**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.

**Key Words**

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

*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; 11]. 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 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.

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>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft altitude above mean sea level (m)</td>
<td>Location = Facility altitude and &lt; 1,000 ft (m).</td>
<td>ft (m)</td>
</tr>
<tr>
<td>Facility antenna height above site surface (m)</td>
<td>&gt; 1.5 ft and &lt; 2,000 ft (m).</td>
<td>ft (m)</td>
</tr>
<tr>
<td>Frequency</td>
<td>100 to 20,000 MHz</td>
<td>MHz</td>
</tr>
</tbody>
</table>

**Secondary Parameters, Specified, Computed, Estimated, or Assumed.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorption, at surface (mm)</td>
<td>Calculated or specified</td>
<td>dB (km)</td>
</tr>
<tr>
<td>Oxygen options</td>
<td>Calculated or specified</td>
<td>dB (km)</td>
</tr>
<tr>
<td>Water vapor options</td>
<td></td>
<td>dB (km)</td>
</tr>
<tr>
<td>Effective altitude correction factor options</td>
<td></td>
<td>dB (km)</td>
</tr>
<tr>
<td>Effective reflection surface elevation above mean sea level</td>
<td>As set or specified</td>
<td>ft (m)</td>
</tr>
<tr>
<td>Facility antenna type options</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Counterpoise diameter</td>
<td>As set or specified</td>
<td>ft (m)</td>
</tr>
<tr>
<td>Height above site surface</td>
<td></td>
<td>ft (m)</td>
</tr>
<tr>
<td>Surface options</td>
<td>Poor, average, or good ground, or fresh or sea water, concrete, or metal</td>
<td></td>
</tr>
<tr>
<td>Polarization options</td>
<td>Horizontal or vertical</td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Height above sea level</td>
<td>The height above sea level is a critical factor for many installations.</td>
<td></td>
</tr>
<tr>
<td>Type options</td>
<td>The type of option selected can significantly affect the performance of the system.</td>
<td></td>
</tr>
<tr>
<td>Minimum monthly mean surface reflectivity</td>
<td>This parameter is crucial for determining the efficiency of the system.</td>
<td></td>
</tr>
<tr>
<td>Surface reflection lobing options</td>
<td>The accuracy of surface reflection lobing is essential for precise system operation.</td>
<td></td>
</tr>
<tr>
<td>Terrain elevation above sea level at site</td>
<td>The elevation of the site affects the system's performance.</td>
<td></td>
</tr>
<tr>
<td>Parameter, ( \theta )</td>
<td>The parameter ( \theta ) is a key factor in the system's design.</td>
<td></td>
</tr>
<tr>
<td>Type options</td>
<td>The type of option selected for ( \theta ) can impact the system's efficiency.</td>
<td></td>
</tr>
<tr>
<td>Time availability options</td>
<td>The availability of time is a critical consideration for system operation.</td>
<td></td>
</tr>
</tbody>
</table>

(a) Copies of this table may be used to provide data for computer runs: printing the data and circling desired options. The units of measurement in the table should be the same as those used in the program. Some parameters are common to all three programs. However, additional information is provided for each program (to 2, 3, and 4) and may be more than one model parameter specification. Where not specified, the desired and undesired facilities are not identical.

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

(c) These parameters are not reproduced on the computer-generated papers. For each such a counterpoise is not present, i.e., zero counterpoise diameter.

(*) Values or options that would be assumed when specific designations are not made or when any are not.
Aircraft altitude above msl

Facility antenna height above site surface

Facility site elevation above msl

Effective reflection surface elevation above msl

Mean sea level (msl)

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 ms1

As shown in figure 1, this elevation is measured above ms1. If not specified it will be taken as the "terrain elevation above ms1 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 only. 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

\[
EIRP = P_{TR} + G_M \text{ dBW} \tag{1}
\]

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. Normalised 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>
<thead>
<tr>
<th>Type</th>
<th>Conductivity (mhos/m)</th>
<th>Dielectric Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor ground</td>
<td>0.001</td>
<td>4</td>
</tr>
<tr>
<td>Average ground</td>
<td>0.005</td>
<td>15</td>
</tr>
<tr>
<td>Good ground</td>
<td>0.02</td>
<td>25</td>
</tr>
<tr>
<td>Sea water</td>
<td>5</td>
<td>81</td>
</tr>
<tr>
<td>Fresh Water</td>
<td>0.01</td>
<td>81</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.01</td>
<td>5</td>
</tr>
<tr>
<td>Metal</td>
<td>10^7</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. Surface Types and Constants
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 $\Delta h$. 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 $\Delta h$. When the angle exceeds $12^\circ$, a warning note will be printed but the run will not be aborted.

Horizon Obstacle Height Above m.s.l

If not specified, this height will be calculated from horizon parameters that are specified and/or by using the terrain parameter $\Delta h$. 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 $\Delta h$ 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

*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.
$N_0$ outside the 250-to-400 N-unit range will result in $N_0$ being set to 301.
If the surface refractivity, $N_s$, calculated from $N_0$ 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 $\Delta h$ [32, table 1]

<table>
<thead>
<tr>
<th>Type of Terrain</th>
<th>$\Delta h$ (feet)</th>
<th>$\Delta h$ (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water or very smooth plains</td>
<td>0 - 20</td>
<td>0 - 5</td>
</tr>
<tr>
<td>Smooth plains</td>
<td>20 - 70</td>
<td>5 - 20</td>
</tr>
<tr>
<td>Slightly rolling plains</td>
<td>70 - 130</td>
<td>20 - 40</td>
</tr>
<tr>
<td>Rolling plains</td>
<td>130 - 260</td>
<td>40 - 80</td>
</tr>
<tr>
<td>Hills</td>
<td>260 - 490</td>
<td>80 - 150</td>
</tr>
<tr>
<td>Mountains</td>
<td>490 - 980</td>
<td>150 - 300</td>
</tr>
<tr>
<td>Extremely rugged mountains</td>
<td>&gt;2,000</td>
<td>&gt;700</td>
</tr>
</tbody>
</table>

**Terrain Parameter $\Delta h$**

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)

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

(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)

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

(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\(^{(a)}\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Model Parameters, Specification Required</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/U signal ratios (dB)</td>
<td>Up to 30 values may be specified in space below for a particular program run.</td>
<td></td>
</tr>
<tr>
<td>Station separation</td>
<td>0.1 to 1,000 n mi</td>
<td></td>
</tr>
</tbody>
</table>

**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**

<table>
<thead>
<tr>
<th>Abscissa grid intervals</th>
<th>&lt; difference between limits</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Left-hand limit</td>
<td>&gt; 0, &lt; right-hand limit</td>
<td></td>
</tr>
<tr>
<td>Right-hand limit</td>
<td>&lt; 1,000 n mi</td>
<td></td>
</tr>
<tr>
<td>Ordinate grid intervals (Aircraft altitude)</td>
<td>&lt; difference between limits</td>
<td>ft</td>
</tr>
<tr>
<td>Lower Limit</td>
<td>&lt; Upper limit</td>
<td></td>
</tr>
<tr>
<td>Upper Limit</td>
<td>&lt; 300,000 ft</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>&lt; 35 characters or spaces</td>
<td>ft</td>
</tr>
</tbody>
</table>

\(^{(a)}\) 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

\[ S = d_D + d_U \text{ n mi} \]  \hspace{1cm} (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.,

$$P_I = S_a + A_e \text{ dBW.} \quad (3)$$

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).

23
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 0.000023 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

UNDISRED 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
PARAMETFR: 0 FT
TYPE: AVERAGE GROUND
TIME AVAILABILITY: FOR INSTANTANEOUS LEVELS EXCEEDED

* COMPUTEL' VALUE

Figure 9. Sample parameter sheet, station separation program, undesired facility.
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:  990 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, $\Delta h$, 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 I (sec. 3.1.1).

Units of measure associated with input parameters are also given in table I, 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, \( \Delta h \), 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.4.3). However, special allowances are not included for (a) ducting [44], (b) rain attenuation [41], (c) rain scatter [35], (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

\[
L(q) = L_b(0.5) + L_{gp} - G_F - G_A - Y(q) \quad \text{dB} \quad (4)
\]

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 \( Y(q) \) 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

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

\[
(\pm \text{ for } q \leq 0.5) \\
(- \text{ otherwise })
\]

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

\[
K = -10 \log(W_R + W_a) \quad \text{dB}. \quad (6)
\]

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

$$S_a(q) = EIRP - L_b(q) - \gamma N - A_e \text{ dB-W/sq m} \tag{7}$$

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 not 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

$$L_b(q) = L_b(50) - Y_z(q) \text{ dB} \tag{8}$$

and

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

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

$$\lambda_m = 299.7925/f \text{ m} \tag{10}$$

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]

$$D/U(q) = D/U(0.5) + Y_{DU}(q) \text{ dB} \tag{11}$$
The median value of D/U(0.5) and the variability \( Y_{DU}(q) \) of D/U are calculated as
\[
D/U(0.5) = [\text{EIRP} - L_b(0.5) + G_N]_{\text{Desired}} - [\text{EIRP} - L_b(0.5) + G_N]_{\text{Undesired}}
\]
and
\[
Y_{DU}(q) = + \sqrt{\left(\frac{Y_{\Sigma}(q)}{\text{Desired}}\right)^2 + \left(\frac{Y_{\Sigma}(1-q)}{\text{Undesired}}\right)^2} \quad \text{dB} \quad (13)
\]
where \( q \) for \( q > 0.5 \) and otherwise. 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,
\[
L_{bf} = 32.45 + 20 \log f + 20 \log r \quad \text{dB} \quad (15)
\]
where \( f \) MHz is frequency and \( r \) km is the shortest facility-to-aircraft ray length.
If \((L_{bf} - 3) < [L_{br} - Y_e(0.1)]\) if lobing option (sec. 3.1.1) is used and the aircraft is within 10 lobes of its radio horizon, or path is beyond line of sight

\[
A_Y = \begin{cases} 
0 & \text{if } (L_{bf} - 3) < [L_{br} - Y_e(0.1)] \\
(L_{bf} - 3) - [L_{br} - Y_e(0.1)] & \text{otherwise}
\end{cases}
\]
dB (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 \(Y_T = 0\) 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.,

\[
L_{br} = L_{bf} + A_T - V_e(0.5, d_e) \text{ dB .}
\]

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 \([3, \text{ sec. 3.6}], a\), 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 \( \theta_{el} \) and \( \theta_{L} \), 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.,
\[ N_s = N_0 \exp(-0.1057 \ h_{rs}) \quad \text{N-units} \quad (18) \]
\[ a_o = 6370 \ \text{km} \quad (19) \]

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

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 \( \theta_{e1} \) are related to each other by the following

\[ \theta_{e1} = \tan^{-1} \left\{ \frac{h_{l1} - h_1}{d_{l1}} - \frac{d_{l1}}{2a} \right\} \ \text{rad} \quad (21) \]
\[ h_{l1} = h_1 + \frac{d_{l1}^2}{2a} + d_{l1} \tan \theta_{e1} \ \text{km} \quad (22) \]

and
\[ d_{l1} = \sqrt{2a(h_{l1} - h_1) + a^2 \tan^2 \theta_{e1} - a \tan \theta_{e1}} \ \text{km} \quad (23) \]

where the \( + \) choice is made such that (23) yields its smallest positive value. If \( d_{l1} \) and/or \( \theta_{e1} \) are not specified, they may be estimated \[32, \text{sec. 2.4}\] using the terrain parameter, \( \Delta h \ \text{km}, \) 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,

\[ d_{ls1} = \sqrt{2a \ h_{e1}} \ \text{km} \quad (24) \]
\[ h_{e} = \text{larger of} \ \{ h_{e1} \ \text{or} \ 0.005 \} \ \text{km} \quad (25) \]
\[ d_{l1} = \text{larger of} \ \left\{ 0.1 \ d_{ls1} \ \text{or} \ \frac{d_{ls1} \ \exp(-0.07 \ \sqrt{\Delta h/h_e})}{d_{ls1}} \right\} \ \text{km} \quad (26) \]

and
The programs allow any two of \( h_L, d_L, \) or \( \theta_e \) to be specified or estimated via \( \Delta h \), and the remaining parameter to be calculated. When a smooth earth is specified, \( \Delta h \) is set to zero, \( h_L \) is set to \( h_{rs} \), \( d_L \) set to \( d_{Ls} \), and \( \theta_e \) 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

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

where

\[
C_e = \ln \frac{N_s}{N_s + \Delta N} \tag{29}
\]

and

\[
\Delta N = -7.32 \exp(0.005577 N_s) \quad \text{N-units/km} \tag{30}
\]

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, \( a_0 \). 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

\[
h_{a2} = h_2 - h_{rs} \text{ km} \quad (31)
\]

and

\[
h_{e2} = h_{a2} - \Delta h_e \text{ km} \quad (32)
\]

However, \( \Delta h_e \) specification is neither required or recommended. When \( \Delta h_e \) 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

\[
d_{LS2} = \begin{cases} \sqrt{2a h_{e2}} & \text{if } h_{e2} \leq 50 \text{ km} \\ a \cos^{-1}[a/(a+h_{e2})] & \text{otherwise} \end{cases} \text{ km.} \quad (33)
\]

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

\[
h_{e2} = \begin{cases} h_{a2} - \Delta h_e & \text{if } \Delta h_e \text{ is specified} \\ \text{lesser of} \begin{cases} h_{a2} \\ \{d_{LS2}^2/(2a) \text{ if } \theta_{s2} \leq 0.1 \text{ rad} \\ a[\sec (\theta_{s2})-1] \text{ otherwise} \end{cases} \text{ otherwise} \end{cases} \text{ km} \quad (34)
\]

where

\[
\theta_{s2} = \frac{d_{LS2}}{a} \text{ rad} \quad (35)
\]
The $d_{L2}$ 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 $\Delta h_e$, $d_{L2}$ 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 $\Delta h_e$ 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.,

$$h_{eL} = h_{L1} - h_{rs} \text{ km} \quad (36)$$

$$d_{SL} = \sqrt{2a h_{eL}} \text{ km} \quad (37)$$

and

$$d_{L2} = \begin{cases} d - d_{L1} & \text{if } d - d_{L1} \leq d_{SL} + d_{L2} \\ d_{L2} & \text{otherwise} \end{cases} \text{ km} \quad (38)$$

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

\[ \theta_e = \begin{cases} \tan^{-1} \left[ \frac{h_e - h_2}{d_{L2}} - \frac{d_{L2}}{2a} \right] & \text{if } d_{L2} = d - d_{L1} \\ \text{or} \\ \tan^{-1} \left[ -\frac{h_2}{d_{L2}} - \frac{d_{L2}}{2a} \right] & \text{otherwise} \end{cases} \text{ rad.} \quad (39) \]

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

\[ d_{ML} = \begin{cases} a \left( \cos^{-1} \left[ \frac{(a+h_1) \cos \theta_1}{(a+h_2)} - \theta_1 \right] \right) & \text{if } \Delta h_e \text{ is specified} \\ d_{L1} + d_{rt} & \text{otherwise} \end{cases} \text{ km.} \quad (40) \]

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 $\psi_L$ (fig. 13). This angle is related to $\psi_e$ by

$$\psi_L = \psi_e + \frac{d_{L1}}{a} \text{ rad.} \quad (41)$$

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 $d < d_{ML}$, 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, $\Delta r$ 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, $r_0$ 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 $a_0$ from (19); (b) grazing angle, $\psi$ 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 $\Delta r$ 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, $\Delta r$, calculations (not drawn to scale).
\[ z = (a_o/a) - 1 \]  
\[ k_a = 1/(1 + z \cos \psi) \]  
\[ a_a = a_o \, k_a \, \text{km} \]  
\[ \Delta h_a = h_{a2} - h_{e2} \, \text{km} \]  
\[ \Delta h_a = \Delta h_e \frac{(a_a - a_o)}{(a - a_o)} \, \text{km} \]  

\[ h_2 = \begin{cases} 
  h_{a2} - \Delta h_a & \text{for earth} \\
  h_{a2} - \Delta h_a - h_{cg} & \text{for counterpoise}
\end{cases} \, \text{km} \]  

\[ H_1 = \begin{cases} 
  h_{e1} & \text{for earth} \\
  h_{fc} & \text{for counterpoise}
\end{cases} \, \text{km} \]  

\[ z_{1,2} = a_a + H_{1,2} \, \text{km} \]  

\[ \theta_{1,2} = \cos^{-1} \left[ \frac{a_a \cos (\psi)}{z_{1,2}} \right] - \psi \, \text{rad} \]  

\[ D_{1,2} = z_{1,2} \sin \theta_1, \, \text{km} \]  

\[ H_{1,2}' = \begin{cases} 
  D_{1,2} \tan \psi & \text{for } \psi < 1.56 \, \text{rad} \\
  H_{1,2} & \text{otherwise}
\end{cases} \, \text{km} \]  

\[ \alpha = \begin{cases} 
  \tan^{-1} \left[ \frac{(H_{2}' - H_1')}{(D_1 + D_2)} \right] & \text{for } \psi < 1.56 \, \text{rad} \\
  \psi & \text{otherwise}
\end{cases} \, \text{km} \]  

\[ r_o = \begin{cases} 
  \frac{(D_1 + D_2)}{\cos \alpha} & \text{for } \psi < 1.56 \, \text{rad} \\
  H_2 - H_1 & \text{otherwise}
\end{cases} \, \text{km} \]  

\[ r_{12} = \begin{cases} 
  \frac{(D_1 + D_2)}{\cos \psi} & \text{for } \psi < 1.56 \, \text{rad} \\
  H_1 + H_2 & \text{otherwise}
\end{cases} \, \text{km} \]
\[ \Delta r = 4 \frac{H_1^* H_2}{(r_0 + r_{12})} \text{ km} \quad (56) \]

\[ \theta_h = \alpha - \theta_1 \text{ rad} \quad (57) \]

\[ \theta_{er} = \psi + \theta_1 \text{ rad} \quad (58) \]

\[ \theta_o = \theta_1 + \theta_2 \text{ rad} \quad (59) \]

and

\[ d = a \theta_o \text{ km} \quad (60) \]

An effective earth radius, \( a_a \), and an effective aircraft altitude, \( H_2 \), that varies with \( \psi \) 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 \( \cos \psi \) is not \(-1\) [3, eq. 3.23].

**Effective specular reflection coefficient** for reflection from the earth, \( R_g \exp(-j\phi) \), has a magnitude \( R_g \) and a phase \( \phi \). Allowances are included for the effect on reflection coefficient of (a) reflecting area illumination (antenna gain), (b) surface dielectric constant \( \varepsilon \) and conductivity \( \sigma \) mho/m from table 2, (c) polarization, (d) surface roughness, and (e) wavelength \( \lambda_m \) 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 \( f \exp(-j\phi) \) [6, sec. 11.1] and the reflection reduction factor \( F_{oh} \) [32, eqs. 3, 3.5, 3.6]. That is

\[ \varepsilon_c = \varepsilon - j 60\lambda_m \sigma \quad (61) \]

\[ \psi = \text{grazing angle (fig. 17)} \]

\[ Y_c = \sqrt{\varepsilon_c - \cos^2 \psi} \quad (62) \]

and

\[ R \exp(-j\phi) = \begin{cases} 
\frac{\sin(\psi) - Y_c}{\sin(\psi) + Y_c} & \text{for horizontal polarization} \\
\frac{\varepsilon_c \sin(\psi) - Y_c}{\varepsilon_c \sin(\psi) + Y_c} & \text{for vertical polarization}
\end{cases} \quad (63) \]
With $\Delta h_m$ as the terrain parameter (m) from table 3 and $d$ as the great circle path distance (km) as shown in figure 16,

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

$$\sigma_h = \begin{cases} 0.39 \Delta h_d & \text{for } \Delta h_d \leq 4 \text{ m} \\ 0.78 \Delta h_d \exp(-0.5\Delta h_d^{1/4}) & \text{otherwise} \end{cases} \text{ m} \quad (65)$$

and

$$F_{ch} = \exp(-2\pi\sigma_h \sin(\psi)/\lambda_m). \quad (66)$$

Further,

$$g = \begin{cases} \cos \theta_{er} & \text{if } |\theta_{er}| \leq 83^\circ \text{ for cosine option where } \\ 0.12589 & \text{otherwise} \end{cases} \text{ } \theta_{er} \text{ is from (58)}$$

$$10^{G_N/20} \text{ with } G_N \text{ from fig. 2 for DME and TACAN options}$$

$$1 \text{ for isotropic option}$$

$$[1+(2|\theta_{er} - \theta_t|/\theta_{HP})^{2.5}]^{-0.5} \text{ for JTAC option where the beam tilt above horizontal is } \theta_t \text{ and the half-power beamwidth is } \theta_{HP} \text{ degree, both in the same units as } \theta_{er}$$

and

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

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

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

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:

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

$$d_c = \text{counterpoise diameter (km),}$$

$$\theta_{ce} = \tan^{-1}(2 h_{fc}/d_c) \text{ rad}$$

(70)

$$r_c = 0.5 d_c/\cos \theta_{ce} \text{ km}$$

(71)

$$\psi = \text{grazing angle (fig. 17)}$$

$$\theta_{kg} = |\theta_{ce} - \theta_{er}| \text{ rad}$$

(72)

where $$\theta_{er}$$ is determined from (58)

$$\lambda = \lambda_m/1000 \text{ km}$$

(73)

where $$\lambda_m$$ is from (10)

$$\gamma_v = \sqrt{2 r_c/\lambda}$$

(74)

$$v_g = \pm 2 \gamma_v \sin(\theta_{kg}/2) \left( - \text{ for } \theta_{er} < \theta_{ce} \right)$$

(75)

$$\theta_{kc} = |\theta_{ce} - \theta_{h}| \text{ rad}$$

(76)

where $$\theta_{h} \text{ rad, determined from (57) for reflection from the earth, is used as the grazing angle } \psi_c \text{ for counterpoise reflection and}$$

$$v_g = \pm 2 \gamma_v \sin(\theta_{kc}/2) \left( - \text{ for } \theta_{h} > \theta_{ce} \right)$$

(77)
Figure 17. Geometry for determination of earth reflection diffraction parameter, $\psi$, associated with counterpoise shadowing.

Figure 18. Geometry for determination of counterpoise reflection diffraction parameter, $\psi$, 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, $\phi_{kg,c}$ rad, factors from $v_{g,c}$.

Ray combining is performed as follows:

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

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

$f_{g,c}$ 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.

$d_c = \text{counterpoise diameter (km)},$

$\lambda = \text{wavelength (km) from (73)}$

$$R_{Tg} = \begin{cases} R_g & \text{if } d_c < 0 \\ f_g R_g & \text{otherwise} \end{cases} \text{ (sec. 3.1) used}$$

$$R_{Tc} = \begin{cases} 0 & \text{if } \Delta r_g > \lambda/6 \\ R_g & \text{if } d_c < 0 \\ f_g R_g & \text{otherwise} \end{cases}$$

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

$g_D = \text{value of } g \text{ for direct ray from (67) with } \theta_{er} \text{ set to } \theta_h \text{ from (57)}.$
\[ W_{RO} = |g_D| R_T g \exp(-j\phi_T g) + R_T c \exp(-j\phi_T c)|^2 + 0.0001 \quad (81) \]

and

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

Diffraction is included in the line-of-sight calculations near the radio horizon by using (a) the largest within-the-horizon distance, \( d_0 \) km, from (140), at which diffraction effects are considered negligible (sec. A.4.3); (b) the value of \(-P_{RO}\) from (82) at \( d_0 \), \( A_0 \) 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 \( (d < d_{ML}) \) from

\[ M_L = \frac{A_{ML} + P_{RO}}{d_{ML} - d_0} \text{ dB/km} \quad (83) \]

and

\[ A_T = \begin{cases} -P_{RO} & \text{if } d < d_0 \\ M_L (d - d_0) - P_{RO} & \text{if } d_0 \leq d \leq d_{ML} \end{cases} \text{ dB} \quad (84) \]

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

*Decibels greater than the free-space power level.
I
Starting with $\psi$ (0 to 89°), generate tables of $\Delta r$ from (56) and $d$ via (60) for reflection from the earth.

II
Interpolate between values in the $\psi$, $\Delta r$, $d$ tables (block I) to determine distances required to plot lobing associated with earth reflection for (a) the first 10 lobes ($\Delta r$ up to 10 $\lambda$) inside the smooth earth radio horizon, or (b) near the horizon lobe. Critical $\Delta r$'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, $\psi_c$'s, are determined from $\psi_c = \arcsin(0.5 \Delta r_c/h_{fc})$ for critical $\Delta r_c$ 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 $\psi$ values for (43) are obtained by interpolation within the $\psi$, $\Delta r$, $d$ table of block I.

Figure 19. Block diagram of procedure used in line-of-sight calculations.
diffraction considerations. In this section details are given concern-
ing (a) rounded earth diffraction calculations, (b) knife-edge calcula-
tions, (c) the determination of the distance, $d_0$, 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 ($d > d_{ML}$).

**Rounded earth diffraction** is treated using referenced methods
[32, eq. 3.28, etc.; 40, sec. 8.2]. Rounded earth diffraction attenua-
tion, $A_{pr}$, for path "p" is calculated as follows:

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

\[
h_{pe1,2} = \text{effective height (km) for terminal 1 or 2 of path } p
\]

\[
d_{pL} = d_{pL1} + d_{pL2} \text{ km} \quad (85)
\]

\[
a = \text{effective earth radius from (20)}
\]

\[
f = \text{frequency (MHz)}
\]

\[
d_{pLS} = \text{smooth earth horizon distance for path } p
\]

\[
d_3 = \text{larger of } \left\{ \begin{array}{c} d_{pL} + 0.5(a^2/f)^{1/3} \\ d_{pLS} \end{array} \right\} \text{ km} \quad (86)
\]

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

\[
a_{1,2} = d_{pL1,2}^2/(2 h_{pe1,2}) \text{ km} \quad (88)
\]

\[
\theta_{pe1,2} = \text{horizon elevation angle (rad) for terminal 1, or 2 of path } p
\]
\[ \theta_{pe} = \theta_{pe1} + \theta_{pe2} \text{ rad} \]  
\[ \theta_{3,4} = \theta_{pe} + \frac{d_{3,4}}{a} \text{ rad} \]  
\[ a_{3,4} = \frac{(d_{3,4} - d_{PL})}{\theta_{3,4}} \text{ rad} \]  
\[ \sigma = \text{conductivity (mho/m) from table 2} \]  
\[ x = 18000 \text{ c/f} \]  
\[ \varepsilon = \text{dielectric constant from table 2} \]  
\[ K_{d} = 0.36278 f^{-1/3} \left[ (\varepsilon - 1)^2 + x^2 \right]^{-1/4} \]  
\[ K_{1,2,3,4} = \begin{cases} K_{d} a_{1,2,3,4}^{-1/3} & \text{for horizontal polarization} \\ \text{or} & 1,2,3,4 \\ K_{d} a_{1,2,3,4}^{-1/3} \left[ \varepsilon^2 + x^2 \right]^{1/2} & \text{for vertical polarization} \end{cases} \]  
\[ B_{1,2,3,4} = 416.4 f^{1/3} (1.607 - K_{1,2,3,4}) \]  
\[ x_{1,2} = B_{1,2} a_{1,2}^{-2/3} d_{PL1,2} \text{ km} \]  
\[ \nu_{1,2} = 0.0134 x_{1,2} \exp(-0.005 x_{1,2}) \]  
\[ y_{1,2} = 40 \log(x_{1,2}) \cdot 117 \text{ dB} \]  
\[ x_{3,4} = B_{3,4} a_{3,4}^{-2/3} (d_{3,4} - d_{PL}) + x_{1} + x_{2} \]  
\[ G_{1,2,3,4} = 0.0575 \left[ x_{1,2,3,4} - 10 \log \sigma_{1,2,3,4} \right] \]
When \(0 < x_{1,2} \leq 200\)

\[
F_{1,2} = \begin{cases} 
  \{ y_{1,2} \text{ if } |y_{1,2}| < 117 \} \text{ if } 0 \leq K_{1,2} < 10^{-5} \\
  -117 \text{ otherwise} \\
  y_{1,2} \text{ if } 10^{-5} \leq K_{1,2} < 1 \\
  \text{and } x_{1,2} \geq -450/\log K_{1,2}^3 \\
  \text{or} \\
  20 \log(K_{1,2}) - 15 + 2.5(10)^{-5}x_{1,2}^2/K_{1,2} \\
  \text{otherwise}
\end{cases}
\]

\text{dB (101)}

When \(200 < x_{1,2} \leq 2000\)

\[W_{1,2} y_{1,2} + (1-W_{1,2}) G_{1,2}\]

When \(x_{1,2} > 2000\)

\[G_{1,2}\]

\[
A_{3,4} = G_{3,4} - F_{1} - F_{2} - 20 \quad \text{dB} \quad (102)
\]

\[
M_{pr} = (A_{4} - A_{3})/(d_{4} - d_{3}) \quad \text{dB/km} \quad (103)
\]

\[
A_{pro} = A_{4} - M_{pr} d_{4} \quad \text{dB} \quad (104)
\]

\[
A_{pr} = A_{pro} + M_{pr} d_{p} \quad (105)
\]

\[
h_{m1,2} = 1000 \ h_{pe1,2} \quad \text{m} \quad (106)
\]

and

\[
B_{N1,2} = 1.607 - K_{1,2} \quad (107)
\]

Then \(G_{ph1,2}\) are obtained with subroutine \text{GHBAR} [sec. B.4.1] by using value of \(a_{1,2}, f, B_{N1,2}, K_{1,2}, d_{pl1,2}, \text{and } h_{m1,2}\) where \text{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 $h_{heel}$ to $h_{heel}$ paths. Knife-edge diffraction is calculated for the $h_{el1}$ to $h_{Ke2}$ and $h_{el1}$ to $h_{heel}$ paths.

This formulation is used to determine rounded earth diffraction lines, $(105)$ and $G_{ph1,2}$ (discussed under knife-edge diffraction in the next paragraph) values for two paths illustrated in figure 20. The first involves diffraction over the facility horizon obstacle only where the subscript $p$ is replaced by $K$ so that:

(a) \[ d_{KL1} = d_{L1} \text{ km} \] \hspace{1cm} (108)

with $d_{L1}$ from figure 14 and

(b) \[ h_{Ke1,2} = h_{el1,2} \text{ km} \] \hspace{1cm} (110)
where

\[ h_{e1} = h_1 - h_{rs} \text{ km} \quad (111) \]

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

\[ d_{KLs} = d_{Ls1} + d_{Ls2} \text{ km} \quad (112) \]

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

\[ \theta_{KC1,2} = \theta_{e1,2} \text{ rad} \quad (113) \]

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) \[ h_{ee1} = h_{L1} - h_{rs} \text{ km} \quad (114) \]

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

\[ h_{ee2} = h_{e2} \text{ km} \quad (115) \]

from (34),

(b) \[ d_{ee1,2} = \sqrt{2a h_{ee1,2}} \text{ km} \quad (116) \]

where \( a \) is from (20),

(c) \[ d_{eeL} = d_{eL1} + d_{eL2} \text{ km} \quad (117) \]

and

(d) \[ \theta_{ee1,2} = \tan^{-1} \left( \frac{h_{ee1,2}}{d_{ee1,2}} - \frac{d_{eL1,2}}{2a} \right) \text{ rad} \quad (118) \]

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 $h_{el}$ to $h_{Ke2}$ and from $h_{el}$ to $h_{ee2}$. Parameters discussed in the previous paragraph are used in these calculations. That is, $G_{Khl}$, $G_{Khl2}$ and $G_{ehl}$, $G_{ehl2}$ are determined as per discussion following (107) where calculations are based on parameters for subscript K and e paths (fig. 20). Further:

$$A_{KK} = 6 - G_{Khl} - G_{Khl2} \text{ dB}$$

(119)

$$\theta_v = \theta_{el} + \theta_{ee2} + (d_{eLS} + d_{L1})/a \text{ rad}$$

(120)

where $\theta_{el}$ is from figure 14, $\theta_{ee2}$ is from (118), $d_{eLS}$ is from (117), $d_{L1}$ is from figure 14, and $a$ is from (20).

$$v_h = 2.583 \sin(\theta_v) \sqrt{fd_{L1}d_{eLS}/(d_{L1} + d_{eLS})}$$

(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

$$A_{eK} = A_h - G_{ehl} - G_{Khl} - 20 \log f_h \text{ dB}$$

(122)

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

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

(123)

where $d_{ML}$ is from (40)

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

(124)

and
\[ A_K = M_K d + A_{K_0} \text{ dB} \]  \hspace{1cm} (125)

where \( d \text{ km} \) is the great circle path distance.

The distance \( d_0 \text{ km} \) 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:

\[ \theta_h = \sin^{-1} \left[ \frac{0.5}{2.853} \right] \sqrt{\frac{d_{ML}/f_{L1}}{d_{KL2}}} \text{ rad} \]  \hspace{1cm} (126)

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

\[ \theta_5 = \theta_h - \theta_{el} \text{ rad} \]  \hspace{1cm} (127)

where \( \theta_{el} \) is from figure 14,

\[ d_{L5} = -a \theta_5 + \sqrt{(a \tan \theta_5)^2 - [(h_1 - h_{L1})/(2a)]} \text{ km} \]  \hspace{1cm} (128)

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

\[ d_5 = d_{L5} + d_{L1} \text{ km} \]  \hspace{1cm} (129)

\[ h_{s2} = h_2 - \Delta h_e \text{ km} \]  \hspace{1cm} (130)

where \( h_2 \) is aircraft altitude above msl and \( \Delta h_e \) is from (45)

\[ \theta_{e5} = \tan^{-1} \left[ \frac{h_{L1} - h_{s2}}{d_{L5} - d_{L5}/2a} \right] \text{ rad} \]  \hspace{1cm} (131)

\[ \theta_6 = \theta_{el} + \theta_{e5} + (d_5/a) \text{ rad} \]  \hspace{1cm} (132)

\[ v_5 = 2.583 \sin(\theta_6) \sqrt{f_{L1} d_{L5}/d_5} \text{ rad} \]  \hspace{1cm} (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

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

and

$$W = \begin{cases} 
1 \text{ when } d_{ML} \geq d_{KLS} \\
0 \text{ when } d_{ML} \leq 0.9 \ d_{KLS} \\
0.5 \left\{ + \cos \left[ \frac{\pi (d_{KLS} - d_{ML})}{0.1 d_{KLS}} \right] \right\} \text{ otherwise} 
\end{cases} \quad (135)$$

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 $d_0$, respectively,

$$A_5 = \begin{cases} 
A_{r5} \text{ if } W > 0.999 \\
A_{K5} \text{ if } W < 0.001 \\
(1-W) A_{K5} + W A_{r5} \text{ otherwise} 
\end{cases} \quad \text{dB} \quad (136)$$

$$A_{ML} = \begin{cases} 
A_{rML} \text{ if } W > 0.999 \\
A_{KK} \text{ if } W < 0.001 \\
(1-W) A_{KK} + W A_{rML} \text{ otherwise} 
\end{cases} \quad \text{dB} \quad (137)$$

$$M_0 = (A_{ML} - A_5)/(d_{ML} - d_0) \text{ dB/km} \quad (138)$$

and

$$A_0 = A_{ML} - M_0 \ d_{ML} \text{ dB} \quad (139)$$

and

$$d_0 = -A_0/M_0 \text{ km} \quad (140)$$

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, $d_0$, and the maximum
line-of-sight distance, \(d_{\text{ML}}\), (b) using these points to define a linear diffraction line with slope \(M_0\) and intercept \(A_0\), and (c) using this line to define the distance \(d_0\) 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 \((d > d_{\text{ML}})\) 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).

\[
A_b = \begin{cases} 
A_{rK} & \text{if } W > 0.999 \\
A_{Ke} & \text{if } W < 0.001 \\
(1-W)A_{Ke} + W A_{rK} & \text{otherwise}
\end{cases} \quad \text{dB} \tag{141}
\]

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

\[
M_d = \frac{(A_{ML} - A_6)}{(d_{ML} - d_{L1} - d_{eLS})} \quad \text{dB/km} \tag{142}
\]

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

\[
A_{do} = A_{ML} - M_d d_{ML} \quad \text{dB} \tag{143}
\]

and

\[
A_d = M_d d + A_{do} \quad \text{dB} \tag{144}
\]

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 \(> 20\) dB and the slope of the \(A_s\) versus \(d\) curve, \(M_s\), is \(< M_d\) where \(M_s\) is determined using successive \(A_s\) calculations (sec. A.4.4) for distances greater than \(d_{ML}\). Then
\[
A_T = \begin{cases} 
A_d & \text{if } A_{sx} \geq A_{dx} \\
A_s + \left( \frac{A_{sx} - A_{ML}}{d_x - d_{ML}} \right) (d - d_x) & \text{otherwise} \\
\text{lesser of } A_d \text{ or } A_s & \text{for all shorter distances previously considered} \\
A_s & \text{otherwise} 
\end{cases} \text{ for } d_{ML} < d < d_x \\
\text{for } d_x < d 
\]

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:

\begin{align*}
\mathbf{d} &= \text{great circle path distance (km)} \\
\mathbf{a} &= \text{effective earth radius from (20)} \\
\theta_{e1} &= \text{facility horizon elevation angle (rad) via figure 14} \\
\theta_{e2} &= \text{aircraft horizon elevation angle (rad) from (39)} \\
h_1 &= \text{elevation of facility antenna (km) above msl} \\
h_{es2} &= \text{effective altitude of aircraft (nm) above msl}
\end{align*}
\[ h_{es2} = h_2 - \Delta h_e \] \hspace{1cm} \text{km} \hspace{1cm} (146)

where \( h_2 \) is the aircraft altitude above mean sea level and \( \Delta h_e \) is obtained from (45).

\[ \alpha_{oo} = \frac{d}{2a} + \theta_{e1} + \frac{h_1 - h_{es2}}{d} \] \hspace{1cm} \text{rad} \hspace{1cm} (147)

\[ \beta_{oo} = \frac{d}{2a} + \theta_{e2} - \frac{h_1 - h_{es2}}{d} \] \hspace{1cm} \text{rad} \hspace{1cm} (148)

\[ \theta_{oo} = \alpha_{oo} + \beta_{oo} \] \hspace{1cm} \text{rad} \hspace{1cm} (149)

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

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

\[ \theta_{o1,2} = \begin{cases} 
0 & \text{for smooth earth} \\
\theta_{e1,2} + \frac{d_{L1,2}}{a} & \text{otherwise}
\end{cases} \] \hspace{1cm} \text{rad} \hspace{1cm} (150)

\[ Y_{s1} = \frac{d \theta_{oo}}{\theta_{oo}} - d_{L1} \] \hspace{1cm} \text{km} \hspace{1cm} (151)

\[ Y_{s2} = \frac{d \alpha_{oo}}{\theta_{oo}} - d_{L2} \] \hspace{1cm} \text{km} \hspace{1cm} (152)

\[ d_{s1,2} = \begin{cases} 
Y_{s1,2} & \text{if } \theta_{o1,2} > 0 \\
Y_{s1,2} - \frac{a}{\theta_{o1,2}} & \text{otherwise}
\end{cases} \] \hspace{1cm} \text{km} \hspace{1cm} (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

\[ \alpha_o = \alpha_{oo} + \Delta \alpha_o \] \hspace{1cm} \text{rad} \hspace{1cm} (154)
\[ \beta_0 + \beta_{00} + \Delta \beta_0 \quad \text{rad} \] (155)

\[ \theta = \alpha_0 + \beta_0 \quad \text{rad} \] (156)

\[ S_I = \frac{\alpha_0}{\beta_0} \] (157)

\[ s = \begin{cases} S_I & \text{if } S_I \leq 1 \\ 1/S_I & \text{otherwise} \end{cases} \] (158)

\[ D_s = d - d_{L1} - d_{L2} \quad \text{km} \] (159)

\[ h_v = D_s \ s \ \theta/(1 + s)^2 \quad \text{km} \] (160)

\[ h_o = d_s \ \theta(1 + s)^2 \quad \text{km} \] (161)

\[ \eta = 0.031 - (2.32 \ N_s/10^3) + (5.67 \ N_s^2/10^6) \] (162)

\[ \eta_s = 0.5696 \ h_o [1 + \eta] \ \exp[-3.8 \ \left( \frac{h_o}{10^6} \right)\varepsilon] \] (163)

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

\[ \lambda = \text{wavelength (km) from (73)} \]

\[ v_\alpha = 4\pi \ h_1 \ \alpha_0/\lambda \] (165)

\[ v_\beta = 4\pi \ h_{es2} \ \beta_0/\lambda \] (166)

\[ v_1 = \begin{cases} v_\alpha & \text{if } S_I \leq 1 \\ v_\beta & \text{otherwise} \end{cases} \] (167)

\[ \text{and} \]

70
\[ v_2 = \begin{cases} v_B & \text{if } S_I \leq 1 \\ v_\alpha & \text{otherwise} \end{cases} \] 

(168)

A value for \( H_0 \) is obtained with subroutine HCHNOT (sec. B.4.1) by using values of \( s, \eta_s, \) 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 \( d, \theta, N_s, \) and \( s \) where FDTETA is based on a referenced method [7, sec. 11.1]. Then

\[ A_s = 10 \log f - 40 \log d + F_{d\theta} + H_0 - F_0 - 32.45 \text{ dB} \]  

(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 $H_y$, $H_2$, and $a_\gamma$ are defined in the text for line-of-sight, single horizon, and two horizon paths.

- $A_t = \phi + 0.5 \pi$
- $H_t = T_{eo,w} + a_\gamma$
- $H_q = H_1 + a_\gamma$
- $H_z = \text{lesser of } (H_t \text{ or } H_2 + a_\gamma)$

When $H_1 < T_{eo,w}$
- $A_q = \sin^{-1}(H_q \sin A_t / H_z)$
- $A_e = -(A_t + A_q)$
- $T_{eo,w} = \begin{cases} H_t - H_q & \text{if } A_q < 0.02 \text{ rad} \\ H_q \sin A_e / \sin A_q & \text{otherwise} \end{cases} \text{ km}$

When $T_{eo,w} = H_1$
- $H_q \sin A_t$
- $0$ if $H_t < H_c$ or $A_t < \frac{\pi}{2}$
- $2 H_t \sin [\cos^{-1}(H_c / H_t)]$ otherwise \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 [13, table A.2], respectively (not drawn to scale).
\[ H_2 = h_{ee1} \text{ from (114)}, a_\gamma = a \text{ from (20), and } \beta = \theta_{e1} \text{ from figure 14. For the second set } H_1 = H_L1, H_2 = h_{e2} \text{ from (34), } a_\gamma = a, \text{ and } \beta = -\theta_{e2} - \frac{(d - d_{L1})}{a} \text{ where } \theta_{e2} \text{ is from (36). Values for } r_{eo,w} \text{ are then obtained using}
\]
\[ r_{eo,w} = r_{1eo,w} + r_{2eo,w} \text{ km } . \tag{170} \]

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 \(h_{ee2}\) \text{ km at distance } d_{S1} \text{ km from (153), } \theta_{o1} \text{ rad from (150), and } a \text{ km; i.e.,}
\]
\[ H_v = h + d \tan \theta_{o1} + d_{S1}^2/(2a) \text{ km } . \tag{171} \]

In the first set of calculations, \(H_1 = h_{e1}, H_2 = H_v, a_\gamma = a, \text{ and } \beta = \theta_{e1}. \) For the second set, \(H_1 = \text{ lesser of } \{H_v \text{ or } H_{e2}\}, H_2 = \text{ greater of } \{H_v \text{ or } H_{e2}\}, a_\gamma = a, \text{ and } \beta = \text{ greater of } \{-\theta_{e2} \text{ or } -\theta_{e2} - \frac{(d - d_{L1} - d_{S1})}{a}\}. \)

Surface absorption rates for oxygen and water vapor, \(\gamma_{oo,w} \text{ dB/km}\) are used with effective ray lengths, \(r_{eo,w} \text{ km}\), to obtain an estimate for atmospheric absorption, \(A_a \text{ dB}\); i.e.,
\[ A_a = \gamma_{oo} r_{eo} + \gamma_{ow} r_{ew} \text{ dB } . \tag{172} \]

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 \(Y_{\#}(q)\)
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 \( q < 0.5 \) 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 \( \theta_h \) in their elevation angle correction function [40, fig. III.24] by \( \theta_h \), where \( \theta_h \) is the elevation angle of the facility-to-aircraft direct ray from (57); and (c) conditional limiting of \( Y_e(q) \) values \( q < 0.1 \). The \( \theta_h \) 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 \( \Delta h_e \) 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

\[
d_{Lo1} = \sqrt{18000 \, h_{e1}} \text{ km} \quad (173)
\]

where \( h_{e1} \) is from (111)

\[
d_{Lo2} = \begin{cases} d_{LoR} \text{ if } \Delta h_e \text{ not specified} \\ \sqrt{18000 \, h_{a2}} \text{ otherwise} \end{cases} \text{ km} \quad (174)
\]

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

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

where \( f \) MHz is frequency

\[
d_M = d_{Lo1} + d_{Lo2} + d_{ds} \text{ km} \quad (176)
\]
\[
d_e = \begin{cases} 
130d/d_M & \text{for } d \leq d_M \\
130 + d - d_M & \text{otherwise}
\end{cases} \text{ km} \tag{177}
\]

where \( d \text{ km} \) is great circle path distance and

\[
V(0.5) = Y(0.1) = \left[ C_1 d_e^{n_1} - f_2 \right] \exp(-C_3 d_e^{n_3}) + f_2 \text{ dB} \tag{178}
\]

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 \( f_\infty \) depend on whether \( V(0.5) \) \citep[Table III.5, Climate 1,][]{40}, \( Y(0.1) \) \citep[Table III.3, all hours all year,][]{40}, or \( Y(0.9) \) \citep[Table III.4, all hours all year][]{40} is being calculated. Then

\[
f_{\theta h} = 0.5 - \pi^{-1} \tan^{-1}\left[20 \log(32 \theta_h)\right] \tag{179}
\]

\[
Y_e(0.1) = f_{\theta h} Y(0.1) \text{ dB} \tag{180}
\]

\[
Y_e(0.9) = f_{\theta h} Y(0.9) \text{ dB} \tag{181}
\]

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

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).

\[
Y_e(0.0001) = \begin{cases} 
3.33 Y_e(0.1) & \text{for lobing} \\
\text{lesser of } \{ Y_T \} & \text{lesser of } \{ Y_T, Y_e(0.1) \} & \text{otherwise}
\end{cases} \text{ dB} \tag{183}
\]
where the lobing option is discussed in sec. 3.1.1, $L_{br}$ is from (17) and $A_{y}$ is from (15),

\[
Y_{e}(0.001) = \begin{cases} 
\text{lesser of} & \{2.73 \ Y_{e}(0.1) \ \\
\text{or} & Y_{T} \} \ 	ext{for lobing} \\
\text{lesser of} & \{2.73 \ Y_{e}(0.1) \ \\
\text{or} & L_{b}(0.5)-(L_{bf}-5.8)\} \ 	ext{otherwise} 
\end{cases} 
\] dB (184)

\[
Y_{e}(0.01) = \begin{cases} 
\text{lesser of} & \{1.95 \ Y_{e}(0.1) \ \\
\text{or} & Y_{T} \} \ 	ext{for lobing} \\
\text{lesser of} & \{1.95 \ Y_{e}(0.1) \ \\
\text{or} & L_{br}+A_{y}-(L_{bf}-5)\} \ 	ext{otherwise} 
\end{cases} 
\] dB (185)

\[
Y_{B} = L_{b}(0.5) - (L_{bf} + 80) \text{ dB} \quad (186)
\]

\[
Y_{e}(0.99) = \begin{cases} 
\text{greater of} & \{1.82 \ Y_{e}(0.9) \ \\
\text{or} & Y_{B} \} \ 	ext{for lobing} \\
1.82 \ Y_{e}(0.9) \ 	ext{otherwise} 
\end{cases} 
\] dB (187)

\[
Y_{e}(0.999) = \begin{cases} 
\text{greater of} & \{2.41 \ Y_{e}(0.9) \ \\
\text{or} & Y_{B} \} \ 	ext{for lobing} \\
2.41 \ Y_{e}(0.9) \ 	ext{otherwise} 
\end{cases} 
\] dB (188)

\[
Y_{e}(0.9999) = \begin{cases} 
\text{greater of} & \{2.90 \ Y_{e}(0.9) \ \\
\text{or} & Y_{B} \} \ 	ext{for lobing} \\
2.90 \ Y_{e}(0.9) \ 	ext{otherwise} 
\end{cases} 
\] dB (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.,

\[
V_e(0.5, d_e) = f_{th} V(0.5) \text{ dB .} \tag{190}
\]

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 exceed \( d \)" 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:

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

\[
F_{AY} = \begin{cases} 
1 & \text{if } A_Y < 0 \\
0.1 & \text{if } A_Y > 6 \\
0.5[1.1 + 0.9 \cos(\pi A_Y/6)] & \text{otherwise}
\end{cases} \tag{191}
\]

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

\[
F_{Ar} = \begin{cases} 
0 & \text{for lobing (table 1)} \\
1 & \text{for } \Delta r > \lambda/2 \\
0.1 & \text{for } \Delta r < \Delta r_0 = \lambda/6 \\
1.1 - 0.9 \cos \left[ \frac{3\pi (\Delta r - \Delta r_0)}{2\lambda} \right] & \text{otherwise}
\end{cases} \tag{192}
\]
\[ R_s = R_{tg} F_{AY} F_{Dr} \]  

where \( R_s \) is the specular contribution to relative multipath power, and \( R_{tg} \) is from (78). \( F_{doh} \) 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 \( F_{oh} \) from (66)

\[
F_{doh} = \begin{cases} 
0.01 + 9.46 F_{oh}^2 & \text{if } F_{oh} < 0.00325 \\
6.15 F_{oh} & \text{if } 0.00325 \leq F_{oh} \leq 0.0739 \\
0.45 + \sqrt{0.000893 - (F_{oh} - 0.1026)^2} & \text{if } 0.0739 < F_{oh} < 0.1237 \\
0.601 - 1.06 F_{oh} & \text{if } 0.1237 \leq F_{oh} < 0.3 \\
0.01 + 0.875 \exp(-3.88 F_{oh}) & \text{otherwise} 
\end{cases}
\]  

(194)

\[ R_d = R_{tg} F_{doh}/F_{oh} \]  

(195)

where \( R_d \) is the diffuse contribution to relative multipath power and

\[ W_R = \begin{cases} 
R_s + R_d & \text{for line-of-sight (}d < d_{ML}\text{)} \\
0 & \text{otherwise} 
\end{cases} \]  

(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, \( r \), of (67), (c) shadowing of the reflecting area by the counterpoise with \( f_g \) of (78), and (d) surface roughness via \( F_{oh} \) of (66). This formulation for \( F_{oh} \) [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... "].
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;

$$F = \begin{cases} 10 \log (f r_{ew}^3) - 84.26 & \text{if } d \leq d_{ML} \\ \text{and is not calculated otherwise} & \end{cases} \text{dB} \quad (197)$$

$$K_t = \begin{cases} 40 \text{ dB if } F < 0.14 \\ -20 \text{ dB if } F > 18.4 \\ \text{obtained from curves}[40, \text{fig. V.1}] \end{cases} \text{dB} \quad (198)$$

and

$$W_a = 10^{-K_t/10} \quad (199)$$

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 $Y_n(0.99) = -F$ 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 $\theta$ 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.,

$$MK_a = (-20-K_{ML})/0.02618 \text{ dB/rad}$$

and

$$K_t = \begin{cases} \text{obtained via (198) if } d \leq d_{ML} \\ -20 \text{ if } \theta > 0.02618 \text{ rad} \\ K_{ML} + M_{Ka} \text{ if } \theta \leq 0.02618 \text{ rad} \end{cases} \text{ dB}. \quad (201)$$

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 $\theta$ at which short-term fading for beyond-the-horizon paths can be characterized as Rayleigh fading ($K = -20 \text{ dB}$), and (201) includes a linear interpolation between the horizon ($\theta = 0$, $K_t = K_{ML}$) and Rayleigh fading ($\theta = 0.02618 \text{ rad}$, $K_t = -20 \text{ dB}$) 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.
Table 2. 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 PONAV (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.
Figure 24. Parameter card types for the service volume program, SRVLOM. 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 J = -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>
<thead>
<tr>
<th>Parameter Card</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1K</td>
<td>Code for units to be used with input. The units given for variables in this table are correct only when 1K is used. NOTE: 1K=0 terminates a PCB run.</td>
</tr>
<tr>
<td>HFI</td>
<td>Height of facility antenna (feet above site surface).</td>
</tr>
<tr>
<td>JTA</td>
<td>Code for facility antenna pattern: (1) isotropic, (2) DME, (3) ICA (ICN-2).</td>
</tr>
<tr>
<td>JTC</td>
<td>Code for facility antenna vertical pattern: (1) 45° (1.37 m), (2) 25°, (3) 7.5°, (4) 5°, (5) 3°, (6) 1.5°, (7) 1°, and (8) 0.5°.</td>
</tr>
<tr>
<td>JTP</td>
<td>Code for facility antenna horizontal pattern.</td>
</tr>
<tr>
<td>JTR</td>
<td>Code for facility antenna reference plane.</td>
</tr>
<tr>
<td>JTS</td>
<td>Code for facility antenna site elevation.</td>
</tr>
<tr>
<td>JTK</td>
<td>Code for facility antenna effectiveness.</td>
</tr>
<tr>
<td>JTW</td>
<td>Code for facility antenna ground effect.</td>
</tr>
<tr>
<td>JTG</td>
<td>Code for facility antenna ground plane.</td>
</tr>
<tr>
<td>JTO</td>
<td>Code for facility antenna rotation.</td>
</tr>
<tr>
<td>JTS</td>
<td>Code for facility antenna type.</td>
</tr>
<tr>
<td>JTE</td>
<td>Code for facility antenna elevation.</td>
</tr>
<tr>
<td>JTI</td>
<td>Code for facility antenna height.</td>
</tr>
<tr>
<td>JTL</td>
<td>Code for facility antenna location.</td>
</tr>
<tr>
<td>JTN</td>
<td>Code for facility antenna number.</td>
</tr>
<tr>
<td>JTF</td>
<td>Code for facility antenna function.</td>
</tr>
<tr>
<td>JTS</td>
<td>Code for facility antenna site elevation.</td>
</tr>
<tr>
<td>JTK</td>
<td>Code for facility antenna effectiveness.</td>
</tr>
<tr>
<td>JTP</td>
<td>Code for facility antenna rotation.</td>
</tr>
<tr>
<td>JTS</td>
<td>Code for facility antenna type.</td>
</tr>
<tr>
<td>JTI</td>
<td>Code for facility antenna function.</td>
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<tr>
<td>JTS</td>
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</tr>
<tr>
<td>JTK</td>
<td>Code for facility antenna effectiveness.</td>
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<tr>
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<td>JTS</td>
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<tr>
<td>JTP</td>
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</tr>
<tr>
<td>JTS</td>
<td>Code for facility antenna type.</td>
</tr>
<tr>
<td>JTI</td>
<td>Code for facility antenna function.</td>
</tr>
<tr>
<td>Code</td>
<td>Value</td>
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<td>------</td>
<td>-------</td>
</tr>
<tr>
<td>KD</td>
<td>1 2 2</td>
</tr>
<tr>
<td>EERP</td>
<td>1 2 2</td>
</tr>
<tr>
<td>ILB</td>
<td>1 2 2</td>
</tr>
<tr>
<td>ADENT</td>
<td>2 3 3</td>
</tr>
<tr>
<td>HAI</td>
<td>2 3 -</td>
</tr>
<tr>
<td>DHEI</td>
<td>2 3 -</td>
</tr>
<tr>
<td>ENO</td>
<td>2 3 3</td>
</tr>
<tr>
<td>AOI</td>
<td>2 3 3</td>
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<tr>
<td>AWT</td>
<td>2 3 3</td>
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<td>F</td>
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<td>DMIN</td>
<td>2 3 -</td>
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<td>DMAx</td>
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<td>XC</td>
<td>2 3 1</td>
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<td>PMIN</td>
<td>2 3 -</td>
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<tr>
<td>YC</td>
<td>2 3 1</td>
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<tr>
<td>IA</td>
<td>2 3 3</td>
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<tr>
<td>ADNT</td>
<td>3 4 3</td>
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<td>IS</td>
<td>- 1 1</td>
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<tr>
<td>SMIN</td>
<td>- 1 -</td>
</tr>
<tr>
<td>SMAX</td>
<td>- 1 -</td>
</tr>
<tr>
<td>SNC</td>
<td>- 1 -</td>
</tr>
<tr>
<td>CD</td>
<td>- 1 -</td>
</tr>
<tr>
<td>S</td>
<td>- - 1</td>
</tr>
<tr>
<td>LH</td>
<td>- - 1</td>
</tr>
<tr>
<td>LE</td>
<td>- - 1</td>
</tr>
<tr>
<td>SX(I)</td>
<td>- - 1</td>
</tr>
</tbody>
</table>
Table 7. FORTRAN input variables for parameter cards (Cont'd)

<table>
<thead>
<tr>
<th>Fortran Input Variables</th>
<th>Parameter Card Type Number For</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SX(2)</td>
<td>- - 1</td>
<td>Abscissa value for left-hand limit of service volume graph (n mi).</td>
</tr>
<tr>
<td>SY(1)</td>
<td>- - 1</td>
<td>Ordinate value for top limit of service volume graph (feet).</td>
</tr>
<tr>
<td>SY(2)</td>
<td>- - 1</td>
<td>Ordinate value for bottom limit of service volume graph (feet).</td>
</tr>
<tr>
<td>JJ</td>
<td>- -</td>
<td>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 not read in.</td>
</tr>
<tr>
<td>ACHT</td>
<td>- - 4</td>
<td>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.</td>
</tr>
<tr>
<td>DEHT</td>
<td>- - 5</td>
<td>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.</td>
</tr>
<tr>
<td>PR</td>
<td>- - 6</td>
<td>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.</td>
</tr>
</tbody>
</table>

* If the undesired facility has different parameters in the DOVERU and SRVOLM programs, a second set of cards 2, 3 (and if necessary, 4) follow the first set in DOVERU and in the SRVOLM program, another set 2 and 3 follow the last PR or signal ratio card (6).
Initialize by reading in TABLES (sec. B.4.2) and setting up constants

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

Read input parameters (table 7, fig. 22) and convert all distance and heights to kilometers, and all angles to radian.

Compute other necessary parameters not given such as facility horizon parameters (fig. 14), and print parameter sheet (fig. 5).

Call DEFRAC (sec. B.4.1) to obtain diffraction lines (sec. A.4.3).

Call ALOS (sec. B.4.1) to obtain values for plotting in the line-of-sight region (sec. A.4.2).

Beginning of loop for beyond-horizon distance points.

Call SCATTER (sec. B.4.1) to calculate forward scatter attenuation (sec. A.4.4). Compare this with defraction attenuation, and select the appropriate value via (144).

If the "instantaneous" time availability option is used (table 1), long-term variability obtained using ZD (sec. B.4.1) is combined with short-term variability from YK (sec. B.4.1) by using CONLUT (sec. B.4.1). Otherwise long-term variability is obtained.

Attenuation values, including atmospheric absorption (sec. A.4.5) are combined with variability, values of power density obtained via (7) and stored for plotting.

End of loop for beyond-the-horizon distance values.

Call PLTGRPH (sec. B.4.1) to set up graph and plot points.

Loop back for new set of parameters.

If no new parameter, program ends.

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(*1H1)
6 FORMAT(2X*INPUT*21X*WORKING VALUE*1)
7 FORMAT(12F6.0*12+2F6.0*313*312*F6.0*11)
8 FORMAT(2A8*2F6.0*F4.0*3F6.0*212F5.0*F4.0*12)
12 FORMAT(1X*F5.1)
50 FORMAT(7F7.0*1X)
71 FORMAT(*14F5.1)
106 FORMAT(*X* DML IS LESS THAN ZERO. ABORTING RUN *)
118 FORMAT(1F5.3*7F5.2*)
110 FORMAT(*1AR)
505 FORMAT(*1F7.4*)

C FORMAT STATEMENTS FOR PARAMETER SHEET AND WORK SHEET

700 FORMAT(*PARAMETERS FOR ITS PROPAGATION MODEL*1A8*32X*AB+2X*A
4X RUN*1/
701 FORMAT(32X*REQUIRED OR FIXED*/132X*----------*1/15X*AIR
12RAFT ALTITUDE:*F8.0* FT ABOVE MSL*)
702 FORMAT(15X*FACILITY ANTENNA HEIGHT:*F7.1* FT ABOVE SITE SURFACE
*)
703 FORMAT(*F0.1*FREQUENCY:*F6.0* MHz*)
704 FORMAT(24X*ECIFICATION OPTIONAL*/29X*----------*1/4/15X*ABOSORPTION:
OXYGEN:*F7.5* M/CM2/7X*WATER VAPOR:*F9.5
4*F8.0* MHz*)
705 FORMAT(15X*EFFECTIVE ALTITUDE CORRECTION FACTOR:*F6.0* FT* A2
5X/15X*EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL:*F7.0* F
5F*13X*EQUIVALENT ELECTRICALLY RADIATED POWER:*F6.1* DBW*1/
5X*FACILITY ANTENNA TYP* *F5A1*)
706 FORMAT(20X*CIVIL AIRCRAFT DIAMETER:*F5.0* FT*25X*HEIGHT:*F5.0
6*FT ABOVE SITF SURFACE*1/25X*SURFACE*2AB *)
707 FORMAT(2X*POLARIZATION*1/32)
708 FORMAT(15X*HORIZONTAL DISTANCE:*F7.2* MI FROM FACILITY*
4X*AZ/20X*ELEVATION ANGLE:*13X*/12*12* DEG/SEC ABOVE
*HORIZONTAL*12*20X*HEIGHT:*F6.0* FT ABOVE MSL* A2)
709 FORMAT(15X*MINIMUM RAINY MEAN SURFACE REFRACTIVITY:*1/20X*F3.0*
*1/15X* AT SL LEVEL:*F3.0* N UNITS*)
710 FORMAT(15X*THRESHOLD ELEVATION AT SITE:*F6.0* FT ABOVE MSL*/20X*
*PARAMETER:*F5.0* FT*72X*TYPE*:12A1)
711 FORMAT(15X*PLUT LIMITS:*25A*----------*15X*AVAILA POWER:
*F5.0* F*13X*DBW*17X*DISTANCE:*F5.0* *F5.0* N M*)
712 FORMAT(*X*F0.1*PLOW TOO HIGH IONOSPHERIC EFFECTS*1/25X*MAY
9 BE IMPORTANT*)
713 FORMAT(*X*F0.1*F0.1*PLOW TOO HIGH IONOSPHERIC EFFECTS*1/25X*MAY
3 BE IMPORTANT*)
714 FORMAT(20X*IN ADDITION: SURFACE WAVE CONTRIBUTIONS SHOULD*1/15X* *
*RF CONSIDERED*)
715 FORMAT(20X*RF CONSIDERED*)
716 FORMAT(*RF CONSIDERED*)
717 FORMAT(*RF CONSIDERED*)
718 FORMAT(*RF CONSIDERED*)
719 FORMAT(*RF CONSIDERED*)
720 FORMAT(*RF CONSIDERED*)
721 FORMAT(*RF CONSIDERED*)
722 FORMAT(*RF CONSIDERED*)
723 FORMAT(*RF CONSIDERED*)
724 FORMAT(*RF CONSIDERED*)
725 FORMAT(*RF CONSIDERED*)
DIMENSION CFK(3),CMK(3),CFM(3),CMKM(3),CFKM(3)
DIMENSION ACM(101),AND(101),SCM(101),AD(101),RW(101)
DIMENSION PACM(101),V(101),SC(127)
DIMENSION MTE(5),DOM(6)
DIMENSION VF(101),SV(101)
DIMENSION PH(35),Q(35),A(35),PAQ(101),PQK(50),PQC(50)
DIMENSION TY(3),V(3),Y(3),Z(3),X(3),F(3)
DIMENSION RE(3),AD(35),BD(35),ALM(12)
COMMON/RHTC/NSQH,HCQH,QH,CHQH,CHQHQH,CHQH,CHQHQH
COMMON/EGAP/IVLP(IVLP),XTX
COMMON/PARAM/HF,HR,HRD,TL,DR,T,GF,T,GT,TR,TRK,GMG,
XGAW

NOT REPRODUCIBLE
CUMMON (COMMON NAME) IN ARTIFICIAL INLUSION.

COMMON (COMMON NAME) IN ARTIFICIAL INLUSION.

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COMMON (COMMON NAME) IN ARTIFICIAL INLUSION.

COMMON (COMMON NAME) IN ARTIFICIAL INLUSION.

COMM...
PRINT 709, DHEI,PDH,HPF1,EIRP,(FAT(I,IFA),I=1,5)
IF(INC1>0) GO TO 789
IF(INC2>0) GO TO 789

C --------------COUNTERPOISE PARAMETERS CONVERTED-----------

NOC=1
DCW=DC1*CFK(IK)  $ HCW=HC1*CFK(IK)
PRINT 706+DC1+HC1+CCCI(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.9) ICAR=1
HC=HT-FTS-HCW
788 CONTINUE
PRINT 777, (POI(I,IPL),I=1,2)

C -----HORIZON AND INITIAL TAKE-OFF ANGLE COMPUTATIONS-----

PDS=PTS+PHS+PAS(1)
IF(KD=LF,1) GO TO 755
HLT=HT+CFK(IK)  $ DLT=DHOI*CMK(IK)
HLS=HLT-HT
DG=IDG+$ AMN=1MM+$ SEC=ISEC
TET=RAD((DG1+((SEC/60)+AMN)/60,1))  $ ATET=ABS(TET)
TATET=TAN(TET)
IF(KE,GT.0) GO TO 782
IF(DLT,LT.20) GO TO 741
779 IF(KE1,LT.0) PRINT 780
750 IF(TET.LT.0) PRINT 752
975 IF(DLT,LT.0) PRINT 752
750 CONTINUE

PRT=PTS+DHOI*PTS+MN*ISEC+PTS+HHOI+PHS
773 CONTINUE

C -----------------------------------------------

PRINT 709, ENO
IF(1B) GO TO 762
PRINT 778

763 PRINT 710, SUR+DHSI*(TSC(I,KSC),I=1,1)
PRINT 729+(VYD(I,KK),I=1,5)
PRINT 776, PCON
PRINT 724, PAS(2)
IF(DMAX.GT.1000) DMAX=1000
770 IF(ICAR,GT.0) PRINT 800

C -----------------------------------------------

PRINT 4
PRINT 747, IDT,IXT,OMD
PRINT 5  S  PRINT 6
PRINT VARFOR+ADENT+ADNT
PRINT 731+HAI+H2
PRINT 732+HFT+HFS
PRINT 733+FREK
PRINT 734+AOI+GAP+PXH
PRINT 735,AWI*GAM+PXH
PRINT 736+DHEI+EUR+PDH
PRINT 737+EIRP+PIRP
PRINT 738,IFA+(FAT(I,IFA),I=1,5)
IF(NOC,LT.1) GO TO 754
PRINT 779, DC1+DCW
PRINT 740, MCI+HCW
PRINT 741, ICC1+ICCI(I,ICC),I=1,2
754 CONTINUE
PRINT 5
PRINT 742+HFRI+HTE
IF(FGT.160.) GO TO 304
GO1=+0.21*SINF(5.22*ALOG10(F/200.1))1+1.28
GO9=+0.18*SINF(5.22*ALOG10(F/200.1))1+1.23
306 CONTINUE
PRINT 728+H2+HAC+HRP+HRE
PRINT 743+IPL+(POL(1+1PL)+1=1+2)
PRINT 745+PD5+MHOI+DLT
PRINT 746+PTS+IGM+IMN+ISEC+TET
PRINT 747+PHS+HHOT+HLT
PRINT 748+ENO+ENS
PRINT 726+EARF+EFRT
PRINT 749+SURT+ETS
PRINT 750+DSM+DH
PRINT 751+KSC+(TSCI+KSC)+1=1+2
IF(GLR) GO TO 764
PRINT 785
765 PRINT 775+PDCON
PRINT 779+(VYD(1+KK)+1=1+5)
PRINT 774+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.*CUBERT(F(CUBTR)
DSL=0.50+DSD
ALAM=2.97925+F
PRINT 4 $ CALL PAGE(0)
THREX=3.9*ALOG10(FREK)
ICF=0
DSL=DSL+DSL
AFP=32.5*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=DNM*CMK(IK)
IF(DNM*F.0) GO TO 107
D+DML $ TWEND=20.*ALOG10(D) $ ALFS=AFP+TWEND
HTP+HRT
TRE=THRT-HR)/DLR-(DLR/(2.*EFRT))
TRE=ATANF(TRE)
TATES=T(RE+HR)/DRP-(DRP/(2.*EFRT))
TAMES=ATANF(TAMES)
IF(HTP+HR)+LE.0) 15+14
15 DHRT=DLR+DLT $ GO TO 13
14 DHRT=DLT+DLT+SQRT((2*EFRT)(HLT-1-1-1-1-1-1-1))
13 CONTINUE
HTD=HT $ HRD=HR $ HLD=HLT
CALL DFFRAC
GVD=Gain(TET) $ GDD=20.*ALOG10(GVD)
SMD=INT(DNM/1.1)+1. $ AMD=AWD+SWP
AD=AR+2.5
UZR=AMD/SWP
PRH=-AMD-GDD) $ WRH=10.*G(PPRH.*1)
Z=ALOG10(WRH)-2.*
C-------------------------------PRINT STATEMENTS------------------------
PRINT 772
PRINT 767+HRE+HRE+DLT+DLR+ENS+EFRT+FREK+ALAM+FET+TER
PRINT 773

NOT REPRODUCIBLE
PRINT 768, HT, HR + DH, AED, SLP, DLST, DLR, DNM, ALFS, AMD, DZ, WRH
PRINT 761, PR, AMD, SMP, ZH
PRINT 5, CALL PAGE(6)

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

C ---------------------------------- BEYOND THE HORIZON CALCULATIONS ---------------------
KFD = 0
DO 900 NSP = 1 + 5
MZS = MTH(NSP)
IF(MZS <= E0) GO TO 907
DO 901 MS = 1 + MZS
D = SPD * CMK(IK), DNM = SPD
IF(IDGT, DRP) GO TO 17
DLR = DLT
HLR = HLT
TATER = ((HLR - HR) / DLR) - (DLR / (2. * EFRTH))
TER = ATANF(TATER)
19 CONTINUE
IF(KFD <= 140) GO TO 41
40 KS = 0
KS = 1
ACD(KS) = ARD
AND(KS) = DML
AMOD = DMOD
EC1 = HLT - EFRTH
EC2 = HREEFRTH
EC2 = HLT - HRP + EFRTH
CALL SORD(EC1, EC2, DLT, TET + RO1, RW1)
CALL SORB(EC2, EC3, EFRTH, DLR + TER + RO2 + RW2)
REO = RO1 + RO2
REW = RW1 + RW2
AA = GA0 * RO1 + GAW * RW
REW(1) = RFW
40 CONTINUE
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(IDGT, DRP) GO TO 44
DLR = DLT
HLR = HLT
TATER = ((HLR - HR) / DLR) - (DLR / (2. * EFRTH))
TER = ATANF(TATER)
45 CONTINUE
CALL SCATTER
SCT(KS) = ALSC - ALFS
AAD(KS) = AA
REW(KS) = REW
IF(SCT(KS) <= LT + 20.) GO TO 31
KR = KR + 1
IF(KR <= LF + 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 <= 0) GO TO 49
IF(SSP > 0) 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 KC = 1, KP
D = AND(KG)

96
DNM=D*KNNIKI S SPD=DNM
TWEND=20.*ALOG10(D) S ALFS=AFP+TWEND
ATT=ACD(KG)
AA=AAD(KG) SREW=RW(KG) S THETA=TET+TER+(D/EFTH)
ASSIGN 36 TO KT
GO TO 200
36 CONTINUE
43 CONTINUE
SPD=DNM $MZS=6$ $KFD=1$ $GO TO 37
48 IF(SC(T(KP))GE=ACD(KP)) GO TO 33
ACD(KP)=SC(T(KP))
SLP=(ACD(KP)-ARD)/(AND(KP)-DML)
AED=ACD(KP)-AND(KP)*SLP
ASSIGN 35 TO KT
DD=AND(KP)
DNM=D*KNNIKI S SPD=DNM
TWEND=20.*ALOG10(D) S ALFS=AFP+TWEND
ATT=ATD(SPDP0)
AMOD=CMOD
AA=AAD(KG) SREW=RW(KG) S THETA=TET+TER+(D/EFTH)
GO TO 200
35 CONTINUE
34 CONTINUE
AMOD=OMOD
ASSIGN 37 TO KT
ATD=ATD(SLP*D)
TWEND=20.*ALOG10(D) S ALFS=AFP+TWEND
IF(D*GT*HRP) GO TO 24
HLR=HLT
DLR=D-DLT S TATER=((HLT-HR)/(DLR-(DLR/(2.*EFTH)))
TERM=ATAN(TATER)
29 CONTINUE
CALL SCATTER
ATS=ATS+ALFS
IF(ATS.LE.ATD) GO TO 46
ATT=ATT+D S THETA=TET+TER+(D/EFTH) $GO TO 200
46 ATT=ATS $KFD=2 S AMOD=SMOD $GO TO 200
42 CONTINUE
AMOD=SMOD
TWEND=20.*ALOG10(D) S ALFS=AFP+TWEND
CALL SCATTER
AT=ALS=ALFS S ATT=ATS S ASSIGN 37 TO KT
200 CONTINUE
C----------------------LONG-TERM POWER FADING-----------------------
IF(D*LE=DSL1) 311,312
311 OEEU(1340.*D)/DSL1 $GO TO 313
312 OEFa230.+D-DSL1 $GO TO 313
313 CALL VZ(DFE=DG1*G9+AD) NCT=NCT+1
PFS=IPRD-ALFS PL=ATTS
AL1=A1+PL+AD(13) $AY=A10-ALIM
IF(AY.LT.0) AY=0.
DO 11 K=1,35
BD(K)=PL+AD(K)-AY
11 CONTINUE
97
DO 12 K=1,12
ALLM=ALLM(K)
IF(BD(K).GT.ALLM) BD(K)=ALLM
12 CONTINUE

---VALUES PUT INTO PLOTTING ARRAY---
BX(NCT+6)=BX(NCT+7)=DX(NCT,8)=DNM
BX(NCT+1)=BX(NCT+2)=DX(NCT,4)=DNM
IF(KK9GT.1) GO TO 20

23 PGS=PFS+GDD
BY(NCT+1)=PGS
BY(NCT+3)=PGS+BD(2)-AA
BY(NCT+5)=PGS+BD(3)-AA
BY(NCT+7)=PGS+BD(4)-AA
BY(NCT+9)=PGS+BD(6)-AA
PFY(NCT+1)=PGS+BD(2)-AA
PFY(NCT+3)=PGS+BD(10)-AA
PFY(NCT+5)=PGS+BD(12)-AA

PRINT STATEMENTS-------------------------------
PRINT 't60tDNM9(BY(NCToLZ),LZs1,8)(PFY(NCToMW
X ,AMOD
CALL PAGE(1)

C------------------PLOTTING OF GRAPH-------------
SX(1)=DMAX $ SX(2)=DMIN $ SY(1)=PMAX $ SY(2)=PMIN
DO 904 K=1,8
904 NUKK=NCT
NS(1)=9 $ NS(2)=NS(3)-NS(4)=1
LUD=0 $ LL=0
NS(5)=NS(6)=1
IG=0 $ IG=1
CALL PLTGRPH
GO TO 100

C----------------------TROPOSPHERIC MULTIPATH------
17 TER=TES $ DLR=DRP $ HLR=HRP $ TATER=TATES $ GO TO 19

20 DO 21 I=1,135
QA(I)=RD(I)-PL
POA(I)=P(I)
21 CONTINUE
IF(THETA.GE.TPTH) GO TO 26
IF(THETA.LE.E0) GO TO 27
BK=NA(THETA,TPTH,TLTH,TPK,TDHNK)
26 CONTINUE
CALL YIKK(BK,PQA,OK)
CALL CONLUT(QA,OK,PQA,35+1,0,PQC,0C)
DO 22 I=1,135
22 BD(I)=QC(I)+PL
GO TO 23
24 TER=TES $ DLR=DRP $ HLR=HRP $ TATE=N=TATES $ GO TO 25
26 BK=TPK $ GO TO 28
27 BK=RDHK $ GO TO 28
44 TER=TES $ DLR=DRP $ HLR=HRP $ TATER=N=TATES $ GO TO 45

--------------------CALCULATION OF RAY BENDING--------------------

50 PDH=PAS(2)
HP2=H2-HRP $ HP1=H1-HRP
DUM=0.0 $ ZER=0.0 $ GLIM=-1.56
QNS=329, $ QHC=HP1 $ QHA=HP2 $ QHS=HRP
CALL RAYTRAC(DUM)
RY=TRACRAY(ZER)
DSS=QDD
QNS=ENS $ QHC*ZER $ QHA=HP2 $ QHS=HRP
CALL RAYTRAC(DUM)
RY=TRACRAY(ZER)
DLSR=QDD $ TSL2=DLSR/EFRTM
IF(TSL2.LE.1) GO TO 53
R2E=EFRTM/COSF(TSL2)
HRE=R2E-EFRTM
54 IF(HRE+HP2) HRE=HP2
HR=HRE-HRP $ EAC=H2-HRP-HRE
DHE1=EAC*CKM(1K)
JK=-1.
GO TO 55
53 HRE=(DLSR*DLZR)/(2.*EFRTM) $ GO TO 54

56 CALL ASORD(F,AOI,AWI)
PXH=PAS(2) $ GO TO 57
58 TEM=TEM+(DLT/EFRTM)
IF(KD.LE.1) TEM=0.0
QNS=ENS $ QHC=HLT-HRP $ QHA=HP2 $ QHS=HRP
RY=TRACRAY(ZER)
DLSR=QDD $ TSL2=DLSR/EFRTM
IF(TSL2.LE.1) DLT=I.DLT*1.*DLST
IF(DLT.GT.(3**DLSfL')
OHO=DLT*CKN(1K)
GO TO 759
730 TRM=I.1*(4/LST1*(TRM-(4.*HTE))
 IF(TET*GT,TWDG) TET=TWDG
 CALL RAM weapon(TET*IDG*IMN*STC)
 ISEC=XINTF(ISEC)
 PTS=PAS(2) $ TATE=TANF(TET)
 GO TO 758
780 XTRM=SQRTF(EFRTM*EFRTM*TATET*TATET+I2.*EFRTM*HLT(I))
 YTM=-EFRTM*TATET $ DLT=YTRM-XTRM
 IF((DLT.LE.0.1) DLT=YTRM-XTRM
PDS=PAS(2)
DHOI=DLT* CKM(1K) $ GO TO 783
780 TATE=(HLTS/DLT)-(DLT/I2.*EFRTM) $ TET=ATANF(TATE)
PTS=PAS(2)
784 CALL RADEMS(TET*IDG*IMN*SEC)

NOT REPRODUCIBLE
ISEC=INTF(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=ATAN(TATET)
HLT=HRP $ HHOI=HLT*CKM(IK) $ DH=0.
GO TO 784

769 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, FOTETA, 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 $T_{DULCS}$ (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. 1), interpolate from array for undesired facility for corresponding isotropic power values, call COUT (sec. B.4.1) to combine distributions via (13), and store points for plotting.

Loop back for new station separation value

Call PLTN (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 20. Block diagram for station separation program, DOPE.AU.
C

PROGRAManova

C R O N I L E  F O R  M O D E L  A N G  73

3 FORMAT(1X,1X,3F10.4)
4 FORMAT(1X)
5 FORMAT(I1)
6 FORMAT(A2)
7 FORMAT(I10)
8 FORMAT(A2)
9 FORMAT(A2)
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IXT=ITIMFDAY(IXT)
TT(1)=ADENT(1) $ TT(2)=ADENT(2) $ CMAX=SMAX
TT(3)=TT(4)=TT(5)=ADNT(1)=ADNT(2)=ADNT(3)=PAS

--- 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(50,99,OAT,H1A)
ENCODE(8329TG,H2A)
IF(IS.GT.1) GO TO 15
NK=43-(21*IA/2)
ENCODE(779,VARFOR,NK)

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

16 CALL POWSUB

--- PRINT STATEMENTS ---
PRINT 700011(PFY(LA+LB=1,6)+LA=1,NCT)
PRINT 5
MCK=NCT/2 $ CALL PAGE(MCK)

--- CALCULATION OF D/U RATIOS ---
S=SMIN
DA(1)=DV5 $ DA(2)=D50 $ DA(3)=D95
JCT=0

--- PRINT STATEMENTS ---
PRINT 781 $ PRINT 792 $ CALL PAGE(2)

--- INPUT OF CARD TYPE 2 ---
READ 7,1,KH,F1,F2,F3,F4,F5,F6,F7,F8,F9,F10,F11,F12,F13,F14,F15,F16,F17,F18,F19,F20
X1=M*SUC1,55+K*K+K,F1R+F,F1R

--- INPUT OF CARD TYPE 3 ---
ADNT(1)=ADNT(2)=ADNT(3)=PAS

--- IF IA GREATER THAN 16 INPUT OF CARD TYPE 4 ---
IF(IA.GT.16) READ 110,ADNT
NK=43-(21*IA/2)
ENCODE(48,779,VARFOR,NK)

--- OBTAINING ISOTROPIC POWER ARRAY FOR UNDESIRED STATION ---
CALL POWSUB

--- PRINT STATEMENTS ---
PRINT 90011(PFY(LA+LB=1,6)+LA=1,NCT)
PRINT 5
MCK=NCT/2 $ CALL PAGE(MCK)

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

--- CALCULATION OF D/U RATIOS ---
28 S=SMIN
DA(1)=DV5 $ DA(2)=D50 $ DA(3)=D95
JCT=0

--- PRINT STATEMENTS ---
PRINT 781 $ PRINT 792 $ CALL PAGE(2)

--- IF IA GREATER THAN 16 INPUT OF CARD TYPE 4 ---
IF(IA.GT.16) READ 110,ADNT
NK=43-(21*IA/2)
ENCODE(48,779,VARFOR,NK)

--- OBTAINING ISOTROPIC POWER ARRAY FOR UNDESIRED STATION ---
CALL POWSUB

--- PRINT STATEMENTS ---
PRINT 90011(PFY(LA+LB=1,6)+LA=1,NCT)
PRINT 5
MCK=NCT/2 $ CALL PAGE(MCK)

--- PRINT STATEMENTS ---
PRINT 781 $ PRINT 792 $ CALL PAGE(2)

--- IF IA GREATER THAN 16 INPUT OF CARD TYPE 4 ---
IF(IA.GT.16) READ 110,ADNT
NK=43-(21*IA/2)
ENCODE(48,779,VARFOR,NK)

--- OBTAINING ISOTROPIC POWER ARRAY FOR UNDESIRED STATION ---
CALL POWSUB

--- PRINT STATEMENTS ---
PRINT 90011(PFY(LA+LB=1,6)+LA=1,NCT)
PRINT 5
MCK=NCT/2 $ CALL PAGE(MCK)

--- PRINT STATEMENTS ---
PRINT 781 $ PRINT 792 $ CALL PAGE(2)
```plaintext
JCT=JCT+1
BX(JCT)=BX(JCT+1)=BX(JCT+2)=BX(JCT+3)=BX(JCT+4)=S
S
UFS=PFY(I+2) $ UPW=PFY(I+3) $ UV5=PFY(I+4) $ USO=PFY(I+5) $ U5=PFY(I+6)
23 BY(JCT+1)+DFS-UFS $ REFV=DPW-UPW $ DB(1)=UV5 $ DB(2)=U50 $ DB(3)=U95
CALL CONLUTIDA+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+5+DD+DU+DF+UFS+DPW+UPW+(BY(JCT,K)+K=1+4)
CALL PAGE(1)
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
S
NS(1)=9 $ NS(2)=NS(3)=NS(4)=1
LYD=0 $ LUD=+1 $ LL=4
IG=IG+1
CALL PLTNU
GO TO 100
C
LOOPING BACK TO START FOR NEW SET OF PARAMETERS------
15 NK=43-(19+A1/2)
ENCODF(A8+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

NOT REPRODUCIBLE
```
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, FOTETA, 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.
Figure 27. Block diagram for service volume program SRVOLM.
PROGRAM SRVVOLM

C ROUTINE FOR MODEL AUG 73

4 FORMAT(* PROGRAM IS FINISHED *)
4 FORMAT(1H)
5 FORMAT(1H)
5 FORMAT(2A8+2F8.0+F4.0+3F6.0+28X+12)
7 FORMAT(12F6.0+2I12+3F6.0+12+2F6.0+12+F6.0+12+2F6.0+12+2F6.0+12+2F6.0+12+2F6.0+12+2F6.0+12)
8 FORMAT(F4.0+2F6.0+F5.0+12)
9 FORMAT(12+F4.0+2I12+3F4.0+F6.0+2F6.0+12)
12 FORMAT(F4.0+F4.X)
50 FORMAT(F7.0+1X)
71 FORMAT(F5.0+2F5.0)
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(3X*PARAMETERS FOR SERVICE VOLUME CURVES*+/34X*ITS MODEL*+X8+30X+8+2X+AB* RUN*+/
701 FORMAT(3X*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*+/27X*WATER VAPOR*+/F9.5+4/29X*DB/KM*+/27X*
705 FORMAT(15X*EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL*+/F7.0+
5/15X*EQUIVALENT ISOTROPICALLY RADIATED POWER*+/F6.1+DB
5W*+/15X*FACILITY ANTENNA TYPE*+/S5A8)
706 FORMAT(20X*COUNTERPOISE DIAMETER*+/F5.0*FT*+/25X*HEIGHT*+/F5.0+6*FT ABOVE SITE SURFACE*+/25X*SURFACE*+/2AB)
707 FORMAT(20X*POLARIZATION*+/2A8)
708 FORMAT(15X*HORIZON OBSTRUCTION DISTANCE*+/F7.2*N MI FROM FACILITY*8/24X+/-12+/-12+/-12+/-12*DEG/MIN/SEC ABOVE
8 HORIZONTAL*+/24X+/-12+/-12+/-12+/-12*FT ABOVE MSL*+/2A8)
709 FORMAT(15X*MINIMUM MONTHLY MEAN SURFACE REFRACIIVITY*/+/20X*F3.0,9
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(F5.0+15F5.0+1)
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+1A1))
715 FORMAT(20X*ANTENNA TOO HIGH RAY BENDING OVERESTIMATED*/+/
716 FORMAT(20X*ANTENNA TOO LOW SURFACE WAVE SHOULD BE**+/25X**CONSIDERED*)
717 FORMAT(20X*FREQUENCY TOO LOW, IONOSPHERIC EFFECTS MAY BE*/+/25X**IMPORTANT*)
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**UNRELIABLE**BLE*)
724 FORMAT(15X*A2*COMPUTED VALUE*)
725 FORMAT(20X*TYPE*+/2A8*A1)
726 FORMAT(15X*F9.0+N MI*)
728 FORMAT(29X*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*13(F3.0+A1)+20X*13(F3.0+A1)
732 FORMAT(12X*H:FIT TO SURFACE*+/F8.4+KM*)

108
733 FORMAT(12X,'FREQUENCY', P5*0t' MHZ
734 FORMAT(12X,' ACO)', F9.5, '/KM
735 FORMAT(12X,* A(W)', F9*906/KM *9F'S.1,
736 FORMAT(12X,*,EIRP *79F9*906W *9F'S.1,
737 FORMAT(12X,*F ANT *6X12* 2X+5A8
738 FORMAT(12X,* D/U RATIOS IN DB:*10(F3*0,AlI))
739 FORMAT(12X,*EIRP *79F9*906W *9F'S.1,
740 FORMAT(12X,*H(FR)*F8.0, ' FT ABOVE REFLECTION*F8.4,* KM*)
741 FORMAT(12X,*,POLARIZATION*12*1OX.2A8)
742 FORMAT(12X,*COUNTERPOISE*,12,1OX.2A8)
743 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
744 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
745 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
746 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
747 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
748 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
749 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
750 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
751 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
752 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
753 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
754 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
755 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
756 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
757 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
758 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
759 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
760 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
761 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
762 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
763 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
764 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
765 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
766 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
767 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
768 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
769 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
770 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
771 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
772 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
773 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
774 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
775 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
776 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
777 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
778 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
779 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
780 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
781 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
782 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
783 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
784 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
785 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
786 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
787 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
788 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
789 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
790 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
791 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
792 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
793 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
794 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
795 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
796 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
797 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
798 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
799 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
800 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
801 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
802 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
803 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
804 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
805 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
806 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
807 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
808 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
809 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
810 FORMAT(12X,*SURFACE REFLECTION LOBING: DETERMINES MEDIAN*)
811 FORMAT(12X,*SURFACE REFLECTION LOBING: CONTRIBUTES TO VARIABILITY *x*)
COMMON  PDY(125,5), DE(125), DRU(125,4), DED(125), MU(25), PM(25,1), PY(25)
X=PX(25,4), PXD(25,4), A(25), B(25), MCT(25)
COMMON  PLV/UD/LYD/SXH, SHY, TG/SX(12), SY(12), TT(6), XC, YC, AAT
COMMON  RYTC/ONS/QHC, OHA, OQD
COMMON  DALT/TALD(2O), TAFL(4,7,20)
COMMON  VV/VF(36,17)
COMMON  PLV/PLW/LUDLYDSHXSHYTGSX(2htSY(2), TT(6), XC, YCAAT
COMMON  PLV/PLW/LUDLYDSHXSHYTGSX(2htSY(2), TT(6), XC, YCAAT
COMMON  SCAT/P, HT(11), RE, AL(11), XG, WIC, WDM, MAX, MZRIKEACH2, ICCHFCPRHDSLIEIRP,
XOG19QG99KKoZHPRDHV, ILB
COMMON  SCAT/P, HT(11), RE, AL(11), XG, WIC, WDM, MAX, MZRIKEACH2, ICCHFCPRHDSLIEIRP,
XOG19QG99KKoZHPRDHV, ILB
DATA  (ONID=8H AUG 73
DATA  (CFK=0.001, 1.00030489, 0.0003048)
DATA  (CMK=1. .1.60914491, .852)
DATA  (CFM=199*3048, 3048)
DATA  (CKM=1000, 3280, 839895, 3280, 839895)
DATA  (CKN=1, 6213711922, 5399568334)
DATA  (POL=8H HORIZON93HTALoSH VERTICA91HL98H CIRCULAolklR)
DATA  IFAT=1OH ISOTROPIC, 3I1H ) 94H XH ) 39H 8-LOOP ARRAY (COSINE VERTICAL PATTERN) 39H 8-LOOP ARRAY (COSINE VERTICAL PATTERN) 39H 1017II IIOR II (COSINE VERTICAL PATTERN) 1H +
DATA  (TSC=16H SEA WATER 16H GOOD GROUND 16H AVERAGE GROUND 16H POOR GROUND 16H FRESH WATER 16H CONCRETE 16H METALLIC )
DATA  (PAS=2H 1H)
DATA  (VYD=33H FOR HOURS MEDIAN LEVELS EXCEEDED 33H FOR INSTANTANEOUS LEVELS EXCEEDED)
DATA  (TCC=16H SEA WATER 16H GOOD GROUND 16H AVERAGE GROUND 16H POOR GROUND 16H FRESH WATER 16H CONCRETE 16H METALLIC )
DATA  (PAS=1H)
DATA  (CM=12)
DATA  (LP=921, 1, 3)
DATA  (AP=8H FREE SP 8H 5 = 8H 50 = 8H 95 = )
FNA(FX, FA, FB) = (FX-FB) / (FA-FB) + FD
FNB(FRX, FRA, FRB) = (FRX-FRB) / (FRA-FRB)
FNC(FFX, FCC, FFD) = (FFX*(FCC-FFD) + FFD)
IDT=I8DATE(IDX)
DP(1)=.01  $ DP(2)=.50  $ DP(3)=.95
IG=0  $ JF=0  $ 20*0.0000001  $ ERTH=6370.
RAD=0174529252  $ DEG=.57+2977951  $ TWDG=12*RAD
C
PRE-PROGRAM INPUT OF TABLES
READ 108, (TAV(I), (TAH(J), (J=1.7), I*1, 175)
READ 71, (TALD(I), (TAFL(I), (J=1.7), I*1, 12), K=1, 20)
READ 71, (DUMB, (TAFL(I), (J=1, 7), I*3, 4), K=1, 20)
READ 505, (VF(1), (J=1, 36), J=1, 3)
READ 505, (VF(1), (J=1, 36), J=4, 17)
C
----- PROGRAM START WITH CARD 1 -----  
100 READ 9, IS, DXSM, SLH, LE, SA, XC, SY, TC
IF (IS=LE) GO TO 451
IX=ITMEDAY(I1X)
DO 200 J=1, IS
C
----- START OF LOOP FOR TWO FACILITIES"
C ---------- INPUT OF CARD 2 -----------
READ 7,1*HFI,IFA,IPL,SUR*HPFI,DHSI,KSC,DCI,HC1,ICC,DMO1,HNO1,1DG
XIMN*ISEC,KE,KD,EIRP,1LB
C ---------- INPUT OF CARD 3 -----------
READ 8*ADNT,ADNT,ENG,A01,AWI,F*IA
TT(1)=ADENT(1) $ TT(2)=ADENT(2) $ TT(6)=PAS(1)
TT(3)=ADENT(1) $ TT(4)=ADENT(2) $ TT(9)=ADENT(3)
CMAX=OMAX
IF(J*GT*1) GO TO 15
NK=63-(IA*1A)/2
ENCIDE(4)799*VARFOR*NK
14 PRINT 4
C ---------- START OF PARAMETER SHEET ----------
HFS=HFI*CFK(I) % FREQ=F
PRINT 700*OMD*IDT*IXT
PRINT VARFOR*ADNT,ADNT
PRINT 5
PRINT 701
IF(J*GT*1) GO TO 820
C ---------- INPUT OF CARDS OF AIRCRAFT ALTITUDES --------
READ 711*(ACH0(I),I=1*LH)
C ---------- INPUT OF ALTITUDE CORRECTION FACTORS IF SPECIFIED ---
IF(J*GT*0) READ 711*(DEHT(I),I=1*LH)
C ---------- INPUT OF CARDS OF D/U RATIOS -----------
READ 711*(PR(I),I=1*LE)
820 LL=LH-1
IF(LL*GT*24) GO TO 769
IF(LL*GE17) GO TO 768
IF(LL*GE10) GO TO 767
IF(LL*GT*3) GO TO 766
PRINT 714,(ACH0(I),CM=1(LL),ACH0(LH))
770 LL=LE-1
IF(LE*GT*23) GO TO 721
IF(LE*GT*19) GO TO 720
PRINT 716,(PR(I),CM=1(LL),PR(LE))
777 PRINT 702*HFI
IF(HFI*LT*0) GO TO 825
IF(HFI*GT*O000) PRINT 715
IF(HFI*LT*1.5) PRINT 716
PRINT 703*FREK
IF(LE*GT*100) GO TO 805
806 IF(LE*GT*27) GO TO 100
IF(LE*GT*5000) PRINT 718
IF(LE*GT*17000) GO TO 807
808 IF(LE*GT*100000) GO TO 100
ALAM=2997925/F
PRINT 752*5
PRINT 5
IF(A01*LT*0.0) GO TO 56
PXH=PAS(1)
47 GAO=GAI % GAI=GAI
PRINT 704*GAI*PXH,GAI,PXH
IF(SUR*GT*15000) ICAR=1
IF(SUR*LT*0.0) GO TO 530
841 IRP=EIRP
FTS=SUR*FFK(I)
HRP=HPF*CFK(I)
IF(FTS*LT*0) FTS=0.
IF(DHSI*LT*0) DHSI=0.
DM=DHSI*CFK(I)
IF(ENG*LT*250.0 OR ENG*GT*400.0) GO TO 801
802 EN5=CNO*EXPF*0.105*HRP).
NOT REPRODUCIBLE
IF(ENS*LE*250.) GO TO 803
804 EFRI=ERTH/(1.+4.649*EXPFI+0.575*ENS))
FART=EFTH*CKM(IK)
HT=HF*ETS $ HT=HT
IF(HPR*GT.HT) GO TO 825
HTE=HTE-HPR $ DLT=GQRTF(2.*EFRI*HT)
HFRI=HTE*CKM(IK)
PRINT 705;HPRI*FIRP*(FAT(I;IFAI);I=1,5)
IF(DCI*LE*2.0) GO TO 789
IF(ICC*LE*2.0) GO TO 789
C -------------------COUNTERPOSE 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((DCW*GT.1524) ICAR=1
IF((HCW*GT.HFS) GO TO 825
HFC=HTE-ETS=HCW
788 CONTINUE
PRINT 707;POL(I=1,IPL);I=1,2)
C ------HORIZON AND INITIAL TAKE-OFF ANGLE COMPUTATIONS------
PDS=PTS=PHS=PAS(1)
IF(KDLE.1) GO TO 755
HLT=HHOI*CFK(IK) $ DLT=DHOI*CMK(IK)
DLT=HLT-HT
DG=1DG $ AMN=IMN $ SEC=SEC
TET=RAO(DG+(1SEC/60.+AMN)/60.) $ ATET=ABSFTET
TATET=TANFTET
IF(KF.EQ.3) GO TO 752
IF(DLT.LE.1) GO TO 781
759 IF(KF.EQ.3) GO TO 752
758 IF(TET.LT.T0) GO TO 752
HLT=DLT*TATET $ HHOI=HLT*CFK(IK)
PHS=PAS(2)
783 CONTINUE
IF(DLT.LE.1) OR DLT.GT.(3.1*DLST) PRINT 809
IF(TET+GT.20059951) PRINT 810
IF(HHOI.GT.15000.) ICAR=1
PRINT 708;DHOI+PDS=IDG*1MN+ISEC+PTS=HHOI+PHS
C ---------------------------------------------------------------
PRINT 725;ITYD(I=KD)+I=1,3)
PRINT 709;ENS+END
IF(IFL*GT.0) GO TO 762
PRINT 778
763 PRINT 710;SUB+DHSI+TSIC(I=K5)+I=1,2)
PRINT 799;VYDF(I=KK)+I=1,5)
PRINT 74;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 VARP+FADEN+ADMT
PRINT 701;S
PRINT 792=HFI+HFS
PRINT 794=F+FRK
PRINT 734;AOI+GAP;PXH
PRINT 735;AWI+GAP;PXH
PRINT 777;EIRP+EIRP
PRINT 738;IFA*(FAT(I;IFAI)+I=1,5)
IF (NOCC-LT-1) GO TO 754
PRINT 739+DCI+DCW
PRINT 740+HCI+HCW
PRINT 741+ICC+CCCI(I+ICC)+1=I+2
754 CONTINUE
PRINT 5
PRINT 742+HPRI+HIF
PRINT 743+IPL*(POL(I+IPL)+I=I+2)
771 PRINT 745+PDS+DHI+DLT
PRINT 746+PT5+10G-I+MN+ISEC+TET
PRINT 747+PHS+HHOI+HLT
PRINT 748+TN+ANE
PRINT 750+AM+DE
PRINT 751+KSC+TSC(I+KSC)+I=I+2
IF (ILB.GT.0) GO TO 764
PRINT 785
765 PRINT 729+VYDI(I+KK)+I=I+3
PRINT 724+PAS(2)
IF (ICAR.GT.O) PRINT 800
C--------------------- END OF PRELIMINARY PRINTING---------------------
IF (IS.LT.1) GO TO 201
QAW(J)+GAW $ QCW(J)+DCW $ QHW(J)+HCW $ JIC(J)+ICC
QHPR(J)+HP $ QERP(J)+ERP $ JKK(J)+KK $ JLB(J)+LB
QHT(J)+HT $ QHLT(J)+HHT $ QHFS(J)+HFS $ QDM(J)+DM
QHTE(J)+HTE $ QDLT(J)+DLT $ QENS(J)+ENS $ QFK(J)+FK
QET(J)+EFTH $ QTE(J)+TET $ JKD(J)+KD $ QAO(J)+AO
QDLST(J)+DLST $ JPL(J)+IPL $ JKSC(J)+KSC $ JFA(J)+FA
QHC+HFC
C--------------------- END OF LOOP FOR TWO FACILITIES---------------------
201 PRINT 6
CALL PAGE(-1)
ENCODE+J+7G1 $ IFILE=0
MH+1
DO 60 LD=1,LH
HAI+ACTH(LD)
L+HAI+CFK(IK)
IFILE+IFILE+1
IF (IS.LT.1) GO TO 202
206 CONTINUE
IF (IJ+LT-1) GO TO 63
ALAM+3.097925/F
PDH+PAS(1)
EAC=DEHT(LD)+CFK(IK)
HR=F=HAC
HRE+HR+HP $ DLSR*SQRT(F2)*HR*EFTH)
MAS+H2-ETS $ HRS+HR-ETS $ HRE+HR-HP
IF (HRE.GE.50) DLSR*EFTH*ACOS(F(EFTH/(EFTH+HRE))
DSD+3.*SQRT(F2000.*HTE)+3.*SQRT(F2000.*HRE)
64 CONTINUE
C---------------------PRINT STATEMENTS---------------------
PRINT 796+ HAI+DEHT(LD)+PDH $ CALL PAGE(1)
C
C---------------------OBTAINING ISOTROPIC POWER ARRAY---------------------
CALL PWSR
C---------------------PRINT STATEMENTS---------------------
PRINT 900+(JPFYLA+LB)+LB=16)+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:NCD
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

-------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=5-DE(N)  $ IF(DU.LE.0) GO TO 25
DO 20 I=1:NCT
20 CONTINUE

I=1

22 IF(IS.LE.1) I=2
L=I-1

DRAT=FN(B(DU+PFY(I+1),PFY(I+1)))
UF5=FN(DRAT+PFY(I+1),PFY(I+1))  $ UPW=FN(DRAT+PFY(I+1),PFY(I+1))

UV5=FN(DRAT+PFY(I+1),PFY(I+1))  $ U50=FN(DRAT+PFY(I+1),PFY(I+1))

U95=FN(DRAT+PFY(I+1),PFY(I+1))  $ GO TO 28

21 UPW=PFY(I+1)  $ UPW=PFY(I+1)  $ UV5=PFY(I+1)
U50=PFY(I+1)  $ U95=PFY(I+1)

28 CONTINUE

JCT=JCT+1

26 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),(DRI(JCT,K)), K=1:4

73 CONTINUE

END FILE 2

PRINT 5  $ CALL PAGE(1)

C

---------END of Aircraft Altitude Loop---------

114
DO 40 M=1*LE
LYD=0 $ LUD*1
IG=IG+1
ENCOD{8*32*AAT) PR(M)

C------------------------PLT## OF GRAP#------------------------

CALL PLTVOL

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

DO 41 JL=1*4
DO 65 J=1*JH
MUI(J)=WMI(J)=0
65 CONTINUE
IF IFL=0
RE#I N 2
DO 62 L=1*JH
IF IFL=FL#1
READ (2) KFILE,BCHT*LCT
IF(KFILE#NE=IFILE) G## 100
DO 74 J=1*LCT
READ (2) DED(IE),(1(DRI,J)+J5)) JG=1*4)
74 CONTINUE
SK1FILE 2
JCT=LCT
DO 42 JK=1+JCT
JW=JK-1
IF(PR(M)##GE#DRU(JK,JL) AND PR(M)##LE#DRU(JM,JL)) G## 43
IF(PR(M)##LE#DRU(JK,JL) AND PR(M)##GE#DRU(JM,JL)) G## 44
42 CONTINUE
62 CONTINUE
61 LS=LPM(JL)
DO 66 KC=1*4
J=0
DO 67 J=1*JH
IF(MO(J)##LT#KC) G## 67
IF(PY(I)##GT#SY(I1) OR PX(J)##LT#SX(I)) G## 67
IF(PY(I)##LT#SY(I2) OR PX(J)##GT#SX(J)) G## 67
J=J+1 $ B(J)=PY(I) $ A(J)=PX(I)
67 CONTINUE
IF(JL##6*6)
C-------------------------PRINT STATEMENTS--------------------
68 PRINT 713,PR(M),APC1(JL)!(AINN)##BINN)##NN=1*J
PRINT 5
NPG#(J/6)+2 $ CALL PAGE(NPG)

C-------------------------END OF GRAPH-------------------------
115
C--------LOOPING BACK TO START FOR NEW SET OF PARAMETERS---------

43 MUI(1)=MUI(1)+1
  KC=MUI(1)
  IF(KC.GT.4) GO TO 61
  XRDFNAPR(M)+DRU(JM+JL)+DED(JM)+DED(JK)
  PY(I)=ACT(I) S PXU(I+KC)=XRDFNAPR(M)+DRU(JM+JL)+DED(JM)+DED(JK)
  GO TO 42
44 MDI(1)=MDI(1)+1
  KC=MDI(1)
  IF(KC.GT.4) GO TO 61
  XRDFNAPR(M)+DRU(JM+JL)+DED(JM)+DED(JK)
  PY(I)=ACT(I) S PXD(I+KC)=XRDFNAPR(M)+DRU(JM+JL)+DED(JM)+DED(JK)
  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-(120+IA)/2
  ENCODE(48.798, VARFOR)NK
  GO TO 14
53 HRE=DLRSR*DLRSR/EFRTH
  GO TO 54
56 CALL ASORP(FAOIPAWI) PXRUPAS(2)
  GO TO 57
C ----------------------- CALCULATION OF RAY BENDING-------------------
63 HP2=H2-HRP
  DUM=0.0 S ZER=0.0 S QLIM=-1.56
  QNS=329. S QHC=HP1 S QHA=HP2 S QHS=HRP
  CALL RAYTRAC(DUM)
  RY=TRACRAYQ(1)
  DSO=QOD
  QNS=ENS S QHC=ZER S QHA=HP2 S QHS=HRP
  CALL RAYTRAC(DUM)
  RY=TRACRAYQ(1)
  DLSR=QOD S TSL2=DLRSR/EFRTH
  IF(TSL2.LE.1) GO TO 53
  R2E=EFRTH/COS(TSL2)
  HRE=R2E-EFRTH
54 IF(HRE.GT.HP2) HRE=HP2
  HR=HRE+HRP
  EAC=HP2-HRP-HRE
  HAS=H2-ETS S HRS=HR-ETS
  DEHTL(IP)=EAC+C4(J)
  PDH=PGAS(2) S GO TO 64
107 PRINT 106 S GO TO 100
C ------------------------TWO FACILITY CALCULATIONS-----------------
202 J=1 $ ASSIGN 203 TO JC
205 HTE=QHT(J) $ DLT=QLT(J) $ ENS=ENS(J) $ F=OFK(J)
  EFRTH=QETF(J) S TET=QET(J) S KJD=J+K(J) S GAE=QAOJ(J)
  GAW=QAW(J) S DCD=QCW(J) $ HCD=QCH(J) $ ICA=J(J)
  HRP=QHRP(J) S EIRP=QERP(J) S KK=J(J) S LBJ=LBJ(J)
  HT=QHT(J) S HLT=QLT(J) S HFS=QHFS(J) S DJH=QDMH(J)
  DLST=QLST(J) S IP=JPl(J) S KSC=J+K(J) S IFA=JFA(J)
  FREK=F
  GO TO 206
------------P A R T O F P A R A M E T E R S H E E T P R I N T I N G------------
710 PRINT 774,1,IPR111,CMII1*1,LL1*PR1LE1 $ GO TO 777
711 PRINT 774,1,IPR111,CMII1*1,LL1*PR1LE1 $ GO TO 777
712 PRINT 770 $ GO TO 763
713 PRINT 784 $ GO TO 765
714 PRINT 772,1,ACH111,CMII1*1,LL1*ACH111H $ GO TO 770
715 PRINT 774,1,ACH111,CMII1*1,LL1*ACH111H $ GO TO 770
716 PRINT 776,1,ACH111,CMII1*1,LL1*ACH111H $ GO TO 770
717 PRINT 778,1,ACH111,CMII1*1,LL1*ACH111H $ GO TO 770
718 PRINT 779,1,ACH111,CMII1*1,LL1*ACH111H $ GO TO 770
719 PRINT 780,1,ACH111,CMII1*1,LL1*ACH111H $ GO TO 770

C ---------------HORIZON PARAMETER CALCULATIONS------------------
781 HE=MAX1F(HTE*+005)
DLT=DLST*EXP(-07*SQRTF(DH/HE))
PDS=PAS(2)
IF(DLT<LT,1#DLST) DLT=1#DLST
IF(DLT<TL,1#DLST) DLT=3#DLST
HOI=DLT*CKN(K1)
GO TO 749
782 TRM=1#DLT(DLST/DLT)-1)
TET=(1#DLT#TRM-4#HTE)
IF(TET<UT#HWD1) TET=WGD
CALL RADMSITE(TET,IMN+SEC)
ISFC*INTF(SEC)
PIS=PAS(2)
TATF=TAN(TET)
GO TO 748
783 TRM*DLT*CKN(K1) $ GO TO 783
784 TATF=(HLS/DLT-IDLT/2#HFRH) $ TET=TAN(TATF)
PIS=PAS(2)
CALL RADMSITE(TET,IMN+SEC)
ISFC*INTF(SEC) $ GO TO 783
785 -------------------SMOOTH EARTH PARAMETERS----------------------
786 DLT=DLST $ HOI=DLT*CKN(K1)
TATF=-HTE/DLT-(DLT/12#HFRH) $ TET=TAN(TATF)
HLT=HRP $ HOI=HLY*CKN(K1) $ DH=0.
GO TO 786
787 HLT=DLT#TET $ IDLT#DLT(DLT/2#HFRH) $ GO TO 753
788 HFC=0. $ GO TO 788
789 HC=0. $ END=301 $ GO TO RN2
790 TK=250. $ ICAR=1 $ GO TO 804
791 ICAR=1 $ PRINT 717 $ GO TO 806
792 ICAR=1 $ PRINT 719 $ GO TO 808
793 PRINT RN2 $ GO TO 100
794 ICAR=1 $ HCI=0. $ GO TO 829
795 ICAR=1 $ SUR=0. $ GO TO 831

C -------------------TERMINATION OF PROGRAM-----------------------
851 CONTINUE
CALL CRTPLT(0,0,0,0,20)
PRINT 4
PRINT 2
CALL EXIT
END

NOT REPRODUCIBLE
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(H)
760 FORMAT(1X*F7*2+12F8*1+F6*1+2F5*1+2F6*1)
766 FORMAT(1X*D N M I FREE SPACE 50% 5% 95% 90% 99% 
X 99.9% 99.9% 99.99% 1% 1% 10% PL AA AY
X K DEE)
DIMENSION XCONW5),NTM(5)
DIMENSION CFK(3),CMK(3),CNM(3),CKN(3)
DIMENSION GLD(8),DI(200),D2(200),D3(200)
DIMENSION HTX(2),ZT(2),TEA(2),DA(2),HR(2)
DIMENSION SL(24)
DIMENSION SPGRD(3)
DIMENSION RE(3),RO(35),VD(35)
DIMENSION ALM(3),AN(35)
DIMENSION P(35),QC(50),QA(50),PQA(50),POK(50),QOK(50),PO(50)
DIMENSION YV(5),SV(10)
COMMON/EGAP/IPqLi4,IDT, IXT
COMMON/PARAM/HTE*IIREDDLTDLRENSEFRTHFREKALAM,1ETTER,KDGAO,
XGAW
COMMON/DIFFR/HIT ihil, DH,AD, DLP,LST, DLSR, IPL, KSC, ITL, HR, AWD, SWP
COMMON/SIGHT/DCM, DCMAX, DML, DZR, PIK, EAC, II2, ICC, IIDC, PRH, DSL, PIRP,
XGKI, QGK, PTY, 200, 4, KI, ZH, DHT, ILB
COMMON/PLTD/LUD, LLL, NUM(8), MS(18), PX(2), SY(2), TT(6), XC, YC, BX(200), B
XY(200), LYD, AAT, TG
COMMON/SPLIT/L1, L2, NX(140), Y1(140), D6(140), XS(55), XD(55), XR(55), YS
X(55), YD(55), YR(55), L3S(25), ZD(25), ZR(25)
DATA (CFK=0.01+0.005+0.00004, 0.003048)
DATA (P1[1]=1.131)=0.0001+0.0002+0.0005+0.001+0.002+0.005+0.001
X(002)+0.005+0.01+0.02+0.05+0.10+0.15+0.20+0.30+0.40+0.50+0.60+0.70+0.80+0.90+1.00
X(15)+98+99+995+998+999+9995+9998+9999+99995+99998+99999
DATA (CMK=0.1+0.1)+609344+1.852)
DATA (CFM=0.006, 0.0248)
DATA (CKM=1000+3280+839898+3280+839895)
DATA (CKN=+621371122+5399568034)
DATA (XCON=1.5+10+25+0.1
DATA (NTM=10+19+30+10+0)
DATA (GLD=0.0+1.2+3.4+5+7+5+1)
DATA (ALM=6.2+6.15+6.08+6.0+5.95+5.88+5.8+5.65+5.35+5.00+) 
X(4.5+3.7)
DATA (SPGRD=0.0+0.06+1)
DATA (SLD=2.5+7.1+1.2+1.5+1.7+2+2.5+3+3.5+4+5+6+7+8+10)
X(20+15+10+8+5+4+3+2+1+0)
COMPLEX AT1,AT2

119
FNA(FX*FA*FB*FC*FD)=((FX-FB)*(FC-FD)/(FA-FB)+FD
BSP1=3183098862
RAD=0174329252 $ DEG=57.29577951 $ TWDG=12.0*RAD
ALIM=3.
P1=3*14192654 $ TWP1=6.283185307
F=FREK
P2=1.570796327 $ CPI2=1.56
DKAX=DMAX*CMK(IK)
ALFP=32.45+20.0*ALOG10(FREK)
ALTR2=ALAM/2.
ASP2=0.25 $ ASPB=0.25
ASPc=ASPA*ASPB*(6.0-E-8)*F
TWPILA=TWP/ALAM
DTRO=ALAM/6.
ERTH=6370.
AD=ERTH $ EFNF=ERTH
PKL=3+(3.*P1)/(ALAM))
NCT=0
NOCT=0
PRINT 766
.CALL PAGE(1)
.IF (XCC=GT.0) NOC=1
CDR=20.95841232*F
.IF (NOC.LE.0) GO TO 502
RCW=DCW*5 $ BTC=ATANF(HFC/RCW)
ABTC=ABS(FBTC) $ RIC=RCW/COSF(BTC) $ SQRT=SQRTF(2.*RIC/ALAM)
MD=HFC-RCW $ TWHC=2.*HFC
503 CONTINUE
L1=L2=N=0
TWH=2.*HTE
C ------SETTING UP OF TABLE OF SI, DELTA R AND DISTANCE------
LE=7 $ IF(ILB.GT.0) LE=11
DO 61 K=1.LE
IF(LK.LE.4) GO TO 120
LB=13-LK $ GRD=FLOATF(LD) $ 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.*OLSTI))
IF(SI.GT.P12) SI=P12
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.L10
GRD=FLOATF(LA)
DO 151 LG=1.L4
GO TO (155,156,157,158), LG
155 GRD=4.*GRD-1./4. $ GO TO 159
156 GRD=GRD $ GO TO 159
157 GRD=(4.*GRD+1./4. $ GO TO 159
158 GRD=(7.*GRD+1./2. $ GO TO 159
159 APDR=GRD*ALAM
.IF(APDR.GT.TWHT) GO TO 162
SI=ASINF(APDR/TWHT)
.IF(SI.GT.P12) SI=P12
ASSIGN 152 TO KR $ GO TO 66
120
152 L1=L1+1 $ XS(L1)=S1 $ XD(L1)=DR $ XR(L1)=D
   SI=SQRTF(APDR/(2.*DLS1))
   ASSIGN 153 TO KR $ GO TO 66
153 L2=L2+1 $ YS(L2)=S1 $ 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)=S1 $ ZD(L3)=DR $ ZR(L3)=D
67 CONTINUE
   SI=P12
   L3=L3+1 $ ZS(L3)=S1 $ ZD(L3)=WHT $ 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=FLOATFLA) $ DR=ALAM/GRD $ LD=L+1
   IF(DR.GT.WHT) GO TO 25
86 CONTINUE
   D=DINTER(DR)
   IF(DR.GT.DML) GO TO 70
   LR=LR+1 $ D1(LR)=D
70 CONTINUE
25 CONTINUE
   IF(DR.LE.0) GO TO 163
   DO 172 LA=1,10
   GND=FLOATFLA)
   DO 173 LG=1,4
      GO TO (155,166,167,168), 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.WHT) GO TO 163
   D=DINTER(DR)
   IF(DR.GT.DML) GO TO 172
   LR=LR+1 $ D1(LR)=D
173 CONTINUE
172 CONTINUE
163 CONTINUE
   IF(LR.LT.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+D3+D+D1+L)
160 LR=0
   SPD=1
   DO 800 NSP=1,5
   MZS=NTM(NSP)
   IF(MZS.LE.0) GO TO 107
   DO 881 MNS=MZS
   D=SPD*CMFD(MNS)
   IF(DR.GT.DML) GO TO 107
   LR=LR+1 $ D3(LR)=D
803 SPD=SPD+XCON(NSP)

121
801 CONTINUE
SPD*SPD=XC\(N\)SP
NPP=NSP+1
IF(NPP*GT.51 GO TO 107
IF(XCON[NPP]*EQ.01 GO TO 107
IF(NPP*ED.01 GO TO 107
IXD=INTF(SPD/XCON[NPP])
SPD=XC\(N\)P*FLOATF(I\(XD\)1)+XCON[NPP]
800 CONTINUE
107 CONTINUE
CALL TSHE\(D\)1+LS+D3+LR+D2+LX) IF(NO\(C\)+LÉ.o) GO TO 75
C  ----------------CALCULATION OF COUNTERPOISE STRATIGIC POINTS------
LZ=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\(O\)+DML) GO TO 604
LR=LR+1
D3(LR)=D
604 IF(LK+LT=9) GO TO 600
603 CONTINUE
600 CONTINUE
60 CONTINUE
CIM=D3(LR) #$ CCIM=D3(1)
DO 69 I=1+LR
LV=LR+1+1
69 D(1)+D3(LV)
CALL TSHE\(D\)1+LR+D2+LX+D3+LK)
134 DO 129 LV=1+LK
ICPT=0
13 SI=INTERL3(LV)
ASSIGN 28 TO KR
C  -----------------RAY OPTICS GEOMETRY-------------------
66 CSSI=COSF(SI)
SNSI=SINF(SI) $ SI=SQ=SNSI*SNSI
AK=SINFE1 $ ZE=1./AK=1. $ AKE=1+1.(Z2+CSSI)
AIFT=AK *AK $ DHE=EACR(AKE-1)/AK=1.
HTX(1)+HTE $ HL+H2+DHE $ HTX(2)+HL+HRP $ HCL+HL+CKM(1K)
IF(I\(C\)PT+GT=0) GO TO 77
A=AIFT
78 CONTINUE
DO 62 LC=1+2
Z(LC)=Z(LC)+ACOSF(A*CSSI/Z(LC)) $ TEA(LC)=ACOSF(A*CSSI/Z(LC))
DAI(LC)+Z(LC)+SINF(TEA(LC))
IF(SI+GT=56) GO TO 63
HPR(LC)=DAI(LC)+TANF(SI)
62 CONTINUE
6 DX=A\(R\)SF(Z(Z1)+Z(Z2))
IF(SI+GT+PT2) GO TO 64
AFA=TANF(HPR2)-HPR(1))/DA(1)+DA(2))
RO=DA(1)+DA(2)*COSF(AFA) $ R12=DA(1)+DA(2)+CSSI
IF(R0+L1+DTX) R0+DTX

122
CA=AF-A-TEA(1) TH=TEA(1)+TEA(2)
DR=4.0*HPR(1)+HPR(2)/(R0+R12)
BA=CA
CD=CA+DE
D=AF+TH
IF(DLT0D) D=0.
DMD*DECM(I)
GO TO KR(65+20+123+132+133+124+40+152+153).

C

20 IF(DLT0.01) GO TO 129
IF(DGT*0.02) GO TO 111
ALFS=AF+26*ALOG10(R0)
PF5=PIR-PALFS
GOD=GAIN(1A)
GOD=20.0*ALOG10(GOD)
Z=Z(2)-Z(1)
Z4=(Z(1)*COSF(BA))/Z(2)
IF(DH+LE+0.0) GO TO 42
DHD=DHD-(1.0*.0.02*EXP(-0.02*D))*100.
44 CALL SOR(Z(1)+Z(2);;AR0+BA)
AA=GAO+RE(1)+GAW+RE(2)
51 IF(II+GT+0.0 AND SILE=SILIM) GO TO 35
IF(DRGEALA) GO TO 34
IF(DRLE=DTR) GO TO 26
FDR=(1.0-0.0*EXP(-0.02*D))*100.
43 CONTINUE
CALL RECC(SIFPKS;1,DHDRCPIC)
GAM=(TEA(1)+SIL)
GAMD=GA+DE
GOD=GAIN(GA)
RD=G0*0.0
REG=REG
IF(NOCLE+0.0) GO TO 500

C

CALCULATION OF COUNTERPOISE CONTRIBUTION----
TEG=ABTC-ABSF(SI+TEA(1)) TEG=ABSF(TEG)
VFGD=2.*SINF(TEG)*5.0*SQVT
IF(ABSF(GA)+LT+ABTC) VFGD=-VFGD
CALL FRENEL(VFGD,FPGD+PHIG)
REG=REG+FPGD
RDG=RDG*FPGD
TRM3=PH1+P12*VFGD*FPGD
IF(DLTD+LIM+ORD+GT+CCIM) GO TO 146
SIC=CA
TEC=ABSF(BTC-CA) DARC=2.*HFC*SINF(1)
SITI=SIC GOC=GAIN(SITI)
VFCP=2.*SINF(TEC)*5.0*SQVT
IF(ABSFC+GT+ABTC) VFCP=-VFCP
CALL FRENEL(VFCP,FPCP+PHIC)
CALL RECC(SIFIC+F1+1C+T1; DHD+RC+PICC+RDC)
RCL=RC+GOC
REC=RCL+FPCP
EXPC=(TWPILA+DARC)+PICC+PHIC+P12*VFCP*VFCP11
ATRM=REC+ORC*EXP) BTRM=REC+SINF*EXP)
ATI=CMPLX(ATRM+BTRM)
147 CONTINUE

C

CALCULATION OF LOBING CONTRIBUTION-----
IF(S11L+GT+CCIM) GO TO 135
EXPG=(TWPILA+DARC)+PICC+TRM
ATRM=REC+ORC*EXP) BTRM=REC+SINF*EXP)

123
NOT REPRODUCIBLE
C  -----------------SUMMATION OF TERMS-------------------
136  AT2=CMPLX(ATRM*BTRM)
    WRL=CMPLX(QOD*AT1+AT2)  $ WR=WRL+WR+0.001
    PR=10.*ALOG10(WR)
    IF(D.LE.DZR) GO TO 148
    IF(LV.EQ.1) GO TO 148
    PL=MAX(PWL+DZR*PR+PZ)
    WE=10.*PL
149 CONTINUE

C  -----------------LONG-TERM POWER FADEING-----------------

    PL=PL+GD1
    IF(D.LE.0.) GO TO 38
    IF(D.LE.DSL1) GO TO 301

301  DEE=(130.*D1/D1L) $ GO TO 303
302  DE=130.*D1L $ GO TO 303
303  CALL VZD(DEE+1G1+1G9+AD1)
    IF(CA.LE.0.) GO TO 32
    IF(CA*GE.1.) GO TO 33
    FTH=5.-5.SP1*ATANG1(2.0*A1OG10(32.*CA))
    IF(FTH.LE.0.+0.) GO TO 33
52  AL10=PL+(AD1+131+1FTH) $ AY=AL10-ALIM
    IF(AY.LE.0.) AY=0.
53  IF(ILB+GT.0.*AND.S1*LE.*SILIM) GO TO 22
    DO 31 K=1,35
        VD(K)=AD1*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

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

NCT=NCT+1
B1X=NCT*111,11B1X(NCT*2)=B1X(NCT+4)=D1M
B1X(NCT*5)=B1X(NCT+6)=B1X(NCT+7)=B1X(NCT+8)=D1M
    IF(KK*GT.1) GO TO 20
23  PGS=PGS+GD1
    BY(NCT*1)=PGS
    BY(NCT+3)=PGS+BD1(12)-AA $ BY(NCT+2)=PGS+BD1(18)-AA
    BY(NCT+5)=PGS+BD1(23)-AA $ BY(NCT+4)=PGS+BD1(24)-AA
    BY(NCT+7)=PGS+BD1(29)-AA $ BY(NCT+6)=PGS+BD1(26)-AA
    PFSY(NCT+1)=PGS+BD1(14)-AA $ PFSY(NCT+2)=PGS+BD1(11)-AA
    PFSY(NCT+3)=PGS+BD1(10)-AA $ PFSY(NCT+4)=PGS+BD1(13)-AA
    PRINT 760,D1M*BY(NCT+LZ)+LZ=81,181,11PFSY(NCT+M1)+M1=1.4,1,PL+AA*AY*1X+DEE
    CALL PAGE11
129 CONTINUE
111 CONTINUE
    NUI=1 $ 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)=P1(I)
    QA(I)=BD1(I)-PL
30  CONTINUE
    IF(FAY*LE.0.) GO TO 15
IF(AY.GE.6.0) GO TO 16
FAV=(1.1+10.9*COSF(AY/6.1*PI))/2.*
17 CONTINUE
RSP=FDR+FAY
IF(RE(2).LE.0.0) GO TO 46
RKL=10.*ALOOG10(ASPDKRE(2)**9)
ACK=FDRSP(RK) $ WA=10.*ACK
46 RST=(RSP*RSP)+(RG**RG)+WA
IF(RST+LE.0.0) GO TO 37
BK =+10.*ALOOG10(RST)
IF(BK+LT.-40.0) BK=-40.
47 CALL YIKK(BK,PQK,K)
RDH*BK
CALL CONLIQA,QQA,35++,+0,,PQC,QC)
DO 27 I=1,35
27 RN(I)=QCI+PL
GO TO 29
37 BK=-40. $ GO TO 47
C----------------------- LOSING MODE-----------------------
22 AY=0.
TLIM=20.*ALOG10(GOD+RLG+RLC)
BLIM =8.0
DO 36 K=1,35
VD(K)=AD(K)*FTH ' BD(K)=PL+VD(K)-AA
IF(BD(K).GT.LIM) BD(K)=LIM
IF(BD(K).LT.BLIM) RN(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 HPRLC=HTX(LC) $ GO TO 62
45 WA=0.001 $ GO TO 46
64 AFA=51 $ RO=HTX(2)-HTX(1) $ R12=HTX(1)+HTX(2) $ GO TO 68
75 DO 76 LX=1,35
76 DLK(LK)=1,2(LK)
LK=LX
4O TO 134
77 HTX(1)=HFC $ HTX(2)=HTX(2)-HD1 $ AAEF+HD1
ICT=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 SL=0. $ DR=0. $ DLST=DLSR $ GO TO 123
135 ATRM=0. $ BTRM=0. $ GO TO 136
164 D11=D21 $ L5=1 $ SILIM=0. $ GO TO 160
500 TRM=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=SQT=0. $ HDI=HTE $ GO TO 503
601 GND=GLDILK) $ GO TO 602
END
125
Subroutine ASORP is used in the calculation of atmospheric absorption (sec. A.4.5) to obtain surface absorption rates, $\gamma_{00W}$ 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 $\gamma_{00W}$ values for frequencies up to 100 GHz.

```fortran
SUBROUTINE ASORP(FX, AO, AW)
C ROUTINE FOR MODEL AUG 73
C
19 FORMAT(5X*FREQUENCY IS TOO HIGH FOR ABSORPTION TABLE USING VALUE
XS FOR 100 GHz*)
DIMENSION ZX(13), ZW(51), FZ(51)
+ (ZX=10., 50., 100., 150., 200., 250., 300., 350., 400., 450., 500., 550., 600., 650., 700., 750., 800., 850.,
+ 900.),
+ 64., 65., 66., 67., 68., 69., 70., 71., 72., 73., 74., 75., 76., 77., 78., 79., 80., 81., 82., 83., 84.,
+ 85., 86., 87., 88., 89., 90., 91., 92., 93., 94., 95., 96., 97., 98., 99., 100.),
TEN=10.*
F=F*FX
IF(F>10.) GO TO 20
DO 10 I=1, 13
IF(F<FX(I)) GO TO 11
10 CONTINUE
GO TO 20
11 IF(I.EQ.1) I=2
12 L=1-
13 A=ALOG10(F)
B=ALOG10(FZ(I))
C=ALOG10(FZ(L))
R=ALOG10(FZ(I)/FZ(L))
D=ALOG10(FX(I))
F=ALOG10(ZX(I))
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=2.214 AO=ZW(I) RETURN
21 Aw=.0000 RETURN
END
```

126
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

L=0.5 SUBROUTINE FOR NOVERU
C ROUTINE FOR MODEL AUG 73

5 FORMAT(1H1)

DIMENSION XCON(5), NIM(5)
DIMENSION CKF(3), CMK(3), CFM(3), CKN(3)
DIMENSION GLD(18), D1(200), D2(200), D3(200)
DIMENSION HX(12), Y1(12), EPA(2), DAI(2), HPR(2)
DIMENSION SGRD(10)
DIMENSION RE(2), BD(5), VD(35)
DIMENSION ALM(17), AM(15)
DIMENSION Q3(50), QA(50), PQ(50), PK(50), PQ(50)
DIMENSION YV1(15), SV1(15)

COMMON/CTPR/HRT, DHT, AED, SLP, DLS, IPL, KSC, HLT, HRT, AWD, SWP
COMMON/PANOUT/NTC, PFY(200)
COMMON/PARAM/ITE, RED, DLT, DLR, CNS, EFRTH, 2REK, ALAM, TET, TET, KD, GAO, KGAM

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,

COMMON/SIGHT/DCW, KCW, DM1, DML, JZ1, JZ2, HAC, H2, ICC, HFC, PRH, DML, PRH, PIRF,
DKAX=DMA*CMK(IK)
ALP=32.45+20.*ALOG10(FREK)
ALAM=ALAM/2*
ASP=0.25 $ ASPB=0.25
ASPC=ASP*ASPB*26.6*E-9*F
TWPILA=TWPILA/ALAM
DTRO=ALAM/6*
ERTH=6370*
AO=ERTH $ EFN=EFRTH
PKL=((3.*P1)/(ALAM))
NCT=0
NOC=0
IF(IACC*GT.0) NOC=1
CNR=20.05841232*F
IF(NOC.LE.0) GO TO 502
RCW=DCT*5 $ BTC=ATANF(HEC/RCW)
ABTC=ABSF(BTC) $ RIC=RCW/COSF(BTC) $ SQTF=SQRTF(2.*RIC/ALAM)
HD=HFC*HEC $ TWHC=2.*HEC
CONTINUE
L1=L2=N=0
TWHC=2.*HTE

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

LE=12 $ IF(I1B*GT.0) LE=11
DO 61 K=L+1
IF(LK.LT.4) GO TO 120
LB=L=LK $ GRD=FLOATF(LB) $ APDR=ALAM/GRD
61 CONTINUE

101 IF(APDR.LE.0.) GO TO 122
SI=ATN1F(APDR/TWHT)
ASSIGN 65 TO KR $ GO TO 66
65 L1=L1+1 $ X5(L1)=SI $ XD(L1)=DR
XR(L1)=DR
IF(APDR.LE.0.) GO TO 122
SI=SQRTF(APDR/(2.*DLST))
IF(SI.GT.P12) SI=P12
ASSIGN 123 TO KR $ GO TO 66
123 L2=L2+1 $ Y5(L2)=SI $ YD(L2)=DR
YR(L2)=DR
61 CONTINUE

71 CONTINUE

151 CONTINUE

71 CONTINUE

IF(I1B*LE.0) GO TO 162
DO 150 LA=1+10
GND=FLOATF(LA)
DO 151 LC=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=ATN1F(APDR/TWHT)
IF(SI.GT.P12) SI=P12
ASSIGN 153 TO KR $ GO TO 66
153 L2=L2+1 $ Y5(L2)=SI $ YD(L2)=DR $ YR(L2)=D
YR(L2)=D
71 CONTINUE

161 CONTINUE
160 CONTINUE
162 L3=0
DO 67 (LK=1+24
SI=SINF(LK)*RAD

128
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 $ GRO=FLOAT(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 $ DI(LR)=D
70 CONTINUE
25 CONTINUE
IF(LR*LT*0) GO TO 163
DO 172 LA=1,10
GND=FLOAT(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=(12*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 $ DI(LR)=D
172 CONTINUE
163 CONTINUE
153 CONTINUE
IF(LR=154+164
154 DI(LR)= $ SILINT=SINTER(D)
DO 11 LA=1,LR
LV=LR+1-LA
11 D3(LA)=D1(LV)
D2(LR)=DZR
CALL TSMESH(D2+1,D3+LR+D1+L3)
160 LR=0
SPD=1
DO 80 U=1,NSP+5
MS=MTH(NSP)
IF(MS*LT*0) GO TO 107
DO 80 MS=1,MS
D=SPD*CM(K)
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=FD+0) GO TO 107
IXD=INTF(SPD/XCON(NPP))
L3=L3*XCON(NPP)+FLOAT(IXD)XCON(NPP)
800 CONTINUE
107 CONTINUE
CALL TSMESH(D1+L5+D3+LX+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
DO 603 LG=1,4
FLG=LG
GND=(1/(4.*FLK)+FLG)/4
602 APDR=GND*ALAM
IF(APDR.GT.TWHC) GO TO 29
SI=ASIN(APDR/TWHC)
ICPT=1
END 602
ASSIGN 40 TO KR $ GO TO 66
40 CONTINUE
IF(100.GT.DML) GO TO 604
LR=LR+1
DO 603 CONTINUE
603 CONTINUE
29 CONTINUE
PRINT 5 $ CALL PAGE111
CLIMUO3(LR) $ CCIMUO3(1)
DO 69 In1.LR
LV=LR+1-1
69 D1(LV)=D1(LV)+1
CALL TSMESH(D1+L5+D3+LX+L5+D2)
ICPT=ICPT+1
31 SI=SINTER(n3(LV))
ASSIGN 28 TO KR
C -----------------R AY OPTICS GEOMETRY-----------------

66 CSSI=COSF(SI)
SNSI=SINF(SI)
AKO=EFT/AD
ZE=(1./AKO)-1.
AKE=1+1/(1+1*(ZE*CSSI))
AEFT=AD*AKE
DHE=EAC*(AKE-1)/(AKO-1)
HTX(1)=HTE
HL=H2-DHE
HTX(2)=HL*HP
HCL=HL*CKMI
IF(ICPT.GT.0) GO TO 77

78 CONTINUE
DO 62 LC=1,2
Z(LC)=A+HTX(LC) $ TEA(LC)=ACOSF(A*CSSI/Z(LC))-S
DA(LC)=Z(LC)-S
IF(SI.GT.1) GO TO 63
HPR(LC)=DA(LC)-TANF(SI)
62 CONTINUE
D1=ACOSF(Z1)-Z2)
IF(SI.GT.CP2) GO TO 64
AFA=ATANF(HPR(1)*HPR(1)/DA(1)+DA(21))
RO*(DA(1)+DA(2))/COSF(AFA)
R12*(DA(1)+DA(2))/CSSI
IF(RO.LT.DTX) RO=DTX
68 CA=AFA-TEA(L1)
TH=TEA(1)+TEA(L1)
DR=HPR(1)*HPR(2)/RO+R12
BA=CA
CD=CA*DEG
D=A*FET*TH
IF(DL.TE.0) D=0
DNM=DEGC
GO TO KR(65,28,123,132,133,124,40,152,153)
C ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

10 IF(DLT=.LT.0.01) GO TO 129
   IF(DLT=.GT.DML) GO TO 111
   ALFS=ALF+PLA*ALNG10(WR)
   PRS=PRN-ALFS
   GD=GAIN(Al)
   BPD=PB*ALNG10(GD)
   Z2=Z(2,2)
   Z1=Z(1,1)+GDF(PLA)/Z2
   IF(DLT=.EQ.0.01) GO TO 42
   DMD=DMD*(1.-10.*EXP(-0.02*(D1)))#1000.
   CALL SINRIZ(1.,2.,3.,4.0,BVAR2)
   AA=GAC*RE(2)+GAW*RE(12)
   GO TO 91
91 IF(LM*GT.0.-AND.5*SI*LE*SLIM) GO TO 95
   IF(DL*GT.5) GO TO 94
   IF(DL*GT.DTRG0) GO TO 26
   FMN(1,1).EQ.10.*COS(PLK*(1.0-DR-DTRG0)))#15
   CALL PFRS(PFC,PJ2,PLW0,PPIC,PPR,11)
   GAM=TETA(1)+511  $ GAMD=GAM*DEG $ GOG*GAIN(AG)
   ROG=RO+CGG
   REC=AO
   REG=RAG
   RLC=REG
   IF(NOC+LE.0) GO TO 500

C ~~~~~~~~~CALCULATION OF COUNTERPOISE CONTRIBUTION~~~~~~~~~~~~~~~~~~~~
   TEG=ABSF-ABS(F(AL+TEA(1))) $ TEG=ABS(F(EG)
   VFGD=2.*SIN(F(ETI))#5*SOVT
   IF(FRABS(ET1)LT.ATBC) VFGD=VFGD
   CALL FRENEL(VFGD,PFGD,PHIG)
   RFD=ROG*PFGD
   RM=ROG*PFGD
   THN=PHIG(PI2*VFGD#VFGD)
   IF(DL.5*CLIM) GO TO 146
   SIG=CA
   TEC=ABS(TBC-C1) $ DARC=2.*HFC*INF(ICA)
   SIT1=SIG  $ GOC=GAIN(SIT1)
   VFCP=2.*SIN(F(TEC))#5*SOVT
   IF(FRABS(TEC)GT.ATBC) VFCP=VFCP
   CALL FRENEL(VFCP,PCP,PHIC)
   CALL RECC1SIC(F,TIC,PI1+1+DHD+RC*PICC*RDC)
   RLC=RC*GIC
   REC=RC*FCP
   EXP=1.*TPILA*DARC+PICC*PHIC*(PI2*VFCP#VFCP)
   ATM=REC*COS(F(EXPC)) $ BTRM=REC*SINF(EXPC)
   ATC=CMPLX(ATRM,BTRM)
147 CONTINUE

C ~~~~~~~~~~~CALCULATION OF LOBING CONTRIBUTION~~~~~~~~~~~~~~~~~~~~~~~~~~
   IF(S1*GT.SLIM) GO TO 135
   EXPG=1.*TPILA*OR+P1+TRM3
   ATM=REC*COS(F(EXPG)) $ BTRM=REC*SINF(EXPG)

C ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~SUMMATION OF TERMS~~~~~~~~~~~~~~~~~
140 AT2=CMPLX(ATRM+BTRM)
   WRL=WRL*G(COD+AT1+AT2) $ WRL=WRL*WRL+.0001
   PR=10.*ALNG10(WR)
   IF(DL*LE.DZS) GO TO 148
   IF(LV=EQ.1) GO TO 148
   PL=FMNA(DML*DZ2*PRH*PZ1)
   VL=10.*#PL
149 CONTINUE

NOT REPRODUCIBLE
C  -------------------LONG-TERM POWER FADE-------------------

PL=PL-PLGPI
IF(DL=LE+0) GO TO 38
IF(DL=LE+DSL1) 301,302
301 DEE=I30.*0/DSDL $ GO TO 303
302 DEE=I30.+D-DSL1 $ GO TO 303
303 CALL VZD(DEE=2O1+GO9+AD)
IF(IA=LE+0) GO TO 32
IF(IA=LE+0) GO TO 33
FTH=-5-BSP*ATANF(2O.*ALOG1O(4.*CA))
IF(FTH-LE+0) GO TO 33
IF(AY=AL10+ALIM
IF(AY=LE+0) AQ=0
53 IF(AY<GT=AD+AND5=SLE+SLIM) GO TO 22
DO 31 K=1,35
VDK=ADK#FTH-AY $ BDK=PL+VDK
31 CONTINUE
DO 50 K=1,12
ALLM=ALM(K)
IF(BD(K).GT.ALLM) BD(K)=ALLM
50 CONTINUE
74 CONTINUE

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

NCT=NCT+1
IF(KK.GT.1) GO TO 20
29 PGS=PFS+PD
PFL=PFS+PL-DD
PFY(NCT+1)=DNM $ PFY(NCT+2)=PFS $ PFY(NCT+3)=PFL
PFY(NCT+4)=BD(12)-PL $ PFY(NCT+5)=BD(18)-PL
PFY(NCT+6)=BD(24)-PL
129 CONTINUE
119 CONTINUE
RETURN

C  ----------------------RETURN FROM POWSUB----------------------

15 FAY=1 $ GO TO 17
16 FAY=0 $ GO TO 17

C  -------------------------TROPOSPHERIC Mpath-------------------------

20 DO 30 l=1,35
POA(l)=P(l)
OA(l)=AD(l)-PL
30 CONTINUE
IF(AY=LE+0) GO TO 15
IF(AY=LE+6) GO TO 16
FAY=(I+1*0+9*COSF(AY/6.*PI))/2.
17 CONTINUE
RSP=REG#FDR#FAY
IF(RE(2)+LE+0) GO TO 45
RKE=1O.*ALOG1O(ASPC(RE(2)**3))
ACK=FDASP(RK) $ WA=1O.*1*ACK
46 RST(RSP*RSP)+(RDG#RDG)+WA
IF(RST+LE+0) GO TO 37
PK=10.*ALOG10(RST)
IF(BK=LE+0) BK=-40.
47 CALL YIKK(BK#POK#PK)
RDHK=HK
CALL CONLUT(QA=OK,PQA+35+1*0#PQC,QC)
DO 27 l=1,35
27 BD(I)=QC(I)+PL
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(1H1)
DIMENSION XCON(5), NTMIS(5)
DIMENSION CFK(5), CMK(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(2)
DIMENSION SGRD(3)
DIMENSION REL(3), VD(95)
DIMENSION ALM(12), AD(95)
DIMENSION PI(35), QA(150), PK(150), QK(150), QPQ(50)
DIMENSION YV(10), SV(10)
COMMON/EGAP/IP, LN, IDT, IXT
COMMON/PAOUT/NTC, IFY(125, 6), JJ+HP1, HP2
COMMON/PARAM/HE, RE+DLT, DLR, ENS, EFRTH, FREQ, ALAM, TET, TER, KD, GAO
COMMON/DIFPR/HT, HR, DH, AED, SLP, PLS, DLST, DLST, DLST, IFL, KSC, HLT
COMMON/SIGHT/DCW, ICM, DML, DZR, IK, EAC, H2, ICC, HHF, PRH, DLI, PIRP
COMMON/SPL/L1, L2, M(140), Y(140), D6:140, X5(155), XD(155), XR(155), YS
COMMON/IDC/1, 15, 15, 15, 25, 25, 25, 25, 25, 25, 25
COMMON/PCOM/D1, D3, D4, D5, D6, D7, D8, D9, D10
DATA (CFK), 0.001, 0.003, 0.048, 0.003
DATA ((PI)), 0.01, 0.02, 0.05, 0.05, 30.0, 60.0, 30.0, 60.0, 60.0, 30.0, 60.0, 90.0
DATA (GLD), 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
DATA (SPGRD), 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
DATA (SID), 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0
DATA (SPGRD), 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
DATA (SID), 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0
DATA (ALM), 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0
DATA (SPGRD), 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
DATA (SID), 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0
DATA (ALM), 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0
DATA (SPGRD), 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
DATA (SID), 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0
DATA (ALM), 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0, 6.0
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=FLOAT(F(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=SORTF(APDR/(2*DLST))
IF(SL.GT.P12) SI=P12
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*LT.0) GO TO 162
DO 150 LA=1,10
GND=FLOAT(F(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.P12) SI=P12
ASSIGN 152 TO KR $ GO TO 66

152 L1=L1+1 $ XS(L1)=SI $ XD(L1)=DR $ XR(L1)=D
SI=SORTF(APDR/(2*DLST))
ASSIGN 153 TO KR $ GO TO 66

153 L2=L2+1 $ YS(L2)=SI $ YD(L2)=DR $ YR(L2)=D
141 CONTINUE
150 CONTINUE
162 L3=0
DO 67 LK=1,124
SI=SID(LK)*RAD
ASSIGN 125 TO KR $ GO TO 66

67 CONTINUE
SI=P12
L3=L3+1 $ ZS(L3)=SI $ ZD(L3)=DR
ZR(L3)=D

67 CONTINUE
SI=P12
L3=L3+1 $ ZS(L3)=SI $ ZD(L3)=TWHT $ ZR(L3)=0.
CALL TABLE(DUM)

C. USING TABLE TO OBTAIN STRATEGIC DISTANCE POINTS

LP=0
DO 70 LA=1,LE
IF(LA*LT.4) GO TO 88
LB=13-LA $ GRD=FLOAT(F(LB)) $ DR=ALAM/GRD $ LD=LD+1
IF(DR*GT.TWHT) GO TO 25

86 CONTINUE
DX=DINTER(DR)
IF(DR*GT.DML) GO TO 70
LP=LR+1 $ DL(LR)=D
70 CONTINUE
25 CONTINUE
IF(ILB.LF.0) GO TO 163
DO 172 LA=1,10
GND=FLOAT(LA)
DO 173 LG=14
GO TO (165+166+167+168)*LG
165 GRD=(4.*GND-1.)/4. $ GO TO 169
166 GRD=GND $ GO TO 169
167 GRD=14.*GND+1.)/4. $ GO TO 169
168 GRD=17.*GND+1.)/2. $ GO TO 169
169 DR=GRD*ALAM
IF(DR.GT.TWHC) GO TO 163
D=INTER(DR)
IF(D.GT.DML) GO TO 172
LR=LR+1 $ D1(LR)=D
173 CONTINUE
172 CONTINUE
163 CONTINUE
154 D=D1(LR) $ SILIM=INTER(D)
DO 11 LA=1,LR
LV=LR+1-LA
11 D3(LA)=D1(LV)
D2(11)=D2R
CALL TSMESH(D2+1,D3,LR+1,L5)
160 LR=0
SPD=1
DO 800 NSP=1,5
M2S=NFS(NSP)
IF(M2S.LF.0) GO TO 107
DO 801 M2S=1,M2S
D=SPD*CMK(IK)
IF(D.GT.DML) GO TO 107
LR=LR+1 $ D2(LR)=D
803 SPD=SPD-XCON(NSP)
801 CONTINUE
SPD=SPD-XCON(NSP)
NPP=NSP+1
IF(NPP.LT.5) GO TO 107
IF(XCON(NPP).EQ.0) GO TO 107
IF(NPP.EQ.0) GO TO 107
IXN=INTF(SPD/XCON(NPP))
SPD=(XCON(NPP)*FLOAT(IK)+XCON(NPP)
800 CONTINUE
107 CONTINUE
CALL TSMESH(D1+1,D3+1,LR+1,L5)
C *******CALCULATION OF COUNTERPOISE STRATEGIC POINTS*******
IF(INOC.LF.0) GO TO 75
LR=0
DO 600 IK=1,13
IF(ILK.LT.9) GO TO 601
FLK=IK-8
DO 603 LG=1,14
FLG=LG
GND=(14.*FLK+FLG)/4.
602 APDR=GND*ALAM
IF(APDR.GT.TWHC) GO TO 29
SI=ASINF(APDR/TWHC)
1CPT=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(ILK.LT.9) GO TO 600
CONTINUE
PRINT 5 $ CALL PAGE(1)
CLIM=D3(LR) $ CCIM=D3(1)
DO 69 I=1,LR
LV=LR+1-I
69 D11=L(M1(LV))
CALL TSFMSH(D1, LR, D2, LX, D3, LK)
DO 134 LV=1, LK
ICPT=0
13 SI=SINTER(D3(LV))
ASSIGN 2A TO KR
C
---------------------RAY OPTICS GEOMETRY---------------------
CSSI=COSE(SI)
SNSI=SAFE(SI) $ S150=SAE(SI) $ SNSI=AKE=1/(1+12E*CSE(SI))
AEF=A0*AKE $ DHE=AE*AKE/(AK0-1)
AHT=H(TE*H) $ HL=H2*DHE $ HTX=H2+H*ALFS(AK0, ATE)
IF(77) 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(56) GO TO 63
HPR(LC)=DA(LC)*TANF(1) $ DA(LC)/HPR(LC)/CSSI
IF(R0LTDTX) RO=D7TX
68 CA=AHT-TEA $ TH=TEA+TEA $ R12=DA+DA/7CSSI
IF(DGTY.1) GO TO 129
IF(D0.01) GO TO 111
ALFS=A0+20*ALOG10(RD)
PFS=P7IP-APFS
GO=SBS(A1)
GPD=20*ALOG10(GOD)
Z1=Z(Z)-Z1
Z4=Z(Z)*COSF(BA)/Z1
IF(D0E0.01) GO TO 42
DHD=2*EXPF(-2*D7000)
44 CALL SOR(1)+Z(Z)+1/3/3/R0+BA/RE
AA=RF*RE+1*GAM*RE
51 IF(DR0+AND+S1+S7IL) GO TO 35
IF(DR0+AL2) GO TO 34
IF(DR0+G70) GO TO 26
FDR=1+10.9*COSF(PKL*1 DR-D70)) $ 5
43 CONTINUE
CALL REC(S1+F7+IPL0+DHD+R+PIC+RD)
GA=(TEA(1)+SI) $ GAMD+GAMDEG $ GOG+GAINGA
NOT REPRODUCIBLE
RDG=RD*GOG
REC=O.O
RFG=RD*GOG
RCG=REG
IF(NOC.LF.O) GO TO 500

C CALCULATION OF COUNTERPOISE CONTRIBUTION---------

TEG=ABTC-ABSF(SI+TEA(I)) $ TEG=ABS(TEG)
VFGD=SINIF(TEG)+SOVT
IF(ABSF(GA)+LT+ABTC) VFGD=VFGD
CALL FRENEL(VFGD+FPGD+PHIG)
REG=REG*FPGD
RDG=RD*GFGD
TRM3*PHIG+12182*VFGD*VFGD
IF(D.LT.CLIM.OR@D@GT*CCIM) GO TO 146

SIC=CA
TEC=ABSF(BTC-CA) $ DARC=2.*HFC*SINF(CA)
SIT=SI-C $ GOC=GAIN(SIT)
VFCP=SINF(TEC)+SOVT
IF(ABSFICA+GT+ABTC) VFCP=VFCP
CALL FRENEL(VFCP+FPFC+PHIC)
CALL RECC(51C,FdICCIPL,1,DHDRCPICCRDC)
RLC=RCNGO
REC=RLC*FPFC
EXPG=(VFCPTFPCP+PHICI
CALL FRENC(VFCP+FPFC+PHIC)
ATRM=REG*COSF(EXPG, $ BTRM=REG*SINF(EXPG)
AT1=CMPLX(ATMS+ATRM)
147 CONTINUE

C CALCULATION OF LOBING CONTRIBUTION----------

IF(SHGT.5.SILIM) GO TO 135
EXPG=TWPILA*DR)+PI+TRM3
ATRM=REG*COSF(EXPG) $ BTRM=REG*SINF(EXPG)

C SUMMATION OF TERMS-----------------------------

AT2=CMPLX(ATRM+BTRM)
WRL=CABS(GOD+AT1+AT2) $ WR=WRL+WRL+0001
PP=10.*ALOG10(WR)
IF(D.LE.DZR) GO TO 148
IF(LV*EQ.1) GO TO 148
PL=FA(AI*IM+DML+DZP+PRH+PZ)
WL=10.*PP *(1.*PL)
149 CONTINUE

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

PL=PL-GPD
IF(D.LE.0.) GO TO 38
IF(D.LF.DSL1) GO TO 302
301 DEE=1130.*D/DSDL $ GO TO 303
302 DEE=130.*D/DSDL $ GO TO 303
303 CALL VZD(SEE=DD1+99+AD)
IF(CA=LEO+1) GO TO 32
IF(LEGE1+1) GO TO 33
F 135-BSPI(*ATANF2U+ALOG10(2,2*CA))
52 AL20=PL-AD13+FTH $ AY=AL1N-ALIM
IF(AY=LET+0.) AY=0.
53 IF(LB+GT+0. AND SI+LE+SLIM) GO TO 22
DO 31 K=135
31 CONTINUE
DO 50 K=04
ALLM=ALM1K
IF(BD(K)+GT+ALLM) BD(K)=ALLM
CONTINUE

VALUES PUT INTO ISOTROPIC POWER ARRAY

CONTINUE

RETURN

RETURN TO PWSRB

TROPOSPHERIC MULTIPATH

CONTINUE

LOBING MODE

GO TO 43

GO TO 52

GO TO 53

GO TO 43

GO TO 43
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].
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(RLT.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,F8.3)
6 FORMAT(5X,10F7.1,F8.4,F8.3,F7.1)
7 FORMAT(5X,6F7.1,F8.4,F8.3,F7.1)
51 FORMAT(10X,*UL7 DL8 TEC1 TEC2 TE4 AC3 D3 AC
X4 U4 AV4 GHT ARK AK5 *)
52 FORMAT(5X,2F7.1,F8.4,F8.3,F7.1)
57 FORMAT(8X,*AK3 AK4 D DK4 GHI GH2 W AMD
X AFD SWP AMD AK5 DK5*)
60 FORMAT(18X,*AR3 AR4 D3 D4 AK3 AK4 D DK4
X GHI GH2 W AMD AED SWP AMD AK5 DK5*)
61 FORMAT(8X,*AR3 AR4 D3 D4 W AMD AED*)
71 FORMAT(10X,*W,14X*D8,14X*DL5,12X*DL*)
70 FORMAT(4(12X,E15.5))

COMMON/DIFPR/HRT*HR+AMD+DLS1+DLS2+IPX+KL+SHT*HRP+AWD+SWP
COMMON/PARAM/HTE+HRE+DL1+DL2+ENS+AL+TE1+TE2+KG+GAW
DIMENSION ES(73,7)
REAL K1,K2,K4,K4,K4
DATA(K5.5,0.1,0.2,0.001,0.010,0.100,1.000)
DATA(E=81.25,15.4,15.4,15.4,15.4,15.4)
FNC(1)=416.4/(F**THIRD*(1.607-C)
FNC(1)=16278/(1+COL**THIRD((E-1.*2+(X*X))**2.5))
FNC(1)=14529654
IPOL=IPX-1
THIRD=1.5
$ TWIRD=2**3.

141
C  CALCULATION OF GHBAR AND W

B5=1.607-K1
B6=1.607-K2
GHI=GHBAR(F*A1+B5*K1+DL1+H1E)
GH2=GHBAR(F*A2+B6*K2+DL2+H2E)
AK3=6.-GHI-GH2
IF(D*D+DL) GO TO 41
IF(D+FE(CW+DLS)) GO TO 50
W=.5*(1.+COSF(CPI*(DLS-D))/DLS*(1.-CWF1))

C-------------------------------PRINT STATEMENTS-----------------------------
PRINT 71
PRINT 75+W=DLS=DLS+DL
CALL PAGE(2)
C-------------------------------CALCULATION OF ROUNDED EARTH DIFFRACTION

CONTINUE
D3=DL+.5*(A*A/F)**THIRD
DL7=DL1 $ DL8=DL2
ASSIGN 25 TO JD
IF (D3<DL) D3=DL
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)
CONTINUE
B1=FNC(K1)
B2=FNC(K2)
B3=FNC(K3)
B4=FNC(K4)
X1=B1*DL7/A1**TMTRD
X2=B2*DL8/A2**TMTRD
X3=X1+X2+(B3*(D3-DL)/A3**TMTRD)
X4=X1+X2+(B4*(D4-DL)/A4**TMTRD)
IF(K1.GE.1) K1=99999
IF(X1.GE.99999) GO TO 17
IF(K1.LE.0.0001) GO TO 16
XL1=450./AESF(ALG10(K1)**3)
IF(X1.GE.XL1) GO TO 16
FX1=20.*ALOG10(K1)-(2.5*E-5*X1*X1/K1)-15.

20 IF(K2.GE.1.) K2=.099999
    IF(X2.GT.2000.) GO TO 19
    IF(K2.LE.0.001) GO TO 18
    XL2=450./ABS(ALOG10(K2)**3)
    IF(X2.GE.XL2) GO TO 18
    FX2=20.*ALOG10(K2)+(2.5*E-5*X2*X2/K2)-15.

21 GX4=0.5751*X4-10.*ALOG10(X4)
    AC2=GX3-FX1-FX2-20.
    GO TO JD(+25.+26)

17 FX1=0.5751*X1-10.*ALOG10(K1)
    IF(X1.GT.2000.) GO TO 20
    W1=.0134*X1*EXP(-.005*X1)
    FX1=W1+40.*ALOG10(K1)-117.
    IF(X2.GT.X1) GO TO 18
    FX2=0.5751*X2-10.*ALOG10(K2)
    IF(X2.GT.2000.) GO TO 21
    W2=.0134*X2*EXP(-.005*X2)
    FX2=W2+40.*ALOG10(K2)-117.
    GO TO 21

16 T=40.*ALOG10(K1)-117.
    T1=-117.
    T2=MINIF((ABSFT(T1)+(ABSFT(T2)))
    FX1=T
    IF (T1 = ABSFT(T1)) FX1=T1
    GO TO 20

19 FX2=0.5751*X2-10.*ALOG10(K2)
    IF(X2.GT.2000.) GO TO 21
    W2=.0134*X2*EXP(-.005*X2)
    FX2=W2+40.*ALOG10(K2)-117.
    GO TO 21

18 T=40.*ALOG10(K2)-117.
    T1=-117.
    T2=MINIF((ABSFT(T1)+(ABSFT(T2)))
    FX2=T
    IF (T2 = ABSFT(T1)) FX2=T2
    GO TO 21

25 AR3=AC3 $ AR4=AC4
    DR4=DA4 $ DR3=D3
    AMS=(AR4-AR3)/(D4-D3) $ AES=AR4-AMS*DA
    IF(W1.GT.999) GO TO 44

C CALCULATION OF SINGLE KNIFE EDGE WITH GHBAR

45 CONTINUE
    IF(HLI.LE.0.) GO TO 43
    TH1=ATANF((HSR/HL1)-(DL1/TWA1))
    TH4=ASINF(DL4/SORTF(D1*DL4/HL4))
    TH5=(-(TH+TH1)) $ ATH5=ATANF(TH5)
    DLK5=ATH5+SORTF(ATH5+ATH5+(HSR*TWA1))
    DKL5=DLK5+DL1
    TE5=ATANF(-HSR/DLK5)-(DLK5/TWA1)
    TH4=TE1+TE4+DK4/A4
    TH5=SORF((F*DL5*DLK5)/DK5) $ V5=2.583*SINF(TH5)*TM5
    CALL FRENEL(V5+FV5+PM5)
    AV5=+0.01*ALOG10(FV5)
    ANM5=(AV5-AK5)/(DK5-D3)
    ANM=AK5-AK5/D3
    DLST7=SORF((HL1*TWA1)) $ DLST7=SORF((HL2*TWA1))
    DL7=DLST7 $ DL8=DLST7 $ DL=DL7+DL8
    DLK=DL
    ASSIGN A1 TO JD
    A1=INL7*NL7/(2.*HL1) $ A2=INLB*DLB/(2.*HL2)
    K1=FND(A1) $ K2=FND(A2)
    IF((PDL*FD0).LE.0) GO TO 29
    K1=FNK(K1) $ K2=FNK(K2)

29 TEC1=ATANF(-HL1/DL1)-(DL1/TWA1))
    TEC2=ATANF(-HL2/DL2)-(DL2/TWA1)
    TE=TEC1+TEC2

76 CONTINUE
    IF(A1.0) GO TO 9
    A2=INLB*DLB/(2.*HL2)
    K2=FND(A2) $ K2=FNK(K2)
    TEC2=ATANF(-HL2/DL2)-(DL2/TWA1)
    TE=TEC1+TEC2

NOT REPRODUCIBLE

143
D3=DL+5*(A*A/F)**THIRD
GO TO 30
26 B7=1.607-K1
B8=1.607-K2
GH7=GHBAR(1+F+2*DL7+HP1)
AC7=IAC4-AC3/(D4-D3 ) & ARS=AC4-AC7#DLK4
ARK=ARS+AC7#DLK4
TE4=ATANF((HLT-HR)/DLK4)-(DLK4/TWA1)
DK4=DLK4#DL1
TH=TE4+TE1+(DK4/A)
TM2=SQRTE((F#DL1#DLK4)/DK4) & V4=2.583*SINF(TH)*TM2
CALL FRENEL(V4+FV*PH)
AV4=20.4*AL0GIO(FV)
AK5=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,AV4,D4,AV5,GH1,GH2,AK4
CALL PAGE(2)
C ------------------------------------PRINT STATEMENTS---------------------
PRINT 55
PRINT 56,AK4,AK5,DK4,DK5,AC3,AC4,D4,AV5,GH1,GH2,AK5
PRINT 57
PRINT 58,AK3,AK4,DK4,DK5,AC3,AC4,D4,AV5,GH1,GH2,AK5
CALL PAGE(2)
C ------------------------------------PRINT STATEMENTS---------------------
PRINT 61
PRINT 62,AR3,AR4,DR3,DR4,AK3,AK4,DK4,DK5
CALL PAGE(2)
C ------------------------------------PRINT STATEMENTS---------------------
PRINT 65
PRINT 66,AR3,AR4,DR3,DR4,AK3,AK4,DK4,DK5
CALL PAGE(2)
C ------------------------------------PRINT STATEMENTS---------------------
PRINT 69
PRINT 70,AR3,AR4,DR3,DR4,AK3,AK4,DK4,DK5
CALL PAGE(2)
RETURN
36 AED=AEK & AMD=AMKD & SWP=AMK5 & AWD=AWK
------------------------------------PRINT STATEMENTS---------------------
PRINT 57
PRINT 71,AK3,AK4,DK4,DK5
CALL PAGE(2)
C ------------------------------------PRINT STATEMENTS---------------------
PRINT 61
PRINT 62,AR3,AR4,DR3,DR4,AK3,AK4,DK4,DK5
CALL PAGE(2)
RETURN
41 GOTO 42
43 AED=AEK & AMD=AMKD & SWP=AMK5 & AWD=AWK
------------------------------------PRINT STATEMENTS---------------------
PRINT 61
PRINT 62,AR3,AR4,DR3,DR4,AK3,AK4,DK4,DK5
CALL PAGE(2)
RETURN
50 W=0. & GO TO 45
END
Deliberate 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].

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 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 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].
IF (ARG) 10*10+11
10 I=1
GO TO 12
11 IF (ARG=.113*14*14
14 I=41
GO TO 12
13 DO 15 I=I+1
15 CONTINUE
16 RATA=(ARG-TBA(I-1))/TBA(I)-TBA(I-1)
ASSIGN 20 TO K1
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=I+1
IENS=SNS(J)34*30*33
33 CONTINUE
34 RATN=(ENS-SNS(J-1))/SNS(J)-SNS(J-1)
ASSIGN 22 TO MI
GO TO K1,(20*21)
12 ASSIGN 21 TO K1
GO TO 17
30 ASSIGN 24 TO MI
GO TO K1,(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 M1,(22*24,23)
21 CALA=A(I,J)
CALB=B(I,J)
CALC=C(I,J)
GO TO M1,(22*24,23)
22 CALA=RATA(CALHA-CALA)+CALA
CALB=RATA(CALHB-CALB)+CALB
CALC=RATA(CALHC-CALC)+CALC
24 DAO.01*4*(CALB.001*CALC#DS)*CALA
IF IF(ADO)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 IF 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(SJ
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 = -5
C K HAS THE OPPOSITE SIGN OF 101 BUT THE SAME AS THE IRE PAPER
COMMON/VF/VF(36,17)
AVEF(YN*YN1+YN1*YN)/YN*(T-XN)/YN*(T-XN1)/(XN1-XN)
R=-5
DO 1 I=1,17
IF(R-VF(27,I)) 3,2,1
1 CONTINUE
I=17
2 AK=VF(I,1,1)
GO TO 6
3 IF(I<10) GO TO 2
AK=AVEF(VF(I+1-1)+VF(271-1)*VF(I+1)+VF(271)*R)
3 FDASP=AK
RETURN
END

FDTETA

Subroutine FDTETA is used in calculations for the scatter region
(sec. A.4.4) to determine values of $F_{d0}$ 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.

SURROUENT FDTETA(I1*D1;S1+DB)
C ROUTINE FOR MODEL AUG 73
C SUBROUTINE TO CALCULATE THE ATTENUATION FUNCTION
DIMENSION TAD(25),TAFD(25,4)
COMMON/DLAT/TAD(20),TAFL(4,7:20)
35 FORMAT(51H DIHETA IS TOO LARGE FOR TABLE, USE GRAPH MANUALLY)
DATA(ENS=250,=101,=350,=400.)
DATA(TS=0151+1,2,3+57+1J)
DATA(TAD=001+02,03+04,06+08,11,2+3,4+5,6+78,9,1+2,)
X3+4,5+6,7+8,9,10,11)
DATA(TAD=(TAD(I,1),1,1+25),J=1,14)=-7455885939,975,1329,1067,10
X9,6+118,8+123,9+127,7130,6+133,135+136,8+138,3139,9+140,2+154
X9,158,6+162,166,169,170,9,172,5+75,6+84,790,2+93,8,99,3
X103+100,115+120,3+124,1269,129,3,131,4,133,2,134,6+136,1145
X3+151,155,158,4+161,163,4+165,5,167,4+169,2+171,2,80,3,85,7,89,5
X94,8+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
X879,2+83,0+88,4+92,195,1+104,2+109,5,119,3116,2+118,6+129,6,122
X4+124,1+125,4+134,5,140,2+144,4+147,7,150,5,153,5,155,2,157,1,159,1

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E=E1
D=D1
S=S1
DO 10 I=1,4
IF (E-ENS(I)) MOD 11 = 10
10 CONTINUE
11 IF (I-1) MOD 12 = 13
12 I=2
13 J=I-1
RTE=(E-ENS(J))/ENS(I-ENS(J))
IF (D-I) MOD 16 = 14
14 DO 16 K=1,25
IF (O-D*K) MOD 17 = 16
16 CONTINUE
17 IF (K-I) MOD 18 = 19
18 K=2
19 L=K-1
RTD=(O-TAD(L))/(TAD(K)-TAD(L))
DB1=(RTD*(TFL(K)-TFL(L))-TFL(K)+TFL(L))
DB2=(RTD*(TFL(K)-TFL(L))-TFL(K)+TFL(L))
DB=(RTE*(DB1-DB2))
GO TO 20
20 IF (D-I) MOD 100 = 15
21 DB=0
GO TO 20
22 IF (I=2) MOD 23 = 24
23 K=2
24 L=K-2
RTD=(O-TAD(L))/(TAD(K)-TAD(L))
IF (S-I) MOD 25 = 26
25 S=01
26 DO 27 M=1,27
IF (S-TS(M)) MOD 28 = 27
27 CONTINUE
28 IF (M-I) MOD 29 = 30
29 M=2
30 N=M-1
RTS=(S-TS(N))/(TS(M)-TS(N))
DO 31 KL=1,2
31 DO 32 N=1,2
DBS(N)=(RTD*(TFL(I+J,K)-TFL(I+J,L))+TFL(I+J,L))
J=J+1
32 CONTINUE
1=1-1
DBT(KL)=(RTS*(DBS(1)-DBS(2)))+DBS(2)
31 CONTINUE
DB=(RTE*(DBT(I)-DBT(2)))+DBT(2)
20 RETURN
END
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].

```fortran
SUBROUTINE FRENEL(V, FV, PH)
  INTEGER I, J
  REAL SUMX, SUMY
  COMPLEX PZ, CZ
  PI = 3.141592654
  TWP = PI / 2
  IF (V .EQ. 0.0) GO TO 71
  IF (V .GE. 5.0) GO TO 74
  PT = V * TWP
  CPSI = TWP * (PT - INT(PT))
  X = V * PT 
  25 IF (X .GT. 4.0) GO TO 10
  PX = COSF(X) * SORHF(X / 4)
  PY = SINF(X) * SORHF(X / 4)
  SUMX = 1.59576914
  SUMY = 3.3E-8
  XN = 1
  DO 100 I = 1, 11
    XN = XN * X / 4
    SUMX = SUMX + XN
    XN = XN * X / 4
    SUMY = SUMY + G1 * XN
  100 SUMX = SUMX + XN
  SUMY = SUMY + XN
  CZ = CMPLX(SUMX, SUMY)
  PZ = CMPLX(PX, PY)
  CX = REAL(CZ)
  CY = AIMAG(CZ)
  GO TO 30
  10 PX = COSF(X) * SORHF(X / 4)
  PY = SINF(X) * SORHF(X / 4)
  XN = 1
  SUMX = 0
  SUMY = 0
  XN = XN * 4 / X
  SUMX = SUMX + G1 * XN
  SUMY = SUMY + G1 * XN
  200 SUMX = SUMX + XN
```

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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), DA(8)
DATA(RA)=90.,76.,63.,54.,48.,36.,33.,30.,24.,18.,12.,9.,6.,3.,1.,0.,0.,0.,0.
DATA(RB)=79.,72.,65.,58.,51.,44.,37.,30.,23.,16.,9.,3.,0.,0.,0.,0.,0.,0.
DATA(IFL)=FA*FB*FC/FD/(IFA*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 DA = 57.29577951
DO 21 I=1,8
   IF(D-DA(I)) CONTINUE
   I=8
21 GAIN=10.*DG(L)*0.5 $ RETURN
23 IF(I.EQ.1) GO TO 22
   GD=FN(A(I)+DA(I)DG(L))
   GAIN=10.*GD*0.5 $ RETURN
C ------------- GAIN FOR RTA-2 ANTENNA -------------
30 DA=AS+29577951
   DO 31 I=1,24
      IF(D-RA(I)) CONTINUE
      I=24
32 GAIN=10.*((RB(I)=7.4)*0.5) $ RETURN
33 IF(I.EQ.1) GO TO 32
   RD=FN(A(I)+RA(I)RB(L))
   GAIN=10.*((RD=7.4)*0.5) $ RETURN
C ------------- GAIN FOR VOR ANTENNA (COSINE PATTERN) --------------
40 GAIN=10.*COSF(A)
   IF(GAIN.LT.--12589) GAIN=-12589
   RETURN
C ------------------- GAIN FOR ILS LOCALIZER -------------------
50 GAIN=10.*COSF(A)
   IF(GAIN.LT.--12589) GAIN=-12589
   RETURN
C ------------------- GAIN FOR GLIDE SLOPE -------------------
60 GAIN=10.*COSF(A)
   IF(GAIN.LT.--12589) GAIN=-12589
   RETURN
C ----------------------- JTAC 20 DEG BEAM TILT 20 DEG H HPBW ------------------------
70 DA=AS+29577951
   TLT=20.* HPBW=20.* TERM=ABS(D-TLT)
   GAIN=1.+((TERM/HPBW)**2.5)**(1.0.5)
   RETURN
C ----------------------- JTAC 8 DEG BEAM TILT -----------------------
80 DA=AS+29577951
   TLT=8.* HPBW=1.95545258
   TERM=ABS(D-TLT)
   GAIN=1.+((TERM/HPBW)**2.5)**(1.0.5)
   RETURN
END
Function GHBAR is used in calculations for the diffraction region (sec. A.4.3) to determine values of $G_{\text{kh}},2$ and $G_{\text{en}},2$ for (119) and (122). These are special values for $G_{\text{ph}},2$ 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].
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/YAH1 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.
55 IF(ETAS-1)17,18,19
17 DEHO=3.6*ALGS*ALGQ
   ASSIGN 3 TO M
   QS=QS*
   IF(QS=.999995)24+16+80
80 IF(QS=.1000005)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*1.6-ALGIO(ETAS)*ALGS*ALGQ
   ASSIGN 34 TO K
   ASSIGN 30 TO M
   DO 39 KL=1
   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))
42 R1=VR*(1.+S))
28 TTT=S=R1*R1*(1.-TERP(R1))
   HOO=10.*ALGIO1(TTT)
   GO TO 36
39 R1=VT*(1.+1/S))
38 R2=VR*(1.+S))
   UP=2*(1.-S+S*Q#Q)
   BAS=R2*R2*(TERP(R1)-TERP(R2))
   TTT=UP/BAS
   IF(TTT)45945946
45 HCO=0.
   GO TO 36
46 HOO=10.*ALGIO1(TTT)
   GO TO 36
44 R1=VT*(1.+1/S))
   R2=R1
   IF(R1-n103674748
47 HOO=64.9
   GO TO 36
48 IF(R1=.90+160+65+45
25 DO 61 I=1+1
60 IF(R1=TAR(I))63+62+61
61 CONTINUE
62 HOO=TAHO(I)
   GO TO 36
63 L=I+1
   HOO=((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=30.
   GO TO L*(25,26,27,28)
30 DO 64 I=1+1
63 IF(V-TAVC)64+65+66
64 CONTINUE
65 KM=1
   RAT=1.
GO TO K*(33,34)
66 KM=1-1
   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(I+KM)-TAH1(I+1)))+TAH1(I+1)
   GO TO L*(25,26,27,29)
34 HV=(RAT*(TAH1(KL,KM)-TAH1(KL+I)))+TAH1(KL)
   HV=(RAT*(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=HON+ETAS*(HO1-HO0)
   IF(HO1)*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)

ROUTINE FOR MODEL AUG 73

ROUTINE WILL PLOT THE FOLLOWING LINES ACCORDING TO CODE KL
KL=1-CONTINUOUS LINE  KL=2-SHORT DASHED LINE  KL=3X X X X X
KL=4-DASH-DX XLINE  KL=5-+++++
KL=6-LONG-DASH-SHORT-DASH LINE  KL=7-LONG-DASH-X LINE
KL=8-LIGHT LINE  KL=9-DOTTED LINE
DIMENSION A(1000), B(1000)
DIMENSION X(10), Y(10), IDH(2)
DATA (IDH=3H+O+X+3H+O+)

IF (K.L.EQ.1) GO TO 11
IF (K.L.EQ.8) GO TO 52
IF (K.L.EQ.2 OR K.L.EQ.4 OR K.L.EQ.6) GO TO 30
IF (K.L.EQ.9) GO TO 30

SCX=SKX $ SCY=SKY

----------

KIUS FOR LIGHT LINE----------

10 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=B(K)/SCX
CY=B(K)/SCY
DY=B(K)/SCY
XT=DX-CX $ YT=DY-CY
CL=SORTF((XT*XT)+(YT*YT))
L=INTF(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
CONTINUE
65 I=I+1
C(I)=A(K+1)
D(I)=R(K+1)
CONTINUE
GO TO 10+12+13+14+15+16+17+18+39+KL

----------

KIUS FOR CONTINUOUS LINE----------

10 CALL CRTPLT(0,0,0,0,8)
CALL CRTPLT(0,0,1,0,1)
RETURN

----------

KIUS FOR DOTTED LINE----------

39 CALL CRTPLT(C,0,0,0,8)
CALL CRTPLT(C,0,1,1,17)
RETURN

11 CALL CRTPLT(0,0,0,0,8)
CALL CRTPLT(A+B,0,1,1)
RETURN

52 CALL CRTPLT(0,0,0,0,8)
CALL CRTPLT(A+B,1,0,1)
RETURN

----------

KIUS FOR X X X X X LINE----------

13 ILA=4
ILH=IDH(1)
CALL CRTPLT(D,0,0,ILH+ILA+5)
CALL CRTPLT(C,0,1,0+1)
RETURN

----------

KIUS FOR + + + + + LINE----------

15 ILA=0
ILH=IDH(2)
CALL CRTPLT(D,0,0,ILH+ILA+5)

156
CALL CRTPLT(C+D+1+0+1)
RETURN

-------- KL#2 FOR SHORT DASHED LINE --------

12 IF(I.JLT,3) GO TO 10
N=1

20 L=N+1 SKN=N+2
X(1)=C(N) SY[1]=D(N)
X(2)=C(L) SY[2]=D(L)
IF(L.EQ.1) GO TO 19
X(3)=C(KN) SY[3]=D(KN)
KA=KN+1
IF(KA.EQ.1) GO TO 23
CALL CRTPLT(0+0+0+0+8)
CALL CRTPLT(X+Y+3+0+1)
N=N+3
IF(N.GE.1) RETURN
GO TO 20

19 CALL CRTPLT(0+0+0+0+8)
CALL CRTPLT(X+Y+2+0+1)
RETURN

-------- KL#4 DASH X DASH LINE --------

14 IF(I.LT.4) GO TO 10
N=1

22 L=N+1 SKN=N+2
X(1)=C(N) SY[1]=D(N)
X(2)=C(L) SY[2]=D(L)
IF(L.EQ.1) GO TO 19
X(3)=C(KN) SY[3]=D(KN)
KA=KN+1
KB=KN+5
CALL CRTPLT(0+0+0+0+8)
CALL CRTPLT(X+Y+3+0+1)
IF(KN.EQ.1) RETURN
X(1)=C(KA) SY[1]=D(KA)
IF(KB.EQ.1) GO TO 31
ILH=TN(1)
ILA=4
CALL CRTPLT(0+0+0+ILH+ILA+5)
CALL CRTPLT(X+Y+1+0+1)
N=N+4
IF(N.GE.1) RETURN
GO TO 22

23 X(1)=C(KA) SY[1]=D(KA)
CALL CRTPLT(0+0+0+0+8)
CALL CRTPLT(X+Y+4+0+1)
RETURN

25 X(1)=C(KB) SY[1]=D(KB)
CALL CRTPLT(0+0+0+0+8)
CALL CRTPLT(X+Y+5+0+1)
RETURN

-------- KL#6 FOR LONG DASH SHORT DASH LINE --------

16 IF(I.LT.4) GO TO 10
N=1

26 L=N+1 SKN=N+2 SKA=N+3 SKB=N+4
KC=N+5 KD=N+6 KE=N+7
X(1)=C(N) SY[1]=D(N)
X(2)=C(L) SY[2]=D(L)
IF(L.EQ.1) GO TO 19
X(3)=C(KN) SY[3]=D(KN)
IF(KN.EQ.1) GO TO 21
IF(KA.EQ.1) GO TO 23
X(1)=C(KA) SY[1]=D(KA)
IF(KB.EQ.1) GO TO 25
X(1)=C(KB) SY[1]=D(KB)
IF(KC.EQ.1) GO TO 27
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(1X)
6 FORMAT(6X,2I4)
COMMON/EGAP/IP,LN,NDY,IXT
IF(N.GE.1) RETURN
GO TO 10
17 IF(IA.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.1) GO TO 19
X(3)=C(KN) $Y(3)=D(KN)
IF(KN.EQ.1) GO TO 21
IF(KA.EQ.1) GO TO 23
CALL CRTPLT(X,Y,0,0,0,0,0)
CALL CRTPLT(X,Y,0,0,0,0,0)
X(1)=C(KA) $Y(1)=D(KA)
ILA=4
TLH=TDH(1)
CALL CRTPLT(X,Y,0,0,TLH,ILA,5)
CALL CRTPLT(C,D,1,0,0,1)
N=N+4
IF(N.GE.1) RETURN
GO TO 28
27 X(1)=C(KC) $Y(1)=D(KC)
CALL CRTPLT(X,Y,0,0,0,0,0)
CALL CRTPLT(X,Y,0,0,0,0,0)
RETURN
29 X(1)=C(KF) $Y(1)=D(KF)
CALL CRTPLT(X,Y,0,0,0,0,0)
CALL CRTPLT(X,Y,0,0,0,0,0)
RETURN
30 $SKX=5
$SKY=5
GO TO 18
31 X(2)=C(KR) $Y(2)=D(KB) $ GO TO 19
END
```
Subroutine PLTDU is used only in the station separation program to construct graphs. It is similar to PLTGRPH.
Subroutine PLTGRPH is used only 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*12:* IS OVER 100 POINTS*)
23 FORMAT(13.5F)
27 FORMAT(12.6F)
29 FORMAT(9.15F)
30 FORMAT(11.7F)
32 FORMAT(4X,14)
36 FORMAT(4X,4F)
41 FORMAT(4X,4F)
42 FORMAT(4X,4F)
43 FORMAT(1X,F5.3)
46 FORMAT(14.4X)
DIMENSION TL(3), TH(6), TA(2), TB(2), TC(2), TD(2), TE(3)
DIMENSION AX(2), AY(2), C(2), X(2), Y(2)
DIMENSION S(2), T(2)
DIMENSION A(200), B(200)
DIMENSION I(14), AN(13), DT(13)
COMMON/PLTN/TLNU(SH), AX, AY, C, X, Y, S, T
COMMON/LYD, LA, LAAT, T, I
COMMON/EXT, IP, LM, 100, X
DATA (IT=1) H $24M M E JOHNSON EXT 3587+1H

162
DATA (AN=24H DISTANCE IN N M I)
DATA (BT=40H POWER DENSITY IN D1B,W/19SQ M)
DATA (MS=19+9+3+7)
DATA (CTL=17HR19UN 11C9DE11)
DATA (TE=24I9WITH D1B EIRP)
DATA (TH=5AI9LITUDEFT)
DATA (TA=16H FREE SPACE)
DATA (TH=16H UPPER%) DATA (TC=16H MIDDLE%) DATA (TD=16H LOWER%)
XL=5X(2)+(8*90*SCX)
LM(1)=1 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=1
CALL CRTPLT(XL,YL,LM,1,XT,10)
YL=(H(1)-(3.40*SCY)
XL=5X(7)+(8*90*SCX)
S(1)=5X(2)+(7.3*SCX)
S(2)=5X(2)+(8*1*SCX)
T(1)=T(2)=YL
CALL LINE(9*ST,2*SHX,SHY)
LM(1)=2 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=1
CALL CRTPLT(XL,YL,LM,1,XT,10)
YL=(H(1)-(3.40*SCY)
T(1)=T(2)=YL
CALL LINE(9*ST,2*SHX,SHY)
LM(1)=2 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=1
CALL CRTPLT(XL,YL,LM,1,XT,10)
YL=(H(1)-(4.51*SCY)
T(1)=T(2)=YL
CALL LINE(9*ST,2*SHX,SHY)
LM(1)=2 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=1
CALL CRTPLT(XL,YL,LM,1,XT,10)

---------------
PLOTTING GRAPH------------------
DO 12 K=1,LL
N=NU(K) $ LS=NS(K)
J=0
DO 10 I=1,N
IF(J(Y(I,K)+GT,SY(1),OR.BX(I,K)+LT,SX(2))) GO TO 10
IF(J(Y(I,K)+LT,SY(2),OR.BX(I,K)+GT,SX(1))) GO TO 10
J=J+1
IF(J.Y(200)) GO TO 13
A(J)=BX(I,K) $ B(J)=BY(I,K)
10 CONTINUE
11 CALL LINF(LS,AS,N,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 SRVVMOL
C ROUTINE FOR FTPL MODEL AUG 73
14 FORMAT(* CAPACITY OF LINE*12,* IS OVER 100 POINTS*)
24 FORMAT(14*9)
27 FORMAT(14*6)

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DIMENSION IT(5), AN(4), BT(5)
DIMENSION TL(3), TH(4), TA(2), TB(2), TC(2), TD(2), TE(2)
DIMENSION AK(2), AT(2), G(2), H(2), LM(6), X(2), Y(2)
DIMENSION S(2), T(2)

DATA IT = 4, 2, 4, 1, 0, 24, 12, 5, 1, 2, 8
DATA AN = 3, 1, 9, 5, 0, 4, 3, 8, 6, 1, 6, 6, 9, 5, 2, 7
DATA BT = 3, 1, 9, 5, 0, 4, 3, 8, 6, 1, 6, 6, 9, 5, 2, 7

DATA TL = 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
DATA TH = 25, 1, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2,
DATA TA = 16, 1, 9, 1, 0, 9, 1, 0, 9, 1, 0, 9, 1, 0, 9, 1,
DATA TC = 3, 5, 9, 2, 7, 2, 7, 1, 2, 7, 1, 2, 7, 1, 2, 7,
DATA TE = 16, 1, 9, 1, 0, 9, 1, 0, 9, 1, 0, 9, 1, 0, 9, 1,
DATA TD = 16, 1, 9, 1, 0, 9, 1, 0, 9, 1, 0, 9, 1, 0, 9, 1,
DATA TS = 0

C -------------------------DRAWING GRID-------------------------

C -------------------------DRAWING PERIMETER-------------------------

SCX = (SX(1) - SX(2))/10.
SCY = (SY(1) - SY(2))/10.
G(1) = SX(1) + 0.5 * SCX
G(2) = SX(2) - 1.0 * SCX
H(1) = SY(1) + 4.8 * SCY
H(2) = SY(2) - 1.2 * SCY
SNX = G(1) - G(2)/100.
SND = H(1) - H(2)/100.
PY = 3 * SCY
AX(1) = SX(1) + SCY
AX(2) = SX(2) + SCY
AY(1) = SY(1) + SCY
AY(2) = SY(2) + SCY
HD1 = 0
HD2 = 0
NX = ((SX(1) - SX(2))/XC)
NY = ((SY(1) - SY(2))/YC) + 1.4
CALL CRTPLT(6, 1, IT, AT, 1)
CALL CRTPLT(X, Y, 2, 0, 1)

C -------------------------LABELING GRID-------------------------

GY = SY(1)
GX = SX(2) - 1.95 * SCX

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AS*SY(2)

00 22 I=1,LY
IF(LYD+GT+0) GO TO 16
KL=GY*TS $ IFLYD+LT+0) KL=XABSFL(KL)
ENCOD(8,32+AL) KL
LM(I)=1 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=1
CALL CRTPLT(GX+GY+LM+AL+10)
GY=GY-TC
IF(GY+LY+AS) GO TO 44

22 CONTINUE
EX=GX(2) $ GY=SY(2)-(2#SCY)
DO 24 I=1,IX
IF(IX+LT+1) GO TO 25
IX=EX
IF(IX+LT+0) GO TO 35
IF(IX+LT+0) GO TO 26
IF(IX+GT+99+1) GO TO 41
ENCOD(8,27+AL) IX
GX=EX-(75#SCX)
GO TO 28

33 LX=1+1 $ GO TO 34
34 LY=1+1 $ GO TO 99
16 YA=GY $ IFLYD+LT+0) YA=XABSFL(YA)
IF(LYD=2)17X=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(IX+GT+99+1) GO TO 31
ENCOD(8,23+AL) IX
GX=EX-(415#SCX)
GO TO 28
35 ENCODE(8,36+AL) EX
GO TO 37
37 GX=EX-(225#SCX)
GO TO 28
25 ENCODE(8,29+AL) EX
GX=EX-(415#SCX)
GO TO 28
26 ENCODE(8,30+AL) IX
GX=EX
28 LM(I)=1 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=1
CALL CRTPLT(GX+GY+LM+AL+10)
EX=EX+CX
IF(IX+GT+SX(1)) EX=SX(1)
24 CONTINUE

C--------------------------DRAWING LEGEND--------------------------

YL=1 I0#SCY+SY(2)
XL=SX(2)-()85#SCX
LM(I)=5 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=2
CALL CRTPLT(XL+YL+LM+BT+10)
LM(I)=4 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=2
YL=SY(2)-(460#SCY)
XL=SX(2)+1 2.5#SCX
CALL CRTPLT(XL+YL+LM+AN+10)
XL=SX(2)+1 4#SCX
YL=H(I)+1)14#Sцы)
LM(I)=6 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=2
CALL CRTPLT(XL+YL+LM+TT+10)
YL=H(I)+1)14#Sцы)
LM(I)=5 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=2
CALL CRTPLT(XL+YL+LM+TF+10)
XL=SX(2)+1 3.8#SCX
LM(I)=1 SLM(2)=1 SLM(3)=0 SLM(4)=0 SLM(5)=0 SLM(6)=2

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POWSUB

Subrou P OWSUB is used only 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(1H1)
6 FORMAT(20X,*,INPUT*,21X,*,WORKING VALUE*)
106 FORMAT(*X*, 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
8X*, RUN,*,//)
701 FORMAT(32X,*,REOUIRED OR FIXED*,/32X,*,----------------------
32X,*,AIR
CRAFT ALTITUDE: *,F8.0*, FT ABOVE MSL*)
702 FORMAT(15X,*,FACILITY ANTENNA HEIGHT: *,F7.1*, FT ABOVE SITE SURFACE)
703 FORMAT(15X,*,FREQUENCY: *,F6.0*, MHZ*)
704 FORMAT(12X,*,SPECIFICATION OPTIONAL*,/29X,*,-----------------------
29X,*,AIR
CRAFT ALTITUDE: *,F8.0*, FT ABOVE MSL*)
705 FORMAT(15X,*,EFFECTIVE REFLECTION SURFACE ELEVATION ABOVE MSL: *,F7.0*, F
5X*,/15X,*,EQUIVALENT ISOTROPICALLY RADIATED POWER: *,F6.1*, DBW*/1
55X*,FACILITY ANTENNA TYPE: *,A8*)
706 FORMAT(20X,*,COUNTERPOISE DIAMETER: *,F5.0*, FT*)
707 FORMAT(20X,*,POLARIZATION: *,A8*)
708 FORMAT(15X,*,HORIZON OBSTACLE DISTANCE: *,F7.2*, N MI FROM FACILITY*)
709 FORMAT(15X,*,MINIMUM MONTHLY MEAN SURFACE REFRACTIVITY: *,F7.0*, F
95X*,/15X,*,EQUIVALENT ISOTROPICALLY RADIATED POWER: *,F6.1*, DBW*/1
55X*,FACILITY ANTENNA TYPE: *,A8*)
710 FORMAT(20X,*,ANTENNA HEIGHT TOO HIGH, IONOSPHERIC EFFECTS*,/25X,*,MAY
2 BE IMPORTANT*)
711 FORMAT(20X,*,AIRCRAFT TOO LOW, TERRAIN BEYOND FACILITY *,/25X,*,HORI
ZON MAY BE IMPORTANT*)
712 FORMAT(20X,*,IN ADDITION, SURFACE WAVE CONTRIBUTIONS SHOULD*,/15X,*,MAY
BE CONSIDERED*)
713 FORMAT(20X,*,ANTENNA TOO HIGH, RAY BENDING OVERESTIMATED*,/1)
714 FORMAT(20X,*,ANTENNA TOO LOW, SURFACE WAVE SHOULD BE*,/25X,*,CONSID
ERED*)
715 FORMAT(20X,*,FREQUENCY TOO LOW, IONOSPHERIC EFFECTS MAY BE*,/25X,*,I
MPORTANT*)
716 FORMAT(20X,*,ATTENUATION AND/OR SCATTERING FROM HYDROMETEORS*,/25X,
*,RAIN, ETC) MAY BE IMPORTANT*)
717 FORMAT(20X,*,ATMOSPHERIC ABSORPTION ESTIMATES MAY BE*,/25X,*,UNRELI
ABLE*)
718 FORMAT(15X,*,A7,*,(COMPUTED VALUE*)
719 FORMAT(20X,*,TYPE: *,A1)
720 FORMAT(20X,*,TIME: *,A1)
721 FORMAT(12X,*,FARTH *,F9.0*, N MI)
722 FORMAT(12X,*,FREQUENCY: *,F8.4*, MHZ)
723 FORMAT(12X,*,TIME: *,F8.4*, DEG/SEC)
724 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
725 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
726 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
727 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
728 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
729 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
730 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
731 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
732 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
733 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
734 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
735 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
736 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
737 FORMAT(12X,*,DILUTION: *,F8.4*, FT)
DATA (PAS=2H,2H*PAS)
DATA (IP=11*1=1351=00001,00002,00005,00001,0002,0005,001*,X002,005,01,02,05,1*15,20,30,40,50,60,70,80,85,90,*X95,99,999,9999,99999,999999,9999999,99999999)
DATA (TYD=17H SMOOTH EARTH +17H IRREGULAR TERRAIN)
DATA (MTM=20.10.100)
DATA (YCON=5.10.25.00.*0)
DATA (CCI=16H SEA WATER +16H GOOD GROUND +16H AVERAGE GROUND
X +16H POOR GROUND +16H FRESH WATER +16H CONCRETE +16H METALLIC)
DATA (DMOD=8H DIFRACT) $ DATA (SMOD=8H SCATTER)
DATA (CMOD=8H COMBINE)
DATA (FX=FA+FB+FC,F=FA*FC,FB/FA,FC/FA,F=(FA+FB+FC)
IF (FX>F0+FB+FC) PRINT 701,1
IF (FX>F0+FB+FC) PRINT 702,1
IF (FX>F0+FB+FC) PRINT 703,1
IF (FX>F0+FB+FC) PRINT 704,1
IF (FX>F0+FB+FC) PRINT 705,1
IF (FX>F0+FB+FC) PRINT 706,1
IF (FX>F0+FB+FC) PRINT 707,1
IF (FX>F0+FB+FC) PRINT 708,1
IF (FX>F0+FB+FC) PRINT 709,1
IF (FX>F0+FB+FC) PRINT 710,1
IF (FX>F0+FB+FC) PRINT 711,1
IF (FX>F0+FB+FC) PRINT 712,1
IF (FX>F0+FB+FC) PRINT 713,1
IF (FX>F0+FB+FC) PRINT 714,1
IF (FX>F0+FB+FC) PRINT 715,1
IF (FX>F0+FB+FC) PRINT 716,1
IF (FX>F0+FB+FC) PRINT 717,1
IF (FX>F0+FB+FC) PRINT 718,1
IF (FX>F0+FB+FC) PRINT 719,1
IF (FX>F0+FB+FC) PRINT 720,1
IF (FX>F0+FB+FC) PRINT 721,1
IF (FX>F0+FB+FC) PRINT 722,1
IF (FX>F0+FB+FC) PRINT 723,1
IF (FX>F0+FB+FC) PRINT 724,1
IF (FX>F0+FB+FC) PRINT 725,1
IF (FX>F0+FB+FC) PRINT 726,1
IF (FX>F0+FB+FC) PRINT 727,1
IF (FX>F0+FB+FC) PRINT 728,1
IF (FX>F0+FB+FC) PRINT 729,1
IF (FX>F0+FB+FC) PRINT 730,1
IF (FX>F0+FB+FC) PRINT 731,1
IF (FX>F0+FB+FC) PRINT 732,1
IF (FX>F0+FB+FC) PRINT 733,1
IF (FX>F0+FB+FC) PRINT 734,1
IF (FX>F0+FB+FC) PRINT 735,1
IF (FX>F0+FB+FC) PRINT 736,1
IF (FX>F0+FB+FC) PRINT 737,1
IF (FX>F0+FB+FC) PRINT 738,1
IF (FX>F0+FB+FC) PRINT 739,1
IF (FX>F0+FB+FC) PRINT 740,1
IF (FX>F0+FB+FC) PRINT 741,1
IF (FX>F0+FB+FC) PRINT 742,1
IF (FX>F0+FB+FC) PRINT 743,1
IF (FX>F0+FB+FC) PRINT 744,1
IF (FX>F0+FB+FC) PRINT 745,1
IF (FX>F0+FB+FC) PRINT 746,1
IF (FX>F0+FB+FC) PRINT 747,1
IF (FX>F0+FB+FC) PRINT 748,1
IF (FX>F0+FB+FC) PRINT 749,1
IF (FX>F0+FB+FC) PRINT 750,1
IF (FX>F0+FB+FC) PRINT 751,1
IF (FX>F0+FB+FC) PRINT 752,1
IF (FX>F0+FB+FC) PRINT 753,1
IF (FX>F0+FB+FC) PRINT 754,1
IF (FX>F0+FB+FC) PRINT 755,1
IF (FX>F0+FB+FC) PRINT 756,1
IF (FX>F0+FB+FC) PRINT 757,1
IF (FX>F0+FB+FC) PRINT 758,1
IF (FX>F0+FB+FC) PRINT 759,1
IF (FX>F0+FB+FC) PRINT 760,1
IF (FX>F0+FB+FC) PRINT 761,1
IF (FX>F0+FB+FC) PRINT 762,1
IF (FX>F0+FB+FC) PRINT 763,1
IF (FX>F0+FB+FC) PRINT 764,1
IF (FX>F0+FB+FC) PRINT 765,1
IF (FX>F0+FB+FC) PRINT 766,1
IF (FX>F0+FB+FC) PRINT 767,1
IF (FX>F0+FB+FC) PRINT 768,1
IF (FX>F0+FB+FC) PRINT 769,1
IF (FX>F0+FB+FC) PRINT 770,1
IF (FX>F0+FB+FC) PRINT 771,1
IF (FX>F0+FB+FC) PRINT 772,1
IF (FX>F0+FB+FC) PRINT 773,1
IF (FX>F0+FB+FC) PRINT 774,1
IF (FX>F0+FB+FC) PRINT 775,1
IF (FX>F0+FB+FC) PRINT 776,1
IF (FX>F0+FB+FC) PRINT 777,1
IF (FX>F0+FB+FC) PRINT 778,1
IF (FX>F0+FB+FC) PRINT 779,1
IF (FX>F0+FB+FC) PRINT 780,1
IF (FX>F0+FB+FC) PRINT 781,1
IF (FX>F0+FB+FC) PRINT 782,1
IF (FX>F0+FB+FC) PRINT 783,1
IF (FX>F0+FB+FC) PRINT 784,1
IF (FX>F0+FB+FC) PRINT 785,1
IF (FX>F0+FB+FC) PRINT 786,1
IF (FX>F0+FB+FC) PRINT 787,1
IF (FX>F0+FB+FC) PRINT 788,1
IF (FX>F0+FB+FC) PRINT 789,1
IF (FX>F0+FB+FC) PRINT 790,1
IF (FX>F0+FB+FC) PRINT 791,1
IF (FX>F0+FB+FC) PRINT 792,1
IF (FX>F0+FB+FC) PRINT 793,1
IF (FX>F0+FB+FC) PRINT 794,1
IF (FX>F0+FB+FC) PRINT 795,1
IF (FX>F0+FB+FC) PRINT 796,1
IF (FX>F0+FB+FC) PRINT 797,1
IF (FX>F0+FB+FC) PRINT 798,1
IF (FX>F0+FB+FC) PRINT 799,1
IF (FX>F0+FB+FC) PRINT 800,1
IF (FX>F0+FB+FC) PRINT 801,1
IF (FX>F0+FB+FC) PRINT 802,1
IF (FX>F0+FB+FC) PRINT 803,1
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C------------------------ COUNTERPOISE PARAMETERS CONVERTED---------------------
NOC=1
DCW=DCI*CFK(IK) $ HCW=HCI*CFK(IK)
PRINT 706,DCI,HC19D9CCHIIC9#lw1,2'
IF(HC!.LT.O.) GO TO 828
829 IF(HC!.GT.5000) ICAR=1
IF (DCW.GT.5000) ICAR=1
IF(HCW.GT.HFS) GO TO 825
HFC=HT-ETS-HCW
788 CONTINUE
PRINT 707,(POL(I IPL).1,2)
C---------- HORIZON AND INITIAL TAKE-OFF ANGLE COMPUTATIONS--------
PDI-PTS=PHS-PASI 1
IF(KD.LE.1) GO TO 755
HLT=HHO1*CFK(IK) $ DLT=DHO1*CMK(IK)
PRINT 759,HLT,DLT,597580
758 IF(TET.LT.0) GO TO 781
IF(KE.GT.1) GO TO 759
752 IF(DLT.LT.0) PRINT 809
IF(TET.GT.7) PRINT 810
778 IF(LR.GT.0) GO TO 762
PRINT 778
763 PRINT 710,PHS*(PHS-1/2)
IF(DMAx.GT.1000.) UMAX=10000.
IF(ICAR.GT.0) PRINT 800
C-------------------------START OF WORK SHEET---------------------------
PRINT 4
PRINT 797,1D7+1X1,41
PRINT 5 $ PRINT 6
PRINT VARFOR,ADENTS,ADNT
PRINT 791+HA1+H2
CALL OEFAC
GVD=GAIN(TET) $ GDD=20*$LOG10(GVD)
SMD=2DINT(FDNM/1.1)+1.1+1. $ AMD=AMD+(SWP*D)
ATD=ARP+AMD
DDR=AMD/85
PRH=(AMD-GDD) $ WRH=10**($PRH*1)
ZH=ALOG10(WRH)-2.

C

---------------------LINE-OF-SIGHT---------------------

C

--------------------BEYOND THE HORIZON CALCULATIONS-----------------------

KFD=0
DO 900 N5P=1+5
M5S=MTM(N5P)
IF(M5S=1.9=0) GO TO 907
DO 901 N5C=1+M5S
D=SPC*CMK(IK) $ DN=5SPD
IF(D>GT.DHRP) GO TO 17
DLR=N-DLT
HLR=DLT
TATER=((HLR-HR1/DLR)-(DLR/2+*EFRTH)
TFR=ATAN(TATER)

19 CONTINUE
IF(KFD=140+4)42
40 K5=0 $ KR=0
K5=1 $ ACD(K5)=AMD $ AND(K5)=DML
AMD=DMON
EC1=HILE+EFRTH $ EC2=HRE+EFRTH $ EC3=HRT+EFRTH
CALL SORR(E1+EC3+EFRTH+DLT+TET+R01+RW1)
CALL SORR(E2+EC3+EFRTH+DLT+TER+R02+RW2)
RRM=R01+R02 $ RR=RW1+RW2 $ ALF=GAO*RE0+GAW*REW
REW=R01+RW1+RW2 $ AA=GA0*RE0+GAW*REW
REW=REW

R1=REW
A0=11=AA
DO 30 KC=1,100
K5=KC+1
DN=DNM*CMK(IK)
SPD=DNM
ACD(K5)=AMD+(SL0*N)
AND(K5)=0
TWEND=20*$LOG10(D) $ ALF=AF+TWEND
IF(D>GT.DHRP) GO TO 44
HLR=DLT
DLR=D-DLT $ TATER=((HLR-HR1/DLR)-(DLR/2+*EFRTH)
TFR=ATAN(TATER)

60 CONTINUE
CALL SCATTER
SCT=KS+ALF-AFS
AM=(K5-1)+AA $ RW(KS)=REW
IF(TS+K5,12+0)+ GO TO 31
KR=R+1
IF(KR=LEF+1) GO TO 31
KPS=K+1

11 DN=DNM*1
91 CONTINUE
PRINT 14 $ KFD=1 $ GO TO 53
14 IF(MAT=19+1*IF)THE MILE LIMIT GOING DIFFRACTION...)
49 YP=0 $ GO TO 31
49 DO 43 IF=1+AP
DN=CAR(K5+1,1) $ SPD=DNM

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TWEND=20.*ALOG10(D) $ ALFS=AFP+TWEND
ATT=ACD(KP)
AA=AAD(KP) $ REW=RW(KP)$ THETA=TET+TER+(D/EFRT)
ASSIGN 36 TO KT
GO TO 200
36 CONTINUE
33 CONTINUE
SPD=DNM $ MZ=6 $ KD=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)
ARD=ACD(KP)-(AND(KP)*SLP)
ASSIGN 35 TO KT
DO 34 KG=1,KP
D=AND(KP)
DN=DN*(CKN(KP)$ SPD=DNM
TWEND=2n.*ALOG10(D) $ ALFS=AFP+TWEND
ATD=AFD*(SLP*D)
ATT=ATD
AMOD=(MD
AA=AAD(KP) $ REW=RW(KP)$ THETA=TET+TER+(D/EFRT)
GO TO 200
34 CONTINUE
34 CONTINUE
41 CONTINUE
AMOD=MMD
ASSIGN 37 TO KT
ATD=AFD*(SLP*D)
TWEND=2n.*ALOG10(D) $ ALFS=AFP+TWEND
IF(D+DHF.1 DHRP) GO TO 24
HLR=HHT
DLR=D-PLT $ TAT=(HLT-HR)/(DLR-(D+DHF))*TFR=ATANF(TAT)
23 CONTINUE
CALL SCATTER
AT=ALSC-ALFS
IF(ATS.T.E .ATD) GO TO 46
ATT=ATD $ THETA=TET+TER+(D/EFRT) $ GO TO 200
46 AT=ATS $ KD=3 $ AMOD=SMOD $ GO TO 200
42 CONTINUE
AMOD=SMOD
TWEND=2n.*ALOG10(D) $ ALFS=AFP+TWEND
CALL SCATTER
AT=ALSC-ALFS $ AT=ATS $ ASSIGN 37 TO KT
200 CONTINUE
C----------LONG-TERM POWER FADEING----------
311 DEE=(130.*D/DSSL) $ GO TO 313
312 DEE=(130.*D/DSSL) $ GO TO 313
313 CALL VZD(DEE+GG1+GG9+ADI)
NCT=NCT+$ W=S+R(KP-ALFS)
PL=AT
AL=+PL+AD($)
AY=AL=ALIM
IF(AY.LT.0.0) AY=0.0
DO 11 K=1,15
BD(K)+PL+AD(K)-AY
11 CONTINUE
DO 12 K=1,12
AL(1)-ALM1
IF(IND=1,ALM) BD(K)=ALM
12 CONTINUE
C--VALUES PUT INTO ISOlROPIC POWER ARRAY--

IF(K.RI,.FL.1) GO TO 20
PGS=PFS+ODD
PFV=PGS+PL:AA
PRY(PNT,+1)*DNN $ PFO(PNT;2)*PGS $ PFO(PNT;3)*PFV
PFO(PNT;4)*BD(12)-PL $ PFO(PNT;5)*BD(18)-PL
PFO(PNT;6)*BD(24)-PL
IF(SPD.GE.OMAX) GO TO 907
GO TO K!,35,36,371
37 CONTINUE
903 SPD=SPD+YCON(NSP)
901 CONTINUE
SPD=SPD+YCON(NSP)
NPP=NSP+1
IF(NPP.GE.5) GO TO 907
IF(YCON(NPP).*EQ.0) GO TO 907
IF(NPP.EQ.0) GO TO 907
IDX=INT(SP/1/YCON(NSP))
SPD=YCON(NPP)*FLOAT(IIDX))YONCON(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
POA(I)=P(I)
21 CONTINUE
IF(THTA.GE.TPTH) GO TO 26
IF(THTA.LT.0) GO TO 27
RK=FNAI.THTA.1PTHT,LTH+TPE,PRHK)
28 CONTINUE
CALL YIKK(RK,PK,OK)
CALL COUUT(IQA,OK,POA,35,1,0,PQC, QC)
DO 22 I=1,35
22 BD(I)=QC+PL
GO TO 23
24 TER=TES $ DLR=DRP $ HLR=HRP $ TATER=TATES $ GO TO 25
26 RK=TPE $ GO TO 28
27 RK=PRHK $ GO TO 28
44 TER=TES $ DLR=DRP $ HLR=HRP $ TATER=TATES $ GO TO 45

C----------------------CALCULATION OF RAY BENDING---------------------

50 PUN+PS/2)
HP2=H2-HRP $ HP1=H1-HRP
DUM=O.O $ ZER=O.O $ QLM=1.56
QNS=329 $ QHC=HP1 $ QHA=HP2 $ QNS=HRP
CALL RAYTRAC(DUM)
RY=TRACRAY(GLIM)
QNS+ENS $ QHC+ZER $ QHA+HRP $ QNS=HRP
CALL RAYTRAC(DUM)
RY=TRACRAY(ZER)
DL=DO $ TFL2=DL/ERTH
IF(TFL2.LT.1) GO TO 53
R2=ERTH/CUSF(TFL2)
HR=HR+R2-FFRTH
53 IF(HRE.GT.HP2) HR=HP2
HR=HR+HRP $ EACH=H2-HRP-HRE
DHE=FAC*CKM1(IK)

176
JK=-1
GO TO 55
53 HRE=(DLST*DLST)/((2.*EFRTH)) $ GO TO 54

56 CALL ASORP(F+AOJ,AWI)
PXH=PAS(2) $ GO TO 57
58 TEH=TET+(DLT/EFRTH)
QNS=ENS $ QHC=HLT-HRP $ QHA=HP2 $ QHS=HRP
RT=TRACTAY(TEH) $ DLR=QQD $ DML=DLT+DLR $ GO TO 59
107 PRINT 106 $ GO TO 400
304 QG1=QG9+1.05 $ GO TO 306
752 HRTs=DLR*HRT+IDLT/((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=MAXIF((HTE+.005)
DLT=DLST*EXP((-0.7*SORTF(DH/HE))
PDS=PAS(2)
IF(DLT<LT,(1#DLST)) DLT+=1#DLST
IF(DLT<LT,(1#DLST)) DLT=3#DLST
HDH=DLT*CKN(IK)
GO TO 759
790 TRM=1.3#DHI((DLST/DLT)-1.)
TRM=1.3#DHI((DLST/DLT)-1.)
TET=(0.5/DLST)*(TRM-4*HTE)
PTF=TET/TWDG TET=TWDG
CALL RADEMS(TET,TDG,IMM,SEC)
SSEC=INTF(SSEC)
PTS=PAS(2)
TATE=TANF(TET)
GO TO 758
782 XTRM=SORTF((EFRT*EFRT*TATE*TATE)+((2.*EFRT*HLTS)))
YTRM=EFRT*TATE $ DLT=YTRM-XTRM
IF(DLT<0) $ DLT=YTRM-XTRM
PDS=PAS(2)
HDH=DLT*CKN(IK) $ GO TO 788
780 TATE=(DLST/DLT)-(DLST/((2.*EFRTH)) $ TET=TANF(TATE)
PTS=PAS(2)
784 CALL RADEMS(TET,TDG,IMM,SEC)
SSEC=INTF(SSEC) $ GO TO 783
C
-----------------------SMOOTH EARTH PARAMETERS-----------------------
755 PT=PDS=PAS(2)
DLT=DLST $ DHO=DLT*CKN(IK)
TATE=(LT+HLTS)/(DLST/((2.*EFRTH)) $ TET=TANF(TATE)
HRT=HRT $ HDH=HRT*CKN(IK) $ DH=0.
GO TO 784
789 HFC=0. $ GO TO 788
801 ICAR=1 $ ENO=501. $ 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 $ HCF=0. $ GO TO 829
830 ICAR=1 $ SUR=0. $ GO TO 831
C
-----------------------ABORTION OF PROGRAM-----------------------
400 PRINT 840 $ CALL EXIT
END

177
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 PSWRB**

```fortran
C ROUTINE FOR MODEL AUG 73
4 FORMAT(1H1)
5 FORMAT(1H1)
6 FORMAT(20X*"INPUT",2X*"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),Q(50),QA(50),PAQ(50),PAQ(50),Q(50)
DIMENSION RE(2),AD(35),BD(35),ALM(12)
COMMON/FGAP/IP,LN,IDT,IXT
COMMON/RTY/NSO,QHC,GHA,QHD,QAD
COMMON/PRMHE/HEF,DLT,DLR,FNS,FR,FRK,ALAM,TER,TER,KD,GAO,
XGAW
COMMON/PANUT/NCT,PFY(125,61),JH,PH1,PH2
COMMON/SIGT/DCW,HCW,NMX,DML,DMR,IKs,EAC,H2,IAC,HFC,PRH,DL1,E1RP,
XG(1),QG,KT,PH,RLH,ILB
COMMON/SKTPKHT/H,R,ALSCT,TFW,THF,HLT,HLR,THETA,HPR,AA,REW
COMMON/DTPR/HID,HRD,DLI,SLP,DLST,DLRS,APK,SC,CHPL,HRP,AW,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 (PI)=1.91,-0.0001,-0.0002,-0.0005,-0.002,-0.005,-0.01,-
X0.02,-0.05,-0.1,-0.2,-0.5,1,1,15,20,30,40,50,60,70,80,85,90,-
DATA(MTM=20,10,30,0,0)
DATA(YCON=5,,10,25,0,0,0)
DATA (DMOD=8H DIFRACT) $ DATA (SMOD=8H SCATTER)
DATA (CMOD=8H COMBINE)
DATA (CFK=1,001,003048,0003048)
DATA (CMK=1,621371922,5399568034)
DATA (CFM=1,3280,39895,3280,39895)
DATA (CFM=1,3048,3048)
DATA (CMK=1,609344,1852)
FNA(FX,FA,FB,FC,FD)*((FX-FB)*(FC-FA)/(FA-FB))+FD
TP=2617997878E-2 $ TLTH=0 $ TPK=20
F=FREX
ASPA=0.25 $ ASPR=0.25
NOC=0
ASPC=ASPA*ASPR*(A,E-8)*F
IF(E>0.1600) GO TO 304
QG(1,125,15,27,100101F/200)+1+28
QG(1,15,22,100101F/200)+1+23
306 DSY=3,5SORT((2000,HEI)+3,5WKT12000,HEI)
CUBTR=100/F
DSD=6%CUBERT(CUBTR)
```

178
C ------HORIZON POINT DISTANCE AND PARAMETER CALCULATION------

IF (JJ.LT.1) GO TO 58
TRM=((HTE*EFRTH)*COS(TET))/(HRT+EFRTH)
DML=EFRTH*(ACOS(TRM)-TET)
59
DNM=DML*CKN(IK)
IF (DNL.LE.0) GO TO 107
D=DML $ DLR=D-DLT $ TWEND=20.*ALOG10(D) $ ALFS=AFP+TWEND
HTP=HRP
DRP=DLR
TATER=((HRT-HRT)/DLR)-(DLR/2.*EFRTH))
TER=ATANF(TATER)
TES=ATANF(TATER)
IIF (HRT-HRT).LE.0*15.14
15 DHRP=DLR+DLT $ GO TO 13
14 DHRP=DLR+DLR+SORTF(12.*EFRTH+11HRT-HRT))
13 CONTINUE

HTP=HT $ HRD=HR $ HLD=HLT $ HPP=HRT
CALL DEFRAF
GVD=GAIN(TET) $ GDD=20.*ALOG10(GVD)
SPD=11.INTF(DNM/1.1)*1.1+1. $ AMD=AWD+1SWP*D)
ATD=ARD=AMD
DZR=(AWD/SWP)
PRH=(AMD-GDD) $ WRH=10.*((PRH*1)
Z=ALOG10(WRH+2
C -----------LINE-OF-SIGHT-------------------------
CALL CLOS
SPD=SWP/2
C ----------BEYOND THE HORIZON CALCULATIONS-----------
KFD=0
DO 900 NSP=1+5
MZN=MIM(NSP)
IF (MZN.LE.0) GO TO 907
DO 901 MXS=1+MZN
D=SPD*CMK(IK) $ DNMS=SPD
IF (D.LT.DHRP) GO TO 17
DLR=D-DLT
HLR=HLT
TATER=((HLR-HRT)/DLR)-(DLR/2.*EFRTH))
TER=ATANF(TATER)
19 CONTINUE

IF (KFD-140.41.42
40 KS=0 $ KR=0
KS=1 $ ACID(KS)=ARD $ AND(KS)=DML
AMOD=MOD
EC1=HTE+EFRTH $ EC2=HRT+EFRTH $ EC3=HRT-HRT+EFRTH
CALL SORBE(1,EC1,EC3,EFRTH+DT,TER+RO1+RW1)
CALL SORBE(2,EC2,EFRTH+DL,TER+RO2+RW2)
REO=RO1+RO2 $ Rew=RW1+RW2 $ AA=GAO*REO+GAW*REW
RW1+REW
AAD(KS+1)
DO 30 KC=1+100
KS=K+1

179
\[ D = D \cdot N \cdot M \cdot \text{CMK}(K) \]
\[ \text{SPD} = \text{DNM} \]
\[ \text{ACD}(K) = \text{AE} + (\text{SLP} \cdot D) \]
\[ \text{AND}(K) = D \]
\[ \text{TWEND} = 20 \cdot \text{ALOG10}(D) \quad \text{ALFS} = \text{AFP} + \text{TWEND} \]
\[ \text{IF}(D > \text{DHRP}) \text{ GO TO } 44 \]
\[ \text{HLR} = \text{HLT} \]
\[ \text{DLR} = \text{DLT} \quad \text{TATER} = ((\text{HLT} - \text{HR}) / \text{DLR}) - (\text{DLR} / (2 \cdot \text{EFRTH})) \]
\[ \text{TER} = \text{ATAN} \left( \text{TATER} \right) \]

45 \text{CONTINUE}

\text{CALL SCATTER}
\text{SCT}(K) = \text{ALSC} - \text{ALFS}
\text{IF}(\text{SCT}(K) \geq \text{ALSC}) \text{ GO TO } 31
\text{KR} = \text{KR} + 1
\text{IF}(\text{KR} \leq 1) \text{ GO TO } 31
\text{KP} = \text{KS} - 1
\text{SSP} = (\text{SCT}(K) - \text{SCT}(K) \cdot (\text{AND}(K) - \text{AND}(K))
\text{IF}((\text{SSP} \cdot \text{LE}(1.01)) \text{ GO TO } 49
\text{IF}((\text{SSP} \cdot \text{LE}(\text{SLP})) \text{ GO TO } 48

31 \text{DNM} = \text{DNM} + 1

30 \text{CONTINUE}

\text{PRINT} 14 \quad \text{KFD} = 1 \quad \text{GO TO } 33

14 \text{FORMAT}(5X, \ast \ast \text{BEYOND THE 50 MILE LIMIT DOING DIFFRACTION} \ast \ast)

49 \text{KR} = 0 \quad \text{GO TO } 31

33 \text{DO } 43 \text{ KG} = 1 \cdot \text{KP}
\text{D} = \text{AND}(K) = D \cdot \text{CKN}(K)
\text{DNM} = D \cdot \text{DNM}
\text{TWEND} = 20 \cdot \text{ALOG10}(D) \quad \text{ALFS} = \text{AFP} + \text{TWEND}
\text{ATT} = \text{ACD}(K)
\AA = \text{AAD}(K) \quad \text{REW} = \text{REW}(K) \quad \text{THETA} = \text{TET} + \text{TET} + (D / \text{EFRTH})
\text{ASSIGN } 36 \text{ TO } \text{KT}
\text{GO TO } 200

36 \text{CONTINUE}

43 \text{CONTINUE}

\text{SPD} = \text{DNM} \quad \text{MZS} = 6 \quad \text{KFD} = 1 \quad \text{GO TO } 37

48 \text{IF}(\text{SCT}(K) > \text{ACD}(K)) \text{ GO TO } 33
\text{ACD}(K) = \text{SCT}(K)
\text{SLP} = (\text{ACD}(K) - \text{ARD}) / (\text{AND}(K) - \text{DML})
\text{AED} = \text{ACD}(K) \cdot (\text{AND}(K) \cdot \text{SLP})
\text{ASSIGN } 35 \text{ TO } \text{KT}
\text{DO } 34 \text{ KG} = 1 \cdot \text{KP}
\text{D} = \text{AND}(K) = D \cdot \text{CKN}(K)
\text{DNM} = D \cdot \text{DNM}
\text{TWEND} = 20 \cdot \text{ALOG10}(D) \quad \text{ALFS} = \text{AFP} + \text{TWEND}
\text{ATT} = \text{ACD} + (\text{SLP} \cdot D)
\text{AMOD} = \text{CMOD}
\AA = \text{AAD}(K) \quad \text{REW} = \text{REW}(K) \quad \text{THETA} = \text{TET} + \text{TET} + (D / \text{EFRTH})
\text{GO TO } 200

34 \text{CONTINUE}

37 \text{CONTINUE}

\text{AMOD} = \text{DNM}
\text{ASSIGN } 37 \text{ TO } \text{KT}
\text{ATD} = \text{ACD} + (\text{SLP} \cdot D)
\text{TWEND} = 20 \cdot \text{ALOG10}(D) \quad \text{ALFS} = \text{AFP} + \text{TWEND}
\text{IF}(D > \text{DHRP}) \text{ GO TO } 24
\text{HLR} = \text{HLT}
\text{DLR} = D \cdot \text{DLT} \quad \text{TATER} = ((\text{HLT} - \text{HR}) / \text{DLR}) - (\text{DLR} / (2 \cdot \text{EFRTH}))
\text{TER} = \text{ATAN} \left( \text{TATER} \right)

25 \text{CONTINUE}

\text{CALL SCATTER}
\text{ATS} = \text{ALSC} - \text{ALFS}

180
IF(A T SoLE*AT D) GO TO 46
ATTS = AT D $ TH ETA = T T + T E R + (D/EF R T H) $ GO TO 200
46 ATTS = ATS $ KFD = 2 $ AMOD = SMOD $ GO TO 200
42 CONTINUE
AMOD = SMOD
FDWEND = 2N + ALGSD101 D) $ ALFS = AFP + TWEND
CALL SCATTER
ATS = ALS C - ALFS $ ATTS = ATS $ ASSIGN 37 TO KT
200 CONTINUE
C ----------------------LONG-TERM POWER FA DING----------------------
IF(D LE DSLI) 311, 312
311 DEE = (130 * D) / DSLI $ GO TO 313
312 DEE = (130 + D) / DSLI $ GO TO 313
313 CALL VZD(D EE = QG1 + GQ9 + AD)
NCT = NCT + 1
PF S = E R P = ALFS
PL = - A T S
ALIM = 3
AL = 10 + PL + AD (13) $ AY = AL10 - ALIM
IF(AY LE L T01) AY = 0
DO 11 K = 1, 35
BD(K) = PL + AD(K) - AY
11 CONTINUE
DO 12 K = 1, 12
ALL M = ALM(K)
IF(BD(K) . GT . ALL M) BD(K) = ALL M
12 CONTINUE
C ----------------------VALUES PUT INTO ISOTROPIC POWER ARRAY--------
IF(K . LE . GT + 1) GO TO 20
20 P R S = P FS + ADD
PFL = PGS + PL - AA
PF Y(NCT) = DM $ PF Y (NCT + 2) = PG S $ PF Y(NCT + 3) = PFL
PF Y(NCT + 4) = BD(12) - PL $ PF Y (NCT + 5) = BD(18) - PL
PF Y(NCT + 6) = BD(24) - PL
IF(SPD . GT . DMAX) GO TO 907
GO TO KT(135, 36, 37)
17 CONTINUE
903 SPD = SPD + Y CON(NSP)
901 CONTINUE
SPD = SPD + Y CON(NSP)
NPP = N SP + 1
IF(NPP . GT . 5) GO TO 907
IF(YCON(NPP) . LE . 0) GO TO 907
IF(NPP . EQ . 0) GO TO 907
IXD = INTF(SPD/YCON(NPP))
SPD = (YCON(NPP) + FLOAT (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, 15
QAI(I) = BD(I) - PL
POA(I) = PI
21 CONTINUE
IF(TH ETA . LE . TP TH) GO TO 26
IF(TH ETA . GT . TP TH) GO TO 26
BK = FNAI(TH ETA + TP TH + TL TH + TPK + RDTH)
28 CONTINUE
CALL YIKK(BK, PQK, OK)
CALL CONCLUT(QA, OK, POA + 35 + 1 + 0 + PQC + QC)
DO 22 I=1,31
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=RDK $ GO TO 28
44 TER=TES $ DLR=DRP $ HLR=HRP $ TATER=TATES $ GO TO 45
58 TEH=TET+(DLT/EFRT)
   IF(ID=LE1) TEH=0.0
   QHS=ENS $ QHC=HLT-DRP $ QHA=HP $ QFS=HRP
   RT=TRACRAYS(TEH) $ DLR=SDD $ DML=DLT+DLR $ GO TO 59
C -------------------------------------------------ABORTION OF PROGRAM-------------------------
107 PRINT 106 $ PRINT 840 $ CALL EXIT
304 QGI=QG9=1.05 $ GO TO 106
END

RADEMS

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

C SUBROUTINE RADEMS(ARG,IDE,IMI,SEC)
C ROUTINE FOR MODEL AUG 73
C SUBROUTINE TO CHANGE RADANS TO DEGREES, MINUTES AND SECONDS

DE=ABS(ARG)*57.2957795
IDE=INT(DF1)
AMINT=60.*(IDE-FLOAT(IDE))
IMI=INT(AMINT)
SEC=(AMINT-FLOAT(AMINT))*60.
IF(SEC.GT.59.99991) GO TO 9
7 IF(IMI.GT.59) GO TO 8
6 IDE=5*SIGN(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.

182
FUNCTION RAYTRACTII

C ROUTINE FOR MODEL AUG 73
COMMON/RRTC/EINS+HRC+HAs+D
DIMENSION A(25),RI(25),EN(25),HS(25),TEI(25),R(25)

DATA(H=0.00+0.01+0.02+0.05+1.02+3.01+5.01+7.01+1.022+2.03+3.048+5.07+1
X0+2.0+3.0+4.0+5.0+7.0+1+110+100+225+350+750+1750)

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

DN=-7.32*EXP(0.00577*ENS) $ CE=LOGF(ENS/(ENS+DN))
AZ=6370.
DUM=0.0
AS=A+H+H
DO 10 I=1+25
  EN(I)=EXP(-CE*HI)
  R(I)=AZ+H(I)+H
10 CONTINUE

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

ENTRY TRACRAY

TE=IT
RC=AZ+H+H $ RA=AZ+H+H
ENC=+1.0E-6*ENS*EXP(-CE*H) $ RIC=1+ENC
ENA=+1.0E-6*ENS*EXP(-CE*H) $ RIA=1+ENA
BALL=0. $ ATE=TE
IF(TE.GE.0.0) GO TO 41
IF(R(I).LE.RC) GO TO 73
X=(R(I)-RC)/(RC-RI)
Z=(ENS-RI)/ENS
W=(EN(I)-EN)/RI
TEG=2.0*ASIN(SQR(2*X/R(I)) $ GO TO 72
72 IF(TE.GT.TEG) TE=TEG
  ATE=ARSF(TEG)
  IF(ATE.GE.0.0) GO TO 41
  DO 70 I=1+25
    Y=ALOSIF(I)*A(I+1) $ X=(R(I)-RC)/RC
    W=(EN(I)-EN)*COSF(ATE)/RI
    X=Y+Z-W
  IF(X.LT.0.0) GO TO 70
  DO 70 CT=SQR(2*H*C*X/R(I))
  IF(CT.LT.0.0) GO TO 60
  70 CONTINUE
B=2.0*ASIN(FT)
BALL=2.0*CT-A(I+1)/A(I+1)*1
TE=CT $ NK=I+1
DO 80 I=NK+25
RT=R(I) $ RIT=R(I)
IF(RI.GT.RC) GO TO 61
62 L=I-1
X=R(LI+LRI/RTRI)
TEI(LI+LACOSF(COSF(TEI(LI)))*X)
Y=X-A(I+1)/A(I+1)*X
B=ALL+LIEI(LI+LTFI(LI))$ X
NL=I
IF(RI.GT.RC) GO TO 40
80 CONTINUE
40 CONTINUE
Subroutine RECC is used in calculating reflective coefficients via (61) through (69), and (195).
IF(SI GE P12) GO TO 300
SISI = SINF(SI)
COSI = COSF(SI)
IF(SI = LE 0.0) GO TO 15
SOSI = SORF(SI)
16 IF(SI = GT 0.0) GO TO 19
IF(DH = LE 4.0) GO TO 17
SH = 7.0 DH = EXPF(-5.0 DH = 25)
18 IF(DH = GT 0.0) GO TO 30
SH = 7.0 DH = EXPF(-5.0 DH = 25)
19 IF(DH = GT 0.0) GO TO 30
DX = (SH = SIGF(FK/299 * 1925)
IF(DX = GT 0.0) GO TO 32
IF(DX = GT 0.0) GO TO 33
IF(DX = GT 0.0) GO TO 34
18 PD = 946.0 DX = DX = 0.01
36 CONTINUE
25 IF(TM = 7.0) 10 = 11 + 20
10 ASSIGN 12 TO N
GO TO 6
11 CONTINUE
ASSIGN 13 TO N
6 X = 18000.0 SGF1/SI FK
TRM = FP1 / (COSF F 1)
TUPS = SORF((TRM TRMP + X X) TRM
P = SORF(TUPS + 5.0)
GO TO N(12 = 13)
12 Q = X / (2.0 0)
DENOM = (P*P) + (Q*0)
B = 1.0 / DENOM
AM = (2.0 0) / DENOM
RS = (1.0 + (B SSI 1 SSI) / (1.0 + (B SSI 1 SSI) + (AM SSI)))
R = SORF(RS)
TOP = 0.0
BOT = SSI
P
CALL RTATAN(TOP , BOT, TRA)
TOP = Q
BOT = SSI
GO TO 14
13 Q = X / (2.0 0)
DENOM = (P*P) + (Q*0)
B = 1.0 / DENOM
AM = (2.0 0) / DENOM
RS = (1.0 + (B SSI 1 SSI) / (1.0 + (B SSI 1 SSI) + (AM SSI)))
R = SORF(RS)
TOP = (X SSI 1) - 0
BOT = SSI P
CALL RTATAN(TOP, BOT, TRA)
TOP = (X SSI) Q
BOT = SSI P
GO TO 14
14 CALL RTATAN(TOP, BOT, TRA)
P = TRA - TRP
IC = TRA TRP
15 SSSI = D GO TO 16
17 SH = 999.0 DH = GO TO 18
19 SH = 0.0 DX = 1.0 DH = GO TO 25
20 IC = 1
MP = 1.0 MP = 1.0 GO TO 11
21 RLMP = RETURN
22 IC = 2
RV = R PV = PIC MP = MP = 1.0 GO TO 10
23 IC = 0
RH = R PH = PIC
TEK = (((RV RV) + (RH RH) + (2.0 RH COSF(PH PV)))
IF(ER = LE 0.0) GO TO 30
R = SORF(TEK) /
71 TOP = (RH SINF(PH)) + (RV SINF PV)
BOT = (RH COSF(PH)) + (RV COSF PV)
IF(BOT = EQ 0.0) GO TO 24 .
CALL RTATAN(TOP+PC,PC)
P=PC $ GO TO 51
24 P=PI/2 $ GO TO 51
30 R=0.0 $ GO TO 31
32 PD=10.875*EXP(-3.88*DX)+0.01 $ GO TO 36
33 PD=1-1.06*DX+0.601 $ GO TO 36
34 PD=0.45*SQRT(F+0.00043-(DX-1.026)**2) $ GO TO 36
35 PD=6.15*DX $ GO TO 36
51 IF(MS*GF*1) GO TO 21
R=0*PD $ RETURN
52 IF(NP*EQ*2) GO TO 53
GO TO 51
53 CONTINUE
GO TO 51
300 SI=PI2 $ SI=1.0 $ COSI=0.0 $ SOSI=1.0 $ GO TO 16
301 SLO. $ SI=0.0 $ COSI=1.0 $ SOSI=0.0 $ 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
SUBROUTINE TO FIND ARCTANGENT IN THE CORRECT QUADRANT

PI=3.141592654
TWOPI=6.283185308
IF(IDENM)1121
IF(THPM)12176
IF(THPM)12129
IF(THETA+PI/2) GO TO 1A
IF(THETA-PI/2) GO TO 1A
IF(DENOM)1211+12
IF(THETA+PI) GO TO 1A
IF(DENOM)121A+14
IF(DENOM)121A+16
IF(THPM) 1A+1A
RETURN
1A ANGLE=PI-ANGLE $ RETURN
14 IF(DENOM)121A+1A
17 ANGLE-PI-ANGLE
18 RETURN
11 ANGLE=0.0
END
SUBROUTINE SCATTER

Subroutine SCATTER calculates basic transmission loss for scatter paths and is used in determining scatter attenuation (sec. A.4.4).

C ROUTINE FOR MODEL AUG 73

DIMENSION RE(2)
COMMON/PARAM/HFEN*HRFED*DLT*ENS*EFRTH*FREK*ALAM*THET*THFR*KD,
XGAS*GAW
COMMON/SCATSR/HTS*HRS*SUM*TWEND*THRK*HLT*HLR*THETA*HTP*AA*REW
FRP1=12.567

19 DLCT=DLT
IF (lX*LE*1) GO TO 10
THRT=THET+(DLCT/EFTRH)

22 DLCR=DLR
THOR=THET+(DLCR/EFTRH)

24 AOO=(D/(2.*EFTRH))+THET((HTS-HRS)/D)
BOO=(D/(2.*EFTRH))+THET-(HTS-HRS)/D)
DS=D-DFCT-DLCR
IF (DS*LE*1) DS=0.
THOO=AOO+BOO
DSR=((D*BOO)/THOO)-DLCT

25 DST=DSR-AABS(EFTRH*THRT)

26 DST=((D*AOO)/THOO)-DLCR

27 DSR=DSR-ABSF(EFTRH*THOTH)

28 CALL DELTA(THOT,DSR,ENS,DAO)
AO=AOO+DAO
CALL DELTA(THOR,DSR,ENS,DSR)
BO=BOO+DBO
S*AO/RO
THETA=AO+BO
VT=FRP1*HFEN*AO
VRK=FRP1*HRFED*BO
IF (5-1)*29*29+30

10 CONTINUE
S*1/S
VT*VTK
VRP*VTK
GO TO 31

29 CONTINUE
VT*VTK
VRP=VTK

31 TERM=(5*THETA)/(1+1)+(1+1)
HI=TFR*DS
HSMD=TFRM*DS
DTHL=DT*THETA
TR=EXPF((0000038*HSMD)**6)
T2=*031+(*00023*ENS)+(*0000056*ENS)
ETAS=(496*HSMD+4*TR2*TR1)
FO=1*086+(ETAS/HSMD)**(HSMD-M1)*HLT-HLR
IF (THETA*LE*0.) DTH=0.
VT=VTP/ALAM
C ---CALCULATION OF OXYGEN AND WATER VAPOR RAYS ---------

EC1#HTS=HTP*EFRTH $ EC2=HRS=HTP*EFRTH
HET=HTL=HTP*EFRTH $ HER=HRL=HTP*EFRTH
IF(DS#0.001)GO TO 11
14 CALL SORB(EC1#HET#EFRTH#DLT#HET#RE)
RE0=RE(1) $ REW=RE(2)
CALL SORB(EC2#HER#EFRTH#DLR#HER#RF)
RE0=RE0+RE(1) $ REW=REW+RE(2)
12 AA=GA#RE0#CAW#REW
RETURN
313 DRL=0. $ GO TO 314
10 THOT=THOR=0. $ DLR=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#HET#RE)
RE0=RE(1) $ REW=RE(2)
CALL SORB(EC2#HV#EFRTH#DAR#HER#RF)
RE0=RE0+RE(1) $ REW=REW+RE(2)
GO TO 17
END

SORB

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

Function TABLE is used to set up and obtain values from a table of grazing angle, \( \psi \); corresponding values of path length difference, \( \Delta r \); 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 S1
C ENTER DINTER WITH DELTA R AND GET DISTANCE
C ENTER SINTER WITH DISTANCE AND GET S1

COMMON/EGAP/IPLNIDTIXT
COMMON/SPLIT/L1=12,N=140,X=140,Y=140,D6=140,XS=55,YD=55,XR=55,YS
X=55,YD=55,YR=55,L3=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,YR,L2,AS,AD,AR,L3)
CALL TRMESH(AS,AD,AR,L5,ZS,ZD,ZR,L3,YD,D6)
M=N
DO 21 I=1,N
SD=Y(I)*57.29577951
71 CONTINUE
TABL=DUM $ RETURN

101 FORMAT(3I5) "OUT OF RANGE FOR INTERPOLATION"
ENTRY TINTER
IF(XINT-X(1)) GT 7+1+2
1 YINT=Y(1)
   TABL=YINT $ RETURN
2 K=1
3 IF(XINT-X(K+1)) GT 6+4+5
4 YINT=Y(K+1)
   TABL=YINT $ RETURN
5 K=K+1
6 YINT=(XINT-X(K))*Y(K+1)-Y(K))/(X(K+1)-X(K))+Y(K)
   TABL=YINT $ RETURN
```

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TERP

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

```fortran
DIMENSION A(1),B(1),C(1),R(1),S(1),T(1),X(1),Y(1),Z(1)
N=0
DO 10 I=1,NA+1
9 X(I)=A(1)  Y(I)=B(1)  Z(I)=C(1)  I=I+1
IF(I.GT.NA+1)GO TO 12
8 X(I)=R(I)  Y(I)=S(I)  Z(I)=T(I)  J=J+1
IF(J.GT.NR)GO TO 12
7 X(I)=A(1)  Y(I)=B(1)  Z(I)=C(1)  I=I+1  J=J+1
IF(I.GT.NA)GO TO 12
6 X(I)=R(I)  Y(I)=S(I)  Z(I)=T(I)  I=I+1  J=J+1
IF(J.GT.NR)GO TO 12
5 X(I)=R(I)  Y(I)=S(I)  Z(I)=T(I)  I=I+1  J=J+1
IF(I.GT.NA)GO TO 12
4 X(I)=R(I)  Y(I)=S(I)  Z(I)=T(I)  I=I+1  J=J+1
IF(I.GT.NA)GO TO 12
3 X(I)=R(I)  Y(I)=S(I)  Z(I)=T(I)  I=I+1  J=J+1
IF(I.GT.NA)GO TO 12
2 X(I)=R(I)  Y(I)=S(I)  Z(I)=T(I)  I=I+1  J=J+1
IF(I.GT.NA)GO TO 12
1 X(I)=R(I)  Y(I)=S(I)  Z(I)=T(I)  I=I+1  J=J+1
IF(I.GT.NA)GO TO 12
CONTINUE
GO TO 12
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).
```
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(I),R(I),X(I)
  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)12,9
  11 IF(J.GT.NR)3,4
  5 LI=J
   DO 16 LI=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(DEC31,G9,A)

DIMENSION B(35)

1*Y(35)*A(30):

CROUTINE FOR MODEL AUG 73

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

DATA(C1=2.49E-4,5.26E-4,1.59E-5)
DATA(C2=3.70E-9,1.47E-6,1.56E-11)
DATA(C3=1.0E-7,7.5E-7,5.77E-8)
DATA(CN1=2.06+1.97,2.32)
DATA(CN2=2.98+2.31+4.36)
DATA(CN3=3.15+2.90+3.25)
DATA(FN=1.2+5.4+0.9)
DATA(FM=8.4,10.6+3.9)

12 DO 13 I=1,31
X=FIN(I)+FM(I)-FIN(I)*EXPFI-C2(I)*DE**CN(I)

13 Z(I)=EXPF(I)*C3(I)*DE**CN(I)+X

Y(I)=Z(I)/X

DO 18 K=1,35

Y(K)=Y(I)*Z(K)

CONTINUE

RETURN

END
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 NAKAGAMI-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),1=1,35)-.000,.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,.9999,.99995,.99998,.99999)
AVER(T+XN+YN1+XN1) = (YN1*(T-XN) - YN*(T-XN1))/(XN1-XN)

1 CONTINUE
1 I = 1+1
IF(T - VF(I)) 3,2,1
DO 4 J = 1,35
V(J) = VF(J+1)
4 PV(J) = P(J)
GO TO 6

2 IF(I.EQ.1) GO TO 2
3 IF(1+1) GO TO 2
DO 5 J = 1,35
V(J) = AVF(VF(J+1)+1)+VF1+1)+VF(J+1)+VF1+1)
5 PV(J) = P(J)
6 DO 7 J = 1,35
7 V(J) = V(J)
RETURN
END
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/TAH

This table is used by subroutine HCHNOT.

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<td>415</td>
<td>615</td>
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<td>4125</td>
<td>5410</td>
<td>6650</td>
<td>9650</td>
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<td>615</td>
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<td></td>
<td>2000</td>
<td>460</td>
<td>670</td>
<td>1550</td>
<td>4770</td>
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<td>670</td>
</tr>
<tr>
<td></td>
<td>1900</td>
<td>490</td>
<td>730</td>
<td>1930</td>
<td>5430</td>
<td>7060</td>
<td>9350</td>
<td>12800</td>
<td>4500</td>
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</tr>
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<td></td>
<td>1800</td>
<td>520</td>
<td>790</td>
<td>2200</td>
<td>6120</td>
<td>7960</td>
<td>10700</td>
<td>14800</td>
<td>4570</td>
<td>100</td>
<td>790</td>
</tr>
<tr>
<td></td>
<td>1700</td>
<td>550</td>
<td>850</td>
<td>2500</td>
<td>6810</td>
<td>8870</td>
<td>12100</td>
<td>16800</td>
<td>4630</td>
<td>100</td>
<td>850</td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td>590</td>
<td>920</td>
<td>2850</td>
<td>7500</td>
<td>9780</td>
<td>13500</td>
<td>18800</td>
<td>4700</td>
<td>100</td>
<td>920</td>
</tr>
<tr>
<td></td>
<td>1500</td>
<td>640</td>
<td>990</td>
<td>3200</td>
<td>8200</td>
<td>10700</td>
<td>15900</td>
<td>20800</td>
<td>4770</td>
<td>100</td>
<td>990</td>
</tr>
</tbody>
</table>

---

**B. 4.2. TABLES**

This table is used by subroutine HCHNOT.
This table is used by subroutine FDTIA.
This table is used by subroutines FDASP and YIKK.

<table>
<thead>
<tr>
<th>TABLE VF</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Value</th>
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</tr>
</thead>
<tbody>
<tr>
<td>-400000</td>
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</tr>
<tr>
<td>-02487</td>
<td>-02357</td>
</tr>
<tr>
<td>-02255</td>
<td>-02148</td>
</tr>
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<td>-01998</td>
<td>-01878</td>
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<tr>
<td>-01750</td>
<td>-01568</td>
</tr>
<tr>
<td>-01417</td>
<td></td>
</tr>
</tbody>
</table>
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 catalogued in section 13.4. Many are similar to those used in [17, 18, 20, 31, 40, 47]. 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.

\[
\begin{align*}
1 \text{ foot} &= 3.048 \times 10^{-2} \text{ kilometer} \\
1 \text{ statute mile} &= 5280 \text{ feet} \\
1 \text{ statute mile} &= 1.609344 \text{ kilometers} \\
1 \text{ nautical mile} &= 1.852 \text{ kilometers} \\
1 \text{ radian} &= 57.29577951 \text{ degrees}
\end{align*}
\]

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.

\[
\begin{align*}
a &= \text{Effective earth radius (km) calculated from (20).} \\
a_a &= \text{An adjusted effective earth radius (km) calculated using (44) and shown in figure 16.} \\
a_0 &= \text{Actual earth radius, 6370 km to about three significant figures.} \\
a_y &= \text{An effective earth radius (km) used in figure 21 and defined for different path types in section A.4.5.} \\
a_{1,2} &= \text{Effective earth radii from (88).} \\
a_{3,4} &= \text{Effective earth radii from (91).} \\
\text{ANT.} &= \text{Antenna (fig. 6).}
\end{align*}
\]
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_a$</td>
<td>Atmospheric absorption (dB) from (172).</td>
</tr>
<tr>
<td>$A_d$</td>
<td>Attenuation (dB) associated with diffraction over terrain, from (144).</td>
</tr>
<tr>
<td>$A_{do}$</td>
<td>Intercept (dB) for the beyond-the-horizon combined diffraction attenuation line, from (143).</td>
</tr>
<tr>
<td>$A_{dx}$</td>
<td>$A_d$ dB at $d_x$, from (144).</td>
</tr>
<tr>
<td>$A_e$</td>
<td>Effective area (dB - sq. m) of an isotropic antenna (sec. 3.2.1 footnote) from (9).</td>
</tr>
<tr>
<td>$A_{e,q,t}$</td>
<td>Angles (rad) defined and used in figure 21 only.</td>
</tr>
<tr>
<td>$A_{ek}$</td>
<td>Knife-edge diffraction attenuation (dB) for path $p = e$ (122).</td>
</tr>
<tr>
<td>$A_h$</td>
<td>Attenuation (dB) used in (122).</td>
</tr>
<tr>
<td>$A_K$</td>
<td>Attenuation (dB) associated with beyond-the-horizon knife-edge diffraction, from (125).</td>
</tr>
<tr>
<td>$A_{KK}$</td>
<td>Knife-edge diffraction for path $p = K$ (fig. 20), from (119).</td>
</tr>
<tr>
<td>$A_{ko}$</td>
<td>Intercept (dB) for the beyond-the-horizon knife-edge diffraction attenuation line, from (124).</td>
</tr>
<tr>
<td>$A_{K5}$</td>
<td>Knife-edge diffraction loss $f_5$ expressed in decibels from (134).</td>
</tr>
<tr>
<td>$A_{ML}$</td>
<td>Combined diffraction attenuation (dB) at $d_{ML}$, from (136).</td>
</tr>
<tr>
<td>$A_o$</td>
<td>Intercept (dB) for the within-the-horizon combined diffraction attenuation line, from (139).</td>
</tr>
<tr>
<td>$A_{pr}$</td>
<td>Attenuation (dB) of rounded earth diffraction for path $p$, from (105).</td>
</tr>
<tr>
<td>$A_{pro}$</td>
<td>Intercept (dB) of rounded earth diffraction line for path $p$, from (104).</td>
</tr>
<tr>
<td>Arcsin</td>
<td>Inverse sin $\omega$ (rad), principal value.</td>
</tr>
<tr>
<td>$A_{rK}$</td>
<td>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).</td>
</tr>
<tr>
<td>$A_{rML}$</td>
<td>Rounded earth diffraction attenuation (dB) obtained from (105) with parameters for path $p=K$ (fig. 20) and $d_p = d_{ML}$.</td>
</tr>
<tr>
<td>$A_{r5}$</td>
<td>Rounded earth diffraction attenuation (dB) obtained from (105) with parameters for path $p=K$ (fig. 20) and $d_p = d_5$.</td>
</tr>
</tbody>
</table>
As Terrain attenuation (dB) associated with forward scatter (169).

$A_s$ dB at $d_x$, from (169).

$A_{sx}$ 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).

$A_{3,4}$ Attenuation (dB) from (102).

$A_5$ Combined diffraction attenuation (dB) at $d_5$, from (136).

$A_6$ Combined diffraction attenuation (dB) at $d=d_L + d_{ELS}$, 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).
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dB-W/sq m (DB-W/SQ M)</td>
<td>Units for power density in terms of decibels greater than 1 W/sq m, $10 \log$ (power density expressed in watts per square meter).</td>
</tr>
<tr>
<td>dBW (DBW)</td>
<td>Power (dB) greater than unit power (W), $10 \log$ (power expressed in watts).</td>
</tr>
<tr>
<td>$d_c$</td>
<td>Counterpoise diameter (km).</td>
</tr>
<tr>
<td>$d_{ds}$</td>
<td>Distance (km) beyond the radio horizon at which diffraction and scatter attenuation are approximately equal for a smooth earth, from (175).</td>
</tr>
<tr>
<td>$d_e$</td>
<td>Effective distance (km) from (177).</td>
</tr>
<tr>
<td>$d_{eLs}$</td>
<td>$d_{PLs}$ km for path $p = e$ (fig. 20), from (117).</td>
</tr>
<tr>
<td>$d_{eL1,2}$</td>
<td>$d_{PL1,2}$ km for path $p = e$ (fig. 20), from (116).</td>
</tr>
<tr>
<td>$d_o$</td>
<td>The largest distance (km) in the line-of-sight region at which diffraction effects associated with terrain are considered negligible, from (140).</td>
</tr>
<tr>
<td>$d_p$</td>
<td>Great Circle distance (km) for path $p$ (fig. 20).</td>
</tr>
<tr>
<td>$d_{pL}$</td>
<td>Total horizon distance (km) for path $p$ from (85).</td>
</tr>
<tr>
<td>$d_{pLs}$</td>
<td>Total smooth earth horizon distance (km) for path $p$ (sec. A.4.3).</td>
</tr>
<tr>
<td>$d_{PL1,2}$</td>
<td>Radio horizon distances (km) for path $p$ (sec. A.4.3).</td>
</tr>
<tr>
<td>$d_{rt}$</td>
<td>Distance (km) from the horizon to the aircraft as shown in figure 13 and used in (40).</td>
</tr>
<tr>
<td>$d_{sL}$</td>
<td>Smooth earth horizon distance (km) for facility horizon shown in figure 15 and calculated from (37).</td>
</tr>
<tr>
<td>$d_{s1,2}$</td>
<td>Distances (km) calculated from (153).</td>
</tr>
<tr>
<td>$d_x$</td>
<td>A distance (km) just beyond the radio horizon where $A_s \approx 20$ dB and $M_s &lt; M_d$.</td>
</tr>
<tr>
<td>$d_{D,U}$</td>
<td>Great Circle distance (n mi) from aircraft to desired and undesired facility, respectively (fig. 4).</td>
</tr>
<tr>
<td>$d_{KLs}$</td>
<td>$d_{PLs}$ km for path $p = K$ (fig. 20) as per (112).</td>
</tr>
<tr>
<td>$d_{KL1,2}$</td>
<td>$d_{PL1,2}$ (108) and (109).</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>$d_{LoR}$</td>
<td>Distance (km) discussed prior to (173).</td>
</tr>
<tr>
<td>$d_{Lo1,2}$</td>
<td>Smooth earth horizon distances (km) calculated from (173) or (174).</td>
</tr>
<tr>
<td>$d_{Ls1}$</td>
<td>Facility smooth earth horizon distance (km) from (24).</td>
</tr>
<tr>
<td>$d_{Ls2}$</td>
<td>Aircraft smooth earth horizon distance (km), from (33).</td>
</tr>
<tr>
<td>$d_{L1}$</td>
<td>Facility-to-horizon distance (km) shown in figure 13; determined from figure 14 and from (23) or (26).</td>
</tr>
<tr>
<td>$d_{L2}$</td>
<td>Aircraft-to-horizon distance (km) shown in figure 15 and determined from (38).</td>
</tr>
<tr>
<td>$d_{L5}$</td>
<td>A distance (km) from (128).</td>
</tr>
<tr>
<td>$d_M$</td>
<td>A distance (km) from (176).</td>
</tr>
<tr>
<td>$d_{ML}$</td>
<td>Maximum line-of-sight distance (km shown in fig. 13) from (40).</td>
</tr>
<tr>
<td>$d_3$</td>
<td>A distance (km) from (86).</td>
</tr>
<tr>
<td>$d_4$</td>
<td>Distance (km) used in rounded earth diffraction calculation (87).</td>
</tr>
<tr>
<td>$d_5$</td>
<td>A distance (km) from (129).</td>
</tr>
<tr>
<td>DME</td>
<td>Distance Measuring Equipment (fig. 2), an air navigation aid used to provide aircraft with distance information.</td>
</tr>
<tr>
<td>D/U</td>
<td>Desired-to-Undesired signal ratio (dB) available at the terminals of an ideal (lossless) isotropic receiving antenna (sec. 3.1.2).</td>
</tr>
<tr>
<td>D/U(q)</td>
<td>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).</td>
</tr>
<tr>
<td>D/U(0.5)</td>
<td>D/U(q) dB at median (q=0.5) level, from (12).</td>
</tr>
<tr>
<td>$D_s$</td>
<td>Distance (km) between radio horizons, calculated via (159).</td>
</tr>
<tr>
<td>$D_{1,2}$</td>
<td>Distances (km) shown in figure 16 and calculated via (51).</td>
</tr>
<tr>
<td>$\exp(\ )$</td>
<td>Exponential; e.g., $\exp(2) = e^2$.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Definition</td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
</tr>
<tr>
<td>E</td>
<td>East longitude (fig. 3 only).</td>
</tr>
<tr>
<td>EIRP</td>
<td>Equivalent Isotropically Radiated Power (dBW) calculated using (1).</td>
</tr>
<tr>
<td>ERP</td>
<td>Effective Radiated Power (sec. 3.1.1), 2.15 dB less than EIRP.</td>
</tr>
<tr>
<td>f</td>
<td>Frequency (MHz).</td>
</tr>
<tr>
<td>ft</td>
<td>feet</td>
</tr>
<tr>
<td>ft-MSL</td>
<td>Elevation (ft) above MSL.</td>
</tr>
<tr>
<td>ft-ss</td>
<td>Elevation (ft) above facility site surface.</td>
</tr>
<tr>
<td>( f_g,c )</td>
<td>Knife-edge diffraction loss factors determined with subroutine FRENEL from ( v_g,c ), used in (78) and (79).</td>
</tr>
<tr>
<td>( f_h )</td>
<td>Knife-edge diffraction loss factor obtained for ( v_h ) via subroutine FRENEL (sec. 13.4.1), used in (122).</td>
</tr>
<tr>
<td>( f_{m,2,\infty} )</td>
<td>Parameters defined following (178).</td>
</tr>
<tr>
<td>( f_{oh} )</td>
<td>Elevation angle correction factor, from (179).</td>
</tr>
<tr>
<td>( f_5 )</td>
<td>Knife-edge diffraction loss factor obtained for ( v_5 ) from subroutine FRENEL (sec. B.4.1), used in (134).</td>
</tr>
<tr>
<td>F</td>
<td>Fade margin (dB) from (197).</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration.</td>
</tr>
<tr>
<td>FORTRAN</td>
<td>FORmula TRANslating &quot;language&quot; or coding used with computers in lieu of &quot;machine language&quot;. Many such languages are used and FORTRAN itself has several variations.</td>
</tr>
<tr>
<td>( F_{AY} )</td>
<td>Reflection reduction factor associated with ( A_Y ), from (191).</td>
</tr>
<tr>
<td>( F_{d\theta} )</td>
<td>Attenuation function (dB) obtained from subroutine FDTEMA (sec. B.4.1), used in (169).</td>
</tr>
<tr>
<td>( F_{d\omega} )</td>
<td>Reflection reduction factor associated with diffuse reflection, from (194).</td>
</tr>
<tr>
<td>( F_0 )</td>
<td>Correction term (dB) in scatter attenuation which allows for the reduction of scattering efficiency at greater heights in the atmosphere (164).</td>
</tr>
</tbody>
</table>
\[ F_{1,2} \] Parameters (dB) from (101).

\[ F_{\text{sh}} \] Specular reflection reduction factor associated with surface roughness, from (66).

\[ F_{\Delta r} \] Reflection reduction factor associated with \( \Delta r \), 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 \( \theta_e \) set to \( \theta_h \) from (57) for line-of-sight paths or \( \theta_e \) from figure 14 for beyond-the-horizon paths.

\[ g_D \] Normalized voltage gain for facility antenna from (67) with \( \theta_e = \theta_h \) from (58).

\[ \text{GHz} \] Gigahertz \((10^9 \text{ Hz})\).

\[ G_A \] 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.

\[ G_{e\phi 1,2} \] \( G_{\phi 1,2} \) 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).

\[ G_{\text{H1,2}} \] Values (dB) for the residual height gain function (sec. A.4.3) from subroutine GHBAR (sec. B.4.1), used in (119).

\[ G_{K\phi 1,2} \] Values (dB) of the residual height gain function for path \( K \) from subroutine GHBAR, used in (122).

\[ G_{p\phi 1,2} \] 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 (23).

\[ h_{\text{a2}} \] 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).

$h_{el1}$ Effective height (km) of facility antenna above the effective reflection surface, from (111).

$h_{el2}$ 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).

$h_{ml,2}$ $h_{pel,2}$ 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).

$h_{Ke1,2}$ $h_{pel,2}$ 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).
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h_{1,2}$</td>
<td>Facility antenna height $h_1$, or aircraft altitude in kilometers above msl (fig. 13).</td>
</tr>
<tr>
<td>$H_{c,q,t,z}$</td>
<td>Heigths (km) defined and illustrated in figure 21.</td>
</tr>
<tr>
<td>$H_0$</td>
<td>Frequency gain function (dB) obtained from subroutine HCHOT (sec. B.4.1), used in (169).</td>
</tr>
<tr>
<td>$H_v$</td>
<td>Height (km) of scattering volume above effective reflection surface, from (171).</td>
</tr>
<tr>
<td>$H_1$</td>
<td>An antenna height (km) shown in figure 16, from (48).</td>
</tr>
<tr>
<td>$H_2$</td>
<td>An antenna height (km) shown in figure 16, from (47).</td>
</tr>
<tr>
<td>$H_{1,2}'$</td>
<td>Heights (km) shown in figure 16, from (52).</td>
</tr>
<tr>
<td>$H_{y1,2}$</td>
<td>Heights (km) used in figure 21 and defined for different path types in section A.4.5.</td>
</tr>
<tr>
<td>ILS</td>
<td>Instrument Landing System (sec. 3.1.1), an air navigation aid used in landing.</td>
</tr>
<tr>
<td>ITS</td>
<td>Institute for Telecommunication Sciences.</td>
</tr>
<tr>
<td>$j$</td>
<td>$\sqrt{-1}$.</td>
</tr>
<tr>
<td>JTAC</td>
<td>Joint Technical Advisory Committee.</td>
</tr>
<tr>
<td>km (km)</td>
<td>Kilometer ($10^3$ m).</td>
</tr>
<tr>
<td>$k_a$</td>
<td>An adjusted earth radius factor, from (43).</td>
</tr>
<tr>
<td>$K_d$</td>
<td>A parameter calculated from (93).</td>
</tr>
<tr>
<td>$K_t$</td>
<td>K value associated with tropospheric multipath, from (198) or (201).</td>
</tr>
<tr>
<td>$K$</td>
<td>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 $Y_{\mu}(q)$, from (6).</td>
</tr>
<tr>
<td>$K_{ML}$</td>
<td>K value at the radio horizon. Used in (201).</td>
</tr>
<tr>
<td>$K_{1,2,3,4}$</td>
<td>Parameters calculated from (94).</td>
</tr>
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</table>
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.

$\min$ Minute (deg/60).

$mhos/m$ Conductivity (mho) per unit length (m).

$msl$ Mean sea level.

$M_d$ Slope (dB/km) of combined diffraction line for beyond-the-horizon, from (142).

$MHz$ 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).
Ms  Slope (dB/km) of $A_v$ versus $d$ curve, determined using successive $A_v$ calculations for distances greater than $d_{ML}$. Discussed following (144).

MK  Slope (dB/km) for the beyond-the-horizon knife-edge diffraction line, from (123).

Mc  Slope (dB/km) of the $K$ value line used just beyond the radio horizon (200).

ML  Slope (dB/km) of the diffraction attenuation line used just inside the radio horizon, from (83).

n mi  Nautical mile.

(N MI)  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).

No  Minimum monthly mean surface refractivity (N-units) referred to msl (fig. 3).

Ns  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).

PI  Power (dBW) available at the terminals of an ideal (lossless) isotropic receiving antenna, from (3).

PRO  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
Shortest facility to aircraft ray length (km); calculated as \( r \) 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).

\( r_{1eo,w} \) Partial effective ray lengths (km) for oxygen or water vapor absorption calculations; calculated using the relationships given in figure 21.

\( r_{2eo,w} \) 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 (70) or counterpoise from (79) reflection.

\( \text{RTA-2} \) A TACAN antenna type.

\( s \) Path asymmetry factor in forward scatter (158).

\( \text{sec} \) Secant (1/cos).
sec  Second (min/60).
(Sec)
sin  Sine.
ss  Facility site surface.
(SS)
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_α,β  Parameters calculated from (165) and (166).
v_1,2  Parameters calculated from (167) and (168).
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<th>Description</th>
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<td>$V_5$</td>
<td>A knife-edge diffraction parameter, from (133).</td>
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<td>$V_{e}(0.5, d_e)$</td>
<td>Variability adjustment term (dB), from (190).</td>
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<tr>
<td>VOR</td>
<td>VHF Omni Range (sec. 3.1.1), an air navigation aid used to provide aircraft with bearing information.</td>
</tr>
<tr>
<td>VHF</td>
<td>Very High Frequency (30 to 300 MHz).</td>
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<tr>
<td>$V(0.5)$</td>
<td>A parameter (dB) from (178).</td>
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<td>W</td>
<td>West longitude (fig. 3 only).</td>
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<tr>
<td>$W_{a}$</td>
<td>A weighting factor used in combining knife-edge and rounded earth diffraction attenuations, from (135).</td>
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<tr>
<td>$W_{R}$</td>
<td>A relative power level for the Rayleigh fading component associated with surface reflection multipath (sec. A.6), from (196).</td>
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<tr>
<td>$W_{R0}$</td>
<td>A relative power level associated with the ray optics formulation used in the line-of-sight region, from (81).</td>
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<td>$W_{1,2}$</td>
<td>Parameters calculated from (97).</td>
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<td>x</td>
<td>A parameter calculated from (92).</td>
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<td>$x_{1,2}$</td>
<td>Parameters (km) calculated from (96).</td>
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<td>$Y_{1,2}$</td>
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<tr>
<td>$Y_{e}(q)$</td>
<td>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 $Y_{e}(q)$.</td>
</tr>
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</table>
$Y_{DU}(q)$  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).

$Y_n(q)$  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).

$Y'_X(q)$  Total variability (dB greater than median) of received power about its median, $Y'_X(0.5)=0$, 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).

$\alpha$  An angle (rad) shown in figure 16 and calculated from (53).

$\alpha_0$  An angle (rad) from (154).

$\alpha_{oo}$  An angle (rad) from (147).

$\beta$  An angle (rad) used in figure 21 and defined for different path types in section A.4.5.
\( \beta_0 \) An angle (rad) from (155).

\( \beta_{oo} \) 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).

\( \Delta \alpha_0 \) An angle (rad) obtained via subroutine DELTA (sec. B.4.1), used in (154).

\( \Delta \beta_0 \) An angle (rad) obtained via subroutine DELTA (sec. B.4.1) used in (155).

\( \Delta h \) Terrain parameter (km) estimated using table 3, which is used [32, sec. 2.2] to characterize terrain. It is an asymptotic value of \( \Delta h_d \).

\( \Delta h_a \) An adjusted effective altitude correction factor from (46).

\( \Delta h_e \) Effective altitude correction factor (km) which is specified as input (sec. 3.1.1) or calculated from (45).

\( \Delta h_d \) 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].

\( \Delta h_{ft} \) \( \Delta h \) expressed in feet (table 3).

\( \Delta h_m \) \( \Delta h \) expressed in meters (table 3).

\( \Delta N \) Refractivity gradient (N-units/km) used in defining exponential atmospheres, from (30).

\( \Delta r \) Path length difference (km) for rays shown in figure 16 \((r_{12} - r_0)\) that is calculated from (56).

\( \Delta r_{g,c} \) \( \Delta r \) km from (56) for earth or counterpoise reflection.

\( \varepsilon \) Dielectric constant from table 2.

\( \varepsilon_c \) Complex dielectric constant from (61).

\( n \) A parameter from (162).
\( n_s \) A parameter from (163).

\( \theta \) Angular distance (rad) from (156).

\( \theta_{ce} \) An angle (rad) from (70) and shown in figure 17.

\( \theta_{e1,2} \) \( \theta_{pel,2} \) rad for path \( p = e \) (fig. 20) as per (118).

\( \theta_{er} \) Elevation angle of reflecting point at facility antenna, from (58).

\( \theta_{e1} \) Elevation angle (rad) of horizon at facility (fig. 13); determined using figure 14, from (21) or (27).

\( \theta_{e2} \) Horizon elevation angle (rad) at aircraft, from (39).

\( \theta_{e5} \) An angle (rad) from (131).

\( \theta_h \) Elevation angle (rad) of aircraft at facility (fig. 16), from (57) and (126).

\( \theta_{kc} \) An angle (rad) calculated via (76) and shown in figure 18.

\( \theta_{kg} \) An angle (rad) from (72) and shown in figure 17.

\( \theta_{K1,2} \) \( \theta_{pel,2} \) rad for path \( p = k \) (fig. 20) as per (113).

\( \theta_L \) Elevation angle (rad) of aircraft at facility horizon (fig. 17), from (41).

\( \theta_{pe} \) An angle (rad) from (89).

\( \theta_{pel,2} \) Horizon elevation angles (rad) for path \( p \), described following (88) (sec. A.4.3).

\( \theta_s2 \) An angle (rad) shown in figure 15, from (35).

\( \theta_v \) Diffraction angle (rad) for the \( h \), to \( h_{ee2} \) path shown in figure 20, from (126).

\( \theta_o \) An angle (rad) from (59).

\( \theta_{oo} \) An angle (rad) from (149).

\( \theta_{oll,2} \) Angles (rad) from (150).
\( \theta_{1,2} \) Angles (rad) shown in figure 16 and calculated from (50).
\( \theta_{3,4} \) Angles (rad) from (90).
\( \theta_6 \) First approximation (127) for angle \( \theta_6 \).
\( \lambda \) Wavelength (km) from (73).
\( \lambda_m \) Wavelength (m) from (10).
\( \pi \) The constant 3.141592654.
\( \sigma \) Conductivity (mho/m) from table 2.
\( \sigma_n \) 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].
\( \phi \) Phase advance associated with complex earth reflection coefficient, from (63).
\( \phi_c \) Phase lead (rad) associated with counterpoise reflection, from (69).
\( \phi_g \) Phase lead (rad) associated with earth reflection, from (68).
\( \phi_{kg,c} \) Knife-edge diffraction phase shift determined with FRENEL from \( \psi_{g,c} \).
\( \phi_{Tg,c} \) Phase lead (rad) of adjusted (for counterpoise edge effects) effective reflection coefficient from (80) for earth or counterpoise reflection.
\( \psi \) Grazing angle (rad) shown in figures 16 and 17.
\( \psi_c \) Grazing angle (rad) for reflection from counterpoise.
\( \sim \) Approximately.
\( (\ )^\circ \) Degrees, e.g., 12\(^\circ\).
\( \% \) 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.

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