET*TATET)+(2.*EFRTH*HLTS))
      YTRM=-EFRTH*TATET       $    DLT=YTRM-XTRM
      IF(DLT.LE.0.) DLT=YTRM+XTRM
      PDS=PAS(2)
      DHOI=DLT*CKN(IK)     $    GO TO 783
  780 TATET=(HLTS/DLT)-(DLT/(2.*EFRTH))    $    TET=ATANF(TATET)
      PTS=PAS(2)
  784 CALL RADEMS(TET,IDG,IMN,SEC)
      ISEC=XINTF(SEC)    $    GO TO 783

C     -------------------SMOOTH EARTH PARAMETERS----------------
  755 PTS=PDS=PAS(2)
      DLT=DLST    $    DHOI=DLT*CKN(IK)
      TATET=(-HTE/DLT)-(DLT/(2.*EFRTH))    $    TET=ATANF(TATET)
      HLT=HRP    $    HHOI=HLT*CKM(IK)      $    DH=0.
      GO TO 784
  752 HLTS=DLT*TET   +(DLT*DLT/(2.*EFRTH))     $           GO TO 753
  789 HFC=0.        $    GO TO 788
  801 ICAR=1    $    ENO=301.    $    GO TO 802
  803 ENS=250. $    ICAR=1    $    GO TO 804
  805 ICAR=1    $    PRINT 717    $    GO TO 806
  807 ICAR=1    $    PRINT 719    $    GO TO 808
  825 PRINT 800     $    GO TO 100
  828 ICAR=1           $    HCI=0.    $    GO TO 829
  830 ICAR=1          $    SUR=0.    $    GO TO 831

C     -------------------TERMINATION OF PROGRAM-----------------

  451 CONTINUE
      CALL CRTPLT(0,0,0,0,20)
      PRINT 4
      PRINT 2
      CALL EXIT
      END
```

B.4 SUBPROGRAMS AND TABLES

Subprograms used in POWAV, DOVERU, and SRVVOLM are listed in section B.4.1. Tables used as input data for all three programs are tabulated in section B.4.2.

B.4.1 Subprograms

Subprograms (functions and subroutines) used in POWAV (sec. B.1), DOVERU (sec. B.2) and SRVVOLM (sec. B.3) are listed alphabetically by name in this section. Each listing is preceded by a short discussion and contains some annotation. Listing for system functions (e.g., SINF, COSF, etc.) and system subroutines (e.g., CRTPLT) are not included since they are available to system users, and do not have to be submitted with the programs.

ALOS

Subroutine ALOS is used only with the power density program (sec. B.1) to perform calculations associated with the line-of-sight region (sec. A.4.2). Subroutines BLOS and CLOS are almost identical with ALOS, but are used with other programs.

```
      SUBROUTINE ALOS
C     L-O-S SUBROUTINE FOR POWAV
C     ROUTINE FOR MODEL AUG 73
    5 FORMAT(1H )
  760 FORMAT(1X,F7.2,12F8.1,F6.1,2F5.1,2F6.1)
  766 FORMAT(2X,*D N MI FREE SPACE 50%      5%      95%      90%      99%
     X 99.9% 99.99%    .01%      .1%      1%      10%      PL   AA    AY
     X K  DEE*)
      DIMENSION XCON(5),NTM(5)
      DIMENSION CFK(3),CMK(3),CFM(3),CKM(3),CKN(3)
      DIMENSION GLD(8),D1(200),D2(200),D3(200)
      DIMENSION HTX(2),Z(2),TEA(2),DA(2),HPR(2)
      DIMENSION SID(24)
      DIMENSION SPGRD(3)
      DIMENSION RE(2),BD(35),VD(35)
      DIMENSION ALM(12),AD(35)
      DIMENSION P(35),QC(50),QA(50),PQA(50),PQK(50),QK(50),PQC(50)
      DIMENSION YV(10),SV(10)
      COMMON/EGAP/IP,LN,IDT,IXT
      COMMON/PARAM/HTE,HRE,D,DLT,DLR,ENS,EFRTH,FREK,ALAM,TET,TER,KD,GAO,
     XGAW
      COMMON/DIFPR/HT ,HR ,DH,AED,SLP,DLST,DLSR,IPL,KSC,HLT,HRP,AWD,SWP
      COMMON/SIGHT/DCW,HCW,DMAX,DML,DZR,IK,EAC,H2,ICC,HFC,PRH,DSL1,PIRP,
     XQG1,QG9,PFY(200,4),KK,ZH,RDHK,ILB
      COMMON/PLTD/LUD,LL,NU(8),NS(8),SX(2),SY(2),TT(6),XC,YC,BX(200,8),B
     XY(200,8),LYD,AAT,TG
      COMMON/SPLIT/L1,L2,N,X(140),Y(140),D6(140),XS(55),XD(55),XR(55),YS
     X(55),YD(55),YR(55),L3,ZS(25),ZD(25),ZR(25)
       DATA (CFK=.001,.0003048,.0003048)
       DATA  ((P(I),I=1,35)=.00001,.00002,.00005,.0001,.0002,.0005,.001,.
     X002,.005,.01,.02,.05,.10,.15,.20,.30,.40,.50,.60,.70,.80,.85,.90,.
     X95,.98,.99,.995,.998,.999,.9995,.9998,.9999,.99995,.99998,.99999)
       DATA (CMK=1.,1.609344,1.852)
       DATA (CFM=1.,.3048,.3048)
       DATA (CKM=1000.,3280.839895,3280.839895)
       DATA (CKN=1.,.6213711922,.5399568034)
       DATA(XCON=1.,5.,10.,25.,0.)
       DATA(NTM=10,19,30,10,0)
       DATA (GLD=0.,.1,.2,.3,.4,.5,.75,1.)
       DATA(ALM=-6.2,-6.15,-6.08,-6.0,-5.95,-5.88,-5.8,-5.65,-5.35,-5.0,-
     X4.5,-3.7)
       DATA (SPGRD=0.,.06,.1)
       DATA (SID=.2,.5,.7,1.,1.2,1.5,1.7,2.,2.5,3.,3.5,4.,5.,6.,7.,8.,10.
     X,20.,45.,70.,80.,85.,88.,89.)
       COMPLEX AT1,AT2
```

```
      FNA(FX,FA,FB,FC,FD)=((FX-FB)*(FC-FD)/(FA-FB))+FD
      BSPI=.3183098862
      RAD=.01745329252    $    DEG=57.29577951    $    TWDG=12.*RAD
      ALIM=3.
      PI=3.141592654      $    TWPI=6.283185307
      F=FREK
      PI2=1.570796327       $       CPI2=1.56
      DKAX=DMAX*CMK(IK)
      AFP=32.45+20.*ALOG10(FREK)
      ALA2=ALAM/2.
      ASPA=0.25     $     ASPB=0.25
      ASPC=ASPA*ASPB*(6.E-8)*F
      TWPILA=TWPI/ALAM
      DTRO=ALAM/6.
      ERTH =6370.
      A0=ERTH    $    EFN=EFRTH
      PKL=((3.*PI)/(ALAM))
      NCT=0
      NOC=0
      PRINT 766
      CALL PAGE(1)
      IF(ICC.GT.0) NOC=1
      CDRK=20.95841232*F
      IF(NOC.LE.0) GO TO 502
                           RCW=DCW*.5    $    BTC=ATANF(HFC/RCW)
      ABTC=ABSF(BTC)    $    R1C=RCW/COSF(BTC)  $  SQVT=SQRTF(2.*R1C/ALAM)
      HDI=HTE-HFC      $         TWHC=2.*HFC
  503 CONTINUE
      L1=L2=N=0
      TWHT=2.*HTE
C     ------SETTING UP OF TABLE OF SI, DELTA R AND DISTANCE------
      LE=7    $    IF(ILB.GT.0) LE=11
      DO 61 LK=1,LE
      IF(LK.LT.4) GO TO 120
      LB=13-LK     $    GRD=FLOATF(LB)    $    APDR=ALAM/GRD
  121 IF(APDR.LE.0.) GO TO 122
      IF(APDR.GT.TWHT) GO TO 21
      SI=ASINF(APDR/TWHT)
      ASSIGN 65 TO KR    $    GO TO 66
   65 L1=L1+1    $    XS(L1)=SI    $    XD(L1)=DR
      XR(L1)=D
      IF(APDR.LE.0.) GO TO 122
      SI=SQRTF(APDR/(2.*DLST))
      IF(SI.GT.PI2) SI=PI2
      ASSIGN 123 TO KR    $    GO TO 66
  123 L2=L2+1    $    YS(L2)=SI    $    YD(L2)=DR
      YR(L2)=D
   61 CONTINUE
   21 CONTINUE
      IF(ILB.LE.0) GO TO 162
      DO 150 LA=1,10
      GND=FLOATF(LA)
      DO 151 LG=1,4
      GO TO (155,156,157,158), LG
  155 GRD=(4.*GND-1.)/4.      $     GO TO 159
  156 GRD=GND                 $     GO TO 159
  157 GRD=(4.*GND+1.)/4.      $     GO TO 159
  158 GRD=(2.*GND+1.)/2.      $     GO TO 159
  159 APDR=GRD*ALAM
      IF(APDR.GT.TWHT) GO TO 162
      SI=ASINF(APDR/TWHT)
      IF(SI.GT.PI2) SI=PI2
      ASSIGN 152 TO KR    $    GO TO 66
```

```
152 L1=L1+1    $    XS(L1)=SI    $    XD(L1)=DR     $    XR(L1)=D
    SI=SQRTF(APDR/(2.*DLST))
    ASSIGN 153 TO KR    $    GO TO 66
153 L2=L2+1    $    YS(L2)=SI    $    YD(L2)=DR    $    YR(L2)=D
151 CONTINUE
150 CONTINUE
162 L3=0
    DO 67 LK=1,24
    SI=SID(LK)*RAD
    ASSIGN 124 TO KR    $    GO TO 66
124 L3=L3+1    $    ZS(L3)=SI    $    ZD(L3)=DR
    ZR(L3)=D
 67 CONTINUE
    SI=PI2
    L3=L3+1    $    ZS(L3)=SI    $    ZD(L3)=TWHT $    ZR(L3)=0.
    CALL TABLE(DUM)

C     ----USING TABLE TO OBTAIN STRATIGIC DISTANCE POINTS--------

    LR=0
    DO 70 LA=1,LE
    IF(LA.LT.4) GO TO 88
    LB=13-LA   $    GRD=FLOATF(LB) $ DR=ALAM/GRD    $    LD=LD+1
    IF(DR.GT.TWHT) GO TO 25
 86 CONTINUE
    D=DINTER(DR)
    IF(D.GT.DML) GO TO 70
    LR=LR+1      $     D1(LR)=D
 70 CONTINUE
 25 CONTINUE
    IF(ILB.LE.0) GO TO 163
    DO 172 LA=1,10
    GND=FLOATF(LA)
    DO 173 LG=1,4
    GO TO (165,166,167,168), LG
165 GRD=(4.*GND-1.)/4.      $    GO TO 169
166 GRD=GND                 $    GO TO 169
167 GRD=(4.*GND+1.)/4.      $    GO TO 169
168 GRD=(2.*GND+1.)/2.      $    GO TO 169
169 DR=GRD*ALAM
    IF(DR.GT.TWHT) GO TO 163
    D=DINTER(DR)
    IF(D.GT.DML) GO TO 172
    LR=LR+1      $     D1(LR)=D
173 CONTINUE
172 CONTINUE
163 CONTINUE
    IF(LR)154,164
154 D=D1(LR)    $    SILIM=SINTER(D)
    DO 11 LA=1,LR
    LV=LR+1-LA
 11 D3(LA)=D1(LV)
    D2(1)=DZR
    CALL TSMESH(D2,1,D3,LR,D1,L5)
160 LR=0
    SPD=.1
    DO 800 NSP=1,5
    MZS=NTM(NSP)
    IF(MZS.LE.0) GO TO 107
    DO 801 MXS=1,MZS
    D=SPD*CMK(IK)
    IF(D.GT.DML) GO TO 107
    LR=LR+1      $    D3(LR)=D
803 SPD=SPD+XCON(NSP)
```

```
  801 CONTINUE
      SPD=SPD-XCON(NSP)
      NPP=NSP+1
      IF(NPP.GT.5) GO TO 107
      IF(XCON(NPP).EQ.0.) GO TO 107
      IF(NPP.EQ.0) GO TO 107
      IXD=INTF(SPD/XCON(NPP))
      SPD=(XCON(NPP)*FLOATF(IXD))+XCON(NPP)
  800 CONTINUE
  107 CONTINUE
      CALL TSMESH(D1,L5,D3,LR,D2,LX)
      IF(NOC.LE.0) GO TO 75
C     ---------CALCULATION OF COUNTERPOISE STRATIGIC POINTS------
      LR=0
      DO 600 LK=1,13
      IF(LK.LT.9) GO TO 601
      FLK=LK-8
      DO 603 LG=1,4
      FLG=LG
      GND=((4.*FLK)+FLG)/4.
  602 APDR=GND*ALAM
      IF(APDR.GT.TWHC) GO TO 29
      SI=ASINF(APDR/TWHC)
      ICPT=1
      ASSIGN 40 TO KR   $   GO TO 66
   40 CONTINUE
      IF(D.GT.DML) GO TO 604
      LR=LR+1
      D3(LR)=D
  604 IF(LK.LT.9) GO TO 600
  603 CONTINUE
  600 CONTINUE
   29 CONTINUE
      CLIM=D3(LR)   $   CCIM=D3(1)
      DO 69 I=1,LR
      LV=LR+1-I
   69 D1(I)=D3(LV)
      CALL TSMESH(D1,LR,D2,LX,D3,LK)
  134 DO 129 LV=1,LK
      ICPT=0
   13 SI=SINTER(D3(LV))
      ASSIGN 28 TO KR
C     ----------------RAY OPTICS GEOMETRY----------------------

   66 CSSI=COSF(SI)
      SNSI=SINF(SI)   $   SISQ=SNSI*SNSI
      AKO=EFN/AO   $  ZE=(1./AKO)-1.   $   AKE=1./(1.+(ZE*CSSI))
      AEFT=AO*AKE  $ DHE=EAC*(AKE-1.)/(AKO-1.)
      HTX(1)=HTE   $   HL=H2-DHE   $   HTX(2)=HL-HRP   $  HCL=HL*CKM(IK)
      IF(ICPT.GT.0) GO TO 77
      A=AEFT
   78 CONTINUE
      DO 62 LC=1,2
      Z(LC)=A+HTX(LC) $   TEA(LC)=ACOSF(A*CSSI/Z(LC))-SI
      DA(LC)=Z(LC)*SINF(TEA(LC))
      IF(SI.GT.1.56) GO TO 63
      HPR(LC)=DA(LC)*TANF(SI)
   62 CONTINUE
      DTX=ABSF(Z(1)-Z(2))
      IF(SI.GT.CPI2) GO TO 64
      AFA=ATANF((HPR(2)-HPR(1))/(DA(1)+DA(2)))
      RO=(DA(1)+DA(2))/COSF(AFA)   $   R12=(DA(1)+DA(2))/CSSI
      IF(RO.LT.DTX) RO=DTX
```

```
   68 CA=AFA-TEA(1)   $   TH=TEA(1)+TEA(2)
      DR=4.*HPR(1)*HPR(2)/(R0+R12)
      BA=CA
      CD=CA*DEG
      D=AEFT*TH
      IF(D.LT.0.) D=0.
      DNM=D*CKN(IK)
      GO TO KR,(65,28,123,132,133,124,40,152,153)
C     ---------------------- ----------------------------------
   28 IF(D.LT.0.01) GO TO 129
      IF(D.GT.DML) GO TO 111
      ALFS=AFP+20.*ALOG10(R0)
      PFS=PIRP-ALFS
      GOD=GAIN(CA)
      GPD=20.*ALOG10(GOD)
      Z3=Z(2)-Z(1)
      Z4=(Z(1)*COSF(BA))/Z(2)
      IF(DH.LE.0.) GO TO 42
      DHD=DH*(1.-(0.8*EXPF(-0.02*D)))*1000.
   44 CALL SORB(Z(1),Z(2),A,R0,BA,RE)
      AA=GAO*RE(1)+GAW*RE(2)
   51 IF(ILB.GT.0.AND.SI.LE.SILIM) GO TO 35
      IF( DR.GE.ALA2) GO TO 34
      IF( DR.LE.DTR0) GO TO 26
      FDR=(1.1-(0.9*COSF(PKL*( DR-DTR0))))*.5
   43 CONTINUE
      CALL RECC(SI,F,KSC,IPL,0,DHD,R,PIC,RD)
      GA=-(TEA(1)+SI)        $   GAMD=GA*DEG  $   GOG=GAIN(GA)
      RDG=RD*GOG
      REC=0.0
      REG=R*GOG
      RLG=REG
      IF(NOC.LE.0) GO TO 500
C     ---------CALCULATION OF COUNTERPOISE CONTRIBUTION----------
      TEG=ABTC-ABSF(SI+TEA(1))   $   TEG=ABSF(TEG)
      VFGD=2.*SINF(TEG*.5)*SQVT
      IF(ABSF(GA).LT.ABTC) VFGD=-VFGD
      CALL FRENEL(VFGD,FPGD,PHIG)
      REG=REG*FPGD
      RDG=RDG*FPGD
      TRM3=PHIG+(PI2*VFGD*VFGD)
      IF(D.LT.CLIM.OR.D.GT.CCIM) GO TO 146
      SIC=CA
      TEC=ABSF(BTC-CA)   $   DARC=2.*HFC*SINF(CA)
      SIT1=-SIC        $ GOC=GAIN(SIT1)
      VFCP=2.*SINF(TEC*.5)*SQVT
      IF(ABSF(CA).GT.ABTC) VFCP=-VFCP
      CALL FRENEL(VFCP,FPCP,PHIC)
      CALL RECC(SIC,F,ICC,IPL,1,DHD,RC,PICC,RDC)
      RLC=RC*GOC
      REC=RLC*FPCP
      EXPC=(TWPILA*DARC)+PICC+(PHIC+(PI2 *VFCP*VFCP))
      ATRM=REC*COSF(EXPC)   $   BTRM=-REC*SINF(EXPC)
      AT1=CMPLX(ATRM,BTRM)
  147 CONTINUE
C     --------------CALCULATION OF LOBING CONTRIBUTION-----------
      IF(SI.GT.SILIM) GO TO 135
      EXPG=(TWPILA*DR)+PIC+TRM3
      ATRM=REG*COSF(EXPG)   $   BTRM=-REG*SINF(EXPG)
```

```
C      -------------------SUMMATION OF TERMS--------------------
  136 AT2=CMPLX(ATRM,BTRM)
      WRL=CABS(GOD+AT1+AT2)     $    WR=WRL*WRL+.0001
      PR=10.*ALOG10(WR)
      IF(D.LE.DZR) GO TO 148
      IF(LV.EQ.1) GO TO 148
      PL=FNA(D,DML,DZR,PRH,PZ)
      WL=10.**(.1*PL)
  149 CONTINUE
C      ----------------LONG-TERM POWER FADING------------------

      PL=PL-GPD
      IF(D.LE.0.) GO TO 38
      IF(D.LE.DSL1) 301,302
  301 DEE=(130.*D)/DSL1    $    GO TO 303
  302 DEE=130.+D-DSL1    $    GO TO 303
  303 CALL VZD(DEE,QG1,QG9,AD)
      IF(CA.LE.0.) GO TO 32
      IF(CA.GE.1.) GO TO 33
      FTH=.5-BSPI*(ATANF(20.*ALOG10(32.*CA)))
      IF(FTH.LE.0.0) GO TO 33
   52 AL10=PL+(AD(13)*FTH)      $    AY=AL10-ALIM
      IF(AY.LT.0.) AY=0.
   53 IF(ILB.GT.0.AND.SI.LE.SILIM) GO TO 22
      DO 31 K=1,35
      VD(K)=AD(K)*FTH-AY      $      BD(K)=PL+VD(K)
   31 CONTINUE
      DO 50 K=1,12
      ALLM=-ALM(K)
      IF(BD(K).GT.ALLM) BD(K)=ALLM
   50 CONTINUE
   24 CONTINUE
C      -------------VALUES PUT INTO PLOTTING ARRAY---------------

      NCT=NCT+1
      BX(NCT,1)=BX(NCT,2)=BX(NCT,3)=BX(NCT,4)=DNM
      BX(NCT,5)=BX(NCT,6)=BX(NCT,7)=BX(NCT,8)=DNM
      IF(KK.GT.1) GO TO 20
   23 PGS=PFS+GPD
      BY(NCT,1)=PGS                 $     BY(NCT,2)=PGS+BD(18)-AA
      BY(NCT,3)=PGS+BD(12)-AA       $     BY(NCT,4)=PGS+BD(24)-AA
      BY(NCT,5)=PGS+BD(23)-AA       $     BY(NCT,6)=PGS+BD(26)-AA
      BY(NCT,7)=PGS+BD(29)-AA       $     BY(NCT,8)=PGS+BD(32)-AA
      PFY(NCT,1)=PGS+BD(4)-AA       $      PFY(NCT,2)=PGS+BD(7)-AA
      PFY(NCT,3)=PGS+BD(10)-AA      $      PFY(NCT,4)=PGS+BD(13)-AA
      PRINT 760,DNM,(BY(NCT,LZ),LZ=1,8),(PFY(NCT,MW),MW=1,4),PL,AA,AY,BK
     X,DEE
      CALL PAGE(1)
  129 CONTINUE
  111 CONTINUE
      NU(1)=NCT     $      RETURN
C      -------------------RETURN TO MAIN PROGRAM-----------------

   15 FAY=1.     $      GO TO 17
   16 FAY=0.1    $      GO TO 17
C      ------------------TROPOSHERIC MULTIPATH------------------
   20 DO 30 I=1,35
      PQA(I)=P(I)
      QA(I)=BD(I)-PL
   30 CONTINUE
      IF(AY.LE.0.) GO TO 15
```

```
      IF(AY.GE.6.) GO TO 16
      FAY=(1.1+(0.9*COSF((AY/6.)*PI)))/2.
   17 CONTINUE
      RSP=REG*FDR*FAY
      IF(RE(2).LE.0.) GO TO 45
      RK=-10.*ALOG10(ASPC*(RE(2)**3))
      ACK=FDASP(RK)     $    WA=10.**(.1*ACK)
   46 RST=((RSP*RSP)+(RDG*RDG)+WA)
      IF(RST.LE.0.) GO TO 37
      BK   =+10.*ALOG10(RST)
      IF(BK.LT.-40.) BK=-40.
   47 CALL YIKK(BK,PQK,QK)
      RDHK=BK
      CALL CONLUT(QA,QK,PQA,35,+1.,0.,PQC,QC)
      DO 27 I=1,35
   27 BD(I)=QC(I)+PL
      GO TO 23

   37 BK=-40.    $    GO TO 47
C     --------------------LOBING MODE------------------------------
   22 AY=0.
      TLIM=+20.*ALOG10(GOD+RLG+RLC)
      BLIM=-80.
      DO 36 K=1,35
      VD(K)=AD(K)*FTH     $    BD(K)=PL+VD(K)-AA
      IF(BD(K).GT.TLIM) BD(K)=TLIM
      IF(BD(K).LT.BLIM) BD(K)=BLIM
      BD(K)=BD(K)+AA
   36 CONTINUE
      GO TO 24

   26 FDR=0.1    $    GO TO 43
   32 FTH=1.0      $    GO TO 52
   33 FTH=0.0    $    AY=0.0    $    GO TO 53
   34 FDR=1.    $    GO TO 43
   35 FDR=0.        $      GO TO 43
   38 DEE=0.              $     GO TO 303
   42 DHD=0.0    $    GO TO 44
   63 HPR(LC)=HTX(LC)        $      GO TO 62
   45 WA=.0001      $      GO TO 46
   64 AFA=SI   $     R0=HTX(2)-HTX(1)   $    R12=HTX(1)+HTX(2)   $   GO TO 68
   75 DO 74 LK=1,LX
   74 D3(LK)=D2(LK)
      LK=LX
      LR=LX
      GO TO 134
   77 HTX(1)=HFC     $     HTX(2)=HTX(2)-HDI     $     A=AEFT+HDI
      ICPT=0    $    GO TO 78
   88 GRD=SPGRD(LA)    $     DR=ALAM*GRD     $   LD=LD+1   $   GO TO 86
  120 GRD=SPGRD(LK)    $ APDR=ALAM*GRD     $  GO TO 121
  122 SI=0.    $     DR=0.    $      D=DLST+DLSR     $     GO TO 123
  135 ATRM=0.    $     BTRM=0.    $     GO TO 136
  164 D1(1)=DZR    $     L5=1    $    SILIM=0.     $     GO TO 160
  500 TRM3=0.0
  146 ATRM=0.    $     BTRM=0.     $     AT1=CMPLX(ATRM,BTRM)     $ RLC=0.0
      GO TO 147
  148 PL=PR      $     PZ=PR     $      WL=WR     $     GO TO 149
  502 BTC=SQVT=0.    $    HDI=HTE     $    GO TO 503
  601 GND=GLD(LK)     $     GO TO 602
      END
```

ASORP

Subroutine ASORP is used in the calculation of atmospheric absorption (sec. A.4.5) to obtain surface absorption rates, $\gamma_{oo,w}$ dB/km, for oxygen and water vapor when such values are not provided as input (table 1). Interpolation between available values [40, fig. 3.1] is used to provide $\gamma_{oo,w}$ values for frequencies up to 100 GHz.

```
      SUBROUTINE ASORP(FK,AO,AW)
C     ROUTINE FOR MODEL AUG 73
   19 FORMAT(5X*FREQUENCY IS TOO HIGH FOR ABSORPTION TABLE   USING VALUE
     XS FOR 100 GHZ*)
      DIMENSION ZX(53),ZW(53),FZ(53)
      DATA(FZ=.10,.15,.205,.30,.325,.35,.40,.55,.70,1.0,1.52,2.0,3.0,3.4
     F,4.0,4.9,8.3,10.2,15.0,17.0,20.0,22.0,23.0,25.0,26.,30.,32.0,33.,3
     F5.,37.,38.,40.,42.,43.,44.,47.,48.,51.,54.,58.,59.,60.,61.,62.,63.
     F,64.,68.,70.,72.,76.,84.,90.,100.)
      DATA(ZX=.00019,.00042,.00070,.00096,.0013,.0015,.0018,.0024,.003,.
     X0042,.005,.007,.0088,.0092,.010,.011,.014,.015,.017,.018,.020,.021
     X,.022,.024,.027,.030,.032,.035,.040,.044,.050,.060,.070,.090,.100,
     X.15,.23,.50,1.8,4.0,7.0,15.0,8.0,5.0,3.0,1.7,1.2,.90,.50,.35,.20,.
     X14,.10)
      DATA(ZW=13(0.0),.0001,.00017,.00034,.0021,.009,.025,.045,.10,.22,.
     W20,.16,.15,.11,.14,.10,.099,.098,.0963,.0967,.0981,.0987,.099,.100
     W,.101,.103,.109,.118,.120,.122,.127,.130,.132,.138,.154,.161,.175,
     W.20,.25,.34,.56)
      TEN=10.
      F=FK*.001
      IF(F.LT..1) F=.1
      IF(F.GT.100.) GO TO 20
      DO 10 I=1,53
      IF(F-FZ(I))12,11,10
   10 CONTINUE
      GO TO 20
   12 IF(I.EQ.1) I=2
   13 L=I-1
      A=ALOG10(F)    $    B=ALOG10(FZ(I))    $    C=ALOG10(FZ(L))
      R=(A-C)/(B-C)
      D=ALOG10(ZX(I))    $    E=ALOG10(ZX(L))
      AR=(R*(D-E))+E       $    AO=TEN**AR
      IF(I.LE.13) GO TO 21
      G=ALOG10(ZW(I))    $    H=ALOG10(ZW(L))
      WR=(R*(G-H))+H    $    AW=TEN**WR
      RETURN
   20 PRINT 19    $    AO=.10    $    AW=.56    $    RETURN
   11 AO=ZX(I)    $    AW=ZW(I)    $    RETURN
   21 AW=0.0000     $    RETURN
      END
```

BLOS

Subroutine BLOS is used only with the station separation program (sec. B.2), and is similar to ALOS and CLOS, which are used with the other programs. BLOS performs calculations associated with the line-of-sight region (sec. A.4.2).

```
      SUBROUTINE BLOS
C     L-O-S SUBROUTINE FOR DOVERU
C     ROUTINE FOR MODEL AUG 73

    5 FORMAT(1H )
      DIMENSION XCON(5),NTM(5)
      DIMENSION CFK(3),CMK(3),CFM(3),CKM(3),CKN(3)
      DIMENSION GLD(8),D1(200),D2(200),D3(200)
      DIMENSION HTX(2),Z(2),TEA(2),DA(2),HPR(2)
      DIMENSION SID(24)
      DIMENSION SPGRD(3)
      DIMENSION RE(2),BD(35),VD(35)
      DIMENSION ALM(12),AD(35)
      DIMENSION P(35),QC(50),QA(50),PQA(50),PQK(50),QK(50),PQC(50)
      DIMENSION YV(10),SV(10)
      COMMON/FGAP/IP,LN,IDT,IXT
      COMMON/DIFPR/HT ,HR ,DH,AED,SLP,DLST,DLSR,IPL,KSC,HLT,HRP,AWD,SWP
      COMMON/PAOUT/NCT,PFY(200,6)
      COMMON/PARAM/HTE,HRE,D,DLT,DLR,ENS,EFRTH,FREK,ALAM,TET,TER,KD,GAO,
     XGAW
      COMMON/SIGHT/DCW,HCW,DM1X,DML,DZR,IK,EAC,H2,ICC,HFC,PRH,DSL1,PIRP,
     XQG1,QG9,KK,ZH,RDHK,ILB
      COMMON/SPLIT/L1,L2,N,X(140),Y(140),D6(140),XS(55),XD(55),XR(55),YS
     X(55),YD(55),YR(55),L3,ZS(25),ZD(25),ZR(25)
      DATA (CFK=.001,.0003048,.0003048)
      DATA  ((P(I),I=1,35)=.00001,.00002,.00005,.0001,.0002,.0005,.001,.
     X002,.005,.01,.02,.05,.1 ,.15,.20,.30,.40,.50,.60,.70,.80,.85,.90,.
     X95,.98,.99,.995,.998,.999,.9995,.9998,.9999,.99995,.99998,.99999)
      DATA (CMK=1.,1.609344,1.852)
      DATA (CFM=1.,.3048,.3048)
      DATA (CKM=1000.,3280.839895,3280.839895)
      DATA (CKN=1.,.6213711922,.5399568034)
      DATA(XCON=1.,5.,10.,25.,0.)
      DATA(NTM=10,19,30,10,0)
      DATA (GLD=0.,.1,.2,.3,.4,.5,.75,1.)
      DATA(ALM=-6.2,-6.15,-6.08,-6.0,-5.95,-5.88,-5.8,-5.65,-5.35,-5.0,-
     X4.5,-3.7)
      DATA (SPGRD=0.,.06,.1)
      DATA (SID=.2,.5,.7,1.,1.2,1.5,1.7,2.,2.5,3.,3.5,4.,5.,6.,7.,8.,10.
     X,20.,45.,70.,80.,85.,88.,89.)
      COMPLEX AT1,AT2
      FNA(FX,FA,FB,FC,FD)=((FX-FB)*(FC-FD)/(FA-FB))+FD
      BSPI=.3183098862
      RAD=.01745329252    $    DEG=57.29577951    $    TWDG=12.*RAD
      ALIM=3.
      PI=3.141592654      $    TWPI=6.283185307
      F=FREK
      PI2=1.570796327         $      CPI2=1.56
```

```
      DKAX=DMAX*CMK(IK)
      AFP=32.45+20.*ALOG10(FREK)
      ALA2=ALAM/2.
      ASPA=0.25    $    ASPB=0.25
      ASPC=ASPA*ASPB*(6.E-8)*F
      TWPILA=TWPI/ALAM
      DTRO=ALAM/6.
      ERTH =6370.
      AO=ERTH   $   EFN=EFRTH
      PKL=((3.*PI)/(ALAM))
      NCT=0
      NOC=0
      IF(ICC.GT.0) NOC=1
      CDRK=20.95841232*F
      IF(NOC.LE.0) GO TO 502
                             RCW=DCW*.5   $   BTC=ATANF(HFC/RCW)
      ABTC=ABSF(BTC)   $   R1C=RCW/COSF(BTC)   $   SQVT=SQRTF(2.*R1C/ALAM)
      HDI=HTE-HFC      $        TWHC=2.*HFC
  503 CONTINUE
      L1=L2=N=0
      TWHT=2.*HTE

C     ------SETTING UP OF TABLE OF SI, DELTA R AND DISTANCE------

      LE=7   $   IF(ILB.GT.0) LE=11
      DO 61 LK=1,LE
      IF(LK.LT.4) GO TO 120
      LB=13-LK   $   GRD=FLOATF(LB)   $   APDR=ALAM/GRD
  121 IF(APDR.LE.0.) GO TO 122
      IF(APDR.GT.TWHT) GO TO 21
      SI=ASINF(APDR/TWHT)
      ASSIGN 65 TO KR   $   GO TO 66
   65 L1=L1+1   $   XS(L1)=SI   $   XD(L1)=DR
      XR(L1)=D
      IF(APDR.LE.0.) GO TO 122
      SI=SQRTF(APDR/(2.*DLST))
      IF(SI.GT.PI2) SI=PI2
      ASSIGN 123 TO KR   $   GO TO 66
  123 L2=L2+1   $   YS(L2)=SI   $   YD(L2)=DR
      YR(L2)=D
   61 CONTINUE
   21 CONTINUE
      IF(ILB.LE.0) GO TO 162
      DO 150 LA=1,10
      GND=FLOATF(LA)
      DO 151 LG=1,4
      GO TO (155,156,157,158), LG
  155 GRD=(4.*GND-1.)/4.      $    GO TO 159
  156 GRD=GND                 $    GO TO 159
  157 GRD=(4.*GND+1.)/4.      $    GO TO 159
  158 GRD=(2.*GND+1.)/2.      $    GO TO 159
  159 APDR=GRD*ALAM
      IF(APDR.GT.TWHT) GO TO 162
      SI=ASINF(APDR/TWHT)
      IF(SI.GT.PI2) SI=PI2
      ASSIGN 152 TO KR   $   GO TO 66
  152 L1=L1+1   $   XS(L1)=SI   $   XD(L1)=DR    $   XR(L1)=D
      SI=SQRTF(APDR/(2.*DLST))
      ASSIGN 153 TO KR   $   GO TO 66
  153 L2=L2+1   $   YS(L2)=SI   $   YD(L2)=DR   $   YR(L2)=D
  151 CONTINUE
  150 CONTINUE
  162 L3=0
      DO 67 LK=1,24
      SI=SID(LK)*RAD
```

```
      ASSIGN 124 TO KR    $    GO TO 66
  124 L3=L3+1    $    ZS(L3)=SI    $    ZD(L3)=DR
      ZR(L3)=D
   67 CONTINUE
      SI=PI2
      L3=L3+1    $    ZS(L3)=SI    $    ZD(L3)=TWHT $    ZR(L3)=0.
      CALL TABLE(DUM)
C     ----USING TABLE TO OBTAIN STRATEGIC DISTANCE POINTS---------
      LR=0
      DO 70 LA=1,LE
      IF(LA.LT.4) GO TO 88
      LB=13-LA   $    GRD=FLOATF(LB) $ DR=ALAM/GRD    $    LD=LD+1
      IF(DR.GT.TWHT) GO TO 25
   86 CONTINUE
      D=DINTER(DR)
      IF(D.GT.DML) GO TO 70
      LR=LR+1     $     D1(LR)=D
   70 CONTINUE
   25 CONTINUE
      IF(ILB.LE.0) GO TO 163
      DO 172 LA=1,10
      GND=FLOATF(LA)
      DO 173 LG=1,4
      GO TO (165,166,167,168), LG
  165 GRD=(4.*GND-1.)/4.      $    GO TO 169
  166 GRD=GND                 $    GO TO 169
  167 GRD=(4.*GND+1.)/4.      $    GO TO 169
  168 GRD=(2.*GND+1.)/2.      $    GO TO 169
  169 DR=GRD*ALAM
      IF(DR.GT.TWHT) GO TO 163
      D=DINTER(DR)
      IF(D.GT.DML) GO TO 172
      LR=LR+1     $     D1(LR)=D
  173 CONTINUE
  172 CONTINUE
  163 CONTINUE
      IF(LR)154,164
  154 D=D1(LR)    $    SILIM=SINTER(D)
      DO 11 LA=1,LR
      LV=LR+1-LA
   11 D3(LA)=D1(LV)
      D2(1)=DZR
      CALL TSMESH(D2,1,D3,LR,D1,L5)
  160 LR=0
      SPD=.1
      DO 800 NSP=1,5
      MZS=NTM(NSP)
      IF(MZS.LE.0) GO TO 107
     DO 801 MXS=1,MZS
     D=SPD*CMK(IK)
     IF(D.GT.DML) GO TO 107
     LR=LR+1     $    D3(LR)=D
 803 SPD=SPD+XCON(NSP)
 801 CONTINUE
     SPD=SPD-XCON(NSP)
     NPP=NSP+1
     IF(NPP.GT.5) GO TO 107
     IF(XCON(NPP).EQ.0.) GO TO 107
     IF(NPP.EQ.0) GO TO 107
     IXD=INTF(SPD/XCON(NPP))
     SPD=(XCON(NPP)*FLOATF(IXD))+XCON(NPP)
 800 CONTINUE
 107 CONTINUE
```

```
      CALL TSMESH(D1,L5,D3,LR,D2,LX)
      IF(NOC.LE.0) GO TO 75
C     ----------CALCULATION OF COUNTERPOISE STRATEGIC POINTS------
      LR=0
      DO 600 LK=1,13
      IF(LK.LT.9) GO TO 601
      FLK=LK-8
      DO 603 LG=1,4
      FLG=LG
      GND=((4.*FLK)+FLG)/4.
  602 APDR=GND*ALAM
      IF(APDR.GT.TWHC) GO TO 29
      SI=ASINF(APDR/TWHC)
      ICPT=1
      ASSIGN 40 TO KR   $   GO TO 66
   40 CONTINUE
      IF(D.GT.DML) GO TO 604
      LR=LR+1
      D3(LR)=D
  604 IF(LK.LT.9) GO TO 600
  603 CONTINUE
  600 CONTINUE
   29 CONTINUE
      PRINT 5   $   CALL PAGE(1)
      CLIM=D3(LR)   $   CCIM=D3(1)
      DO 69 I=1,LR
      LV=LR+1-I
   69 D1(I)=D3(LV)
      CALL TSMESH(D1,LR,D2,LX,D3,LK)
  134 DO 129 LV=1,LK
      ICPT=0
   13 SI=SINTER(D3(LV))
      ASSIGN 28 TO KR
C     ---------------RAY OPTICS GEOMETRY----------------------
   66 CSSI=COSF(SI)
      SNSI=SINF(SI)   $   SISQ=SNSI*SNSI
      AKO=EFN/AO   $  ZE=(1./AKO)-1.   $   AKE=1./(1.+(ZE*CSSI))
      AEFT=AO*AKE  $ DHE=EAC*(AKE-1.)/(AKO-1.)
      HTX(1)=HTE   $   HL=H2-DHE   $   HTX(2)=HL-HRP   $  HCL=HL*CKM(IK)
      IF(ICPT.GT.0) GO TO 77
      A=AEFT
   78 CONTINUE
      DO 62 LC=1,2
      Z(LC)=A+HTX(LC) $   TEA(LC)=ACOSF(A*CSSI/Z(LC))-SI
      DA(LC)=Z(LC)*SINF(TEA(LC))
      IF(SI.GT.1.56) GO TO 63
      HPR(LC)=DA(LC)*TANF(SI)
   62 CONTINUE
      DTX=ABSF(Z(1)-Z(2))
      IF(SI.GT.CPI2) GO TO 64
      AFA=ATANF((HPR(2)-HPR(1))/(DA(1)+DA(2)))
      RO=(DA(1)+DA(2))/COSF(AFA)   $   R12=(DA(1)+DA(2))/CSSI
      IF(RO.LT.DTX) RO=DTX
   68 CA=AFA-TEA(1)   $   TH=TEA(1)+TEA(2)
      DR=4.*HPR(1)*HPR(2)/(RO+R12)
      BA=CA
      CD=CA*DEG
      D=AEFT*TH
      IF(D.LT.0.) D=0.
      DNM=D*CKN(IK)
      GO TO KR,(65,28,123,132,133,124,40,152,153)
```

```
C     ---------------------- -------------------------------

   28 IF(D.LT.0.01) GO TO 129
      IF(D.GT.DML) GO TO 111
      ALFS=AFP+20.*ALOG10(RO)
      PFS=PIRP-ALFS
      GOD=GAIN(CA)
      GPD=20.*ALOG10(GOD)
      Z3=Z(2)-Z(1)
      Z4=(Z(1)*COSF(BA))/Z(2)
      IF(DH.LE.0.) GO TO 42
      DHD=DH*(1.-(0.8*EXPF(-0.02*D)))*1000.
   44 CALL SORB(Z(1),Z(2),A,RO,BA,RE)
      AA=GAO*RE(1)+GAW*RE(2)
   51 IF(ILB.GT.0.AND.SI.LE.SILIM) GO TO 35
      IF( DR.GE.ALA2) GO TO 34
      IF( DR.LE.DTRO) GO TO 26
      FDR=(1.1-(0.9*COSF(PKL*( DR-DTRO))))*.5
   43 CONTINUE
      CALL RECC(SI,F,KSC,IPL,0,DHD,R,PIC,RD)
      GA=-(TEA(1)+SI)        $    GAMD=GA*DEG  $    GOG=GAIN(GA)
      RDG=RD*GOG
      REC=0.0
      REG=R*GOG
      RLG=REG
      IF(NOC.LE.0) GO TO 500

C     ---------CALCULATION OF COUNTERPOISE CONTRIBUTION----------
      TEG=ABTC-ABSF(SI+TEA(1))   $    TEG=ABSF(TEG)
      VFGD=2.*SINF(TEG*.5)*SQVT
      IF(ABSF(GA).LT.ABTC) VFGD=-VFGD
      CALL FRENEL(VFGD,FPGD,PHIG)
      REG=REG*FPGD
      RDG=RDG*FPGD
      TRM3=PHIG+(PI2*VFGD*VFGD)
      IF(D.LT.CLIM.OR.D.GT.CCIM) GO TO 146
      SIC=CA
      TEC=ABSF(BTC-CA)   $    DARC=2.*HFC*SINF(CA)
      SIT1=-SIC        $ GOC=GAIN(SIT1)
      VFCP=2.*SINF(TEC*.5)*SQVT
      IF(ABSF(CA).GT.ABTC) VFCP=-VFCP
      CALL FRENEL(VFCP,FPCP,PHIC)
      CALL RECC(SIC,F,ICC,IPL,1,DHD,RC,PICC,RDC)
      RLC=RC*GOC
      REC=RLC*FPCP
      EXPC=(TWPILA*DARC)+PICC+(PHIC+(PI2 *VFCP*VFCP))
      ATRM=REC*COSF(EXPC)   $    BTRM=-REC*SINF(EXPG)
      AT1=CMPLX(ATRM,BTRM)
  147 CONTINUE

C     --------------CALCULATION OF LOBING CONTRIBUTION-----------
      IF(SI.GT.SILIM) GO TO 135
      EXPG=(TWPILA*DR)+PIC+TRM3
      ATRM=REG*COSF(EXPG)   $    BTRM=-REG*SINF(EXPG)

C     -------------------SUMMATION OF TERMS---------------------
  136 AT2=CMPLX(ATRM,BTRM)
      WRL=CABS(GOD+AT1+AT2)     $    WR=WRL*WRL+.0001
      PR=10.*ALOG10(WR)
      IF(D.LE.DZR) GO TO 148
      IF(LV.EQ.1.) GO TO 148
      PL=FNA(D,DML,DZR,PRH,PZ)
      WL=10.**(.1*PL)
  149 CONTINUE
```

```
C     ----------------LONG-TERM POWER FADING------------------

      PL=PL-GPD
      IF(D.LE.0.) GO TO 38
      IF(D.LE.DSL1) 301,302
  301 DEE=(130.*D)/DSL1    $    GO TO 303
  302 DEE=130.+D-DSL1    $    GO TO 303
  303 CALL VZD(DEE,QG1,QG9,AD)
      IF(CA.LE.0.) GO TO 32
      IF(CA.GE.1.) GO TO 33
      FTH=.5-BSPI*(ATANF(20.*ALOG10(4.*CA)))
      IF(FTH.LE.0.0) GO TO 33
   52 AL10=PL+(AD(13)*FTH)       $     AY=AL10-ALIM
      IF(AY.LT.0.) AY=0.
   53 IF(ILB.GT.0.AND.SI.LE.SILIM) GO TO 22
      DO 31 K=1,35
      VD(K)=AD(K)*FTH-AY       $       BD(K)=PL+VD(K)
   31 CONTINUE
      DO 50 K=1,12
      ALLM=-ALM(K)
      IF(BD(K).GT.ALLM) BD(K)=ALLM
   50 CONTINUE
   24 CONTINUE

C     -------------VALUES PUT INTO PLOTTING ARRAY---------------

      NCT=NCT+1
      IF(KK.GT.1) GO TO 20
   23 PGS=PFS+GPD
      PFL=PGS+PL-AA
      PFY(NCT,1)=DNM      $    PFY(NCT,2)=PGS        $    PFY(NCT,3)=PFL
      PFY(NCT,4)=BD(12)-PL     $       PFY(NCT,5)=BD(18)-PL
      PFY(NCT,6)=BD(24)-PL
  129 CONTINUE
  111 CONTINUE
      RETURN

C     -------------------RETURN TO POWSUB---------------------

   15 FAY=1.      $      GO TO 17
   16 FAY=0.1     $      GO TO 17

C     ------------------TROPOSPHERIC MULTIPATH-----------------

   20 DO 30 I=1,35
      PQA(I)=P(I)
      QA(I)=BD(I)-PL
   30 CONTINUE
      IF(AY.LE.0.) GO TO 15
      IF(AY.GE.6.) GO TO 16
      FAY=(1.1+(0.9*COSF((AY/6.)*PI)))/2.
   17 CONTINUE
      RSP=REG*FDR*FAY
      IF(RE(2).LE.0.) GO TO 45
      RK=-10.*ALOG10(ASPC*(RE(2)**3))
      ACK=FDASP(RK)     $    WA=10.**(.1*ACK)
   46 RST=((RSP*RSP)+(RDG*RDG)+WA)
      IF(RST.LE.0.) GO TO 37
      BK  =+10.*ALOG10(RST)
      IF(BK.LT.-40.) BK=-40.
   47 CALL YIKK(BK,PQK,QK)
      RDHK=BK
      CALL CONLUT(QA,QK,PQA,35,+1.,0.,PQC,QC)
      DO 27 I=1,35
   27 BD(I)=QC(I)+PL
```

```
      GO TO 23
   37 BK=-40.   $   GO TO 47
C     ------------------LOBING MODE----------------------------
   22 AY=0.
      TLIM=+20.*ALOG10(GOD+RLG+RLC)
      BLIM=-80.
      DO 36 K=1,35
      VD(K)=AD(K)*FTH     $    BD(K)=PL+VD(K)-AA
      IF(BD(K).GT.TLIM) BD(K)=TLIM
      IF(BD(K).LT.BLIM) BD(K)=BLIM
      BD(K)=BD(K)+AA
   36 CONTINUE
      GO TO 24

   26 FDR=0.1    $    GO TO 43
   32 FTH=1.0       $    GO TO 52
   33 FTH=0.0    $    AY=0.0    $    GO TO 53
   34 FDR=1.    $    GO TO 43
   35 FDR=0.       $     GO TO 43
   38 DEE=0.               $     GO TO 303
   42 DHD=0.0    $    GO TO 44
   45 WA=.0001      $     GO TO 46
   63 HPR(LC)=HTX(LC)      $      GO TO 62
   64 AFA=SI   $     RO=HTX(2)-HTX(1)   $    R12=HTX(1)+HTX(2)   $   GO TO 68
   75 DO 74 LK=1,LX
   74 D3(LK)=D2(LK)
      LK=LX
      LR=LX
      GO TO 134
   77 HTX(1)=HFC    $    HTX(2)=HTX(2)-HDI    $    A=AEFT+HDI
      ICPT=0    $    GO TO 78
   88 GRD=SPGRD(LA)    $    DR=ALAM*GRD    $   LD=LD+1   $   GO TO 86
  120 GRD=SPGRD(LK)    $ APDR=ALAM*GRD    $   GO TO 121
  122 SI=0.    $    DR=0.    $    D=DLST+DLSR    $    GO TO 123
  135 ATRM=0.    $    BTRM=0.    $    GO TO 136
  164 D1(1)=DZR    $    L5=1    $    SILIM=0.    $    GO TO 160
  500 TRM3=0.0
  146 ATRM=0.    $    BTRM=0.    $    AT1=CMPLX(ATRM,BTRM)    $ RLC=0.0
      GO TO 147
  148 PL=PR    $    PZ=PR    $    WL=WR    $    GO TO 149
  502 BTC=SQVT=0.    $    HDI=HTE    $    GO TO 503
  601 GND=GLD(LK)    $    GO TO 602
      END
```

CLOS

Subroutine CLOS is used only with the service volume program (sec. B.3), and is similar to ALOS and BLOS, which are used with the other programs. CLOS performs calculations associated with the line-of-sight region (sec. A.4.2).

```
      SUBROUTINE CLOS
C     L-O-S SUBROUTINE FOR SRVVOLM
C     ROUTINE FOR MODEL AUG 73
    5 FORMAT(1H )
```

```
      DIMENSION XCON(5),NTM(5)
      DIMENSION CFK(3),CMK(3),CFM(3),CKM(3),CKN(3)
      DIMENSION GLD(8),D1(200),D2(200),D3(200)
      DIMENSION HTX(2),Z(2),TEA(2),DA(2),HPR(2)
      DIMENSION SID(24)
      DIMENSION SPGRD(3)
      DIMENSION RE(2),BD(35),VD(35)
      DIMENSION ALM(12),AD(35)
      DIMENSION P(35),QC(50),QA(50),PQA(50),PQK(50),QK(50),PQC(50)
      DIMENSION YV(10),SV(10)
      COMMON/EGAP/IP,LN,IDT,IXT
      COMMON/PAOUT/NCT,PFY(125,6),JJ,HP1,HP2
      COMMON/PARAM/HTE,HRE,D,DLT,DLR,ENS,EFRTH,FREK,ALAM,TET,TER,KD,GAO,
     XGAW
      COMMON/DIFPR/HT ,HR ,DH,AED,SLP,DLST,DLSR,IPL,KSC,HLT,HRP,AWD,SWP
      COMMON/SIGHT/DCW,HCW,DMAX,DML,DZR,IK,EAC,H2,ICC,HFC,PRH,DSL1,PIRP,
     XQG1,QG9,KK,ZH,RDHK,ILB
      COMMON/SPLIT/L1,L2,N,X(140),Y(140),D6(140),XS(55),XD(55),XR(55),YS
     X(55),YD(55),YR(55),L3,ZS(25),ZD(25),ZR(25)
      DATA (CFK=.001,.0003048,.0003048)
      DATA  ((P(I),1=1,35)=.00001,.00002,.00005,.0001,.0002,.0005,.001,.
     X002,.005,.01,.02,.05,.10,.15,.20,.30,.40,.50,.60,.70,.80,.85,.90,.
     X95,.98,.99,.995,.998,.999,.9995,.9998,.9999,.99995,.99998,.99999)
      DATA (CMK=1.,1.609344,1.852)
      DATA (CFM=1.,.3048,.3048)
      DATA (CKM=1000.,3280.839895,3280.839895)
      DATA (CKN=1.,.6213711922,.5399568034)
      DATA(XCON=1.,5.,10.,25.,0.)
      DATA(NTM=10,19,30,10,0)
      DATA (GLD=0.,.1,.2,.3,.4,.5,.75,1.)
      DATA(ALM=-6.2,-6.15,-6.08,-6.0,-5.95,-5.88,-5.8,-5.65,-5.35,-5.0,-
     X4.5,-3.7)
      DATA (SPGRD=0.,.06,.1)
      DATA (SID=.2,.5,.7,1.,1.2,1.5,1.7,2.,2.5,3.,3.5,4.,5.,6.,7.,8.,10.
     X,20.,45.,70.,80.,85.,88.,89.)
      COMPLEX AT1,AT2
      FNA(FX,FA,FB,FC,FD)=((FX-FB)*(FC-FD)/(FA-FB))+FD
      BSPI=.3183098862
      RAD=.01745329252    $    DEG=57.29577951    $    TWDG=12.*RAD
      ALIM=3.
      PI=3.141592654      $    TWPI=6.283185307
      F=FREK
      PI2=1.570796327        $      CPI2=1.56
      DKAX=DMAX*CMK(IK)
      AFP=32.45+20.*ALOG10(FREK)
      ALA2=ALAM/2.
      ASPA=0.25     $     ASPB=0.25
      ASPC=ASPA*ASPB*(6.E-8)*F
      TWPILA=TWPI/ALAM
      DTRO=ALAM/6.
      ERTH =6370.
      AO=ERTH    $    EFN=EFRTH
      PKL=((3.*PI)/(ALAM))
      NCT=0
      NOC=0
      IF(ICC.GT.0) NOC=1
      CDRK=20.95841232*F
      IF(NOC.LE.0) GO TO 502
                           RCW=DCW*.5    $    BTC=ATANF(HFC/RCW)
      ABTC=ABSF(BTC)    $    R1C=RCW/COSF(BTC)   $   SQVT=SQRTF(2.*R1C/ALAM)
      HDI=HTE-HFC       $         TWHC=2.*HFC
  503 CONTINUE
      L1=L2=N=0
      TWHT=2.*HTE
```

```
C      ------SETTING UP OF TABLE OF SI, DELTA R AND DISTANCE------

      LE=7   $   IF(ILB.GT.0) LE=11
      DO 61 LK=1,LE
      IF(LK.LT.4) GO TO 120
      LB=13-LK   $   GRD=FLOATF(LB)   $   APDR=ALAM/GRD
  121 IF(APDR.LE.0.) GO TO 122
      IF(APDR.GT.TWHT) GO TO 21
      SI=ASINF(APDR/TWHT)
      ASSIGN 65 TO KR   $   GO TO 66
   65 L1=L1+1   $   XS(L1)=SI   $   XD(L1)=DR
      XR(L1)=D
      IF(APDR.LE.0.) GO TO 122
      SI=SQRTF(APDR/(2.*DLST))
      IF(SI.GT.PI2) SI=PI2
      ASSIGN 123 TO KR   $   GO TO 66
  123 L2=L2+1   $   YS(L2)=SI   $   YD(L2)=DR
      YR(L2)=D
   61 CONTINUE
   21 CONTINUE
      IF(ILB.LE.0) GO TO 162
      DO 150 LA=1,10
      GND=FLOATF(LA)
      DO 151 LG=1,4
      GO TO (155,156,157,158), LG
  155 GRD=(4.*GND-1.)/4.      $   GO TO 159
  156 GRD=GND                 $   GO TO 159
  157 GRD=(4.*GND+1.)/4.      $   GO TO 159
  158 GRD=(2.*GND+1.)/2.      $   GO TO 159
  159 APDR=GRD*ALAM
      IF(APDR.GT.TWHT) GO TO 162
      SI=ASINF(APDR/TWHT)
      IF(SI.GT.PI2) SI=PI2
      ASSIGN 152 TO KR   $   GO TO 66
  152 L1=L1+1   $   XS(L1)=SI   $   XD(L1)=DR   $   XR(L1)=D
      SI=SQRTF(APDR/(2.*DLST))
      ASSIGN 153 TO KR   $   GO TO 66
  153 L2=L2+1   $   YS(L2)=SI   $   YD(L2)=DR   $   YR(L2)=D
  151 CONTINUE
  150 CONTINUE
  162 L3=0
      DO 67 LK=1,24
      SI=SID(LK)*RAD
      ASSIGN 124 TO KR   $   GO TO 66
  124 L3=L3+1   $   ZS(L3)=SI   $   ZD(L3)=DR
      ZR(L3)=D
   67 CONTINUE
      SI=PI2
      L3=L3+1   $   ZS(L3)=SI   $   ZD(L3)=TWHT $   ZR(L3)=0.
      CALL TABLE(DUM)

C      ----USING TABLE TO OBTAIN STRATEGIC DISTANCE POINTS--------

      LR=0
      DO 70 LA=1,LE
      IF(LA.LT.4) GO TO 88
      LB=13-LA   $   GRD=FLOATF(LB) $ DR=ALAM/GRD   $   LD=LD+1
      IF(DR.GT.TWHT) GO TO 25
   86 CONTINUE
      D=DINTER(DR)
      IF(D.GT.DML) GO TO 70
      LR=LR+1   $   D1(LR)=D
   70 CONTINUE
   25 CONTINUE
```

```
      IF(ILB.LE.0) GO TO 163
      DO 172 LA=1,10
      GND=FLOATF(LA)
      DO 173 LG=1,4
      GO TO (165,166,167,168), LG
  165 GRD=(4.*GND-1.)/4.      $   GO TO 169
  166 GRD=GND                 $   GO TO 169
  167 GRD=(4.*GND+1.)/4.      $   GO TO 169
  168 GRD=(2.*GND+1.)/2.      $   GO TO 169
  169 DR=GRD*ALAM
      IF(DR.GT.TWHT) GO TO 163
      D=DINTER(DR)
      IF(D.GT.DML) GO TO 172
      LR=LR+1     $     D1(LR)=D
  173 CONTINUE
  172 CONTINUE
  163 CONTINUE
      IF(LR)154,164
  154 D=D1(LR)    $    SILIM=SINTER(D)
      DO 11 LA=1,LR
      LV=LR+1-LA
   11 D3(LA)=D1(LV)
      D2(1)=DZR
      CALL TSMESH(D2,1,D3,LR,D1,L5)
  160 LR=0
      SPD=.1
      DO 800 NSP=1,5
      MZS=NTM(NSP)
      IF(MZS.LE.0) GO TO 107
      DO 801 MXS=1,MZS
      D=SPD*CMK(IK)
      IF(D.GT.DML) GO TO 107
      LR=LR+1     $     D3(LR)=D
  803 SPD=SPD+XCON(NSP)
  801 CONTINUE
      SPD=SPD-XCON(NSP)
      NPP=NSP+1
      IF(NPP.GT.5) GO TO 107
      IF(XCON(NPP).EQ.0.) GO TO 107
      IF(NPP.EQ.0) GO TO 107
      IXD=INTF(SPD/XCON(NPP))
      SPD=(XCON(NPP)*FLOATF(IXD))+XCON(NPP)
  800 CONTINUE
  107 CONTINUE
      CALL TSMESH(D1,L5,D3,LR,D2,LX)
C     ----------CALCULATION OF COUNTERPOISE STRATEGIC POINTS------
      IF(NOC.LE.0) GO TO 75
      LR=0
      DO 600 LK=1,13
      IF(LK.LT.9) GO TO 601
      FLK=LK-8
      DO 603 LG=1,4
      FLG=LG
      GND=((4.*FLK)+FLG)/4.
  602 APDR=GND*ALAM
      IF(APDR.GT.TWHC) GO TO 29
      SI=ASINF(APDR/TWHC)
      ICPT=1
      ASSIGN 40 TO KR    $    GO TO 66
   40 CONTINUE
      IF(D.GT.DML) GO TO 604
      LR=LR+1
      D3(LR)=D
  604 IF(LK.LT.9) GO TO 600
```

```
603 CONTINUE
600 CONTINUE
 29 CONTINUE
    PRINT 5    $    CALL PAGE(1)
    CLIM=D3(LR)    $    CCIM=D3(1)
    DO 69 I=1,LR
    LV=LR+1-I
 69 D1(I)=D3(LV)
    CALL TSMESH(D1,LR,D2,LX,D3,LK)
134 DO 129 LV=1,LK
    ICPT=0
 13 SI=SINTER(D3(LV))
    ASSIGN 28 TO KR
C        ----------------RAY OPTICS GEOMETRY-----------------------
 66 CSSI=COSF(SI)
    SNSI=SINF(SI)    $    SISQ=SNSI*SNSI
    AKO=EFN/AO    $  ZE=(1./AKO)-1.    $    AKE=1./(1.+(ZE*CSSI))
    AEFT=AO*AKE   $ DHE=EAC*(AKE-1.)/(AKO-1.)
    HTX(1)=HTE    $    HL=H2-DHE    $    HTX(2)=HL-HRP    $  HCL=HL*CKM(IK)
    IF(ICPT.GT.0) GO TO 77
    A=AEFT
 78 CONTINUE
    DO 62 LC=1,2
    Z(LC)=A+HTX(LC) $    TEA(LC)=ACOSF(A*CSSI/Z(LC))-SI
    DA(LC)=Z(LC)*SINF(TEA(LC))
    IF(SI.GT.1.56) GO TO 63
    HPR(LC)=DA(LC)*TANF(SI)
 62 CONTINUE
    DTX=ABSF(Z(1)-Z(2))
    IF(SI.GT.CPI2) GO TO 64
    AFA=ATANF((HPR(2)-HPR(1))/(DA(1)+DA(2)))
    RO=(DA(1)+DA(2))/COSF(AFA)    $    R12=(DA(1)+DA(2))/CSSI
    IF(RO.LT.DTX) RO=DTX
 68 CA=AFA-TEA(1)    $    TH=TEA(1)+TEA(2)
    DR=4.*HPR(1)*HPR(2)/(RO+R12)
    BA=CA
    CD=CA*DEG
    D=AEFT*TH
    IF(D.LT.0.) D=0.
    DNM=D*CKN(IK)
    GO TO KR,(65,28,123,132,133,124,40,152,153)
C        ---------------------- ----------------------------------
 28 IF(D.LT.0.01) GO TO 129
    IF(D.GT.DML) GO TO 111
    ALFS=AFP+20.*ALOG10(RO)
    PFS=PIRP-ALFS
    GOD=GAIN(CA)
    GPD=20.*ALOG10(GOD)
    Z3=Z(2)-Z(1)
    Z4=(Z(1)*COSF(BA))/Z(2)
    IF(DH.LE.0.) GO TO 42
    DHD=DH*(1.-(0.8*EXPF(-0.02*D)))*1000.
 44 CALL SORB(Z(1),Z(2),A,RO,BA,RE)
    AA=GAO*RE(1)+GAW*RE(2)
 51 IF(ILB.GT.0.AND.SI.LE.SILIM) GO TO 35
    IF( DR.GE.ALA2) GO TO 34
    IF( DR.LE.DTRO) GO TO 26
    FDR=(1.1-(0.9*COSF(PKL*( DR-DTRO))))*.5
 43 CONTINUE
    CALL RECC(SI,F,KSC,IPL,0,DHD,R,PIC,RD)
    GA=-(TEA(1)+SI)        $    GAMD=GA*DEG  $    GOG=GAIN(GA)
```

```
      RDG=RD*GOG
      REC=0.0
      REG=R*GOG
      RLG=REG
      IF(NOC.LE.0) GO TO 500
C     ---------CALCULATION OF COUNTERPOISE CONTRIBUTION---------
      TEG=ABTC-ABSF(SI+TEA(1))   $   TEG=ABSF(TEG)
      VFGD=2.*SINF(TEG*.5)*SQVT
      IF(ABSF(GA).LT.ABTC) VFGD=-VFGD
      CALL FRENEL(VFGD,FPGD,PHIG)
      REG=REG*FPGD
      RDG=RDG*FPGD
      TRM3=PHIG+(PI2*VFGD*VFGD)
      IF(D.LT.CLIM.OR.D.GT.CCIM) GO TO 146
      SIC=CA
      TEC=ABSF(BTC-CA)   $   DARC=2.*HFC*SINF(CA)
      SIT1=-SIC       $ GOC=GAIN(SIT1)
      VFCP=2.*SINF(TEC*.5)*SQVT
      IF(ABSF(CA).GT.ABTC) VFCP=-VFCP
      CALL FRENEL(VFCP,FPCP,PHIC)
      CALL RECC(SIC,F,ICC,IPL,1,DHD,RC,PICC,RDC)
      RLC=RC*GOC
      REC=RLC*FPCP
      EXPC=(TWPILA*DARC)+PICC+(PHIC+(PI2 *VFCP*VFCP))
      ATRM=REC*COSF(EXPC)   $   BTRM=-REC*SINF(EXPC)
      AT1=CMPLX(ATRM,BTRM)
  147 CONTINUE
C     --------------CALCULATION OF LOBING CONTRIBUTION-----------
      IF(SI.GT.SILIM) GO TO 135
      EXPG=(TWPILA*DR)+PIC+TRM3
      ATRM=REG*COSF(EXPG)   $   BTRM=-REG*SINF(EXPG)
C     -------------------SUMMATION OF TERMS---------------------
  136 AT2=CMPLX(ATRM,BTRM)
      WRL=CABS(GOD+AT1+AT2)    $    WR=WRL*WRL+.0001
      PR=10.*ALOG10(WR)
      IF(D.LE.DZR) GO TO 148
      IF(LV.EQ.1) GO TO 148
      PL=FNA(D,DML,DZR,PRH,PZ)
      WL=10.**(.1*PL)
  149 CONTINUE
C     ----------------LONG-TERM POWER FADING--------------------

      PL=PL-GPD
      IF(D.LE.0.) GO TQ 38
      IF(D.LE.DSL1) 301,302
  301 DEE=(130.*D)/DSL1   $   GO TO 303
  302 DEE=130.+D-DSL1   $   GO TO 303
  303 CALL VZD(DEE,QG1,QG9,AD)
      IF(CA.LE.0.) GO TO 32
      IF(CA.GE.1.) GO TO 33
      FTH=.5-BSPI*(ATANF(20.*ALOG10(32.*CA)))
      IF(FTH.LE.0.0) GO TO 33
   52 AL10=PL+(AD(13)*FTH)     $    AY=AL10-ALIM
      IF(AY.LT.0.) AY=0.
   53 IF(ILB.GT.0.AND.SI.LE.SILIM) GO TO 22
      DO 31 K=1,35
      VD(K)=AD(K)*FTH-AY      $      BD(K)=PL+VD(K)
   31 CONTINUE.
      DO 50 K=1,12
      ALLM=-ALM(K)
      IF(BD(K).GT.ALLM) BD(K)=ALLM
```

```
   50 CONTINUE
   24 CONTINUE
C     ----------VALUES PUT INTO ISOTROPIC POWER ARRAY------------

      NCT=NCT+1
      IF(KK.GT.1) GO TO 20
   23 PGS=PFS+GPD
      PFL=PGS+PL-AA
      PFY(NCT,1)=DNM      $    PFY(NCT,2)=PGS        $    PFY(NCT,3)=PFL
      PFY(NCT,4)=BD(12)-PL     $       PFY(NCT,5)=BD(18)-PL
      PFY(NCT,6)=BD(24)-PL
  129 CONTINUE
  111 CONTINUE
      RETURN
C     -------------------RETURN TO PWSRB-------------------------

   15 FAY=1.      $      GO TO 17
   16 FAY=0.1     $      GO TO 17
C     ------------------TROPOSPHERIC MULTIPATH-------------------
   20 DO 30 I=1,35
      PQA(I)=P(I)
      QA(I)=BD(I)-PL
   30 CONTINUE
      IF(AY.LE.0.) GO TO 15
      IF(AY.GE.6.) GO TO 16
      FAY=(1.1+(0.9*COSF((AY/6.)*PI)))/2.
   17 CONTINUE
      RSP=REG*FDR*FAY
      IF(RE(2).LE.0.) GO TO 45
      RK=-10.*ALOG10(ASPC*(RE(2)**3))
      ACK=FDASP(RK)     $    WA=10.**(.1*ACK)
   46 RST=((RSP*RSP)+(RDG*RDG)+WA)
      IF(RST.LE.0.) GO TO 37
      BK  =+10.*ALOG10(RST)
      IF(BK.LT.-40.) BK=-40.
   47 CALL YIKK(BK,PQK,QK)
      RDHK=BK
      CALL CONLUT(QA,QK,PQA,35,+1.,0.,PQC,QC)
      DO 27 I=1,35
   27 BD(I)=QC(I)+PL
      GO TO 23

   37 BK=-40.    $    GO TO 47
C     -------------------LOBING MODE-----------------------------
   22 AY=0.
      TLIM=+20.*ALOG10(GOD+RLG+RLC)
      BLIM=-80.
      DO 36 K=1,35
      VD(K)=AD(K)*FTH     $    BD(K)=PL+VD(K)-AA
      IF(BD(K).GT.TLIM) BD(K)=TLIM
      IF(BD(K).LT.BLIM) BD(K)=BLIM
      BD(K)=BD(K)+AA
   36 CONTINUE
      GO TO 24

   26 FDR=0.1    $    GO TO 43
   32 FTH=1.0       $    GO TO 52
   33 FTH=0.0    $    AY=0.0    $    GO TO 53
   34 FDR=1.    $    GO TO 43
   35 FDR=0.       $    GO TO 43
```

```
 38 DEE=0.             $     GO TO 303
 42 DHD=0.0    $    GO TO 44
 45 WA=.0001     $     GO TO 46
 63 HPR(LC)=HTX(LC)      $       GO TO 62
 64 AFA=SI  $     R0=HTX(2)-HTX(1)   $    R12=HTX(1)+HTX(2)   $  GO TO 68
 75 DO 74 LK=1,LX
 74 D3(LK)=D2(LK)
    LK=LX
    LR=LX
    GO TO 134
 77 HTX(1)=HFC    $    HTX(2)=HTX(2)-HDI    $    A=AEFT+HDI
    ICPT=0    $    GO TO 78
 88 GRD=SPGRD(LA)    $    DR=ALAM*GRD    $  LD=LD+1   $   GO TO 86
120 GRD=SPGRD(LK)    $ APDR=ALAM*GRD    $  GO TO 121
122 SI=0.    $    DR=0.    $    D=DLST+DLSR    $    GO TO 123
135 ATRM=0.    $    BTRM=0.    $    GO TO 136
164 D1(1)=DZR    $    L5=1    $    SILIM=0.     $     GO TO 160
500 TRM3=0.0
146 ATRM=0.    $    BTRM=0.    $    AT1=CMPLX(ATRM,BTRM)    $ RLC=0.0
    GO TO 147
148 PL=PR    $    PZ=PR    $    WL=WR    $    GO TO 149
502 BTC=SQVT=0.    $    HDI=HTE    $    GO TO 503
601 GND=GLD(LK)    $    GO TO 602
    END
```

CONLUT

Subroutine CONLUT is used in performing the root-sum-square operation involved in (5) and (13). This method of combining variabilities is similar to the method suggested by Rice et al. [40, eq. V.5] and is the same as the method used by Tary et al. [42, eq. 25].

```
      SUBROUTINE CONLUT(A,B,C,N,R,RHO,P,D)
C     ROUTINE FOR MODEL AUG 73
      DIMENSION A(1),B(1),C(1),P(1),D(1),X(100),Y(100)
      DIMENSION Z(50)
      IF(A(N).LT.A(1)) GO TO 10
      DO 11 I=1,N
   11 X(I)=A(I)
   12 IF(B(N).LT.B(1)) GO TO 13
      IF(R.LT.0.) GO TO 14
   15 DO 16 I=1,N
   16 Y(I)=B(I)
   17 DO 18 I=1,N
      P(I)=C(I)
      IF(C(I).GT..499.AND.C(I).LT..501) M=I
   18 CONTINUE
      Z(M)=X(M)+(R*Y(M))
      DO 19 I=1,N
      IF(I.EQ.M) GO TO 19
      YA=X(I)-X(M)    $    YB=Y(I)-Y(M)
      YU=SQRTF((YA*YA)+(YB*YB)+(2.*R*RHO*YA*YB))
      IF(I.LT.M) GO TO 20
      Z(I)=Z(M)+YU    $    GO TO 19
   20 Z(I)=Z(M)-YU
   19 CONTINUE
```

```
      DO 23 I=1,N
      K=N-I+1
   23 D(I)=Z(K)
      RETURN
   10 DO 21 I=1,N
      K=N-I+1
   21 X(I)=A(K)
      GO TO 12
   13 IF(R.LT.0.) GO TO 15
   14 DO 22 I=1,N
      K=N-I+1
   22 Y(I)=B(K)
      GO TO 17
      END
```

DEFRAC

Subroutine DEFRAC is used to calculate attenuation at the radio horizon and other parameters associated with the diffraction region (sec. A.4.3). Some of these parameters are used in line-of-sight calculations, e.g., (81).

```
      SUBROUTINE DEFRAC

C     SUBROUTINE TO COMPUTE DIFFRACTION ATTENUATION
C     ROUTINE FOR MODEL AUG 73

    5 FORMAT(5X, 4F7.1,F8.4,2F8.3)
    6 FORMAT(5X,10F7.1,F8.4,5F8.3,F7.1)
    7 FORMAT(5X, 6F7.1,F8.4,5F8.3,F7.1)
   51 FORMAT(8X,*DL7     DL8      TEC1      TEC2       TE4       AC3     D3       AC
     X4      D4      AV4      GH7       ARK      AKS *)
   52 FORMAT(5X,2F7.1,3F8.4,8F7.1)
   57 FORMAT(8X,*AK3      AK4        D      DK4     GH1      GH2        W        AMD
     X      AED      SWP      AWD      AK5      DK5*)
   60 FORMAT(8X,*AR3      AR4       D3       D4      AK3      AK4       D       DK4
     X GH1      GH2       W       AMD       AED      SWP     AWD      AK5      DK5*)
   61 FORMAT(8X,*AR3      AR4       D3       D4          W       AMD        AED*)
   71 FORMAT(10X*W*,14X*D*,14X*DLS*,12X*DL*)
   70 FORMAT(4(2X,E15.5))

      COMMON/DIFPR/HT,HR,DH,AED,AMD,DLS1,DLS2,IPX,KSC,HLT,HRP,AWD,SWP
      COMMON/PARAM/HTE,HRE,D,DL1,DL2,ENS,A,F,ALAK,TE1,TE2,KD,GAO,GAW
      DIMENSION ES(7),EE(7)
      REAL K1,K2,K3,K4,K5,K6
      DATA(ES=5.,.02,.005,.001,.010,.010,10.E+06)
      DATA(EE=81.,25.,15.,4.,81.,5.,1.)
      FNC(C)=416.4*(F**THIRD)*(1.607-C)
      FND(C)=.36278/((C*F)**THIRD*(((E-1.)**2+(X*X))**.25))
      FNE(C)=C*SQRTF(E*E+X*X)
      PI=3.141592654
      IPOL=IPX-1
      THIRD=1./3.     $     TWTRD=2./3.
```

```
      H1E=1000.*HTE   $   H2E=HRE*1000.
      HST=HT-HLT   $   HSR=HR-HLT   $   HLR=HLT
      HL1=(HLT-HRP)     $      HL2=HR-HRP
      HP1=HL1*1000.   $   HP2=HL2*1000. $ ALAM=ALAK*1000.
      S=ES(KSC)     $     E=EE(KSC)
      DLS=DLS1+DLS2   $   DL=DL1+DL2   $   TE=TE1+TE2
      CW=0.9    $    CU=.193573364   $   TWA=2.*A
      X=18000.*S/F
      A1=DL1*DL1/(2.*HTE)
      A2=DL2*DL2/(2.*HRE)
      K1=FND(A1)
      K2=FND(A2)
      IF(IPOL.EQ.0) GO TO 3
      K1=FNE(K1)
      K2=FNE(K2)
    3 CONTINUE

C     CALCULATION OF GHBAR AND  W

      B5=1.607-K1
      B6=1.607-K2
      GH1=GHBAR(F,A1,B5,K1,DL1,H1E)
      GH2=GHBAR(F,A2,B6,K2,DL2,H2E)
      AK3=6.-GH1-GH2
      IF(D.GE.DLS) GO TO 41
      IF(D.LE.(CW*DLS)) GO TO 50
      W=0.5*(1.+COSF((PI*(DLS-D))/(DLS*(1.-CW))))
C     ----------------------PRINT STATEMENTS-------------------
      PRINT 71
      PRINT 70,W,D,DLS,DL
      CALL PAGE(2)
C     ---------------------- ---------------------------------
      IF(W.LT..001) GO TO 45

C     CALCULATION OF ROUNDED EARTH DIFFRACTION

   42 CONTINUE
      D3=DL+.5*(A*A/F)**THIRD
      DL7=DL1   $   DL8=DL2
      ASSIGN 25 TO JD
      IF (D3.LT.DLS) D3=DLS
   30 D4=D3+(A*A/F)**THIRD
      T3=TE+D3/A
      T4=TE+D4/A
      A3=(D3-DL)/T3
      A4=(D4-DL)/T4
      K3=FND(A3)
      K4=FND(A4)
      IF (IPOL = 0) GO TO 2
      K3=FNE(K3)
      K4=FNE(K4)
 2    CONTINUE
      B1=FNC(K1)
      B2=FNC(K2)
      B3=FNC(K3)
      B4=FNC(K4)
      X1=B1*DL7/A1**TWTRD
      X2=B2*DL8/A2**TWTRD
      X3=X1+X2+(B3*(D3-DL)/(A3**TWTRD))
      X4=X1+X2+(B4*(D4-DL)/(A4**TWTRD))
      IF(K1.GE.1.) K1=.99999
      IF(X1.GT.200.) GO TO 17
      IF(K1.LE.00001) GO TO 16
      XL1=450./ABSF(ALOG10(K1)**3)
      IF(X1.GE.XL1) GO TO 16
```

```
      FX1=20.*ALOG10(K1)+(2.5*1.E-5*X1*X1/K1)-15.
   20 IF(K2.GE.1.) K2=.99999
      IF(X2.GT.200.) GO TO 19
      IF(K2.LE.00001) GO TO 18
      XL2=450./ABSF(ALOG10(K2)**3)
      IF(X2.GE.XL2) GO TO 18
      FX2=20.*ALOG10(K2)+(2.5*1.E-5*X2*X2/K2)-15.
   21 GX3=.05751*X3-10.*ALOG10(X3)
      GX4=.05751*X4-10.*ALOG10(X4)
      AC3=GX3-FX1-FX2-20.
      AC4=GX4-FX1-FX2-20.
      GO TO JD,(25,26)
   17 FX1=.05751*X1-(10.*ALOG10(X1))
      IF(X1.GT.2000.) GO TO 20
      W1=.0134*X1*EXPF(-.005*X1)
      FX1=W1*(40.*ALOG10(X1)-117.)+(1.-W1)*FX1
      GO TO 20
16    T=40.*ALOG10(X1)-117.
      T1=-117.
      T2=MIN1F((ABSF(T)),(ABSF(T1)))
      FX1=T
      IF (T2 = ABSF(T1)) FX1=T1
      GO TO 20
   19 FX2=.05751*X2-(10.*ALOG10(X2))
      IF(X2.GT.2000.) GO TO 21
      W2=.0134*X2*EXPF(-.005*X2)
      FX2=W2*(40.*ALOG10(X2)-117.)+(1.-W2)*FX2
      GO TO 21
18    T=40.*ALOG10(X2)-117.
      T1=-117.
      T2=MIN1F((ABSF(T)),(ABSF(T1)))
      FX2=T
      IF (T2 = ABSF(T1)) FX2=T1
      GO TO 21
   25 AR3=AC3   $   AR4=AC4
      DR4=D4    $   DR3=D3
      AMS=(AR4-AR3)/(D4-D3)      $      AES=AR4-AMS*D4
      IF(W.GT..999) GO TO 43

C     CALCULATION OF SINGLE KNIFE EDGE WITH GHBAR

   45 CONTINUE
      IF(HL1.LE.0.) GO TO 43
      TH1=ATANF((HST/DL1)-(DL1/TWA))
      TH=ASINF(CU*SQRTF(D/(F*DL1*DL2)))
      TH5=-(-TH+TH1)   $   ATH5=A*TANF(TH5)
      DLK5=-ATH5+SQRTF(ATH5*ATH5+(HSR*TWA))
      DK5=DLK5+DL1
      TE5=ATANF((-HSR/DLK5)-(DLK5/TWA))
      TH5=TE1+TE5+(DK5/A)
      TM5=SQRTF((F*DL1*DLK5)/DK5)      $      V5=2.583*SINF(TH5)*TM5
      CALL FRENEL(V5,FV5,PH5)
      AV5=-20.*ALOG10(FV5)
      AMK5=(AV5-AK3)/(DK5-D)
      AWK=AK3-(AMK5*D)
      DLST7=SQRTF(HL1*TWA)      $     DLSR7=SQRTF(HL2*TWA)
      DL7=DLST7    $    DL8=DLSR7    $    DL=DL7+DL8
      DLK4=DL
      ASSIGN 26 TO JD
      A1=(DL7*DL7)/(2.*HL1)   $   A2=(DL8*DL8)/(2.*HL2)
      K1=FND(A1)      $      K2=FND(A2)
      IF(IPOL.EQ.0) GO TO 29
      K1=FNE(K1)      $      K2=FNE(K2)
   29 TEC1=ATANF((-HL1/DL7)-(DL7/TWA))
      TEC2=ATANF((-HL2/DL8)-(DL8/TWA))
   28 TE=TEC1+TEC2
```

```
      D3=DL+.5*(A*A/F)**THIRD
      GO TO 30
   26 B7=1.607-K1
      B8=1.607-K2
      GH7=GHBAR(F,A1,B7,K1,DL7,HP1)
      AC7=(AC4-AC3)/(D4-D3)      $      ARS=AC4-AC7*DLK4
      ARK=ARS+AC7*DLK4
      TE4=ATANF(((HLT-HR)/DLK4)-(DLK4/TWA))
      DK4=DLK4+DL1
      TH=TE1+TE4+(DK4/A)
      TM2=SQRTF((F*DL1*DLK4)/DK4)      $     V4=2.583*SINF(TH)*TM2
      CALL FRENEL(V4,FV,PH)
      AV4=-20.*ALOG10(FV)
      AKS=AV4-GH1-GH7+ARK
      AMKD=(AKS-AK3)/(DK4-D)           $    AEK=AK3-(AMKD*D)
C     -----------------------PRINT STATEMENTS-------------------
      PRINT 51
      PRINT 52,DL7,DL8,TEC1,TEC2,TE4,AC3,D3,AC4,D4,AV4,GH7,ARK,AKS
      CALL PAGE(2)
C     ----------------------------------------------------------
      AK4=AEK+DK4*AMKD      $    WK=1.-W
      AK5=AWK+DK5*AMK5
      IF(W.LT..001) GO TO 36


C      COMBINATION OF ROUNDED EARTH AND KNIFE EDGE DIFFRACTION

       AT3=(WK*AK3)+(W*(AES+(AMS*D)))
       AT4=(WK*AK4)+(W*(AES+(AMS*DK4)))
       AT5=(WK*AK5)+(W*(AES+(AMS*DK5)))
       AMD=(AT4-AT3)/(DK4-D)      $    AED=AT3-(AMD*D)
       SWP=(AT5-AT3)/(DK5-D)      $    AWD=AT3-(SWP*D)
C      -----------------------PRINT STATEMENTS-------------------
       PRINT 60
       PRINT 6,AR3,AR4,DR3,DR4,AK3,AK4,D,DK4,GH1,GH2,W,AMD,AED,SWP,AWD,AK
      X5,DK5
       CALL PAGE(2)
C      ---------------------- ----------------------------------
       RETURN

    36 AED=AEK    $    AMD=AMKD    $    SWP=AMK5     $     AWD=AWK
C      -----------------------PRINT STATEMENTS-------------------
       PRINT 57
       PRINT 7,AK3,AK4,D,DK4,GH1,GH2,W,AMD,AED,SWP,AWD,AK5,DK5
       CALL PAGE(2)
C      ---------------------- ----------------------------------
       RETURN

    41 W=1.    $    GO TO 42

    43 AED=AES    $    AMD=AMS    $    AWD=AES    $    SWP=AMS
C      -----------------------PRINT STATEMENTS-------------------
       PRINT 61
       PRINT 5,AR3,AR4,DR3,DR4,W,AMD,AED
       CALL PAGE(2)
C      ---------------------- ----------------------------------
       RETURN

    50 W=0.    $ . GO TO 45
       END
```

DELTA

Subroutine DELTA is used in the calculation of attenuation for scatter. Specifically, it is used to obtain values of $\Delta\alpha_0$ and $\Delta\beta_0$ for (153) and (154). DELTA is based on CCIR recommendations [7, fig. 18].

```
      SUBROUTINE DELTA(ARG,DS,ENS,DAO)
C     ROUTINE FOR MODEL AUG 73

C     ROUTINE TO CALCULATE CORRECTION FACTOR FOR ALPHA AND BETA NOUGHT

      DIMENSION TBA(41),A(41,4),B(41,4),C(41,4)
      DIMENSION SNS(4)
      DATA(SNS=250.,301.,350.,400.)
      DATA(TBA=0.0,.0025,.005,.0075,.01,.0125,.015,.0175,.02,.0225,.025,
     X.0275,.03,.0325,.035,.0375,.04,.0425,.045,.0475,.05,.0525,.055,.05
     X75,.06,.0625,.065,.0675,.07,.0725,.075,.0775,.08,.0825,.085,.0875,
     X.09,.0925,.095,.0975,.1)
      DATA(((A(I,J),I=1,41),J=1,4)=.23,.32,.42,.5,.6,.68,.76,.83,.92,1.0
     X2,1.1,1.16,1.23,1.31,1.*8,1.43,1.5,1.55,1.59,1.62,1.68,1.7,1.72,1.
     X74,1.76,1.78,1.8,1.82,1.82,1.83,1.83,1.85,1.85,5(1.87),1.85,1.85,1
     X.83,.62,.72,.8,.92,1.0,1.11,1.2,1.29,1.39,1.45,1.53,1.6,1.7,1.77,1
     X.82,1.9,1.96,2.0,2.05,2.1,2.13,2.15,2.17,5(2.18),2.17,2.16,2.15,2.
     X13,2.13,2.12,2.11,2.09,2.05,2.03,2.00,1.99,1.97,1.22,1.31,1.4,1.5,
     X1.58,1.67,1.73,1.82,1.9,2.0,2.05,2.13,2.2,2.28,2.33,2.4,2.43,2.5,2
     X.52,2.57,6(2.6),2.58,2.57,2.53,2.51,2.49,2.46,2.42,2.39,2.35,2.3,2
     X.27,2.22,2.17,2.14,2.1,1.9,2.0,2.09,2.16,2.22,2.3,2.39,2.45,2.51,2
     X.61,2.66,2.72,2.78,2.82,2.89,2.93,2.99,3.0,3.05,3.07,3(3.09),3.07,
     X3.05,3.02,2.99,2.95,2.9,2.87,2.82,2.79,2.73,2.69,2.63,2.58,2.51,2.
     X45,2.4,2.32,2.27)
      DATA(((B(I,J),Y=1,41),J=1,4)=-.12,-.08,0.0,.12,.25,.4,.52,.7,.82,.
     X96,1.08,1.22,1.32,1.42,1.51,1.6,1.7,1.77,1.83,1.87,1.93,1.98,2.02,
     X2.06,2.12,2.15,2.19,2.22,2.25,2.28,2.31,2.33,2.36,2.4,2.42,2.45,2.
     X48,2.5,2.52,2.55,2.58,.12,.3,.5,.65,.82,1.0,1.17,1.32,1.51,1.67,1.
     X82,1.97,2.11,2.24,2.32,2.49,2.61,2.69,2.8,2.87,2.94,3.02,3.06,3.11
     X,3.15,3.2,3.22,3.27,3.31,3.33,3.37,3.4,3.44,3.47,3.5,3.53,3.56,3.5
     X8,3.61,3.62,3.65,.17,.59,.89,1.18,1.45,1.7,1.95,2.18,2.39,2.58,2.7
     X6,2.9,3.04,3.17,3.31,3.41,3.5,3.6,3.68,3.77,3.83,3.91,3.97,4.03,4.
     X08,4.13,4.19,4.23,4.27,4.33,4.36,4.4,4.44,4.47,4.52,4.56,4.6,4.63,
     X4.66,4.69,4.73,.45,.86,1.24,1.63,2.0,2.32,2.63,2.9,3.17,3.4,3.62,3
     X.71,3.99,4.14,4.28,4.43,4.54,4.65,4.74,4.84,4.92,5.01,5.07,5.13,5.
     X2,5.26,5.31,5.36,5.41,5.45,5.49,5.53,5.57,5.62,5.65,5.68,5.72,5.76
     X,5.8,5.84,5.88)
      DATA(((C(I,J),I=1,41),J=1,4)=2.68,2.59,2.51,2.43,2.34,2.26,2.18,2.
     X09,2.01,1.93,1.84,1.76,1.69,1.61,1.54,1.48,1.41,1.36,1.26,1.2,1.16
     X,1.10,1.07,1.04,1.01,.98,.94,.91,.88,.87,4(.86),3(.85),.86,.86,.87
     X,.88,3.13,3.01,2.87,2.76,2.67,2.56,2.45,2.34,2.24,2.16,2.05,1.96,1
     X.86,1.76,1.68,1.58,1.51,1.43,1.33,1.31,1.23,1.19,1.15,1.12,1.08,1.
     X04,1.01,.97,.93,.89,.84,.76,.71,.64,.61,.57,.53,.51,.47,.42,.40,4.
     X15,3.92,3.72,3.5,3.32,3.12,2.91,2.74,2.58,2.41,2.25,2.12,1.97,1.83
     X,1.75,1.65,1.55,1.45,1.38,1.28,1.24,1.17,1.11,1.05,1.0,.95,.85,.8,
     X.79,.75,.72,.66,.62,.58,.53,.51,.49,.47,.43,.41,.4,5.55,5.18,4.85,
     X4.55,4.3,4.07,3.83,3.68,3.5,3.35,3.2,3.08,2.95,2.82,2.72,2.62,2.53
     X,2.47,2.4,2.31,2.27,2.2,2.15,2.11,2.07,2.02,2.0,1.97,1.93,1.9,1.89
     X,1.87,1.84,1.82,1.8,1.79,1.79,1.78,1.77,1.76,1.75)
```

```
   IF(ARG)10,10,11
10 I=1
   GO TO 12
11 IF(ARG-.1)13,14,14
14 I=41
   GO TO 12
13 DO 15 I=1,41
   IF(ARG-TBA(I))16,12,15
15 CONTINUE
16 RATA=(ARG-TBA(I-1))/(TBA(I)-TBA(I-1))
   ASSIGN 20 TO KI
17 IF(ENS-250.)18,18,19
18 J=1
   GO TO 30
19 IF(ENS-400.)31,32,32
32 J=4
   GO TO 30
31 DO 33 J=1,4
   IF(ENS-SNS(J))34,30,33
33 CONTINUE
34 RATN=(ENS-SNS(J-1))/(SNS(J)-SNS(J-1))
   ASSIGN 22 TO MI
   GO TO KI,(20,21)
12 ASSIGN 21 TO KI
   GO TO 17
30 ASSIGN 24 TO MI
   GO TO KI,(20,21)
20 CALA=RATA*(A(I,J)-A(I-1,J))+A(I-1,J)
   CALB=RATA*(B(I,J)-B(I-1,J))+B(I-1,J)
   CALC=RATA*(C(I,J)-C(I-1,J))+C(I-1,J)
   GO TO MI,(22,24,23)
21 CALA=A(I,J)
   CALB=B(I,J)
   CALC=C(I,J)
   GO TO MI,(22,24,23)
22 CALHA=CALA
   CALHB=CALB
   CALHC=CALC
   ASSIGN 23 TO MI
   J=J-1
   GO TO KI,(20,21)
23 CALA=RATN*(CALHA-CALA)+CALA
   CALB=RATN*(CALHB-CALB)+CALB
   CALC=RATN*(CALHC-CALC)+CALC
24 DAO=.001*((.01*DS*(CALB-.001*CALC*DS))-CALA)
   IF(DAO)27,28,28
27 DAO=0.0
28 RETURN
   END
```

FDASP

Function FDASP is used in calculations associated with tropospheric multipath (sec. A.4.6 following eq. 195). It used the VF tables which are tabulated in this section under TABLES to obtain the variable K. The K value obtained has a sign that is the opposite of that used in (6), and elsewhere [40, fig. VI], but the same as that of Norton et al. [38, table 1] from which the data were taken.

```
      FUNCTION FDASP(S)
C     ROUTINE FOR MODEL AUG 73

C     K IS BASED ON RATIO OF S TO .990
C     THIS NAKAGAMA-RICE DIST. HAS TABLES FROM NORTON 55 IRE PAGE 1360
C     THE VF TABLES ARE THE NEGATIVE OF THE K IRE TABLES AND THEREFORE
C     R = -S
C     K HAS THE OPPOSITE SIGN OF 101 BUT THE SAME AS THE IRE PAPER
      COMMON/VV/VF(36,17)
      AVEF(YN,XN,YN1,XN1,T)=(YN1*(T - XN) - YN*(T - XN1))/(XN1 - XN)
      R=-S
      DO 1 I=1,17
      IF(R-VF(27,I)) 3,2,1
    1 CONTINUE
      I=17
    2 AK=VF(1,I)
      GO TO 6
    3 IF(I.EQ.1) GO TO 2
      AK=AVEF(VF(1,I-1),VF(27,I-1),VF(1,I),VF(27,I),R)
    6 FDASP=AK
      RETURN
      END
```

FDTETA

Subroutine FDTETA is used in calculations for the scatter region (sec. A.4.4) to determine values of $F_{d\theta}$ for (169). It uses the TALD/TAFL which is based on data from CCIR recommendations [7, sec. 11.1], and is tabulated in this section under TABLES.

```
      SUBROUTINE FDTETA(E1,D1,S1,DB)
C     ROUTINE FOR MODEL AUG 73

C     SUBROUTINE TO CALCULATE THE ATTENUATION FUNCTION

      DIMENSION TAD(25),TAFD(25,4)
      DIMENSION TS(7),ENS(4),DBS(2),DBT(2)
      COMMON/DLAT/TALD(20),TAFL(4,7,20)
   35 FORMAT(51H  DTHETA IS TOO LARGE FOR TABLE, USE GRAPH MANUALLY)
      DATA(ENS=250.,301.,350.,400.)
      DATA(TS=.01,.1,.2,.3,.5,.7,1.)
      DATA(TAD=.01,.02,.03,.04,.06,.08,.1,.2,.3,.4,.5,.6,.7,.8,.9,1.,2.,
     X3.,4.,5.,6.,7.,8.,9.,10.)
      DATA(((TAFD(I,J),I=1,25),J=1,4)=79.5,88.5,93.9,97.5,102.9,106.7,10
     X9.6,118.8,123.9,127.7,130.6,133.,135.,136.8,138.3,139.9,149.2,154.
     X9,158.8,162.,164.6,167.,169.,170.9,172.5,75.6,84.7,90.2,93.8,99.3,
     X103.,106.,115.,120.3,124.,126.9,129.3,131.4,133.2,134.6,136.1,145.
     X3,151.,155.,158.4,161.,163.4,165.5,167.4,169.2,71.2,80.3,85.7,89.5
     X,94.8,98.5,101.5,110.5,115.8,119.6,122.4,124.9,126.8,128.7,130.3,1
     X31.8,141.2,146.8,150.9,154.,156.8,159.2,161.2,163.1,164.7,64.6,73.
     X8,79.2,83.0,88.4,92.1,95.1,104.2,109.5,113.3,116.2,118.6,120.6,122
     X.4,124.,125.4,134.5,140.2,144.4,147.7,150.5,153.,155.2,157.1,159.)
```

```
      E=E1
      D=D1
      S=S1
      DO 10 I=1,4
      IF(E-ENS(I))11,11,10
   10 CONTINUE
   11 IF(I-1)12,12,13
   12 I=2
   13 J=I-1
      RTE=(E-ENS(J))/(ENS(I)-ENS(J))
      IF(D-10.)14,14,33
   14 DO 16 K=1,25
      IF(D-TAD(K))17,17,16
   16 CONTINUE
   17 IF(K-1)18,18,19
   18 K=2
   19 L=K-1
      RTD=(D-TAD(L))/(TAD(K)-TAD(L))
      DB1=(RTD*(TAFD(K,I)-TAFD(L,I)))+TAFD(L,I)
      DB2=(RTD*(TAFD(K,J)-TAFD(L,J)))+TAFD(L,J)
      DB=(RTE*(DB1-DB2))+DB2
      GO TO 20
   33 IF(D-1000.)15,15,34
   34 PRINT 35
      CALL PAGE(1)
      DB=0.
      GO TO 20
   15 DO 21 K=1,20
      IF(D-TALD(K))22,22,21
   21 CONTINUE
      K=20
   22 IF(K-1)23,23,24
   23 K=2
   24 L=K-1
      RTD=(D-TALD(L))/(TALD(K)-TALD(L))
      IF(S-.01)25,26,26
   25 S=.01
   26 DO 27 M=1,7
      IF(S-TS(M))28,28,27
   27 CONTINUE
   28 IF(M-1)29,29,30
   29 M=2
   30 N=M-1
      RTS=(S-TS(N))/(TS(M)-TS(N))
      DO 31 KL=1,2
      J=M
      DO 32 N=1,2
      DBS(N)=(RTD*(TAFL(I,J,K)-TAFL(I,J,L)))+TAFL(I,J,L)
      J=J-1
   32 CONTINUE
      I=I-1
      DBT(KL)=(RTS*(DBS(1)-DBS(2)))+DBS(2)
   31 CONTINUE
      DB=(RTE*(DBT(1)-DBT(2)))+DBT(2)
   20 RETURN
      END
```

FRENEL

Subroutine FRENEL is used in knife-edge diffraction calculations to determine the loss factor and phase shift associated with diffracted waves (see text following eqs. 77 and 121). It is based on the Fresnel integrals [40, sec. III.3].

```
      SUBROUTINE FRENEL(V,FV,PH)
C     ROUTINE FOR MODEL AUG 73

C     SUBROUTINE TO CALCULATE THE FRESNEL INTEGRAL

      DIMENSION A(11),B(11),G(11),D(11)
      COMPLEX PZ,SZ,CZ
      DATA (A=-1.702E-6,-6.808568854,-5.76361E-4,6.920691902,-1.6898657E
     X-2,-3.05048566,-7.5752419E-2,8.50663781E-1,-2.5639041E-2,-1.502309
     X60E-1,3.4404779E-2)
      DATA(B=4.255387524,-9.281E-5,-7.7800204,-9.520895E-3,5.075161298,-
     X1.38341947E-1,-1.363729124,-4.03349276E-1,7.02222016E-1,-2.1619592
     X9E-1,1.9547031E-2)
      DATA (G=-2.4933975E-2,3.936E-6,5.770956E-3,6.89892E-4,-9.497136E-3
     X,1.1948809E-2,-6.748873E-3,2.4642E-4,2.102967E-3,-1.21793E-3,2.339
     X39E-4)
      DATA (D=2.3E-8,-9.351341E-3,2.3006E-5,4.851466E-3,1.903218E-3,-1.7
     X122914E-2,2.9064067E-2,-2.7928955E-2,1.6497308E-2,-5.598515E-3,8.3
     X8386E-4)
      PI=3.141592654     $     TWPI=2.*PI
      IF(V.EQ.0.) GO TO 71
      IF(V.GE.5.) GO TO 74
      PT=V*V*.25   $   CPSI=TWPI*(PT-INTF(PT))
      X=V*V*PI*.5
   25 IF(X.GT.4.) GO TO 10
    5 PX=COSF(X)*SQRTF(X/4.)
      PY= SINF(-X)*SQRTF(X/4.)
      SUMX=1.59576914
      SUMY=-3.3E-8
      XN= 1.
      DO 100 I = 1, 11
      XN=XN*X/4.
      SUMX=SUMX+A(I)*XN
  100 SUMY=SUMY+B(I)*XN
      SZ=CMPLX(SUMX,SUMY)
      PZ=CMPLX(PX,PY)
      CZ=SZ*PZ
      C=REAL(CZ)       $       S=AIMAG(CZ)
      GO TO 30
   10 PX=COSF(X)*SQRTF(4./X)
      PY=SINF(-X)*SQRTF(4./X)
      XN=1.
      SUMX=0.
      SUMY=.199471140
      DO 200 I = 1, 11
      XN=XN*4./X
      SUMX=SUMX+G(I)*XN
  200 SUMY=SUMY+D(I)*XN
```

```
      SZ=CMPLX(SUMX,SUMY)
      PZ=CMPLX(PX,PY)
      CZ=SZ*PZ
      C=REAL(CZ)    $    S=AIMAG(CZ)
      C=C+.5   $    S=S-.5
   30 S=ABSF(S)
      IF(V.LT.0.) GO TO 70
      FV=.5*SQRTF((1.-(C+S))**2+(C-S)**2)
      Y=C-S    $    W=1.-(C+S)
   75 PH=ATAN2(Y,W)
      PH=PH-CPSI
      AP=ABSF(PH)     $    APX=AP-TWPI*INTF(AP/TWPI)
      IF(PH.LT.0.) GO TO 37
      PH=APX
   39 IF(PH.LT.0.) PH=TWPI+PH
      RETURN
   37 PH=-APX    $    GO TO 39
   71 FV=.5     $    PH=0.    $    GO TO 39
   74 FV=.22508/V    $    PH=.78539816    $    GO TO 39
   70 FV=.5*SQRTF((1.+(C+S))**2+(C-S)**2)
      Y=-(C-S)    $    W=1.+(C+S)    $    GO TO 75
      END
```

GAIN

Function GAIN determines the relative facility antenna voltage gain associated with a particular facility antenna at a specific elevation angle. It is used to obtain the g of (67) and the g_D of (81). Gain values may be calculated directly or obtained by interpolating between values taken from figure 2.

```
      FUNCTION GAIN(X)
C     ROUTINE FOR MODEL AUG 73

      COMMON/GAT/IFA
      DIMENSION RA(24),RB(24)
      DIMENSION DA(8),DG(8)
      DATA(RA=-90.,-76.,-60.,-54.,-51.5,-48.,-36.,-33.,-30.,-24.,-18.,-1
     X2.,-9.,-6.,-2.5,0.,3.,8.,12.,24.,36.,57.,84.,90.)
      DATA(RB=-29.,-22.,-26.5,-27.4,-21.7,-20.,-5.5,-4.2,-3.5,-4.5,-7.3,
     X-11.8,-10.,-3.5,-1.,4.,6.5,7.4,7.,-1.4,-1.5,-9.5,-4.,-13.0)
      DATA (DA=-6.,0.,2.5,5.,7.5,7.51,14.99,15.0)
      DATA (DG=-8.,-6.,-3.,0.,-3.0,-20.,-20.01,-30.)
      FNA(FX,FA,FB,FC,FD)=((FX-FB)*(FC-FD)/(FA-FB))+FD
      A=X
      GO TO (10,20,30,40,50,60,70,80),IFA
C     --------- GAIN FOR ISOTROPIC ANTENNA ------------
   10 GAIN =1.    $    RETURN
C     --------- GAIN FOR DME ANTENNA ------------------
   20 D=A*57.29577951
```

```
      DO 21 I=1,8
      IF(D-DA(I))23,22,21
   21 CONTINUE
      I=8
   22 GAIN=10.**(DG(I)*.05)   $   RETURN
   23 IF(I.EQ.1) GO TO 22
      L=I-1
      GD=FNA(D,DA(I),DA(L),DG(I),DG(L))
      GAIN=10.**(GD*.05)   $   RETURN
C     --------- GAIN FOR RTA-2 ANTENNA ---------------
   30 D=A*57.29577951
      DO 31 I=1,24
      IF(D-RA(I))33,32,31
   31 CONTINUE
      I=24
   32 GAIN=10.**((RB(I)-7.4)*.05)  $   RETURN
   33 IF(I.EQ.1) GO TO 32
      L=I-1
      RD=FNA(D,RA(I),RA(L),RB(I),RB(L))
      GAIN=10.**((RD-7.4)*.05)    $    RETURN
C     --------- GAIN FOR VOR ANTENNA (COSINE PATTERN) -----------
   40 GAIN=1.00*COSF(A)
      IF(GAIN.LT..12589) GAIN=.12589
      RETURN
C     --------------- GAIN FOR ILS LOCALIZER ------------------
   50 GAIN=1.00*COSF(A)
      IF(GAIN.LT..12589) GAIN=.12589
      RETURN
C     --------------- GAIN FOR GLIDE SLOPE --------------------
   60 GAIN=1.00*COSF(A)
      IF(GAIN.LT..12589) GAIN=.12589
      RETURN
C     ------------------ JTAC 20 DEG BEAM TILT 20 DEG H HPBW -----------
   70 D=A*57.29577951
      TLT=20.  $ HPBW=20.
      TERM=ABSF(D-TLT)
      GAIN=(1.+((TERM/HPBW)**2.5))**(-0.5)
      RETURN
C     --------------JTAC 8 DEG BEAM TILT    ---------------
   80 D=A*57.29577951
      TLT=8.
      HPBW=1.959545258
      TERM=ABSF(D-TLT)
      GAIN=(1.+((TERM/HPBW)**2.5))**(-0.5)
      RETURN
      END
```

GHBAR

Function GHBAR is used in calculations for the diffraction region (sec. A.4.3) to determine values of $G_{K\bar{h}1,2}$ and $G_{e\bar{h}1,2}$ for (119) and (122). These are special values for $G_{p\bar{h}1,2}$ which is discussed following (107). GHBAR is based on CCIR recommendations [7, eq. 64, fig. 31; 40, eq. 7.6, fig. 7.2] and includes a weighting function [20, eq. 17].

```
      FUNCTION GHBAR (F,A,B,AK,DHOR,HE)
C     ROUTINE FOR MODEL AUG 73
    6 FORMAT(5X,*K GREATER THAN .1  GHBAR NOT CORRECT*)
    7 FORMAT(5X,*HBAR IS GREATER THAN 100*)
      WG=2.     $     PIG=3.141592654
      HB=2.2325*B*B*(F*F/A)**.33333333*(.001*HE)
      IF(AK.GT..1) PRINT 6
      IF(HB.GE.2.5) GO TO 10
      IF(AK.GT..05) GO TO 11
      IF(HB.LT..3) GO TO 12
      GHBAR=-6.5-1.67*HB+6.8*ALOG10(HB)
   13 IF(AK.LE..01) GO TO 2
      GHB=GHBAR
   11 IF(HB.LT..25) GO TO 14
      GHT=-5.9-1.9*HB+6.6*ALOG10(HB)
   15 IF(AK.GT..05) GO TO 16
      GHBAR=GHT-(GHT-GHB)*((.05-AK)/.04)
2     CONTINUE
      FRE=300.*SQRTF(.2997925*DHOR/F)
      IF(HE.LE.FRE) GO TO 3
      IF(HE.GE.(WG*FRE)) GO TO 4
      GW=.5*(1.+COSF(PIG*(HE-FRE)/FRE))
      GHBAR=GHBAR*GW      $     GO TO 3
    4 GHBAR=0.
    3 IF(HB.GT.100.) PRINT 7
      RETURN
   10 GHBAR=-6.6-.013*HB-2.*ALOG10(HB)
      GO TO 2
   12 GHBAR=1.2-13.5*HB+15.*ALOG10(HB)          $     GO TO 13
   14 GHT=-13.9+24.1*HB+3.1*ALOG10(HB)     $     GO TO 15
   16 GHB=GHT
      IF(HB.LT.0.1) GO TO 17
      GHT=-4.7-2.5*HB+7.6*ALOG10(HB)
   18 GHBAR=GHT-(GHT-GHB)*((.1-AK)/.05)       $     GO TO 2
   17 GHT=-13.     $     GO TO 18
       END
```

HCHNOT

Subroutine HCHNOT is used in calculations for the scatter region (sec. A.4.4) to determine values of H_0 for (169). It uses the TAV/TAH1 table which is based on data from CCIR recommendations [7, sec. 11.4], and is tabulated in this section under TABLES. Function TERP is also used.

```
      SUBROUTINE HCHNOT(ETAS,S,VT,VR,HO)
C     ROUTINE FOR MODEL AUG 73

C     SUBROUTINE TO CALCULATE THE FREQUENCY GAIN FUNCTION

      DIMENSION TAR(114),TAHO(114)
      DIMENSION TETA(7)
      COMMON/VAT/TAV(175),TAH1(7,175)
      DATA(TETA=1.,2.,5.,10.,20.,50.,100.)
      DATA(TAR=.01,.012,.014,.016,.018,.02,.022,.024,.026,.028,.03,.032,
     X.036,.04,.045,.05,.055,.06,.065,.07,.075,.08,.085,.09,.095,.1,.11,
     X.12,.13,.14,.15,.16,.17,.18,.19,.2,.22,.24,.26,.28,.30,.32,.34,.36
     X,.38,.4,.45,.5,.55,.6,.65,.7,.75,.8,.85,.9,.95,1.0,1.1,1.2,1.3,1.4
     X,1.5,1.6,1.7,1.8,1.9,2.0,2.1,2.2,2.3,2.4,2.5,2.6,2.7,2.8,2.9,3.0,3
     X.2,3.4,3.6,3.8,4.0,4.2,4.4,4.6,4.8,5.0,5.2,5.6,6.0,6.5,7.0,7.5,8.0
     X,8.5,9.0,9.5,10.0,12.0,14.0,16.0,18.0,20.0,25.0,30.0,35.0,40.0,50.
     X0,60.0,70.0,80.0,90.0,99.0)
      DATA(TAHO=64.3,62.0,60.0,58.4,57.0,55.7,54.3,53.2,52.2,51.2,50.3,4
     X9.7,48.0,46.8,45.2,44.0,42.8,41.8,40.8,40.0,39.0,38.2,37.5,36.8,36
     X.2,35.7,34.5,33.5,32.7,31.8,31.0,30.2,29.6,28.9,28.2,27.8,26.6,25.
     X7,24.8,23.8,23.1,22.5,21.8,21.2,20.7,20.2,18.9,17.9,17.0,16.0,15.3
     X,14.8,14.0,13.42,12.92,12.4,11.93,11.55,10.75,10.03,9.42,8.95,8.4,
     X8.0,7.6,7.2,6.85,6.6,6.28,6.0,5.75,5.5,5.27,5.02,4.81,4.62,4.46,4.
     X3,4.15,3.73,3.5,3.28,3.1,2.93,2.75,2.6,2.45,2.35,2.2,2.0,1.82,1.65
     X,1.45,1.32,1.2,1.1,1.0,.92,.82,.6,.47,.38,.3,.24,.2,.17,.13,.1,.07
     X,.04,.02,.01,2(0.0))
      J=0
      IF(VT-40.)10,11,11
   11 IF(VR-40.)12,13,13
   13 HO=0.
      RETURN
   12 J=2
      GO TO 14
   10 J=1
      IF(VR-40.)15,14,14
   15 J=J+2
   14 Q=VR/VT
      IF(S-.1)50,50,51
   50 ALGS=-1.
      GO TO 52
   51 ALGS=ALOG10(S)
   52 IF(Q-10.)53,54,54
   54 ALGQ=1.
      GO TO 55
   53 IF(Q-.1)56,56,59
   56 ALGQ=-1.
      GO TO 55
   59 ALGQ=ALOG10(Q)
```

```
55 IF(ETAS-1.)17,18,19
17 DEHO=3.6*ALGS*ALGQ
   ASSIGN 35 TO M
   QS=Q*S
   IF(QS-.999995)24,16,80
80 IF(QS-1.000005)16,16,24
16 J=J+1
24 GO TO (41,42,43,44),J
18 ASSIGN 30 TO M
36 DEHO=3.6*ALGS*ALGQ
   KL=1
   ASSIGN 33 TO K
   GO TO (21,22,23,23),J
19 DEHO=6.*(.6-ALOG10(ETAS))*ALGS*ALGQ
   ASSIGN 34 TO K
   ASSIGN 30 TO M
   DO 39 KL=1,7
   IF(ETAS-TETA(KL))58,57,39
39 CONTINUE
57 KN=KL
   RATN=1.
49 GO TO (21,22,23,23),J
58 KN=KL-1
   RATN=(ETAS-TETA(KN))/(TETA(KL)-TETA(KN))
   GO TO 49
41 R1=VT*(1.+(1./S))
   GO TO 28
42 R1=VR*(1.+S)
28 TTT=.5*R1*R1*(1.-TERP(R1))
   H00=-10.*ALOG10(TTT)
   GO TO 36
43 R1=VT*(1.+(1./S))
   R2=VR*(1.+S)
   UP=2.*(1.-S*S*Q*Q)
   BAS=R2*R2*(TERP(R1)-TERP(R2))
   TTT=UP/BAS
   IF(TTT)45,45,46
45 H00=0.
   GO TO 36
46 H00=10.*ALOG10(TTT)
   GO TO 36
44 R1=VT*(1.+(1./S))
   R2=R1
   IF(R1-.010)47,47,48
47 H00=64.3
   GO TO 36
48 IF(R1-90.)60,45,45
60 DO 61 I=1,114
   IF(R1-TAR(I))63,62,61
61 CONTINUE
62 H00=TAHO(I)
   GO TO 36
63 LI=I-1
   H00=(((R1-TAR(LI))/(TAR(I)-TAR(LI)))*(TAHO(I)-TAHO(LI)))+TAHO(LI)
   GO TO 36
21 ASSIGN 25 TO L
20 V=VT
31 IF(V-.018)32,32,38
32 HV=70.
   GO TO L,(25,26,27,29)
38 DO 64 I=1,175
   IF(V-TAV(I))64,65,66
64 CONTINUE
65 KM=I
   RAT=1.
```

```
      GO TO K,(33,34)
   66 KM=I-1
      RAT= (V-TAV(I))/(TAV(KM)-TAV(I))
      GO TO K,(33,34)
   22 ASSIGN 26 TO L
      V=VR
      GO TO 31
   23 ASSIGN 27 TO L
      GO TO 20
   33 HV=(RAT*(TAH1(1,KM)-TAH1(1,I)))+TAH1(1,I)
      GO TO L,(25,26,27,29)
   34 HV1=(RAT*(TAH1(KL,KM)-TAH1(KL,I)))+TAH1(KL,I)
      HV2=(RAT*(TAH1(KN,KM)-TAH1(KN,I)))+TAH1(KN,I)
      HV=(RATN*(HV1-HV2))+HV2
      GO TO L,(25,26,27,29)
   25 HOT=HV
      HOR=0.
      GO TO 37
   26 HOR=HV
      HOT=0.
      GO TO 37
   27 HOT=HV
      ASSIGN 29 TO L
      V=VR
      GO TO 31
   29 HOR=HV
   37 AHO=(HOT+HOR)/2.
      IF(AHO-DEHO)67,68,68
   67 HO1=HOT+HOR
   69 IF(HO1)70,71,71
   70 HO1=0.
   71 GO TO M,(30,35)
   68 HO1=AHO+DEHO
      GO TO 69
   30 HO=HO1
      GO TO 73
   35 HO=HO0+(ETAS*(HO1-HO0))
      IF(HO)72,73,73
   72 HO=0.
   73 RETURN
      END
```

LINE

Subroutine LINE is used in plotting different types of lines.

```
      SUBROUTINE LINE(KL,A,B,J,SKX,SKY)
C     ROUTINE FOR MODEL AUG 73

C     ROUTINE WILL PLOT THE FOLLOWING LINES ACCORDING TO CODE KL
C     KL=1-CONTINUOUS LINE    KL=2-SHORT DASHED LINE    KL=3X X X X X
C     KL=4-DASH-DX XLINE      KL=5-+ + + + +
C     KL=6-LONG-DASH-SHORT-DASH LINE      KL=7-LONG-DASH-X X LINE
C     KL=8-LIGHT LINE       KL=9-DOTTED LINE
```

```
      DIMENSION A(1000),B(1000)
      DIMENSION C(2000),D(2000)
      DIMENSION X(10),Y(10),IDH(2)
      DATA (IDH=3H+0X,3H+0+)
      IF(KL.EQ.1) GO TO 11
      IF (KL.EQ.8) GO TO 52
      IF(KL.EQ.2.OR.KL.EQ.4.OR.KL.EQ.6) GO TO 30
      IF(KL.EQ.9) GO TO 30
      SCX=SKX $ SCY=SKY
C     -------------------KL=8 FOR LIGHT LINE ------------------
   18 JN=J-1
      I=0
      DO 63 K=1,JN
      I=I+1
      C(I)=A(K)
      D(I)=B(K)
      CX=A(K)/SCX
      DX=A(K+1)/SCX
      CY=B(K)/SCY
      DY=B(K+1)/SCY
      XT=DX-CX $ YT=DY-CY
      CL=SQRTF((XT*XT)+(YT*YT))
      L=XINTF(CL)
      SM=XT/CL
      SSM=YT/CL
      IF(L.LE.0) GO TO 65
      DO 64 JK=1,L
      AX=CX+SM
      AY=CY+SSM
      I=I+1
      C(I)=AX*SCX
      D(I)=AY*SCY
      CX=AX
      CY=AY
   64 CONTINUE
   65 I=I+1
      C(I)=A(K+1)
      D(I)=B(K+1)
   63 CONTINUE
      GO TO (10,12,13,14,15,16,17,18,39),KL
C     -------------------KL=1 FOR CONTINUOUS LINE---------------
   10 CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(C,D,I,0,1)
      RETURN
C     -------------------KL=9 FOR DOTTED LINE ------------------
   39 CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(C,D,I,1,17)
      RETURN
   11 CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(A,B,J,1,1)
      RETURN
   52 CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(A,B,J,0,1)
      RETURN
C     -------------------KL=3 FOR X X X X X LINE ---------------
   13 ILA=4
      ILH=IDH(1)
      CALL CRTPLT(0.,0,ILH,ILA,5)
      CALL CRTPLT(C,D,I,0,1)
      RETURN
C     -------------------KL=5 FOR + + + + + LINE ---------------
   15 ILA=0
      ILH=IDH(2)
      CALL CRTPLT(0.,0,ILH,ILA,5)
```

```
      CALL CRTPLT(C,D,I,0,1)
      RETURN
C     ------------------KL=2 FOR SHORT DASHED LINE-------------
   12 IF(I.LT.3) GO TO 10
      N=1
   20 L=N+1 $KN=N+2
      X(1)=C(N) $Y(1)=D(N)
      X(2)=C(L) $Y(2)=D(L)
      IF(L.EQ.I) GO TO 19
      X(3)=C(KN) $Y(3)=D(KN)
      KA=KN+1
      IF(KA.EQ.I) GO TO 23
   21 CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,3,0,1)
      N=N+3
      IF(N.GE.I) RETURN
      GO TO 20
   19 CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,2,0,1)
      RETURN
C     ------------------KL=4 DASH X DASH LINE -----------------
   14 IF(I.LT.3) GO TO 10
      N=1
   22 L=N+1 $KN=N+2
      X(1)=C(N) $Y(1)=D(N)
      X(2)=C(L) $Y(2)=D(L)
      IF(L.EQ.I) GO TO 19
      X(3)=C(KN) $Y(3)=D(KN)
      KA=KN+1
      KB=N+5
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,3,0,1)
      IF(KN.EQ.I) RETURN
      X(1)=C(KA) $Y(1)=D(KA)
      IF(KB.EQ.I) GO TO 31
      ILH=IDH(1)
      ILA=4
      CALL CRTPLT(0.,0,ILH,ILA,5)
      CALL CRTPLT (X,Y,1,0,1)
      N=N+4
      IF(N.GE.I) RETURN
      GO TO 22
   23 X(4)=C(KA) $Y(4)=D(KA)
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,4,0,1)
      RETURN
   25 X(5)=C(KB) $Y(5)=D(KB)
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,5,0,1)
      RETURN
C     ------------------KL=6 FOR LONG DASH SHORT DASH LINE------
   16 IF(I.LT.4) GO TO 10
      N=1
   26 L=N+1 $KN=N+2 $KA=N+3 $KB=N+4
      KC=N+5 $ KD=N+6 $ KE=N+7
      X(1)=C(N) $Y(1)=D(N)
      X(2)=C(L) $Y(2)=D(L)
      IF(L.EQ.I) GO TO 19
      X(3)=C(KN) $Y(3)=D(KN)
      IF(KN.EQ.I) GO TO 21
      IF(KA.EQ.I) GO TO 23
      X(4)=C(KA) $Y(4)=D(KA)
      IF(KB.EQ.I) GO TO 25
      X(5)=C(KB) $Y(5)=D(KB)
      IF(KC.EQ.I) GO TO 27
```

```
      X(6)=C(KC) $Y(6)=D(KC)
      X(7)=C(KD) $Y(7)=D(KD)
      IF(KE.EQ.I) GO TO 29
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,7,0,1)
      N=N+7
      IF(N.GE.I) RETURN
      GO TO 26
C     --------------------KL=7 FOR LONG DASH X X LINE ------------
   17 IF(I.LT.3) GO TO 10
      N=1
   28 L=N+1 $KN=N+2 $KA=N+3
      X(1)=C(N) $Y(1)=D(N)
      X(2)=C(L) $Y(2)=D(L)
      IF(L.EQ.I) GO TO 19
      X(3)=C(KN) $Y(3)=D(KN)
      IF(KN.EQ.I) GO TO 21
      IF(KA.EQ.I) GO TO 23
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,3,0,1)
      X(1)=C(KA)$Y(1)=D(KA)
      ILA=4
      ILH=IDH(1)
      CALL CRTPLT(0.,0,ILH,ILA,5)
      CALL CRTPLT(C,D,I,0,1)
      N=N+4
      IF(N.GE.I) RETURN
      GO TO 28
   27 X(6)=C(KC) $Y(6)=D(KC)
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,6,0,1)
      RETURN
   29 X(8)=C(KE) $Y(8)=D(KE)
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,8,0,1)
      RETURN
   30 SCX=SKX*.5
      SCY=SKY*.5
      GO TO 18
   31 X(2)=C(KB) $ Y(2)=D(KB) $ GO TO 19
      END
```

PAGE

Subroutine PAGE is used to structure printing associated with program runs such that each page contains no more than 52 lines and is numbered and dated.

```
      SUBROUTINE PAGE(N)
C     ROUTINE FOR MODEL AUG 73
    4 FORMAT(1H1)
    6 FORMAT(*  PAGE*,I4,2(2X,A8))
      COMMON/EGAP/IP,LN,IDT,IXT
      IF(N)10,11,12
```

```
 10 IP=0
 11 IP=IP+1
    LN=1
    PRINT 6,IP,IDT,IXT
 13 RETURN
 12 LN=LN+N
    IF(LN.LT.53)13,14
 14 PRINT 4
    GO TO 11
    END
```

PLTDU

Subroutine PLTDU is used only in the station separation program to construct graphs. It is similar to PLTGRPH.

```
      SUBROUTINE PLTDU
C     PLOT SUBROUTINE FOR DOVERU
C     ROUTINE FOR MODEL AUG 73
   14 FORMAT(*   CAPACITY OF LINE*,I2,* IS OVER 100 POINTS*)
   23 FORMAT(I3,5X)
   27 FORMAT(I2,6X)
   29 FORMAT(F3.1,5X)
   30 FORMAT(I1,7X)
   32 FORMAT(4X,I4)
   36 FORMAT(F4.0,4X)
   41 FORMAT(4X,F4.1)
   42 FORMAT(4X,F4.2)
   43 FORMAT(3X,F5.3)
   46 FORMAT(I4,4X)
      DIMENSION IT(5),AN(4),BT(5)
      DIMENSION TL(3),TH(4),TA(2),TB(2),TC(2),TD(2),TE(4)
      DIMENSION AX(2),AY(2),G(2),H(2),LM(6),X(2),Y(2)
      DIMENSION S(2),T(2)
      DIMENSION A(200),B(200)
      COMMON/PLTD/LUD,LL,NU(8),NS(8),SX(2),SY(2),TT(5),XC,YC,BX(200,8),B
     XY(200,8),LYD,AAT,TG
      COMMON/EGAP/IP,LN,IDT,IXT
      DATA (NS=1,9,9,3,5,7)
      DATA (AN=28HS↓9TATION SEPARATION IN N MI)
      DATA (BT=35H        D/U ↓9SIGNAL RATIO IN D↓1B )
      DATA (IT=1H ,24H    M E JOHNSON EXT 3587,1H )
      DATA (TL=17HR↓9UN ↓1C↓9ODE↓1: )
      DATA (TE=32HD↓9ESIRED DISTANCE↓1:      ↓9N MI)
      DATA (TH=25HA↓9LTITUDE↓1:           ↓9FT)
      DATA (TA=16HF↓9REE SPACE     )
      DATA (TB=16H(↓9UPPER↓1)   5%)
      DATA (TC=16H(↓9MIDDLE↓1) 50%)
      DATA (TD=16H(↓9LOWER↓1)  95%)
C     -------------------DRAWING PERIMETER-----------------------
      SCX=(SX(1)-SX(2))/10.
      SCY=(SY(1)-SY(2))/10.
      G(1)=SX(1)+(0.3*SCX)
      G(2)=SX(2)-(1.0*SCX)
      H(1)=SY(1)+(4.8*SCY)
```

```
      H(2)=SY(2)-(1.2*SCY)
      SHX=(G(1)-G(2))/100.
      SHY=(H(1)-H(2))/100.
      PY=.3*SCY
      AX(1)=SX(2) $AX(2)=SX(1) $AY(1)=SY(2) $AY(2)= H(1)-(3.*SCY)
      LD1=0
      LD2=0
      NX=((SX(1)-SX(2))/XC)
      NY=((SY(1)-SY(2))/YC)+1.4
      CALL CRTPLT(G,H,5,IT,2)
      CALL CRTPLT(AX,AY,0,1,14)
C     -------------------DRAWING GRID----------------------------
      LX=NX+1
      LY=NY+1
      Y(1)=SY(1) $ Y(2)=SY(2) $ X(1)=SX(2)
      DO 20 I=1,NX
      X(1)=X(1)+XC $X(2)=X(1)
      IF(X(1).GE.SX(1)) GO TO 33
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,2,0,1)
   20 CONTINUE
   34 X(1)=SX(2) $ X(2)=SX(1) $ Y(1)=SY(1)
      Y(2)=Y(1)
      DO 21 I=1,NY
      IF(Y(1).LE.SY(2)) GO TO 38
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,2,0,1)
      Y(1)=Y(1)-YC $Y(2)=Y(1)
   21 CONTINUE
C     -------------------LABELING GRID---------------------------
   39 GY=SY(1) $ GX=SX(2)-(.95*SCX)
      AS=SY(2)
      DO 22 I=1,LY
      IF(LYD.GT.0) GO TO 16
      KL=GY   $   IF(LUD.LT.0) KL=XABSF(KL)
      ENCODE(8,32,AL) KL
   44 LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(GX,GY,LM,AL,10)
      GY=GY-YC
      IF(GY.LT.AS) GY=SY(2)
   22 CONTINUE
      EX=SX(2) $ GY=SY(2)-(.2*SCY)
      DO 24 I=1,LX
      IF(XC.LT.1.) GO TO 25
      IX=EX
      IF(EX.LT.0.) GO TO 35
      IF (EX.LT.10.) GO TO 26
      IF(EX.GT.99.) GO TO 41
      ENCODE(8,27,AL) IX
      GX=EX-(.075*SCX)
      GO TO 28
   33 LX=I+1    $     GO TO 34
   38 LY=I   $   GO TO 39
   16 YA=GY      $   IF(LUD.LT.0) YA=ABSF(YA)
      IF(LYD-2)17,18,19
   17 ENCODE(8,41,AL)YA   $   GO TO 44
   18 ENCODE(8,42,AL)YA   $   GO TO 44
   19 ENCODE(8,43,AL)YA   $   GO TO 44
   41 IF(EX.GT.999.) GO TO 31
      ENCODE(8,23,AL) IX
      GX=EX-(.15*SCX)
      GO TO 28
   35 ENCODE(8,36,AL) EX
```

```
      GO TO 37
   31 ENCODE(8,46,AL) IX
   37 GX=EX-(.225*SCX)
      GO TO 28
   25 ENCODE(8,29,AL) EX
      GX=EX-(.15*SCX)
      GO TO 28
   26 ENCODE(8,30,AL)IX
      GX=EX
   28 LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(GX,GY,LM,AL,10)
      EX=EX+XC
      IF(EX.GT.SX(1)) EX=SX(1)
   24 CONTINUE
      YL=(  0.7*SCY)+SY(2)
      XL=SX(2)-(.85*SCX)
      LM(1)=5 $LM(2)=1 $LM(3)=1 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,BT,10)
      LM(1)=4 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      YL=SY(2)-(.60*SCY)
      XL=SX(2)+(  3.0*SCX)
      CALL CRTPLT(XL,YL,LM,AN,10)

C     -------------------DRAWING LEGEND-------------------------
      XL=SX(2)+(.4*SCX)
      YL=H(1)-(3.40*SCY)
      LM(1)=5 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TT,10)
      YL=H(1)-(3.90*SCY)
      LM(1)=4 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TE,10)
      XL=SX(2)+(3.4*SCX)
      LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TG,10)
      XL=SX(2)+(.4*SCX)
      YL=H(1)-(4.40*SCY)
      LM(1)=4 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TH,10)
      XL=SX(2)+(2.05*SCX)
      LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,AAT,10)
      XL=SX(2)+(6.50*SCX)
      YL=H(1)-(2.60*SCY)
      LM(1)=3 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TL  ,10)
      XL=SX(2)+(7.70*SCX)
      LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,IDT,10)
      XL=SX(2)+(8.90*SCX)
      LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,IXT,10)
      YL=H(1)-(3.40*SCY)
      XL=SX(2)+( 8.3*SCX)
      S(1)=SX(2)+(7.3*SCX)
      S(2)=SX(2)+(8.1*SCX)
      T(1)=T(2)=YL
      CALL LINE(9,S,T,2,SHX,SHY)
      LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TA,10)
      YL=H(1)-(3.77*SCY)
      T(1)=T(2)=YL
      CALL LINE(1,S,T,2,SHX,SHY)
      LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TB,10)
      YL=H(1)-(4.14*SCY)
```

```
      T(1)=T(2)=YL
      CALL LINE(1,S,T,2,SHX,SHY)
      LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TC,10)
      YL=H(1)-(4.51*SCY)
      T(1)=T(2)=YL
      CALL LINE(1,S,T,2,SHX,SHY)
      LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TD,10)
C     -------------------PLOTTING GRAPH-----------------------
      DO 12 K=1,LL
      N1=NU(K)   $   LS=NS(K)
      J=0
      DO 10 I=1,N1
      IF(BY(I,K).GT.SY(1).OR.BX(I,K).LT.SX(2)) GO TO 10
      IF(BY(I,K).LT.SY(2).OR.BX(I,K).GT.SX(1)) GO TO 10
      J=J+1
      IF(J.GT.200) GO TO 13
      A(J)=BX(I,K)   $   B(J)=BY(I,K)
   10 CONTINUE
   11 CALL LINE(LS,A,B,J,SHX,SHY)
   12 CONTINUE
      RETURN
   13 PRINT 14,LL      $   CALL PAGE(1)   $  J=200.   $   GO TO 11
      END
```

PLTGRPH

Subroutine PLTGRPH is used <u>only</u> in the power density program to construct graphs. It is similar to PLTDU.

```
      SUBROUTINE PLTGRPH
C     PLOT SUBROUTINE FOR POWAV
C     ROUTINE FOR MODEL AUG 73
   14 FORMAT(*   CAPACITY OF LINE*,I2,* IS OVER 100 POINTS*)
   23 FORMAT(I3,5X)
   27 FORMAT(I2,6X)
   29 FORMAT(F3.1,5X)
   30 FORMAT(I1,7X)
   32 FORMAT(4X,I4)
   36 FORMAT(F4.0,4X)
   41 FORMAT(4X,F4.1)
   42 FORMAT(4X,F4.2)
   43 FORMAT(3X,F5.3)
   46 FORMAT(I4,4X)
      DIMENSION TL(3),TH(4),TA(2),TB(2),TC(2),TD(2),TE(3)
      DIMENSION AX(2),AY(2),G(2),H(2),LM(6),X(2),Y(2)
      DIMENSION S(2),T(2)
      DIMENSION A(200),B(200)
      DIMENSION IT(5),AN(3),BT(5)
      COMMON/PLTD/LUD,LL,NU(8),NS(8),SX(2),SY(2),TT(6),XC,YC,BX(200,8),B
     XY(200,8),LYD,AAT,TG
      COMMON/EGAP/IP,LN,IDT,IXT
      DATA (IT=1H ,24H    M E JOHNSON EXT 3587,1H )
```

```
      DATA (AN=24H     D↓9ISTANCE IN N MI )
      DATA (BT=40H       P↓9OWER DENSITY IN D↓1B-W/↓9SQ M   )
      DATA (NS=1,9,9,3,5,7)
      DATA (TL=17HR↓9UN ↓1C↓9ODE↓1:)
      DATA(TE=24H↓9WITH           D↓1BW EIRP )
      DATA (TH=25HA↓9LTITUDE↓1:           ↓9FT)
      DATA (TA=16HF↓9REE SPACE     )
      DATA (TB=16H(↓9UPPER↓1)   5%)
      DATA (TC=16H(↓9MIDDLE↓1) 50%)
      DATA (TD=16H(↓9LOWER↓1)  95%)

C     -------------------DRAWING PERIMETER---------------------
      SCX=(SX(1)-SX(2))/10.
      SCY=(SY(1)-SY(2))/10.
      G(1)=SX(1)+(0.3*SCX)
      G(2)=SX(2)-(1.0*SCX)
      H(1)=SY(1)+(4.8*SCY)
      H(2)=SY(2)-(1.2*SCY)
      SHX=(G(1)-G(2))/100.
      SHY=(H(1)-H(2))/100.
      PY=.3*SCY
      AX(1)=SX(2) $AX(2)=SX(1) $AY(1)=SY(2) $AY(2)= H(1)-(3.*SCY)
      LD1=0
      LD2=0
      NX=((SX(1)-SX(2))/XC)
      NY=((SY(1)-SY(2))/YC)+1.4
      CALL CRTPLT(G,H,5,IT,2)
      CALL CRTPLT(AX,AY,0,1,14)

C     -------------------DRAWING GRID--------------------------
      LX=NX+1
      LY=NY+1
      Y(1)=SY(1) $ Y(2)=SY(2) $ X(1)=SX(2)
      DO 20 I=1,NX
      X(1)=X(1)+XC $X(2)=X(1)
      IF(X(1).GE.SX(1)) GO TO 33
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,2,0,1)
   20 CONTINUE
   34 X(1)=SX(2) $ X(2)=SX(1) $ Y(1)=SY(1)
      Y(2)=Y(1)
      DO 21 I=1,NY
      IF(Y(1).LE.SY(2)) GO TO 38
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,2,0,1)
      Y(1)=Y(1)-YC $Y(2)=Y(1)
   21 CONTINUE

C     -------------------LABELING GRID------------------------
   39 GY=SY(1) $ GX=SX(2)-(.95*SCX)
      AS=SY(2)
      DO 22 I=1,LY
      IF(LYD.GT.0) GO TO 16
      KL=GY    $    IF(LUD.LT.0) KL=XABSF(KL)
      ENCODE(8,32,AL) KL
   44 LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(GX,GY,LM,AL,10)
      GY=GY-YC
      IF(GY.LT.AS) GY=SY(2)
   22 CONTINUE
      EX=SX(2) $ GY=SY(2)-(.2*SCY)
      DO 24 I=1,LX
      IF(XC.LT.1.) GO TO 25
      IX=EX
      IF(EX.LT.0.) GO TO 35
```

```
      IF (EX.LT.10.) GO TO 26
      IF(EX.GT.99.) GO TO 41
      ENCODE(8,27,AL) IX
      GX=EX-(.075*SCX)
      GO TO 28
   33 LX=I+1     $     GO TO 34
   38 LY=I   $   GO TO 39
   16 YA=GY     $   IF(LUD.LT.0) YA=ABSF(YA)
      IF(LYD-2)17,18,19
   17 ENCODE(8,41,AL)YA   $   GO TO 44
   18 ENCODE(8,42,AL)YA   $   GO TO 44
   19 ENCODE(8,43,AL)YA   $   GO TO 44
   41 IF(EX.GT.999.) GO TO 31
      ENCODE(8,23,AL) IX
      GX=EX-(.15*SCX)
      GO TO 28
   35 ENCODE(8,36,AL) EX
      GO TO 37
   31 ENCODE(8,46,AL) IX
   37 GX=EX-(.225*SCX)
      GO TO 28
   25 ENCODE(8,29,AL) EX
      GX=EX-(.15*SCX)
      GO TO 28
   26 ENCODE(8,30,AL)IX
      GX=EX
   28 LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(GX,GY,LM,AL,10)
      EX=EX+XC
      IF(EX.GT.SX(1)) EX=SX(1)
   24 CONTINUE
      YL=(  0.7*SCY)+SY(2)
      XL=SX(2)-(.85*SCX)
      LM(1)=5 $LM(2)=1 $LM(3)=1 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,BT,10)
      LM(1)=3 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      YL=SY(2)-(.60*SCY)
      XL=SX(2)+(  3.0*SCX)
      CALL CRTPLT(XL,YL,LM,AN,10)
C     -------------------DRAWING LEGEND-----------------------
      XL=SX(2)+(.4*SCX)
      YL=H(1)-(3.40*SCY)
      LM(1)=6 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TT,10)
      YL=H(1)-(3.90*SCY)
      LM(1)=3 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TE,10)
      XL=SX(2)+(0.8*SCX)
      LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TG,10)
      XL=SX(2)+(.4*SCX)
      YL=H(1)-(4.40*SCY)
      LM(1)=4 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TH,10)
      XL=SX(2)+(2.05*SCX)
      LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,AAT,10)
      XL=SX(2)+(6.50*SCX)
      YL=H(1)-(2.60*SCY)
      LM(1)=3 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TL  ,10)
      XL=SX(2)+(7.70*SCX)
      LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,IDT,10)
```

```
      XL=SX(2)+(8.90*SCX)
      LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,IXT,10)
      YL=H(1)-(3.40*SCY)
      XL=SX(2)+( 8.3*SCX)
      S(1)=SX(2)+(7.3*SCX)
      S(2)=SX(2)+(8.1*SCX)
      T(1)=T(2)=YL
      CALL LINE(9,S,T,2,SHX,SHY)
      LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TA,10)
      YL=H(1)-(3.77*SCY)
      T(1)=T(2)=YL
      CALL LINF(1,S,T,2,SHX,SHY)
      LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TB,10)
      YL=H(1)-(4.14*SCY)
      T(1)=T(2)=YL
      CALL LINE(1,S,T,2,SHX,SHY)
      LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TC,10)
      YL=H(1)-(4.51*SCY)
      T(1)=T(2)=YL
      CALL LINE(1,S,T,2,SHX,SHY)
      LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(XL,YL,LM,TD,10)
C     -------------------PLOTTING GRAPH------------------------
      DO 12 K=1,LL
      N1=NU(K)   $    LS=NS(K)
      J=0
      DO 10 I=1,N1
      IF(BY(I,K).GT.SY(1).OR.BX(I,K).LT.SX(2)) GO TO 10
      IF(BY(I,K).LT.SY(2).OR.BX(I,K).GT.SX(1)) GO TO 10
      J=J+1
      IF(J.GT.200) GO TO 13
      A(J)=BX(I,K)    $    B(J)=BY(I,K)
   10 CONTINUE
   11 CALL LINF(LS,A,B,J,SHX,SHY)
   12 CONTINUE
      RETURN
   13 PRINT 14,LL       $    CALL PAGE(1)    $   J=200.    $    GO TO 11
      END
```

PLTVOL

Subroutine PLTVOL is used only in the service volume program to set up graphs. It does not draw the contour lines.

```
      SUBROUTINE PLTVOL
C     PLOT SUBROUTINE FOR SRVVOLM
C     ROUTINE FOR MODEL AUG 73

   14 FORMAT(*   CAPACITY OF LINE*,I2,* IS OVER 100 POINTS*)
   23 FORMAT(I3,5X)
   27 FORMAT(I2,6X)
```

```
   29 FORMAT(F3.1,5X)
   30 FORMAT(I1,7X)
   32 FORMAT(4X,I4)
   36 FORMAT(F4.0,4X)
   41 FORMAT(4X,F4.1)
   42 FORMAT(4X,F4.2)
   43 FORMAT(3X,F5.3)
   46 FORMAT(I4,4X)
      DIMENSION IT(5),AN(4),BT(5)
      DIMENSION TL(3),TH(4),TA(2),TB(2),TC(2),TD(2),TE(5)
      DIMENSION AX(2),AY(2),G(2),H(2),LM(6),X(2),Y(2)
      DIMENSION S(2),T(2)
      COMMON/PLVD/LUD,LYD,SHX,SHY,TG,SX(2),SY(2),TT(6),XC,YC,AAT
      COMMON/EGAP/IP,LN,IDT,IXT
      DATA (IT=1H ,24H    M E JOHNSON EXT 3587,1H )
      DATA (AN=31HD↓9ESIRED PATH DISTANCE IN N MI)
      DATA (BT=39H A↓9IRCRAFT ALTITUDE IN THOUSANDS OF FT)
      DATA (TL=17HR↓9UN ↓1C↓9ODE↓1:)
      DATA (TE=34HS↓9TATION SEPARATION↓1:      ↓9N MI)
      DATA (TH=25HD/U ↓9RATIO↓1:      ↓9D↓1B)
      DATA (TA=16HF↓9REE SPACE     )
      DATA (TB=16H(↓9OUTTER↓1)  5%)
      DATA (TC=16H(↓9MIDDLE↓1) 50%)
      DATA (TD=16H(↓9INNER↓1)  95%)
      TS=.001
C     -------------------DRAWING PERIMETER-------------------------
      SCX=(SX(1)-SX(2))/10.
      SCY=(SY(1)-SY(2))/10.
      G(1)=SX(1)+(0.3*SCX)
      G(2)=SX(2)-(1.0*SCX)
      H(1)=SY(1)+(4.8*SCY)
      H(2)=SY(2)-(1.2*SCY)
      SHX=(G(1)-G(2))/100.
      SHY=(H(1)-H(2))/100.
      PY=.3*SCY
      AX(1)=SX(2) $AX(2)=SX(1) $AY(1)=SY(2) $AY(2)= H(1)-(3.*SCY)
      LD1=0
      LD2=0
      NX=((SX(1)-SX(2))/XC)
      NY=((SY(1)-SY(2))/YC)+1.4
      CALL CRTPLT(G,H,5,IT,2)
      CALL CRTPLT(AX,AY,0,1,14)
C     ---------------------DRAWING GRID----------------------------
      LX=NX+1
      LY=NY+1
      Y(1)=SY(1) $ Y(2)=SY(2) $ X(1)=SX(2)
      DO 20 I=1,NX
      X(1)=X(1)+XC $X(2)=X(1)
      IF(X(1).GE.SX(1)) GO TO 33
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,2,0,1)
   20 CONTINUE
   34 X(1)=SX(2) $ X(2)=SX(1) $ Y(1)=SY(1)
      Y(2)=Y(1)
      DO 21 I=1,NY
      IF(Y(1).LE.SY(2)) GO TO 38
      CALL CRTPLT(0,0,0,0,8)
      CALL CRTPLT(X,Y,2,0,1)
      Y(1)=Y(1)-YC $Y(2)=Y(1)
   21 CONTINUE
C     ---------------------LABELING GRID--------------------------
   39 GY=SY(1) $ GX=SX(2)-(.95*SCX)
```

```
      AS=SY(2)
      DO 22 I=1,LY
      IF(LYD.GT.0) GO TO 16
      KL=GY*TS   $ IF(LUD.LT.0) KL=XABSF(KL)
      ENCODE(8,32,AL) KL
   44 LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(GX,GY,LM,AL,10)
      GY=GY-YC
      IF(GY.LT.AS) GY=SY(2)
   22 CONTINUE
      EX=SX(2) $ GY=SY(2)-(.2*SCY)
      DO 24 I=1,LX
      IF(XC.LT.1.) GO TO 25
      IX=EX
      IF(EX.LT.0.) GO TO 35
      IF (EX.LT.10.) GO TO 26
      IF(EX.GT.99.) GO TO 41
      ENCODE(8,27,AL) IX
      GX=EX-(.075*SCX)
      GO TO 28
   33 LX=I+1      $      GO TO 34
   38 LY=I    $    GO TO 39
   16 YA=GY       $    IF(LUD.LT.0) YA=ABSF(YA)
      IF(LYD-2)17,18,19
   17 ENCODE(8,41,AL)YA    $    GO TO 44
   18 ENCODE(8,42,AL)YA    $    GO TO 44
   19 ENCODE(8,43,AL)YA    $    GO TO 44
   41 IF(EX.GT.999.) GO TO 31
      ENCODE(8,23,AL) IX
      GX=EX-(.15*SCX)
      GO TO 28
   35 ENCODE(8,36,AL) EX
      GO TO 37
   31 ENCODE(8,46,AL) IX
   37 GX=EX-(.225*SCX)
      GO TO 28
   25 ENCODE(8,29,AL) EX
      GX=EX-(.15*SCX)
      GO TO 28
   26 ENCODE(8,30,AL)IX
      GX=EX
   28 LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
      CALL CRTPLT(GX,GY,LM,AL,10)
      EX=EX+XC
      IF(EX.GT.SX(1)) EX=SX(1)
   24 CONTINUE
C     -------------------DRAWING LEGEND-----------------------------
      YL=(  0.7*SCY)+SY(2)
      XL=SX(2)-(.85*SCX)
      LM(1)=5 $LM(2)=1 $LM(3)=1 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,BT,10)
      LM(1)=4 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      YL=SY(2)-(.60*SCY)
      XL=SX(2)+(  2.5*SCX)
      CALL CRTPLT(XL,YL,LM,AN,10)
      XL=SX(2)+(.4*SCX)
      YL=H(1)-(3.40*SCY)
      LM(1)=6 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TT,10)
      YL=H(1)-(3.90*SCY)
      LM(1)=5 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
      CALL CRTPLT(XL,YL,LM,TE,10)
      XL=SX(2)+(3.8*SCX)
      LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
```

```
CALL CRTPLT(XL,YL,LM,TG,10)
XL=SX(2)+(.4*SCX)
YL=H(1)-(4.40*SCY)
LM(1)=4 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
CALL CRTPLT(XL,YL,LM,TH,10)
XL=SX(2)+(2.25*SCX)
LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=2
CALL CRTPLT(XL,YL,LM,AAT,10)
XL=SX(2)+(6.50*SCX)
YL=H(1)-(2.60*SCY)
LM(1)=3 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
CALL CRTPLT(XL,YL,LM,TL ,10)
XL=SX(2)+(7.70*SCX)
LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
CALL CRTPLT(XL,YL,LM,IDT,10)
XL=SX(2)+(8.90*SCX)
LM(1)=1 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
CALL CRTPLT(XL,YL,LM,IXT,10)
YL=H(1)-(3.40*SCY)
XL=SX(2)+( 8.3*SCX)
S(1)=SX(2)+(7.3*SCX)
S(2)=SX(2)+(8.1*SCX)
T(1)=T(2)=YL
CALL LINE(9,S,T,2,SHX,SHY)
LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
CALL CRTPLT(XL,YL,LM,TA,10)
YL=H(1)-(3.77*SCY)
T(1)=T(2)=YL
CALL LINE(2,S,T,2,SHX,SHY)
LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
CALL CRTPLT(XL,YL,LM,TB,10)
YL=H(1)-(4.14*SCY)
T(1)=T(2)=YL
CALL LINE(1,S,T,2,SHX,SHY)
LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
CALL CRTPLT(XL,YL,LM,TC,10)
YL=H(1)-(4.51*SCY)
T(1)=T(2)=YL
CALL LINE(3,S,T,2,SHX,SHY)
LM(1)=2 $LM(2)=1 $LM(3)=0 $LM(4)=0 $LM(5)=0 $LM(6)=1
CALL CRTPLT(XL,YL,LM,TD,10)
RETURN
END
```

POWSUB

Subroutine POWSUB is used <u>only</u> in the station separation program. It performs parameter conversions, prints parameter sheet(s), and obtains an array of isotropic power values versus distance for both desired and undesired facilities.

```
      SUBROUTINE POWSUB
C     ROUTINE FOR MODEL AUG 73
    4 FORMAT(1H1)
    5 FORMAT(1H )
    6 FORMAT(20X,*INPUT*,21X,*WORKING VALUE*)
  106 FORMAT(5X,* DML IS LESS THAN ZERO.   ABORTING RUN *)
C           FORMAT STATEMENTS FOR PARAMETER SHEET AND WORK SHEET
  700 FORMAT(18X,*PARAMETERS FOR ITS PROPAGATION MODEL *,A8,/24X,A8,2X,A
     X8,* RUN*,//)
  701 FORMAT(32X,*REQUIRED OR FIXED*,/32X,*----------------- *,/15X,*AIR
     1CRAFT ALTITUDE:*,F8.0,* FT ABOVE MSL*)
  702 FORMAT(15X,*FACILITY ANTENNA HEIGHT:*,F7.1,* FT ABOVE SITE SURFACE
     X*)
  703 FORMAT(15X,*FREQUENCY:*,F6.0,* MHZ*)
  704 FORMAT(29X,*SPECIFICATION OPTIONAL*,/29X,*----------------------*,
     4/15X,*ABSORPTION: OXYGEN*,F9.5,* DB/KM*,A2,/27X,*WATER VAPOR*,F9.5
     4,*DB/KM*,A2)
  705  FORMAT(15X,*EFFECTIVE ALTITUDE CORRECTION FACTOR: *,F6.0,* FT*,A2
     5,/15X,*EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL:*,F7.0,* F
     5T*,/15X,*EQUIVALENT ISOTROPICALLY RADIATED POWER: *,F6.1,* DBW*,/1
     55X,*FACILITY ANTENNA TYPE: *,5A8)
  706 FORMAT(20X,*COUNTERPOISE DIAMETER:*,F5.0,* FT*,/25X,*HEIGHT:*,F5.0
     6,* FT ABOVE SITE SURFACE *,/25X,*SURFACE:*,2A8)
  707 FORMAT(20X,*POLARIZATION:*,2A8)
  708 FORMAT(15X,*HORIZON OBSTACLE DISTANCE:*,F7.2,* N MI FROM FACILITY*
     8,A2,/20X,*ELEVATION ANGLE:  *,I3,*/*,I2,*/*,I2,* DEG/MIN/SEC ABOVE
     8 HORIZONTAL*,A2,/20X,*HEIGHT:*,F6.0,* FT ABOVE MSL*,A2)
  709 FORMAT(15X,*MINIMUM MONTHLY MEAN SURFACE REFRACTIVITY:*,/20X,F3.0,
     9* N-UNITS     AT SEA LEVEL: *,F3.0,* N-UNITS*)
  710 FORMAT(15X,*TERRAIN ELEVATION AT SITE:*,F6.0,* FT ABOVE MSL*,/20X,
     A*PARAMETER:*,F5.0,* FT*,/20X,*TYPE: *,2A8)
  712 FORMAT(20X*ANTENNA HEIGHT TOO HIGH, IONOSPHERIC EFFECTS*,/25X,*MAY
     2 BE IMPORTANT*)
  713 FORMAT(20X,*AIRCRAFT TOO LOW, TERRAIN BEYOND FACILITY *,/25X,*HORI
     3ZON MAY BE IMPORTANT*)
  714 FORMAT(20X,*IN ADDITION, SURFACE WAVE CONTRIBUTIONS SHOULD*,/15X,*
     4BE CONSIDERED*)
  715 FORMAT(20X,*ANTENNA TOO HIGH, RAY BENDING OVERESTIMATED*,/)
  716 FORMAT(20X,*ANTENNNA TOO LOW, SURFACE WAVE SHOULD BE*,/25X,*CONSID
     6ERED*)
  717 FORMAT(20X,*FREQUENCY TOO LOW, IONOSPHERIC EFFECTS MAY BE*,/25X,*I
     7MPORTANT*,//)
  718 FORMAT(20X,*ATTENUATION AND/OR SCATTERING FROM HYDROMETEORS*,/25X,
     8*(RAIN, ETC) MAY BE IMPORTANT*)
  719 FORMAT(20X,*ATMOSPHERIC ABSORPTION ESTIMATES MAY BE*,/25X,*UNRELIA
     9BLE*)
  724 FORMAT(/15X,A2,*COMPUTED VALUE*)
  725 FORMAT(20X,*TYPE: *,2A8,A1)
  726 FORMAT(12X,*EARTH*,F9.0 ,* N MI               *,F8.0,* KM*)
  728 FORMAT(12X,*HRE= *,F8.4,*-*,F8.4,*-*,F8.4,* = *,F8.4,* KM*)
  729 FORMAT(15X,*TIME AVAILABILITY:  *,4A8,A1,//)
  731 FORMAT(12X,* H(A) *,F8.0,* FT MSL             *,F8.4,* KM MSL*)
  732 FORMAT(12X,* H(F) *,F8.1,* FT TO SURFACE      *,F8.4,* KM *)
  733 FORMAT(12X,*FREQUENCY*, F5.0,* MHZ            *,F8.0,*  MHZ *)
  734 FORMAT(12X,* A(O)*, F9.5,* DB/KM              *,F8.5,* DB/KM*,A2)
  735 FORMAT(12X,* A(W)*,F9.5 ,* DB/KM              *,F8.5,* DB/KM*,A2)
  736 FORMAT(12X,*D(HE) *,F8.0,*                    *,F8.4,* KM*,A2)
  737 FORMAT(12X,*EIRP *,F9.1 ,* DBW                *,F8.1,*  DBW *)
  738 FORMAT(12X,*F ANT *,6X,I2, 2X,5A8)
  739 FORMAT(12X,* D(C) *,F8.0,* FT                 *,F8.4,* KM*)
```

```
740 FORMAT(12X,* H(C) *,F8.0,* FT ABOVE SURFACE   *,F8.4,* KM*)
741 FORMAT(12X,*COUNTERPOISE*,I2,10X,2A8)
742 FORMAT(12X,*H(FR) *,F8.0,* FT ABOVE REFLECTION*,F8.4,* KM*)
743 FORMAT(12X,*POLARIZATION*,I2,10X,2A8)
745 FORMAT(10X,A2,*D(HO) *,F8.2,* N MI FROM HORIZON  *,F8.2,* KM*)
746 FORMAT(10X,A2,*E(HO) *,I2,*/*,I2,*/*,I2,* DEG/MIN/SEC*,7X,F8.5,* R
   6ADIANS*)
747 FORMAT(10X,A2,*H(HO) *,F8.0,* FT MSL                *,F8.4,* KM*)
748 FORMAT(12X,* N(O)*,F9.0 ,* N-UNITS        N(S) *,F8.0,* N-UNITS*)
749 FORMAT(12X,*H(SUR)*,F8.0,* FT MSL               *,F8.4,* KM*)
750 FORMAT(12X,*DH(SUR)*,F7.0,* FT                   *,F8.4,* KM*)
751 FORMAT(12X,*TERRAIN*,5X,I2,10X,2A8)
756 FORMAT(25X,2A8)
757 FORMAT(12X*INPUT PARAMETERS FOR *,A8,2X,A8,* RUN*,/12X*OF *,A8,* A
   1IR/GROUND MODEL*,//)
778 FORMAT(15X,*SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
   X*)
779 FORMAT(15X,*SURFACE REFLECTION LOBING:  DETERMINES MEDIAN*)
785 FORMAT(12X,*SURFACE REFLECTION LOBING:  CONTRIBUTES TO VARIABILITY
   X*)
786 FORMAT(12X,*SURFACE REFLECTION LOBING:  DETERMINES MEDIAN*)
800 FORMAT(//10X,*SOME PARAMETERS ARE OUT OF RANGE*)
809 FORMAT(20X,*DLT IS LESS THAN .1XDLST OR GREATER THAN 3XDLST*)
810 FORMAT(20X,*INITIAL TAKE-OFF ANGLE GREATER THAN 12 DEG.*)
840 FORMAT(5X,*PROGRAM IS BEING ABORTED FOR WRONG PARAMETERS*)

      DIMENSION CFK(3),CMK(3),CFM(3),CKM(3),CKN(3)
      DIMENSION ACD(101),AND(101),SCT(101),AAD(101),RW(101)
      DIMENSION PAS(2)
      DIMENSION FAT(5,8),CCI(2,7),POL(2,3),TSC(2,7)
      DIMENSION MTM(5),YCON(5)
      DIMENSION YV(10),SV(10)
      DIMENSION P(35),QC(50),QA(50),PQA(50),PQK(50),QK(50),PQC(50)
      DIMENSION TYD(3,2),VYD(5,2)
      DIMENSION RE(2),AD(35),BD(35),ALM(12)
      COMMON/EGAP/IP,LN,IDT,IXT
      COMMON/RYTC/QNS,QHC,QHA,QHS,QQD
      COMMON/PAINP/NK,HFI,NPL,SUR,HPFI,DHSI,NSC,DCI,HCI,NCC,DHOI,HHOI,ID
     XG,IMN,ISEC, KE,MK,MD,EIRP,NLB,HAI,DHEI,ENO,AOI,AWI,F,IA,ADENT(2),A
     XDNT(3),VARFOR(6),CMAX
      COMMON/PARAM/HTE,HRE,D,DLT,DLR,ENS,EFRTH,FREK,ALAM,TET,TER,KD,GAO,
     XGAW
      COMMON/PAOUT/NCT,PFY(200,6)
      COMMON/SIGHT/DCW,HCW,DM1X,DML,DZR,IK,EAC,H2,ICC,HFC,PRH,DSL1,PIRP,
     XQG1,QG9,KK,ZH,RDHK,ILB
      COMMON/SCATPR/HT,HR,ALSC,TWEND,THRFK,HLT,HLR,THETA,HTP,AA,REW
      COMMON/DIFPR/HTD,HRD,DH,AED,SLP,DLST,DLSR,IPL,KSC,HLD,HRP,AWD,SWP
      COMMON/GAT/IFA
      DATA (QMD=8H AUG 73 )
      DATA (CFK=.001,.0003048,.0003048)
      DATA (CMK=1.,1.609344,1.852)
      DATA (CFM=1.,.3048,.3048)
      DATA (CKM=1000.,3280.839895,3280.839895)
      DATA (CKN=1.,.6213711922,.5399568034)
      DATA (POL=8H HORIZON,3HTAL,8H VERTICA,1HL,8H CIRCULA,1HR)
      DATA (FAT=10H ISOTROPIC,3(1H ),4H DME,4(1H ),14H TACAN (RTA-2),3(1
     XH ),39H 4-LOOP ARRAY (COSINE VERTICAL PATTERN),39H 8-LOOP ARRAY (C
     XOSINE VERTICAL PATTERN),34H I OR II (COSINE VERTICAL PATTERN),1H ,
     X40HJTAC TILTED 20 DEG WITH 40 HALF-POW B.W.,17HJTAC TILTED 8 DEG,2
     X(1H ))
      DATA(ALM=-6.2,-6.15,-6.08,-6.0,-5.95,-5.88,-5.8,-5.65,-5.35,-5.0,-
     X4.5,-3.7)
      DATA(TSC=16H SEA WATER       ,16H GOOD GROUND     ,16H AVERAGE GROUN
     XD ,16H POOR GROUND     ,16H FRESH WATER     ,16H  CONCRETE       ,16H
     X   METALLIC     )
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```
      DATA (PAS=2H  ,2H* )
      DATA  ((P(I),I=1,35)=.00001,.00002,.00005,.0001,.0002,.0005,.001,.
     X002,.005,.01,.02,.05,.1 ,.15,.20,.30,.40,.50,.60,.70,.80,.85,.90,.
     X95,.98,.99,.995,.998,.999,.9995,.9998,.9999,.99995,.99998,.99999)
      DATA(VYD=33HFOR HOURLY MEDIAN LEVELS EXCEEDED,33HFOR INSTANTANEOUS
     X LEVELS EXCEEDED)
      DATA(TYD=17HSMOOTH EARTH     ,17HIRREGULAR TERRAIN)
      DATA (MTM=20,10,30,0,0)
      DATA (YCON=5.,10.,25.,0.,0.)
      DATA(CCI=16H SEA WATER       ,16H GOOD GROUND    ,16H AVERAGE GROUN
     XD ,16H POOR GROUND     ,16H FRESH WATER     ,16H  CONCRETE       ,16H
     X   METALLIC      )
      DATA (DMOD=8H DIFRACT)  $  DATA (SMOD=8H SCATTER)
      DATA (CMOD=8H COMBINE)
      FNA(FX,FA,FB,FC,FD)=((FX-FB)*(FC-FD)/(FA-FB))+FD
      IK=NK    $    IPL=NPL    $    KSC=NSC    $    ICC=NCC    $    ILB=NLB
      KK=MK    $    KD=MD     $     DMAX=CMAX
      TPTH=2.617993878E-2   $    TLTH=0.      $    TPK=20.
      ASPA=0.25     $     ASPB=0.25
      ZO=.00000001
      ICAR=0
      RAD=.01745329252    $    DEG=57.29577951    $    TWDG=12.*RAD
      PI=3.141592654     $    ERTH=6370.      $     NOC=1
C     -----------------START OF PARAMETER SHEET-----------------
      PRINT 4
      PRINT 700,QMD,IDT,IXT
      PRINT VARFOR,ADENT,ADNT
      H2=HAI*CFK(IK)     $     HFS=HFI*CFK(IK)     $    FREK=F
      PRINT 701,HAI
      IF(HAI.GT.300000.) ICAR=1
      IF(HAI.GT.150000.) PRINT 712
      IF(HAI.LT.500.) PRINT 713
      IF(HAI.LT.1.5) PRINT 714
      IF(HAI.LT.0.) GO TO 825
      PRINT 702,HFI
      IF(HFI.LT.0.) GO TO 825
      IF(HFI.GT.9000.) PRINT 715
      IF(HFI.LT.1.5) PRINT 716
      PRINT 703,FREK
      IF(F.LT.100.)GO TO 805
  806 IF(F.LT.20.) GO TO 400
      IF(F.GT.5000.) PRINT 718
      IF(F.GT.17000.) GO TO 807
  808 IF(F.GT.100000.) GO TO 400
      PRINT 5
      IF(AOI.LT.0.) GO TO 56
      PXH=PAS(1)
   57 GAO=AOI    $    GAW=AWI
      PRINT 704,GAO,PXH,GAW,PXH
      IF(SUR.GT.15000.) ICAR=1
      IF(SUR.LT.0.) GO TO 830
  831 ASPC=ASPA*ASPB*(6.E-8)*F
      PIRP=EIRP
      HRP=HPFI*CFK(IK)
      IF(HAI.LT.(HPFI+500.)) ICAR=1
      ETS=SUR*CFK(IK)    $    HAS=H2-ETS
      IF(ETS.LT.0.) ETS=0.
      IF(SUR.GT.15000.) ICAR=1
      IF(HAS.LT.HFS) GO TO 770
      IF(DHSI.LT.0.) DHSI=0.
      DH=DHSI*CFK(IK)
      IF(ENO.LT.250..OR.ENO.GT.400.) GO TO 801
  802 ENS=ENO*EXPF(-0.1057*HRP)
      IF(ENS.LE.250.) GO TO 803
```

```
 804 EFRTH=ERTH/(1.-.04665*EXPF(.005577*ENS))
     EART=EFRTH*CKN(IK)
     HT=HFS+ETS              $      H1=HT
     IF(HRP.GT.H1) GO TO 825
     HTE=HT-HRP              $    DLST=SQRTF(2.*EFRTH*HTE)
     HFRI=HTE*CKM(IK)
     IF(DHEI.LT.0.) GO TO 50
     EAC=DHEI*CFK(IK)
     PDH=PAS(1)
     HR=H2-EAC     $   HRS=HR-ETS
     HRE=HR-HRP     $     DLSR=SQRTF(2.*HRE*EFRTH)
     IF(HRE.GE.50.) DLSR=EFRTH*ACOSF(EFRTH/(EFRTH+HRE))
     DS0=3.*SQRTF(2000.*HTE)+3.*SQRTF(2000.*HRE)
     JK=1
  55 PRINT 705,DHEI,PDH,HPFI,EIRP,(FAT(I,IFA),I=1,5)
     IF(DCI.LE.ZO) GO TO 789
     IF(ICC.LE.0) GO TO 789
C    -------------COUNTERPOISE PARAMETERS CONVERTED------------
     NOC=1
     DCW=DCI*CFK(IK)    $    HCW=HCI*CFK(IK)
     PRINT 706,DCI,HCI,(CCI(I,ICC),I=1,2)
     IF(HCI.LT.0.) GO TO 828
 829 IF(HCI.GT.500.) ICAR=1
     IF (DCW.GT..1524) ICAR=1
     IF(HCW.GT.HFS) GO TO 825
     HFC=HT-ETS-HCW
 788 CONTINUE
     PRINT 707,(POL(I,IPL),I=1,2)
C    ------HORIZON AND INITIAL TAKE-OFF ANGLE COMPUTATIONS------
     PDS=PTS=PHS=PAS(1)
     IF(KD.LE.1) GO TO 755
     HLT=HHOI*CFK(IK)    $    DLT=DHOI*CMK(IK)
     HLTS=HLT-HT
     DG=IDG  $  AMN=IMN  $  SEC=ISEC
     TET=RAD*(DG+(((SEC/60.)+AMN)/60.))    $    ATET=ABSF(TET)
     TATET=TANF(TET)
     IF(KE.EQ.3) GO TO 782
     IF(DLT.LE.ZO) GO TO 781
 759 IF(KE-1)730,758,780
 758 IF(TET.LT.0.) GO TO 752
     HLTS=DLT*TATET+(DLT*DLT/(2.*EFRTH))
 753 HLT=HLTS+HFS+ETS    $    HHOI=HLT*CKM(IK)
     PHS=PAS(2)
 783 CONTINUE
     IF(DLT.LT.(.1*DLST).OR.DLT.GT.(3.*DLST)) PRINT 809
     IF(TET.GT..20943951) PRINT 810
     IF(HHOI.GT.15000.) ICAR=1
     PRINT 708,DHOI,PDS,IDG,IMN,ISEC,PTS,HHOI,PHS
C    ----------------------------------------------------------
     PRINT 725,(TYD(I,KD),I=1,3)
     PRINT 709,ENS,ENO
     IF(ILB.GT.0) GO TO 762
     PRINT 778
 763 PRINT 710,SUR,DHSI,(TSC(I,KSC),I=1,2)
     PRINT 729,(VYD(I,KK),I=1,5)
     PRINT 724,PAS(2)
     IF(DMAX.GT.1000.) DMAX=1000.
     IF(ICAR.GT.0) PRINT 800

C    ------------------START OF WORK SHEET------------------
     PRINT 4
     PRINT 757,IDT,IXT,QMD
     PRINT 5   $   PRINT 6
     PRINT VARFOR,ADENT,ADNT
     PRINT 731,HAI,H2
```

```
      PRINT 732,HFI,HFS
      PRINT 733,F,FREK
      PRINT 734,AOI,GAO,PXH
      PRINT 735,AWI,GAW,PXH
      PRINT 736,DHEI,EAC,PDH
      PRINT 737,EIRP,EIRP
      PRINT 738,IFA,(FAT(I,IFA),I=1,5)
      IF(NOC.LT.1) GO TO 754
      PRINT 739,DCI,DCW
      PRINT 740,HCI,HCW
      PRINT 741,ICC,(CCI(I,ICC),I=1,2)
  754 CONTINUE
      PRINT 5
      PRINT 742,HFRI,HTE
      IF(F.GT.1600.) GO TO 304
      QG1=(.21*SINF(5.22*ALOG10(F/200.)))+1.28
      QG9=(.18*SINF(5.22*ALOG10(F/200.)))+1.23
  306 CONTINUE
      PRINT 728,H2,EAC,HRP,HRE
      PRINT 743,IPL,(POL(I,IPL),I=1,2)
      PRINT 745,PDS,DHOI,DLT
      PRINT 746,PTS,IDG,IMN,ISEC,TET
      PRINT 747,PHS,HHOI,HLT
      PRINT 748,ENO,ENS
      PRINT 726,EART,EFRTH
      PRINT 749,SUR,ETS
      PRINT 750,DHSI,DH
      PRINT 751,KSC,(TSC(I,KSC),I=1,2)
      IF(ILB.GT.0) GO TO 764
      PRINT 785
  765 PRINT 729,(VYD(I,KK),I=1,5)
      PRINT 724,PAS(2)
      IF(ICAR.GT.0) PRINT 800
      PRINT 4
C     --------------END OF PRELIMINARY PRINTING----------------

      CUBTR=100./F
      DSD=65.*CUBERTF(CUBTR)
      DSLI=DSO+DSD
      ALAM=.2997925/F
      THRFK=30.*ALOG10(FREK)
      ICPT=0
      DLS=DLST+DLSR
      AFP=32.45+20.*ALOG10(FREK)
      DKAX=DMAX*CMK(IK)
C     ----HORIZON POINT DISTANCE AND PARAMETER CALCULATION-------
      IF(JK.LT.0) GO TO 58
      TRM=((HTE+EFRTH)*COSF(TET))/(HRE+EFRTH)
      DML=EFRTH*(ACOSF(TRM)-TET)
      DLR=DML-DLT
   59 DNM=DML*CKN(IK)
      IF(DML.LE.0.) GO TO 107
      D=DML    $    TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      HTP=HRP
      DRP=DLSR
      TATER=((HLT-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
      TATES=((HRP-HR)/DRP)-(DRP/(2.*EFRTH))
      TES=ATANF(TATES)
      IF((HLT-HRP).LE.0.) 15,14
   15 DHRP=DLSR+DLT      $    GO TO 13
   14 DHRP=DLT+DLSR+SQRTF(2.*EFRTH*(HLT-HRP))
   13 CONTINUE

      HTD=HT    $    HRD=HR    $   ,HLD=HLT
```

```
      CALL DEFRAC
      GVD=GAIN(TET)     $    GDD=20.*ALOG10(GVD)
      SMD=((INTF(DNM/1.))*1.)+1.     $    AMD=AWD+(SWP*D)
      ATD=ARD=AMD
      DZR=-(AWD/SWP)
      PRH=-(AMD-GDD)          $    WRH=10.**(PRH*.1)
      ZH=ALOG10(WRH)-2.
C     ------------------LINE-OF-SIGHT----------------------------
      CALL BLOS
      SPD=SMD+2.
C     -------------BEYOND THE HORIZON CALCULATIONS---------------
      KFD=0
      DO 900 NSP=1,5
      MZS=MTM(NSP)
      IF(MZS.LE.0) GO TO 907
      DO 901 MXS=1,MZS
      D=SPD*CMK(IK)     $     DNM=SPD
      IF(D.GT.DHRP) GO TO 17
      DLR=D-DLT
      HLR=HLT
      TATER=((HLR-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
   19 CONTINUE
      IF(KFD-1)40,41,42
   40 KS=0          $         KR=0
      KS=1    $    ACD(KS)=ARD    $    AND(KS)=DML
      AMOD=DMOD
      EC1=HTE+EFRTH    $    EC2=HRE+EFRTH    $    EC3=HLT-HRP+EFRTH
      CALL SORB(EC1,EC3,EFRTH,DLT,TET,RO1,RW1)
      CALL SORB(EC2,EC3,EFRTH,DLR,TER,RO2,RW2)
      REO=RO1+RO2    $    REW=RW1+RW2    $    AA=GAO*REO+GAW*REW
                  RW(1)=REW
                  AAD(1)=AA
      DO 30 KC=1,100
      KS=KS+1
      D=DNM*CMK(IK)
      SPD=DNM
      ACD(KS)=AED+(SLP*D)
      AND(KS)=D
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      IF(D.GT.DHRP) GO TO 44
      HLR=HLT
      DLR=D-DLT    $    TATER=((HLT-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
   45 CONTINUE
      CALL SCATTER
      SCT(KS)=ALSC-ALFS
      AAD(KS)=AA    $    RW(KS)=REW
      IF(SCT(KS).LT.20.) GO TO 31
      KR=KR+1
      IF(KR.LE.1) GO TO 31
      KP=KS-1
      SSP= (SCT(KS)-SCT(KP))/(AND(KS)-AND(KP))
      IF(SSP.LE.(-.01)) GO TO 49
      IF(SSP.LE.SLP) GO TO 48
   31 DNM=DNM+1.
   30 CONTINUE
      PRINT 14      $      KFD=1     $    GO TO 33
   14 FORMAT(5X,*BEYOND THE 50 MILE LIMIT  DOING DIFFRACTION*)
   49 KR=0    $    GO TO 31
   33 DO 43 KG=1,KP
      D=AND(KG)
      DNM=D*CKN(IK)    $     SPD=DNM
```

```
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      ATTS=ACD(KG)
      AA=AAD(KG)   $   REW=RW(KG)$   THETA=TET+TER+(D/EFRTH)
      ASSIGN 36 TO KT
      GO TO 200
   36 CONTINUF
   43 CONTINUE
      SPD=DNM    $    MZS=6    $    KFD=1    $    GO TO 37
   48 IF(SCT(KP).GE.ACD(KP)) GO TO 33
      ACD(KP)=SCT(KP)
      SLP=(ACD(KP)-ARD)/(AND(KP)-DML)
      AED=ACD(KP)-(AND(KP)*SLP)
      ASSIGN 35 TO KT
      DO 34 KG=1,KP
      D=AND(KG)
      DNM=D*CKN(IK)    $    SPD=DNM
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      ATD=AED+(SLP*D)
      ATTS=ATD
      AMOD=CMOD
      AA=AAD(KG)   $   REW=RW(KG)$   THETA=TET+TER+(D/EFRTH)
      GO TO 200
   35 CONTINUE
   34 CONTINUE
      SPD=DNM    $    MZS=6    $    KFD=2    $    GO TO 37
   41 CONTINUE
      AMOD=DMOD
      ASSIGN 37 TO KT
      ATD=AED+(SLP*D)
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      IF(D.GT.DHRP) GO TO 24
      HLR=HLT
      DLR=D-DLT    $    TATER=((HLT-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
   25 CONTINUE
      CALL SCATTER
      ATS=ALSC-ALFS
      IF(ATS.LE.ATD) GO TO 46
      ATTS=ATD    $    THETA=TET+TER+(D/EFRTH)      $   GO TO 200
   46 ATTS=ATS  $  KFD=2    $    AMOD=SMOD    $    GO TO 200
   42 CONTINUE
      AMOD=SMOD
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      CALL SCATTER
      ATS=ALSC-ALFS    $    ATTS=ATS    $    ASSIGN 37 TO KT
  200 CONTINUE
C     ----------------LONG-TERM POWER FADING--------------------
      IF(D.LE.DSL1) 311,312
  311 DEE=(130.*D)/DSL1    $    GO TO 313
  312 DEE=130.+D-DSL1    $    GO TO 313
  313 CALL VZD(DEE,QG1,QG9,AD)
      NCT=NCT+1
      PFS=PIRP-ALFS
      PL=-ATTS
      ALIM=3.
      AL10=PL+AD(13)            $    AY=AL10-ALIM
      IF(AY.LT.0.) AY=0.
      DO 11 K=1,35
      BD(K)=PL+AD(K)-AY
   11 CONTINUE
      DO 12 K=1,12
      ALLM=-ALM(K)
      IF(BD(K).GT.ALLM) BD(K)=ALLM
   12 CONTINUE
```

```
C      -----------VALUES PUT INTO ISOTROPIC POWER ARRAY-----------
       IF(KK.GT.1) GO TO 20
   23  PGS=PFS+GDD
       PFL=PGS+PL-AA
       PFY(NCT,1)=DNM     $   PFY(NCT,2)=PGS        $    PFY(NCT,3)=PFL
       PFY(NCT,4)=BD(12)-PL     $       PFY(NCT,5)=BD(18)-PL
       PFY(NCT,6)=BD(24)-PL
       IF(SPD.GT.DMAX) GO TO 907
       GO TO KT,(35,36,37)
   37  CONTINUE
  903  SPD=SPD+YCON(NSP)
  901  CONTINUE
       SPD=SPD+YCON(NSP)
       NPP=NSP+1
       IF(NPP.GT.5) GO TO 907
       IF(YCON(NPP).EQ.0.) GO TO 907
       IF(NPP.EQ.0) GO TO 907
       IXD=INTF(SPD/YCON(NPP))
       SPD=(YCON(NPP)*FLOATF(IXD))+YCON(NPP)
  900  CONTINUE
  907  CONTINUE
  100  CONTINUE
       RETURN
C-----------------------RETURN TO MAIN PROGRAM-----------------------

   17  TER=TES   $   DLR=DRP   $   HLR=HRP   $  TATER=TATES   $  GO TO 19
C      ------------------TROPOSPHERIC MULTIPATH-----------------
   20  DO 21 I=1,35
       QA(I)=BD(I)-PL
       PQA(I)=P(I)
   21  CONTINUE
       IF(THETA.GE.TPTH) GO TO 26
       IF(THETA.LE.0.)  GO TO 27
       BK=FNA(THETA,TPTH,TLTH,TPK,RDHK)
   28  CONTINUE
       CALL YIKK(BK,PQK,QK)
       CALL CONLUT(QA,QK,PQA,35,+1.,0.,PQC,QC)
       DO 22 I=1,35
   22  BD(I)=QC(I)+PL
       GO TO 23

   24  TER=TES   $   DLR=DRP   $   HLR=HRP   $   TATER=TATES   $  GO TO 25
   26  BK=TPK    $   GO TO 28
   27  BK=RDHK   $    GO TO 28
   44  TER=TES   $   DLR=DRP   $   HLR=HRP   $   TATER=TATES   $  GO TO 45
C      -----------------CALCULATION OF RAY BENDING--------------
   50  PDH=PAS(2)
       HP2=H2-HRP    $    HP1=H1-HRP
       DUM=0.0     $     ZER=0.0     $    QLIM=-1.56
       QNS=329.   $    QHC=HP1    $    QHA=HP2    $    QHS=HRP
       CALL RAYTRAC(DUM)
       RY=TRACRAY(QLIM)
       DS0=QQD
       QNS=ENS     $    QHC=ZER    $    QHA=HP2    $    QHS=HRP
       CALL RAYTRAC(DUM)
       RY=TRACRAY(ZER)
       DLSR=QQD   $    TSL2=DLSR/EFRTH
       IF(TSL2.LE..1)  GO TO 53
       R2E=EFRTH/COSF(TSL2)
       HRE=R2E-EFRTH
   54  IF(HRE.GT.HP2) HRE=HP2
       HR=HRE+HRP   $    EAC=H2-HRP-HRE
       DHEI=EAC*CKM(IK)
```

```
      JK=-1
      GO TO 55
   53 HRE=(DLSR*DLSR)/(2.*EFRTH)            $      GO TO 54

   56 CALL ASORP(F,AOI,AWI)
      PXH=PAS(2)      $     GO TO 57
   58 TEH=TET+(DLT/EFRTH)
      QNS=ENS    $    QHC=HLT-HRP    $    QHA=HP2    $    QHS=HRP
      RY=TRACRAY(TEH)    $    DLR=QQD    $    DML=DLT+DLR    $    GO TO 59
  107 PRINT 106      $      GO TO 400
  304 QG1=QG9=1.05     $    GO TO 306
  752 HLTS=DLT*TET   +(DLT*DLT/(2.*EFRTH))     $            GO TO 753
  762 PRINT 779    $    GO TO 763
  764 PRINT 786    $    GO TO 765
  770 PRINT 800    $    GO TO 400

C     --------------HORIZON PARAMETER CALCULATIONS--------------
  781 HE=MAX1F(HTE,.005)
      DLT=DLST*EXPF(-.07*SQRTF(DH/HE))
      PDS=PAS(2)
      IF(DLT.LT.(.1*DLST)) DLT=.1*DLST
      IF(DLT.GT.(3.*DLST)) DLT=3.*DLST
      DHOI=DLT*CKN(IK)
      GO TO 759
  730 TRM=1.3*DH*((DLST/DLT)-1.)
      TRM=1.3*DH*((DLST/DLT)-1.)
      TET=(.5/DLST)*(TRM-(4.*HTE))
      IF(TET.GT.TWDG) TET=TWDG
      CALL RADEMS(TET,IDG,IMN,SEC)
      ISEC=XINTF(SEC)
      PTS=PAS(2)
      TATET=TANF(TET)
      GO TO 758
  782 XTRM=SQRTF((EFRTH*EFRTH*TATET*TATET)+(2.*EFRTH*HLTS))
      YTRM=-EFRTH*TATET       $    DLT=YTRM-XTRM
      IF(DLT.LE.0.) DLT=YTRM+XTRM
      PDS=PAS(2)
      DHOI=DLT*CKN(IK)     $    GO TO 783
  780 TATET=(HLTS/DLT)-(DLT/(2.*EFRTH))    $    TET=ATANF(TATET)
      PTS=PAS(2)
  784 CALL RADEMS(TET,IDG,IMN,SEC)
      ISEC=XINTF(SEC)    $    GO TO 783
C     -------------------SMOOTH EARTH PARAMETERS---------------
  755 PTS=PDS=PAS(2)
      DLT=DLST    $    DHOI=DLT*CKN(IK)
      TATET=(-HTE/DLT)-(DLT/(2.*EFRTH))    $    TET=ATANF(TATET)
      HLT=HRP    $    HHOI=HLT*CKM(IK)     $    DH=0.
      GO TO 784

  789 HFC=0.         $    GO TO 788
  801 ICAR=1    $    ENO=301.    $    GO TO 802
  803 ENS=250. $    ICAR=1    $    GO TO 804
  805 ICAR=1    $    PRINT 717    $    GO TO 806
  807 ICAR=1    $    PRINT 719    $    GO TO 808
  825 PRINT 800     $    GO TO 400
  828 ICAR=1            $    HCI=0.    $    GO TO 829
  830 ICAR=1          $    SUR=0.     $    GO TO 831

C     ------------------ABORTION OF PROGRAM-------------------

  400 PRINT 840          $      CALL EXIT
      END
```

PSWRB

Subroutine PSWRB is used only with the service volume program. It obtains an isotropic power versus distance array for both desired and undesired facility for each aircraft altitude considered.

```
      SUBROUTINE PWSRB

C     ROUTINE FOR MODEL AUG 73

    4 FORMAT(1H1)
    5 FORMAT(1H )
    6 FORMAT(20X,*INPUT*,21X,*WORKING VALUE*)
  106 FORMAT(5X,* DML IS LESS THAN ZERO.   ABORTING RUN *)
  840 FORMAT(5X,*PROGRAM IS BEING ABORTED FOR WRONG PARAMETERS*)
      DIMENSION CFK(3),CMK(3),CFM(3),CKM(3),CKN(3)
      DIMENSION ACD(101),AND(101),SCT(101),AAD(101),RW(101)
      DIMENSION MTM(5),YCON(5)
      DIMENSION YV(10),SV(10)
      DIMENSION P(35),QC(50),QA(50),PQA(50),PQK(50),QK(50),PQC(50)
      DIMENSION RE(2),AD(35),BD(35),ALM(12)
      COMMON/EGAP/IP,LN,IDT,IXT
      COMMON/RYTC/QNS,QHC,QHA,QHS,QQD
      COMMON/PARAM/HTE,HRE,D,DLT,DLR,ENS,EFRTH,FREK,ALAM,TET,TER,KD,GAO,
     XGAW
      COMMON/PAOUT/NCT,PFY(125,6),JJ,HP1,HP2
      COMMON/SIGHT/DCW,HCW,DM1X,DML,DZR,IK,EAC,H2,ICC,HFC,PRH,DSL1,EIRP,
     XQG1,QG9,KK,ZH,RDHK,ILB
      COMMON/SCATPR/HT,HR,ALSC,TWEND,THRFK,HLT,HLR,THETA,HTP,AA,REW
      COMMON/DIFPR/HTD,HRD,DH,AED,SLP,DLST,DLSR,IPL,KSC,HLD,HRP,AWD,SWP
      COMMON/GAT/IFA
      DATA(ALM=-6.2,-6.15,-6.08,-6.0,-5.95,-5.88,-5.8,-5.65,-5.35,-5.0,-
     X4.5,-3.7)
      DATA  ((P(I),I=1,35)=.00001,.00002,.00005,.0001,.0002,.0005,.001,.
     X002,.005,.01,.02,.05,.1 ,.15,.20,.30,.40,.50,.60,.70,.80,.85,.90,.
     X95,.98,.99,.995,.998,.999,.9995,.9998,.9999,.99995,.99998,.99999)
      DATA (MTM=20,10,30,0,0)
      DATA (YCON=5.,10.,25.,0.,0.)
      DATA (DMOD=8H DIFRACT)  $  DATA (SMOD=8H SCATTER)
      DATA (CMOD=8H COMBINE)
      DATA (CFK=.001,.0003048,.0003048)
      DATA (CKN=1.,.6213711922,.5399568034)
      DATA (CKM=1000.,3280.839895,3280.839895)
      DATA (CFM=1.,.3048,.3048)
      DATA (CMK=1.,1.609344,1.852)
      FNA(FX,FA,FB,FC,FD)=((FX-FB)*(FC-FD)/(FA-FB))+FD
      TPTH=2.617993878E-2   $   TLTH=0.     $   TPK=20.
      F=FREK
      ASPA=0.25    $    ASPB=0.25
      NOC=0
      ASPC=ASPA*ASPB*(6.E-8)*F
      IF(F.GT.1600.) GO TO 304
      QG1=(.21*SINF(5.22*ALOG10(F/200.)))+1.28
      QG9=(.18*SINF(5.22*ALOG10(F/200.)))+1.23
  306 DS0=3.*SQRTF(2000.*HTE)+3.*SQRTF(2000.*HRE)
      CUBTR=100./F
      DSD=65.*CUBERTF(CUBTR)
```

```
      DSL1=DS0+DSD
      THRFK=30.*ALOG10(FREK)
      ICPT=0
      DLS=DLST+DLSR
      AFP=32.45+20.*ALOG10(FREK)
      F=FREK
      DKAX=DMAX*CMK(IK)
C     ----HORIZON POINT DISTANCE AND PARAMETER CALCULATION-------

      IF(JJ.LT.1) GO TO 58
      TRM=((HTE+EFRTH)*COSF(TET))/(HRE+EFRTH)
      DML=EFRTH*(ACOSF(TRM)-TET)
   59 DNM=DML*CKN(IK)
      IF(DML.LE.0.) GO TO 107
      D=DML   $   DLR=D-DLT   $  TWEND=20.*ALOG10(D) $  ALFS=AFP+TWEND
      HTP=HRP
      DRP=DLSR
      TATER=((HLT-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
      TATES=((HRP-HR)/DRP)-(DRP/(2.*EFRTH))
      TES=ATANF(TATES)
      IF((HLT-HRP).LE.0.) 15,14
   15 DHRP=DLSR+DLT      $    GO TO 13
   14 DHRP=DLT+DLSR+SQRTF(2.*EFRTH*(HLT-HRP))
   13 CONTINUE

      HTD=HT   $   HRD=HR   $   HLD=HLT   $   HPP=HRP
      CALL DEFRAC
      GVD=GAIN(TET)    $   GDD=20.*ALOG10(GVD)
      SMD=((INTF(DNM/1.))*1.)+1.     $   AMD=AWD+(SWP*D)
      ATD=ARD=AMD
      DZR=-(AWD/SWP)
      PRH=-(AMD-GDD)         $    WRH=10.**(PRH*.1)
      ZH=ALOG10(WRH)-2.

C     -----------------LINE-OF-SIGHT---------------------------
      CALL CLOS
      SPD=SMD+2.

C     ------------BEYOND THE HORIZON CALCULATIONS-------------
      KFD=0
      DO 900 NSP=1,5
      MZS=MTM(NSP)
      IF(MZS.LE.0) GO TO 907
      DO 901 MXS=1,MZS
      D=SPD*CMK(IK)     $    DNM=SPD
      IF(D.GT.DHRP) GO TO 17
      DLR=D-DLT
      HLR=HLT
      TATER=((HLR-HR)/DLR)-(DLR/(2.*EFRTH))
      TER=ATANF(TATER)
   19 CONTINUE
      IF(KFD-1)40,41,42
   40 KS=0         $       KR=0
      KS=1    $   ACD(KS)=ARD    $    AND(KS)=DML
      AMOD=DMOD
      EC1=HTE+EFRTH    $   EC2=HRE+EFRTH    $   EC3=HLT-HRP+EFRTH
      CALL SORB(EC1,EC3,EFRTH,DLT,TET,RO1,RW1)
      CALL SORB(EC2,EC3,EFRTH,DLR,TER,RO2,RW2)
      REO=RO1+RO2    $    REW=RW1+RW2    $    AA=GAO*REO+GAW*REW
                     RW(1)=REW
                     AAD(1)=AA
      DO 30 KC=1,100
      KS=KS+1
```

```
   D=DNM*CMK(IK)
   SPD=DNM
   ACD(KS)=AED+(SLP*D)
   AND(KS)=D
   TWEND=20.*ALOG10(D)   $   ALFS=AFP+TWEND
   IF(D.GT.DHRP) GO TO 44
   HLR=HLT
   DLR=D-DLT   $   TATER=((HLT-HR)/DLR)-(DLR/(2.*EFRTH))
   TER=ATANF(TATER)
45 CONTINUE
   CALL SCATTER
   SCT(KS)=ALSC-ALFS
   AAD(KS)=AA   $   RW(KS)=REW
   IF(SCT(KS).LT.20.) GO TO 31
   KR=KR+1
   IF(KR.LE.1) GO TO 31
   KP=KS-1
   SSP= (SCT(KS)-SCT(KP))/(AND(KS)-AND(KP))
   IF(SSP.LE.(-.01)) GO TO 49
   IF(SSP.LE.SLP) GO TO 48
31 DNM=DNM+1.
30 CONTINUE
   PRINT 14     $     KFD=1    $    GO TO 33
14 FORMAT(5X,*BEYOND THE 50 MILE LIMIT  DOING DIFFRACTION*)
49 KR=0   $   GO TO 31
33 DO 43 KG=1,KP
   D=AND(KG)
   DNM=D*CKN(IK)   $    SPD=DNM
   TWEND=20.*ALOG10(D)   $   ALFS=AFP+TWEND
   ATTS=ACD(KG)
   AA=AAD(KG)   $   REW=RW(KG)$   THETA=TET+TER+(D/EFRTH)
   ASSIGN 36 TO KT
   GO TO 200
36 CONTINUE
43 CONTINUE
   SPD=DNM    $    MZS=6    $    KFD=1   $   GO TO 37
48 IF(SCT(KP).GE.ACD(KP)) GO TO 33
   ACD(KP)=SCT(KP)
   SLP=(ACD(KP)-ARD)/(AND(KP)-DML)
   AED=ACD(KP)-(AND(KP)*SLP)
   ASSIGN 35 TO KT
   DO 34 KG=1,KP
   D=AND(KG)
   DNM=D*CKN(IK)   $    SPD=DNM
   TWEND=20.*ALOG10(D)   $   ALFS=AFP+TWEND
   ATD=AED+(SLP*D)
   ATTS=ATD
   AMOD=CMOD
   AA=AAD(KG)   $   REW=RW(KG)$   THETA=TET+TER+(D/EFRTH)
   GO TO 200
35 CONTINUE
34 CONTINUE
   SPD=DNM    $    MZS=6    $    KFD=2   $   GO TO 37
41 CONTINUE
   AMOD=DMOD
   ASSIGN 37 TO KT
   ATD=AED+(SLP*D)
   TWEND=20.*ALOG10(D)   $   ALFS=AFP+TWEND
   IF(D.GT.DHRP) GO TO 24
   HLR=HLT
   DLR=D-DLT   $   TATER=((HLT-HR)/DLR)-(DLR/(2.*EFRTH))
   TER=ATANF(TATER)
25 CONTINUE
   CALL SCATTER
   ATS=ALSC-ALFS
```

```
      IF(ATS.LE.ATD) GO TO 46
      ATTS=ATD    $    THETA=TET+TER+(D/EFRTH)       $    GO TO 200
   46 ATTS=ATS    $  KFD=2    $    AMOD=SMOD    $    GO TO 200
   42 CONTINUE
      AMOD=SMOD
      TWEND=20.*ALOG10(D)    $    ALFS=AFP+TWEND
      CALL SCATTER
      ATS=ALSC-ALFS    $    ATTS=ATS    $    ASSIGN 37 TO KT
  200 CONTINUE
C     ---------------LONG-TERM POWER FADING--------------------
      IF(D.LE.DSL1) 311,312
  311 DEE=(130.*D)/DSL1    $    GO TO 313
  312 DEE=130.+D-DSL1    $    GO TO 313
  313 CALL VZD(DEE,QG1,QG9,AD)
      NCT=NCT+1
      PFS=EIRP-ALFS
      PL=-ATTS
      ALIM=3.
      AL10=PL+AD(13)             $    AY=AL10-ALIM
      IF(AY.LT.0.) AY=0.
      DO 11 K=1,35
      BD(K)=PL+AD(K)-AY
   11 CONTINUE
      DO 12 K=1,12
      ALLM=-ALM(K)
      IF(BD(K).GT.ALLM) BD(K)=ALLM
   12 CONTINUE
C     ----------VALUES PUT INTO ISOTROPIC POWER ARRAY-----------
      IF(KK.GT.1) GO TO 20
   23 PGS=PFS+GDD
      PFL=PGS+PL-AA
      PFY(NCT,1)=DNM     $    PFY(NCT,2)=PGS       $    PFY(NCT,3)=PFL
      PFY(NCT,4)=BD(12)-PL     $       PFY(NCT,5)=BD(18)-PL
      PFY(NCT,6)=BD(24)-PL
      IF(SPD.GT.DMAX) GO TO 907
      GO TO KT,(35,36,37)
   37 CONTINUE
  903 SPD=SPD+YCON(NSP)
  901 CONTINUE
      SPD=SPD+YCON(NSP)
      NPP=NSP+1
      IF(NPP.GT.5) GO TO 907
      IF(YCON(NPP).EQ.0.) GO TO 907
      IF(NPP.EQ.0) GO TO 907
      IXD=INTF(SPD/YCON(NPP))
      SPD=(YCON(NPP)*FLOATF(IXD))+YCON(NPP)
  900 CONTINUE
  907 CONTINUE
      RETURN

C-----------------------RETURN TO MAIN PROGRAM------------------------

   17 TER=TES   $   DLR=DRP   $   HLR=HRP   $  TATER=TATES   $  GO TO 19
C     -----------------TROPOSPHERIC MULTIPATH-----------------
   20 DO 21 I=1,35
      QA(I)=BD(I)-PL
      PQA(I)=P(I)
   21 CONTINUE
      IF(THETA.GE.TPTH) GO TO 26
      IF(THETA.LE.0.)  GO TO 27
      BK=FNA(THETA,TPTH,TLTH,TPK,RDHK)
   28 CONTINUE
      CALL YIKK(BK,PQK,QK)
      CALL CONLUT(QA,QK,PQA,35,+1.,0.,PQC,QC)
```

```
      DO 22 I=1,35
   22 BD(I)=QC(I)+PL
      GO TO 23

   24 TER=TES    $    DLR=DRP    $    HLR=HRP    $    TATER=TATES    $    GO TO 25
   26 BK=TPK    $    GO TO 28
   27 BK=RDHK    $    GO TO 28
   44 TER=TES    $    DLR=DRP    $    HLR=HRP    $    TATER=TATES    $    GO TO 45
   58 TEH=TET+(DLT/EFRTH)
      IF(KD.LE.1) TEH=0.0
      QNS=ENS    $    QHC=HLT-HRP    $    QHA=HP2    $    QHS=HRP
      RY=TRACRAY(TEH)    $    DLR=QQD    $    DML=DLT+DLR    $    GO TO 59

C     -------------------ABORTION OF PROGRAM----------------------
  107 PRINT 106       $       PRINT 840       $       CALL EXIT

  304 QG1=QG9=1.05    $    GO TO 306
      END
```

RADEMS

Subroutine RADEMS converts an angle expressed in radians to one expressed in degrees, minutes, and seconds.

```
      SUBROUTINE RADEMS(ARG,IDE,IMI,SEC)
C     ROUTINE FOR MODEL AUG 73

C     SUBROUTINE TO CHANGE RADIANS TO DEGREES, MINUTES AND SECONDS

      DE=ABSF(ARG)*57.29577951
      IDE=INTF(DE)
      AMINT=60.*(DE-FLOATF(IDE))
      IMI=INTF(AMINT)
      SEC=(AMINT-FLOATF(IMI))*60.
      IF(SEC.GT.59.99995) GO TO 9
    7 IF(IMI.GT.59) GO TO 8
    6 IDE=XSIGNF(IDE,ARG)
      RETURN
    9 SEC=0.    $    IMI=IMI+1    $    GO TO 7
    8 IDE=IDE+1    $    IMI=0    $    GO TO 6
      END
```

RAYTRAC

Function RAYTRAC performs the raytracing described in the text following figure 14. It is used in calculation of effective aircraft altitude via (34) and effective distance via (177) only when the effective height correction factor (table 1) is not specified.

```
      FUNCTION RAYTRAC(TT)
C     ROUTINE FOR MODEL AUG 73
      COMMON/RYTC/ENS,HC,HA,HS,D
      DIMENSION A(25),RI(25),EN(25),H(25),TEI(25),R(25)
      DATA(H=0.00,.01,.02,.05,.1,.2,.305,.5,.7,1.,1.524,2.,3.048,5.,7.,1
     X0.,20.,30.480,50.,70.,90.,110.,225.,350.,475.)

C     ----------SETING UP ARRAY OF REFRACTIVITY-----------------

      DN=-7.32*EXPF(0.005577*ENS)       $    CE=LOGF(ENS/(ENS+DN))
      AZ=6370.
      DUM=0.0
      AS=AZ+HS
      DO 10 I=1,25
      EN(I)=EXPF(-CE*H(I) )*ENS*1.E-6  $      RI(I)=1.+EN(I)
      R(I)=    AZ+H(I)+HS
   10 CONTINUE
      DO 20 I=2,25
      K=I-1
      DN2N=LOGF(RI(I))-LOGF(RI(K))
      DR2R=LOGF(R(I))-LOGF(R(K))
      A(I)=DN2N/DR2R
   20 CONTINUE
      RAYTRAC=DUM
      TT=0.
      RETURN

C     ----------ENTRANCE FOR TRACING RAY------------------------

      ENTRY TRACRAY
      TE=TT
      RC=    AZ+HC+HS   $ RA=    AZ+HA+HS
      ENC=  +1.E-6*ENS*EXPF(-CE*HC)        $    RIC=1.+ENC
      ENA=  +1.E-6*ENS*EXPF(-CE*HA)        $    RIA=1.+ENA
      BALL=0.           $    ATE=TE
      IF(TE.GE.0.) GO TO 41
      IF(R(1).EQ.RC) GO TO 73
      X=R(1)/(2.*RC)    $    Z=(RC-R(1))/R(1)   $  W=(EN(1)-ENC)/RIC
      TEG=-2.*ASINF(SQRTF(X*(Z-W)))       $    GO TO 72
   73 TEG=0.0
   72 IF(TE.LT.TEG) TE=TEG
      ATE=ABSF(TE)
      IF(TE.GE.0.) GO TO 41
      DO 70 I=2,25
       Y=2.*(SINF(0.5*ATE))**2     $       Z=(R(I)-RC)/RC
      W=(ENC-EN(I))*COSF(ATE)/RI(I)   $    X=Y+Z-W
      IF(X.LT.0.0) GO TO 70
      CT=SQRTF(0.5*RC*X/R(I))
      IF(CT.LE.1.) GO TO 60
   70 CONTINUE
   60 CT=2.*ASINF(CT)
      BALL=2.*CT*(-A(I)/(A(I)+1.))
      TEI(I)=CT     $     NK=I+1
      DO 80 I=NK,25
      RT=R(I)    $    RIT=RI(I)
      IF(RT.GT.RC) GO TO 61
   62 L=I-1
      X=RI(L)*R(L)/(RIT*RT)
      TEI(I)=ACOSF(COSF(TEI(L))*X)
      X=2.*(-A(I))/(A(I)+1.)
      BALL=BALL+(TEI(I)-TEI(L))*X
      NLA=I
      IF(RT=RC) GO TO 40
   80 CONTINUE
   40 CONTINUE
```

```
      IF(NLA.LT.2) NLA=2
      LL=NLA-1              $    TEI(LL)=ATE
      DO 90 I=NLA,25
      LC=I-1
   44 RT=R(I)    $    RIT=RI(I)      $      ENT=EN(I)
      IF(RT.GT.RA) GO TO 46
   47 X=RC/(2.*RT)    $    Y=2.*(SINF(0.5*ATE))**2
      Z=(RT-RC)/RC     $    W=(ENC-ENT)*COSF(ATE)/RIT
      TEI(I)=2.*ASINF(SQRTF(X*(Y+Z-W)))
      X= -A(I)/(A(I)+1.)
      BALL=BALL+((TEI(I)-TEI(LC))*X)
      TEA=TEI(I)    $    IF(R(I).GT.RA) GO TO 100
   90 CONTINUE
      X=RI(25)*R(25)/RA    $    TEA=ACOSF(COSF(TEA)*X)
  100 CA=(TEA-TE+BALL)
      D=AS*CA
      DN=D*.5399568034
      CT=COSF(BALL)    $    ST=SINF(BALL)    $    TNT=TANF(TEA)
      Y=RIA/RIC     $    X=(CT-ST*TNT-Y)/(Y*TANF(TE)-ST-CT*TNT)
      X=ATANF(X)
      CX=TE-X
      CTE=COSF(TEA)
      RAYTRAC=CX
      RETURN
   41 DO 85 NL=2,25
      IF(RC.LE.R(NL)) GO TO 86
   85 CONTINUE
      NL=25
   86 NLA=NL    $    GO TO 40
   46 RIT=RIA    $     RT=RA       $     ENT=ENA     $     GO TO 47
   61 RT=RC    $    RIT=RIC     $     GO TO 62
      END
```

RECC

Subroutine RECC is used in calculating reflective coefficients via (61) through (69), and (195).

```
      SUBROUTINE RECC(XI,FK,IR,NP,MS,DH,R,PIC,RLM)
C       ---NOTE---   THIS ANGLE IS LIKE THE FORMULATION IN TN 101 AND IS
C     PI-C
C     ROUTINE FOR MODEL AUG 73
C             THIS INCLUDES THE CIRCULAR POLARIZATION
      DIMENSION SG(7),EP(7)
      COMMON/EGAP/IP,LN,IDT,IXT
      DATA(EP=81.,25.,15.,4.,81.,5.,1.)
      DATA(SG=5.,.02,.005,.001,.010,.010,10.E+06)
      PI=3.141592654
      PI2=1.57079632
      IC=0
      SI=XI
      TWLD=2.095841232E-2*FK*(-1.)
      I=IR    $    MP=NP
      IF(SI.LE.0.) GO TO 301
```

```
      IF(SI.GE.PI2) GO TO 300
      SISI=SINF(SI)
      COSI=COSF(SI)
      IF(SISI.LE.0.) GO TO 15
      SQSI=SQRTF(SISI)
   16 IF(MS.GT.0) GO TO 19
      IF(DH.LE.4.) GO TO 17
      SH=.78*DH*EXPF(-.5*(DH**.25))
   18 EXDH=EXPF(TWLD*SH*SISI)
      DX=(SH*SISI*FK/299.7925)
      IF(DX.GT.0.3) GO TO 32
      IF(DX.GE.0.1237) GO TO 33
      IF(DX.GT.0.0739) GO TO 34
      IF(DX.GE.0.00325) GO TO 35
      PD=946.*DX*DX+0.01
   36 CONTINUE
   25 IF(MP-2) 10,11,20
   10 ASSIGN 12 TO N
      GO TO 6
   11 CONTINUE
      ASSIGN 13 TO N
    6 X=(18000.*SG(I))/FK
      TRM=EP(I)-(COSI*COSI)
      TUPS=SQRTF((TRM*TRM)+(X*X))+TRM
      P=SQRTF(TUPS*.5)
      GO TO N,(12,13)
   12 Q=X/(2.*P)
      DENOM=(P*P)+(Q*Q)
      B=1./DENOM
      AM=(2.*P)/DENOM
      RS=(1.+(B*SISI*SISI)-(AM*SISI))/(1.+(B*SISI*SISI)+(AM*SISI))
      R=SQRTF(RS)
      TOP=-Q
      BOT=SISI-P
      CALL RTATAN(TOP,BOT,TRA)
      TOP =Q
      BOT=SISI+P
      GO TO 14
   13 Q=X/(2.*P)
      DENOM=(P*P)+(Q*Q)
      B=((EP(I)*EP(I))+(X*X))/DENOM
      AM=(2.*((P*EP(I))+(Q*X)))/DENOM
      RS=(1.+(B*SISI*SISI)-(AM*SISI))/(1.+(B*SISI*SISI)+(AM*SISI))
      R=SQRTF(RS)
      TOP=(X*SISI)-Q
      BOT=(EP(I)*SISI)-P
      CALL RTATAN(TOP,BOT,TRA)
      TOP=(X*SISI)+Q
      BOT=(EP(I)*SISI)+P
   14 CALL RTATAN(TOP,BOT,TRB)
      PIC=TRA-TRB
      IF(IC-1) 52,22,23
   15 SQSI=0.   $   GO TO 16
   17 SH=.39*DH   $   GO TO 18
   19 SH=0.   $   EXDH=1.               $   GO TO 25
   20 IC=1   $   MP=MP-1   $   GO TO 11
   21 RLM=R          $   RETURN
   22 IC=2   $   RV=R   $   PV=PIC   $   MP=MP-1   $   GO TO 10
   23 IC=0   $   RH=R   $   PH=PIC
      TER=   ((RV*RV)+(RH*RH)+(2.*RV*RH*COSF(PH-PV)))
      IF(TER.LE.0.) GO TO 30
      R=SQRTF(TER)/2.
   31 TOP=(RH*SINF(PH))+(RV*SINF(PV))
      BOT=(RH*COSF(PH))+(RV*COSF(PV))
      IF(BOT.EQ.0.) GO TO 24
```

```
      CALL RTATAN(TOP,BOT,PC)
      PIC=PC   $   GO TO 51
   24 PIC=PI/2.  $   GO TO 51
   30 R=0.0   $   GO TO 31
   32 PD=(0.875*EXPF(-3.88*DX))+0.01              $     GO TO 36
   33 PD=(-1.06*DX)+0.601                         $     GO TO 36
   34 PD=0.45+SQRTF(.000843-(DX-.1026)**2)        $     GO TO 36
   35 PD=6.15*DX                                  $     GO TO 36
   51 IF(MS.GE.1) GO TO 21
      RLM=R*PD
      R=R*EXDH       $       RETURN
   52 IF(NP.EQ.2) GO TO 53
      GO TO 51
   53 CONTINUE
      GO TO 51
  300 SI=PI2  $   SISI=1.   $   COSI=0.   $   SQSI=1.   $   GO TO 16
  301 SI=0.   $   SISI=0.   $   COSI=1.   $   SQSI=0.   $   GO TO 16
      END
```

RTATAN

Subroutine RTATAN is used to obtain arctangent values for angles; the angle is placed in a quadrant that is appropriate for phasor manipulations, e.g., (81).

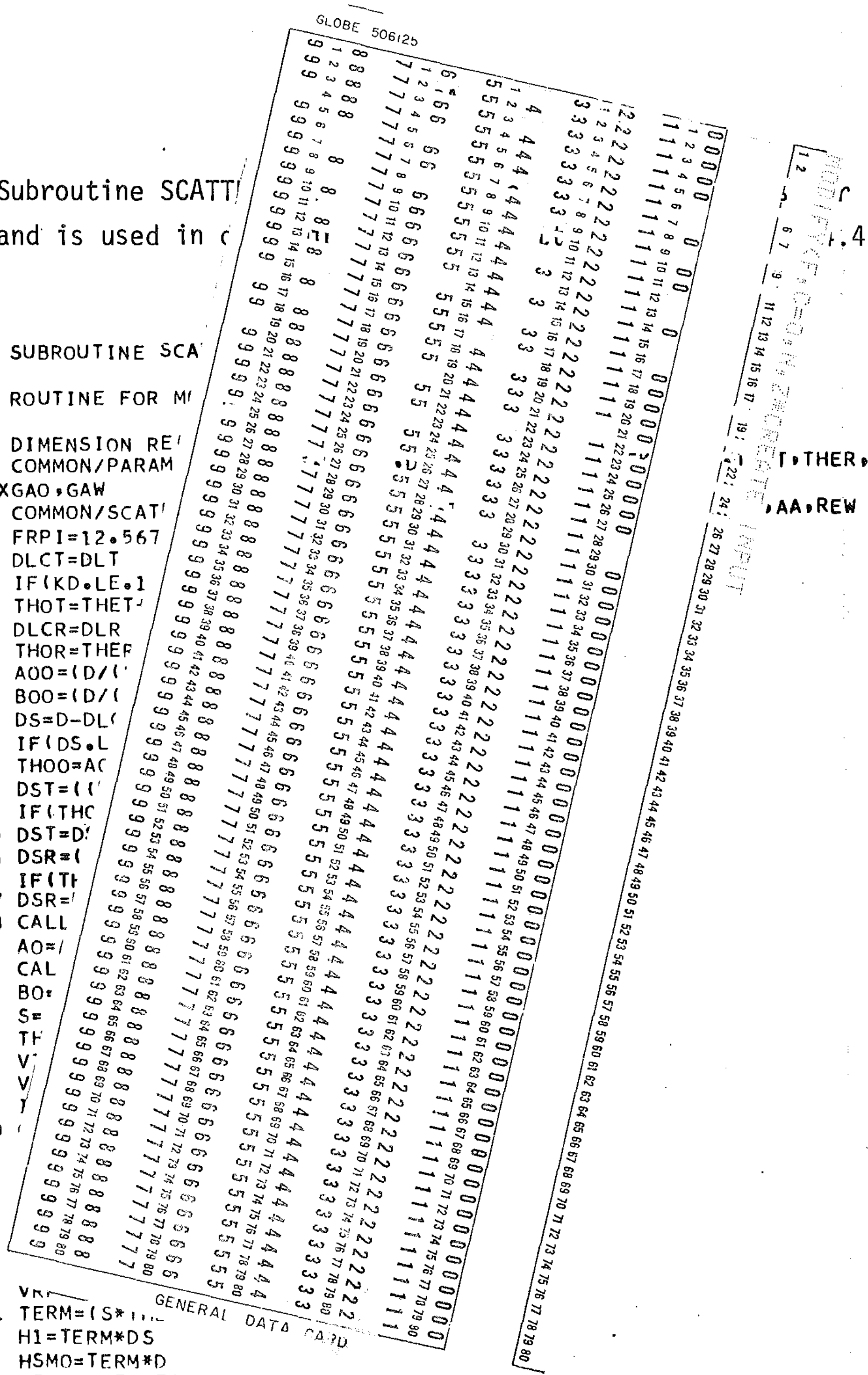
```
      SUBROUTINE RTATAN(TOP,DENOM,ANGLE)
C     ROUTINE FOR MODEL AUG 73

C     SUBROUTINE TO FIND ARCTANGENT IN THE CORRECT QUADRANT

      PI=3.141592654
      TWOPI=6.283185308
      IF(TOP)21,11,21
   21 IF(DENOM)26,27,26
   27 IF(TOP)28,11,29
   29 ANGLE=PI/2.
      GO TO 18
   28 ANGLE=(3.*PI)/2.
      GO TO 18
   26 THETA=TOP/DENOM
      IF(THETA)10,11,12
   10 THETA=THETA*(-1.0)
   12 ANGLE=ATANF(THETA)
      IF(TOP)13,14,14
   13 IF(DENOM)15,16,16
   15 ANGLE=PI+ANGLE
      RETURN
   16 ANGLE=TWOPI-ANGLE
      RETURN
   14 IF(DENOM)17,18,18
   17 ANGLE=PI-ANGLE
   18 RETURN
   11 ANGLE=0.0
      X=SIGNF(1.,TOP)
      Y=SIGNF(1.,DENOM)
      IF(X)19,20,20
   19 IF(Y)15,16,16
   20 IF(Y)17,18,18
      END
```

Subroutine SCATT r scatter

paths and is used in c .4).



```
      SUBROUTINE SCA
C     ROUTINE FOR M
      DIMENSION RE
      COMMON/PARAM                                        T,THER,KD,
     XGAO,GAW                                             ,AA,REW
      COMMON/SCAT
      FRPI=12.567
   19 DLCT=DLT
      IF(KD.LE.1
      THOT=THET
   22 DLCR=DLR
      THOR=THEF
   24 AOO=(D/(
      BOO=(D/(
      DS=D-DL(
      IF(DS.L
      THOO=A(
      DST=((
      IF(THC
   25 DST=D
   26 DSR=(
      IF(TH
   27 DSR=
   28 CALL
      AO=
      CAL
      BO
      S=
      TH
      V
      V
      I
   30
   2
      VR
   31 TERM=(S*
      H1=TERM*DS
      HSMO=TERM*D
      DTHE=D*THETA
      TR1=EXPF(-.0000038*HSMO**6)
      TR2=.031-(.00232*ENS)+(.00000567*ENS*ENS)
      ETAS=.5696*HSMO*(1.+(TR2*TR1))
      FO=1.084*(ETAS/HSMO)*(HSMO-H1-HLT-HLR)
      IF(THETA.LT.0.) DTHE=0.
      VT=VTP/ALAM
```

```
      VR=VRP/ALAM
      CALL HCHNOT(ETAS,S,VT,VR,HO)
  312 IF(THETA.LT.0.) GO TO 313
      CALL FDTETA(ENS,DTHE,S,DB)
  314 SUM=THRFK-TWEND-FO+HO+DB

C     ----CALCULATION OF OXYGEN AND WATER VAPOR RAYS ------------

      EC1=HTS-HTP+EFRTH       $      EC2=HRS-HTP+EFRTH
      HET=HLT-HTP+EFRTH      $      HER=HLR-HTP+EFRTH
      IF(DS.GT..001) GO TO 11
   14 CALL SORB(EC1,HET,EFRTH,DLT,THET,RE)
      REO=RE(1)   $   REW=RE(2)
      CALL SORB(EC2,HER,EFRTH,DLR,THER,RE)
      REO=REO+RE(1)   $   REW=REW+RE(2)
   12 AA=GAO*REO+GAW*REW
      RETURN
  313 DB=0.      $     GO TO 314
   10 THOT=THOR=0.    $   DLCR=DLR    $   GO TO 24
   11 HV=HET+(DST*TANF(THOT))+(DST*DST/(2.*EFRTH))
      IF(DST.LE.0..OR.DSR.LE.0.) GO TO 14
      DAT=DLT+DST
      DAR=DLR+DSR
      CALL SORB(EC1,HV,EFRTH,DAT,THET,RE)
      REO=RE(1)      $      REW=RE(2)
      CALL SORB(EC2,HV,EFRTH,DAR,THER,RE)
      REO=REO+RE(1)   $    REW=REW+RE(2)
      GO TO 12
      END
```

SORB

Subroutine SORB computes the effective ray lengths for oxygen and water vapor, $r_{eo,w}$, that are used in the calculation of atmospheric absorption (sec. A.4.5).

```
      SUBROUTINE SORB(H1,H2,A,RO,CA,RE)
C     ROUTINE FOR MODEL AUG 73
      DIMENSION RE(2),TE(2),H(2)
      TE(1)=3.25   $   TE(2)=1.36
      PI2=1.570796327      $        PI=3.141592654
      BA=CA
      IF(H1.GT.H2) GO TO 10
      HS=H1   $   HL=H2
   11 AT=PI2+BA
      ANUM=HS*SINF(AT)
      DO 22 K=1,2
      H(K)=TE(K)+A
      IF(HL.LE.H(K)) GO TO 83
      IF(H(K).LT.HS) GO TO 81
      AS=ASINF(ANUM/H(K))   $   AE=PI-(AT+AS)
      IF(BA.GT.1.5620) GO TO 24
      IF(AE.EQ.0.) GO TO 24
      RE(K)=(HS*SINF(AE))/SINF(AS)    $    GO TO 22
   24 RE(K)=H(K)-HS
```

```
22 CONTINUE
   RETURN
10 HS=H2    $    HL=H1 $ BA=-(CA+(R0/A))    $    GO TO 11
81 IF(AT.GT.PI2) GO TO 85
   HC=HS*SINF(AT)
   IF(H(K).LF.HC) GO TO 85
   RE(K)=2.*H(K)*SINF(ACOSF(HC/H(K)))
   GO TO 22
83 RE(K)=R0
   GO TO 22
85 RE(K)=0.    $    GO TO 22
   END
```

TABLE

Function TABLE is used to set up and obtain values from a table of grazing angle, ψ; corresponding values of path length difference, Δr; and great circle path distance, d. It is used in calculations for the line-of-sight region (fig. 19).

```
      FUNCTION TABLE(XINT)
C     ROUTINE FOR MODEL AUG 73

C     ENTER TINTER WITH DELTA R AND GET SI
C     ENTER DINTER WITH DELTA R AND GET DISTANCE
C     ENTER SINTER WITH DISTANCE AND GET SI

      COMMON/EGAP/IP,LN,IDT,IXT
      COMMON/SPLIT/L1,L2,N,X(140),Y(140),D6(140),XS(55),XD(55),XR(55),YS
     X(55),YD(55),YR(55),L3,ZS(25),ZD(25),ZR(25)
      DIMENSION AS(110),AD(110),AR(110)
C     --------------SET UP ARRAY-----------------------
      DUM=0.
      CALL TRMESH(XS,XD,XR,L1,YS,YD,YR,L2,AS,AD,AR,L5)
      CALL TRMESH(AS,AD,AR,L5,ZS,ZD,ZR,L3,Y,X,D6,N)
      M=N
      DO 21 I=1,N
      SD=Y(I)*57.29577951
   21 CONTINUE
      TABLE=DUM    $    RETURN

  101 FORMAT(31H OUT OF RANGE FOR INTERPOLATION)

      ENTRY TINTER
      IF(XINT-X(1))7,1,2
    1 YINT=Y(1)
      TABLE=YINT    $    RETURN
    2 K=1
    3 IF(XINT-X(K+1))6,4,5
    4 YINT=Y(K+1)
      TABLE=YINT    $    RETURN
    5 K=K+1
      IF(M-K)8,8,3
    6 YINT=((XINT-X(K))*(Y(K+1)-Y(K))/(X(K+1)-X(K)))+Y(K)
      TABLE=YINT    $    RETURN
```

```
  7 PRINT 101
    TABLE=Y(1)    $    RETURN
  8 PRINT 101
    TABLE=Y(M)    $    RETURN

    ENTRY DINTER
    IF(XINT-X(1))17,11,12
 11 TABLE=D6(1)    $    RETURN
 12 K=1
 13 IF(XINT-X(K+1))16,14,15
 14 TABLE=D6(K+1)    $    RETURN
 15 K=K+1
    IF(M-K)18,18,13
 16 TABLE=((XINT-X(K))*(D6(K+1)-D6(K))/(X(K+1)-X(K)))+D6(K)
    RETURN
 17 PRINT 101
    TABLE=D6(1)    $    RETURN
 18 PRINT 101
    TABLE =D6(M)    $    RETURN

    ENTRY SINTER
    IF(XINT-D6(1))32,31,37
 31 TABLE=Y(1)    $    RETURN
 32 K=1
 33 IF(XINT-D6(K+1))35,34,36
 34 TABLE=Y(K+1)    $    RETURN
 35 K=K+1
    IF(M-K)38,38,33
 36 TABLE=((XINT-D6(K))*(Y(K+1)-Y(K))/(D6(K+1)-D6(K)))+Y(K)
    RETURN
 37 PRINT 101
    TABLE=Y(1)    $    RETURN
 38 PRINT 101
    TABLE =Y(M)    $    RETURN
    END
```

TERP

Function TERP is used in subroutine HCHNOT to obtain values for parameters used in the calculation of H_0 for (169).

```
      FUNCTION TERP(ARG)
C     ROUTINE FOR MODEL AUG 73

C     ROUTINE TO FIND H(R1) AND H(R2)

      DIMENSION TABR(144),TAHR(144)
      DATA(TABR=100.0,95.0,90.0,85.0,80.0,75.0,70.0,65.0,60.0,55.0,50.0,
     X48.0,45.0,43.0,40.0,38.  ,35.0,33.0,30.0,28.0,26.0,24.0,22.0,20.0,1
     X9.0,18.0,17.0,16.0,15.0,14.0,13.0,12.0,11.0,10.0,9.5,9.0,8.5,8.0,7
     X.5,7.0,6.5,6.0,5.5,5.0,4.8,4.6,4.4,4.2,4.0,3.8,3.6,3.4,3.2,3.0,2.8
     X,2.6,2.4,2.2,2.0,1.9,1.8,1.7,1.6,1.5,1.4,1.3,1.2,1.1,1.0,.95,.9,.8
     X5,.8,.75,.7,.65,.6,.55,.5,.45,.4,.38,.36,.34,.32,.3,.28,.26,.24,.2
     X2,.2,.18,.16,.14,.12,.1,.09,.08,.07,.065,.06,.055,.05,.045,.04,.03
     X8,.036,.034,.032,.03,.028,.026,.024,.022,.02,.018,.016,.014,.012,.
     X01,.009,.008,.007,.0065,.006,.0055,.005,.0045,.004,.0038,.0036,.00
     X34,.0032,.003,.0028,.0026,.0024,.0022,.002,.0018,.0016,.0014,.0012
     X,.001)
```

```
      DATA(TAHR=.999805,.99978,.999765,.99973,.9997,.999655,.999605,.999
     X54,.99945,.99935,.99922,.99918,.99903,.99893,.99879,.99865,.9984,.
     X9982,.9978,.9975,.9971,.9966,.996,.9952,.9948,.994,.9933,.9926,.99
     X17,.9903,.989,.987,.9845,.9818,.98,.978,.9755,.9726,.9695,.9655,.9
     X61,.956,.948,.941,.938,.932,.928,.923,.918,.91,.902,.895,.887,.876
     X,.864,.85,.835,.815,.795,.78,.77,.755,.74,.725,.707,.683,.67,.645,
     X.623,.61,.595,.58,.56,.54,.525,.51,.485,.465,.445,.41,.385,.375,.3
     X6,.35,.335,.32,.295,.28,.264,.25,.232,.212,.193,.173,.152,.13,.129
     X,.108,.094,.089,.083,.076,.07,.063,.057,.054,.052,.049,.046,.044,.
     X0405,.038,.035,.0325,.03,.027,.024,.021,.0182,.0152,.0139,.0122,.0
     X108,.01,.0093,.0085,.0078,.007,.0062,.0059,.0056,.0053,.005,.00465
     X,.0044,.00405,.00375,.00345,.00315,.0028,.0025,.0022,.00188,.00158
     X)
      IF(ARG-.001)15,15,16
   15 TERP=.00158
      RETURN
   16 IF(ARG-100.)10,11,11
   11 TERP=.999805
      RETURN
   10 DO 12 KH=1,144
      IF(ARG-TABR(KH))12,13,14
   12 CONTINUE
   14 KL=KH-1
      TERP=((ARG-TABR(KH))/(TABR(KL)-TABR(KH)))*(TAHR(KL)-TAHR(KH))+TAHR
     X(KH)
      RETURN
   13 TERP=TAHR(KH)
      RETURN
      END
```

TRMESH

Subroutine TRMESH sorts and merges two tables of three element arrays in an ascending order. It is used in calculations associated with the line-of-sight region (fig. 19).

```
      SUBROUTINE TRMESH(A,B,C,NA,R,S,T,NR,X,Y,Z,N)
C     ROUTINE FOR MODEL AUG 73
      DIMENSION A(1),B(1),C(1),R(1),S(1),T(1),X(1),Y(1),Z(1)
      I=J=1   $    N=0
    4 N=N+1
      IF(A(I)-R(J))9,7,8
    9 X(N)=A(I)    $    Y(N)=B(I)    $    Z(N)=C(I)    $    I=I+1
      IF (I.GT.NA)5,4
    8 X(N)=R(J)    $    Y(N)=S(J)    $    Z(N)=T(J)    $    J=J+1
      IF(J.GT.NR)3,4
    7 X(N)=A(I)    $    Y(N)=B(I)    $    Z(N)=C(I)    $    I=I+1    $    J=J+1
      IF(I.GT.NA) 10,11
   10 IF(J.GT.NR) 12,5
   11 IF(J.GT.NR)3,4
    5 LI=J
      DO 16 LE=LI,NR
      N=N+1   $    X(N)=R(LE)    $    Y(N)=S(LE)    $    Z(N)=T(LE)
   16 CONTINUE
      GO TO 12
```

```
   3 LI=I
     DO 18 LE=LI,NA
     N=N+1    $    X(N)=A(LE)    $    Y(N)=B(LE)   $    Z(N)=C(LE)
  18 CONTINUE
  12 RETURN
     END
```

TSMESH

Subroutine TSMESH sorts and merges two tables of single element arrays in an ascending order. It is used in calculations associated with the line-of-sight region (fig. 19).

```
      SUBROUTINE TSMESH(A,NA,R,NR,X,N)
C     ROUTINE FOR MODEL AUG 73
      DIMENSION A(1),R(1),X(1)
      I=J=1    $    N=0
    4 N=N+1
      IF(A(I)-R(J))9,7,8
    9 X(N)=A(I)    $    I=I+1
      IF (I.GT.NA)5,4
    8 X(N)=R(J)    $    J=J+1
      IF(J.GT.NR)3,4
    7 X(N)=A(I)    $    I=I+1    $    J=J+1
      IF(I.GT.NA) 10,11
   10 IF(J.GT.NR) 12,5
   11 IF(J.GT.NR)3,4
    5 LI=J
      DO 16 LE=LI,NR
      N=N+1    $    X(N)=R(LE)
   16 CONTINUE
      GO TO 12
    3 LI=I
      DO 18 LE=LI,NA
      N=N+1    $    X(N)=A(LE)
   18 CONTINUE
   12 RETURN
      END
```

VZD

Subroutine VZD is used to calculate long-term (hourly median) variability (sec. A.5).

```
      SUBROUTINE VZD(DE,G1,G9,A)
C     ROUTINE FOR MODEL AUG 73
      DIMENSION B(35)
      DIMENSION C1(3),C2(3),C3(3),CN1(3),CN2(3),CN3(3),FM(3),FIN(3),Z(3)
     1,Y(35),A(50)

C   . MIXED--ALL YEAR TIME BLOCK YS AND CONTINENTAL V(50)

      DATA(C1=2.93E-4,5.25E-4,1.59E-5)
      DATA(C2=3.78E-8,1.57E-6,1.56E-11)
      DATA(C3=1.02E-7,4.70E-7,2.77E-8)
      DATA(CN1=2.00,1.97,2.32)
      DATA(CN2=2.88,2.31,4.08)
      DATA(CN3=3.15,2.90,3.25)
      DATA(FIN=3.2,5.4,0.0)
      DATA(FM=8.2,10.0,3.9)
   12 DO 13 I=1,3
      X=FIN(I)+((FM(I)-FIN(I))*EXPF(-C2(I)*DE**CN2(I)))
   13 Z(I)=(((C1(I)*DE**CN1(I))-X)*EXPF(-C3(I)*DE**CN3(I)))+X
      Y(13)=-Z(1)*G9
      Y(23)=Z(2)*G1
      Y(1)=3.3279*Y(13)
      Y(2)=3.2052*Y(13)
      Y(3)=3.0357*Y(13)
      Y(4)=2.9025*Y(13)
      Y(5)=2.7622*Y(13)
      Y(6)=2.5675*Y(13)
      Y(7)=2.4112*Y(13)
      Y(8)=2.2458*Y(13)
      Y(9)=2.0098*Y(13)
      Y(10)=1.8150*Y(13)
      Y(11)=1.6025*Y(13)
      Y(12)=1.2835*Y(13)
      Y(14)=0.8087*Y(13)
      Y(15)=0.6567*Y(13)
      Y(16)=0.4092*Y(13)
      Y(17)=0.1976*Y(13)
      Y(18)=0.0000
      Y(19)=0.1976*Y(23)
      Y(20)=0.4092*Y(23)
      Y(21)=0.6567*Y(23)
      Y(22)=0.8087*Y(23)
      Y(24)=1.3265*Y(23)
      Y(25)=1.7166*Y(23)
      Y(26)=1.9507*Y(23)
      Y(27)=2.2000*Y(23)
      Y(28)=2.5280*Y(23)
      Y(29)=2.7310*Y(23)
      Y(30)=2.9180*Y(23)
      Y(31)=3.1680*Y(23)
      Y(32)=3.3320*Y(23)
      Y(33)=3.4560*Y(23)
      Y(34)=3.6900*Y(23)
      Y(35)=3.8150*Y(23)
   17 DO 18 I=1,35
      KN=36-I
      B(I)=Y(I)+Z(3)
      A(KN)= B(I)
   18 CONTINUE
      RETURN
      END
```

YIKK

Subroutine YIKK is used to determine short-term (within-the-hour) for a specified value for the parameter K of (6). It uses the VF tables which are tabulated in this section under TABLES to obtain the Nakagami-Rice distribution [40, fig. VI] that corresponds to K. Actually, the K used in YIKK has a sign that is the opposite of that used in (6), and Rice et al. [40, fig. VI], but is the same as that of [38, table 1] from which the data were taken.

```
      SUBROUTINE YIKK(T,PV,V)
C     ROUTINE FOR MODEL AUG 73

C     THIS NAKAGAMA-RICE DIST.  HAS TABLES FROM NORTON 55 IRE PAGE 1360
C     THE TABLES ARE THE NEGATIVE OF THE KK IRE TABLES BUT ARE CHANGED
C     BEFORE GOING OUT OF THE ROUTINE
C     K HAS THE OPPOSITE SIGN OF 101 BUT THE SAME AS THE IRE PAPER

      DIMENSION P(35),PV(50),V(50)
      COMMON/VV/VF(36,17)
      DATA  ((P(I),I=1,35)=.00001,.00002,.00005,.0001,.0002,.0005,.001,.
     X002,.005,.01,.02,.05,.10,.15,.20,.30,.40,.50,.60,.70,.80,.85,.90,.
     X95,.98,.99,.995,.998,.999,.9995,.9998,.9999,.99995,.99998,.99999)
      AVEF(YN,XN,YN1,XN1) = (YN1*(T - XN) - YN*(T - XN1))/(XN1 - XN)
      DO 1 I = 1,14
      IF(T - VF(1,I)) 3,2,1
    1 CONTINUE
      I = 14
    2 DO 4 J = 1,35
      V(J) = VF(J+1,I)
    4 PV(J) = P(J)
      GO TO 6
    3 IF(I.EQ.1) GO TO 2
      DO 5  J = 1,35
      V(J) = AVEF(VF(J+1,I-1),VF(1,I-1),VF(J+1,I),VF(1,I))
    5 PV(J) =  P(J)
    6 DO 7 J=1,35
    7 V(J)=-V(J)
      RETURN
      END
```

B. 4.2. TABLES

The programs all require that a set of data cards be read before any input parameters are read (figs. 25, 26, 27). Tabulations of these tables are provided in the order required by READ statements of the programs. Each table is identified by the FORTRAN variables used in the READ statements associated with it.

TABLE TAV/TAH1

This table is used by subroutine HCHNOT.

40000	000	000	000	000	050	200	530	37000	000	000	000	000	065	225	575
35000	000	000	000	010	075	250	615	34000	000	000	000	013	078	260	640
33000	000	000	000	015	080	270	650	30000	000	000	000	020	100	310	720
27000	000	000	000	030	115	355	800	25000	000	000	000	040	125	400	860
23000	000	000	000	050	14	440	930	20000	000	000	010	060	160	520	1055
16000	000	010	030	085	210	670	1290	15000	010	015	038	100	230	720	1350
14000	015	020	045	110	250	775	1430	13000	020	025	060	120	270	840	1510
12000	023	040	072	130	290	905	1610	11000	025	050	080	150	325	1000	1720
10000	035	060	100	170	365	1090	1850	9500	040	070	117	180	390	1150	1930
9000	050	073	123	200	425	1205	2000	8500	055	080	130	220	455	1270	2080
8000	060	090	155	245	500	1350	2175	7500	070	110	175	270	545	1425	2280
7000	075	120	200	305	600	1500	2390	6800	080	126	210	320	630	1540	2430
6600	085	130	223	340	650	1580	2480	6400	090	140	230	355	680	1615	2530
6200	100	149	245	375	710	1650	2580	6000	105	160	255	400	740	1700	2640
5800	110	170	270	420	780	1740	2690	5600	120	175	285	440	810	1790	2760
5400	125	185	300	465	850	1830	2820	5200	130	200	320	495	890	1880	2890
5000	140	220	335	515	930	1940	2950	4800	150	225	350	550	980	2000	3030
4600	160	240	375	580	1030	2050	3100	4400	170	255	395	620	1080	2120	3180
4200	175	275	425	655	1150	2190	3270	4000	190	290	455	700	1210	2260	3350
3800	210	315	484	750	1280	2350	3450	3600	223	330	520	800	1350	2430	3500
3400	240	360	560	860	1430	2515	3600	3200	260	380	610	925	1515	2610	3710
3000	280	415	660	1000	1600	2720	3810	2900	295	426	680	1040	1650	2775	3890
2800	310	440	709	1070	1700	2840	3950	2700	325	460	740	1115	1750	2900	4020
2600	340	478	770	1155	1800	2960	4090	2500	350	500	800	1200	1860	3030	4130
2400	370	520	830	1250	1925	3100	4200	2300	390	545	873	1295	2010	3175	4300
2200	415	570	915	1350	2050	3260	4370	2100	435	600	960	1400	2120	3340	4450
2000	460	630	1005	1465	2200	3420	4520	1950	475	645	1030	1500	2230	3470	4580
1900	490	660	1055	1530	2275	3510	4620	1850	500	678	1080	1570	2320	3570	4680
1800	520	700	1120	1600	2360	3610	4710	1750	535	720	1150	1630	2400	3680	4750
1700	550	745	1180	1670	2450	3720	4800	1650	570	770	1215	1700	2500	3780	4860
1600	590	790	1250	1750	2550	3810	4910	1550	610	820	1280	1790	2600	3860	4990
1500	640	845	1320	1840	2650	3920	5010	1450	660	870	1355	1880	2710	3980	5090

1400	680	900	1390	1940	2760	4020	5130	1350	710	930	1430	1980	2810	4100	5210
1300	740	965	1480	2040	2890	4160	5280	1250	775	1005	1525	2100	2950	4230	5340
1200	800	1045	1580	2160	3020	4290	5400	1150	830	1085	1628	2230	3100	4370	5490
1100	870	1130	1695	2300	3170	4420	5570	1050	910	1180	1751	2370	3240	4500	5630
1000	950	1230	1820	2440	3340	4610	5720	980	975	1260	1840	2480	3365	4630	5780
960	995	1285	1870	2510	3400	4670	5800	940	1010	1310	1900	2540	3440	4700	5830
920	1035	1330	1930	2580	3460	4740	5880	900	1060	1360	1960	2610	3490	4790	5920
880	1080	1380	1995	2650	3510	4820	5960	860	1100	1410	2023	2680	3560	4890	6000
840	1130	1430	2060	2775	3590	4920	6030	820	1150	1465	2090	2760	3630	4950	6090
800	1180	1490	2125	2800	3680	5000	6110	780	1210	1523	2165	2850	3710	5030	6170
760	1240	1555	2205	2890	3780	5090	6210	740	1265	1585	2250	2935	3800	5130	6260
720	1295	1622	2290	2980	3850	5190	6300	700	1320	1655	2335	3020	3900	5210	6330
680	1350	1690	2375	3070	3960	5280	6400	660	1380	1730	2430	3120	4000	5310	6460
640	1420	1770	2475	3180	4050	5380	6500	620	1450	1820	2523	3240	4100	5430	6560
600	1490	1860	2570	3290	4150	5490	6610	590	1510	1875	2595	3320	4180	5500	6630
580	1525	1900	2625	3350	4200	5530	6680	570	1550	1924	2650	3380	4230	5570	6710
560	1570	1950	2676	3410	4260	5600	6740	550	1590	1975	2705	3440	4300	5630	6780
540	1610	1997	2740	3470	4330	5680	6800	530	1630	2025	2770	3490	4370	5700	6830
520	1660	2050	2795	3500	4400	5720	6880	510	1675	2072	2825	3520	4420	5750	6900
500	1700	2110	2855	3540	4480	5790	6930	490	1730	2130	2890	3590	4500	5810	6980
480	1760	2167	2925	3610	4520	5870	7000	470	1780	2195	2960	3650	4580	5900	7000
460	1810	2220	2990	3690	4610	5930	7000	450	1840	2267	3030	3730	4630	5990	7000
440	1870	2290	3065	3780	468	6010	7000	430	1900	2330	3110	3800	4710	6070	7000
420	1930	2360	3140	3850	4770	6090	7000	410	1950	2390	3177	3880	4800	6120	7000
400	1990	2435	3225	3930	4830	6170	7000	390	2025	2470	3270	3970	4890	6210	7000
380	2060	2505	3310	4010	4920	6270	7000	370	2090	2547	3360	4080	4980	6320	7000
360	2140	2590	3400	4100	5020	6370	7000	350	2165	2628	3446	4150	5080	6400	7000
340	2210	2670	3500	4200	5120	6460	7000	330	2250	2717	3550	4250	5190	6500	7000
320	2300	2760	3600	4300	5220	6560	7000	310	2350	2810	3650	4390	5290	6610	7000
300	2390	2870	3700	4450	5320	6680	7000	290	2440	2920	3750	4490	5390	6710	7000
280	2490	2979	3800	4530	5460	6790	7000	270	2550	3030	3880	4600	5510	6850	7000
260	2600	3090	3920	4650	5590	6920	7000	250	2660	3155	4000	4720	5630	7000	7000
240	2720	3220	4050	4800	5710	7000	7000	230	2780	3290	4120	4880	5800	7000	7000
220	2850	3365	4200	4950	5880	7000	7000	210	2940	3390	4280	5020	5950	7000	7000
200	3010	3480	4350	5100	6030	7000	7000	190	3100	3560	4440	5200	6120	7000	7000
180	3175	3630	4520	5300	6210	7000	7000	170	3275	3730	4620	5400	6310	7000	7000
160	3370	3830	4720	5500	6430	7000	7000	150	3470	3930	4820	5600	6520	7000	7000
140	3520	4050	4950	5700	6650	7000	7000	130	3640	4190	5080	5850	6800	7000	7000
120	3780	4300	5200	5990	690	7000	7000	110	3920	4470	5350	6130	7000	7000	7000
100	4080	4600	5500	6300	7000	7000	7000	095	4150	4700	5600	6380	7000	7000	7000
090	4250	4800	5700	6480	700	7000	7000	085	4330	4890	5790	6580	7000	7000	7000
080	4470	5000	5890	6680	7000	7000	7000	075	4560	5110	6000	6790	7000	7000	7000
070	4680	5220	6110	6900	7000	7000	7000	068	4720	5290	6190	7000	7000	7000	7000
066	4790	5330	6210	7000	7000	7000	7000	064	4830	5380	6300	7000	7000	7000	7000
062	4880	5440	6340	7000	700	7000	7000	060	4930	5500	6400	7000	7000	7000	7000
058	4990	5550	6430	7000	7000	7000	7000	056	5050	5620	6500	7000	7000	7000	7000
054	5100	5690	6580	7000	700	7000	7000	052	5180	5740	6630	7000	7000	7000	7000
050	5230	5800	6700	7000	7000	7000	7000	048	5300	5880	6770	7000	7000	7000	7000
046	5380	5980	6840	7000	700	7000	7000	044	5440	6040	6920	7000	7000	7000	7000
042	5530	6130	7000	7000	7000	7000	7000	040	5620	6210	7000	7000	7000	7000	7000
038	5700	6300	7000	7000	700	7000	7000	036	5800	6400	7000	7000	7000	7000	7000
034	5900	6500	7000	7000	7000	7000	7000	032	6000	6600	7000	7000	7000	7000	7000
030	6100	6700	7000	7000	700	7000	7000	028	6230	6830	7000	7000	7000	7000	7000
026	6370	6990	7000	7000	7000	7000	7000	024	6500	7000	7000	7000	7000	7000	7000
022	6680	7000	7000	7000	700	7000	7000	020	6840	7000	7000	7000	7000	7000	7000
018	7000	7000	7000	7000	7000	7000	7000								

TABLE TALD/TAFL

This table is used by subroutine FDTETA.

10	1721	1723	1724	1725	1726	1727	1727	1685	1686	1688	1689	1690	1691	1691
15	1783	1787	1790	1793	1797	1799	1799	1747	1750	1753	1758	1762	1764	1764
20	1830	1834	1838	1842	1847	1850	1851	1794	1798	1803	1808	1817	1821	1823
30	1897	1904	1914	1922	1930	1933	1934	1861	1869	1883	1895	1904	1912	1913
40	1945	1959	1969	1980	1990	1996	1996	1908	1931	1955	1966	1976	1984	1984
50	1984	2002	2015	2027	2037	2043	2046	1949	1979	2009	2022	2033	2039	2042
60	2015	2041	2057	2068	2084	2093	2095	1980	2019	2055	2062	2078	2085	2088
70	2043	2075	2091	2107	2126	2135	2138	2008	2064	2087	2103	2122	2131	2134
80	2067	2100	2121	2139	2162	2172	2176	2031	2089	2116	2137	2158	2168	2173
100	2107	2150	2180	2204	2234	2247	2252	2069	2139	2175	2205	2229	2241	2250
150	2177	2244	2295	2334	2375	2389	2403	2143	2240	2294	2334	2375	2395	2402
200	2231	2317	2388	2442	2503	2526	2544	2198	2317	2391	2443	2507	2528	2545
250	2273	2382	2471	2546	2631	2656	2677	2241	2382	2472	2541	2630	2665	2684
300	2308	2440	2544	2635	2743	2776	2802	2278	2442	2549	2631	2745	2789	2811
350	2338	2494	2615	2721	2842	2885	2915	2309	2496	2618	2723	2848	2900	2929
400	2366	2544	2685	2798	2932	2982	3017	2337	2544	2685	2809	2943	2999	3034
500	2411	2637	2822	2942	3112	3176	3254	2386	2635	2818	2953	3133	3197	3244
600	2449	2718	2954	3086	3292	3370	3480	2428	2719	2939	3097	3323	3395	3454
800	2510	2883	3214	3374	3652	3758	3932	2498	2881	3181	3385	3703	3791	3874
1000	2559	3038	3474	3662	4012	4146	4384	2556	3043	3423	3673	4083	4187	4294
10	1642	1644	1646	1647	1648	1649	1649	1580	1582	1584	1585	1588	1589	1590
15	1705	1709	1712	1716	1721	1727	1727	1644	1647	1656	1662	1669	1680	1680
20	1752	1757	1763	1770	1780	1785	1788	1691	1697	1711	1719	1730	1743	1749
30	1820	1829	1846	1862	1879	1886	1891	1759	1777	1797	1814	1832	1853	1859
40	1868	1886	1919	1941	1962	1973	1975	1808	1837	1872	1897	1917	1938	1943
50	1908	1937	1981	2005	2028	2035	2040	1848	1886	1933	1966	1990	2006	2013
60	1939	1982	2030	2052	2077	2086	2088	1879	1931	1988	2023	2048	2063	2070
70	1967	2023	2072	2095	2120	2129	2132	1907	1972	2040	2075	2096	2116	2122
80	1991	2059	2109	2133	2159	2168	2173	1931	2011	2080	2118	2139	2160	2166
100	2031	2107	2172	2190	2228	2240	2246	1972	2081	2154	2197	2217	2235	2240
150	2105	2216	2289	2307	2367	2382	2395	2048	2205	2280	2327	2359	2380	2392
200	2158	2295	2386	2437	2495	2525	2538	2103	2302	2380	2431	2493	2520	2530
250	2201	2366	2477	2547	2622	2663	2696	2149	2376	2475	2529	2618	2648	2665
300	2244	2425	2560	2645	2738	2785	2803	2187	2435	2556	2634	2735	2775	2785
350	2278	2480	2623	2734	2840	2902	2920	2221	2490	2627	2720	2848	2890	2900
400	2311	2532	2700	2808	2930	3005	3028	2250	2540	2690	2793	2952	2983	3006
500	2365	2627	2812	2947	3110	3211	3244	2300	2627	2803	2935	3097	3164	3218
600	2412	2718	2908	3086	3290	3417	3460	2350	2710	2891	3077	3242	3345	3430
800	2488	2880	3100	3364	3650	3829	3892	2434	2850	3067	3361	3532	3707	3854
1000	2550	3016	3292	3632	4010	4241	4324	2505	2968	3243	3645	3822	4069	4278

TABLE VF

This table is used by subroutines FDASP and YIKK.

```
-400000 -02581 -02487 -02357 -02255 -02148 -01998 -01878 -01750 -01568 -01417
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  00639  00790  01016  01270  01440  01596  01786  01919  02045  02202  02314
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  12165  13161  13882  14561  15427  16053-200000 -22901 -22126 -21055 -20214
 -19343 -18111 -17110 -16037 -14486 -13184 -11738 -09524 -07508 -06072 -05003
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-108939-103997- 99845- 95253- 88326- 82238- 75154- 63565- 52137- 43470- 36584
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 214076 253935 284060 314174 353974 384077 408586 439805 462389
```

APPENDIX C.

LIST OF SYMBOLS

This list includes most of the abbreviations, acronyms, and symbols used in this report except for those used in the computer listings of section B. FORTRAN variables used in providing input for the programs are described in table 7, and subprograms and input data tables are cataloged in section 13.4. Many are similar to those used in [17, 18, 20, 32, 40, 42]. The units given for symbols in this list are those required by or resulting from equations as given in this report and are applicable except when other units are specified. The following relationships are provided as a convenience to the reader.

1 foot = 3.048×10^{-4} kilometer
1 statute mile = 5280 feet
1 statute mile = 1.609344 kilometers
1 nautical mile = 1.852 kilometers
1 radian = 57.29577951 degrees

In the following list, the English alphabet precedes the Greek alphabet, letters precede numbers, and lower-case letters precede upper-case letters. Miscellaneous symbols and notations are given after the alphabetical items.

a	Effective earth radius (km) calculated from (20).
a_a	An adjusted effective earth radius (km) calculated using (44) and shown in figure 16.
a_o	Actual earth radius, 6370 km to about three significant figures.
a_γ	An effective earth radius (km) used in figure 21 and defined for different path types in section A.4.5.
$a_{1,2}$	Effective earth radii from (88).
$a_{3,4}$	Effective earth radii from (91).
ANT.	Antenna (fig. 6).

A_a	Atmospheric absorption (dB) from (172).
A_d	Attenuation (dB) associated with diffraction over terrain, from (144).
A_{do}	Intercept (dB) for the beyond-the-horizon combined diffraction attenuation line, from (143).
A_{dx}	A_d dB at d_x, from (144).
A_e	Effective area (dB - sq. m) of an isotropic antenna (sec. 3.2.1 footnote) from (9).
$A_{e,q,t}$	Angles (rad) defined and used in figure 21 only.
A_{eK}	Knife-edge diffraction attenuation (dB) for path p = e (122).
A_h	Attenuation (dB) used in (122).
A_K	Attenuation (dB) associated with beyond-the-horizon knife-edge diffraction, from (125).
A_{KK}	Knife-edge diffraction for path p=K (fig. 20), from (119).
A_{Ko}	Intercept (dB) for the beyond-the-horizon knife-edge diffraction attenuation line, from (124).
A_{K5}	Knife-edge diffraction loss f_5 expressed in decibels from (134).
A_{ML}	Combined diffraction attenuation (dB) at d_{ML}, from (136).
A_o	Intercept (dB) for the within-the-horizon combined diffraction attenuation line, from (139).
A_{pr}	Attenuation (dB) of rounded earth diffraction for path p, from (105).
A_{pro}	Intercept (dB) of rounded earth diffraction line for path p, from (104).
Arcsin	Inverse sine (rad), principal value.
A_{rK}	Rounded earth diffraction attenuation (dB) obtained from (105) with parameters for path p=K (fig. 20) and $d_p = d_{L1} + d_{eLs}$, used in (141).
A_{rML}	Rounded earth diffraction attenuation (dB) obtained from (105) with parameters for path p=K (fig. 20) and $d_p = d_{ML}$.
A_{r5}	Rounded earth diffraction attenuation (dB) obtained from (105) with parameters for path p=K (fig. 20) and $d_p = d_5$.

A_s	Terrain attenuation (dB) associated with forward scatter (169).
A_{sx}	A_s dB at d_x, from (169).
A_T	Attenuation (dB) associated with terrain, from (84) or (145).
A_Y	A conditional adjustment factor used to prevent available signal powers from exceeding levels expected for free-space propagation by unrealistic amounts, from (16).
$A_{3,4}$	Attenuations (dB) from (102).
A_5	Combined diffraction attenuation (dB) at d_5, from (136).
A_6	Combined diffraction attenuation (dB) at $d=d_{L1} + d_{eLs}$, from (141).
$B_{N1,2}$	Parameters calculated from (107).
$B_{1,2,3,4}$	Parameters calculated from (95).
cos	Cosine.
Cos^{-1}	Inverse cosine (rad), principal value.
CDC 3800	Control Data Corporation 3800, the computer type used by ITS for batch processing.
C_e	Parameter used in defining exponential atmospheres, from (29).
$C_{1,2,3}$	Parameters defined following (178).
d	Great Circle distance (km) between facility and aircraft. For line-of-sight paths (fig. 16) it is calculated from (60).
deg	Degree.
dB	Decibel, 10 log (dimensionless ratio of powers).
dB/km (DB/KM)	Attenuation (dB) per unit length (km).
dB-sq m (DB-Sq M)	Units for effective area in terms of decibels greater than an effective area of 1 m^2 (sq m), 10 log (area in square meters).

dB-W/sq m (DB-W/SQ M)	Units for power density in terms of decibels greater than 1 W/sq m, 10 log (power density expressed in watts per square meter).
dBW (DBW)	Power (dB) greater than unit power (W), 10 log (power expressed in watts).
d_c	Counterpoise diameter (km).
d_{ds}	Distance (km) beyond the radio horizon at which diffraction and scatter attenuation are approximately equal for a smooth earth, from (175).
d_e	Effective distance (km) from (177).
d_{eLs}	d_{pLs} km for path p = e (fig. 20), from (117).
$d_{eL1,2}$	$d_{pL1,2}$ km for path p = e (fig. 20), from (116).
d_o	The largest distance (km) in the line-of-sight region at which diffraction effects associated with terrain are considered negligible, from (140).
d_p	Great Circle distance (km) for path p (fig. 20).
d_{pL}	Total horizon distance (km) for path p from (85).
d_{pLs}	Total smooth earth horizon distance (km) for path p (sec. A.4.3)
$d_{pL1,2}$	Radio horizon distances (km) for path p (sec. A.4.3).
d_{rt}	Distance (km) from the horizon to the aircraft as shown in figure 13 and used in (40).
d_{sL}	Smooth earth horizon distance (km) for facility horizon shown in figure 15 and calculated from (37).
$d_{s1,2}$	Distances (km) calculated from (153).
d_x	A distance (km) just beyond the radio horizon where $A_s \geq 20$ dB and $M_s \leq M_d$.
$d_{D,U}$	Great Circle distance (n mi) from aircraft to desired and undesired facility, respectively (fig. 4).
d_{KLs}	d_{pLs} km for path p = K (fig. 20) as per (112).
$d_{KL1,2}$	$d_{pL1,2}$ km for path p = K (fig. 20) as per (108) and (109).

d_{LoR}	Distance (km) discussed prior to (173).
$d_{Lo1,2}$	Smooth earth horizon distances (km) calculated from (173) or (174).
d_{Ls1}	Facility smooth earth horizon distance (km) from (24).
d_{Ls2}	Aircraft smooth earth horizon distance (km), from (33).
d_{L1}	Facility-to-horizon distance (km) shown in figure 13; determined from figure 14 and from (23) or (26).
d_{L2}	Aircraft-to-horizon distance (km) shown in figure 15 and determined from (38).
d_{L5}	A distance (km) from (128).
d_M	A distance (km) from (176).
d_{ML}	Maximum line-of-sight distance (km shown in fig. 13) from (40).
d_3	A distance (km) from (86).
d_4	Distance (km) used in rounded earth diffraction calculation (87).
d_5	A distance (km) from (129).
DME	Distance Measuring Equipment (fig. 2), an air navigation aid used to provide aircraft with distance information.
D/U	Desired-to-Undesired signal ratio (dB) available at the terminals of an ideal (lossless) isotropic receiving antenna (sec. 3.1.2).
D/U(q)	D/U values (dB) exceeded for a fraction q of the time. These values may represent instantaneous levels or hourly median levels depending upon the time availability option selected (sec. 3.1.2), and are calculated via (11).
D/U(0.5)	D/U(q) dB at median (q=0.5) level, from (12).
D_s	Distance (km) between radio horizons, calculated via (159).
$D_{1,2}$	Distances (km) shown in figure 16 and calculated via (51).
exp( )	Exponential; e.g., $\exp(2) = e^2$.

E	East longitude (fig. 3 only).
EIRP	Equivalent Isotropically Radiated Power (dBW) calculated using (1).
ERP	Effective Radiated Power (sec. 3.1.1), 2.15 dB less than EIRP.
f	Frequency (MHz).
ft (FT)	feet
ft-MSL	Elevation (ft) above MSL.
ft-ss	Elevation (ft) above facility site surface.
$f_{g,c}$	Knife-edge diffraction loss factors determined with subroutine FRENEL from $v_{g,c}$, used in (78) and (79).
f_h	Knife-edge diffraction loss factor obtained for v_h via subroutine FRENEL (sec. 13.4.1), used in (122).
$f_{m,2,\infty}$	Parameters defined following (178).
$f_{\theta h}$	Elevation angle correction factor, from (179).
f_5	Knife-edge diffraction loss factor obtained for v_5 from subroutine FRENEL (sec. B.4.1), used in (134).
F	Fade margin (dB) from (197).
FAA	Federal Aviation Administration.
FORTRAN	FORmula TRANslating "language" or coding used with electronics computers in lieu of "machine language". Many such languages are used and FORTRAN itself has several variations.
F_{AY}	Reflection reduction factor associated with A_Y, from (191).
$F_{d\theta}$	Attenuation function (dB) obtained from subroutine FDTETA (sec. B.4.1), used in (169).
$F_{d\sigma h}$	Reflection reduction factor associated with diffuse reflection, from (194).
F_o	Correction term (dB) in scatter attenuation which allows for the reduction of scattering efficiency at greater heights in the atmosphere (164).

$F_{1,2}$	Parameters (dB) from (101).
$F_{\sigma h}$	Specular reflection reduction factor associated with surface roughness, from (66).
$F_{\Delta r}$	Reflection reduction factor associated with Δr, from (192).
g	Normalized voltage antenna gain for the facility antenna at the elevation angle associated with the direct ray (figs. 13 and 16). Calculated using the formulation given for g in (67) but with θ_{er} set to θ_h from (57) for line-of-sight paths or θ_{el} from figure 14 for beyond-the-horizon paths.
g_D	Normalized voltage gain for facility antenna from (67) with $\theta_{er} = \theta_h$ from (58).
GHz	Gigahertz (10^9 Hz).
G_A	Gain (dB greater than isotropic) of aircraft antenna used in and discussed after (4); current model assumes $G_A = 0$ (isotropic) for D/U calculations.
$G_{e\bar{h}1,2}$	$G_{p\bar{h}1,2}$ dB for path $p = e$ (fig. 20), used in (122).
G_F	Gain (dB greater than isotropic) of facility antenna used in and discussed after (4).
$G_{\bar{h}1,2}$	Values (dB) for the residual height gain function (sec. A.4.3) from subroutine GHBAR (sec. B.4.1), used in (119).
$G_{K\bar{h}1,2}$	Values (dB) of the residual height gain function for path K from subroutine GHBAR, used in (122).
$G_{p\bar{h}1,2}$	Values (dB) for the residual height gain function (sec. A.4.3) for path p, from subroutine GHBAR (sec. B.4.1); described following (107).
G_M	Gain (dB greater than isotropic) for main beam (maximum) of facility antenna, used in (1).
G_N	Normalized gain (dB relative to the maximum gain, G_M) of the facility antenna in the direction of interest (fig. 2), used in (7).
$G_{1,2,3,4}$	Parameters (dB) from (100).
h	Height (km) above msl used in (28).
h_{a2}	Actual aircraft altitude (km) above the effective reflection surface from (31).

h_{cg}	Height (km) of the counterpoise above facility site surface and used in (47).
h_e	Effective height (km) calculated from (25) and used in (26).
$h_{eel,2}$	$h_{pel,2}$ km for path $p = e$ (fig. 20) from (114) and (115).
h_{es2}	Effective aircraft altitude (km) above msl, above (146).
h_{eL}	Elevation (km) of facility horizon above the effective reflection surface, from (36).
h_{e1}	Effective height (km) of facility antenna above the effective reflection surface, from (111).
h_{e2}	Effective altitude (km) of aircraft above the effective reflection surface, from (32) or (34).
h_{fc}	Height (km) of facility antenna above its counterpoise, used in (48).
$h_{m1,2}$	$h_{pel,2}$ expressed in meters from (106).
h_o	Height (km) of the intersection of horizon rays above a straight line between the antennas in forward scatter (161).
$h_{pel,2}$	Effective antenna heights (km) for path p (sec. A.4.3).
h_{rs}	Elevation (km) of effective reflecting surface above msl (fig. 13).
h_{s2}	A height (km) from (130).
h_v	A height (km) from (160).
$h_{Kel,2}$	$h_{pel,2}$ km for path $p = K$ (fig. 20), from (110).
h_{L1}	Elevation (km) of facility horizon above msl (fig. 13), from figure 14 and (22).
h_{L2}	Elevation (km) of aircraft horizon above msl (fig. 15) and used in (164).

$h_{1,2}$	Facility antenna height h_1, or aircraft altitude in kilometers above msl (fig. 13).
$H_{c,q,t,z}$	Heights (km) defined and illustrated in figure 21.
H_o	Frequency gain function (dB) obtained from subroutine HCHOT (sec. B.4.1), used in (169).
H_v	Height (km) of scattering volume above effective reflection surface, from (171).
H_1	An antenna height (km) shown in figure 16, from (48).
H_2	An antenna height (km) shown in figure 16, from (47).
$H'_{1,2}$	Heights (km) shown in figure 16, from (52).
$H_{\gamma 1,2}$	Heights (km) used in figure 21 and defined for different path types in section A.4.5.
ILS	Instrument Landing System (sec. 3.1.1), an air navigation aid used in landing.
ITS	Institute for Telecommunication Sciences.
j	$\sqrt{-1}$.
JTAC	Joint Technical Advisory Committee.
km (KM)	Kilometer (10^3 m).
k_a	An adjusted earth radius factor, from (43).
K_d	A parameter calculated from (93).
K_t	K value associated with tropospheric multipath, from (198) or (201).
K	The ratio (dB) between the steady component of received power and the Rayleigh fading component that is used to determine the appropriate Nakagami-Rice distribution [40, sec. V.2] for $Y_\pi(q)$, from (6).
K_{ML}	K value at the radio horizon. Used in (201).
$K_{1,2,3,4}$	Parameters calculated from (94).

log	Common (base 10) logarithm.
L_{bf}	Basic transmission loss (dB) for free space, from (15).
L_{br}	A reference level of basic transmission loss (dB), from (17).
$L_{b(q)}$	Basic transmission loss (dB) values not exceeded during a fraction q of the time. These values may represent instantaneous levels or hourly median levels depending upon the time availability option selected (sec. 3.1.2), and are calculated using (8).
$L_{b(0.5)}$	$L_b(q)$ dB for $q = 0.5$, from (14).
L_{gp}	Loss (dB) in path antenna gain used in and discussed after (4); current model assumes $L_{gp} = 0$.
L(q)	Transmission loss (dB) values not exceeded during a fraction q of the time. These values may represent instantaneous levels or hourly median levels depending upon the time availability option selected (sec. 3.1.2), and are calculated using (4).
m	Meters.
min (MIN)	Minute (deg/60).
mhos/m	Conductivity (mho) per unit length (m).
msl (MSL)	Mean sea level.
M_d	Slope (dB/km) of combined diffraction line for beyond-the-horizon, from (142).
MHz (MHZ)	Megahertz (10^6 Hz).
M_o	Slope (dB/km) of the within-the-horizon combined diffraction attenuation line, from (137).
M_{pr}	Slope (dB/km) of rounded earth diffraction line for path p, from (103).

M_s	Slope (dB/km) of A_s versus d curve, determined using successive A_s calculations for distances greater than d_{ML}. Discussed following (144).
M_K	Slope (dB/km) for the beyond-the-horizon knife-edge diffraction line, from (123).
M_{Ka}	Slope (dB/km) of the K value line used just beyond the radio horizon (200).
M_L	Slope (dB/km) of the diffraction attenuation line used just inside the radio horizon, from (83).
n mi (N MI)	Nautical mile.
$n_{1,2,3}$	Parameters defined following (178).
N	North latitude (fig. 3 only).
N	Refractivity (N-units) for a height h in an exponential atmosphere; calculated via (28).
N_o	Minimum monthly mean surface refractivity (N-units) referred to msl (fig. 3).
N_s	Minimum monthly mean surface refractivity (N-units) at effective reflection surface, calculated from N_o via (18).
N-units	Units of refractivity [3, sec. 1.3] corresponding to 10^6 (refractive index -1).
P_I	Power (dBW) available at the terminals of an ideal (lossless) isotropic receiving antenna, from (3).
P_{RO}	A relative power level (dB) associated with the ray optics formulation used in the line-of-sight region, from (82).
P_{TR}	Total power (dBW) radiated from the facility antenna, used in (1).
q	Dimensionless fraction of time used in time availability specifications, e.g., D/U(q), $L_b(q)$, $S_a(q)$, etc.
rad	Radians

r	Shortest facility to aircraft ray length (km); calculated as r_o from (54) for line-of-sight paths, and taken as d otherwise.
r_c	A distance (km) from (71).
$r_{eo,w}$	Effective ray length (km) for oxygen or water vapor absorption calculations, from (170).
r_o	The direct ray length (km) shown in figure 16 and calculated from (54).
$r_{1eo,w}$ and $r_{2eo,w}$	Partial effective ray lengths (km) for oxygen or water vapor absorption calculations; calculated using the relationships given in figure 21.
$r_{1,2}$	Segments of reflected ray path shown in figure 16, and components of r_{12}.
r_{12}	Total length (km) of reflected ray of figure 16, from (55).
R	Magnitude of complex plane earth reflection coefficient from (63).
R_c	Magnitude of effective reflection coefficient associated with counterpoise reflection, from (69).
R_d	Diffuse component of surface reflection multipath, from (195).
R_g	Magnitude of effective reflection coefficient for earth reflection, from (68).
R_s	Specular component of surface reflection multipath, from (193).
$R_{Tg,c}$	Magnitude of adjusted (for counterpoise edge effects) effective reflection coefficient for earth from (78) or counterpoise from (79) reflection.
RTA-2	A TACAN antenna type.
s	Path asymmetry factor in forward scatter (158).
sec	Secant (1/cos).

sec (SEC)	Second (min/60).
sin	Sine.
ss (SS)	Facility site surface.
S	Great Circle separation (n mi) between desired and undesired facilities, calculated from (2).
S	South latitude (fig. 3 only).
S_a	Power density (dB-W/sq m), an output of the power density program (3.2.1).
$S_a(q)$	S_a values (dB-W/sq m) exceeded for a fraction of the time. These values may represent instantaneous levels depending upon the time availability option selected (sec. 3.1.2), and are calculated from (7).
SHF	Super-High Frequency (3 to 30 GHz).
S_I	A parameter calculated from (157).
tan	Tangent.
Tan^{-1}	Inverse tangent (rad) with principal value.
TACAN	TACtical Air Navigation (fig. 2), an air navigation aid used to provide aircraft with distance and bearing information.
$T_{eo,w}$	Height (km) associated with atmospheric absorption (caption, fig. 21).
UHF	Ultra-High Frequency (300 to 3000 MHz).
v_c	Knife-edge diffraction parameter used to determine f_c, from (77).
v_g	Knife-edge diffraction parameter used to determine f_g, from (75).
v_h	Knife-edge diffraction parameter for the h_{e1} to h_{e22} path shown in figure 20, from (121).
$v_{\alpha,\beta}$	Parameters calculated from (165) and (166).
$v_{1,2}$	Parameters calculated from (167) and (168).

v_5	A knife-edge diffraction parameter, from (133).
$V_e(0.5,d_e)$	Variability adjustment term (dB), from (190).
VOR	VHF Omni Range (sec. 3.1.1), an air navigation aid used to provide aircraft with bearing information.
VHF	Very High Frequency (30 to 300 MHz).
$V(0.5)$	A parameter (dB) from (178).
W	West longitude (fig. 3 only).
W	A weighting factor used in combining knife-edge and rounded earth diffraction attenuations, from (135).
W_a	A relative power level for the Rayleigh fading component associated with tropospheric multipath (sec. A.7), from (199).
W_R	A relative power level for the Rayleigh fading component associated with surface reflection multipath (sec. A.6), from (196).
W_{RO}	A relative power level associated with the ray optics formulation used in the line-of-sight region, from (81).
$W_{1,2}$	Parameters calculated from (97).
x	A parameter calculated from (92).
$x_{1,2}$	Parameters (km) calculated from (96).
$x_{3,4}$	Parameters (km), from (99).
$y_{1,2}$	Parameters (dB), from (98).
Y_B	A parameter (dB) from (186).
Y_c	A parameter from (62).
$Y_e(q)$	Variability (dB greater than median) of hourly median received power about its median, $Y_e(0.5) = 0$, where q is the fraction of hours during which a particular level is exceeded. Section A.5 describes methods used to calculate $Y_e(q)$.

$Y_{DU}(q)$	Total variability (dB greater than median) of D/U about its median, $Y_{DU}(0.5)=0$, where q is the fraction of time for which a particular value is exceeded. These values may represent instantaneous levels or hourly median levels depending upon the time availability option selected (sec. 3.1.2). Calculated from (13).
$Y_{s1,2}$	Parameters from (151) or (152).
Y_T	A parameter (dB) from (182).
Y_v	A parameter calculated from (74).
$Y(0.1)$	A parameter (dB) from (178).
$Y(0.9)$	A parameter (dB) from (178).
$Y_\pi(q)$	Variability (dB greater than median) of received power used to describe short-term (within-the-hour) fading associated with multipath where q is the fraction of time during which a particular level is exceeded. It is used in and is discussed after (5).
$Y_\Sigma(q)$	Total variability (dB greater than median) of received power about its median, $Y_T(0.5)=0$, where q is the fraction of time for which a particular value is exceeded. These values may represent instantaneous levels or hourly median levels depending upon the time availability option selected (sec. 3.1.2). Calculated via (5).
z	A parameter from (42).
$z_{1,2}$	Parameters (km) from (49).
α	An angle (rad) shown in figure 16 and calculated from (53).
α_o	An angle (rad) from (154).
α_{oo}	An angle (rad) from (147).
β	An angle (rad) used in figure 21 and defined for different path types in section A.4.5.

β_o	An angle (rad) from (155).
β_{oo}	An angle (rad) from (148).
$\gamma_{oo,W}$	Surface absorption rates (dB/km) for oxygen or water vapor; if values are not provided as input (sec. 3.1.1), they are estimated via subroutine ASORP (sec. B.4.1).
$\Delta\alpha_o$	An angle (rad) obtained via subroutine DELTA (sec. B.4.1), used in (154).
$\Delta\beta_o$	An angle (rad) obtained via subroutine DELTA (sec. B.4.1) used in (155).
Δh	Terrain parameter (km) estimated using table 3, which is used [32, sec. 2.2] to characterize terrain. It is an asymptotic value of Δh_d.
Δh_a	An adjusted effective altitude correction factor from (46).
Δh_e	Effective altitude correction factor (km) which is specified as input (sec. 3.1.1) or calculated from (45).
Δh_d	Interdecile range of terrain heights (m) above and below a straight line fitted to elevations above msl; estimated from (64) which is based on previous work [32, eq. 3].
Δh_{ft}	Δh expressed in feet (table 3).
Δh_m	Δh expressed in meters (table 3).
ΔN	Refractivity gradient (N-units/km) used in defining exponential atmospheres, from (30).
Δr	Path length difference (km) for rays shown in figure 16 ($r_{12}-r_o$) that is calculated from (56).
$\Delta r_{g,c}$	Δr km from (56) for earth or counterpoise reflection.
ε	Dielectric constant from table 2.
ε_c	Complex dielectric constant from (61).
η	A parameter from (162).

η_s	A parameter from (163).
θ	Angular distance (rad) from (156).
θ_{ce}	An angle (rad) from (70) and shown in figure 17.
$\theta_{eel,2}$	$\theta_{pel,2}$ rad for path p = e (fig. 20) as per (118).
θ_{er}	Elevation angle of reflecting point at facility antenna, from (58).
θ_{el}	Elevation angle (rad) of horizon at facility (fig. 13); determined using figure 14, from (21) or (27).
θ_{e2}	Horizon elevation angle (rad) at aircraft, from (39).
θ_{e5}	An angle (rad) from (131).
θ_h	Elevation angle (rad) of aircraft at facility (fig. 16), from (57) and (126).
θ_{kc}	An angle (rad) calculated via (76) and shown in figure 18.
θ_{kg}	An angle (rad) from (72) and shown in figure 17.
$\theta_{Kel,2}$	$\theta_{pel,2}$ rad for path p = K (fig. 20) as per (113).
θ_L	Elevation angle (rad) of aircraft at facility horizon (fig. 13), from (41).
θ_{pe}	An angle (rad) from (89).
$\theta_{pel,2}$	Horizon elevation angles (rad) for path p, described following (88) (sec. A.4.3).
θ_{s2}	An angle (rad) shown in figure 15, from (35).
θ_v	Diffraction angle (rad) for the h_{e1} to h_{ee2} path shown in figure 20, from (126).
θ_o	An angle (rad) from (59).
θ_{oo}	An angle (rad) from (149).
$\theta_{o1,2}$	Angles (rad) from (150).

$\theta_{1,2}$	Angles (rad) shown in figure 16 and calculated from (50).
$\theta_{3,4}$	Angles (rad) from (90).
θ_5	First approximation (127) for angle θ_6.
θ_6	An angle (rad) from (132).
λ	Wavelength (km) from (73).
λ_m	Wavelength (m) from (10).
π	The constant 3.141592654.
σ	Conductivity (mho/m) from table 2.
σ_h	The root-mean-square deviation (m) of terrain and terrain clutter within the limits of the first Fresnel zone in the dominant reflecting plane; estimated from (65) which is based on previous work [32, eqs. 3.6a, 3.6b].
ϕ	Phase advance associated with complex earth reflection coefficient, from (63).
ϕ_c	Phase lead (rad) associated with counterpoise reflection, from (69).
ϕ_g	Phase lead (rad) associated with earth reflection, from (68).
$\phi_{kg,c}$	Knife-edge diffraction phase shift determined with FRENEL from $v_{g,c}$.
$\phi_{Tg,c}$	Phase lead (rad) of adjusted (for counterpoise edge effects) effective reflection coefficient from (80) for earth or counterpoise reflection.
ψ	Grazing angle (rad) shown in figures 16 and 17.
ψ_c	Grazing angle (rad) for reflection from counterpoise.
$\sim$	Approximately.
$(\ )^\circ$	Degrees, e.g., 12°.
%	Percent.

APPENDIX D

INDEX TO EQUATIONS

An index to equations is provided in this appendix. Equation number (Eq. #), independent variable (I. Var.), and page are provided for each equation.

Eq. #	I. Var.	Page	Eq. #	I. Var.	Page
1	EIRP	10	31	h_{a2}	46
2	S	22	32	h_{e2}	46
3	P_I	23	33	d_{Ls2}	46
4	L(q)	37	34	h_{e2}	46
5	$Y_\Sigma(q)$	38	35	$\theta_{[illegible]2}$	46
6	K	38	36	h_{eL}	47
7	$S_a(q)$	39	37	d_{sL}	47
8	$L_b(q)$	39	38	d_{L2}	47
9	A_e	39	39	θ_{e2}	48
10	λ_m	39	40	d_{ML}	48
11	D/U(q)	39	41	θ_L	49
12	D/U(0.5)	40	42	z	51
13	$Y_{DU}(q)$	40	43	k_a	51
14	$L_b(0.5)$	40	44	a_a	51
15	L_{bf}	40	45	Δ_{he}	51
16	A_Y	41	46	Δh_a	51
17	L_{br}	41	47	H_2	51
18	N_s	43	48	H_1	51
19	a_o	43	49	$z_{1,2}$	51
20	a	43	50	$\theta_{1,2}$	51
21	θ_{e1}	43	51	$D_{1,2}$	51
22	h_{L1}	43	52	$H'_{1,2}$	51
23	d_{L1}	43	53	α	51
24	d_{Ls1}	43	54	r_o	51
25	h_e	43	55	r_{12}	51
26	d'_{L1}	43	56	Δr	52
27	θ_{e1}	44	57	θ_h	52
28	N	44	58	θ_{er}	52
29	C_e	44	59	θ_o	52
30	ΔN	44	60	d	52

Eq. #	I. Var.	Page
61	ε_c	52
62	Y_c	52
63	$R\exp(-j\ \phi)$	52
64	Δh_d	53
65	σ_h	53
66	$F\sigma_h$	53
67	g	53
68	$R_g\exp(-j\phi\ g)$	53
69	$R_c\exp(-j\phi\ c)$	53
70	θ_{ce}	54
71	r_c	54
72	θ_{kg}	54
73	λ	54
74	Y_v	54
75	v_g	54
76	θ_{kc}	54
77	v_c	54
78	R_{Tg}	56
79	R_{Tc}	56
80	$\phi_{Tg,c}$	56
81	W_{RO}	57
82	P_{RO}	57
83	M_L	57
84	A_T	57
85	d_{pL}	59
86	d_3	59
87	d_4	59
88	$a_{1,2}$	59
89	θ_{pe}	60
90	$\theta_{3,4}$	60
91	$a_{3,4}$	60
92	x	60
93	K_d	60
94	$K_{1,2,3,4}$	60
95	$B_{1,2,3,4}$	60
96	$x_{1,2}$	60
97	$W_{1,2}$	60
98	$y_{1,2}$	60
99	$x_{3,4}$	60
100	$G_{1,2,3,4}$	60
101	$F_{1,2}$	61
102	$A_{3,4}$	61
103	M_{pr}	61
104	A_{pro}	61
105	A_{pr}	61
106	$h_{m1,2}$	61
107	$B_{N1,2}$	61
108	$d_{KL1,2}$	62
109	d_{KL2}	62
110	$h_{Kel,2}$	62
111	h_{el}	63
112	d_{KLs}	63
113	$\theta_{Kel,2}$	63
114	h_{eel}	63
115	h_{ee2}	63
116	$d_{eL1,2}$	63
117	d_{eLs}	63
118	$\theta_{eel,2}$	63
119	A_{KK}	64
120	θ_v	64
121	v_h	64
122	A_{eK}	64
123	M_K	64
124	A_{Ko}	64
125	A_K	65
126	θ_h	65
127	θ_5	65
128	d_{L5}	65
129	d_5	65
130	h_{s2}	65

Eq. #	I. Var.	Page
131	θ_{e5}	65
132	θ_6	65
133	v_5	65
134	A_{K5}	66
135	W	66
136	A_5	66
137	A_{ML}	66
138	M_o	66
139	A_o	66
140	d_o	66
141	A_6	67
142	M_d	67
143	A_{do}	67
144	A_d	67
145	A_T	68
146	h_{es2}	69
147	α_{oo}	69
148	β_{oo}	69
149	θ_{oo}	69
150	$\theta_{o1,2}$	69
151	Y_{s1}	69
152	Y_{s2}	69
153	$d_{s1,2}$	69
154	α_o	69
155	β_o	70
156	θ	70
157	S_I	70
158	s	70
159	D_s	70
160	h_v	70
161	h_o	70
162	η	70
163	η_s	70
164	F_o	70
165	v_α	70
166	v_β	70
167	v_1	70
168	v_2	71
169	A_s	71
170	$r_{eo,w}$	73
171	H_v	73
172	A_a	73
173	d_{Lo1}	74
174	d_{Lo2}	74
175	d_{ds}	74
176	d_M	74
177	d_e	75
178	$\left\{ \begin{matrix} V(0.5) \\ Y(0.1) \\ -Y(0.9) \end{matrix} \right\}$	75
179	$f_{\theta h}$	75
180	$Y_e(0.1)$	75
181	$Y_e(0.9)$	75
182	Y_T	75
183	$Y_e(0.0001)$	75
184	$Y_e(0.001)$	76
185	$Y_e(0.01)$	76
186	Y_B	76
187	$Y_e(0.99)$	76
188	$Y_e(0.999)$	76
189	$Y_e(0.9999)$	76
190	$V_e(0.5, d_e)$	77
191	F_{AY}	77
192	$F_{\Delta r}$	77
193	R_s	78
194	$F_{d\sigma h}$	78
195	R_d	78
196	W_R	78
197	F	79
198	K_t	79
199	W_a	79
200	M_{Ka}	80
201	K_t	80

REFERENCES

[1] Ames, L.A., P. Newman, and T.F. Rogers (1955), VHF tropospheric overwater measurements for beyond the radio horizon, Proc. IRE 43, No. 10, 1369-1373.

[2] Barnett, W.T. (1972), Multipath propagation at 4, 6, and 11 GHz, Bell Sys. Tech. J. 51, No. 2, 321-361.

[3] Bean, B.R., and E. J. Dutton (1966), Radio Meteorology (Dover Publications, Inc., New York, N.Y.).

[4] Bean, B.R., and G.D. Thayer (1959), CRPL Exponential Reference Atmosphere, NBS Mono. 4 (GPO, $0.45)[1].

[5] Beard, C.I. (1961), Coherent and incoherent scattering of microwaves from the ocean, IRE Trans. Ant. Prop. AP-9, No. 5, 470-483.

[6] Beckmann, P., and A. Spizzichino (1963), The Scattering of Electromagnetic Waves from Rough Surfaces, Internatl. Series of Monographs on Electromagnetic Waves 4 (Pergamon Press, New York, N.Y.).

[7] CCIR (1962), Tropospheric wave transmission loss prediction, Internatl. Radio Consultative Committee Study, Document V/23-E for question 185(V) of study program 138(V) (Internatl. Telecommunication Union, Geneva, Switzerland).

[8] Crane, R.K. (1971), Propagation phenomena affecting satellite communication systems operating in the centimeter and millimeter wavelength bands, Proc. IEEE 59, No. 2, 173-188.

[9] Dougherty, H.T. (1967), Microwave fading with airborne terminals ESSA Tech. Rept. IER 58-ITSA 55 (NTIS, N-70-73581)[2].

[10] FAA (1963), TACAN ground station equipment, FAA specification[3], FAA-E-2006.

[11] FAA (1965a), VHF/UHF Air/Ground Communications Frequency Engineering Handbook, FAA Handbook[3], 6050.4A.

[12] FAA (1965b), Radio Frequency Management Principles and Practices; General, Organization and Functions, FAA Handbook[3], 6050.8.

[13] FAA (1967), DME ground station equipment, FAA specification[3], FAA-E-2266.

[14] FAA (1969a), Frequency Management Engineering Principles; Geographical Separation Criteria for VOR, DME, TACAN, ILS, and VOT Frequency Assignments, FAA Handbook[3], 6050.5A.

[15] FAA (1969b), Frequency Management Principles Spectrum Engineering Measurements, FAA Handbook[3], 6050.23.

[16] Frisbie, F.L., D.J. Hamilton, C.D. Innes, F.S. Kadi, and G.M. Kanen (1969), A comparative analysis of selected technical characteristics for several frequency bands available to aeronautical satellite services, Unpublished[4] FAA Report[3].

[17] Gierhart, G.D., and M.E. Johnson (1967), Interference predictions for VHF/UHF air navigation aids, ESSA Tech. Rept. IER 26-ITSA 26 (NTIS, AD 654 924)².

[18] Gierhart, G.D., and M.E. Johnson (1969), Transmission loss atlas for select aeronautical service bands from 0.125 to 15.5 GHz, ESSA Tech. Rept. ERL 111-ITS 79 (GPO, $1.25)¹.

[19] Gierhart, G.D., and M.E. Johnson (1971), Interference predictions for VHF/UHF air navigation aids (supplement to IER 26-ITSA 26 and ERL 138-ITS 95), OT Telecomm. Tech. Memo. OT/ITSTM 19 (NTIS, AD 718 465)².

[20] Gierhart, G.D., and M.E. Johnson (1972), UHF transmission loss estimates for GOES, OT Telecomm. Tech. Memo OT TM-109 (NTIS, COM-73-10339)².

[21] Gierhart, G.D., A.P. Barsis, M.E. Johnson, E.M. Gray, and F.M. Capps (1971), Analysis of air-ground radio wave propagation measurements at 800 MHz, OT Telecomm. Res. and Engrg. Rept. OT/TRER 21 (GPO, $1.00)¹.

[22] Gierhart, G.D., R.W. Hubbard, and D.V. Glen (1970), Electrospace planning and engineering for the air traffic environment, DoT Rept. FAA-RD-70-71 (NTIS, AD 718 447)².

[23] Hawthorne, W.B., and L.C. Daugherty (1965), VOR/DME/TACAN frequency technology, IEEE Trans. Aerospace Nav. Electron. ANE-12, No. 1, 11-15.

[24] ICAO (1968), International Standards and Recommended Practices Aeronautical Telecommunications, Annex 10 I (Internatl. Civil Aviation Organization; Montreal 3, Quebec, Canada).

[25] IEEE (1970), Special issue on air traffic control, Proc. IEEE 58, No. 3.

[26] Janes, H.B. (1955), An analysis of within-the-hour fading in the 100- to 1000-Mc transmission, J. Res. NBS 54, No. 4, 231-250.

[27] Johnson, M.E. (1967), Computer programs for tropospheric transmission loss calculations, ESSA Tech. Rept. IER 45-ITSA 45 ($1.00)¹.

[28] JTAC (1968), Spectrum Engineering - The Key to Progress, Joint Tech. Advisory Committee (IEEE, New York, N.Y.).

[29] JTAC (1970), Radio Spectrum Utilization in Space, Joint Tech. Advisory Committee (IEEE, New York, N.Y.).

[30] Kerr, D.E. (1964), Propagation of Short Radio Waves, MIT Radiation Lab. Series 13 (Boston Tech. Publishers, Inc., Lexington, Mass.).

[31] Lenkurt (1970), Engineering considerations for Microwave Communication Systems (GTE Lenkurt, Dept. C134, San Carlos, Calif., $10.00).

[32] Longley, A.G., and P.L. Rice (1968), Prediction of tropospheric radio transmission loss over irregular terrain, a computer method - 1968, ESSA Tech. Rept. ERL 79-ITS 67 (NTIS, AD 676 874)².

[33] Longley, A.G., and R.K. Reasoner (1970), Comparison of propagation measurements with predicted values in the 20 to 10,000 MHz range, ESSA Tech Rept. ERL 148-ITS 97 (GPO, \$1.00)[1].

[34] Longley, A.G., R.L. Reasoner, and V.L. Fuller (1971), Measured and predicted long-term distributions of tropospheric transmission loss, OT Telecomm. Res. and Engrg. Rept. OT/TRER 16 (GPO, \$2.75)[1].

[35] McCormick, K.S., and L.A. Maynard (1971), Low angle tropospheric fading in relation to satellite communications and broadcasting, IEEE ICC Record 7, No. 12, 18-23.

[36] Norton, K.A. (1953), Transmission loss in radio propagation, Proc. IRE 41, No. 1, 146-152.

[37] Norton, K.A. (1959), System loss in radio-wave propagation, Proc. IRE 47, No. 9, 1661.

[38] Norton, K.A., L.E. Vogler, W.V. Mansfield, and P.J. Short (1955), The probability distribution of the amplitude of a constant vector plus a Rayleigh-distributed vector, Proc. IRE 43, No. 10, 1354-1361.

[39] Reed, H.R., and C.M. Russell (1964), Ultra High Frequency Propagation (Boston Tech. Publishers, Lexington, Mass.).

[40] Rice, P.L., A.G. Longley, K.A. Norton, and A.P. Barsis (1967), Transmission loss predictions for tropospheric communication circuits, NBS. Tech. Note 101, I and II revised (NTIS, AD 687 820 and AD 687 821)[2].

[41] Skerjanec, R.E., and C.A. Samson (1970), Rain attenuation study for 15-GHz relay design, DoT Rept. FAA-RD-70-21 (NTIS, AD 709 348)[2].

[42] Tary, J.J., R.R. Bergman, and G.D. Gierhart (1971), GOES telecommunication study - 1971, OT Telecomm. Tech. Memo OT TM-64 (NTIS, COM 72 10431)[2].

[43] Thayer, G.D. (1967), A rapid and accurate ray tracing algorithm for a horizontally stratified atmosphere, Radio Sci. 1 (New Series), No. 2, 249-252.

[44] Vegara, W.C., J.L. Levatich, and T.J. Carroll (1962), VHF air-ground propagation far beyond the horizon and tropospheric stability, IRE Trans. Ant. Prop. AP-10, No. 5, 608-621.

[45] Whitney, H.E., J. Aarons, and D.R. Seemann (1971), Estimation of the cumulative amplitude probability distribution function of ionospheric scintillations, AF Cambridge Res. Labs. Rept. AFCRL-71-0525, Cambridge, Mass.

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16. Abstract

This report describes three computer programs for use in predicting the service coverage associated with air/ground radio systems operating in the frequency band from 0.1 to 20 GHz. Power density, station separation and service volume programs are used to obtain computer-generated microfilm plots. These are: (1) power density available at a particular altitude versus distance from a ground-based transmitting facility; (2) the desired-to-undesired signal ratio, D/U, available at an isotropic receiving antenna versus the distance separating desired and undesired facilities; and (3) constant D/U contours in the altitude versus distance space between the desired and undesired facilities. A detailed discussion of the propagation model involved and program listings are included in the appendices.

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