NTIA TM-89-139

SINGLE AND AGGREGATE EMISSION LEVEL MODELS FOR INTERFERENCE ANALYSIS

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NTIA TM-89-139

SINGLE AND AGGREGATE EMISSION LEVEL MODELS FOR INTERFERENCE ANALYSIS

Cesar A. Filippi
Steven Litts
Mary Jo Clarke
Robert Gruendl

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Robert A. Mosbacher, Secretary

Alfred C. Sikes, Assistant Secretary
for Communications and Information

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ABSTRACT

This report describes analysis models and software packages developed by the National Telecommunications and Information Administration (NTIA) for the assessment of single-entry and aggregate interference from terrestrial emitters into terrestrial or airborne victim receivers. The menu-driven computer programs are 100% MS-DOS compatible, and provide user options for input/output computations, parametric representations, propagation models and emitter distributions. The flexibility in the scenario creation, parameter selection, and computation mode, renders the models applicable to a wide variety of EMC assessments and conditions. Model descriptions, technical formulations, user manuals, and sample runs are provided in this report.

KEY WORDS

Aggregate Interference

Computer Programs

Coordination Distance Computation

Interference Analysis Models

Received Power Computations

Single-Entry Interference

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INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA) is responsible for managing the Federal Government's use of the radio spectrum. NTIA's responsibilities include establishing policies concerning spectrum assignment, allocation and use, and providing the various departments and agencies with guidance to ensure that their conduct of telecommunications activities is consistent with these policies. In support of these responsibilities, NTIA has undertaken a number of spectrum resource assessments (SRAs). The objectives of these studies are to assess spectrum utilization, identify existing and/or potential compatibility problems between systems of various departments and agencies, provide recommendations for resolving any compatibility conflicts, and recommend changes to promote efficient and effective use of the radio spectrum and to improve spectrum management procedures.

A Draft Notice of Proposed Rulemaking (NPRM) was submitted by the Federal Communications Commission (FCC) to the Interdepartment Radio Advisory Committee (IRAC) on August 1986 (Doc. 25038/1). The NPRM refers to a revision of Parts 2 and 15 of the FCC Rules and Regulations regarding the operation of non-licensed radio frequency devices.

The Technical Subcommittee (TSC) of IRAC performed a preliminary study on this matter, and submitted its initial comments in September 1986 (Doc. 25087) while indicating that further investigation was needed due to the diversity and complexity of the issues involved. The TSC was tasked by IRAC to continue its study on the impact of the proposed revisions on Government operations.

The TSC formed Working Group (WG) 19 to respond to this task, and address any other pertinent issues regarding the FCC Rules and Regulations on non-licensed radio frequency devices. The TSC/WG-19 has conducted several meetings from September 1987 to July 1988 on this matter, where technical developments and policy guidelines have been discussed and/or recommended.

One of the TSC/WG-19 tasks was the development of standardized procedures, analytic models, and computer algorithms for the assessment of the electromagnetic compatibility between non-licensed devices and government systems. In particular, single and aggregate emission effects from non-licensed devices were to be considered with sufficient flexibility to support distinct technical specifications and geographical distributions.

The Spectrum Engineering and Analysis Division (SEAD) and the Analytic Model Development Branch (AMDB) personnel of NTIA have participated in the TSC/WG-19 meetings, and accepted the task to develop single and aggregate analysis models and software packages to assess the potential interference of undesired emissions into terrestrial and airborne station receivers.

OBJECTIVES

The objectives of the NTIA task were as follows.

- Develop a single emitter analysis model that estimates the emission level received by a distant station.
- Develop an aggregate emitter analysis model that estimates the emission level received by a terrestrial or airborne station from a distribution of multiple emitters.

APPROACH

The following approach was employed to accomplish the task objectives:

The FCC Rules and Regulations for non-licensed emission devices were investigated to identify the diverse emission level specifications (parameters, units) to be supported by an analysis model. It was concluded that both field strength and radiated power levels should be provided as input options, along with standardized unit conversions following the TSC/WG-19 guidelines.

A single emitter analysis model was developed with various input/output computation options to support the diverse specifications and the recommended guidelines. Multiple emitter distributions were also modeled, and aggregate received power computation algorithms were developed for terrestrial and airborne station receivers. The software packages were coded in FORTRAN with 100% MS-DOS PC compatibility, and are all available in a single low-density disk. The three distinct packages listed below were developed to simplify the user interaction.

- Single Emitter Analysis Model (SEAM)
- Aggregate Emitter Analysis Model for Terrestrial Receivers (RINGS)
- Aggregate Emitter Analysis Model for Airborne Receivers (PDOME)

The SEAM and RINGS programs have the option of using free space formulas or a propagation model subroutine for the path loss versus distance calculations. The PDOME program uses free space propagation. The propagation model subroutine incorporated into the SEAM and RINGS programs is the Integrated Propagation System (IPS) model.

The sections that follow describe each of these analytical models and software packages. It should be emphasized that even though their development was motivated by non-licensed devices and their emissions, the models and packages can be applied to other electromagnetic compatibility and interference estimation applications involving a single emitter or aggregate emitter distributions.

SECTION 2

SINGLE-EMITTER ANALYSIS MODEL

SEAM TECHNICAL MANUAL

The purpose of this section is to describe the single-emitter analysis model (SEAM) and computation options. A single emitter is considered, and the user can specify the emission level in terms of field strength or radiated power. A direct computation mode estimates the emission levels received (field strength, power, power flux density) at a propagation distance specified by the user. An inverse computation mode estimates the propagation distance required to maintain the received emission level below a threshold level specified by the user.

A propagation model is included in the package as a subroutine for path loss versus distance determination in direct and inverse modes. Any future enhancements of the propagation model can be incorporated without affecting the other computation functions. A free-space propagation option is also provided.

The program is menu-driven with user selection of the computation mode and input parameters as described below. The user is prompted only for those input parameters needed for the computation mode selected, and the ouput data is displayed in various convenient units.

The user selects one of these two options to specify the computation mode and output data:

(1) Direct Mode: the following parameters are computed based on an emitter strength and a propagation distance selected by the user.

- Propagation Loss (L_p) at propagation distance (D)
- Field Strength (E) at propagation distance (D)
- Received Power (P_r) and Spatial Power Density (P_d)

(2) Inverse Mode: the following parameters are computed based on an emitter strength and a receiver threshold selected by the user.

- Propagation loss (L_p) to meet receiver threshold
- Propagation distance (D) to meet receiver threshold

The user also selects one of these two options to specify the propagation loss versus distance computation in either direct or inverse mode:

- Free Space Propagation Formulas
- Integrated Propagation System (IPS) Model

The user also selects one of these two options to specify the emitter strength in either direct or inverse mode:

- Field Strength (E_0) at Reference Distance (D_0)
- Emitter power: user can select either the equivalent isotropically radiated power (EIRP), or the transmitter power (P_t) and transmitter antenna gain (G_t) independently ($EIRP=P_tG_t$).

The user also selects one of these three options to specify the receiver threshold in the inverse computation mode:

- Received Power Level Threshold (P_{rt})
- Received Spatial Power Density Threshold (P_{dt})
- Received Field Strength Threshold (E_t)

The computation process is summarized in Figure 2-1. The user selection of the computation mode and emitter strength options automatically triggers the input parameter prompts, and provides the input/output computation formulas and output data display. The propagation model provides direct or inverse path-loss versus distance conversions according to the computation mode selected.

The input parameters accepted by the package are summarized in TABLE 2-1, along with the output parameters computed. The EIRP is automatically derived if the transmitter power and antenna gain are inputted. The receiver antenna

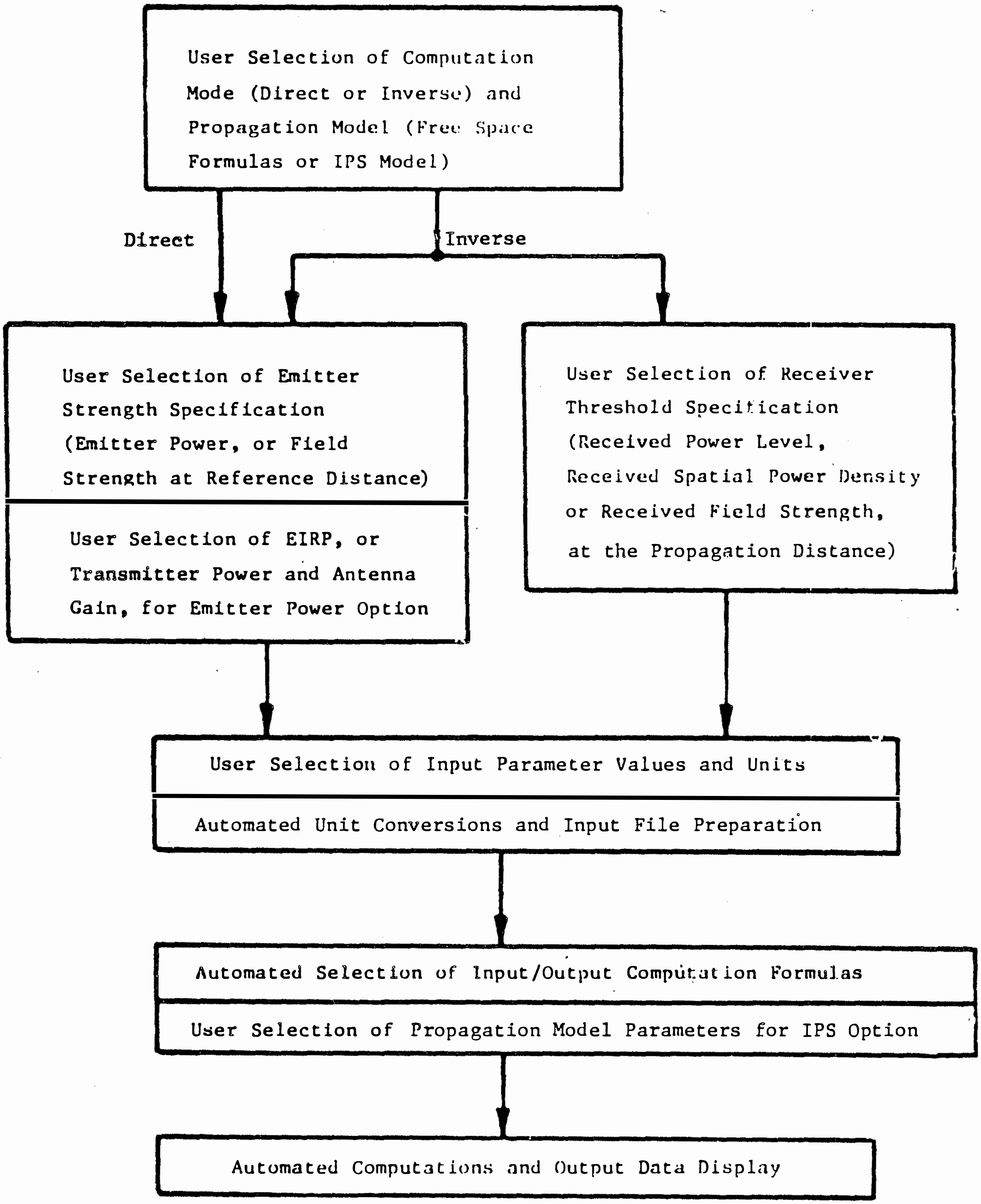


Figure 2-1. SEAM computation process.

TABLE 2-1

SEAM DIRECT AND INVERSE MODE COMPUTATIONS

Direct Mode Inputs	Inverse Mode Inputs
Emission Frequency F(MHz)	Emission Frequency F(MHz)
EIRP(W,mW,nW,dBm,dBW)	EIRP(W,mW,nW,dBm,dBW)
Transmitter Power P_t(W,mW,nW,dBm,dBW)	Field Strength E_o(mV/m,μV/m)
Transmitter Antenna Gain G_t(dBi)	Reference Distance D_o(m)
Field Strength E_o(mV/m,μV/m)	Receiver Power Threshold P_{rt}(dBm)
Reference Distance D_o(m)	Spatial Power Density Threshold P_{dt}(dBm/m^2)
Propagation Distance D(km)	Field Strength Threshold E_t(dBμV/m)
Receiver Antenna Gain G_r(dBi)	Receiver Antenna Gain G_r(dBi)
Receiver Antenna Diameter D_r(m)	Receiver Antenna Diameter D_r(m)

Direct Mode Outputs	Inverse Mode Outputs
Propagation Loss L_p(dB)	Propagation Loss L_p(dB)
Field Strength E(μV/m,dBμV/m)	Propagation Distance D(m)
Received Power P_r(mW,dBm)	
Spatial Power Density P_d(mW/m^2,dBm/m^2)	

Notes

(1) User selects between EIRP, (P_t,G_t), or (E_o,D_o) input to specify the emitter strength, in both direct and inverse modes.

(2) User selects between G_r or D_r input to specify the receiver antenna, in both direct and inverse modes. A default value of G_r = 0.0 dBi is provided.

(3) User selects between P_{rt} or P_{dt} or E_t input to specify the receiver level threshold, in inverse mode only.

(4) User selects free space or IPS propagation model to specify the distance to path loss conversion, with default values and help screen provided for the selection of the IPS model parameters.

(5) All the outputs listed above are provided for the direct or inverse mode, using scientific notation for the non-dB units.

gain is automatically derived if the receiver antenna diameter is inputted, assuming a parabolic dish with an efficiency factor $\eta = 0.55$.

The input/output computations are performed with a set of standard units and formulas. Any units conversion is done before (input file preparation) or after (output data display) the input/output formulas are applied. This permits the potential modification of the input and output units without affecting the set of input/output formulas implemented in the package.

The input/output formulas employed in the direct and inverse mode computations are summarized in TABLES 2-2 and 2-3. Each table consists of two sets of formulas, with one set corresponding to the field strength input option and the other to the emission power input option. The formulas are the logarithmic (dB) versions of the parametric relations described in this section.

The IPS propagation model subroutine also requires antenna height and environmental data as input parameters to be provided by the user. These parameters are inputted via a dedicated IPS screen that includes parameter ranges and help suggestions as illustrated below.

```
Integrated Propagation System Input Screen
------------------------------------------
Site Parameters:
                        Transmitter antenna height =     5.00 m
                           Receiver antenna height =    15.00 m
Ground and Atmosphere Constants:
     Ground conductivity (0.0001-5.0 mho/m) =    0.0050 mho/m
    Ground dielectric constant (1.00-81.00) =    15.00
   Atmospheric refractivity (200.00-450.00) =   301.00
          Transmitter polarization (V or H) =    V

     Suggested :                 Conductivity (mho/m)  Dielectric Constant
      Values   : Average ground      0.005                   15.0
       for     : Poor ground         0.001                    4.0
    Electrical : Good ground         0.020                   25.0
      Ground   : Fresh water         0.010                   81.0
    Constants  : Sea water           5.000                   81.0
```

TABLE 2-2

SEAM DIRECT MODE INPUT/OUTPUT FORMULAS

Case of Field Strength (E_o,D_o) Input Parameter

$E(dB\mu V/m) = -27.6 + E_o(dB\mu V/m) + 20 \log D_o(m) + 20 \log F(MHz) - L_p(dB)$

$P_r(dBm) = -104.8 + E_o(dB\mu V/m) + 20 \log D_o(m) + G_r(dBi) - L_p(dB)$

$P_d(dBm/m^2) = -143.3 + E_o(dB\mu V/m) + 20 \log D_o(m) + 20 \log F(MHz) - L_p(dB)$

$L_p(dB)$ = Direct Propagation Model evaluated at D(m)

Case of EIRP Input Parameter

$E(dB\mu V/m) = 77.2 + EIRP(dBm) + 20 \log F(MHz) - L_p(dB)$

$P_r(dBm) = EIRP(dBm) + G_r(dBi) - L_p(dB)$

$P_d(dBm/m^2) = -38.5 + EIRP(dBm) + 20 \log F(MHz) - L_p(dB)$

$L_p(dB)$ = Direct Propagation Model evaluated at D(m)

Note: The conversion algorithm between the two cases above is $EIRP(dBm) = -104.8 + E_o(dB\mu V/m) + 20 \log D_o(m)$, based on free space propagation at the reference distance $D_o(m)$.

TABLE 2-3

SEAM INVERSE MODE INPUT/OUTPUT FORMULAS

Case of Field Strength (E_o,D_o) Input Parameter

$$L_p(dB) = -104.8 + E_o(dB\mu V/m) + 20 \log D_o(m) + G_r(dB) - P_{rt}(dBm)$$
$$= -143.3 + E_o(dB\mu V/m) + 20 \log D_o(m) + 20 \log F(MHz) - P_{dt}(dBm/m^2)$$
$$= -27.6 + E_o(dB\mu V/m) + 20 \log D_o(m) + 20 \log F(MHz) - E_t(dB\mu V/m)$$

D(m) = Inverse Propagation Model evaluated at L_p(dB)

Case of EIRP Input Parameter

$$L_p(dB) = EIRP(dBm) + G_r(dB) - P_{rt}(dBm)$$
$$= -38.5 + EIRP(dBm) + 20 \log F(MHz) - P_{dt}(dBm/m^2)$$
$$= 77.2 + EIRP(dBm) + 20 \log F(MHz) - E_t(dB\mu V/m)$$

D(m) = Inverse Propagation Model evaluated at L_p(dB)

Note: The conversion algorithm between the two cases above is $EIRP(dBm) = -104.8 + E_o(dB\mu V/m) + 20 \log D_o(m)$, based on free space propagation at the reference distance D_o(m).

The following four examples illustrate the direct and inverse computation modes. The input and output data following the user selection of the computation mode, propagation model, and input parameters, are shown in TABLES 2-4 to 2-7.

TABLE 2-4 illustrates the direct mode computation made with the emitter EIRP input option, and TABLE 2-5 illustrates the corresponding inverse mode computation. The receiver antenna diameter is selected as an input paramter in both modes, and the received power threshold is selected for the inverse mode input option.

TABLE 2-6 illustrates the direct computation mode with the emitter field strength/input option, and TABLE 2-7 illustrates the corresponding inverse mode computations. The receiver antenna gain is selected as an input parameter in both modes, and the received power threshold is selected for the inverse mode input option.

TABLE 2-4

SEAM DIRECT COMPUTATION MODE WITH EMITTER EIRP INPUT

INPUT DATA - Direct Mode

Frequency =	1700.000	MHz
Emitter EIRP =	-13.0	dBm
Propagation distance =	50.00	km
Receiver antenna diameter =	3.0	m

OUTPUT - Direct Mode

Propagation Loss =		178.0 dB
Field Strength =	3.47791E-03 μV/m	-49.2 dBμV/m
Received Power =	1.24991E-16 mW	-159.0 dBm
Spatial Power Density =	3.25565E-17 mW/m^2	-164.9 dBm/m^2

TABLE 2-5

SEAM INVERSE COMPUTATION MODE WITH EMITTER EIRP AND RECEIVED POWER THRESHOLD INPUTS

INPUT DATA - Inverse Mode

Frequency =	1700.000	MHz
Emitter EIRP =	-13.0	dBm
Received power threshold =	-159.0	dBm
Receiver antenna diameter =	3.0	m

OUTPUT - Inverse Mode

Propagation Loss =	178.0	dB
Propagation Distance =	49.982	km

TABLE 2-6

SEAM DIRECT COMPUTATION MODE WITH EMITTER FIELD STRENGTH INPUT

INPUT DATA - Direct Mode

Frequency =	200.000	MHz
Emitter field strength =	500.0	μVm
Reference distance =	30.0	m
Propagation distance =	10.00	km
Receiver antenna gain =	25.0	dBi

OUTPUT - Direct Mode

Propagation Loss =		122.3 dB
Field Strength =	9.55674E-02 μV/m	-20.4 dBμV/m
Received Power =	1.37581E-12 mW	-118.6 dBm
Spatial Power Density =	2.45821E-14 mW/m^2	-136.1 dBm/m^2

TABLE 2-7

SEAM INVERSE COMPUTATION MODE WITH EMITTER FIELD STRENGTH AND RECEIVED POWER THRESHOLD INPUTS

INPUT DATA - Inverse Mode

Frequency =	200.000	MHz
Emitter field strength =	500.0	μV/m
Reference distance =	30.0	m
Received power threshold =	-118.6	dBm
Receiver antenna gain =	25.0	dBi

OUTPUT - Inverse Mode

Propagation Loss =	122.3	dB
Propagation Distance =	10.000	km

SEAM MODEL FORMULATION

The power received (P_r) from an emitter at a distant location can be formulated in terms of the received field strength (E), medium impedance (Z), emission wavelength (λ) or frequency (F), and receiving antenna aperture (A_r), diameter (A_d), efficiency (η) or gain (G_r), as follows

$$P_r(W) = \frac{[E(V/m)]^2}{Z(\Omega)} \cdot A_r(m^2) = \frac{[E(V/m)]^2}{Z(\Omega)} \cdot \eta \frac{\pi}{4} [D_r(m)]^2$$

$$= \frac{[E(V/m)]^2}{Z(\Omega)} \cdot \frac{[\lambda(m)]^2}{4\pi} G_r = \frac{9 \times 10^4}{4\pi Z(\Omega)} \cdot \left[\frac{E(V/m)}{F(MHz)}\right]^2 \cdot G_r \qquad (2\text{-}1)$$

The power received (P_r) can also be formulated in terms of the emission EIRP and path loss (L_p). In free space, the relation $L_p = (4\pi D/\lambda)^2$ also introduces the emission frequency (F) and propagation distance (D) explicitly into the formulation as follows

$$P_r(W) = EIRP(W) \cdot G_r \cdot L_p^{-1} \qquad \text{(general) (2-2)}$$

and

$$P_r(W) = EIRP(W) \cdot G_r \cdot \left(\frac{\lambda}{4\pi D}\right)^2$$

$$= \frac{9 \times 10^4}{(4\pi)^2} \cdot \frac{EIRP(W) \cdot G_r}{[F(MHz)]^2 \cdot [D(m)]^2} \qquad \text{(free space) (2-3)}$$

The power received expression (2-1) can be equated to the expressions (2-2) or (2-3), in order to obtain the relation between the received field strength and the transmitted EIRP as follows

$$E(V/m) = \frac{\sqrt{4\pi Z(\Omega)}}{300} \cdot \sqrt{\frac{EIRP(W)}{L_p}} \cdot F(MHz) \qquad \text{(general) (2-4)}$$

and

$$E(V/m) = \frac{\sqrt{377}}{\sqrt{4\pi}} \cdot \frac{\sqrt{EIRP(W)}}{D(m)} \qquad \text{(free space) (2-5)}$$

The formulas (2-4) and (2-5) can be used to develop field strength conversion relations that account for distance changes. For example, the field strength (E_0) at a reference distance (D_0) from the emitter is specified, and the field strength (E) at a propagation distance (D) from the emitter is to be determined. The relations are derived from the fact that the product $E \cdot \sqrt{L_p/Z}$ in formula (2-4) and the product $E \cdot D$ in formula (2-5) must remain invariant as the propagation distance changes, since the emission EIRP is a constant.

The field strength conversion is simple in free space, since only the propagation distance is involved in a direct proportion. In the general case, the field strength conversion must handle the distance variation through the propagation loss term, as happened with the power received expression. Any medium impedance variation with propagation distance can also be accounted as follows

$$E(V/m\ @\ D\text{-met}) = E_0(V/m\ @\ D_0\text{-met}) \circ (D_0/D) \qquad \text{(free space)} \quad (2\text{-}6)$$

and

$$E(V/m\ @\ D\text{-met}) = E_0(V/m\ @\ D_0\text{-met}) \circ \sqrt{\frac{L_p\ @\ D_0\text{-met}}{L_p\ @\ D\text{-met}}} \circ \sqrt{\frac{Z(\Omega\ @\ D\text{-met})}{Z(\Omega\ @\ D_0\text{-met})}} \qquad \text{(general)} \quad (2\text{-}7)$$

These last two formulas can be used to express the power received (P_r) in terms of the field strength (E_0) at the reference distance (D_0). The results are obtained when formulas (2-6) and (2-7) are used in formula (2-1) as follows

$$P_r(W) = \frac{9 \times 10^4}{4\pi(377)} \circ \left[\frac{E_0(V/m\ @\ D_0\text{-met})}{F(MHz)}\right]^2 \circ (D_0/D)^2 \circ G_r \qquad \text{(free space)} \quad (2\text{-}8)$$

and

$$P_r(W) = \frac{9 \times 10^4}{4\pi\ Z(\Omega\ @\ D_0\text{-met})} \circ \left[\frac{E_0(V/m\ @\ D_0\text{-met})}{F(MHz)}\right]^2 \circ \frac{L_p\ @\ D_0\text{-met}}{L_p\ @\ D\text{-met}} \circ G_r \qquad \text{(general)} \quad (2\text{-}9)$$

The spatial power density $P_d(W/m^2) = E^2(V/m)^2/Z(\Omega)$ can also be expressed in terms of the field strength (E_o) at the reference distance (D_o) using formulas (2-6) and (2-7) as follows

$$P_d(W/m^2) = \frac{1}{377} \cdot [E_o(V/m \text{ @ } D_o\text{-met})]^2 \cdot (D_o/D)^2$$

(free space) (2-10)

and

$$P_d(W/m^2) = \frac{[E_o(V/m \text{ @ } D_o\text{-met})]^2}{Z(\Omega \text{ @ } D_o\text{-met})} \cdot \frac{L_p \text{ @ } D_o\text{-met}}{L_p \text{ @ } D\text{-met}}$$

(general) (2-11)

A special case in-between the free space and general cases occurs when free-space propagation is assumed for the reference distance (D_o), but not for the receiver distance (D). The use of $L_p = (4\pi D_o/\lambda)^2$ at D_o-meters in formulas (2-7), (2-9) and (2-11) yields the following results for this special case.

$$E(V/m \text{ @ } D\text{-met}) = \frac{4\pi}{300} \cdot \frac{[E_o(V/m \text{ @ } D_o\text{-met}] \cdot [D_o(m)]}{\sqrt{L_p \text{ @ } D\text{-met}}/F(MHz)} \cdot \frac{Z(\Omega \text{ @ } D\text{-met})}{377}$$

(special case) (2-12)

and

$$P_r(W) = \frac{4\pi}{377} \cdot \frac{[E_o(V/m \text{ @ } D_o\text{-met}]^2 \cdot [D_o(m)]^2}{[L_p \text{ @ } D\text{-met}]} \cdot G_r$$

(special case) (2-13)

and

$$P_d(W/m^2) = \frac{(4\pi)^2}{9 \times 10^4} \cdot \frac{1}{377} \cdot \frac{[E_o(V/m) \text{ @ } D_o\text{-met}]^2 \cdot [D_o(m)]^2}{L_p \text{ @ } D\text{-met}} \cdot [F(MHz)]^2$$

(special case) (2-14)

These special case formulas have been implemented in the analysis model when the IPS propagation option is selected. A constant medium impedance Z = 377 Ω is used for simplicity, in which case the last factor in formula (2-12) reduces to unity, while formulas (2-13) and (2-14) remain as shown.

SEAM USER MANUAL

The Single-Emitter Analysis Model (SEAM) performs link calculations to estimate received emission levels or propagation distance requirements for a given emitter strength specification. The user has the option to specify the emitter strength as an emission power level, or as a field strength value at a reference distance.

The program supports user-interactive computations and automated unit conversions in direct and inverse modes. The direct mode estimates received emission levels at a propagation distance specified by the user. The inverse mode estimates the propagation distance required to meet a received level threshold specified by the user, up to a 500 km distance limit.

The user selects between free space or the Integrated Propagation System (IPS) model for the path loss versus distance conversions. If the IPS propagation model is selected, the program will require the user to input the propagation model parameters. On-screen help is provided to help the user select parameter values according to the environment.

Hardware Requirements

The SEAM program has been designed to run on any PC with 100% IBM PC compatibility. The program requires a PC monitor (either color or monochrome), and a 5-1/4" floppy drive unit (the media used to transfer the software). Storing the program files on a hard disk will vastly improve the program's execution speed. Approximately 152 K bytes of disk space is needed to store all associated program files. A line printer is not necessary.

Software Requirements

MS or PC DOS operating system version 2.0 or higher is required. In order for the screen display to work properly, the user PC must contain a file named CONFIG.SYS in the root directory containing the following entry.

DEVICE = ANSI.SYS

If file ANSI.SYS does not reside in the root directory of the disk drive used for boot-up, precede the name with the proper path-specifier (disk drive, colon, backslash, plus directory name and second backslash, if applicable).

The following three files must reside on the disk to run the SEAM program. These files require approximately 152 K bytes of disk space.

SEAM.EXE - the program executable file
SEAMPN1.PNL - a PANEL input file used by SEAM
SEAMPN2.PNL - a PANEL input file used by SEAM

Input

The input for the SEAM program is requested on the monitor by an interactive input routine. The user first selects from the computation options, and is then prompted for input parameters and units according to the options chosen. The highlighted area at the bottom of each screen tells the user what to do next. The box just above the highlighted line gives the user all of the possible actions at a given time. This includes aborting the program at any time.

The following options are available for user selection:

- computation mode - direct or inverse
- propagation option - free space or IPS propagation model
- emitter strength option - field strength or emission power level
- receiver antenna option - gain or diameter
- power units - watts, milliwatts, nanowatts, dBm, or dBW
- power level - EIRP(includes antenna gain) or transmitter (excludes antenna gain)
- field strength units - microvolts/meter or millivolts/meter
- receiver threshold - received power, spatial power density, or field strength

The user must also input the following parameters if the IPS model is selected.

- transmitter antenna height - units m
- receiver antenna height - units m
- ground conductivity - units mho/m, range .0001 to 5.0
- ground dielectric constant - no units, range 1.01 to 81.00
- atmospheric refractivity - no units, range 200.00 to 450.00
- transmitter polarization - V for vertical or H for horizontal

Output

The output provided by SEAM depends on whether the program was run in the direct or inverse mode. In both modes, the program calculates the propagation loss. In the direct mode, the received field strength, the received power, and the received spatial power density are also calculated. In the inverse mode, the propagation distance is calculated from the propagation loss.

The output is displayed on the user's screen. If a hard copy of the output is needed, the user can use the shift print screen to generate a hard copy of the results.

Error conditions

The SEAM program requires that the files SEAMPN1.PNL and SEAMPN2.PNL be in the directory from which the program is being run. If one of the files is missing, the program will print the following error message and stop.

```
Program cannot proceed without loading the following file:
SEAMPN1.PNL
Stop - Program terminated.
```

The missing file or files should be loaded into the directory before the program is run again.

Flow Charts

The flow chart in Figure 2-2 shows the relationships between the program pieces. The flow chart in Figure 2-3 gives a logic flow for the model.

SEAM SAMPLE RUNS

Four examples are next provided to show how this program may be used. A brief description of each example is given here.

Example 1 - The program is run in the direct mode using the IPS propagation model. The emitter strength is selected as a field strength at reference distance. The receiver antenna gain option is selected. The units for the field strength parameter are microvolts/meter.

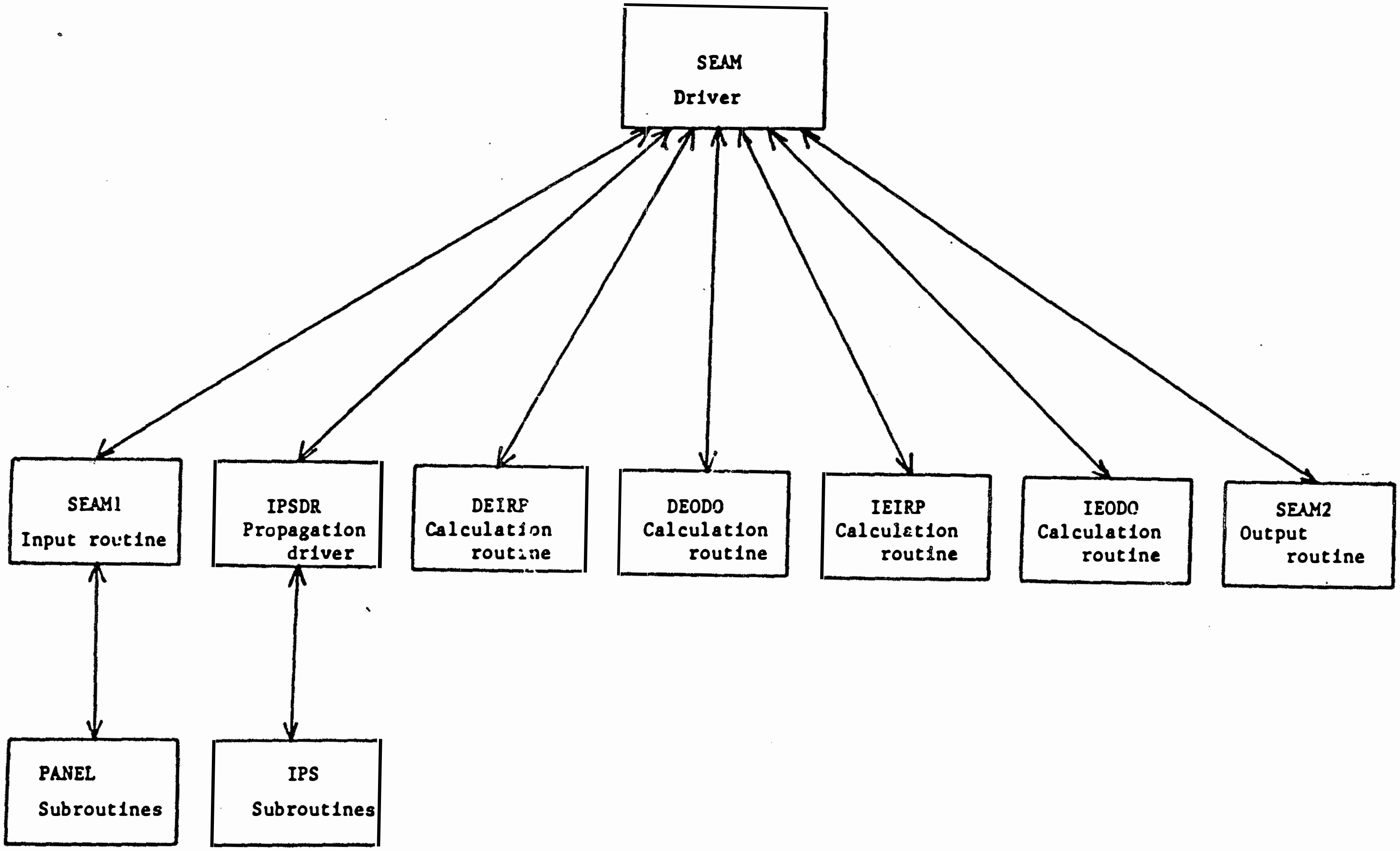


Figure 2-2. SEAM program flow chart.

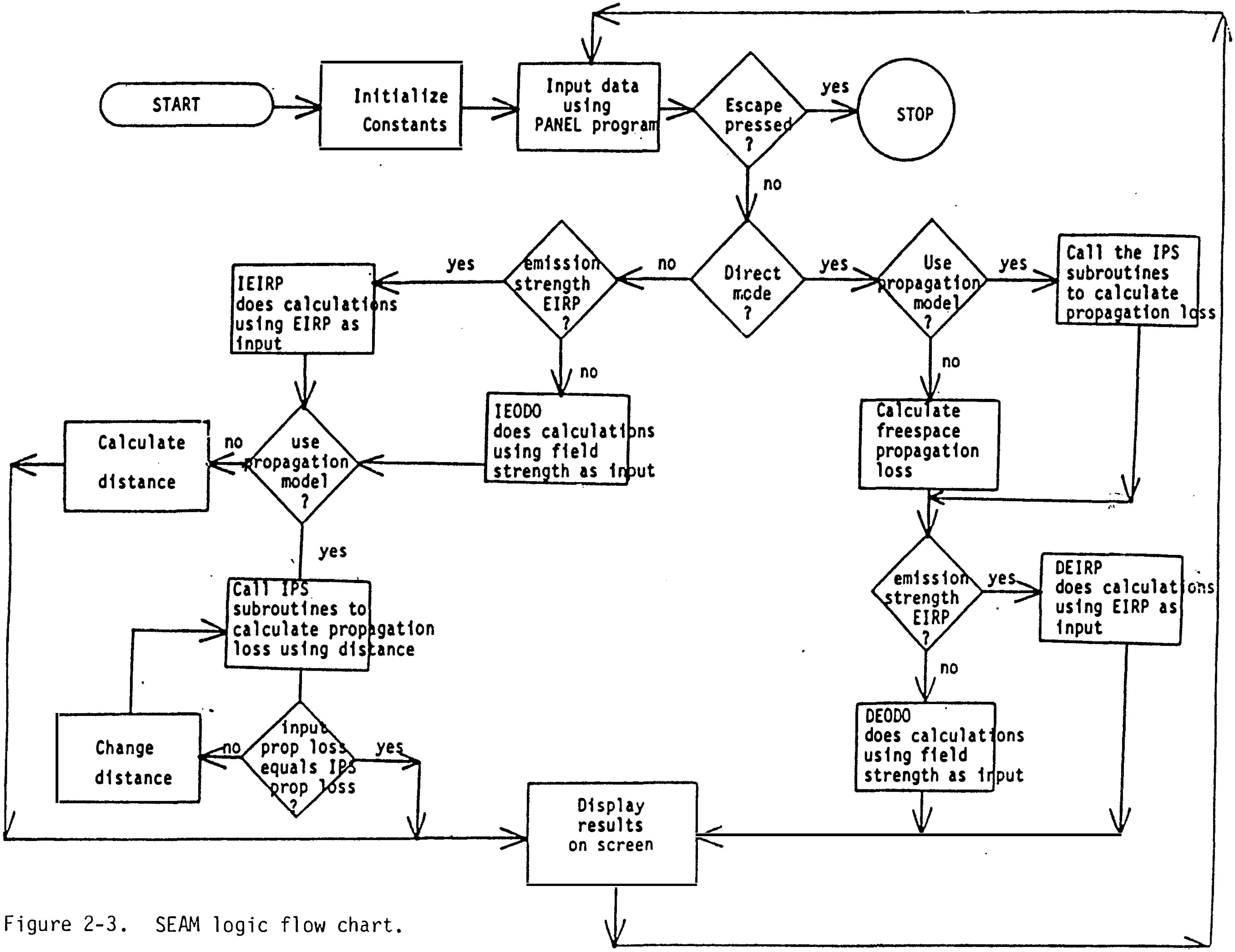


Figure 2-3. SEAM logic flow chart.

Example 2 - The program is run in the inverse mode using the IPS propagation model. This example is the inverse of example 1 and it selects the received power for the threshold specification.

Example 3 - The program is run in the direct mode using the IPS propagation model. The emitter strength is selected as an emission power level, specified as an EIRP value. The receiver antenna diameter option is selected and the program calculates the receiver antenna gain from this value.

Example 4 - The program is run in the inverse mode using the IPS propagation model. This example is the inverse of example 3 and it selects the received power for the threshold specification.

Example 1

Direct Computation Mode

with

Emitter Field Strength Input

SINGLE-EMITTER ANALYSIS MODEL

SEAM is a single-emitter program that supports user-interactive computations and automated unit conversions in direct and inverse modes. The user has the option to specify the emitter strength as an emission power level, or as a field strength value at a reference distance selected by the user.

The direct mode estimates received emission levels (power, spatial power density, field strength) at a propagation distance specified by the user. The inverse mode estimates the propagation distance required to meet a received level threshold specified by the user, up to a 500 km distance limit.

The user selects between free space formulas or the IPS propagation model for the path loss versus distance conversion. On-screen help is provided for the propagation model parameters.

All unit conversions are performed automatically. The output data display is presented in both dB and non-dB units, using scientific notation for the latter.

Reference: Single-Emitter Analysis Model
Cesar A. Filippi, February 1988

F10 = Next screen	Esc = Stop

Press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

The program can use a direct or an inverse computation mode. Press the space bar to choose a computation mode.

computation mode = direct

The program can use either free space propagation or the IPS propagation model. Press the space bar to choose the propagation option.

propagation option = IPS propagation model

The emitter strength can be specified as an emission power level or a field strength at a reference distance. Press the space bar to choose the emitter strength option.

emitter strength option = field strength

The program requires either the receiver antenna gain or diameter as input. Press the space bar to choose the receiver antenna option.

receiver antenna option = gain

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return = select next input field

Make choices then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

The field strength units can be microvolts per meter or millivolts per meter. Press the space bar to choose the field strength units.

field strength units = microvolts/meter

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return = select next input field

Make choices then press F10 to continue

```
                    SINGLE-EMITTER ANALYSIS MODEL

 Integrated Propagation System Input Screen
 ------------------------------------------
 Site Parameters:
                  Transmitter antenna height =    5.00 m
                     Receiver antenna height =   15.00 m
 Ground and Atmosphere Constants:
      Ground conductivity (0.0001-5.0 mho/m) =  0.0050 mho/m
     Ground dielectric constant (1.01-81.00) =   15.00
    Atmospheric refractivity (200.00-450.00) =  301.00
           Transmitter polarization (V or H) =  V

      Suggested :                 Conductivity (mho/m)  Dielectric Constant
       Values   : Average ground      0.005                    15.0
        for     : Poor ground         0.001                     4.0
     Electrical : Good ground         0.020                    25.0
       Ground   : Fresh water         0.010                    81.0
     Constants  : Sea water           5.000                    81.0

  F9  = Previous screen                      Esc = Stop
  F10 = Next screen                  Return     = select next input field

 Enter all input data then press F10 to continue
```

```
                    SINGLE-EMITTER ANALYSIS MODEL

 INPUT DATA - Direct Mode
 ------------------------

                  Frequency =     200.000 MHz

     Emitter field strength =     500.0   uV/m

         reference distance =      30.0   m

       Propagation distance =      10.00  km

      Receiver antenna gain =      25.0   dBi


   F1 = Run program
   F2 = Exit program                          Esc = Stop
   F9 = Previous screen               Return     = select next input field

 Enter all input data then press F1 to perform calculation.
```

```
                    SINGLE-EMITTER ANALYSIS MODEL

 OUTPUT - Direct Mode
 --------------------

       Propagation Loss =           122.3 dB

         Field Strength =  9.55674E-02 uV/m          -20.4 dBuV/m

         Received Power =  1.37583E-12 mW           -118.6 dBm

   Spatial Power Density =  2.45821E-14 mW/m**2      -136.1 dBm/m**2


 Press ENTER to continue
```

Example 2

Inverse Computation Mode

with

Emitter Field Strength and

Received Power Threshold Inputs

SINGLE-EMITTER ANALYSIS MODEL

SEAM is a single-emitter program that supports user-interactive computations and automated unit conversions in direct and inverse modes. The user has the option to specify the emitter strength as an emission power level, or as a field strength value at a reference distance selected by the user.

The direct mode estimates received emission levels (power, spatial power density, field strength) at a propagation distance specified by the user. The inverse mode estimates the propagation distance required to meet a received level threshold specified by the user, up to a 500 km distance limit.

The user selects between free space formulas or the IPS propagation model for the path loss versus distance conversion. On-screen help is provided for the propagation model parameters.

All unit conversions are performed automatically. The output data display is presented in both dB and non-dB units, using scientific notation for the latter.

Reference: Single-Emitter Analysis Model
Cesar A. Filippi, February 1988

F10 = Next screen	Esc = Stop

Press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

The program can use a direct or an inverse computation mode. Press the space bar to choose a computation mode.

computation mode = inverse

The program can use either free space propagation or the IPS propagation model. Press the space bar to choose the propagation option.

propagation option = IPS propagation model

The emitter strength can be specified as an emission power level or a field strength at a reference distance. Press the space bar to choose the emitter strength option.

emitter strength option = field strength

The program requires either the receiver antenna gain or diameter as input. Press the space bar to choose the receiver antenna option.

receiver antenna option = gain

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return = select next input field

Make choices then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

The field strength units can be microvolts per meter or millivolts per meter. Press the space bar to choose the field strength units.

field strength units = microvolts/meter

The inverse mode can use one of three threshold parameters to calculate the propagation distance. Press the space bar to choose this threshold.

threshold = received power

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return = select next input field

Make choices then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

Integrated Propagation System Input Screen

Site Parameters:

Transmitter antenna height = 5.00 m
Receiver antenna height = 15.00 m

Ground and Atmosphere Constants:

Ground conductivity (0.0001-5.0 mho/m) = 0.0050 mho/m
Ground dielectric constant (1.01-81.00) = 15.00
Atmospheric refractivity (200.00-450.00) = 301.00
Transmitter polarization (V or H) = V

Suggested Values for Electrical Ground Constants		Conductivity (mho/m)	Dielectric Constant
	Average ground	0.005	15.0
	Poor ground	0.001	4.0
	Good ground	0.020	25.0
	Fresh water	0.010	81.0
	Sea water	5.000	81.0

F9 = Previous screen　　Esc = Stop
F10 = Next screen　　Return = select next input field

Enter all input data then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

INPUT DATA - Inverse Mode

Frequency = 200.000 MHz

Emitter field strength = 500.0 uV/m

reference distance = 30.0 m

Received power threshold = -118.6 dBm

Receiver antenna gain = 25.0 dBi

F1 = Run program
F2 = Exit program　　Esc = Stop
F9 = Previous screen　　Return = select next input field

Enter all input data then press F1 to perform calculation.

SINGLE-EMITTER ANALYSIS MODEL

OUTPUT - Inverse Mode

Propagation Loss = 122.3 dB

Propagation Distance = 10.000 km

Press ENTER to continue

Example 3

Direct Computation Mode

with

Emitter EIRP Input

SINGLE-EMITTER ANALYSIS MODEL

SEAM is a single-emitter program that supports user-interactive computations and automated unit conversions in direct and inverse modes. The user has the option to specify the emitter strength as an emission power level, or as a field strength value at a reference distance selected by the user.

The direct mode estimates received emission levels (power, spatial power density, field strength) at a propagation distance specified by the user. The inverse mode estimates the propagation distance required to meet a received level threshold specified by the user, up to a 500 km distance limit.

The user selects between free space formulas or the IPS propagation model for the path loss versus distance conversion. On-screen help is provided for the propagation model parameters.

All unit conversions are performed automatically. The output data display is presented in both dB and non-dB units, using scientific notation for the latter.

Reference: Single-Emitter Analysis Model
Cesar A. Filippi, February 1988

F10 = Next screen	Esc = Stop

Press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

The program can use a direct or an inverse computation mode. Press the space bar to choose a computation mode.

computation mode = direct

The program can use either free space propagation or the IPS propagation model. Press the space bar to choose the propagation option.

propagation option = IPS propagation model

The emitter strength can be specified as an emission power level or a field strength at a reference distance. Press the space bar to choose the emitter strength option.

emitter strength option = emission power level

The program requires either the receiver antenna gain or diameter as input. Press the space bar to choose the receiver antenna option.

receiver antenna option = diameter

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return = select next input field

Make choices then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

The power units can be watts, milliwatts, nanowatts, dBW or dBm. Press the space bar to choose the power units.

power units = dBm

The user can specify the transmitter power and antenna gain separately, or combined into an EIRP value. Press space bar to choose this option.

power level = EIRP (includes antenna gain)

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return = select next input field

Make choices then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

Integrated Propagation System Input Screen

Site Parameters:

```
                  Transmitter antenna height =     5.00 m
                     Receiver antenna height =    15.00 m
Ground and Atmosphere Constants:
     Ground conductivity (0.0001-5.0 mho/m) =   0.0050 mho/m
    Ground dielectric constant (1.01-81.00) =    15.00
  Atmospheric refractivity (200.00-450.00) =   301.00
        Transmitter polarization (V or H) =    V
```

Suggested Values for Electrical Ground Constants		Conductivity (mho/m)	Dielectric Constant
	Average ground	0.005	15.0
	Poor ground	0.001	4.0
	Good ground	0.020	25.0
	Fresh water	0.010	81.0
	Sea water	5.000	81.0

```
F9 = Previous screen                Esc = Stop
F10 = Next screen               Return    = select next input field
```

Enter all input data then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

INPUT DATA - Direct Mode

```
          Frequency =    1700.000 MHz
       Emitter EIRP =     -13.0   dBm
Propagation distance =     50.00   km
Receiver antenna diameter =  3.0   m
```

```
F1 = Run program
F2 = Exit program                        Esc = Stop
F9 = Previous screen                 Return   = select next input field
```

Enter all input data then press F1 to perform calculation.

SINGLE-EMITTER ANALYSIS MODEL

OUTPUT - Direct Mode

```
   Propagation Loss =          178.0 dB
     Field Strength =  3.47791E-03 uV/m          -49.2 dBuV/m
     Received Power =  1.24991E-16 mW           -159.0 dBm
Spatial Power Density = 3.25565E-17 mW/m**2     -164.9 dBm/m**2
```

Press ENTER to continue

Example 4

Inverse Computation Mode

with

Emitter EIRP and

Received Power Threshold Inputs

SINGLE-EMITTER ANALYSIS MODEL

SEAM is a single-emitter program that supports user-interactive computations and automated unit conversions in direct and inverse modes. The user has the option to specify the emitter strength as an emission power level, or as a field strength value at a reference distance selected by the user.

The direct mode estimates received emission levels (power, spatial p wer density, field strength) at a propagation distance specified by the user. The inverse mode estimates the propagation distance required to meet a received level threshold specified by the user, up to a 500 km distance limit.

The user selects between free space formulas or the IPS propagation model for the path loss versus distance conversion. On-screen help is provided for the propagation model parameters.

All unit conversions are performed automatically. The output data display is presented in both dB and non-dB units, using scientific notation for the latter.

Reference: Single-Emitter Analysis Model
Cesar A. Filippi, February 1988

F10 = Next screen	Esc = Stop

Press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

The program can use a direct or an inverse computation mode. Press the space bar to choose a computation mode.

computation mode = inverse

The program can use either free space propagation or the IPS propagation model. Press the space bar to choose the propagation option.

propagation option = IPS propagation model

The emitter strength can be specified as an emission power level or a field strength at a reference distance. Press the space bar to choose the emitter strength option.

emitter strength option = emission power level

The program requires either the receiver antenna gain or diameter as input. Press the space bar to choose the receiver antenna option.

receiver antenna option = diameter

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return = select next input field

Make choices then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

The power units can be watts, milliwatts, nanowatts, dBW or dBm. Press the space bar to choose the power units.

power units = dBm

The user can specify the transmitter power and antenna gain separately, or combined into an EIRP value. Press space bar to choose this option.

power level = EIRP (includes antenna gain)

The inverse mode can use one of three threshold parameters to calculate the propagation distance. Press the space bar to choose this threshold.

threshold = received power

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return = select next input field

Make choices then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

Integrated Propagation System Input Screen

Site Parameters:
Transmitter antenna height = 5.00 m
Receiver antenna height = 15.00 m
Ground and Atmosphere Constants:
Ground conductivity (0.0001-5.0 mho/m) = 0.0050 mho/m
Ground dielectric constant (1.01-81.00) = 15.00
Atmospheric refractivity (200.00-450.00) = 301.00
Transmitter polarization (V or H) = V

Suggested Values for Electrical Ground Constants		Conductivity (mho/m)	Dielectric Constant
	Average ground	0.005	15.0
	Poor ground	0.001	4.0
	Good ground	0.020	25.0
	Fresh water	0.010	81.0
	Sea water	5.000	81.0

F9 = Previous screen   Esc = Stop
F10 = Next screen   Return = select next input field

Enter all input data then press F10 to continue

SINGLE-EMITTER ANALYSIS MODEL

INPUT DATA - Inverse Mode

Frequency = 1700.000 MHz

Emitter EIRP = -13.0 dBm

Received power threshold = -159.0 dBm

Receiver antenna diameter = 3.0 m

F1 = Run program
F2 = Exit program   Esc = Stop
F9 = Previous screen   Return = select next input field

Enter all input data then press F1 to perform calculation.

SINGLE-EMITTER ANALYSIS MODEL

OUTPUT - Inverse Mode

Propagation Loss = 178.0 dB

Propagation Distance = 49.982 km

Press ENTER to continue

SECTION 3

AGGREGATE EMITTER ANALYSIS MODEL FOR TERRESTRIAL RECEIVERS

RINGS TECHNICAL MANUAL

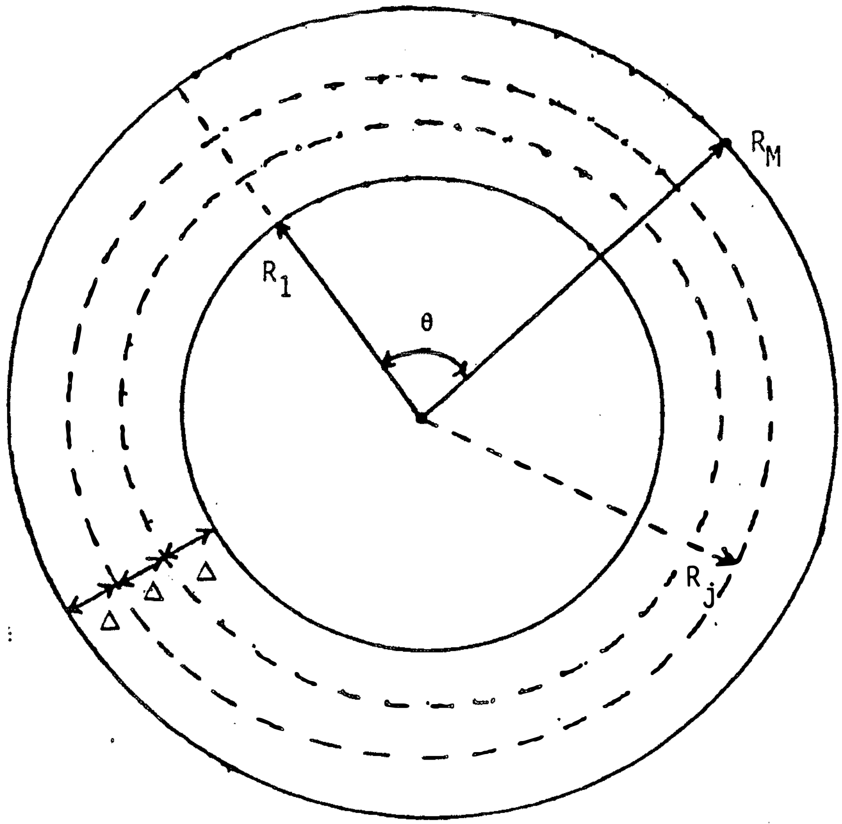
The purpose of this section is to describe the analysis program and computation options of the aggregate emitter analysis model for terrestrial receivers. Multiple emitters with the same emission frequency and emission level are distributed on equally-spaced, concentric, circular rings surrounding a terrestrial station. The model computes the power-sum aggregation into the station receiver for a given beamwidth coverage by the receiving antenna.

The emitters are distributed in an annular region specified by the user via the minimum (inner ring) and maximum (outer ring) radius. The user also specifies the emitter surface density or total number of emitters in the region. The model automatically assigns the number of rings, ring separation, and number of emitters per ring, for a symmetric distribution.

The emission level per emitter can be specified in terms of radiated power or field strength units, and the path loss calculations can be based on free space formulas or a propagation model subroutine. The receiving antenna can be specified in terms of a gain, diameter, or beamwidth units.

A computer program called RINGS has been developed at NTIA for the aggregate received power computation. The program is menu-driven with user selection of the emitter distribution, emission level, and propagation model, as described below.

A sector of the annular region becomes specified by the user selection of an inner radius, outer radius, and sector angle, as shown in Figure 3-1. The sector angle is specified directly as the receiving antenna beamwidth, or computed from an antenna gain or diameter specification. A parabolic antenna with 55% efficiency is assumed for the parameter conversions.



R_1 = inner ring radius (user input)

R_M = outer ring radius (user input)

θ = sector angle (receiving antenna beamwidth, user input or computed from gain or diameter inputted)

K = emitter surface density (user input or computed from total number of emitters inputted).

T = number of emitters in the annulus (user input or computed from emitter surface density inputted)

N = number of emitters in the sector (automatically computed from input parameters)

Δ = ring separation (automatically computed from input parameters)

M = number of rings (automatically computed from input parameters)

N_j = number of emitters in j-th ring (automatically computed from input parameters)

Figure 3-1. RINGS emitter distribution geometry and parameters.

The number of emitters in the sector is computed from the emitter density or total number specified, along with the sector angle. The number of emitters assigned to each ring is proportional to the ring radius. The number of rings and ring separation are automatically set from the input data to provide symmetry in the emitter distribution, so as to not favor their angular separation within a ring or their radial separation between rings at the expense of each other. A detailed description of the emitter distribution logic and formulas is given in the next section.

The emission level per emitter is specified by the user from the following two options.

- Equivalent Isotropically Radiated Power (EIRP)
- Field Strength at Reference Distance

The other input parameters are the emission frequency, and the receiving antenna gain or diameter when the beamwidth is not specified. If the gain is specified, the beamwidth is computed (and vice versa). If the diameter is specified, both the gain and beamwidth are computed. A summary of the input parameters and units is shown in TABLE 3-1.

TABLE 3-1

RINGS INPUT DATA SUMMARY

PARAMETER	UNITS
Inner Radius	km
Outer Radius	km
Emitter Density	number/acre
Number of Emitters	integer
Emission Frequency	megahertz
EIRP	dBm
Field Strength	microvolts/meter
Reference Distance	meters
Antenna Beamwidth	degrees
Antenna Gain	dBi
Antenna Diameter	meters

The user also selects between free space formulas and a propagation model subroutine for the path loss calculations. If the propagation model is selected, the user specifies a set of propagation parameters (e.g., transmit/receive antenna heights, terrain characteristics) with the aid of a help screen that presents various representative values.

The program then computes the power-sum aggregation of the emitter distribution into the station receiver (antenna output terminals). The program also computes the equivalent number of emitters located in the inner ring that would produce the same power-sum into the receiver as that obtained from the emitter distribution in the sector.

It can happen that the sector geometry and emitter distribution parameters specified by the user could result in no emitters assigned to the first (inner) and other lower rings. For example, a large outer/inner radius ratio and a low emitter density (or small number of emitters) could allocate all emitters to the higher rings, since the number of emitters per ring is proportional to the ring radius.

In this case, the program flags such occurrence on the screen, to permit a change of the input parameters by the user if so desired. If the orignal input data is kept, the program proceeds with the aggregate power-sum computation bypassing the empty rings, and the output screen informs the user of the ring radius representing the closest emitters based on the input data provided.

RINGS MODEL FORMULATION

This section presents a simple model for the estimation of the power-sum aggregate interference from identical cochannel emitters surrounding a terrestrial station. All emitters are assumed to have the same emission level and frequency, and the receiving antenna is specified in terms of an effective beamwidth, gain or diameter parameter. Free space formulas or a propagation model subroutine are options for the path loss calculations.

An annular region is specified by the user to identify the surface where the emitters are distributed, along with an emitter surface density or total number of emitters surrounding the station. The receiving antenna beamwidth further restricts the annulus to a sector of emissions received. The emitters are automatically distributed on concentric rings spanning the sector, with the number of emitters per ring being proportional to the ring radius.

Emission Level

The user has the option of specifying the emission level as either the equivalent isotropically radiated power (EIRP) or the field strength (E_0) at a reference distance (D_0) also selected by the user.

The conversion between these two options is automatically performed in the program, by assuming free space propagation to the reference distance. The conversion algorithm is given by

$$\text{EIRP(W)} = \frac{4\pi}{Z_0(\Omega)} \cdot [E_0(\text{V/m}) \cdot D_0(\text{m})]^2 \; , \quad Z_0 = 377\Omega \qquad (3\text{-}1)$$

or

$$\text{EIRP(dBW)} = -14.8 + 20 \log E_0(\text{V/m}) + 20 \log D_0(\text{m}) \qquad (3\text{-}2)$$

The actual units prompted for user input are dBm for the EIRP and µV/m for the field strength. All input or output unit conversions are automatically performed by the program.

Emitter Distribution

The user specifies the annular region by selecting the inner and outer radius (R_1,R_M), and the emitter population by selecting either their surface density (K) or total number (T) in the annulus. These input parameters are related via $T = K \cdot \pi(R_M^2 - R_1^2)$.

The annular region is restricted to a sector by the antenna beamwidth (θ) of the receiving station. The beamwidth may be specified directly, or indirectly via the antenna gain (G_r) or diameter (D_r). A parabolic antenna with efficiency (η) of 0.55 is assumed in the model.

The actual number (N) of emitters in the sector is computed from the input data to trigger the emitter distribution process. The formula applied depends on whether the user specifies the emitter density (K) or total number (T), as follows

$$N = T \cdot \frac{\theta}{2\pi} = K \cdot \frac{\theta}{2} (R_M^2 - R_1^2) \quad , \quad \theta \text{ in radians} \tag{3-3}$$

The emitters are distributed on M concentric rings, including those corresponding to the inner and outer radius. A uniform ring spacing $\Delta = (R_M - R_1)/(M-1)$ is provided, so that the ring locations become set upon selection of the Δ or M parameter. The ring locations are specified by the ring radius given by

$$R_j = R_1 + (j-1)\Delta \quad , \quad j = 1 \text{ to } M \tag{3-4a}$$

$$= R_1 + (j-1) \cdot \frac{R_M - R_1}{M-1} \quad , \quad j = 1 \text{ to } M \tag{3-4b}$$

The emitter distribution is based on having the number N_j of emitters on each ring to be proportional to the ring length $L_j = R_j \cdot \theta$. This condition yields the following M-1 equations to be satisfied by the emitter distribution.

$$\frac{N_j}{N_1} = \frac{R_j}{R_1} \quad , \quad j = 2 \text{ to } M \tag{3-5}$$

The condition $\Sigma N_j = N$ for $j = 1$ to M yields the additional equation needed to solve all the N_j variables from $j = 1$ to M. The solution yields the following distribution in terms of the sector parameters (N, R_1,R_M), and the ring separation (Δ) or number of rings (M) employed.

$$N_j = \frac{2N\Delta}{R_M - R_1 + \Delta} \cdot \frac{R_1 + (j-1)\Delta}{R_M + R_1} \quad , \ j = 1 \text{ to } M \tag{3-6a}$$

$$= \frac{2N}{M} \cdot \frac{(M-1)R_1 + (j-1)\ (R_M - R_1)}{(M-1)\ (R_M + R_1)} \quad , \ j = 1 \text{ to } M \tag{3-6b}$$

The N_j emitters per ring can be considered to be uniformly spaced over the ring length $L_j = R_j \cdot \theta$. The emitter separation on a ring is $S_j = R_j \cdot \theta / N_j$, and is a constant value independent of the ring number (j), as a direct consequence of the emitter distribution based on equation (3-5). This uniform emitter separation on a ring is a function of the sector parameters (N, R_1, R_M), and the ring separation (Δ) or number of rings (M) employed, as follows.

$$S_o = S_j = \frac{\theta(R_M - R_1) + \Delta}{2N\Delta} \cdot (R_M + R_1) \quad , \ j = 1 \text{ to } M \tag{3-7a}$$

$$= \frac{\theta \cdot M}{2N} \cdot (R_M + R_1) \quad , \ j = 1 \text{ to } M \tag{3-7b}$$

Hence, the emitters are separated by the constant S_o of equation (3-7) on any ring, and their separation has a lower bound of Δ from ring to ring. The separation of a proximal pair of emitters located on consecutive rings is not constant, so that the lower bound Δ must be used as a separation measure from ring to ring.

The constant emitter separation (S_0) on a ring is directly proportional to M, and inversely proportional to Δ for $\Delta << R_M - R_1$. Hence, a smaller angular separation on a ring comes at the expense of a larger radial separation (ring separation), and vice versa. There is a compromise in the choice of Δ or M, to avoid excessively close or far emitters, either on a ring or from ring to ring.

A natural choice is to have the emitter separation inversely proportional to $\sqrt{K}$, since K is the emitter surface density (one emitter occupies an area of 1/K). The choice of $\Delta = \delta/\sqrt{K}$, where δ is a proportionality constant, yields $S_0 = \delta^{-1}/\sqrt{K}$, so that the angular separation (S_0) is inversely proportional to δ and the radial separation bound (Δ) is directly proportional to δ. The value $\delta=1$ yields $S_0 = \Delta$ and equates the angular separation to the radial separation bound, whereas other δ-values produce a more asymmetrical compromise in the emitter distribution.

The value of K is specified by the user, or derived based on equation (3-3) when T is specified. A ring separation $\Delta = 1/\sqrt{K}$ is employed in the model, so that the number of rings is $M=1 + \sqrt{K}\,(R_M - R_1)$. These values of Δ or M are used in equations (3-6a) or (3-6b) to automatically compute the number of emitters per ring as a function of the sector parameters (R_1, R_M, θ, K or N).

Power-Sum Aggregation at Terrestrial Receivers

The power received per emitter is P_r = (EIRP) (G_r) (L_p^{-1}), where L_p is the propagation model output or $L_p = (4\pi\lambda/D)^2$ in free space. All emitters located on the same ring are at the same distance $D = R_j$ from the receiver, as given by equation (3-4) with $\Delta = 1/\sqrt{K}$, and will have the same path loss $L_p(j)$ in both free space and propagation model options. Hence, the power received from a single emitter is multiplied by N_j to obtain the power $P_r(j)$ received from all emitters on the same ring.

The power received per ring is added over all rings to obtain the power-sum aggregation of all emitters in the sector, as follows

$$P_r(\text{aggregate}) = (\text{EIRP})\ (G_r) \cdot \sum_{j=1}^{M} [N_j/L_p(j)]$$

(prop model) (3-8)

and

$$P_r(\text{aggregate}) = (\text{EIRP})\ (G_r)\ (\lambda/4\pi)^2 \cdot \sum_{j=1}^{M} (N_j/R_j^2)$$

(free space) (3-9)

In the free space case, the summation of equation (3-9) includes the factor N_j/R_j that is invariant from ring to ring, as per equation (3-5). This factor is given by $R_o = N_j/R_j = S_o/\theta$, and is also independent of θ via equation (3-7). The power-sum aggregation of equation (3-9) thus becomes simplified as follows

$$P_r(\text{aggregate}) = (\text{EIRP})\ (G_r)\ (\lambda/4\pi R_o)^2 \cdot \sum_{j=1}^{M} (R_o/R_j)$$

(free space) (3-10)

where

$$R_o = \frac{R_M - R_1 + \Delta}{2N\Delta} \cdot (R_M + R_1) = \frac{M}{2N} (R_M + R_1) \qquad (3\text{-}11)$$

An equivalent number N_{eq} of emitters can be located on any specific ring (j^*) to produce the same received power as the aggregation based on the emitter distribution. This equivalent number can be obtained from the path loss $L_p(j^*)$ or radius R_{j*}, of the ring in question (e.g., $j^*=1$ for inner ring, $j^*=M$ for outer ring) as follows

$$N_{eq}(j^*) = L_p(j^*) \cdot \sum_{j=1}^{M} [N_j/L_p(j)]$$

(prop model) (3-12)

and

$$N_{eq}(j^*) = (R_{j^*})^2 \cdot \sum_{j=1}^{M} (N_j/R_j^2) = \left(\frac{R_{j^*}}{R_o}\right)^2 \cdot \sum_{j=1}^{M} (R_o/R_j)$$

(free space) (3-13)

An example of RINGS computations is shown in TABLE 3-2, where the two runs presented correspond to the free space and propagation model options, respectively. An emission frequency of 1000 MHz is specified, along with a field strength per emitter of 500 μV/m at a reference distance of 3 meters. An EIRP of -41.3 dBm would have been an equivalent emission level input yielding the same output data.

The inner and outer ring radius from the receiver station are specified as 10 km and 50 km, respectively. The receiver antenna is specified by an antenna gain of 30 dBi, though an antenna diameter of 4.1 meter or an antenna beamwidth of 5.2° would have been equivalent input specifications yielding the same output data.

An emitter surface density of 1.0 per acre is specified in TABLE 3-2. This value induces a total number of 1,840,328 emitters in the 10-50 km annulus, but only 26,365 emitters are in the sector covered by the antenna beamwidth. A ring separation of 0.0064 km and a number 626 of rings is obtained from the input data.

TABLE 3-2

RINGS EXAMPLE WITH EMITTER DENSITY SPECIFIED

Input Parameters

Inner Ring Radius (km)	10.0
Outer Ring Radius (km)	50.0
Emitter Surface Density (#/acre)	1.0
Emission Frequency (MHz)	1000
Emitter Field Strength μV/m	500
Reference Distance (m)	3
Receiver Antenna Gain (dBi)	30

Derived Parameters

Number of Emitters in Annulus	1,840,328
Number of Emitters in Sector	26365
Ring Separation (km)	0.064
Number of Rings	626
Emitter EIRP (dBm)	-41.3
Receiver Antenna Beamwidth (deg)	5.2

Output Parameters

Aggregate Power-Sum Received (dBm)	
Free Space Option	-88.2
Propagation Model Option	-104.0
Number of Equivalent Emitters in Inner Ring	
Free Space Option	3539
Propagation Model Option	787

The emitter aggregation produces a received power-sum of -88.2 dBm with free space and -104.0 dBm with the propagation model. The equivalent number of emitters at 10 km (within the antenna beamwidth) that matches this received power is 3539 with free space and 787 with the propagation model. The distinction in the path loss at 10 km is 112.4 dB with free space versus 121.7 dB with the propagation model.

Another example is shown in TABLE 3-3. The same input parameters as the last example are employed, except that the emitter population is now specified by a total number 1000 of emitters in the annulus. This value induces an emitter density of 0.0054 per acre, and a number of 144 emitters in the sector. A ring separation of 0.87 km and a number 47 of rings is obtained from the input data.

TABLE 3-3

RINGS EXAMPLE WITH NUMBER OF EMITTERS SPECIFIED

<u>Input Parameters</u>	
Inner Ring Radius (km)	10.0
Outer Ring Radius (km)	50.0
Number of Emitters in Annulus	10,000
Emission Frequency (MHz)	1000
Emitter Field Strength (μV/m)	500
Reference Distance (m)	3
Receiver Antenna Gain (dBi)	30
<u>Derived Parameters</u>	
Emitter Surface Density (#/acre)	0.0054
Number of Emitters in Sector	143
Ring Separation (km)	0.87
Number of Rings	47
Emitter EIRP (dBm)	-41.3
Receiver Antenna Beamwidth (deg)	5.2
<u>Output Parameters</u>	
Aggregate Power-Sum Received (dBm)	
Free Space Option	110.8
Propagation Model Option	-125.4
Number of Equivalent Emitters in Inner Ring	
Free Space Option	19
Propagation Model Option	6

The emitter aggregation now produces a received power-sum of -110.8 dBm with free space and -125.4 dBm with the propagation model. The equivalent number of inner ring (10 km) emitters is 19 with free space and 6 with the propagation model. The path loss distinction from the inner ring is the same as in the previous example.

RINGS USER MANUAL

Program RINGS computes the power received at a terrestrial station due to a distribution of identical emitters surrounding the station. The user can specify the antenna gain, diameter, or beamwidth of the terrestrial station. Free space formulas or a propagation model subroutine can be selected for path loss calculations.

The user selects the emitter distribution region (inner and outer radius), the emitter population (surface density or total number), and the emission level and frequency. The emission level can be specified in either field strength or radiated power units.

Hardware and Software Requirements

RINGS may be run on any PC that is 100% MS-DOS compatibile, and requires 150 K bytes of disk space for storage. MS-DOS version 2.0 or higher is necessary. Furthermore ANSI.SYS must be installed in the CONFIG.SYS file. The program files needed for RINGS to be run are:

RINGS.EXE
RINGPNL.PNL

Input

The first input screen is used to determine the computation mode and input parameter options, as follows.

- Propagation option - free space or IPS propagation model
- Emission level option - field strength or eirp
- Receiver antenna option - gain, diameter, or beamwidth
- Emitter population option - total number or surface density

If the IPS Propagation Model has been selected, the following parameters must be entered:

- transmitter antenna height in meters,
- receiver antenna height in meters,
- ground conductivity in meters, between 0.0001 and 5.0 in mho/m,
- ground dielectric constant between 1.01 and 81.0,
- atmospheric refractivity between 200.00 and 450.0,
- transmitter polarization either Vertical or Horizontal

The following units are employed for the other input parameters:

Frequency	MHz
EIRP	dBm
Field Strength	μV/m
Reference Distance	m
Receiver Antenna Gain	dBi
Receiver Antenna Diameter	m
Receiver Antenna Beamwidth	degrees
Inner Ring Radius	km
Outer Ring Radius	km
Number of Emitters	# in 1000's
Density of Emitters	#/acre

Note: the inner ring radius has a lower bound of 0.1 km as a default if the user enters a lower value.

Output

The output screen first summarizes the input scenario created from the input data specified by the user. The screen displays both input and derived parameters to describe the scenario as follows.

- Inner and Outer Ring Radius (km)
- Emitter Density (#/acre)
- Number of Emitters in Annulus
- Number of Emitters in Sector
- Ring Separation (km)
- Number of Rings
- Frequency (MHz)
- EIRP (dBm)
- Field Strength (μV/m) and Reference Distance (m)
- Receiver Antenna Gain (dBi) and Beamwidth (deg)

The scenario summary is important since it provides the user with insight on the effective aggregate emission being accounted, as induced by the input parameters specified. For example, the number of emitters in the sector are those actually contributing to the received power aggregation, yet this number is not inputted but derived as a function of other data specified by the user.

The output screen next displays the aggregate power received at the antenna output terminals from the emitter distribution in the sector covered by the antenna beamwidth. The equivalent number of emitters in the inner ring that produces the same received power is also displayed.

If the inner ring is empty (contains no emitters) in the scenario created by the user input data, and the user elects to proceed with the run, then the aggregate power received corresponds to the contribution from the non-empty rings. The closest non-empty ring radius is displayed, along with a note to state that the number of equivalent emitters computed refers to this closest non-empty ring.

RINGS SAMPLE RUNS

This section presents sample runs of the RINGS program for various input options and parameter values. The following sample runs are presented.

Example 1: Emitter field strength and surface density input

Example 2: Emitter field strength and total number input

Example 3: Emitter EIRP and surface density input

Example 4: Emitter EIRP and total number input

Note: The last two examples illustrate the case where there are no emitters distributed in the first few rings due to the emitter population values inputted.

Example 1

Emitter Field Strength

and

Surface Density Input

RINGS

RINGS is a multiple emitter analysis program that supports user-interactive computations of aggregate interference levels into a terrestrial station receiver.

The user specifies the emitter distibution region, emitter population, emission level and frequency, and receiver antenna, with various parametric aptions that are automatically prompted

The user also selects between free space formulas and the IPS propagation model for path loss calculations. On-screen help is provided for the propagation model parameters.

Reference: RINGS, Aggregate Emitter Analysis Model
Cesar A. Filippi, Robert A. Gruendl, July 1988

F10 = Next screen	Esc = Stop

PRESS F10 TO CONTINUE

RINGS

The program can use either free space propagation or the IPS propagation model. Press the space bar to choose the propagation option.

propagation option = IPS propagation model

The emitter strength can be specified as an emission power level or a field strength at a reference distance. Press the space bar to choose the emitter strength option.

emitter strength option = field strength

The program requires either the receiver antenna gain, diameter, or beamwidth as input. Press the space bar to choose the receiver antenna option.

receiver antenna option = gain

The emitter population can be specified either by a total number or a surface density. Press the space bar to choose the emitter population option.

emitter population option = surface density

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return ↑↓ = select next input field

MAKE CHOICES THEN PRESS F10 TO CONTINUE

RINGS

Integrated Propagation System Input Screen

```
Site Parameters:
                  Transmitter antenna height =     5.00 m
                     Receiver antenna height =    15.00 m
Ground and Atmosphere Constants:
     Ground conductivity (0.0001-5.0 mho/m) =   0.0050 mho/m
    Ground dielectric constant (1.01-81.00) =    15.00
  Atmospheric refractivity (200.00-450.00) =   301.00
         Transmitter polarization (V or H) =   V
```

Suggested :		Conductivity (mho/m)	Dielectric Constant
Values :	Average ground	0.005	15.0
for :	Poor ground	0.001	4.0
Electrical :	Good ground	0.020	25.0
Ground :	Fresh water	0.010	81.0
Constants :	Sea Water	5.000	81.0

```
 F9 = Previous screen                     Esc = Stop
F10 = Next screen                Return ↑↓ = select next input field
```

ENTER ALL INPUT DATA THEN PRESS F10 TO CONTINUE

RINGS

INPUT DATA - Field Strength Mode

```
          Frequency =   1000.000 MHz
Emitter Field Strength =  500.000 uV/m
    Reference Distance =    3.00  m
  Receiver Antenna Gain =   30.0  dBi

     Inner Ring Radius =   10.00 km
     Outer Ring Radius =  100.00 km
    Density of Emitters =   0.250 # / acre
```

```
F1 = Run program
F2 = Exit program                        Esc = Stop
F9 = Previous screen           Return ↑↓ = select next input field
```

MAKE CHOICES THEN PRESS F1 TO CONTINUE

INPUT SCENARIO

Inner radius (km)	10.00	Frequency (MHz)	1000.000
Outer radius (km)	100.00	EIRP (dBm)	-41.28
Emitter density (#/acre)	.250	Field strength (uV/m)	500.00
Number in annulus	1897838.	Reference distance (m)	3.00
Number in sector	27189.	Rcvr ant. gain (dBi)	30.00
Ring separation (km)	.128	Rcvr ant. beamwidth (deg)	5.16
Number of rings	704.		

OUPUT RESULTS

```
          Aggregate power sum received :    -110.09 dBm
Equivalent number of inner-ring emitters :    195.
```

Example 2

Emitter Field Strength

and

Total Number Input

RINGS

RINGS is a multiple emitter analysis program that supports user-interactive computations of aggregate interference levels into a terrestrial station receiver.

The user specifies the emitter distibution region, emitter population, emission level and frequency, and receiver antenna, with various parametric aptions that are automatically prompted

The user also selects between free space formulas and the IPS propagation model for path loss calculations. On-screen help is provided for the propagation model parameters.

Reference: RINGS, Aggregate Emitter Analysis Model
Cesar A. Filippi, Robert A. Gruendl, July 1988

F10 = Next screen	Esc = Stop

PRESS F10 TO CONTINUE

RINGS

The program can use either free space propagation or the IPS propagation model. Press the space bar to choose the propagation option.

propagation option = IPS propagation model

The emitter strength can be specified as an emission power level or a field strength at a reference distance. Press the space bar to choose the emitter strength option.

emitter strength option = field strength

The program requires either the receiver antenna gain, diameter, or beamwidth as input. Press the space bar to choose the receiver antenna option.

receiver antenna option = gain

The emitter population can be specified either by a total number or a surface density. Press the space bar to choose the emitter population option.

emitter population option = total number

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return ↑↓ = select next input field

MAKE CHOICES THEN PRESS F10 TO CONTINUE

RINGS

Integrated Propagation System Input Screen

```
Site Parameters:
                  Transmitter antenna height =     5.00 m
                     Receiver antenna height =    15.00 m
Ground and Atmosphere Constants:
     Ground conductivity (0.0001-5.0 mho/m) =    0.0050 mho/m
    Ground dielectric constant (1.01-81.00) =    15.00
   Atmospheric refractivity (200.00-450.00) =    301.00
        Transmitter polarization (V or H) =      V

    Suggested :                  Conductivity (mho/m)  Dielectric Constant
     Values   : Average ground        0.005                   15.0
      for     : Poor ground           0.001                    4.0
    Electrical : Good ground          0.020                   25.0
     Ground   : Fresh water           0.010                   81.0
    Constants : Sea Water             5.000                   81.0

  F9 = Previous screen                     Esc = Stop
  F10 = Next screen                   Return ↑↓ = select next input field
ENTER ALL INPUT DATA THEN PRESS F10 TO CONTINUE
```

RINGS

INPUT DATA - Field Strength Mode

```
               Frequency =    1000.000 MHz
   Emitter Field Strength =     500.000 uV/m
       Reference Distance =       3.00  m
    Receiver Antenna Gain =      30.0   dBi

        Inner Ring Radius =      10.00 km
        Outer Ring Radius =     100.00 km
       Number of Emitters =    1900.000 # in 1000's

  F1 = Run program
  F2 = Exit program                         Esc = Stop
  F9 = Previous screen                Return ↑↓ = select next input field
MAKE CHOICES THEN PRESS F1 TO CONTINUE
```

INPUT SCENARIO

```
      Inner radius (km)       10.00             Frequency (MHz)  1000.000
      Outer radius (km)      100.00                  EIRP (dBm)    -41.28
Emitter density (#/acre)        .250       Field strength (uV/m)   500.00
      Number in annulus   1900000.        Reference distance (m)     3.00
       Number in sector     27220.          Rcvr ant. gain (dBi)    30.00
    Ring separation (km)        .128   Rcvr ant. beamwidth (deg)     5.16
        Number of rings      704.
```

OUPUT RESULTS

```
       Aggregate power sum received :      -110.09 dBm
Equivalent number of inner-ring emitters :    195.
```

Example 3

Emitter EIRP

and

Surface Density Input

RINGS

RINGS is a multiple emitter analysis program that supports user-interactive computations of aggregate interference levels into a terrestrial station receiver.

The user specifies the emitter distibution region, emitter population, emission level and frequency, and receiver antenna, with various parametric aptions that are automatically prompted

The user also selects between free space formulas and the IPS propagation model for path loss calculations. On-screen help is provided for the propagation model parameters.

Reference: RINGS, Aggregate Emitter Analysis Model
Cesar A. Filippi, Robert A. Gruendl, July 1988

F10 = Next screen	Esc = Stop

PRESS F10 TO CONTINUE

RINGS

The program can use either free space propagation or the IPS propagation model. Press the space bar to choose the propagation option.

propagation option = IPS propagation model

The emitter strength can be specified as an emission power level or a field strength at a reference distance. Press the space bar to choose the emitter strength option.

emitter strength option = eirp

The program requires either the receiver antenna gain, diameter, or beamwidth as input. Press the space bar to choose the receiver antenna option.

receiver antenna option = beam width

The emitter population can be specified either by a total number or a surface density. Press the space bar to choose the emitter population option.

emitter population option = surface density

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return ↑↓ = select next input field

MAKE CHOICES THEN PRESS F10 TO CONTINUE

RINGS

Integrated Propagation System Input Screen

Site Parameters:

Transmitter antenna height =	5.00 m
Receiver antenna height =	15.00 m

Ground and Atmosphere Constants:

Ground conductivity (0.0001-5.0 mho/m) =	0.0050 mho/m
Ground dielectric constant (1.01-81.00) =	15.00
Atmospheric refractivity (200.00-450.00) =	301.00
Transmitter polarization (V or H) =	V

Suggested :		Conductivity (mho/m)	Dielectric Constant
Values	: Average ground	0.005	15.0
for	: Poor ground	0.001	4.0
Electrical	: Good ground	0.020	25.0
Ground	: Fresh water	0.010	81.0
Constants	: Sea Water	5.000	81.0

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return ↑↓ = select next input field

ENTER ALL INPUT DATA THEN PRESS F10 TO CONTINUE

RINGS

INPUT DATA: EIRP mode

```
                  Frequency =    1000.000 MHz
                       EIRP =     -41.3   dBm
 Receiver Antenna Beamwidth =       5.2   degrees

          Inner Ring Radius =      10.00 km
          Outer Ring Radius =     100.00 km
        Density of Emitters =      0.001 # / acre
```

```
F1 = Run program
F2 = Exit program                         Esc = Stop
F9 = Previous screen               Return ↑↓ = select next input field
```

MAKE CHOICES THEN PRESS F1 TO CONTINUE

THE DENSITY OF EMITTERS SPECIFIED RESULTS IN THE FIRST EMITTER BEING PLACED IN RING NUMBER 3 AT A DISTANCE OF 14.98 KM.

CHOOSE FROM THE FOLLOWING BY NUMBER AND THEN PRESS ENTER:
1) ABORT PROGRAM
2) CHANGE PARAMETERS
3) CONTINUE WITH GIVEN DATA

CHOICE: 3

INPUT SCENARIO

Inner radius (km)	10.00	Frequency (MHz)	1000.000
Outer radius (km)	100.00	EIRP (dBm)	-41.28
Emitter density (#/acre)	.001	Rcvr ant. gain (dBi)	30.00
Number in annulus	5023.	Rcvr ant. beamwidth (deg)	5.16
Number in sector	72.		
Ring separation (km)	2.488		
Number of rings	37.		

OUPUT RESULTS

```
       Aggregate power sum received :      -138.41 dBm
Equivalent number of inner-ring emitters :     2.
```

NOTE: Inner ring in output results is located at 14.98 km instead of 10.00 km.

Example 4

Emitter EIRP

and

Total Number Input

RINGS

RINGS is a multiple emitter analysis program that supports user-interactive computations of aggregate interference levels into a terrestrial station receiver.

The user specifies the emitter distibution region, emitter population, emission level and frequency, and receiver antenna, with various parametric aptions that are automatically prompted

The user also selects between free space formulas and the IPS propagation model for path loss calculations. On-screen help is provided for the propagation model parameters.

Reference: RINGS, Aggregate Emitter Analysis Model
Cesar A. Filippi, Robert A. Gruendl, July 1988

F10 = Next screen	Esc = Stop

PRESS F10 TO CONTINUE

RINGS

The program can use either free space propagation or the IPS propagation model. Press the space bar to choose the propagation option.

propagation option = IPS propagation model

The emitter strength can be specified as an emission power level or a field strength at a reference distance. Press the space bar to choose the emitter strength option.

emitter strength option = eirp

The program requires either the receiver antenna gain, diameter, or beamwidth as input. Press the space bar to choose the receiver antenna option.

receiver antenna option = beam width

The emitter population can be specified either by a total number or a surface density. Press the space bar to choose the emitter population option.

emitter population option = total number

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return ↑↓ = select next input field

MAKE CHOICES THEN PRESS F10 TO CONTINUE

RINGS

Integrated Propagation System Input Screen

Site Parameters:
Transmitter antenna height = 5.00 m
Receiver antenna height = 15.00 m
Ground and Atmosphere Constants:
Ground conductivity (0.0001-5.0 mho/m) = 0.0050 mho/m
Ground dielectric constant (1.01-81.00) = 15.00
Atmospheric refractivity (200.00-450.00) = 301.00
Transmitter polarization (V or H) = V

Suggested :		Conductivity (mho/m)	Dielectric Constant
Values :	Average ground	0.005	15.0
for :	Poor ground	0.001	4.0
Electrical :	Good ground	0.020	25.0
Ground :	Fresh water	0.010	81.0
Constants :	Sea Water	5.000	81.0

F9 = Previous screen	Esc = Stop
F10 = Next screen	Return ↑↓ = select next input field

ENTER ALL INPUT DATA THEN PRESS F10 TO CONTINUE

RINGS

INPUT DATA: EIRP mode

```
                    Frequency =    1000.000 MHz
                         EIRP =    -41.3    dBm
Receiver Antenna Beamwidth =         5.2    degrees

            Inner Ring Radius =      10.00 km
            Outer Ring Radius =     100.00 km
           Number of Emitters =      5.000 # in 1000's
```

```
F1 = Run program
F2 = Exit program                       Esc = Stop
F9 = Previous screen          Return ↑↓ = select next input field
```

MAKE CHOICES THEN PRESS F1 TO CONTINUE

THE NUMBER OF EMITTERS SPECIFIED RESULTS IN THE FIRST EMITTER BEING PLACED IN RING NUMBER 3 AT A DISTANCE OF 14.98 KM.

CHOOSE FROM THE FOLLOWING BY NUMBER AND THEN PRESS ENTER:

1) ABORT PROGRAM
2) CHANGE PARAMETERS
3) CONTINUE WITH GIVEN DATA

CHOICE: 3

INPUT SCENARIO

Inner radius (km)	10.00	Frequency (MHz)	1000.000
Outer radius (km)	100.00	EIRP (dBm)	-41.28
Emitter density (#/acre)	.001	Rcvr ant. gain (dBi)	30.00
Number in annulus	5000.	Rcvr ant. beamwidth (deg)	5.16
Number in sector	72.		
Ring separation (km)	2.488		
Number of rings	37.		

OUPUT RESULTS

Aggregate power sum received : -138.41 dBm
Equivalent number of inner-ring emitters : 2.

NOTE: Inner ring in output results is located at 14.98 km instead of 10.00 km.

SECTION 4

AGGREGATE EMITTER ANALYSIS MODEL FOR AIRBORNE RECEIVERS

PDOME TECHNICAL MANUAL

The purpose of this section is to describe the analysis program and computation options of the aggregate emitter analysis model for airborne receivers. Multiple emitters with the same emission frequency and emission level are distributed on a spherical dome on the Earth's surface, according to the emitter distribution options selected. The emission level per emitter can be specified in terms of radiated power or field strength units.

The emitter distribution can be spread or concentrated on the dome surface, and specified by the emitter surface density or total number of emitters. The model computes the power-sum aggregation into an aircraft receiver at a given altitude or range of altitudes. A 4/3 Earth-radius model is assumed for ray-bending effects, and free space propagation is employed for path loss computations.

A computer program called PDOME has been developed at NTIA for the aggregate received power computation. The program is menu-driven with user selection of the distribution model, emission parameters, and output options, as described below.

The emitter distribution model is selected by the user from the following two options:

- Spread Distribution: emitters are distributed to span the visibility limit, which is automatically computed from the aircraft altitude
- Concentrated Distribution: emitters are distributed on a smaller area whose radius is selected by the user independently of the aircraft altitude.

For the concentrated distribution, an error message is automatically flagged on the screen if the user selects a radius that exceeds the visibility limit for the aircraft altitude specified. The user also has the option of selecting either the emitter surface density or the total number of emitters in the concentrated model, and the emitter surface density in the spread model.

The emission level per emitter is specified by the user from the following two options:

- Equivalent Isotropically Radiated Power (EIRP)
- Field Strength at Reference Distance

The other input parameters are the emission frequency and the aircraft altitude. A summary of all the input parameters and units employed is shown in TABLE 4-1.

TABLE 4-1

PDOME INPUT DATA SUMMARY

PARAMETER	UNITS	CONDITION
Aircraft Altitude	feet	Screen Output (not plotter file)
Distribution Radius	kilometers	Concentrated Distribution Model
Emitter Density	number/acre	Spread or Concentrated Distribution Model
Number of Emitters	integer	Concentrated Distribution Model
Emission Frequency	megahertz	- - - -
EIRP	dBm	Radiated Power Level Input
Field Strength	microvolts/meter	Field Strength Level Input
Reference Distance	meters	Field Strength Level Input

The program computes and displays the power-sum aggregation from the emitter distribution into the aircraft receiver, assuming 0 dBi gain for the receiving antenna over the visibility limit (spread model) or distribution radius (concentrated model). A detailed description of the distribution models and power aggregation is given in the next section.

The power-sum aggregation into the aircraft receiver is equivalent to having a certain number of emitters collocated directly beneath the aircraft, at the minimum distance corresponding to the aircraft altitude. The program computes this equivalent number of collocated emitters as an additional output displayed.

The program also computes and displays the power received from a single emitter, when the latter is located directly beneath the aircraft as a worst condition. This value is an important reference level, since the power-sum aggregation of the emitter distribution into the aircraft receiver may not exceed the single-emitter effect if the emitter density specified by the input data is low enough.

The addition of this single-emitter contribution to the power-sum aggregation from the emitter distribution into the aircraft receiver is also displayed. If the single-emitter contribution is significant, the user must decide if a revision of the emitter distribution (model, parameters) is warranted.

The screen output display always includes the following four data items:

- Aggregate power received from emitter distribution, (dBm)
- Equivalent number of collocated emitters (directly below aircraft), (integer)
- Single-emitter power received (emitter directly below aircraft), (dBm)
- Aggregate plus single-emitter power received, (dBm)

A plotter output option is also supported by the program for the aggregate power received from the emitter distribution. Under this option, the user is not prompted for an aircraft altitude, and the program recycles the aggregate power-sum computation for an altitude range of 1000 to 40000 feet. The user assigns a filename to the aggregate power-sum versus altitude data for plotting purposes.

An example of PDOME computations is shown in TABLE 4-2 for a spread distribution with an emitter density of 1.0 per acre. An emission frequency of 1000 MHz was specified, along with a field strength per emitter of 500 μV/m at a reference distance of 3 meters. The two aircraft altitudes considered could represent landing (1000 feet) and cruising conditions (4000 feet) conditions, respectively.

The aggregate power received from the emitter distribution is -94.4 dBm at the low altitude and -96.2 dBm at the high altitude. The small variation in the aggregate power received illustrates how the added visibility at high altitudes introduces more emitters to essentially compensate for the larger path loss and smaller power contribution per emitter.

The equivalent number of collocated emitters needed to match the distribution aggregation is 788 at the low altitude versus 834377 at the high altitudes. The difference between the single and aggregate power received corresponds to this equivalent number with integer roundoff for each altitude case (e.g., 10 log 788 = -94.4 + 123.4). The single-emitter power contribution is insignificant relative to the aggregate effect, at both altitude cases.

An example of the PDOME computation with a concentrated emitter distribution is shown in TABLE 4-3 for the low-altitude case, using the same emission frequency and level per emitter as in the previous example. The number of emitters was set to N = 788, and collocated emitters below the aircraft were first simulated by selecting a small distribution radius of 1 meter (0.001 km), so that the corresponding outputs of TABLE 4-2 were reproduced as verification.

The distribution radius was then increased in TABLE 4-3 to higher values (1.0 m, 10.0 m), so as to distribute the emitters instead of collocating them. The aggregate power received from the emitter distribution then reduced to -100.8 dBm and -116.3 dBm, respectively, relative to the -94.4 dBm obtained when the emitters are collocated. The equivalent number of collocated emitters with the concentrated distribution also reduced to 180 for the 1.0 m radius and to 5 for the 10.0 m radius, relative to the 788 corresponding to the spread distribution.

TABLE 4-2

PDOME EXAMPLE WITH SPREAD EMITTERS DISTRIBUTION

	LOW-ALTITUDE AIRCRAFT CASE	HIGH-ALTITUDE AIRCRAFT CASE
INPUTS		
Output Format	Screen	Screen
Emitter Distribution	Spread	Spread
Emitter Density (per acre)	1.0	1.0
Aircraft Altitude (feet)	1000	40000
Emission Frequency (MHz)	1000	1000
Field Strength (μvolts/meter)	500	500
Reference Distance (m)	3	3
OUTPUTS		
Aggregate power received from emitter distribution (dBm)	-94.4	-96.2
Equivalent number of collocated emitters (directly below aircraft)	788	834377
Single-emitter power received (dBm) (emitter directly below aircraft)	-123.4	-155.4
Aggregate plus single emitter power received (dBm)	-94.4	-96.2

TABLE 4-3

PDOME EXAMPLE WITH CONCENTRATED EMITTERS DISTRIBUTION

	COLLOCATED EMITTERS CASE	DISTRIBUTED EMITTERS CASES	
INPUTS			
Output Format	Screen	Screen	Screen
Emitter Distribution	Concentrated	Concentrated	Concentrated
Number of Emitters	788	788	788
Distribution Radius (km)	0.001	1.0	10.0
Aircraft Altitude (feet)	1000	1000	1000
Emission Frequency (MHz)	1000	1000	1000
Field Strength (μvolts/meter)	500	500	500
Reference Distance (m)	3	3	3
OUTPUTS			
Aggregate power received from emitter distribution (dBm)	-94.4	-100.8	-116.3
Equivalent number of collocated emitters (directly below aircraft)	788	180	5
Single-emitter power received (dBm) (emitter directly below aircraft)	-123.4	-123.4	-123.4
Aggregate plus single-emitter power received (dBm)	-94.4	-100.8	-115.5

The plotter file option was employed to illustrate the power-sum aggregation versus altitude characteristics with the spread distribution. Successive program runs were made with three emitter densities (1.0, 0.3, 0.1 per acre), two emission levels (500 μV/m at 3m, 125 μV/m at 3m), and an emission frequency of 1000 MHz. The output files were combined to obtain the performance characteristics shown in Figure 4-1.

The solid and dotted curves in the top graph correspond to the higher (500 μV/m) and lower (125 μV/m) emission levels, respectively. The six top curves represent the power-sum aggregation of the emitter distribution into the aircraft receiver, and the two bottom curves represent the single-emitter contribution when located directly below the aircraft.

The power-sum aggregation curves exhibit little variation with altitude when compared to their single-emitter counterparts. The increased visibility with altitude produces larger dome surfaces where the emitters spread, and the total number of emitters increases for a given density to compensate for the path loss increase with altitude per emitter.

The vertical distance between any of the power-sum aggregation curves and their single-emitter counterpart is a measure of the magnitude of the aggregation effect in dB. This vertical distance also corresponds to the equivalent number of collocated emitters directly below the aircraft, as illustrated in the bottom graph of Figure 4-1. The increase in the equivalent number with altitude is a direct consequence of the flat nature of the power-sum aggregation curves relative to the single emitter effect.

Another performance characteristic of interest is the variation in the power-sum aggregation with a concentrated distribution, as a function of the number of emitters (N), concentration radius (ℓ), and aircraft altitude (h). The program computations for an emission frequency of 1000 MHz and emission level of 500 μV/m at 3m are shown in Figure 4-2, where the sloped lines represent the power-sum aggregation and the dotted line represents the single emitter contribution.

The three graphs shown correspond to aircraft altitudes of 1000 feet, 5000 feet, and 10000 feet, respectively. Each graph contains various concentration radius values up to the visibility limit determined by the aircraft altitude. The single emitter line is intersected as the number of

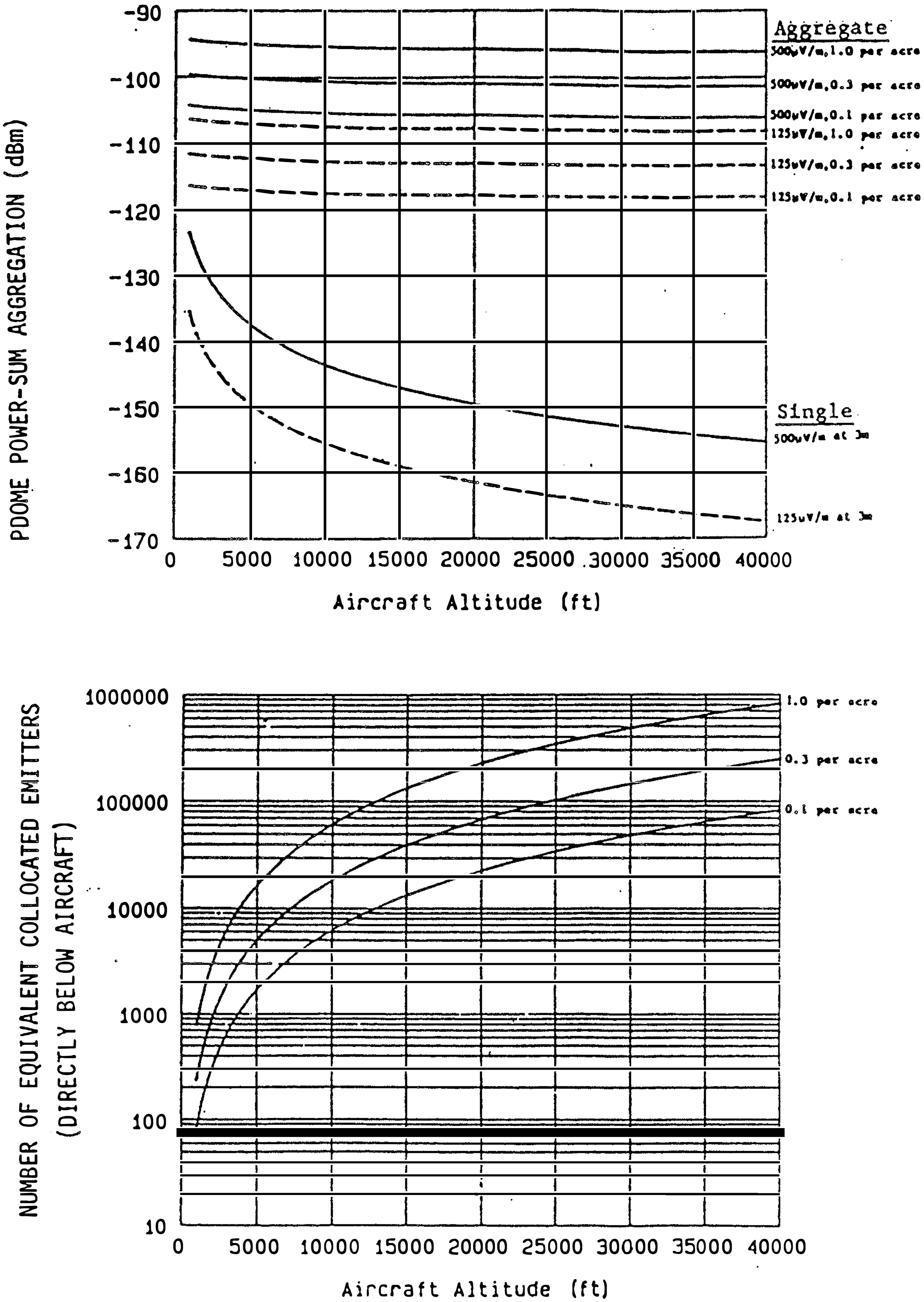


Figure 4-1. PDOME performance characteristics with spread distribution.

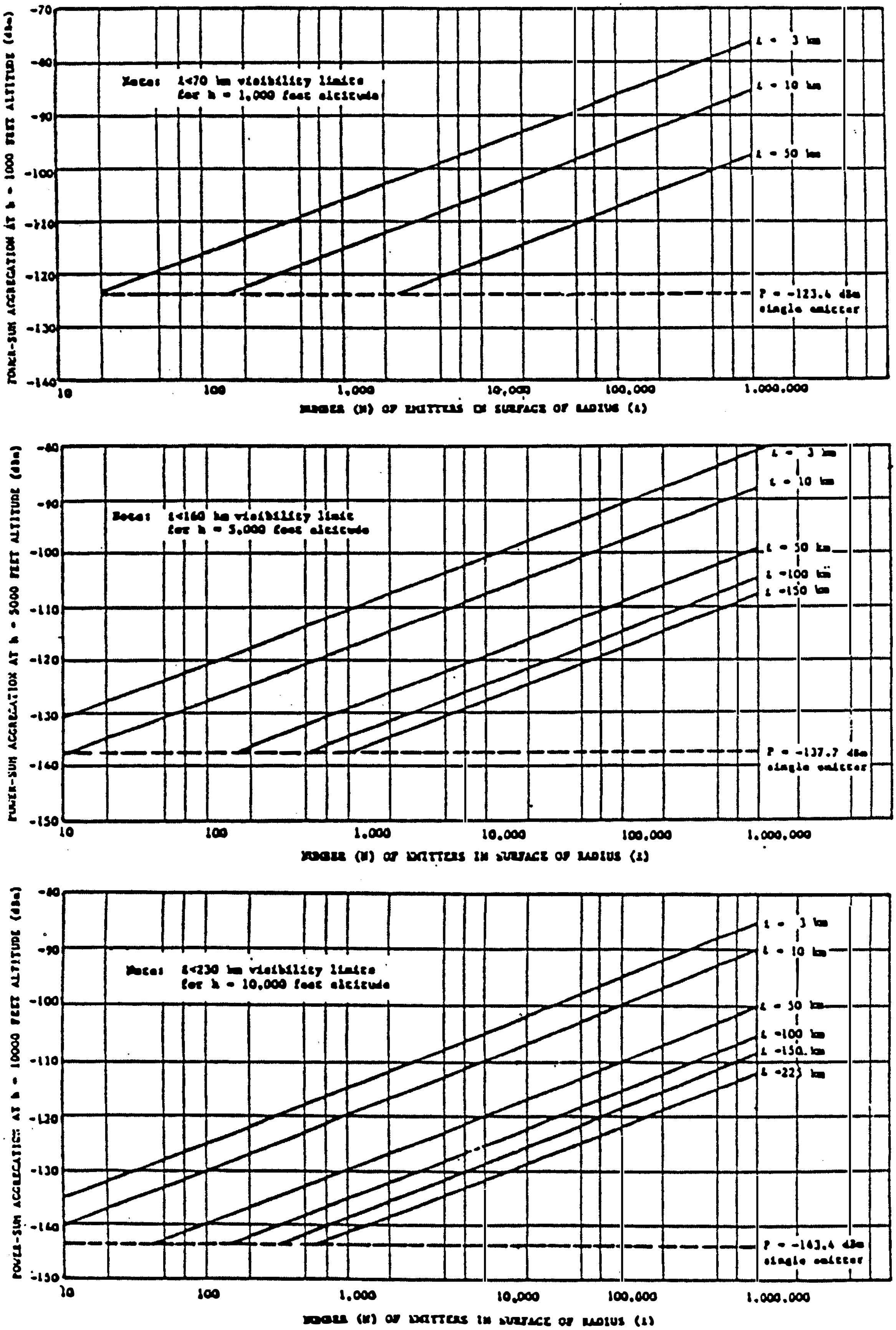


Figure 4-2. PDOME performance characteristics with concentrated distribution.

emitter decreases, with the intersection point representing a distribution equivalent to a single emitter located directly below the aircraft.

PDOME MODEL FORMULATION

This section presents a simple formulation for the estimation of the power-sum aggregate interference from emitters distributed over the Earth's surface into an aircraft receiver. All emitters are assumed to have the same emission level and frequency, and free-space propagation is assumed. The aircraft antenna is assumed to have unit gain over the visibility region determined by the aircraft altitude.

The power-sum aggregate interference is derived by modeling the emitter distribution and integrating their collective effect. Spread and concentrated distribution models are provided with a unified formulation. In the spread model, the emitters are distributed over the entire visibility region determined by the aircraft altitude. In the concentrated model, the emitters are distributed on a smaller region below the aircraft.

The user specifies the aircraft altitude, the emitter density or total number, the emission level, and the emission frequency. In the concentrated model, the user also specifies the radius of the region where the emitters are located.

A standard set of parameter units is employed in the formulation that follows for simplicity. The actual input and output units in the computer program have been selected to represent common usage. All unit conversions are performed automatically by the computation algorithms.

Spread and Concentrated Emitter Distribution Models

An aircraft receiver of altitude (h) is in the line-of-sight of ground emitters distributed on the surface of a spherical dome, as shown in Figure 4-3. The visibility distance (d_v) is a function of the altitude (h) and effective earth radius (r) via the relation $d_v = \sqrt{2rh+h^2}$.

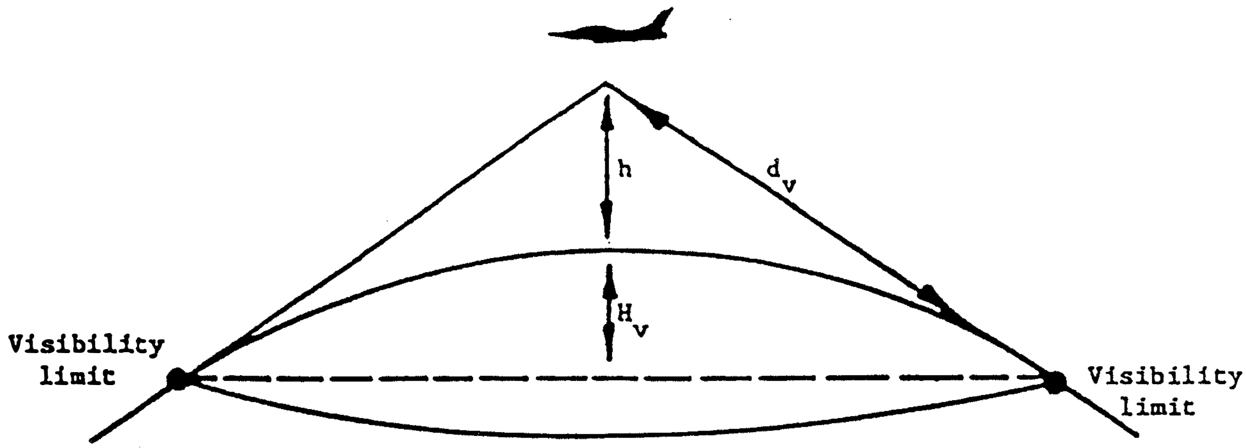


Figure 4-3. PDOME spread distribution model.

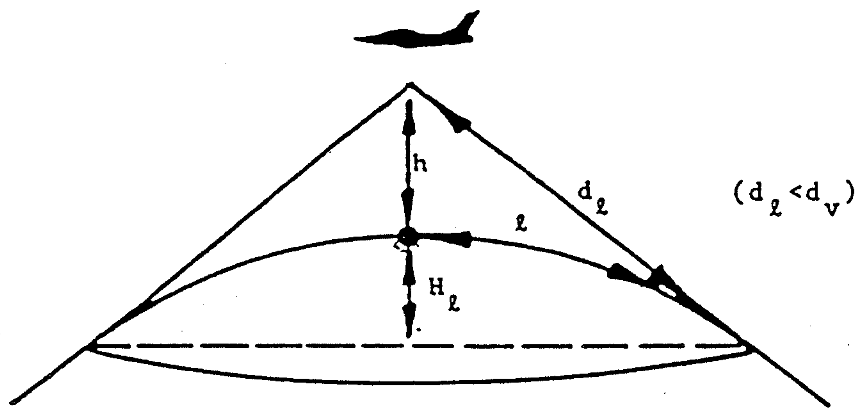


Figure 4-4. PDOME concentrated distribution model.

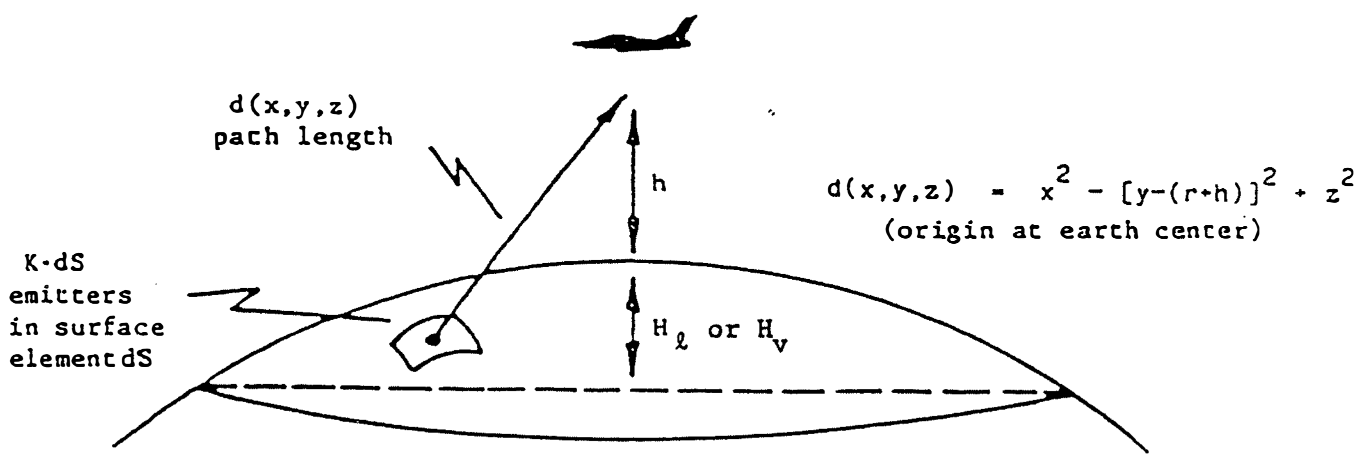


Figure 4-5. PDOME geometry for power-sum integration. $(H = H_v)$

A correction factor (k) can be assigned to the earth radius r_e = 6376 km to correct for ray-bending effects. The effective earth radius is then given by $r = k\ r_e$, where k = 4/3 is useful for low altitudes and introduces small errors at high altitudes.

The dome surface area is given by $A = (2\pi r)H$ as a function of the dome height (H). The maximum height corresponding to the visibility limit is given by $H_v = (rh)/(r+h)$. For example, the visibility dome has about 4 million acres for h = 1000 feet, and 100 million acres for h = 25,000 feet, with a 4/3 earth radius model.

The emitters located near the dome base will experience more signal path loss than those located near the dome top. The ratio between the maximum (d_v) and minimum (h) path distances represents a signal attenuation difference of $20 \log (d_v/h) = 10 \log [2(r/h)+1]$ in free space. For example, the difference is about 47 dB for h = 1000 feet, and 33 dB for h = 25,000 feet, with a 4/3 earth radius model.

If a spread distribution with a density of K emitters per unit area is assumed, then the total number of emitters is given by $N = (2\pi r)KH$ in a dome of height (H). The spread distribution will always use $H = H_v$, so as to include all emitters within the aircraft visibility.

A concentrated distribution can also be specified by considering a surface of radius (ℓ) below the aircraft, as shown in Figure 4-4. The corresponding dome has height $H_\ell = r(1 - \cos(\ell/r))$, and the surface area is given by $A_\ell = 2\pi r^2 (1 - \cos(\ell/r))$. The emitter density (K) and total number (N) are related by $N = KA_\ell$ in the concentrated model. Note that for $\ell \ll r$, the approximation $A_\ell \approx \pi \ell^2$ follows from the $\cos\theta \approx 1 - (\theta^2/2)$ relation.

However, the combination of aircraft altitude (h) and surface radius (ℓ) used in the concentrated model must be compatible with the visibility limits. The minimum altitude (h_{min}) needed to cover a given radius (ℓ) and the maximum radius (ℓ_{max}) visible from a given altitude (h) are given by

$$h_{min} = r \cdot \frac{1 - \cos(\ell/r)}{\cos(\ell/r)} \approx \frac{\ell^2}{2r} \quad \text{for } \ell \ll r \qquad (4\text{-}1)$$

and

$$\ell_{max} = r \cdot \cos^{-1} [r/(r+h)] \approx \sqrt{2hr} \quad \text{for } h, \ell << r \qquad (4\text{-}2)$$

Power-Sum Aggregation at Aircraft Receivers

Each ground emitter is at a distinct distance d(x,y,z) from the aircraft as shown in Figure 4-5, where the relation $x^2 + y^2 + z^2 = r^2$ locates the emitters on the spherical surface. The power received at the aircraft from each emitter is $P(x,y,z) = (P_t G_t G_r) (\lambda/4\pi)^2/d^2(x,y,z)$ in free space, where $(P_t G_t)$ is the emitter EIRP, $G_r = 1$ is the receiver antenna gain, and λ is the emission wavelength. The only distinction between emitters is due to the $d^2(x,y,z)$ variation with the emitter location.

A surface element (dS) in the spherical dome has K•dS emitters as shown in Figure 4-5. The power-sum aggregation is given by $P_r = \iint P(x,y,z)\ K \cdot dS$, where the integration is over the dome surface in question. The outcome can be separated into two terms RHO and INT as shown below, where RHO is a constant multiplier that reflects the emission parameters (P_t, G_t, λ), and INT is the surface integral $\iint (K/D^2) dS$ over a dome of height (H).

$$P_r(\text{aggregate}) = (\text{RHO}) \cdot (\text{INT}) \qquad (\text{power}) \qquad (4\text{-}3)$$

where

$$\text{RHO} = (P_t G_t)\ (\lambda/4\pi)^2 \qquad (\text{power}) \cdot (\text{distance})^2 \qquad (4\text{-}4)$$

$$\text{INT} = K \frac{\pi r}{r+h} \cdot \ln \left[\frac{2(r+h)H+h^2}{h^2}\right] \qquad (\text{distance})^{-2} \qquad (4\text{-}5)$$

and

$$H = H_v = (rh)/(r + h) \qquad \text{for spread model} \qquad (4\text{-}6)$$

$$H = H_\ell = r \cdot [1 - \cos(\ell/r)] \qquad \text{for concentrated model} \qquad (4\text{-}7)$$

In the spread model, the entire visibility dome is always used ($H = H_V$), so that the INT term can be simplified as follows:

$$INT = K \frac{\pi r}{r+h} \cdot \ln [2(r/h)+1] \qquad \text{for spread model} \qquad (4\text{-}8)$$

This last expression can be used to verify the formulation by considering the limiting case where $h >> r$. The visibility dome is then half the earth surface ($H_V = r$), and the INT term becomes $INT = K(2\pi r^2)/h^2 = N/h^2$. This result is correct, since there are $N = K(2\pi r^2)$ emitters in the half-earth surface ($2\pi r^2$), and they appear as an aggregate (N) point source at a common distance (h) to the distant aircraft.

The units of RHO are (power) times (distance)^2, while the units of INT are (distance)$^{-2}$. The units of INT are the units of the emitter density K, so that the only concern is to assure that the λ and K units are the same, or that the proper conversion factors are introduced otherwise.

Equivalent Field-Strength Formulation

The multiplier constant RHO can be specified in terms of a field strength (E) measure. In particular, the field strength E_0 in volt/meter (v/m) at a reference distance of D_0 (meters) from the emission source shall be assumed as the field strength specification.

The conversion from field strength into EIRP is based on equating the expressions $P_r = (P_t G_t G_r)(\lambda/4\pi D)^2$ and $P_r = (\lambda E)^2 G_r/(4\pi Z)$, where Z = 377 ohms in free space. These expressions yield $P_t G_t = 4\pi(E \cdot D)^2/Z$, and the conversion from E_o to $P_t G_t$ is obtained by setting $E = E_o$ and $D = D_o$. For example, the conversion is $P_t G_t(\text{watts}) = 0.3\ [E_{3m}(\text{v/m})]^2$ for D_o = 3 meters in free space, where E_{3m}(v/m) is the field strength at 3 meters from the source.

The net effect is to redefine the multiplier constant as $RHO = \lambda^2 (E_o \cdot D_o)^2/4\pi Z$. This can be expressed in terms of the emission frequency F(MHz) as shown below for free space. For example, D_o = 3 meters yields RHO = 171 $[E_{3m}(\text{v/m})/F(\text{MHz})]^2$ in (watts) (meters)^2.

$$RHO = 19 \left[\frac{E_o(\text{v/m}) \cdot D_o(\text{m})}{F(\text{MHz})}\right]^2 \quad \text{(watts) (meters)}^2 \qquad (4\text{-}9a)$$

$$= \frac{19}{4047} \left[\frac{E_o(\text{v/m}) \cdot D_o(\text{m})}{F(\text{MHz})}\right]^2 \quad \text{(watts) (acres)} \qquad (4\text{-}9b)$$

The last RHO expression above serves to specify the emitter density units as K emitters per acre for the INT computation. This is a convenient unit since it can be given a housing density interpretation. The use of volts/meter (or microvolts/meter) for the field strength and megahertz for the emission frequency are standard units.

Comparison with Single Emitter

The power-sum aggregation from the emitter distribution is next compared to the power received from a single emitter. The latter shall be located directly below the aircraft as a worst single-emitter condition, so that its received power is given by $P_r(\text{single}) = (RHO)(1/h^2)$. The RHO term has the same expression regardless of whether the single (discrete) or aggregate (distributed) case is considered.

The power-sum aggregation will exceed the single-emitter power received at the aircraft when INT $\geq (1/h^2)$. The emitter density (K) appears as a multiplier in the INT term, so that it has a lower bound below which this constraint will not be satisfied. This K-bound varies with the aircraft altitude (h), and also with the surface radius (ℓ) in the concentrated model.

There is also a lower bound induced on the total number (N) of emitters via the relation $N = (2\pi r)KH$. These K and N bounds are formulated below, as the constraint required for the power-sum aggregation to predominate over the single emitter contribution.

$$K \geq \frac{r+h}{\pi r h^2} \cdot \frac{1}{\ln(\alpha+1)} \quad \text{and} \quad N \geq \frac{\alpha}{\ln(\alpha+1)} \qquad (4\text{-}10)$$

where

$$\alpha = \frac{2r}{h} \qquad \text{for the spread model} \qquad (4\text{-}11)$$

$$\alpha = \frac{2r(r+h)}{h^2}\left(1-\cos\frac{\ell}{r}\right) \approx \frac{\pi(r+h)\ell^2}{rh^2} \qquad \text{for the concentrated model}$$

$$(4\text{-}12)$$

The behavior is best understood by rewriting the INT term in the power-sum aggregation as shown below. The N emitters distributed over the dome surface can be interpreted as N' equivalent emitters collocated directly below the aircraft and producing the same power-sum aggregation at the aircraft receiver.

$$\text{INT} = \frac{N'}{h^2} \qquad \text{where} \qquad N' = N \cdot \frac{\ln(\alpha+1)}{\alpha} \qquad (4\text{-}13)$$

The ratio N'/N can be interpreted as the reduction factor needed to compensate for the path loss effects in the relocation. For example, N' < N must occur when the N emitters are spread over a relatively large surface, since the N' emitters will be much closer to the aircraft.

The power-sum aggregation excess over a single emitter contribution is given by 10 log N' in dB units. Hence, N' $\geq$ 1 represents the condition required for the emitter distribution to predominate over the single-emitter case. This condition can be verified to yield the lower bound previously formulated for the number (N) of emitters.

It should be emphasized that the constraint for the power-sum aggregation of the emitter distribution to predominate over the single emitter contribution is not N $\geq$ 1 but rather N' $\geq$ 1. The N emitters correspond to a density K = N/A distributed over a spherical dome of surface area A = $(2\pi r)H$, and the condition N $\geq$ 1 does not assure that the emitter density is large enough to provide INT $\geq$ $(1/h^2)$ as required.

For example, the table below specifies the minimum number N of emitters required for the power-sum aggregation to predominate in the concentrated model, as a function of the aircraft altitude (h) and surface radius (ℓ). The minimum emitter density K = N/A_ℓ can be obtained from the dome surface area given in the table. A 4/3 earth radius is used in all the calculations.

ℓ(km)	A_ℓ(acres)	h=1000'	h=5000'	h=10000'	h=25000'	h=40000'
1	7.76×10^2	N$\geq$5	N$\geq$2	N$\geq$2	N$\geq$2	N$\geq$2
5	1.94×10^4	N$\geq$49	N$\geq$5	N$\geq$3	N$\geq$2	N$\geq$2
10	7.76×10^4	N$\geq$155	N$\geq$12	N$\geq$5	N$\geq$2	N$\geq$2
50	1.94×10^6	N$\geq$2637	N$\geq$155	N$\geq$49	N$\geq$12	N$\geq$6
100	7.76×10^6	---	N$\geq$515	N$\geq$155	N$\geq$34	N$\geq$16
200	3.10×10^7	---	---	N$\geq$515	N$\geq$106	N$\geq$49
300	6.99×10^7	---	---	---	N$\geq$212	N$\geq$95
400	1.24×10^8	---	---	---	---	N$\geq$155
500	1.94×10^8	---	---	---	---	---
(VISIBILITY LIMIT)		(ℓ<70km)	(ℓ<160km)	(ℓ<230km)	(ℓ<360km)	(ℓ<455km)

In summary, the power-sum aggregation from a uniform emitter distribution can actually be smaller than the contribution from a single emitter located directly below the aircraft. On this basis, it is recommended that the power received from one (or more) discrete emitter(s) directly below the aircraft be always compared to the power-sum aggregation of the uniform surface distribution when evaluating received power levels.

PDOME USER MANUAL

Program PDOME computes the power-sum aggregate interference into an aircraft receiver from a distribution of identical earth surface emitters. The program assumes a unit gain aircraft antenna and free-space propagation. The program can list results to either the user screen, or a disk file in a format easily adaptable to plotting.

The user selects the emitter distribution option (spread or concentrated) and parameters (emitter density, total number, concentration radius). The user also selects the emission frequency, and specifies the emission level in either field strength or radiated power units. The aircraft altitude is also specified for a screen output, and a 1000-40000 feet range is automatically provided for the plotter disk file output.

Hardware Requirements

The PDOME program has been designed to run on any PC with 100% IBM PC compatibility. The program requires a PC monitor (either color or monochrome), and a 5-1/4" floppy drive unit (the media used to transfer the program). Approximately 50K of disk space is needed if the user wishes to store the program file to hard disk.

Software Requirements

MS or PC DOS versions 2.0 or greater operating system is required.

Input

NAME	RANGE	UNITS	DESCRIPTION
IOUT	0,1,2	-	0 = abort program, 1 = write results for user selected altitude to screen, 2 = write power vs. altitudes 1000 to 40,000 ft to disk plot file.
IMODEL	0,1,2	-	0 = abort program, 1 = spread emitters throughout visibility, 2 = concentrate emitters within a radius
IEMIT	0,1,2	-	selectable only when IMODEL = 2, 0 = abort program, 1 = emitter density to be inputted (this is also the default for IMODEL = 1), 2 = total number of emitters to be inputted.
IPOWER	0,1,2	-	0 = abort program, 1 = emitter EIRP to be inputted, 2 = emitter field strength and ref. distance.
HA	> 0.	feet	aircraft altitude (IOUT = 1 only).
L	>0. to visible horizon	km	earth surface radius of dome (IMODEL = 2 only)
K	> 0	no./acre	emitter density (IEMIT = 1 only).
N	> 0	-	total number of emitters (IEMIT = 2 only)
EIRP	-	dBm	emitter EIRP (IPOWER = 1 only).
EO	-	micro-volts/m.	emitter field strength at DO (IPOWER = 2).
DO	-	meters	field strength reference distance (IPOWER = 2)
F	-	MHz	emitter frequency

Output

NAME	UNITS	DESCRIPTION
Outputs for screen mode:		
PR	dBm	received power-sum aggregation
PRIMEN	-	equivalent number of collocated emitters
PRSNG	dBm	single-emitter power received
PRTOT	dBm	aggregate plus single-emitter power received
Outputs for disk plot file mode:		
HA	feet	aircraft altitude
PR	dBm	received power-sum aggregation as a function of aircraft altitude (HA)

PDOME SAMPLE RUNS

This section presents sample runs of the PDOME program for various emitter distribution cases and input parameter values. The following sample runs are presented:

1. Spread Distribution with Field Strength and Emitter Density Specified
2. Concentrated Distribution with Field Strength and Emitter Density Specified
3. Concentrated Distribution with Field Strength and Emitter Number Specified
4. Spread Distribution with Radiated Power and Emitter Density Specified
5. Concentrated Distribution with Radiated Power and Emitter Density Specified
6. Concentrated Distribution with Radiated Power and Emitter Number Specified

1. Spread Distribution with Field Strength and Emitter Density Specified

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* Program PDOME - Computes power-sum aggregate interference *
* ------------    into an aircraft receiver from a spread    *
* or concentrated distribution of identical earth surface    *
* emitters, assuming an omni-directional aircraft antenna.   *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

Choose output format from the following:

   1 = screen (power computed at user selected altitude)
   2 = plot   (power vs altitude 1000 to 40,000 ft.)
   0 = abort program

1

Choose emitter distribution model:

   1 = Spread emitter distribution
   2 = Concentrated emitter distribution
   0 = abort program

1

Choose emitter strength units:

   1 = EIRP
   2 = field strength and reference distance
   0 = abort program

2

Enter aircraft altitude (feet) ?
30000

Enter emitter density (number/acre) ?
.05

Enter the field strength (microvolts per meter),
followed by the distance (meters) at which this
field strength is observed from the source ?
1250
30

Enter the emitter frequency (MHz) ?
960
```

```
Summary of inputs:

1. Output format ................... Screen
   Aircraft altitude (ft) .........   30000.0000
   Emitter distribution model ..... Spread
   Emitter density (per acre) .....        .0500

2. Emitter frequency (MHz) ........     960.0000
   Field strength (uvolts/meter) ..    1250.0000
   Distance from source (meters) ..      30.0000

Do you wish to change any of the above inputs (Y or N) ?

2. Emitter frequency (MHz) ........     960.0000
   Field strength (uvolts/meter) ..    1250.0000
   Distance from source (meters) ..      30.0000

Do you wish to change any of the above inputs (Y or N) ?
n

Aggregate power received from emitter distribution ...     -80.72 dBm

Equivalent number of collocated emitters ............      24407.
 (directly below aircraft)

Single emitter power received .......................    -124.60 dBm
 (emitter directly below aircraft)
Aggregate plus single emitter power received ........     -80.72 dBm
```

2. Concentrated Distribution with Field Strength and Emitter Density Specified

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* Program PDOFE - Computes power-sum aggregate interference    *
* ------------   into an aircraft receiver from a spread       *
* or concentrated distribution of identical earth surface      *
* emitters, assuming an omni-directional aircraft antenna.     *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *


Choose output format from the following:

   1 = screen (power computed at user selected altitude)
   2 = plot   (power vs altitude 1000 to 40,000 ft.)
   0 = abort program


Choose emitter distribution model:

   1 = Spread emitter distribution
   2 = Concentrated emitter distribution
   0 = abort program

2

Choose which input you wish to enter:

   1 = emitter density (number per acre)
   2 = total number of emitters
   0 = abort program

1

Choose emitter strength units:

   1 = EIRP
   2 = field strength and reference distance
   0 = abort program

2

Enter aircraft altitude (feet) ?
1500

Enter the surface radius (km) ?
10

Enter emitter density (number/acre) ?
.05

Enter emitter density (number/acre) ?
.05

Enter the field strength (microvolts per meter),
followed by the distance (meters) at which this
field strength is observed from the source ?
1250
30

Enter the emitter frequency (MHz) ?
960

Summary of inputs:

1. Output format .................. Screen
   Aircraft altitude (ft) ..........   1500.0000
   Emitter distribution model ..... Concentrated
   Surface radius (km) ............     10.0000
   Emitter density (per acre) .....      .0500

2. Emitter frequency (MHz) ........    960.0000
   Field strength (uvolts/meter) ..   1250.0000
   Distance from source (meters) ..     30.0000

Do you wish to change any of the above inputs (Y or N) ?


2. Emitter frequency (MHz) ........    960.0000
   Field strength (uvolts/meter) ..   1250.0000
   Distance from source (meters) ..     30.0000

Do you wish to change any of the above inputs (Y or N) ?
n


Aggregate power received from emitter distribution ...     -81.58 dBm

Equivalent number of collocated emitters .............       50.
 (directly below aircraft)

Single emitter power received ........................     -98.50 dBm
 (emitter directly below aircraft)
Aggregate plus single emitter power received .........     -81.50 dBm
```

3. Concentrated Distribution with Field Strength and Emitter Number Specified

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* Program PDOME - Computes power-sum aggregate interference *
* -------------   into an aircraft receiver from a spread   *
* or concentrated distribution of identical earth surface   *
* emitters, assuming an omni-directional aircraft antenna.  *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

Choose output format from the following:

   1 = screen (power computed at user selected altitude)
   2 = plot   (power vs altitude 1000 to 40,000 ft.)
   0 = abort program

1

Choose emitter distribution model:

   1 = Spread emitter distribution
   2 = Concentrated emitter distribution
   0 = abort program

2

Choose which input you wish to enter:

   1 = emitter density (number per acre)
   2 = total number of emitters
   0 = abort program

2

Choose emitter strength units:

   1 = EIRP
   2 = field strength and reference distance
   0 = abort program

2

Enter aircraft altitude (feet) ?
1500

Enter the surface radius (km) ?
10

Enter the total number of emitters ?
10000

Enter the field strength (microvolts per meter),
followed by the distance (meters) at which this
field strength is observed from the source ?
1250
30

Enter the emitter frequency (MHz) ?
960

Summary of inputs:

1. Output format .................. Screen
   Aircraft altitude (ft) .........    1500.0000
   Emitter distribution model ..... Concentrated
   Surface radius (km) ............      10.0000
   Total number of emitters .......    10000

2. Emitter frequency (MHz) ........     960.0000
   Field strength (uvolts/meter) ..    1250.0000
   Distance from source (meters) ..      30.0000

Do you wish to change any of the above inputs (Y or N) ?

2. Emitter frequency (MHz) ........     960.0000
   Field strength (uvolts/meter) ..    1250.0000
   Distance from source (meters) ..      30.0000

Do you wish to change any of the above inputs (Y or N) ?
n

Aggregate power received from emitter distribution ...     -77.47 dBm

Equivalent number of collocated emitters .............      129.
 (directly below aircraft)

Single emitter power received ........................     -98.58 dBm
 (emitter directly below aircraft)
Aggregate plus single emitter power received .........     -77.44 dBm
```

4. Spread Distribution with Radiated Power and Emitter Density Specified

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* Program PDOME - Computes power-sum aggregate interference *
* -------------   into an aircraft receiver from a spread   *
* or concentrated distribution of identical earth surface   *
* emitters, assuming an omni-directional aircraft antenna.  *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *


Choose output format from the following:

   1 = screen (power computed at user selected altitude)
   2 = plot   (power vs altitude 1000 to 40,000 ft.)
   0 = abort program

1


Choose emitter distribution model:

   1 = Spread emitter distribution
   2 = Concentrated emitter distribution
   0 = abort program

1


Choose emitter strength units:

   1 = EIRP
   2 = field strength and reference distance
   0 = abort program

1


Enter aircraft altitude (feet) ?
30000


Enter emitter density (number/acre) ?
.1


Enter the EIRP (dBm) ?
-13


Enter the emitter frequency (MHz) ?
1750
```

```
Summary of inputs:

1. Output format ..................  Screen
   Aircraft altitude (ft) .........   30000.0000
   Emitter distribution model .....  Spread
   Emitter density (per acre) .....        .1000

2. Emitter frequency (MHz) ........    1750.0000
   EIRP (dBm) .....................     -13.0000

Do you wish to change any of the above inputs (Y or N) ?
n


Aggregate power received from emitter distribution ...      -82.64 dBm

Equivalent number of collocated emitters .............      48815.
 (directly below aircraft)


Single emitter power received ........................     -129.52 dBm
 (emitter directly below aircraft)
Aggregate plus single emitter power received .........      -82.64 dBm
```

5. Concentrated Distribution with Radiated Power and Emitter Density Specified

```
**********************************************************
* Program PDOME - Computes power-sum aggregate interference *
* -------------   into an aircraft receiver from a spread   *
* or concentrated distribution of identical earth surface   *
* emitters, assuming an omni-directional aircraft antenna.  *
**********************************************************

Choose output format from the following:

   1 = screen (power computed at user selected altitude)
   2 = plot   (power vs altitude 1000 to 40,000 ft.)
   0 = abort program

1

Choose emitter distribution model:

   1 = Spread emitter distribution
   2 = Concentrated emitter distribution
   0 = abort program

2

Choose which input you wish to enter:

   1 = emitter density (number per acre)
   2 = total number of emitters
   0 = abort program

1

Choose emitter strength units:

   1 = EIRP
   2 = field strength and reference distance
   0 = abort program

1

Enter aircraft altitude (feet) ?
1500

Enter the surface radius (km) ?
10

Enter emitter density (number/acre) ?
.1

Enter the EIRP (dBm) ?
-13

Enter the emitter frequency (MHz) ?
1750
```

```
Summary of Inputs:

1. Output format .................. Screen
   Aircraft altitude (ft) .........   1500.0000
   Emitter distribution model ..... Concentrated
   Surface radius (km) ............     10.0000
   Emitter density (per acre) .....       .1000

2. Emitter frequency (MHz) ........   1750.0000
   EIRP (dBm) .....................    -13.0000

Do you wish to change any of the above inputs (Y or N) ?

   Emitter density (per acre) .....       .1000

2. Emitter frequency (MHz) ........   1750.0000
   EIRP (dBm) .....................    -13.0000

Do you wish to change any of the above inputs (Y or N) ?
n

Aggregate power received from emitter distribution ...     -83.50 dBm

Equivalent number of collocated emitters ............       100.
 (directly below aircraft)

Single emitter power received ........................    -103.50 dBm
 (emitter directly below aircraft)
Aggregate plus single emitter power received .........     -83.45 dBm
```

6. Concentrated Distribution with Radiated Power and Emitter Number Specified

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* Program PDOME - Computes power-sum aggregate interference *
* ------------   into an aircraft receiver from a spread   *
* or concentrated distribution of identical earth surface  *
* emitters, assuming an omni-directional aircraft antenna. *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

Choose output format from the following:

   1 = screen (power computed at user selected altitude)
   2 = plot   (power vs altitude 1000 to 40,000 ft.)
   0 = abort program

1

Choose emitter distribution model:

   1 = Spread emitter distribution
   2 = Concentrated emitter distribution
   0 = abort program

2

Choose which input you wish to enter:

   1 = emitter density (number per acre)
   2 = total number of emitters
   0 = abort program

2

Choose emitter strength units:

   1 = EIRP
   2 = field strength and reference distance
   0 = abort program

1

Enter aircraft altitude (feet) ?
1500

Enter the surface radius (km) ?
10

Enter the total number of emitters ?
5000

Enter the EIRP (dBm) ?
-13

Enter the emitter frequency (MHz) ?
1750

Summary of inputs:

1. Output format .................... Screen
   Aircraft altitude (ft) ..........   1500.0000
   Emitter distribution model ..... Concentrated
   Surface radius (km) ............     10.0000
   Total number of emitters .......   5000

2. Emitter frequency (MHz) .........   1750.0000
   EIRP (dBm) ......................    -13.0000

Do you wish to change any of the above inputs (Y or N) ?

   Total number of emitters .......   5000

2. Emitter frequency (MHz) .........   1750.0000
   EIRP (dBm) ......................    -13.0000

Do you wish to change any of the above inputs (Y or N) ?
n

Aggregate power received from emitter distribution ...     -85.41 dBm

Equivalent number of collocated emitters .............       65.
 (directly below aircraft)

Single emitter power received ........................    -103.50 dBm
 (emitter directly below aircraft)
Aggregate plus single emitter power received .........     -85.34 dBm
```

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report describes analysis models and software packages developed by the National Telecommunications and Information Administration (NTIA) for the assessment of single-entry and aggregate interference from terrestrial emitters into terrestrial or airborne victim receivers. The menu-driven computer programs are 100% MS-DOS compatible, and provide user options for input/output computations, parametric representations, propagation models and emitter distributions. The flexibility in the scenario creation, parameter selection, and computation mode, renders the models applicable to a wide variety of EMC assessments and conditions. Model descriptions, technical formulations, user manuals, and sample runs are provided in this report.

16. Key Words *(Alphabetical order, separated by semicolons)*

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