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Jammer Effectiveness Model

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PREFACE

This work was sponsored by the United States Army National Ground Intelligence Center, Charlottesville, Virginia, under contract P94-91017.

Certain commercial equipment and programs are identified in this report to adequately explain the operation of the program. In no case does such identification imply recommendation or endorsement by the National Telecommunications and Information Administration, nor does it imply that the program or equipment identified is necessarily the best available for this application.

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JAMMER EFFECTIVENESS MODEL

Janet Geikas and Nicholas DeMinco*

The Jammer Effectiveness Model (JEM) is a Windows-based computer program which provides an integrated procedure for modeling propagation effects on telecommunication links and the effect of a jammer on communication links and networks. JEM provides the user with the ability to define equipment such as transmitters, receivers and antennas and then use these definitions in a variety of analyses. JEM can be used easily after only a short learning period.

Key words: jammer, jamming, propagation, communications system models, electronic warfare, countermeasures

1. INTRODUCTION

The Institute for Telecommunication Sciences (ITS) is involved in model development and analysis of the effectiveness of communication links. The first generation of such computer models was called ETSEM (EHF Telecommunication System Engineering Model) [1]. ETSEM modelled the cumulative distribution of bit error rate for digital systems and the signal-to-noise ratio in the worst voice channel for analog systems for terrestrial line-of-sight (LOS) communication links.

Though well-suited for its purpose, ETSEM lacked the potential for expanding to other types of communication paths or allowing modification of output options. The proliferation of personal computers (PCs) generated a need for a simple to use and easy to update computer program that would run on a PC. With this goal in mind, the Analysis of Microwave Operational Scenarios (AMOS) [2] was developed. AMOS is a DOS model which predicts system performance in the 1-100 GHz range. This model has analysis capability for cumulative distribution of clear air attenuation [1, 3, 4], cumulative distribution of rain attenuation [1, 3], cumulative distribution of multipath attenuation [5], diffraction [6], and troposcatter [7].

The size of AMOS stretched the resources of the DOS environment. Thus, with the advent of Windows and the desire to include jamming analyses, the Jammer Effectiveness Model (JEM) was developed. The user interface is programmed in Visual Basic, which is a Windows-based, event-driven programming tool. The analyses are written in FORTRAN and called from Visual Basic using Dynamic Link Libraries (DLLs). The Jammer Effectiveness Model includes all of the analysis capabilities of AMOS and additional jamming scenarios. (At this time, the analyses

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that were included in AMOS still run as a shell from Windows to DOS.) The jamming analyses in JEM are valid in a frequency range of 2 MHz to 20 GHz. At frequencies of 30 MHz or greater, losses are calculated by the Irregular Terrain Model (ITM) [8, 9]. For frequencies less than 30 MHz, ground wave losses are calculated using GW84 [10] and skywave losses are calculated using the Ionospheric Communications Analysis and Prediction Program (IONCAP) [11].

2. RUNNING ENVIRONMENT

JEM requires Windows 3.1 running on an IBM-compatible PC with graphics resolution of 1024 x 768 and 256 colors. Because of speed considerations, it is suggested that the user have a 486 with at least 4 megabytes of RAM. VBRUN300.DLL, MHRUN300.DLL and any .VBX files supplied with JEM must reside in the WINDOWS\SYSTEM directory. The executable and data files that make up JEM must reside in a directory on the C drive named C:\VBEXE. These files add up to approximately 6.5 megabytes. The initial user database is a subdirectory of VBEXE named C:\VBEXE\US. Begin the program by running JEM.EXE.

3. DEFINITIONS

3.1 Help

An on-line help facility is available by clicking any window or button with the right mouse button. Use the left mouse button for all other operations. See Appendix A for a list of Visual Basic errors.

3.2 Scenarios

A scenario is a collection of data on which the user may run an analysis. The data gives details that describe a transmitting site, a receiving site, and in the case of the Jamming and Jammer vs. Network scenarios, a jamming site. There are six scenario types. These include:

The scenarios valid at frequencies between 2 MHz and 20 GHz:
- Jamming
- Jammer vs. Network;

and those valid at frequencies between 1 and 100 GHz:
- Earth-Satellite
- Ground-Aircraft
- Aircraft-Satellite
- Terrestrial (Ground-Ground).

3.3 Types of Analyses

The analyses that are available within each scenario type are:

Jamming

Jammer Footprint: Produces a polar plot of the maximum distance at which the jammer is effective in jamming a receiver/transmitter pair separated by a user-specified distance.

Isopower Contours: Produces a plot of one or more user-specified constant jammer power density levels at the receiver versus azimuth angle about the jammer.

Received Signal Power vs. Distance: Computes received power level versus distance from a transmitter.

Received Jammer Power vs. Distance: Computes received power level vs. distance from a jammer.

Jammer vs. Network

Jammer vs. Network: Computes the effect of a jammer on a network of communication links.

Earth-Satellite

Cumulative Distribution of Rain Attenuation: Calculates the cumulative distribution of the rain attenuation over the range of months specified by the user for a fixed satellite location.

Cumulative Distribution of Clear Air Attenuation: Calculates the cumulative distribution of the clear air attenuation over the range of months specified by the user for a fixed satellite location.

Ground-Aircraft

Attenuation & Received Signal Loss - Loop on Frequency: Calculates the attenuation and RSL for a single point on a flight path for a range of frequencies specified by the user.

Attenuation & Received Signal Loss - Loop on Flight Path: Calculates the attenuation and RSL for a single operating frequency for a set of points in a user-specified aircraft flight path.

Cumulative Distribution of Rain Attenuation: Computes the cumulative distribution of the rain attenuation for a single point on the aircraft flight path and for a single operating frequency specified by the user.

Cumulative Distribution of Clear Air Attenuation: Computes the cumulative distribution of the clear air attenuation for a single point on the aircraft flight path and for a single frequency specified by the user.

Aircraft-Satellite

Attenuation & Received Signal Loss - Loop on Flight Path: Calculates the attenuation and RSL for a single frequency for a set of points on an aircraft flight path.

Attenuation & Received Signal Loss - Loop on Frequency: Calculates the attenuation and RSL on a path between an aircraft and a satellite for a range of frequencies specified by the user.

Attenuation & Received Signal Loss - Loop on Matched Paths: Calculates the attenuation and RSL for a single frequency for a set of user specified matched points for an aircraft flight path and for an orbit path.

Terrestrial (Ground-Ground)

Cumulative Distribution of Rain Attenuation: Calculates the cumulative distribution of rain attenuation over the range of months specified by the user.

Cumulative Distribution of Multipath Attenuation: Calculates the cumulative distribution of multipath attenuation over the range of months specified by the user.

Terrain Profile & Ray Path Plot: Uses the terrain profile data created by the user to define and plot the terrain of a terrestrial path. With this information, the user can then plot the path as well as the ray path and its user-specified Fresnel clearance envelope. The analysis also allows the user to calculate necessary antenna heights in order to ensure the specified Fresnel clearance for this path.

Cumulative Distribution of Clear Air Attenuation: calculates the cumulative distribution of clear air attenuation over the range of months specified by the user.

Troposcatter Attenuation: Calculates either the median long-term troposcatter loss or the median long-term diffraction loss for terrestrial paths that are beyond the horizon. It returns the attenuation of whichever propagation loss is lower.

Link Margin Calculations: Determines the link margin for a terrestrial path for each of the 12 months of the year.

3.4 Equipment

There are 15 kinds of equipment available in JEM. These are the building blocks of the scenario. Each piece of equipment is identified by a name given by the user. Below is a list of equipment types.

Ground Stations	Aircraft Platforms	Satellite Platforms
Receivers	Transmitters	Antennas
Air Jammers	Ground Jammers	Climate Profiles
Horizon Profiles	Atmospheric Profiles	Terrain Profiles
Aircraft Flight Paths	Satellite Orbits	Antenna Patterns

4. FILE OPERATIONS

4.1 Naming Equipment and Scenarios

Each piece of equipment and each scenario is identified by a name given by the user. The names for the following types of equipment are limited to 8 characters using only acceptable DOS characters: Atmospheric Profiles, Horizon Profiles, Aircraft Flight Paths, Orbit Profiles, Terrain Profiles and Antenna Patterns. These equipment files are distinguishable from the others because the files are indeterminate in length. JEM appends a suffix to these names and writes a DOS file. The user should not use a suffix in these names. For the other types of equipment and all the

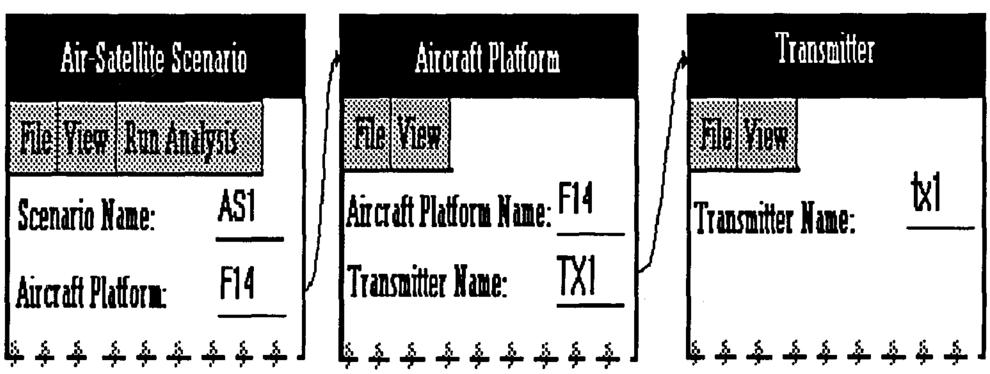

Figure 1. Building a scenario.

scenario types, the name can be 1-30 characters and may include spaces and special characters. Figure 1 is an example showing how a scenario is built using equipment. You see a partial listing of an Air-Satellite Scenario named AS1. This scenario asks for an Aircraft Platform name. The user has typed in F14. F14 refers to an Aircraft Platform which, in turn, refers to a transmitter named TX1. Notice that upper and lower case is not significant. As you build a scenario you may enter equipment names that do not yet exist. Thus, it is not critical whether you define your scenarios or your equipment first. However, if a particular piece of equipment is undefined when the you try to perform an analysis, an error message will be displayed.

4.2 Displaying Equipment and Scenarios

The beginning screen in JEM is shown below in Figure 2. To quit, click on the "Quit" button at any time. For an explanation regarding the "Set Database" button, see Section 4.4. To display either a scenario or a certain equipment type, click twice on your choice.

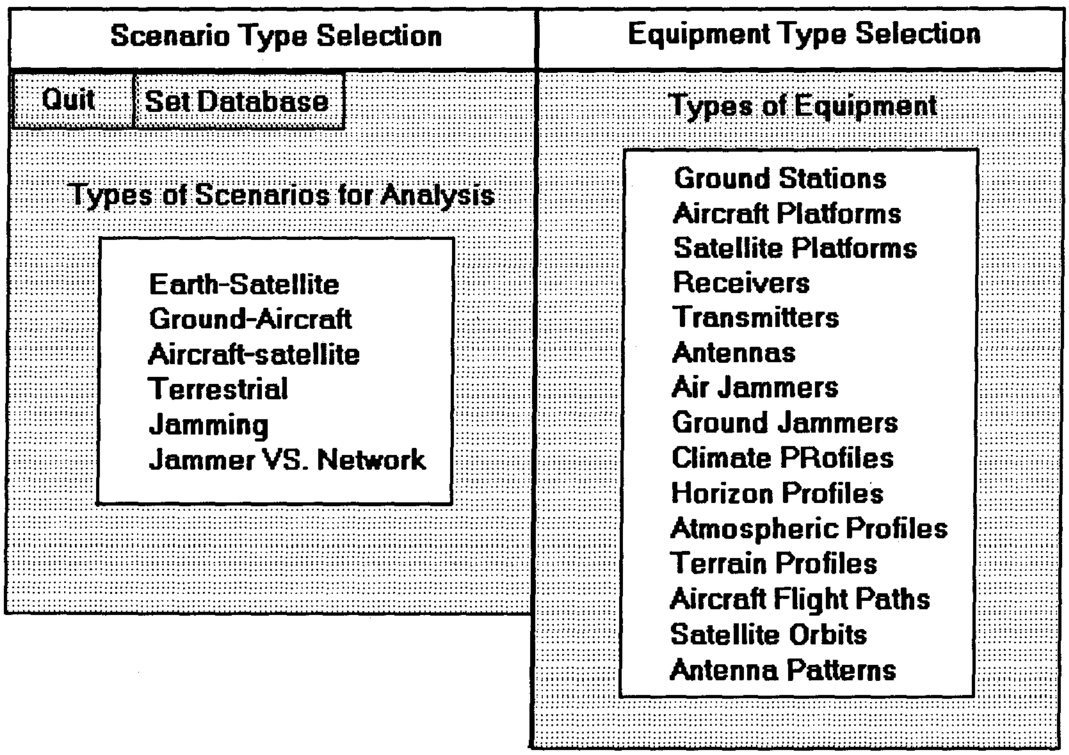

Figure 2. Initial screen of JEM.

The next window shown will be a list of those files that exist in the Current User Database. As an example, clicking twice on "Transmitters" in the Types of Equipment list will produce a list of transmitters such as the one shown below in Figure 3. This particular list indicates that there are three transmitters defined in the Current User Database. To view and edit any one, click twice on your choice. To create a new transmitter, click on the button at the bottom. Notice the arrow

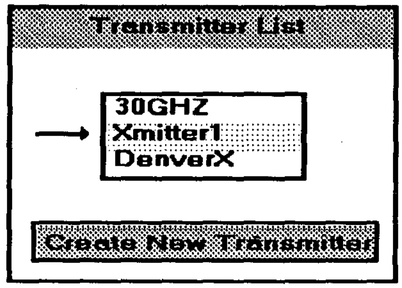

Figure 3. Example of files listed in current user database.

at the left of the list. It is pointing to the currently highlighted transmitter name and may be used to "drag and drop" (rather than type) this name into other equipment where a transmitter name is expected.

4.3 Saving, Deleting, and Copying

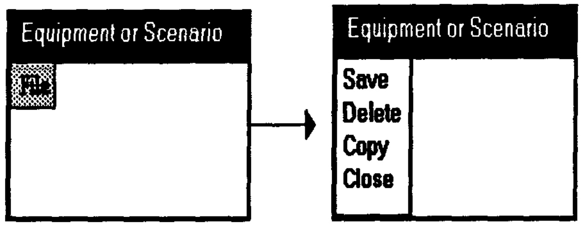

Figure 4. Saving, deleting, and copying

Every equipment and scenario window has a "File" button. Clicking that button with the left mouse button causes a menu to appear as shown above in Figure 4. Click twice on your menu selection.

Save: Writes the scenario or equipment file to the current User Database.

Delete: Removes the scenario or equipment file from the current User Database.

Copy: Copies the scenario or equipment file to another file within the current User Database or to a file in another User Database. The user may choose to rename the file.

Close: Closes the window.

4.4. User Database

Data within JEM is organized in files that detail scenarios and equipment types. These files are stored within User Databases (UDB). A User Database is a DOS directory specifically named within JEM as a User Database. There can be any number of User Databases and the directories can be located on any drive. Equipment and scenario names must be unique within a User Database, that is, there cannot be two transmitters in any User Database named Xmitter. However, a transmitter named Xmitter in UDB1 and a transmitter named Xmitter in UDB2 are distinct entities. The UDB from which JEM is working is called the Current User Database. JEM can interface only with files that are in the Current User Database, although files may be copied by JEM from one UDB to another. Note that the files are written in JEM format and the user should <u>not</u> try to edit any JEM file outside of JEM.

4.4.1 Selecting, Creating, or Deleting a User Database

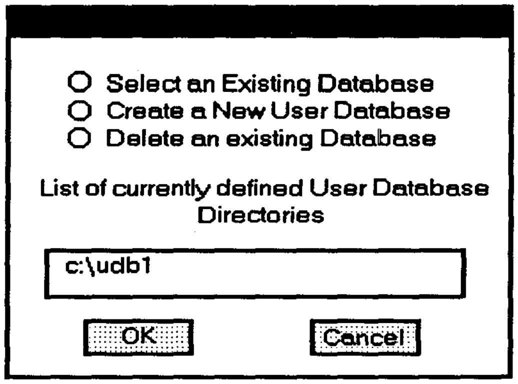

Figure 5. User database window.

Push "Set Database" (See Figure 2) to produce the window as shown above in Figure 5.

Select a database: To select a database (i.e. to make an existing database the Current User Database), click on "Select an Existing Database," highlight your choice from the list of currently defined User Database Directories, and click on OK.

Delete a database: To delete a database, click on "Delete an existing Database," highlight your choice from the list of currently defined User Database Directories, and click on OK. You will be given the option of erasing files and the directory.

Create a new database: To create a new UDB, click on "Create a New User Database" and click on OK. You will be shown a window as in Figure 6. To create a database in a directory that already exists, choose a drive from the Drive List, choose a directory from the Directory List, and click on OK.

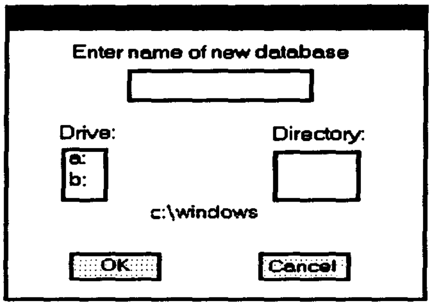

Figure 6. Naming a new database.

Create a new database in a new directory: To create a database in a directory that does not currently exist, choose a drive from the Drive List and choose a directory from the Directory List as above. The directory you are creating will be a subdirectory to the one chosen. Now, type in a directory name in the box at the top of the window and click on OK. In either case, the directory you have chosen is displayed in the lower center (C:\Windows in this example).

5. SCENARIO DEFINITIONS

Each scenario consists of certain data values and equipment names as described below. An analysis will retrieve the data that is included in a scenario and that which is contained within the equipment named by the scenario. Each scenario window has buttons named "File," "View," and "Run Analysis." The functions of the "File" button have been described in Section 4.3. Clicking on "View" presents a menu permitting the user to open a window containing a piece of equipment defined in the scenario. To run an analysis, click on "Run Analysis."

5.1 Jamming Scenarios

Jamming scenarios consist of 3 sites: a transmitter, a receiver, and a jammer. Each of these sites may be ground-based (stationary) or airborne (moving). The format of a jamming scenario is dependent upon these choices which are made at the time of scenario creation. You should

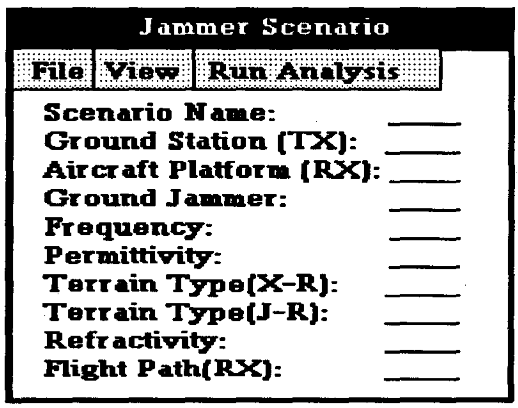

Figure 7. Jamming scenario.

differentiate between a transmitting site or receiving site and between transmitter or receiver equipment type. Figure 7 above shows a Jamming scenario (before values have been filled in) with the transmitter on a ground site as indicated by the requirement of a Ground Station (Tx). The receiver is on an aircraft as indicated by the requirement of an Aircraft Platform (Rx). The jammer is on a ground site as indicated by the requirement of a Ground Jammer. Note that a flight path is required for each airborne site. See Section 5.4 for a description of each entry.

5.2 Jammer vs. Network Scenarios

A Jammer vs. Network scenario (Figure 8) consists of from two to five ground station sites called

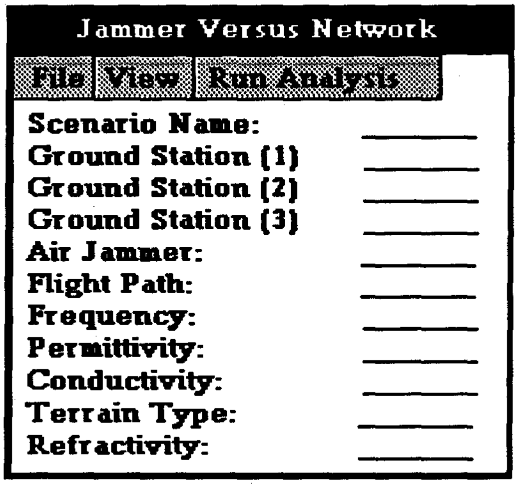

Figure 8.
Jammer vs. Network scenario.

nodes. Each node acts as both a transmitting and receiving site. The jammer may be either a ground jammer (stationary) or an air jammer (moving). The choices of number of nodes and jammer type are made at the time of scenario creation and cannot be changed later. A flight path is required if an air jammer is chosen. See section 5.4 for a description of each entry. After all equipment is fully defined, you may perform an analysis by clicking on the "Run Analysis" button.

5.3 Air-Satellite, Earth-Satellite, Ground-Air, and Terrestrial Scenarios

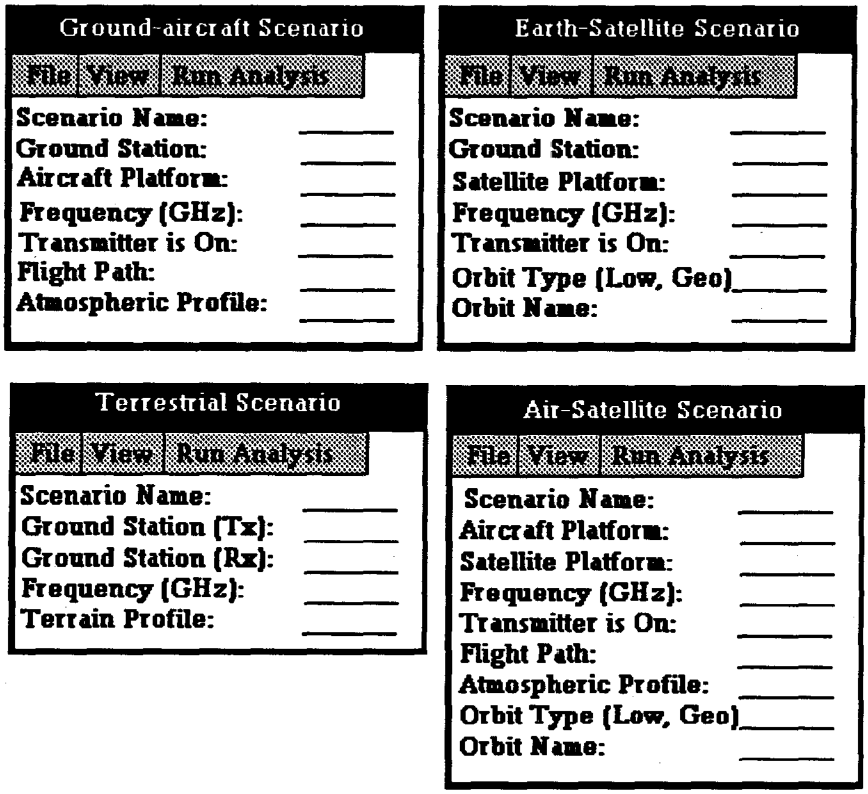

Figure 9. Air-Satellite, Earth-Satellite, Ground-Air, and Terrestrial scenarios.

The four scenarios illustrated in Figure 9 above are characterized by a transmitting site and a receiving site. The location of these sites will determine your choice of scenario type. Thus, if one site is airborne and the other site is on the ground, you would elect to build a Ground-Aircraft scenario. To see equipment that is named in the scenario, click on "View." After all equipment is fully defined, you may perform an analysis by clicking on "Run Analysis." See Section 5.4 for a description of each entry.

5.4 Explanation of Entries

Once a particular scenario window is in view, you can enter or edit values by clicking on any line on the right of the window and typing in the appropriate values. Below are comments on the values to be entered. Note that each name refers to a piece of equipment that has been or will be created within the current database.

Scenario Name: Enter a name of your choice (30 characters or less), unique for this scenario type.

Ground Station: Enter a name (30 characters or less) that refers to a ground station. This is one end of the communications link for all scenarios except Air-Satellite.

Aircraft Platform: Enter a name (30 characters or less) that refers to an aircraft platform. This is one end of your communications link for Ground-Air, Air-Satellite, and some of the jamming scenarios.

Satellite Platform: Enter a name (30 characters or less) that refers to a satellite platform. This is one end of your communications link for Earth-Satellite and Air-Satellite scenarios.

Air Jammer: Enter a name (30 characters or less) that refers to an air jammer.

Ground Jammer: Enter a name (30 characters or less) that refers to a ground jammer.

Frequency: Insert the frequency of your system. The default units are GHz, but you may type in MHz or kHz. The frequency of all equipment used to build a scenario must be identical.

Transmitter is On: This clarifies the site of transmission. Pressing any key when the focus is on this line will show a menu enabling you to specify your choice of sites.

Flight Path: Enter a valid DOSname that refers to an Aircraft Flight Path file. This file defines the path for an aircraft or air jammer named in the scenario.

Atmospheric Profile: Enter a valid DOS name that refers to an Atmospheric Profile that has been or will be created within the Current User Database.

Climate Profile: Enter a valid DOS name that refers to a Climate Profile that has been or will be created within the Current User Database.

Horizon Profile: Enter a valid DOS name that refers to a Horizon Profile that has been or will be created within the Current User Database

Terrain Profile: Enter a valid DOS name that refers to a Terrain Profile.

Orbit Type: Enter the word "Geo" (geosynchronous orbit) or "Low."

Orbit Name: Enter a valid DOS name that refers to a Satellite Orbit file.

Permittivity/Conductivity: The values of permittivity and conductivity are selected in tandem. Pressing any key when the cursor is on these lines causes a menu to appear. You make your selection by clicking and the values will automatically appear on the correct lines. Permissible values for permittivity and conductivity are:

	Relative Permittivity(ε_r)	Conductivity (Siemens/m)
Average Ground	15.	.005
Poor Ground	4.	.001
Good Ground	25.	.020
Fresh Water	81.	.010
Sea Water	81.	5.00

Terrain Type: Pressing any key when the cursor is on these lines causes a menu to appear. Permissible values for terrain type are:

	Delta H
Flat	
Plains	30
Hills	90
Mountains	200
Rugged Mountains	500

Delta H is a parameter used to characterize the statistical aspects of terrain irregularity for frequencies greater than 30 MHz.

Refractivity: Pressing any key when the cursor is on this line causes a menu to appear. Values for refractivity are:

	NS	K Factor
Equatorial	360	1.53
Continental Subtropical	320	1.38
Maritime Subtropical	370	1.58
Desert	280	1.29
Continental Temperate	301	1.33
Maritime Temperate	320	1.38
Maritime Temperate (over sea)	350	1.49

NS is the mean surface refractivity.
K Factor is the ratio of the effective earth's radius to the actual earth's radius.

6. EQUIPMENT

6.1 Ground Stations, Aircraft Platforms, and Satellite Platforms

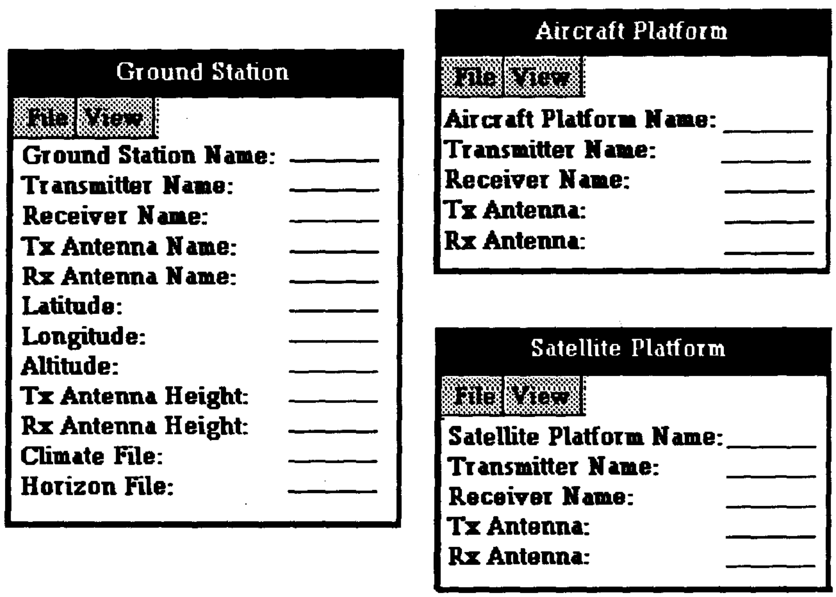

Figure 10. Ground Station, Aircraft Platform, and Satellite Platform windows.

The types of equipment shown in Figure 10 define the transmitting or receiving sites for a particular scenario. See Section 6.2 for comments on each entry.

6.2 Ground Jammers and Air Jammers

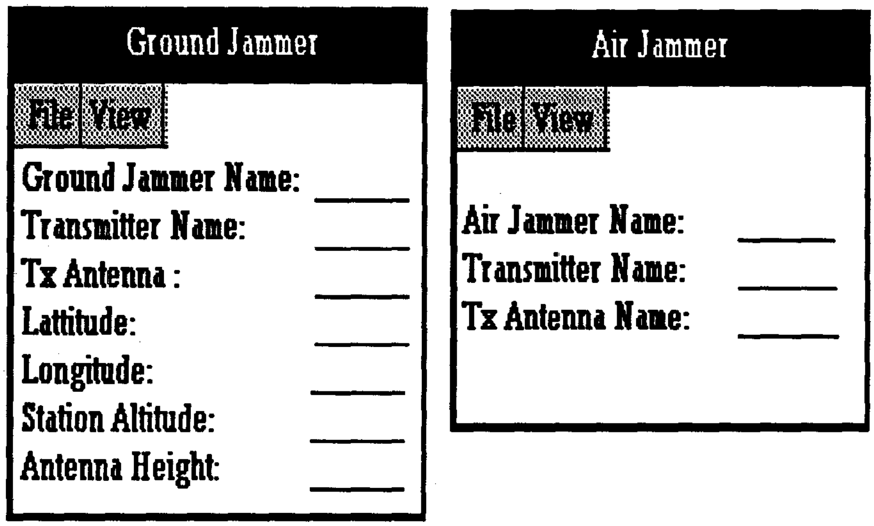

Figure 11. Ground Jammer and Air Jammer windows.

The types of equipment shown in Figure 11 define the jamming site. Use the ground jammer for a stationary jammer and the air jammer for a jammer which is moving. A flight path which defines points along the path, will be associated with the air jammer in the scenario.

Ground Station Name: Defines a name of your choice (30 characters or less), unique for ground stations within this database.

Aircraft Platform Name: Defines a name of your choice (30 characters or less), unique for aircraft platforms within this database.

Satellite Platform Name: Defines a name of your choice (30 characters or less), unique for satellite platforms within this database.

Ground Jammer Name: Defines a name of your choice (30 characters or less), unique for ground jammers within this database.

Air Jammer Name: Defines a name of your choice (30 characters or less), unique for air jammers within this database.

Transmitter Name: Defines a name of your choice (30 characters or less), unique for transmitters within this database.

Receiver Name: Defines a name of your choice (30 characters or less), unique for receivers within this database.

Tx Antenna: A name (30 characters or less) that refers to an antenna that has been or will be created within the Current User Database. The Tx antenna and Rx antennna may be the same.

Rx Antenna: A name (30 characters or less), that refers to an antenna that has been or will be created within the Current User Database. The Tx antenna and Rx antennna may be the same.

Latitude: Pressing any key will bring forth a template in which to enter the latitude in degrees, minutes, seconds, direction (DD,MM,SSD) format.However, jammer analyses ask for locations so you may choose not to enter it here.

Longitude: Pressing any key will bring forth a template in which to enter the longitude in degrees, minutes, seconds, direction (DDD,MM,SSD) format. However, jammer analyses ask for locations so you may choose not to enter it here.

Station Elevation: Altitude of ground above mean sea level. Default units are meters, although feet are also acceptable (type feet or ft, e.g., 300 ft). You may choose not to enter this value here for jamming and jammer vs. network scenarios.

Antenna Height: Height above ground. Default units are meters, althought feet are also acceptable (type feet or ft).

6.3 Transmitters

Figure 12 illustrates a transmitter window.

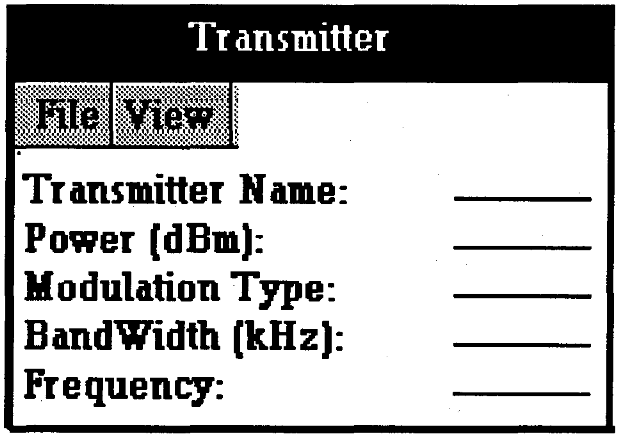

Figure 12. Transmitter window.

Transmitter Name: Enter a name of your choice (30 characters or less), unique for transmitters within this database. Use this name to refer to this transmitter in other equipment.

Power: Enter the power in dBm associated with this transmitter.

Modulation Type: Press any key when the cursor is on this line to see a menu of accptable modulation types. Valid types are: CW, FM AM, RADAR, PULSE, BPSK, QPSK, CPFSK, and SS.

Bandwidth: Enter the instantaneous bandwidth for this transmitter in kHz.

Frequency: Insert frequency of this transmitter. The default units are GHz, but you may enter MHz or kHz. The frequencies of all equipment within a scenario must be equal.

6.4 Receivers

Figure 13 is an example of a receiver window.

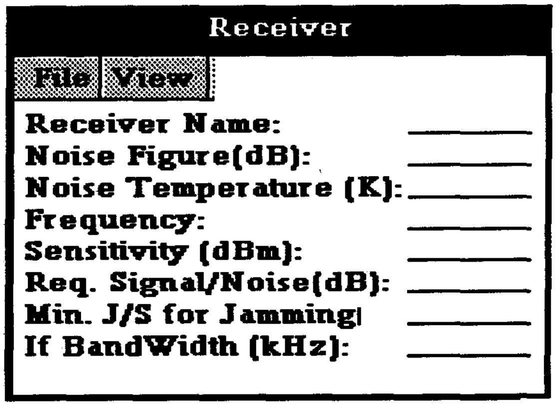

Figure 13. Receiver window.

Receiver Name: A name of your choice (30 characters or less), unique for receivers within this database. Use this name to refer to this receiver in other equipment.

Noise Figure (NF): This is ten times the log of the noise factor (dB).

Noise Temperature (NT): This is the temperature, in Kelvins, corresponding to the noise figure as defined above. These two values are interrelated so that if you enter one the other will change. The relationship is:

$$NF(dB) = 10 \ Log(1 + NT/290).$$

Frequency: Insert frequency of this receiver. The default units are GHz, but you may enter MHz or kHz.

Sensitivity: The minimum signal in dBm that this receiver can detect.

Required Signal to Noise: The ratio in dB of signal power in the occupied bandwidth to the noise power level required for communication.

Minimum Jammer/Received Signal: A ratio in dB of the minimum jammer signal power level to the signal power level at which the receiver can no longer operate.

IF Bandwidth: Enter the bandwidth for this receiver in kHz.

6.5 Antennas

Figure 14 reflects the window that defines an antenna.

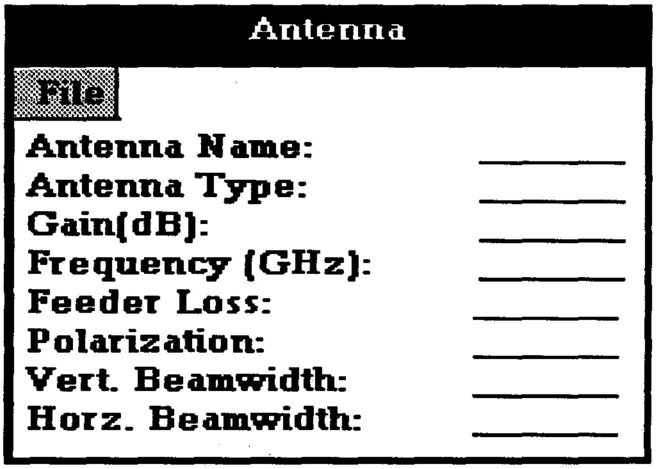

Figure 14. Antenna window.

Antenna Name: A name of your choice (30 characters or less), unique for antennas within this database. This name can be used in other equipment files to refer to this antenna.

Antenna Type: Pressing any key when focus is on this line will show a menu of available types which include Sloping Vee, Inverted L, Monopole, Half-Wave Dipole, Discone, Yagi and user input. If the frequency is 30 MHz or less, you must choose Sloping Vee, Inverted-L, Monopole, or Log Periodic. In this circumstance ($f \leq 30$ MHz) JEM selects an antenna pattern based on antenna type, permittivity, conductivity and frequency.

Gain: This is the antenna gain over an isotropic antenna in decibels (dBi).

Frequency: Insert frequency of this antenna. The default units are GHz, but you may type in MHz or kHz.

Feeder Loss: Enter feeder loss of this antenna.

Polarization: Pressing any key when focus is on this line will show a menu enabling you to select horizontal or vertical polarization.

Vert. Beamwidth: Enter 3 dB vertical beamwidth. Not used in jamming scenarios.

Horz. Beamwidth: Enter 3 dB horizontal beamwidth. Not used in jamming scenarios.

6.6 Antenna Patterns

An antenna pattern reflects gain values for 360 degrees about an antenna (Figure 15). The interval of degrees at which gain values are entered is established at the time the antenna pattern is created. The interval may be 1, 2, 5, or 10 degrees. To edit the gain values, click on the degree value in the list and then edit the gain value in the gain box. If the Symmetrical Option is chosen, setting a gain value at a certain degree will cause the gain at it's reflexive position about the Y-axis to be set to the same value. Many antenna pattern files are supplied with JEM. You may

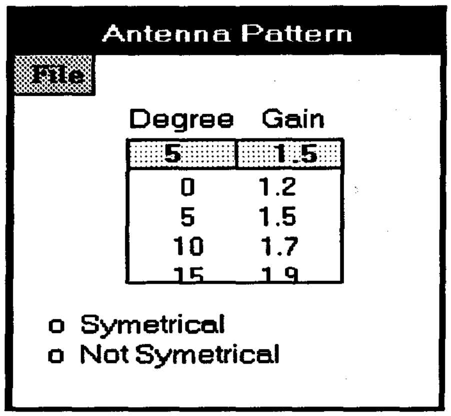

Figure 15. Antenna pattern.

view these files but not edit them. The names of these files are encoded according to the following two configurations. Configuration No. 1 is V*type* or H*type*, where H and V stand for horizontal or vertical polarization and *type* is monopol, dipole, discone, yagi, or logper(log periodic). "Hyagi" is an example of this type. JEM uses these patterns when frequency > 30 MHz and antenna type is as indicated.

Configuration No. 2 has the format HFttnFx where *tt* refers to the type, *n* refers to a permittivity/ conductivity pair and *x* equals the frequency in MHz. See Table 1 for definitions of *tt* and Table 2 for definitions of *n*. JEM chooses these patterns for frequency ≤ 30 MHz according to type, permittivity/conductivity and frequency. Thus the name "HFIL3F24" indicates a pattern for an Inverted L antenna with frequency = 24 MHz, permittivity = 25, and conductivity = .02 s/m.

tt	type
IL	Inverted L
SL	Sloping Vee
LP	Log Periodic

Table 1. *tt* = Antenna Type

n	Perm.	Cond (s/m)
1	15	.005
2	4	.001
3	25	.02
4	81	.01
5	81	5.00

Table 2. *n* = Permittivity/Conductivity

6.7 Flight Paths

A Flight Path Profile is used to define points along a path for an air platform or air jammer (Figure 16). A profile may contain any number of points. Points can be defined in either of two ways: latitude, longitude and altitude or azimuth, range and altitude. Latitude and longitude values are decimal values. Altitude is meters above mean sea level.

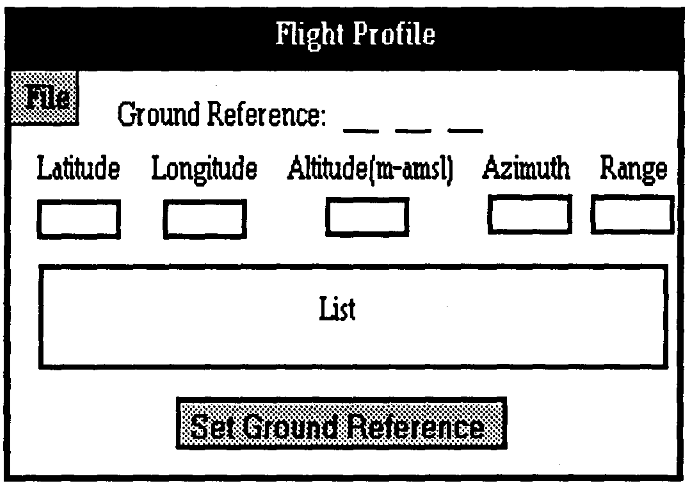

Figure 16. Aircraft Flight Path Profile.

To add a new set of values: Click on the line after the last entry in the list.

To edit values: All editing of values is done in the five boxes labelled Latitude, Longitude, Altitude, Azimuth and Range. Clicking on any set of values in the list causes those values to be displayed in the boxes for editing.

Using Azimuth/range mode: In order to enter values in the azimuth-range mode, a ground reference point (latitude, longitude, altitude) must be defined. To do so, click the "Set Ground Reference" button. You will be given templates to help you enter your values. Your azimuth values will be degrees east of due north from the reference point to path point. Range is kilometers between the two points. When you enter azimuth-range values, JEM computes the latitude and longitude. JEM writes the file using latitude and longitude and then translates each entry to azimuth-range when the file is reopened. Thus, slight changes in value may occur because of computation.

6.8 Terrain Profiles

Terrain Profiles are used in Terrain (Ground Station to Ground Station) scenarios (Figure 17). This file defines the terrain along the path from transmitter station to receiver station. Each entry in the list defines one point. There may be any number of points.

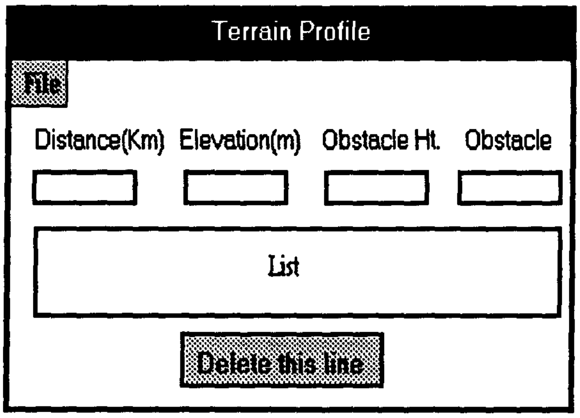

Figure 17. Terrain Profile.

Distance(km): A positive decimal value specifying distance from transmitter.

Elevation(meters): A decimal value specifying elevation at this point.

Obstacle Ht (meters): A decimal value specifying height of obstacle if present.

Obstacle: An alpha field to identify obstacle. This field may be left blank.

To add a new line of data: Enter a new value for distance. That line will be placed in the appropriate spot (sorted according to distance).

To edit data on an existing line: Click on the desired line so that it is highlighted. The current values will be shown in the boxes. You may edit the values in these boxes.

To delete an existing line: Click on the desired line so that it is highlighted. Then click the "Delete this line" button.

6.9 Atmospheric Profiles

An Atmospheric Profile is used in a Ground-Aircraft or Air-Satellite Scenario and describes the layers of atmosphere (Figure 18).

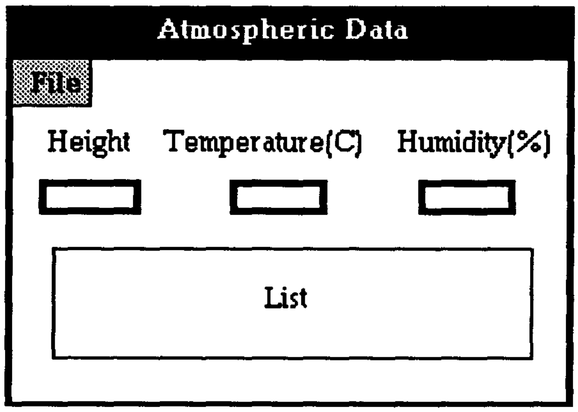

Figure 18. Atmospheric Profile.

Height: This is the height of the lowest point of this layer of the profile. Units are kilometers above the ground, not above sea level.

Temperature: The temperature is in degrees Celsius for this layer.

Humidity: Relative humidity in percent (0 to 100) for this layer. Do not enter the % sign.

To add a new line of data: Enter desired value in the Height box. The data is sorted according to height. JEM will place a new line at the appropriate place in the file according to the value entered.

To edit and delete: See instructions for terrain profiles, Section 6.8.

6.10 Horizon Profiles

Figure 19 shows the window which displays a Horizon Profile.

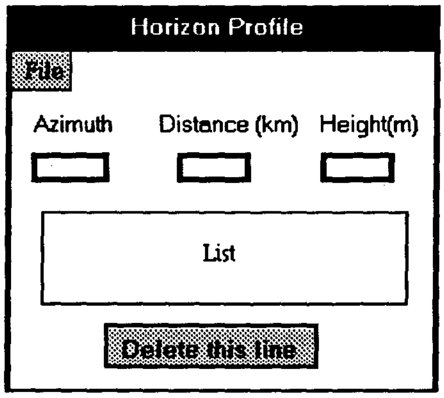

Figure 19. Horizon Profile.

Azimuth: The angle in degrees east of true north from a specific location to the horizon in the desired direction of communication. The value must be an integer.

Distance: The distance (km) from the ground location to the horizon at the above specified azimuth.

Height: The height above mean sea level in meters of the horizon at the above specified azimuth.

To add a new line of data: Click on the Azimuth box and type the desired value. The data is sorted according to Azimuth. JEM will place a new line at the appropriate place in the file according to the value entered. JEM will further update this new line as you enter values for distance and height.

To edit and delete: See instructions for Terrain Profiles in Section 6.8.

6.11 Climate Profiles

A Climate Profile reflects the number of days with precipitation and storms, the mean temperature and rain rate, and the humidity for each month of the year (Figure 20).

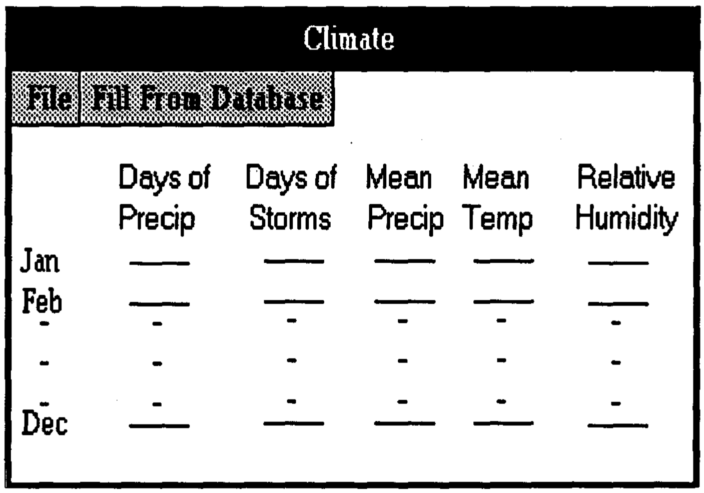

Figure 20. Climate Profile.

The data may be entered manually by entering values on each line or you may allow JEM to interpolate the data from its own meteorological database by pressing "Fill From Database." The interpolation is performed based on latitude and longitude. The values are the average of the average daily maximums and the average daily minimums for each month.

Days of Precipitation: Number of days for each month that precipitation exceeds 3mm.

Days of Storms: Number of days of thunderstorms for each month.

Mean Precipitation: Amount of measurable precipitation (in mm) averaged for each month.

Mean Temperature: Temperature in degrees Celsius averaged for each month.

Relative Humidity: 0 to 100% (do not enter the % sign). The humidity values in the database are calculated using the average of all hourly relative humidity values observed in a specific month.

6.12 Orbit Profiles

An Orbit Path Profile is used to define points along a path of a satellite. A profile may contain any number of points. Points are defined by latitude, longitude, and altitude. Latitude and longitude values are decimal values. Altitude is meters above mean sea level. The Orbit Profile window is shown in Figure 21 below.

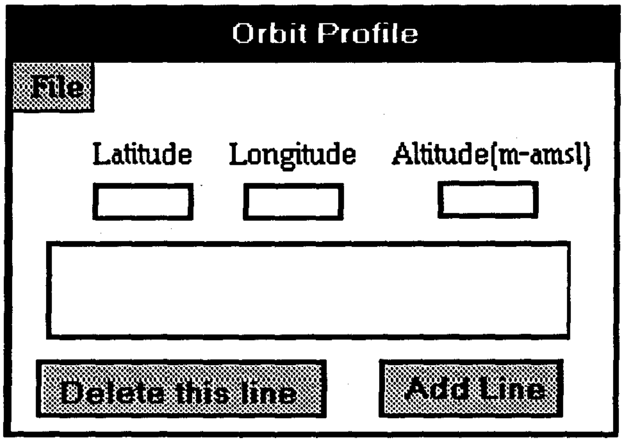

Figure 21. Orbit Path Profile.

To add a new set of values: Click on the line after the last entry in the list.

To edit values: All editing of values is done in the three boxes labelled Latitude, Longitude, and Altitude. Clicking on any set of values in the list, causes those values to be displayed in the boxes for editing.

7. JAMMING ANALYSES

7.1 Jammer Footprint

7.1.1 Introduction

The Jammer Footprint is a polar plot of the minimum distance from the jammer at which a receiver/transmitter pair must be located to communicate in the presence of jamming vs. the azimuth angle about the jammer. Each plot consists of up to four contours of transmitter-to-receiver distances which you have chosen. The transmitter/receiver pair must be outside of the contour in order to be able to communicate.

7.1.2 Program Input

Most of the data used to run a Jammer Footprint analysis is communicated by DOS file from a user-defined scenario in JEM. You will be asked for certain additional input by the analysis.

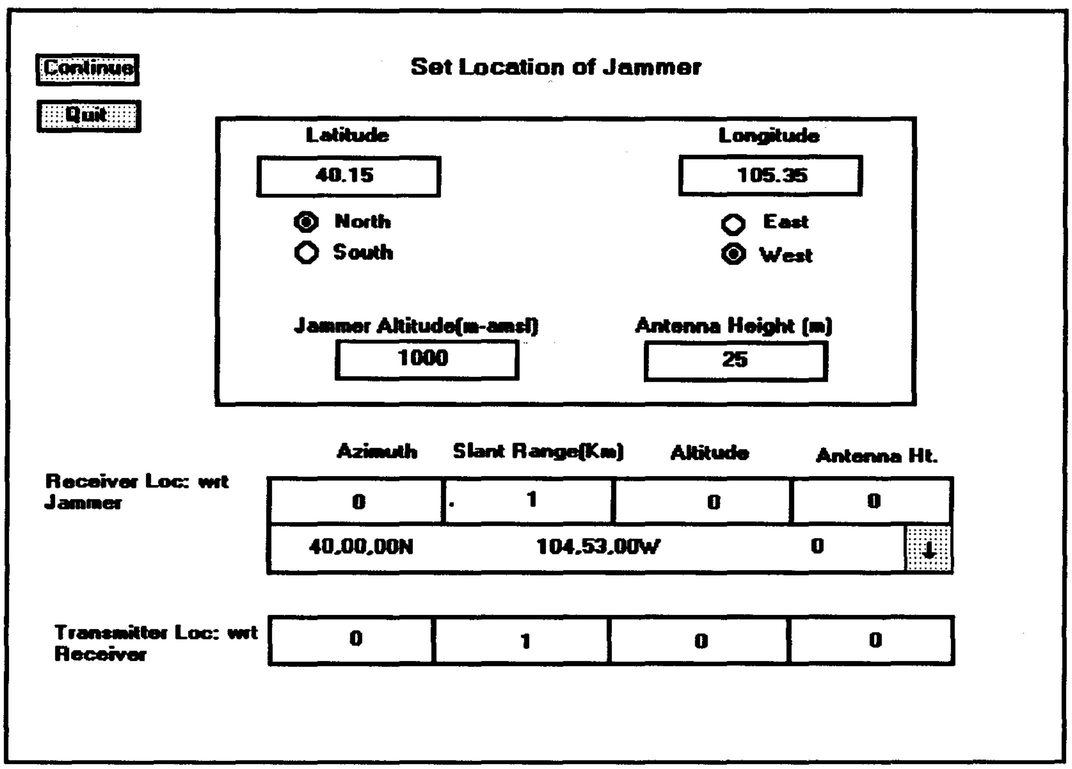

Figure 22. Jammer Footprint: transmitter, receiver, and jammer location.

Site Location

Figure 22 illustrates the window for entering the jammer, receiver and transmitter locations.

Jammer Location: The jammer location is central to a Jammer Footprint. The jammer latitude and longitude specified in JEM will be shown in the jammer location window at the top. Any value displayed in this window may be changed at this time by clicking on the desired box and entering a decimal value. Click on North or South, and East or West, as appropriate.

Receiver Location: The receiver location is defined by an azimuth in degrees east of due north and slant range in kilometers value with respect to the jammer.

Transmitter Location: The transmitter location is defined by azimuth in degrees east of due north and slant range in kilometers with respect to the receiver. The transmitter location specified here is used only to locate the transmitter on the plot. The receiver-transmitter separations which are used to calculate the contours are input elsewhere. (See Transmitter-Receiver Separations on page 32)

If a site is airborne (air platform or air jammer), the points on the flight path are indicated as shown in the receiver location in Figure 22. Click on the gray down arrow to view a list containing each point. Click on the point of your choice. Jammer Footprint will calculate the azimuth and range and display these values in appropriate boxes.

Antenna Direction

The main beam of each antenna can be set in the window shown in Figure 23 below. The transmitter, receiver, and jammer are located relative to the positions that you have set. Each is identified by a color-coordinated triangle as indicated in the upper left corner. Initially, the main beam of the transmitter and receiver are pointed at each other, while the main beam of the

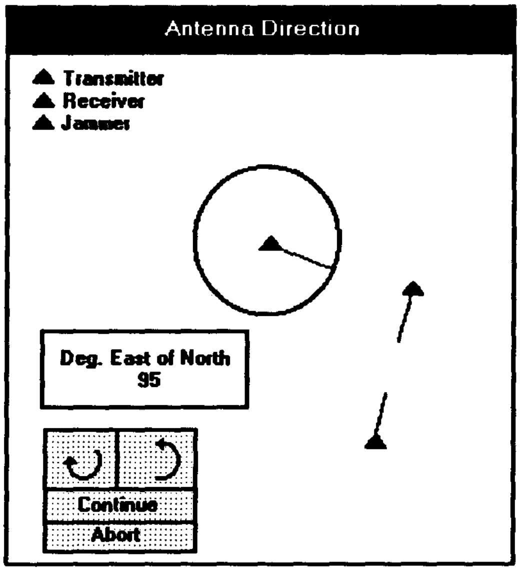

Figure 23. Setting antenna main beam direction.

jammer is pointed at the receiver. To move any of the main beams, click on the triangle representing that site. Then, either enter a decimal value in the box labelled "Deg. East of North" or click on the clockwise or counter-clockwise arrows to move the indicator. The "Deg. East of North" box may be moved if desired by clicking and dragging. Click on "Continue" when ready. Clicking on "Abort" will return processing to the location window.

Transmitter-Receiver Separations

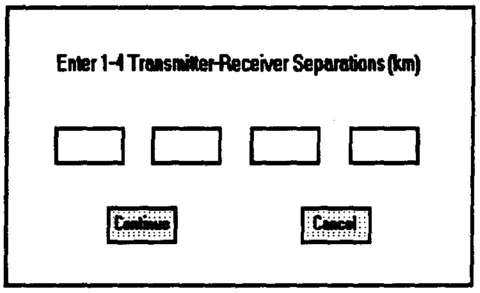

Figure 24. Inputting transmitter/receiver separations.

Jammer Footprint allows from one to four transmitter-receiver separations for each plot. Each value entered will be represented by a contour on the plot. Input these values in the window as illustrated above in Figure 24 by clicking on a box and typing. You may click on continue anytime after entering one to four values.

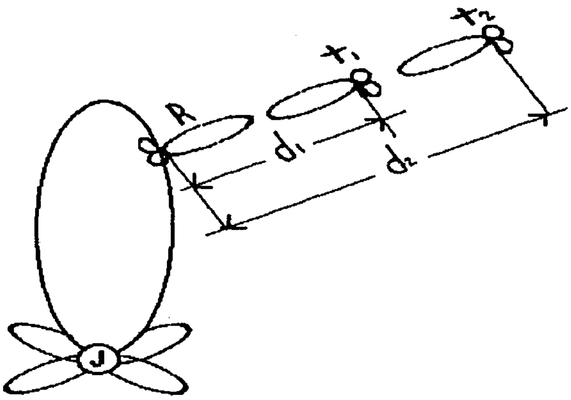

Figure 25. Relative receiver/transmitter positions.

During computation, the transmitters are located on the same fixed radial with respect to the receiver, but at different distances from the receiver. Thus the receiver antenna beam presents the same gain to the jammer for all positions about the jammer. Figure 25 above shows us a possible jammer antenna pattern. The relative positions of receiver and transmitters would remain the same as Jammer Footprint makes the calculations at each position on the jammer pattern.

IONCAP Input

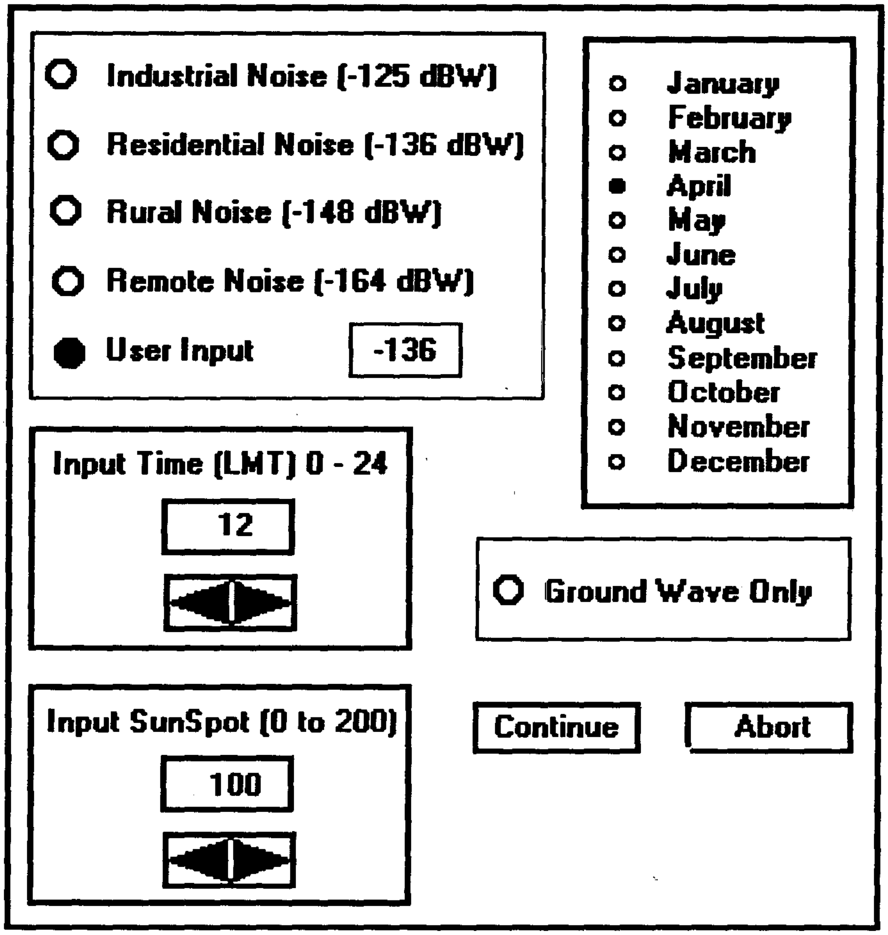

Figure 26. IONCAP input window.

If the frequency for the scenario is less than or equal to 30 MHz, Jammer Footprint includes calculations for the sky wave. In order to do this, Jammer Footprint runs the "Ionospheric Communications Analysis and Prediction" (IONCAP) program [11] which requires additional input. Figure 26 illustrates the input menu for these values.

Noise Level: Click on the noise level desired. This is the expected man-made noise level at the receiver in a 1-Hz bandwidth at 3 MHz. Selecting "User Input" causes a box to appear (as shown in Figure 26) in which you may enter any value.

Time: The time of day for which the analysis will to be performed. The hours are local mean time at the transmitter.

Sunspot Number: The sunspot number of the solar activity for the month of interest. It is the 12-month running average for the month specified. A sunspot number of ten is typical for low solar activity and sunspot numbers between 110 and 130 are typical of high solar activity. Values for time and sunspot may be entered by clicking on the box and typing or clicking on the increasing or decreasing arrows.

Month: Click on the desired month for the analysis. June and December are typical of seasonal extremes.

Ground Wave Only: You have the capability of bypassing IONCAP computations by clicking "Ground Wave Only." Calculations will then be based solely on ground wave propagation losses. Choosing "Ground Wave Only" may save significant processing time. However, IONCAP will be run one time to access the calculated noise figure, so even when choosing "Ground Wave Only," you should choose appropriate values in this window.

Click "Continue" to proceed. Clicking "Abort" will return processing to JEM.

7.1.3. Program Output

Data Output

June 6, 1994

Degrees	DKM at 10 Km	DKM at 30 Km	DKM at 50 Km	DKM at 70 Km
0	11.33	53.22	93.71	126.98
5	11.28	53.07	93.53	126.78
10	11.11	52.61	92.95	126.13
15	10.83	51.87	92.01	125.08
20	10.42	50.78	90.63	123.54
25	9.88	49.41	88.88	121.55
30	9.22	47.80	86.78	119.21
35	8.49	45.89	84.31	116.52
40	7.73	43.81	81.57	113.48
45	6.94	41.52	78.51	110.06
50	6.12	38.92	74.98	106.07
55	5.23	35.82	70.72	101.11
60	4.21	31.97	65.22	94.76
65	3.05	27.07	57.97	86.28
70	1.74	20.94	48.31	74.71
75	0.01	13.67	35.57	58.80
80	0.01	5.34	18.97	35.88

Jammer Scenario
Freq = 31 MHz

Transmitter
Ht = 100 m.
Alt = 2500 m.

Receiver
Ht = 50 m.
Alt = 1000 m.
Req Sig/Noise = 5

Jammer
Ht = 25 m.
Alt = 750 m.
Power = 45 dBm
Max Jmr Rcvd Sig = -5
Jammer Antenna =
Log Periodic

Delta H = 0
Permittivity = 15
Conductivity = .005 mho/m

Continue | Quit | Print to Printer | Print to File | Plot Results

Figure 27. Jammer Footprint data output.

On the example of a Jammer Footprint shown in Figure 27, there are four contours. The user has chosen transmitter-receiver separations of 10, 30, 50, and 70 kilometers as indicated by column headers. The value shown by the contour at each degree is the maximum distance in kilometers the jammer can be from the receiver and still effectively jam communications.

The buttons along the bottom have the following functions.

Continue: Returns to the location window. You may change parameters and run the analysis again.

Quit: Returns processing to JEM.

Print to Printer: Prints the data to the printer associated with Windows.

Print to File: Prints data to a file you have chosen.

Plot Results: Shows Jammer Footprint plot of data.

Plotted Output

Using the same example as Figure 27, Figure 28 illustrates the plotted output of Jammer Footprint. Note that the four contours labelled 10, 30, 50, and 70 indicate transmitter-receiver

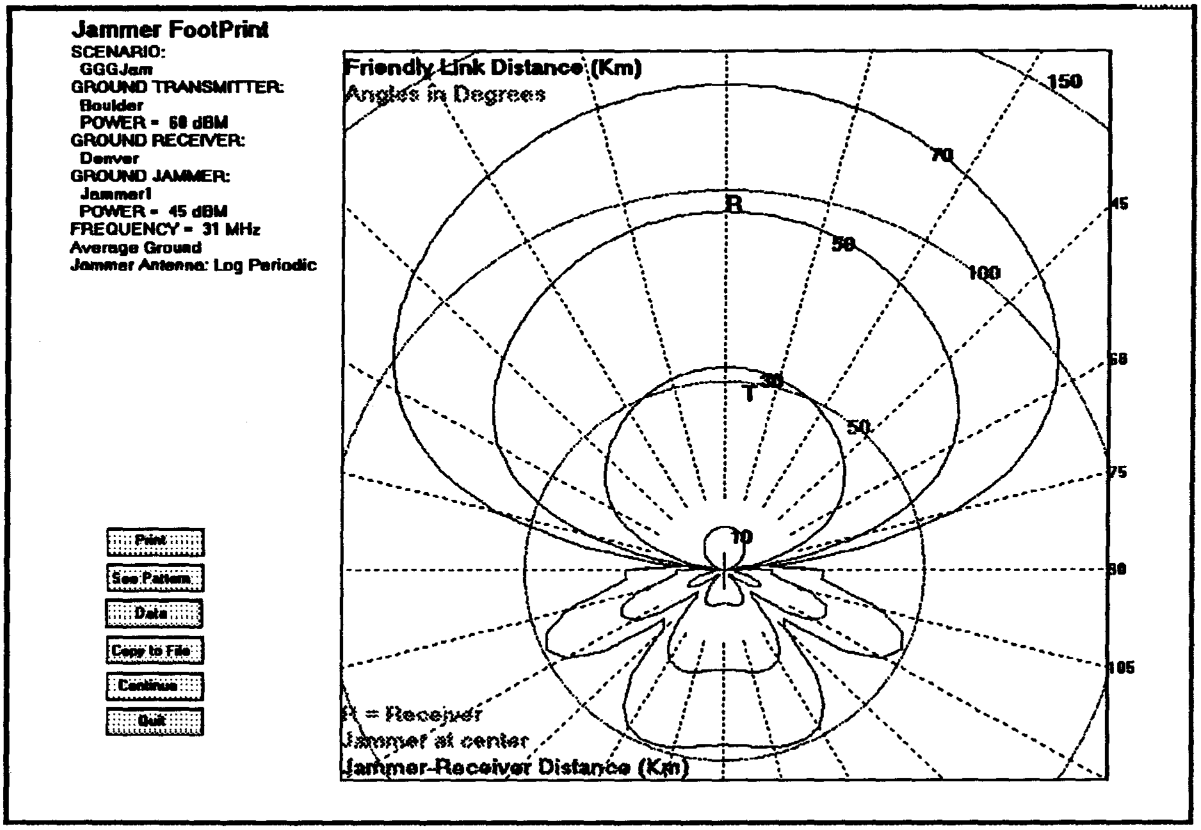

Figure 28. Jammer Footprint plotted output.

separations. The concentric circles with the jammer at the center reflect distances of 50, 100 and 150 km from the jammer. The radials are spaced every 15 degrees. The locations of the receiver and jammer as defined in the location window are shown by "R" and "T," respectively. This footprint tells us that given a transmitter-receiver separation of 30 km, the receiver needs to be approximately 50 km away from the jammer in order to receive transmission if the receiver is located along the jammer's main beam at 0 degrees north. Judging by the actual location of the receiver at 100 km from the jammer, and interpolating between the 50 and 70 km contours, the transmitter may be approximately 54 km away from the receiver and still maintain communication.

The buttons in Figure 28 have the following functions.

Print: Prints the plot to the printer associated with Windows. For landscape printing, make that selection in the Windows print driver accessible through the Control Panel icon. If your printer does not handle graphics, this choice may cause a general protection error.

See Pattern: Allows you to view a small diagram of the jammer antenna pattern.

Data: Brings up a window that displays answers in numerical form as shown in Figure 26.

Copy to File: Copies a bitmap image of the plot into a file of your choice.

Continue: Returns to the location window. User may change parameters which are set within Jammer Footprint and run the analysis again.

Quit: Returns processing to JEM.

7.2 Isopower Contours

7.2.1 Introduction

The Isopower Contour computation is a plot of one or more constant jammer power density levels at the receiver vs. azimuth angle about the jammer. It determines at what distances can the jammer generate certain discrete power density levels at the receiver for each azimuth angle.

7.2.2 Program Input

Most of the data used to run an Isopower Contour analysis is communicated by DOS file from a user-defined scenario in JEM. You will be asked for additional input as the analysis continues, as discussed below.

Site Location

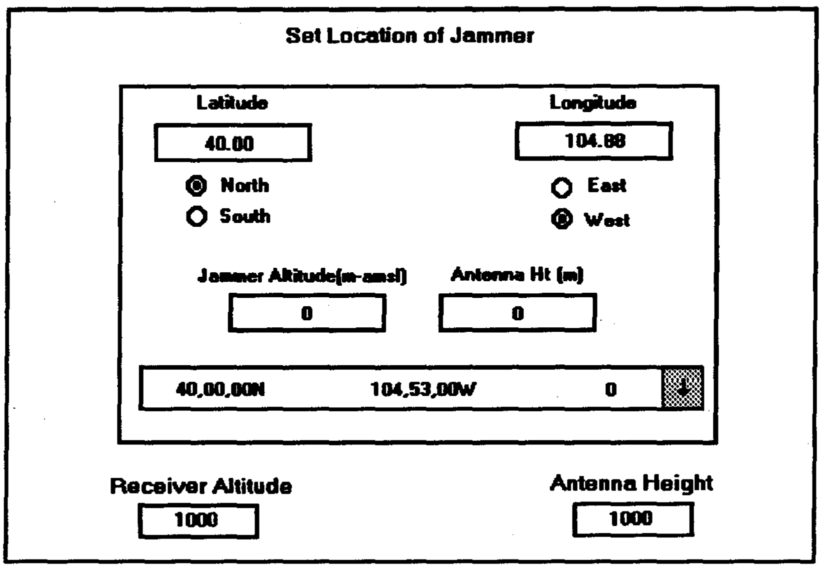

Figure 29. Isopower jammer location.

Isopower contours involve only a receiver and a jammer. Figure 29 above illustrates the window for entering jammer location and receiver altitude and height.

Jammer Location: The jammer latitude and longitude specified in JEM will be shown in the jammer location window at the top. The actual location of the jammer is important only if the frequency is 30 MHz or less, since ionospheric propagation depends on actual geographic location. This example shows an air jammer. The points of the flight path can be seen by clicking the down arrow at the right. Click on the point of your choice. The values chosen will be shown in the jammer latitude, longitude, and altitude boxes.

Receiver Location: Only the receiver height is needed since the calculations within Isopower Contours place the receiver at each azimuth angle about the jammer. The height includes the ground altitude (m-amsl) and the antenna height (meters above ground). Click on "Continue" when all locations have been set.

Power Density Levels

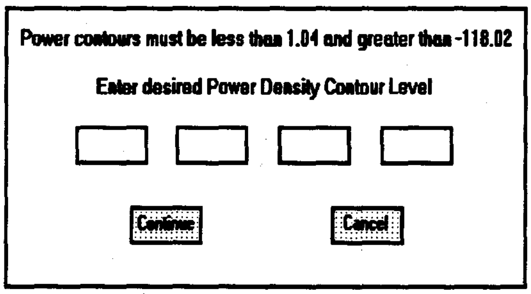

Figure 30. Power density input.

Isopower contours allow for one to four power density levels for each plot. Input these values in the power density window as illustrated in Figure 30 by clicking on a box and typing. The values you input must fall within the range as indicated at the top of the window. This is dependent on the gains and losses of your system. You may click "continue" anytime after entering at least one value.

IONCAP Input

See IONCAP Input, Section 7.1.2 for a description of these parameters.

7.2.3. Program Output

Printed Output

Degrees	DKM at -60 dBm	DKM at -80 dBm	DKM at -100 dBm
0	54.35	124.69	198.69
5	54.21	124.49	198.53
10	53.75	123.84	198.03
15	53.01	122.78	197.21
20	51.92	121.25	196.01
25	50.52	119.30	194.47
30	48.89	117.03	192.61
35	46.98	114.03	190.41
40	44.83	111.31	187.92
45	42.54	107.89	185.12
50	39.88	103.89	181.84
55	36.78	98.98	177.46
60	32.85	92.71	171.29
65	27.86	84.28	162.78
70	21.63	72.84	149.07
75	14.16	57.11	128.45
80	5.61	34.56	95.51

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Jammer Scenario:
GGGJam
Ant. Pattern File:
VLOGPER
Freq. = 31 MHz

JAMMER
Ht. = 10 m.
Alt = 120 m.
Pow = 45 dBm.
Max Jmr Pcvd Sig = -5
Jammer Ant:
Log Periodic

Delta H = 0
Permittivity = 15
Conductivity = .005 mho/m.

Continue | Quit | Print to Printer | Print to File | Plot Results

Figure 31. Isopower printed output.

In the example shown in Figure 31, there are three contours. The user has chosen power density levels of -60, -80, and -100 dBm / sq. meter as indicated by column headers. The value shown at each degree is the distance in kilometers from the jammer that the designated power density exists.

The buttons along the bottom have the following functions.

Continue: Returns to the location window. You may change parameters that were set within Jammer Footprint and run analysis again.

Quit: Returns processing to JEM.

Print to printer: Prints the data to the printer associated with Windows.

Print to File: Prints the data to a file you have chosen.

Plot Results: Shows Jammer Footprint plot of data.

Plotted Output

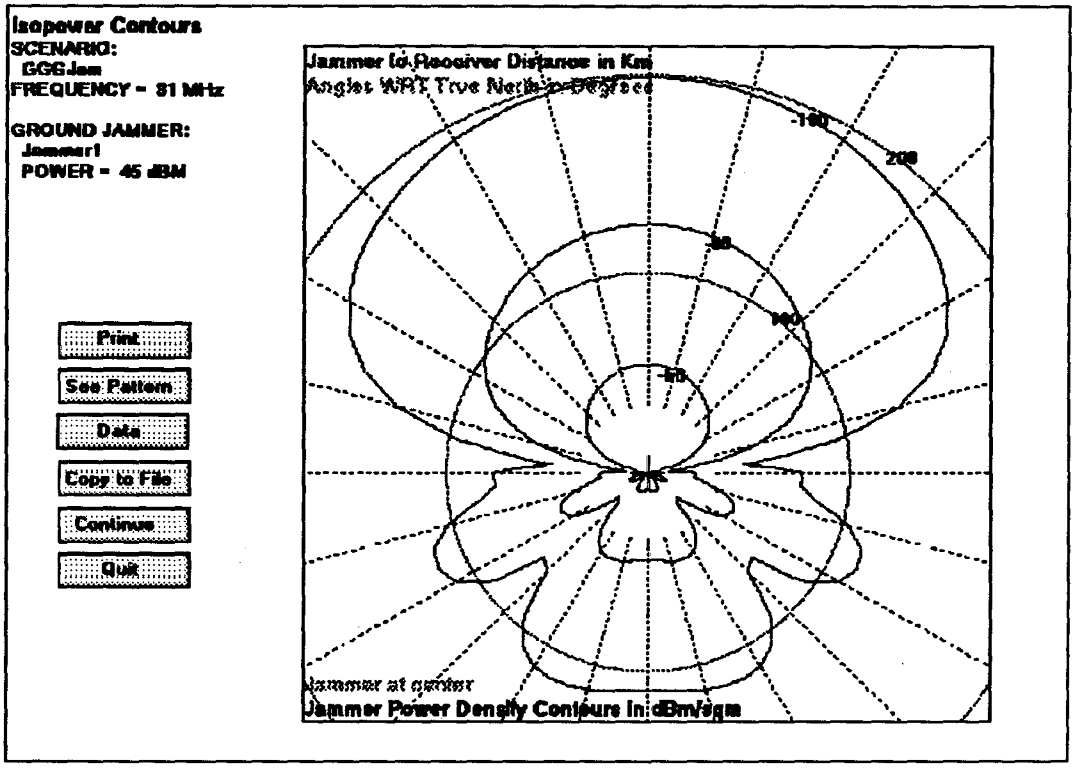

Figure 32. Isopower plotted output.

The data from Figure 31 is shown in a plot in Figure 32. Note the three contours labelled -60, -80, and -100 indicating power level densities. The concentric circles with the jammer at the center reflect distances of 100 and 200 km from the jammer. The radials are always every 15 degrees. The buttons have the following functions.

Print: Prints the plot to the printer associated with Windows. For landscape printing, make that selection in the Windows print driver accessible through the Control Panel icon.

See Pattern: Allows you to view a small diagram of the jammer antenna pattern.

Data: Brings up a window that displays answers in numerical form as shown in Figure 31.

Copy to File: Copies a bitmap image of the plot into a file you have chosen.

Continue: Returns to the location window. You may change parameters and run analysis again.

Quit: Returns processing to JEM.

7.3 Received Power

7.3.1 Introduction

There are two types of analyses which compute received power: Received Signal Power (RSP) computes the received power level vs. distance from a transmitter; and Recieved Jammer Power (RJP) computes the received power level vs. distance from a jammer. They are essentially identical except that one has a jammer and the other has a transmitter. The following is appropriate for both analyses.

7.3.2 Program Input

Most of the data used to run either received power analysis is communicated by DOS file from a user-defined scenario in JEM. You will be asked for certain additional input as the analysis continues, as discussed below.

Site location

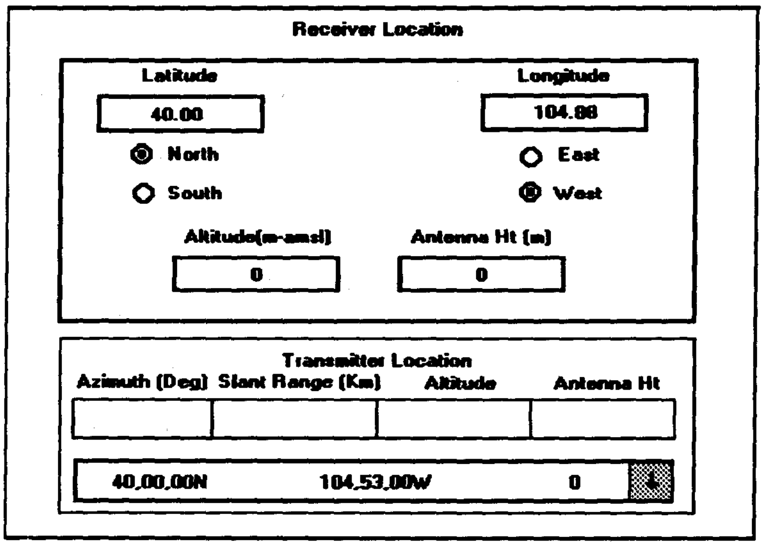

Figure 33. Location window for received power site.

Received Signal Power analyses involve a receiver and a transmitter. Received Jammer Power analyses involve a receiver and a jammer. Figure 33 shows an example of the location window for Received Signal Power. The latitude and longitude of the receiver which you have input in JEM, will be shown at the top. This may be changed if desired. The latitude and longitude location for the transmitter is located in the box with the down arrow. This location is defined relative to the receiver in the azimuth, slant range, and altitude boxes. You may edit the location in these boxes. Once the location is edited, the latitude and longitude is no longer shown because it is no longer valid. This example shows a transmitter located on an air platform. The points of the flight path can be seen by clicking the down arrow at the right. Click on the point of your choice. The values chosen will be translated to azimuth, range, and altitude values relative to the receiver. The location window for Received Jammer power is identical except the location of the jammer is defined instead of the transmitter. Click on "Continue" when all locations have been set. To abort, use the minus sign in the upper left corner.

Antenna Direction

See Antenna Direction in Section 7.1.2 for a description of setting the direction of antenna beams.

IONCAP Input

See IONCAP Input in Section 7.1.2 for a description of these parameters.

Range for Calculations

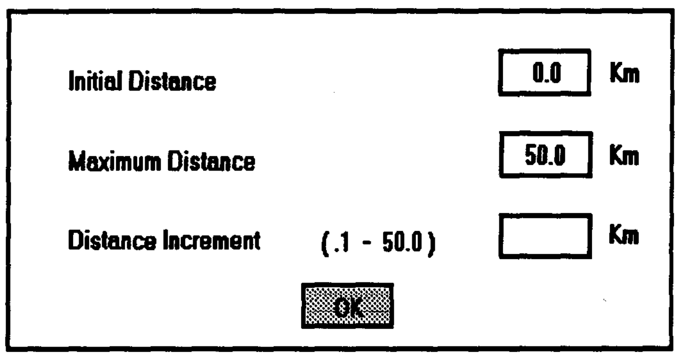

Figure 34. Received power range input.

Calculations are made over the length of the path between the receiver and transmitter, or the jammer as defined by the slant range parameter. This distance is noted as "Maximum Distance." You can specify the initial distance and the increment within the limits specified (Figure 34).

7.3.3. Program Output

Data Output

Options

Scenario Name: Gw (Ground wave only) 06-22-1994
Jammer: New Town Lat: 38.5 Long: -104.9 Alt: 0 m
Receiver: Other Town Lat 39.37 Long: -105.0 Alt: 0 m
Frequency: 10 MHz Polarity: VERTICAL
Refractivity: 320 Epsilon: 25 Sigma: .02
Jammer Antenna: Log Periodic Jammer Power: 50dBm
Receiver Antenna: Monopole

Distance (Km)	Power (dBm)	Losses (dB)
0.0	53.309	4.631
5.0	-26.098	87.238
10.0	-38.771	99.711
15.0	-46.198	107.138
20.0	-51.453	112.393
25.0	-55.578	116.518
30.0	-59.002	119.942
35.0	-61.948	122.888
45.0	-64.548	125.488
50.0	-66.887	127.827
55.0	-69.026	129.966
60.0	-71.004	131.944
65.0	-72.853	133.793

Figure 35. Received power printed output.

The numerical output from RJP and RSP displays the power and losses at each distance increment. For those scenarios with frequency less than or equal to 30 MHz, the output lists the power, ground wave, and sky wave components. In the example of Received Jammer Power shown above in Figure 35, the user has chosen to examine only the ground wave at increments of 5 km. Clicking on "Options" brings forth a menu with the following choices.

Print to printer: Prints the data to the printer associated with Windows.

View Graph: Shows plot of data.

Create Data File: Prints data to a file.

Close Window: Closes data window.

New Profile: Returns to the location window. You may change parameters which were set within analysis and run analysis again.

Quit: Returns processing to JEM.

Plotted Output

Figure 36 shows an example of the plotted output from Received Signal Power. A plot from Received Jammer Power is similar.

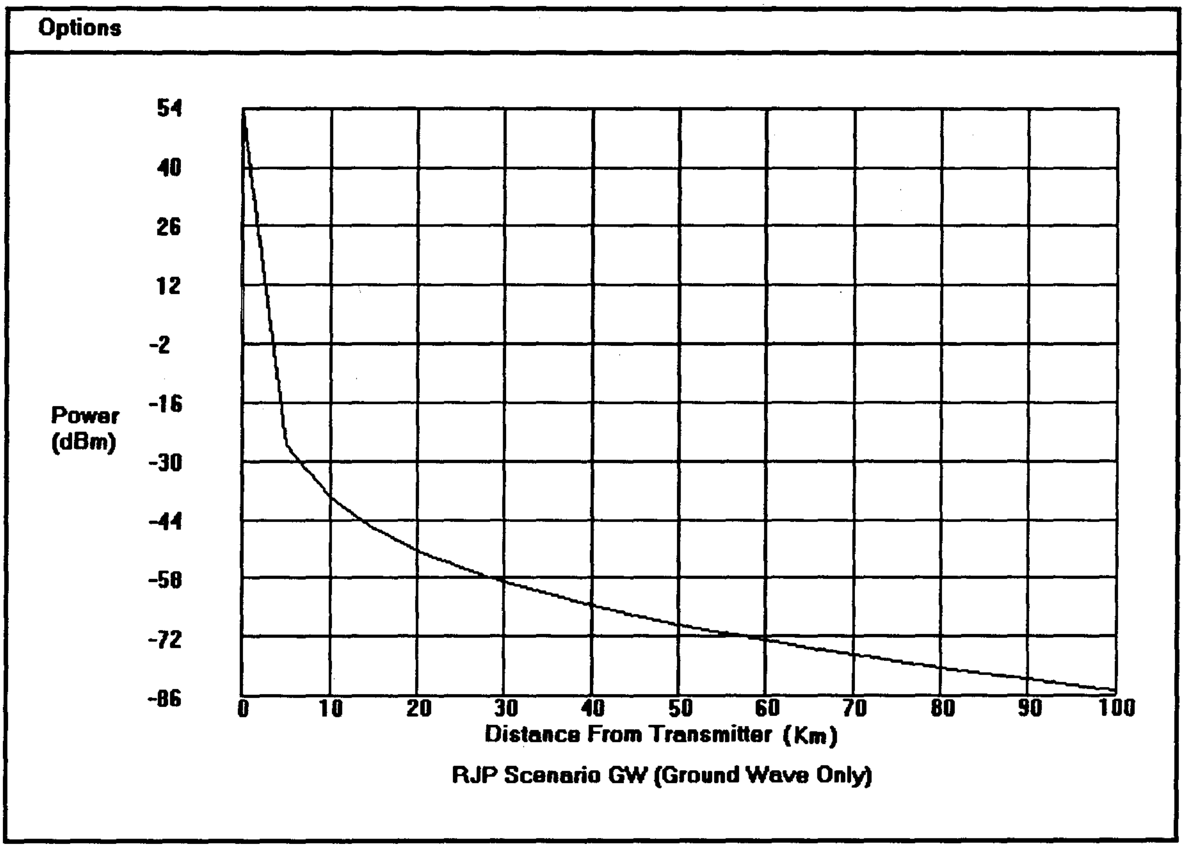

Figure 36. Received power plotted output.

Clicking on "Options" brings forth a menu with the following choices.

Create Graph File: Copies a bitmap image of the plot into a file which you have named.

Close: Closes the graph window. If the data window is not open, this command returns to JEM.

New Profile: Returns to the location window. You may change parameters set within the analysis and run the analysis again.

Quit: Returns processing to JEM.

8. JAMMER VS. NETWORK

8.1 Introduction

Jammer vs. Network (JVN) is an analysis of the effects of a jammer on the communication capabilities between a network of sites. A JVN scenario consists of a jammer and as few as two or as many as five sites. One site is name "Network Control." The location of this site must be established using latitude and longitude coordinates. The location of the other sites and the jammer is established with respect to Network Control via azimuth, range, and altitude. The received power of the communication between each site and every other site is computed. Thus, each site acts as both transmitter and receiver. The computations can be made with or without consideration of the jammer. The jammer may be either airborne or ground-based. The other sites are all ground stations.

8.2 Program Input

Most of the data used to run a Jammer vs. Network analysis is communicated by DOS file from a user-defined scenario in JEM. You will be asked for certain additional input as the analysis continues, as discussed below.

Site Location

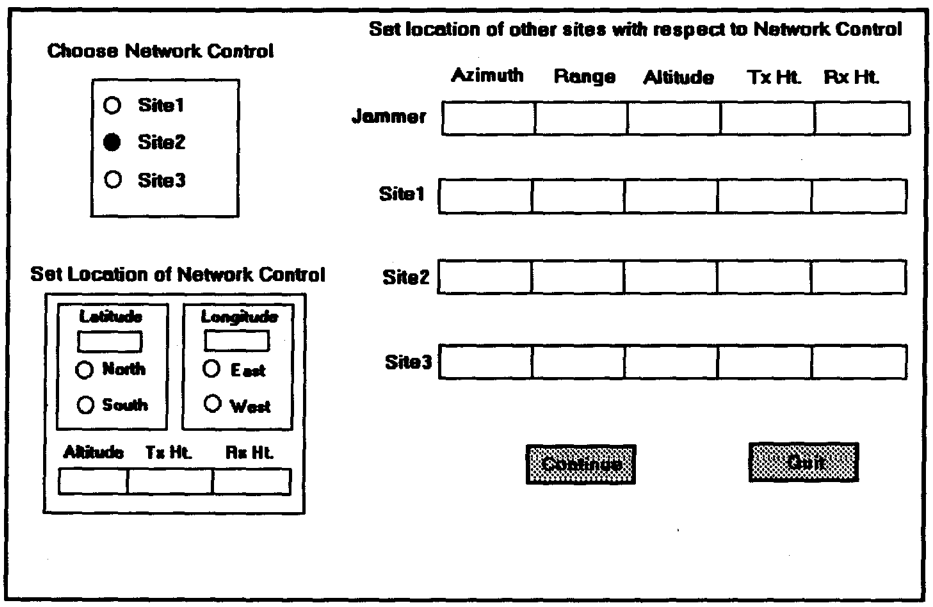

Figure 37. Jammer vs. Network equipment location.

Figure 37 is an example of a window for specifying the locations of JVN sites. This particular JVN scenario has three sites. There are three actions you should take in this window in the following order: 1.) choose Network Control by clicking on your choice in the box in the upper left corner; 2.) set location of Network Control by entering decimal values for latitude and longitude, altitude, and antenna heights in the box in the lower left corner and clicking on North, South, East or West as appropriate; and 3.) set locations of jammer and other sites in relation to Network Control. The location of these sites are defined by an azimuth in degrees east of due north and slant range in kilometers with respect to Network Control. The altitude values are in meters above mean sea level. The antenna heights are in meters. If the jammer site is airborne, the points on the flight path will be available. Click on the gray down arrow to view a list containing each point. Click on the point of your choice. Jammer vs. Network will calculate the azimuth/range and display these values in the appropriate boxes. Click on "Continue" when all locations have been set.

Antenna Direction

The main beam of each antenna can be set in the window shown in Figure 38. The site icons are

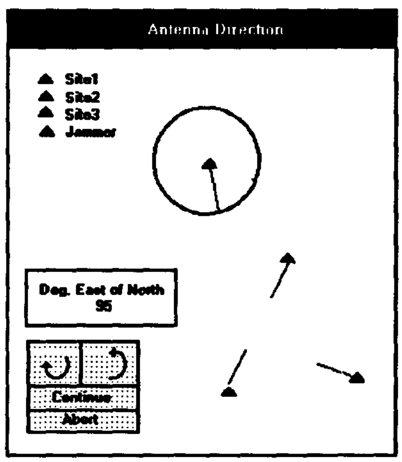

Figure 38. Setting antenna main beam.

located relative to the positions you have set. Each is identified by a color-coordinated triangle as indicated in the upper left corner. Initially, the main beam of the jammer and other sites are pointed at Network Control. To move any of the main beams, click on the triangle representing that site. Then, either enter an integer value in the box labelled "Deg. East of North" or click on the clockwise or counter-clockwise arrows to move the indicator. The "Deg. East of North" box may be moved if desired by clicking and dragging. Click on "Continue" when ready. Clicking on "Abort" will return processing to the location window.

IONCAP Input

If the frequency for the scenario ≤ 30 MHz, Jammer vs. Network includes calculations for the sky wave. In order to do this, Jammer vs. Network runs the IONCAP program which requires additional input. See Section 7.1.2. for a discussion of this program.

8.3 Program Output

Printed Output

Continue   Quit   Print/Plot   Jammer/No Jammer

Jammer vs. Network
(JVNExample)
Current Date
Network Control is SITE1 at 40N 105W
SITE2: 80.074 Degs. 35 Km   SITE3: 95 Degs. 55 Km
Jammer Location : 0 Degs., 112 Km. With Main Beam at 119 Deg.

LINK ESTABLISHED		NO LINK POSSIBLE	
SITE1 - SITE2	20.1dB	SITE2 - SITE3	-11.5dB
SITE1 - SITE3	10.6dB	SITE3 - SITE2	-21.7dB
SITE2 - SITE1	28.6dB		
SITE3 - SITE1	19.8dB		

Values = Interference Margin

Figure 39. Jammer vs. Network printed output.

The example of Jammer vs. Network shown in Figure 39 contains three sites, with "SITE1" being used as Network Control. The values given are the interference margin, that is, the difference between the power at the receiver and the jamming power necessary to disrupt communications. A 3-dB tolerance is used to indicate a region of marginal performance. If the jammer power level at the receiver is within ± 3 dB of that necessary to disrupt communications, then the communication quality is considered marginal and is listed as such. If the calculated received signal/noise ratio is less than the required signal/noise then the link is marked with an asterisk, meaning there is insufficient power.

The menu options along the top have the following functions.

Continue: Returns to the location window. You may change parameters which were set within Jammer vs. Network and run analysis again.

Quit: Returns processing to JEM.

Print/Plot: Presents a menu that allows printing results to a printer, to a file, or plotting the results to the screen.

Jammer/No Jammer: Presents a toggle menu with two choices. Jammer displays results considering the impact of the jammer (default). No Jammer displays results taking no consideration of the presence of the jammer. When the results are viewed with no jammer, the link/no link decision is made solely on the comparison of calculated received signal/noise ratio to required signal/noise ratio. The values printed are the calculated received signal/noise ratio.

Plotted Output

Figure 40 shows a Jammer vs. Network plot with three sites named "SITE1," "SITE2," and "SITE3." The location of each site is represented by its respective number, "1," "2," and "3." The location of the jammer is represented by **. The quality of the link is color-coded on the screen as shown in the legend. On printed media, the quality is shown with different line styles as in Figure 40. The line represents the link quality at the receiver. Thus in Figure 40, the link quality at SITE2 from SITE1 is marginal, while at SITE1 from SITE2 there is no link at all. Likewise, a good link is established at SITE3 from SITE1, but there is no link in the reverse direction.

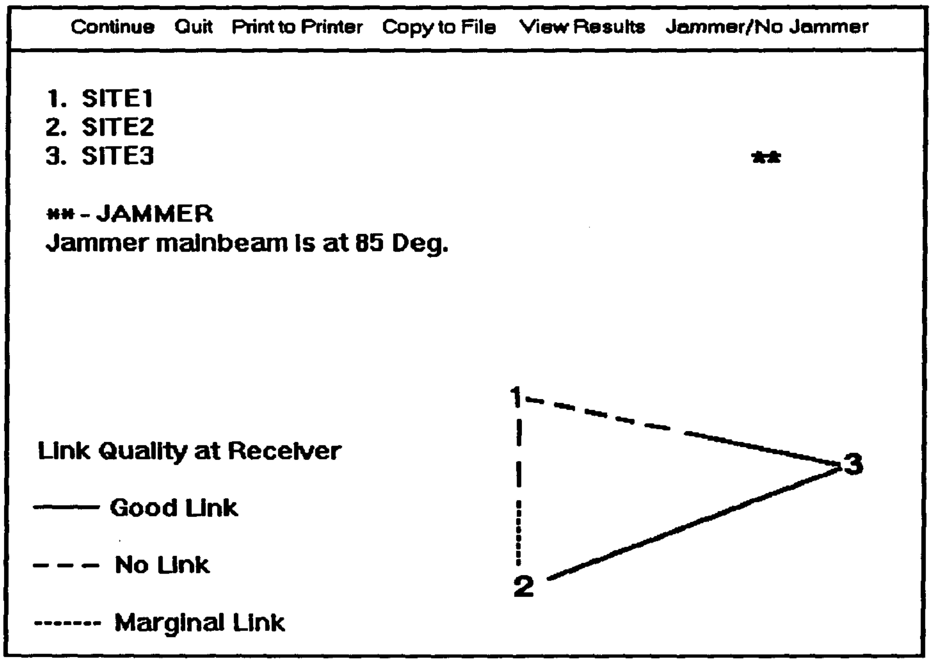

Figure 40. Jammer vs. Network plotted output.

The menu selections present the following options.

Continue: Returns to the location window. You may run analysis again.

Quit: Returns processing to JEM.

Print to Printer: Plots to the printer associated with Windows.

Print to File: Copies a bitmap image of the plot into a file you have chosen.

View Results: Redisplays answers in numerical form as in Figure 39.

Jammer/No Jammer: Presents a toggle menu to view results considering the impact of the jammer (default) or to view results taking no consideration of the presence of the jammer. When the results are viewed with no jammer, the link/no link decision is made solely on the comparison of calculated received signal/noise ratio to required signal/noise ratio.

9. EARTH-SATELLITE ANALYSES

9.1 Cumulative Distribution of Rain Attenuation

The cumulative distribution model of the rain attenuation calculates the distribution over the range of months you have specified. This analysis is performed for the path between the ground station and a designated point from the satellite orbit file.

9.1.1 Program Input

First and Last Month

Figure 41. Month selection window.

Figure 41 illustrates the month selection window. Move the cursor to the month for which you desire to begin running the analysis and hit enter. You will see this screen twice in succession. The second time is asking for the last month for the analysis. The end month must be the same or later than the start month. The analysis cannot sweep from December to January.

Orbit Path Index Point

The index refers to the ordinal number of the point in the satellite orbit file (See Section 6.12) for which you wish to run this analysis. In the example in Figure 42, there are seven points in the orbit file. You must enter a number less than or equal to the number of points defined. You may enter a question mark, "?." This allows you to see a listing of the file in which you may choose the point by moving the cursor and hitting enter.

Reading orbit data from C:\OrbFP.ORB
Input Index for Orbit Flight Location ________
Answer must be between 1 and 7

Figure 42. Flight path index selection window.

The following files must be in directory C:\VBEXE:

AB.DAT: A data file which is provided with JEM of rain attenuation coefficients.

ISOTHERM: A data file which is provided with JEM containing isotherm profile data

ES1.DAT: A file created by JEM which includes all scenario data.

9.1.2 Program Output

Printed Output

Figure 43, shows the losses due to rain attenuation per percentage of time. Thus, the loss for this location at this time of year exceeds 11.4 dB .05% of the time. Since the time span is the month of May, .05% = 22.32 minutes. Looking at the problem another way, the loss is less than 11.4 dB 99.95% of the time. The results are plotted in Figure 44.

Plotted Output

The rain attenuation value in dB is plotted on the x-axis against the base ten logarithm of the percentage of time the attenuation is exceeded along the y-axis (Figure 44).

Cumulative Distribution of Rain Attenuation for a Ground-to-Satellite Path					
%Time	Time		Loss	RSL	From: Boulder
ATTN EXCD			(db)	(dBm)	To: GOES
10.0000	74.40	hr	0.00	80.0	Time Period: MAY
5.0000	37.20	hr	0.00	80.0	Frequency (GHz): 40
2.0000	14.88	hr	0.00	80.0	Path Length (km): 37662
1.0000	7.44	hr	1.40	78.6	Satellite Orbit: EOORB.ORB
0.5000	3.72	hr	1.48	78.5	Elevation Angle (deg): 41.533
0.2000	1.49	hr	4.79	75.2	Azimuth to Sat. (deg): 200.955
0.1000	44.64	min	8.37	71.6	Xmitter Power (dBm): 20
0.0500	22.32	min	11.04	70.0	Xmitter Gain (dBi): 30
0.0200	8.93	min	15.20	64.8	Receiver Gain (dBi): 30
0.0100	4.46	min	17.90	62.1	
0.0050	2.23	min	21.73	58.3	
0.0020	53.57	sec	25.86	54.1	
0.0010	26.78	sec	31.37	48.6	
0.0005	13.39	sec	42.24	37.8	
0.0002	5.36	sec	56.91	23.1	
0.0001	2.68	sec	66.71	13.3	

Figure 43. Rain attenuation printed output.

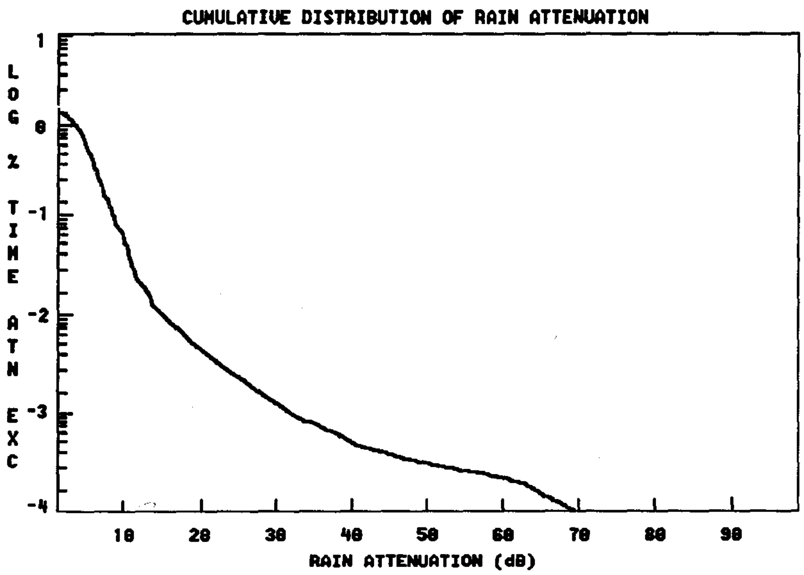

Figure 44. Rain attenuation plot.

9.2 Cumulative Distribution of Clear Air Attenuation

The cumulative distribution of clear air attenuation calculates the distribution over the range of months you have specified. This analysis is performed for the path between the specified ground station and a chosen point on the satellite orbit file. For earth-satellite paths the cumulative distribution of atmospheric water vapor pressure is used to model the cumulative distribution of clear air attenuation.

9.2.1 Program Input

First Month: See Section 9.1.1.

Last Month: See Section 9.1.1.

Index Point of Satellite Orbit Path: See Section 9.1.1.

The following files must be in directory C:\VBEXE.

AB.DAT: A data file provided with JEM that contains rain attenuation coefficients.

ES2.DAT: A data file created by JEM that contains all the scenario data.

9.2.2 Program Output

Printed Output

Figure 45 on the following page shows the losses due to clear air attenuation per percentage of time. Thus, the loss for this location at this time of year exceeds .61 dB .05% of the time. Since the time span is the month of June, .05% = 21.60 minutes. Looking at the problem another way, the loss is less than .61 dB 99.95% of the time.

Plotted Output

The attenuation value is plotted on the x-axis against the base ten logarithm of the percentage of time the attenuation is exceeded along the y-axis (Figure 46).

Cumulative Distribution of Clear Air Attenuation for a Ground-Satellite Path				
%Time ATTN EXCD	Time	Loss (db)	RSL (dBm)	From: Boulder
				To: GOES
10.0000	72.00 hr	0.48	79.5	Time Period: JUN
5.0000	36.00 hr	0.49	79.5	Frequency (GHz): 40
2.0000	14.40 hr	0.51	79.5	Path Length (km): 37662
1.0000	7.20 hr	0.52	79.5	Satellite Orbit: GEOORB.ORB
0.5000	3.60 hr	0.54	79.5	Elevation Angle (deg): 41.533
0.2000	1.44 hr	0.60	79.4	Azimuth to Satellite (deg): 200.955
0.1000	43.20 min	0.61	79.4	Xmitter Power (dBm): 20
0.0500	21.60 min	0.61	79.4	Xmitter Gain (dBi): 30
0.0200	8.64 min	0.63	79.4	Receiver Gain (dBi): 30
0.0100	4.32 min	0.64	79.4	
0.0050	2.16 min	0.69	79.4	
0.0020	51.84 sec	0.69	79.3	
0.0010	25.92 sec	0.72	79.3	
0.0005	12.96 sec	0.73	79.3	
0.0002	5.18 sec	0.76	79.3	
0.0001	12.59 sec	0.77	79.3	

Figure 45. Clear air attenuation printed output.

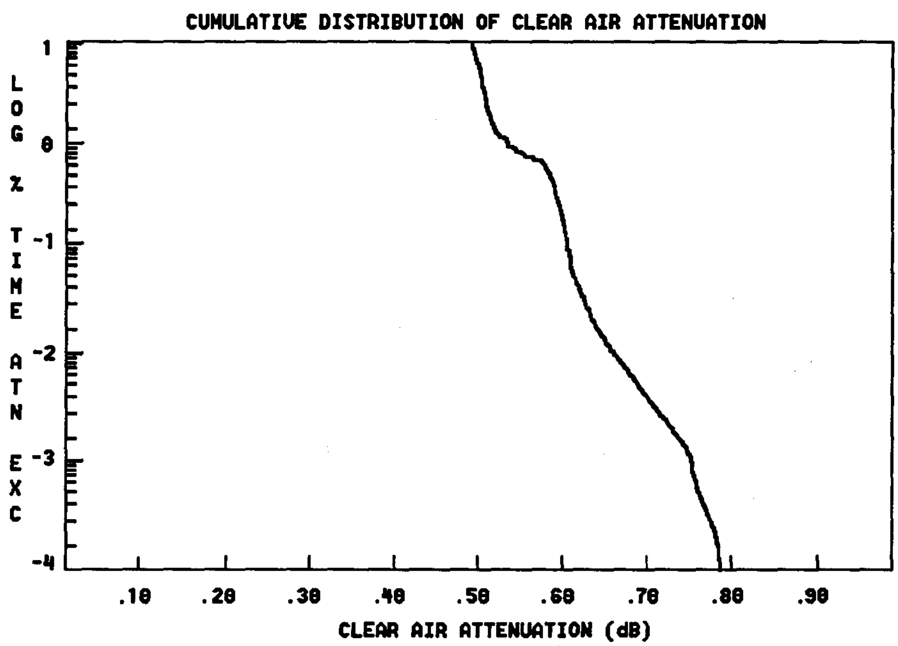

Figure 46. Clear air attenuation plot.

10. GROUND-AIRCRAFT ANALYSES

10.1 Attenuation and RSL - Looping on Frequencies

This analysis calculates the attenuation and Received Signal Loss (RSL) for a range of frequencies specified you have specified along a path between the ground station as defined in JEM, and a point chosen by the user from the aircraft flight path profile.

10.1.1 Program Input

Index Point for Flight Path: Identifies the location of the flight path for which you want to run analysis - Section 9.1.1.

Low Frequency of Loop: Enter starting frequency (in GHz) of loop for frequencies. The default is 10 GHz.

High Frequency of Loop: Enter the final frequency (GHz) value for loop. The default is 100 GHz.

Step Frequency: Enter the interval for the frequency loop. The default is 10 GHz.

Earth's Radius Factor k: enter k factor, default value is 1.3.

The analysis may be cancelled at any time by entering the letter "A" for abort.

The following files must be in directory C:\VBEXE

AB.DAT: A data file which is provided with JEM containing rain attenuation coefficients.

GA1.DAT: A file created by JEM containing all the scenario data.

10.1.2 Program Output

Figure 47 on the following page shows the format of the output.

Ground-Aircraft Analysis: Loop on Frequency for a Single Flight Path Point

From Boulder to F4A

Boulder Latitude: 40' 0' 01N"

Boulder longitude: -105'15'00.0W — Xmitter Power(dBm): 20

F4A Latitude: 40' 2' 50N — Xmitter Gain(dBi): 30

F4A Longitude: -105'15'00.0W — Receiver Gain(dBi): 30

F4A Altitude(m): 3500 — Distance to Aircraft (km): 20.57

Elev. Angle to Aircraft(deg): 27.76 — Azimuth to Aircraft(deg): 290.60

Frequency(GHz)	Attenuation(dB)	RSL(dBm)
10.00	0.02	-40.7
20.00	0.15	-46.8
30.00	0.10	-50.3
40.00	0.14	-52.9
50.00	0.48	-55.1
60.00	30.09	-86.3
70.00	0.66	-58.3
80.00	0.38	-59.1
90.00	0.40	-60.2

Figure 47. Ground-Aircraft - loop on frequency.

10.2 Attenuation and RSL - Looping on Flight Locations

This analysis calculates the attenuation and RSL for a single operating frequency for the points you have defined on an aircraft flight path..

10.2.1 Program Input

Earth's Radius Factor k: Enter k factor. The default value is 1.3.

The analysis may be cancelled at any time by entering the letter "A" for abort. The following files must be in directory C:\VBEXE.

GA2.DAT: A file created by JEM that contains all the scenario data.

OXYGEN.DAT: A file provided with JEM that contains oxygen coefficients.

WATER.DAT: A file provided with JEM that contains water vapor coefficients.

10.2.2 Program Output

There are two choices for printed output, the long form and the short form as shown in Figures 48 and 49.

Ground-Aircraft Analysis - Loop on Flight Path for a Single Frequency

From: Boulder to F4A

Boulder Latitude: 40' 0' 05" Xmitter Power(dBm): 20

Boulder Longitude: -105' 2' 48' Xmitter Gain (dBi): 30

Frequency in GHz: 40 Receiver Gain (dBi): 30

Latitude	Longitude	AZ Ang (deg)	El Ang (deg)	Flight Alt (m)	Path Length (km)	Attenuation (dB)	RSL (dBm)
40.0472	-105.2550	290.60	27.76	3500.00	2.58	0.14	-52.8
40.0500	-105.2500	297.50	35.25	4000.00	2.95	0.15	-54.0
40.0528	-105.2500	303.63	69.07	9000.00	7.17	0.18	-612.8

Figure 48. Ground-Aircraft - loop on flight path; long form.

Ground-Aircraft Analysis - Loop on Flight Path for a Single Frequency

From Boulder to F4A

Boulder Latitude: 40' 0' 05" Xmitter Power (dBm): 20

Boulder Longitude: -105' 02' 48" Xmitter Gain (dBi): 30

Frequency in GHz: 40 Flight Path: Airpath2.FLT

Data Point	Latitude	Longitude	Attenuation (dB)	RSL (dBm)
1	40.04722	-105.25000	0.14	-52.9
2	40.05000	-105.25000	0.15	-54.0
3	40.0600	-105.25000	0.18	-61.8

Figure 49. Ground-Aircraft - loop on flight path; short form.

10.3 Cumulative Distribution of Rain Attenuation

The cumulative distribution of the rain attenuation model calculates the distribution over the range of months you have specified. This analysis is performed for the path between the ground station and a designated point from the aircraft flight path file. The RSL calculation includes the rain attenuation and free space loss.

10.3.1 Program Input

First and Last Month: The last month must be the same as or later than the first month.

Flight Path Index Point: The index refers to the ordinal number of the point in the Aircraft Flight Path File (See Section 6.7) for which you wish to run this analysis.

The following files must be in directory C:\VBEXE.

AB.DAT: A data file which is provided with JEM of rain attenuation coefficients.

ISOTHERM: A data file which is provided with JEM containing isotherm profile data

GA3.DAT: A file created by JEM that includes all scenario data.

10.3.2 Program Output

See Section 9.1.2 for a description of the Rain Attenuation Analysis.

10.4 Cumulative Distribution of Clear Air Attenuation

The model for the cumulative distribution of clear air attenuation calculates the distribution over the range of months you have specified. This analysis is performed for the path between the ground station as specified in JEM and a chosen point on the aircraft flight path file. The only loss considered for the attenuation calculation is the clear air attenuation above free space loss. The RSL calculations include the clear air attenuation and free space loss.

10.4.1 Program Input

First Month: See Section 9.1.1.

Last Month: See Section 9.1.1.

Index Point of Flight Path: See Section 9.1.1.

The following files must be in directory C:\VBEXE.

AB.DAT: A data file which is provide with JEM that contains rain attenuation coefficients.

GA4.DAT: A data file created by JEM that contains all the scenario data.

10.4.2. Program Output

See Section 9.2.2 for a description of the Clear Air Attenuation Analysis.

11. AIRCRAFT-SATELLITE ANALYSES

11.1 Attenuation and RSL - Loop on Aircraft Locations

You will choose a single satellite location from the orbit path file. The attenuation and RSL is then computed for paths between that satellite location and each of the locations designated in the aircraft path file.

11.1.1 Program Input

Index Point for Satellite Orbit Path: The index refers to the ordinal number of the point in the satellite orbit file (see Section 6.12) for which you wish to run this analysis. See Section 9.1 for a fuller description.

Equivalent Earth's Radius Factor k: Defaults is 1.3.

Ground Elevation below Aircraft: Measured in meters.

Rain Rate: Measured in mm/hr. The default value is zero.

While answering these questions, you may abort the analysis by entering "A."

The following files must be in directory C:\VBEXE.

OXYGEN.DAT: A data file provided with JEM containing oxygen coefficients.

WATER.DAT: A data file provided with JEM containing water vapor coefficients.

AS1.DAT: A data file created by JEM including all scenario data.

11.1.2 Program Output

There are two choices of output formats; the long form and the short form as displayed in Figures 50 and 51. These examples show the Attenuation and RSL results at each of the three points defined on the flight path for an aircraft platform named "F4A" from a specific location on the path of a satellite name "SAT."

Aircraft-Satellite Attenuation and RSL Calculations - Loop on Flight Path for a Single Frequency

From SAT to F4ASAT Latitude: 0' 0' 0"

SAT Longitude: 119' 0' 0"	Xmitter Power (dBm): 20
SAT Altitude 35786 Km	Xmitter Gain (dBi): 30
Frequency in GHz: 40	Receiver Gain (dBi): 30
Flight Path Airpath2.FLT	Rain Rate(mm/hr): 20

Aircraft Latitude	Longitude	Az Ang (deg)	El Ang (deg)	Aircraft Altitude (m)	Path (km)	Attenuation (dB)	RSL (dBm)
40.0472	-105.2550	195.88	41.53	3500.00	37661.37	0.16	-136.2
40.0500	-105.2500	195.88	41.53	4000.00	37661.26	0.13	-136.1
40.0428	-105.2500	195.88	41.42	9000.00	37658.16	.03	-136.0

Figure 50. Aircraft-Satellite - loop on flight path; long form.

Aircraft-Satellite Attenuation & RSL Calculations; Loop on Flight Path with Single Frequency				
	From SAT to F4A			
	SAT Latitude: 0' 0' 0"			
	SAT Longitude: 119' 0' 0"		Xmitter Power (dBm): 20	
	SAT Altitude 35786 Km		Xmitter Gain (dBi): 30	
	Frequency in GHz: 40		Receiver Gain (dBi): 30	
	Flight Path Airpath2.FLT			
Data Point #	Latitude	Longitude	Attenuation (dB)	RSL (dBm)
1	40.0472	-105.2550	0.16	-136.2
2	40.0500	-105.2500	0.13	-136.1
3	40.0528	-105.2500	0.03	-136.0

Figure 51. Aircraft-Satellite - loop on flight path; short form.

11.2 Attenuation and RSL - Multiple Frequencies

This analysis requires you to pick one point on each of the flight paths connected with the aircraft and with the satellite. The attenuation and RSL will be calculated along that path looping through a range of frequencies you have defined. The calculated attenuation is the sum of the free space attenuation and the clear air and rain attenuation losses.

11.2.1 Program Input

Index Point for Satellite Orbit Path: The index refers to the ordinal number of a point in the satellite orbit file (See Section 6.12) for which you wish to run this analysis. See Section 9.1 for a fuller description.

Index Point for Aircraft Flight Path: The index refers to the ordinal number of the point in the aircraft flight path file (See section 6.7) for which you wish to run this analysis. See Section 9.1 for a fuller description.

Low Frequency of Loop: Enter starting frequency (in GHz). The default is 10 GHz.

High Frequency of Loop: Enter the final frequency (GHz) value. The default is 100 GHz.

Step Frequency: Enter the interval for the frequency loop. The default is 10 GHz.

Earth's Radius Factor k: Enter the k factor. The default value is 1.3.

Ground Elevation below Aircraft: Measured in meters.

Rain Rate: Measured in mm/hr. The default is zero.

The analysis may be cancelled at any time by entering the letter "A" for abort.

The following files must be in directory C:\VBEXE.

OXYGEN.DAT: A data file provided with JEM containing oxygen coefficients.

WATER.DAT: A data file provided with JEM containing water vapor coefficients.

AS2.DAT: A data file created by JEM including all scenario data and names of necessary JEM files.

11.2.2 Program Output

An example of the program output is shown in Figure 52.

Aircraft-Satellite Attenuation and RSL Calculations; Loop on Frequency

From SAT to F4A
SAT Latitude: 0' 0' 0"
SAT Longitude: 119' 0' 0"
SAT Altitude 35786 Km
F4A Latitude 40' 2' 50
F4A Longitude -105' 15' 00.0
F4A Altitude(m): 3500

Xmitter Power (dBm): 20
Xmitter Gain (dBi): 30
Receiver Gain (dBi): 30
Rain Rate(mm/hr): 20
Distance from F4A to SAT (km): 37661.37

Frequency (GHz)	Attenuation (dB)	RSL (dBm)
30.00	0.06	-133.6
40.00	0.16	-136.2
50.00	0.92	-138.9
60.00	137.97	-277.5

Figure 52. Aircraft-Satellite - loop on frequency.

11.3 Attenuation and RSL - Loop on Matched Points on Flight Paths

The attenuation and RSL is calculated on a one-to-one correspondence of points in the flight paths for the satellite and aircraft.

11.3.1 Program Input

Earth's Radius Factor k: Enter the k factor. The default value is 1.3.

Ground Elevation below Aircraft: Measured in meters.

Rain Rate: Measured in mm/hr. The default is zero.

The analysis may be cancelled at any time by entering the letter "A" for abort. The following files must be in directory C:\VBEXE.

AS3.DAT: A file created by JEM containing all scenario data.

OXYGEN.DAT: A file provided with JEM containing oxygen coefficients.

WATER.DAT: A file provided with JEM containing water vapor coefficients.

11.3.2 Program Output

Printed Output - Short Form

Figure 53 shows the results for loop on matched points in short form.

Aircraft-Satellite Attenuation and RSL Calculations; Loop on Matched Points

Frequency in GHz: 40
Aircraft Flight Path: Airpath2.FLT
Satellite Orbit Path: GeoOrb.Orb
Rain Rate(mm/hr): 20

Xmitter Power (dBm): 20
Xmitter Gain(dBi): 30
Receiver Gain(dBi): 30

Data Point #	Attenuation (dB)	RSL (dBm)
1	6.39	-142.4
2	5.52	-142.5

Figure 53. Aircraft-Satellite - loop on matched points; short form.

Printed Output - Long Form

The orbit path file for the example in Figure 54 has only two points. Therefore, the analysis has two matched points between the files.

Aircraft-Satellite Attenuation and RSL Calculations; Loop on Matched Points						
Frequency in GHz: 40				Xmitter Power (dBm): 20		
Aircraft Flight Path: Airpath2.FLT				Xmitter Gain(dBi): 30		
Satellite Orbit Path: GeoOrb.Orb				Receiver Gain(dBi): 30		
Rain Rate(mm/hr): 20						
Location		Satellite			AirCraft	
Pt. #	Latitude	Longitude	Alt.(km)	Latitude	Longitude	Alt.(m)
1	0.000000	-119.0000	35786.	40.0472	-105.2500	3500.
2	0.000000	-19.000	35786.	40.0500	-105.2500	4000.

Location	Az Ang.	El. Ang.	Path Length	Attenuation	RSL
Pt. #	(deg)	(deg)	(km)	(dB)	(dBm)
1	0.00	0.00	37661.4	6.38	-142.4
2	0.00	0.00	42327.2	5.52	-142.5

Figure 54. Aircraft-Satellite - loop on matched points; long form.

12. TERRESTRIAL ANALYSES

12.1 Cumulative Distribution of Rain Attenuation

This analysis calculates the cumulative distribution of rain attenuation along the path between 2 ground stations over the range of months you have specified. The attenuation calculation considers only the rain attenuation.

12.1.2 Program Input

First Month: The first month for which to perform the analysis.
Last Month: The end month must be the same or later than the start month.

You may enter "A" to abort analysis.

The following files must be in directory C:\VBEXE.

AB.DAT: A data file provided with JEM of rain attenuation coefficients.

ISOTHERM: A data file provided with JEM containing isotherm profile data.

TER.DAT: A file created by JEM that includes all scenario data.

12.1.3 Program Output

See Section 9.1.3 for description of printed and plotted output.

12.2 Cumulative Distribution of Multipath Attenuation

This analysis calculates the cumulative distribution of multipath attenuation for the month when the attenuation is greatest. The only propagation loss considered is the multipath loss above free space loss.

12.2.1 Program Input

Equivalent Earth's Radius Factor k: The default is 1.33.

The following file must be in directory C:\VBEXE

TER.DAT: a file created by JEM containing all the scenario data.

12.2.2 Program Output

Printed Output

Figure 55 shows the losses due to multipath attenuation per percentage of time.

Cumulative Distribution of Multipath Attenuation for a Terrestrial Path

% Time ATTN EXCD	Time (db)	Loss	
10.0000	72.00 hr	6.60	Scenario: MPath
5.0000	36.00 hr	9.61	From: SITE1
2.0000	14.40 hr	13.59	To: SITE2
1.0000	7.20 hr	16.60	Frequency (GHz): 30
0.5000	3.60 hr	19.61	Path Length(km): 42.0620
0.2000	1.44 hr	23.59	Tx Beamwidth: 2
0.1000	43.20 min	26.60	Rx Beamwidth: 2
0.0500	21.60 min	29.61	Min. Ht. at Midpath(m): 67.510
0.0200	8.64 min	33.59	
0.0100	4.32 min	36.60	
0.0050	2.163 min	39.61	
0.0020	51.84 sec	43.59	
0.0010	25.92 sec	46.51	
0.0005	12.96 sec	49.61	
0.0002	5.18 sec	53.59	
0.0001	2.59 sec	56.60	

Figure 55. Terrestrial multipath printed output.

Plotted Output

The plot data option for cumulative distribution of multipath attenuation produces a graph such as shown in Figure 56. The multipath attenuation value in dB is shown on the x-axis and the y-axis is the base ten logarithm of the percentage of time the attenuation is exceeded.

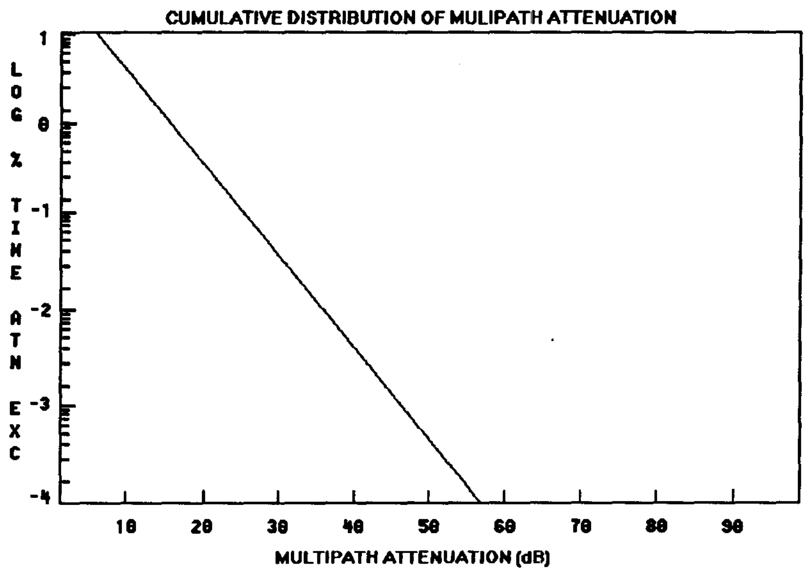

Figure 56. Terrestrial multipath plot.

12.3 Terrain Profile and Ray Path Plot

This analysis uses the terrain profile data you have selected to define and plot the terrain of a terrestrial path. With this information, you can plot the path as well as the ray path and its Fresnel clearance envelope. The analysis also allows you to calculate the antenna heights necessary to ensure the specified Fresnel clearance for this path.

12.3.1 Program Input

Equivalent Earth's Radius Factor: The default is 1.3.

Number of Fresnel Zone Clearances: This is used only for plotted output. The default is zero.

"Antenna Calculation" requests the following information:
Please enter the desired Fresnel clearance.
Please enter the desire Earth radius factor.
Please enter the frequency.
Which antenna height is known; 1=left site, 2=right site, 3=none.

The following file must be in directory C:\VBEXE.

TER.DAT: A file created by JEM that contains all of the scenario data.

12.3.2 Program Output

Printed Output

There are two forms of printed output from this analysis. The first as shown in Figure 57, shows the minimum ray clearance and take-off angles. This is the "Print Data to Screen" option. The "Antenna Calculations" are shown in Figure 58 for a Fresnel clearance of 4.16 with neither antenna height known.

Terrain Profile and Ray Path Information
SITE1 to SITE2

	Coordinates		Elevation(m)	Antenna Ht. (m)
Site	Latitude	Longitude	Above MSL	Above Ground
SITE1	40' 2' 24"	-105' 13' 29.9"	2300	10
SITE2	39' 46' 12"	-105' 52' 47.9"	2500	40

Path Length is 42.0620 kilometers
For an Earth Radius Factor of k = 1.3

RAY PATH MINIMUM CLEARANCE:
Minimum clearance is 12.99 meters at 1 km from SITE1.
Minimum clearance is 4.16 times the first Fresnel zone.
radius at 30 GHz, and 1 km from SITE1.

ANGLES OF ATMOSPHERIC PENETRATION:
Take off angle at SITE1 is .168 degrees.
Take off angle at SITE2 is -.459 degrees.
Minimum angle of penetration is -.459 degrees.

Mean atmospheric pressure on path is 75.48 kPa.
Mean path height form k=4/3 is 151.19 meters.

Figure 57. Terrain profile and ray path output.

Antenna Calculations
Site1 to Site2
To obtain 4.16 First Fresnel clearance(s) at an Earth radius factor of k = 1.3 and a frequency of 30 GHz
The following antenna heights would be required:

Left site Ht (m)	Right site Ht (m)	Min. Clear. (m)	Distance from SITE1 (km)
10.00	34.39	18.41	40.00
20.00	33.87	18.41	40.00
30.00	33.36	18.41	40.00
40.00	32.84	18.41	40.00
50.00	32.33	18.41	40.00
60.00	31.81	18.41	40.00

Figure 58. Antenna calculations options.

Plotted Output

"Plot Profile" produces a plot of the terrain profile, the ray path and the boundary of the n^{th} Fresnel zone clearance. In the example in Figure 59, the lower line is the terrain profile as input by the user. The top solid line is the ray path. The dotted line is the boundary of the n^{th} Fresnel zone clearance.

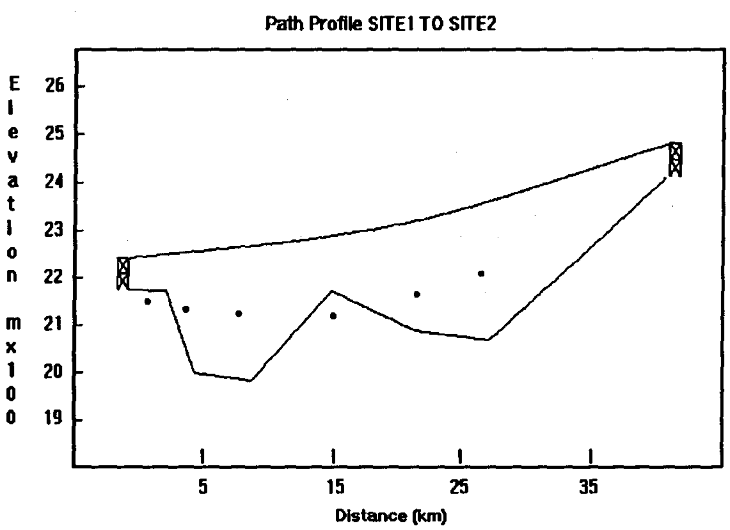

Figure 59. Terrain profile and ray path plot.

12.4 Cumulative Distribution of Clear Air Attenuation

This analysis calculates the cumulative distribution of the clear air attenuation for the path between two ground stations over the range of months you have specified. The only propagation loss considered is the clear air losses above free space loss.

12.4.1 Program Input

Equivalent Earth's Radius Factor k: The default is 1.33.

First Month: See Section 9.1.1.

Last Month: See Section 9.1.1.

The following files must be in directory C:\VBEXE.

AB.DAT: A data file provided with JEM that contains rain attenuation coefficients.

TER.DAT: A data file created by JEM that contains all the scenario data.

12.4.2 Program Output

See Section 9.2 for a description of printed and plotted output for clear air attenuation output.

12.5 Troposcatter/Diffraction Attenuation

This analysis calculates either the median long-term troposcatter loss or the median long-term diffraction loss for terrestrial paths that are beyond the horizon. It returns the attenuation of the lower propagation effect. This analysis includes the free space losses. It should be emphasized that the program assumes the input path is not line-of-sight. The method used to calculate the troposcatter loss is the CCIR Method I which is a simplified version of the National Bureau of Standards procedure described in CCIR Report 238-5 (1986) [12]. The diffraction path loss is calculated as the sum of the free space loss in the absence of any obstacles plus the diffraction loss introduced by the obstacles. The analysis is capable of two cases of diffraction: smooth earth and knife edge. The algorithm for the smooth earth diffraction is based on Roda's [13] simplification of the CCIR expression for the smooth case.

12.5.1 Program Input

Equivalent Earth's Radius Factor k: The default is 1.33.

Type of Surface beneath Horizon 1 and Horizon 2: choices are Land, Water or Unknown. Unknown defaults to land.

Type of terrain along path: The choices are (I)nland, (M)ixed land and water or (U)nknown.

Type of Diffraction Calculations Desired: The choices are (KN)ife-edge or (SM)ooth Earth. You should select smooth earth for water paths or any path without distinct changes in elevation. Or you should select knife-edge for any path with obvious obstacles along it. If you select a smooth earth path and the diffraction model is not valid for the terrain information in the terrain profile, the program will default to the knife-edge diffraction calculation. Unknown defaults to knife-edge.

The following files must be in directory C:\VBEXE.

OXYGEN.DAT: A file provided with JEM containing Oxygen coefficients.

WATER.DAT: A file provided with JEM containing water vapor coefficients.

TER.DAT: A file created by JEM containing all the scenario data.

12.5.2 Program Output

Figure 60 illustrates the output format of troposcatter attenuation analyses.

Troposcatter Attenuation Information
Site1 to Site2

Site	Latitude	Longitude	Elevation(m) Above MSL	Antenna Ht.(m) Above Ground
SITE1	32' 44' 24"	-96' 49' 48"	157	123
SITE2	30' 17' 59.9"	-97' 42' 35.9"	189	55

The Path Length (km) = 283.16
For an Earth Radius Factor of k of 1.3
Operating Frequency (GHz) = .105
CCIR climate type = 6
The scatter angle = 1.87 degrees (32.62 mrad.)

For this path the dominant propagation mode is troposcatter
Troposcatter and free space losses = 111.80 dB
Received signal level for the troposcatter propagation mode = -31.8 dBm

Figure 60. Troposcatter attenuation.

12.6 Terrestrial Link Margin Analysis

This analysis determines the link margin for a terrestrial path for each of the 12 months of the year. The analysis considers the propagation effects of clear air attenuation, free space losses, diffraction and troposcatter. For each case, the median clear air attenuation is calculated. The analysis considers the median climate data at the two ground stations. It assumes that there is no rain along the path and that the suspended water droplet concentration is 0. The analysis determines if the path is line-of-sight or beyond the horizon. For the line-of-sight path, the clear air attenuation is added to the free space losses. For the path that is beyond the horizon, the troposcatter attenuation and diffraction losses are calculated. See Figure 61 for an example of the output.

12.6.1 Program Input

Equivalent Earth's Radius Factor k: The default is 1.3.

Type of Surface beneath Horizon 1 and Horizon 2: The choices are Land, Water or Unknown. Unknown defaults to land.

Type of Terrain along Path: The choices are (I)nland, (M)ixed land and water or (U)nknown.

12.6.2 Program Output

A sample output for the terrestrial link margin analysis is found in Figure 61.

Terrestrial Link Margin Information
For the path from SITE1 to SITE2

The Transmitter (TXANT) is located at 32' 44' 24" and -96' 49' 48"
The Receiver (RXANT) is located at 30' 17' 59.9" and -97' 42' 35.9"
Frequency (GHz): .105 Receiver IF bandwidth(MHz): .1
Path length (km): 283.16 For an Earth Radius Factor of k = 1.3

Month	Losses(dB)	RSL(dBm)	Link Margin(dB)	Propagation Mode
JAN	130.34	-50.3	59.7	Troposcatter
FEB	128.18	-48.2	61.8	Troposcatter
MAR	129.13	-49.1	60.8	Troposcatter
APR	125.41	-45.4	60.8	Troposcatter
MAY	120.06	-40.0	69.9	Troposcatter
JUN	119.73	-39.7	70.3	Troposcatter
JUL	121.48	-41.5	68.5	Troposcatter
AUG	122.78	-42.8	68.5	Troposcatter
SEP	121.89	-41.9	68.1	Troposcatter
OCT	125.10	-45.1	64.9	Troposcatter
NOV	128.71	-48.7	61.3	Troposcatter
DEC	130.71	-50.7	59.3	Troposcatter

Figure 61. Terrestrial link margin.

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APPENDIX A
Visual Basic Error Codes

3	Return without GoSub
5	Illegal function call
6	Overflow
7	Out of memory
9	Subscript out of range
10	Duplicate definition
11	Division by zero
13	Type mismatch
14	Out of string space
17	Can't continue
19	No resume
20	Resume without error
28	Out of stack space
48	Error in loading DLL
49	Bad DLL calling convention
51	Internal error
52	Bad file name or number
53	File not found
54	Bad file mode
55	File already open
57	Device I/O error
58	File already exists
59	Bad record length
61	Disk full
62	Input past end of file
63	Bad record number
64	Bad file name
67	Too many files open
68	Device unavailable
70	Permission denied
71	Disk not ready
75	Path/File access error
76	Path not found
91	Object variable not set
92	For loop not initialized
93	Invalid pattern string
94	Invalid use of null
95	Cannot destroy active form instance
260	No timer available
321	Invalid file format
340	Control array element 'item' does not exist
341	Invalid object array index
342	Not enough room to allocate control array 'item'
343	Object not an array
360	Object already loaded
361	Can't load or unload this object
364	Object was unloaded
365	Unable to unload within this context
380	Invalid property value
381	Invalid property array index
382	'item' property can't be set at run time
383	'item' property is read-only
384	'item' property can't be modified when form is minimized or maximize
385	Must specify index when using property array
386	'item' property not available at run time
387	'item' property can't be set on this control
389	Invalid key
390	No defined value
391	Name not available
392	MDI Child forms cannot be hidden
393	'item' property cannot be read at runtime
394	'item' property is write-only
401	Can't show non-modal form when a modal form is being displayed
402	Must close or hide topmost modal form first
404	MDI Child forms cannot be shown modally
420	Invalid object reference
421	Method not applicable for this object
422	Property 'item' not found
423	Property or control 'item' not found
425	Invalid object use
426	Only one MDI form allowed
460	Invalid clipboard format
480	Can't create AutoRedraw image
481	Invalid picture
482	Printer error
520	Can't empty clipboard
521	Can't open clipboard

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The Jammer Effectiveness Model (JEM) is a Windows-based computer program which provides an integrated procedure for modeling propagation effects on telecommunication links and the effect of a jammer on communication links and networks. JEM provides the user with the ability of defining equipment such as transmitters, receivers and antennas and then using these definitions in a variety of analyses. JEM can be used easily after only a short learning period.

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jammer, jamming, propagation, communications system models, electronic warfare, countermeasures

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