A Database for Propagation Models

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1.0 Introduction

The National Aeronautics and Space Administration's (NASA) Propagation Program supports academic research that models various propagation phenomena in the space research frequency bands. NASA supports such research via schools and institutions prominent in the field. The products of such efforts are particularly useful for researchers in the field of propagation phenomena and telecommunications systems engineers.

The systems engineer usually needs a few propagation parameter values for a system design. Published literature on the subject, such as the CCIR publications, may help somewhat, but often times, the parameter values given in such publications use a particular set of conditions which may not quite include the requirements of the system design. The systems engineer must resort to programming the propagation phenomena model of interest and to obtain the parameter values to be used in the project. Furthermore, the researcher in the propagation field must then program the propagation models either to substantiate the model or to generate a new model. The researcher or the systems engineer must either be a skillful computer programmer or hire a programmer, which of course increases the cost of the effort. An increase in cost due to the inevitable programming effort may seem particularly inappropriate if the data generated by the experiment is to be used to substantiate the already well-established models, or a slight variation thereof.

To help the researcher and the systems engineers, it was recommended by the participants of NASA Propagation Experimenters (NAPEX) XV held in London, Ontario, Canada on June 28 - 29, 1991, that propagation software should be constructed which will contain models and prediction methods of most propagation phenomenon. Moreover, the software should be flexible enough for the user to make slight changes to the models without expending a substantial effort in programming.

2.0 Properties of the Propagation Database

The database described in this paper produces a user-friendly environment with sufficient freedom for the users to model and predict propagation effects. The salient features of the software are as follows:

1. The database contains most, if not all, propagation phenomena models accepted by the propagation community. Access to the models is quite simple and requires only basic computer skills.

2. The database provides a summary description of the model with the parameters and the units of the parameters present therein.

3. The database models contain, where possible, default values for parameters of the model under consideration so that the user does not need to search for the already defined and known values of the parameters. The user can change the default values to more appropriate values.

4. Longer, more involved models are subdivided into steps. Descriptions of each step are available.

5. Extensive charting capabilities are available to the user. Where feasible, the actual charting process is made transparent to the user and involves the user only when a choice must be made between the possible outputs.

6. The user can override any choice made by the program and obtain an output that is appropriate for the application of interest.

7. The database allows changes to the model being run, i.e., changes in mathematical functions and operations using already existing parameters in the model. However, no new definitions of parameters will be permitted.

8. The data to be passed through the model is easily accessed in a straightforward manner with minimal user interface.

9. The database contains, when possible, default data that can be used to run the model and possibly produce the plots. This will be useful in comparing the data generated from a new experiment with already existing data.

10. Every model in the database has the same overall instructions and operating procedure. The user needs to learn how to use only one model in order to use the entire database effectively.

11. All the necessary precautions to ensure the correct use of the database are incorporated in the program. When incorrect inputs are made or when an action conflicts with the general directives of the program, the user is alerted with a warning.

12. User-friendly procedures are used to call the available mathematical functions of Excel software, such as the curve fitting, statistical analysis, etc. This allows the user to apply these functions to the data whenever needed.

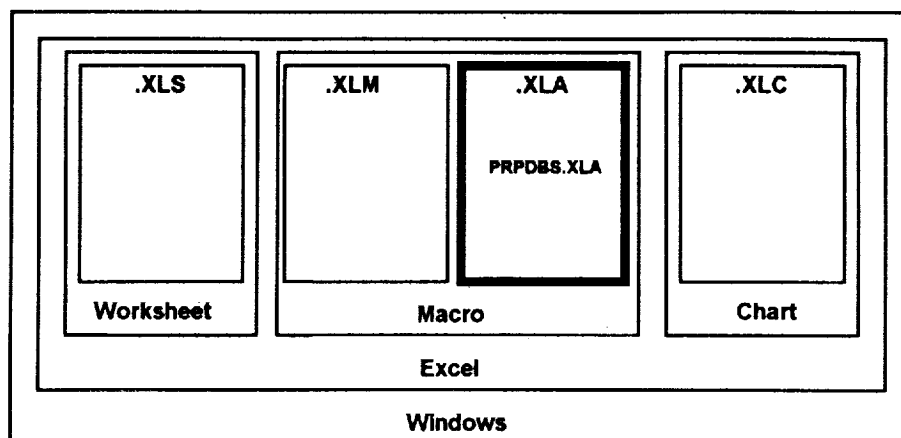13. The database is provided free of cost to the user.

3.0 Software Selection to Host the Propagation Database

A small study was conducted to evaluate the advantages and disadvantages of hosting the Propagation Database Software using a compiler-based program versus a spreadsheet-based program. The results indicate that a final product, such as the database spreadsheet software, has distinct advantages over the compiler-based software.

Of the many commercially available spreadsheet programs, Microsoft Excel was selected to host the Propagation Database software. Excel provides an extensive list of database and mathematical functions necessary to implement the propagation models. Excel also provides charting capabilities that include many versions of two- and three-dimensional charts. Excel also offers the dialog box utility, which can be effectively used for input and output functions of the Propagation Database. Another notable advantage of Excel is that it can call any executable programs written in C, which is a compiler-based program. This arrangement is ideal because it combines the advantages of a spreadsheet environment with the speed of the compiler-based software for number-crunching purposes.

4.0 Software and Hardware Requirements

To run the Propagation Database, Microsoft Windows 3.1 and Microsoft Excel 4.0 or later are required. The following figure shows how the Propagation Database Software interacts with Windows and Excel in the block diagram form. The software is kept under a file called "PRPDBS.XLA"

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│  ┌───────────┐ ┌───────────┐ ┌━━━━━━━━━━━┐ ┌───────────┐ │
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│  │ Worksheet │ │        Macro            │ │   Chart   │ │
│  └───────────┘ └─────────────────────────┘ └───────────┘ │
│                        Excel                              │
│                       Windows                             │
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By the way of hardware requirements, a reasonable PC to run the software would be the 80386 machine accompanied by its math coprocessor chip, 80387, with at least 4 Mbytes of RAM. The clock speed should be at least 20 MHz or more. An 80486-based system with a higher clock speed would be better. Any other computer, such as the 80286-based PC etc., with sufficient RAM will run the software; however, it will be very slow. It is recommended that a color monitor be used so that the charting can be done more effectively. Also, a hard disk having a reasonable storage space (a few megabytes) available for the software is needed. The software is developed for IBM PCs and compatibles. The Macintosh version will also be available soon.

5.0 The Propagation Database

The Propagation Database is divided into six categories: the Ionospheric models, the Tropospheric models, the Land Mobile Systems models, the Effects of Small Particles models, the Rain models, and the Radio Noise models. These six categories are further divided into subcategories to include all the models to be housed in the software.

Ionospheric Models:
Absorption Model, and Scintillation Model

Tropospheric Models:
Index of Refraction Profile Model, Gaseous Attenuation Model, Refraction and Fading Model

Land Mobile Satellite System Models:
Cumulative Distribution of Fade Duration Model, Cumulative Distribution of Non Fade Duration Model, Cumulative Distribution of Phase Fluctuation Model, Diffusely

Scattering Model, Empirical Regression Models, Empirical Roadside Shadowing Model, Large Scale - Small Scale (LS-SS) Coverage Model, Fade State Transition Model, Faraday Rotation Model, Frequency Scattering Model, Geometric Analytic Models, Single Object Model, Multiple Object Scattering Model, Loo's Distribution Model, Log normal Shadowing Model, Raleigh Model, Reflection Coefficient Model, Simplified Log normal Shadowing Model, and Total Shadowing Model

Effect of Small Particles Models:
Cloud Model

Rain Models:
CCIR Model, CCIR Model (Proposed Modification), Global Model, Dutton Dougherty Model, Lin Model, Rice Holmberg Model, and Simple Attenuation Model

Radio Noise Models:
Noise Model

The access to any model is carried out using Excel's dialog box user interface. Each dialog box is divided into six distinct areas to help the user to provide the inputs easily.

The six areas of the dialog box are described below. The first area is used to provide general information about the model selected by the user. This step describes any particular conditions required by the model, the parameter ranges as well as the number of steps the model has, and so on. The second area is used to display formulas describing the model selected. The formula can be modified by the users to a certain extent using legal expressions in Excel. Once the formula is created, the software will use this formula for the current run only. Loading the software again will bring back the original formula. The third area is the input area. This area is used to acquire input parameter(s) for the model. The fourth area is used to display definitions of the input and output parameter(s) used by the model. The fifth area is used to display intermediate or final result(s) of the particular model. The sixth area has a few buttons to help the user and to produce the output(s) of the model (or step). For some models, this area also has buttons to allow creation of a table of output values of the model as a function of the range of the selected input parameter. The following figures show the run of the CCIR rain attenuation model included in the database software.

6.0 Conclusion

A database of various propagation phenomena models that can be used by telecommunications systems engineers to obtain parameter values for systems design is presented. This is an easy-to-use tool and is currently implemented on a PC using Excel software under Windows environment; a Macintosh version of the software will also be available by the end of the year. Anyone desiring a copy of the software should contact the authors.

A Sample Run of the CCIR Rain Attenuation Model

Step 1: Calculates hR, the effective rain height in kilometers. The model used for the effective rain height, h_R, is as follows:

$$h_R = 3.0 + 0.028 * Phi \qquad 0 \le Phi < 36^0$$
$$h_R = 4.0 - 0.075 * (Phi - 36) \qquad Phi \ge 36^0$$

where *Phi* is the station's latitude in degrees, which the user must input (e.g., 37 degrees). The user may then click the output button to see the effective rain height, h_R. Clicking the Step 2 button takes the user to the next step.

CCIR

This Rain model is used to calculate the long-term statistics of the slant-path rain attenuation at a given location for frequencies up to 30 GHz.

Step 1 of 6:

<<< MODEL >>>
Calculate the Effective Rain Height.

If [0 <= Phi < 36] [deg]
hR [km]: =3.0+0.028*Phi

If [Phi >= 36] [deg]
hR [km]: =4.0-0.0075*(Phi-36)

<<< DEFINITION >>>
Phi: Station's Latitude.
hR: Effective Rain Height.

<<< INPUT >>>
Phi [deg]: 37

<<< OUTPUT >>>
hR [km]: 3.99

Help
Output
Step 2
Close

Step 2: Calculates L_S, the slant-path length below rain height in km. The model used for the slant-path length, L_S, is as follows:

$$L_s = \frac{(h_s - h_s)}{\sin(Theta)} \qquad Theta \geq 5^0$$

$$L_s = \frac{2(h_s - h_s)}{\left(\sin^2(Theta) + \frac{2(h_s - h_s)}{R_e}\right)^{1/2} + \sin(Theta)} \qquad Theta < 5^0$$

where h_R is the effective rain height in kilometers, h_S is the height mean sea level of the earth station in km supplied by the user (e.g. 0.632 km.), *Theta* is the elevation angle in degrees, which the user supplies (e.g., 14 degrees), and R_e is the modified earth radius (defaulted to 8500 kilometers), which may be changed if the user desires it. Clicking the output button shows L_S (the slant-path length). Then clicking step 3 takes the user to the next step.

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┌──────────────────────────────── CCIR ────────────────────────────────┐
│ This Rain model is used to calculate the long-term statistics of the slant-path rain attenuation at a given │
│ location for frequencies up to 30 GHz.                                  │
│                                                                         │
│ Step 2 of 6:                                                            │
│                                                                         │
│ ‹‹‹ MODEL ›››                          ‹‹‹ INPUT ›››                    │
│ Calculate Slant-path Length.           hR (km)          [3.99    ]      │
│ If (Theta >= 5) (deg), Ls (km):        hS (km)          [0.632   ]      │
│ =(hR-hS)/SIN(Theta)                    Theta (deg)      [14      ]      │
│ If (Theta < 5) (deg), Ls (km):         Re (km)          [8500    ]      │
│ =(2*(hR-hS))/((((SIN(Theta))^2+(2*(hR-hS            )   │
│                                                                         │
│ ‹‹‹ DEFINITION ›››                     ‹‹‹ OUTPUT ›››                   │
│ hR: Effective Rain Height.             Ls (km)         [13.89   ]       │
│ hS: Height above mean sea level of the                                  │
│ earth station.            ┌────────┐                                    │
│ Theta: Elevation Angle.   │  Help  │                                    │
│ Re: Modified Earth Radius (8500 Km)   ├────────┤                        │
│ Ls: Slant-path length below rain height. │ Output │                     │
│                           ├────────┤                                    │
│                           │ Step 3 │                                    │
│                           ├────────┤                                    │
│                           │ Close  │                                    │
│                           └────────┘                                    │
└─────────────────────────────────────────────────────────────────────────┘
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Step 3: Calculates L_g, the horizontal projection of the slant-path length in kilometers. The model used for the horizontal projection of the slant-path length, L_g, is

$$L_g = L_s \cos(Theta)$$

where, L_S is the slant-path length below rain height in kilometers, *Theta* is the elevation angle in degrees. Clicking the Output button shows L_g (the horizontal projection of the slant-path length). Clicking the Step 4 button takes the user to the next step.

Step 4: Obtains $R_{0.01}$ (dB), the rain intensity exceeded for 0.01% of an average year and calculates $r_{0.01}$, the reduction factor. The model used for the reduction factor, $r_{0.01}$, is

$$r_{0.01} = \frac{1}{1 + L_G/L_0}, \quad L_o = 35\exp(-0.015R_{0.01})$$

where, $R_{0.01}$ is the rain intensity exceeded for 0.01% of an average year in mm/hr and $r_{0.01}$ is the reduction factor. The user needs to select one of the rain climatic zones, e.g., K. These are the CCIR Rain Climatic Zone for the United States. Clicking the Output button shows $r_{0.01}$ (the reduction factor) and clicking the Step 5 button takes the user to the next step.

137

Step 5: Calculates *GammaR*, the specific attenuation using the frequency-dependent coefficient in dB/km. The formula used to calculate *GammaR* is as follows:

$$GammaR = kR_{0.01}^{\alpha},$$

$$k = [k_H + k_V + (k_H - k_V)\cos^2(Theta)\cos(2Tau)] / 2$$

$$\alpha = [k_H\alpha_H + k_V\alpha_V + (k_V\alpha_H - k_V\alpha_V)\cos^2(Theta)\cos(2Tau)] / 2k$$

where, *Theta* is the elevation angle in degrees, *Tau* is the polarization tilt angle in degrees. *k* and *a* are coefficients taken from Table 1 - Regression coefficients for estimating specific attenuation of Reports of the CCIR, 1990. The user inputs the frequency (e.g., 12.5 GHz), and the *Tau*, (e.g., 45) degrees for circular polarization. Clicking the output button shows *GammaR* and clicking the Step 6 button takes the user to the next step.

Step 6: Calculates $A_{0.01}$, the attenuation exceeded for 0.01% of an average year in decibels. The formula used for the attenuation exceeded for an average year, $A_{0.01}$ is:

$$A_{0.01} = GammaR * L_s * r_{0.01}$$

where, GammaR is the specific attenuation using the frequency-dependent coefficient in dB/km, L_s is the slant-path length below rain height in kilometers and $r_{0.01}$ is the reduction factor. Clicking the Output button shows $A_{0.01}$ (the attenuation exceeded for 0.01% of an average year) and clicking the "Other p (%)" button shows attenuation to be exceeded for other percentages of an average year (0.001 to 1.0 %).

This step also calculates attenuation to be exceeded of an average year for other percentages (0.001 - 1.0 %).

The formula used for p percent of the attenuation exceeded of an average year is as follows:

$$A_p = A_{0.01} * 0.12 * p^{-(0.546+0.043\log(p))}$$

where, p is the percentage of the attenuation exceeded (a user input), Ap is the attenuation exceeded for p percent, and $A_{0.01}$ is the attenuation exceeded for 0.01 percent. Clicking the Output button shows Ap, attenuation of p percentage and ratio of $A_p/A_{0.01}$.

When the Close button is clicked the following dialog box appears:

Microsoft Excel

? **Do you want to chart or create table?**

[OK] [Cancel]
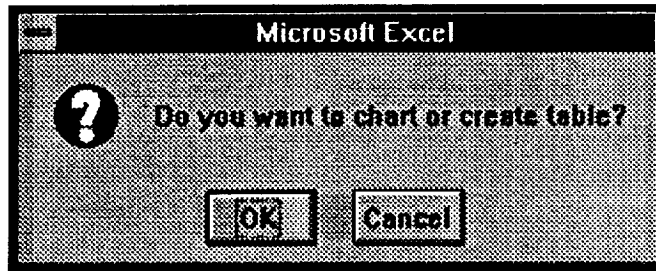
When the OK button is clicked, the following dialog box appears.

Chart:
◯ Rain Rate vs. Attenuation
◉ Frequency vs. Attenuation

[OK]
[Cancel]
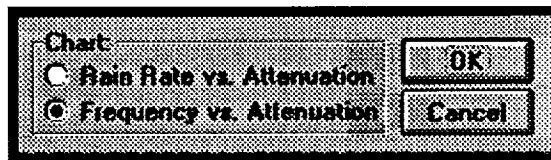
When the user selects a particular option a dialog box appears gathering inputs for that particular option. Here the Frequency versus attenuation button is selected.

Enter Frequency parameter (GHz):
Minimum Value: 1
Maximum Value: 30
Step Size: 1

[OK]
[Cancel]
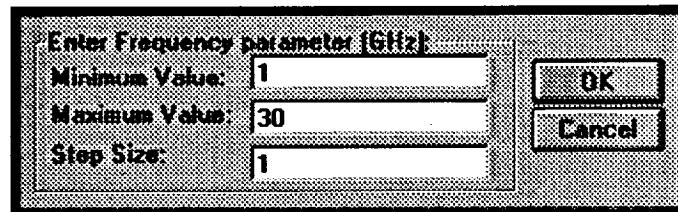
After user inputs the minimum, maximum and step values for the frequency variation and clicks the OK button, a new worksheet will then be invoked to store all of the parameters used, the table, as well as the chart produced. Printing option is available after this step. This concludes the run of the CCIR rain attenuation model.

Session 2

PROPAGATION STUDIES FOR MOBILE/PERSONAL COMMUNICATIONS

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