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A CCIR-BASED PREDICTION MODEL FOR EARTH-SPACE PROPAGATION

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1. BACKGROUND

At present there is no single "best way" to predict propagation impairments to an Earth-Space path. However there is an internationally accepted way — namely that given in the most recent version of CCIR Report 564 of Study Group 5. This paper treats a computer code conforming as far as possible to Report 564. It was prepared for an IBM PS/2 using a 386 chip and for Macintosh SE or Mac II. It is designed to be easy to write and read, easy to modify, fast, have strong graphic capability, contain adequate functions, have dialog capability and windows capability.

Computer languages considered included the following

- Turbo BASIC
- Turbo PASCAL
- FORTRAN
- SMALL TALK
- C++
- MS SPREADSHEET
- MS Excel-Macro
- SIMSCRIPT II.5
- WINGZ

Microsoft Excel-Macro was chosen as the first phase simulation language for the following Characteristics

- strong graphic capability
- about 400 math or control functions
- sophisticated coordinate systems
- window and dialog capability
- easy to customize
- enough resolution and colors for our use
- not too fast at the beginning, because of on-screen processing

2. PROGRAM STRUCTURE

Shown in Figure 1 are the dialog boxes illustrating how the first part of the program would be run. The second part consists of consolidating gaseous attenuation and rain attenuation with the free-space value of the carrier C; and brightness temperature with the noise temperature of the receiving system, to obtain the overall system noise density X_0 or N_0 to yield C/X_0.

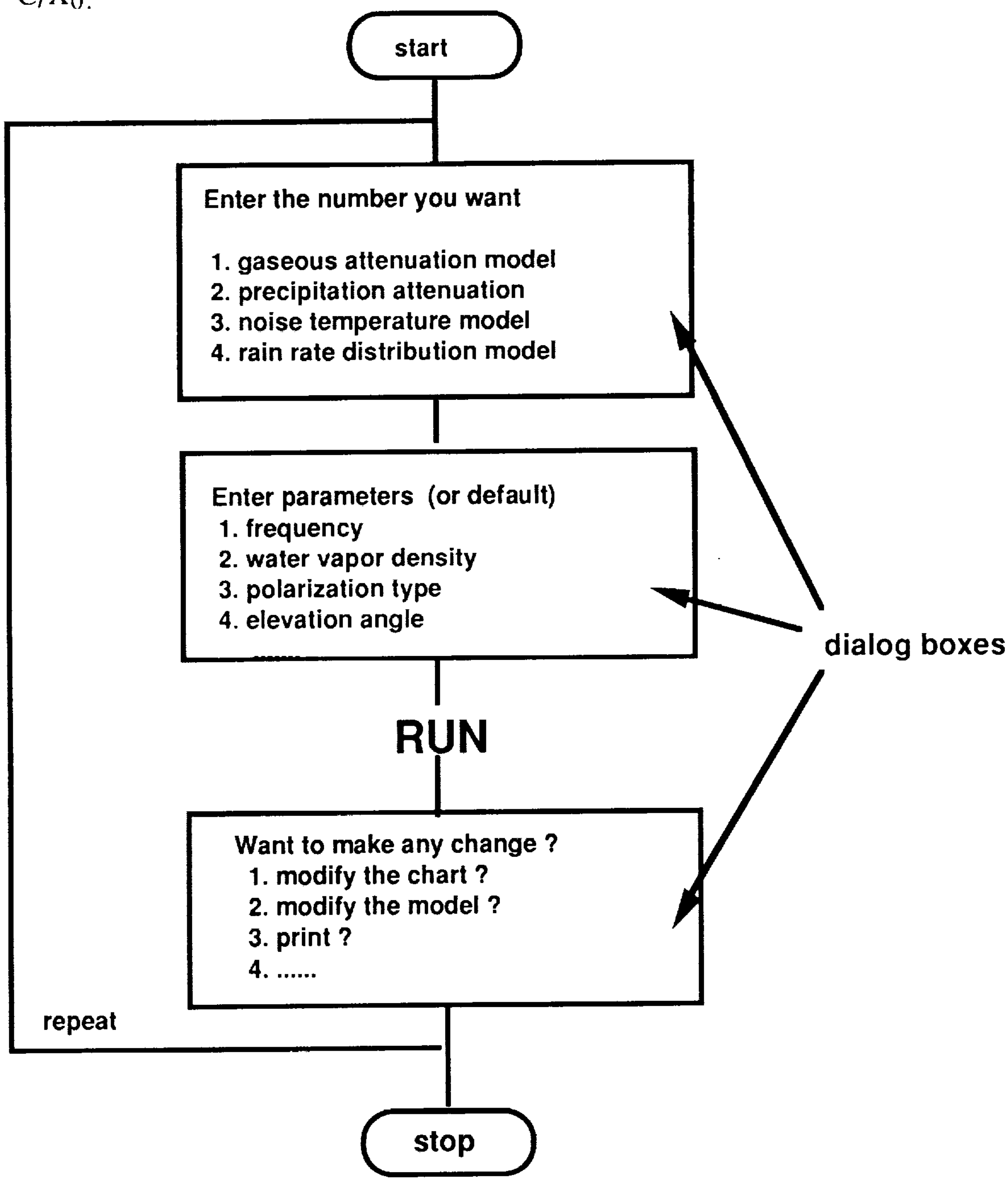

Figure 1 Program Diagram

3. METHOD AND RESULTS

(A) Rain Rate as a Function of percentage of year: CCIR Report 563 (1990) is used as the authority for rain rate. The formula used is

$$P(R>r) = \frac{a e^{-ur}}{r^{b}} \qquad r \geq 2 \text{ mm/h} \qquad (1)$$

where R is rain rate, r is a given rain-rate threshold, u is a parameter depending on climate and geographical features, and

$$a = 10^{-4} R_{0.01}^{b} e^{u R_{0.01}}$$
$$b = 8.22 (R_{0.01})^{-0.548}$$

Figure 2 illustrates this relation applied to 4 CCIR regions (found in Report 563), and Figure 3 illustrates the goodness of fit of equation (1) with the CCIR data in Report 563. As can be seen, beyond 2 mm/h the fit appears very good.

(B) Attenuation due to Rain: CCIR Report 564 (1990) is used to obtain rain attenuation. The specific attenuation γ_r is obtained from

$$\gamma_r = \kappa (R_{0.01})^{\alpha} \qquad \text{dB/km} \qquad (2)$$

where κ and α are tabulated values and are a function of frequency and drop size distribution. The path attenuation A is then given by

$$A = \gamma_r L_s r_{0.01} \quad \text{dB} \qquad (3)$$

where L_s is the adjusted path length through rain, $R_{0.01}$ is the rain rate in mm/h for 0.01% of the time. Figure 4 illustrates these relations in a plot of attenuation vs frequency for four different rain rates.

(C) Gaseous Attenuation: According to the CCIR Report 719 (1990) version, specific attenuation due to oxygen and water vapor are determined as

$$\gamma_0 = [7.19\times10^{-3} + \frac{6.09}{f^2+0.227} + \frac{4.81}{(f-57)^2+1.5}]\, f^2\times10^{-3} \quad \text{dB/km} \quad f\leq 57 \text{ GHz} \qquad (4)$$

$$\gamma_0 = [3.79\times10^{-7} f + \frac{0.265}{(f-63)^2+1.59} + \frac{0.028}{(f-118)^2+1.47}]\, (f+198)^2\times10^{-3} \quad \text{dB/km} \quad 63\leq f\leq 350 \text{ GHz} \qquad (5)$$

$$\gamma_w = [0.05+0.0021\,\rho_w + \frac{3.6}{(f-22.2)^2+8.5} + \frac{10.6}{(f-183.3)^2+9.0} + \frac{8.9}{(f-325.4)^2+26.3}]\,f^2 \rho_w 10^{-4}$$

$$\text{dB/km} \quad f \leq 350\ \text{GHz} \qquad (6)$$

where γ_o and γ_w represent specific attenuation by oxygen and water vapor, f is frequency in GHz, and ρ_w is water vapor density. Total attenuation A_g due to gaseous then is determined as

$$A_g = \frac{\gamma_o h_o e^{-\frac{h_s}{h_o}} + \gamma_w h_w}{\sin\theta} \quad \text{dB} \quad \theta > 10^0 \qquad (7)$$

$$A_g = \frac{\gamma_o h_o e^{-\frac{h_s}{h_o}}}{g(h_o)} + \frac{\gamma_w h_w}{g(h_w)} \quad \text{dB} \quad \theta \leq 10^0 \qquad (6)$$

Figure 5 illustrates attenuation due to the gaseous atmosphere at four different elevation angles, and Figure 6 shows attenuation due to the gaseous atmosphere at four different station heights.

D: Brightness Temperature (upward looking antenna): The general formula used for brightness temperature was based on the model developed by Waters in 1976. Because it is quite complicated, we used a simplified formula which was the combination of two models developed by E. K. Smith (1982) and Waters (1974)

$$A = \int_0^\infty \sum_i^\infty \gamma_i \, dr \approx \int_0^\infty [\gamma_o + \gamma_w] \, dr \qquad (7)$$

$$T_b = \int_0^\infty T(r)\,\gamma(r)\,e^{-\tau(r)} dr + T_\infty e^{-\tau_\infty} \qquad (8)$$

where $\tau(r) = \int_{surf}^{r} \gamma(r')\, dr'$

If $T(r)$ is replaced by a mean path temperature T_m, it can be simplified as

$$T_b = T_m (1 - e^{-\tau})$$

$$\text{or} \quad T_b = T_m (1 - 10^{[-A(dB)/10 \sin\theta]}) \quad \theta \geq 10^{o} \tag{9}$$

where A is the attenuation at zenith direction, T_b is brightness temperature, θ represents elevation angle, L is the loss factor, and τ is the optical depth.

Figure 7 illustrates the brightness temperature at four different elevation angles, and Figure 8 is a comparison of computed results and CCIR data at the conditions of water vapor density 7.5 mm/h and elevation angle 30 degrees. As we can see, the fit is very good in lower frequency range.

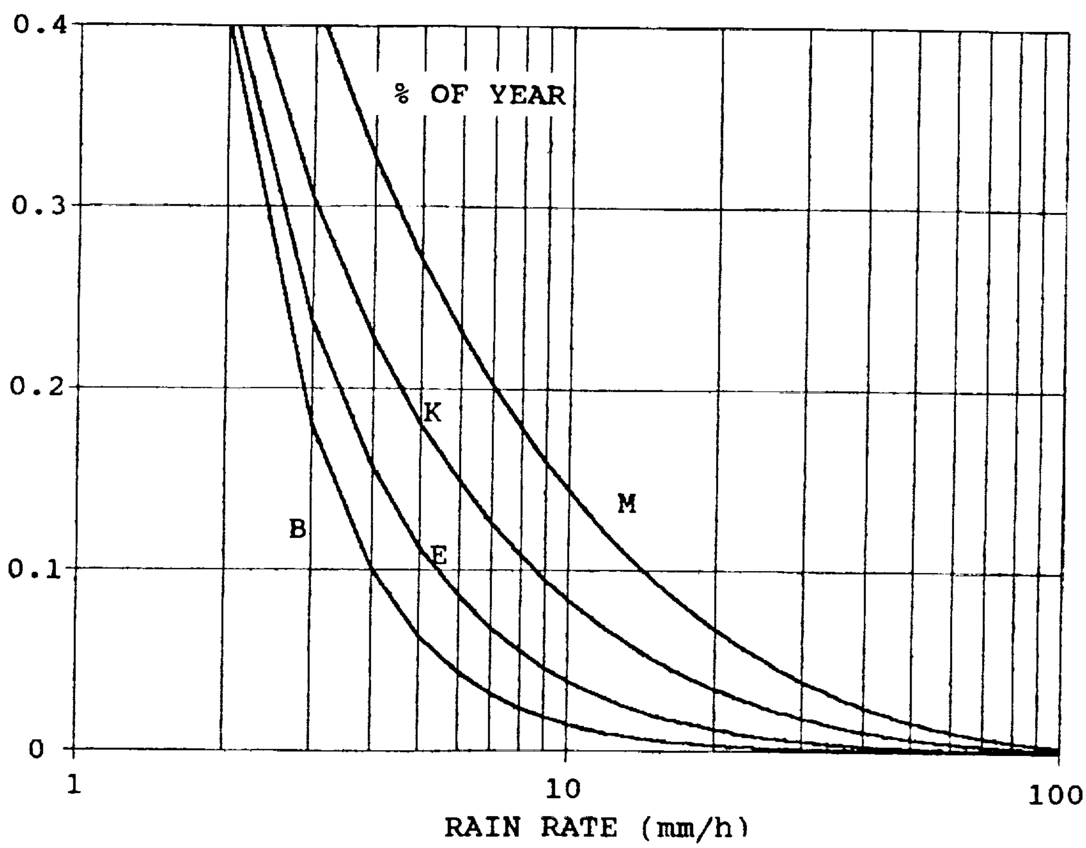

Figure 2 Rain Rate vs % of Year for Regions B, E, K, M

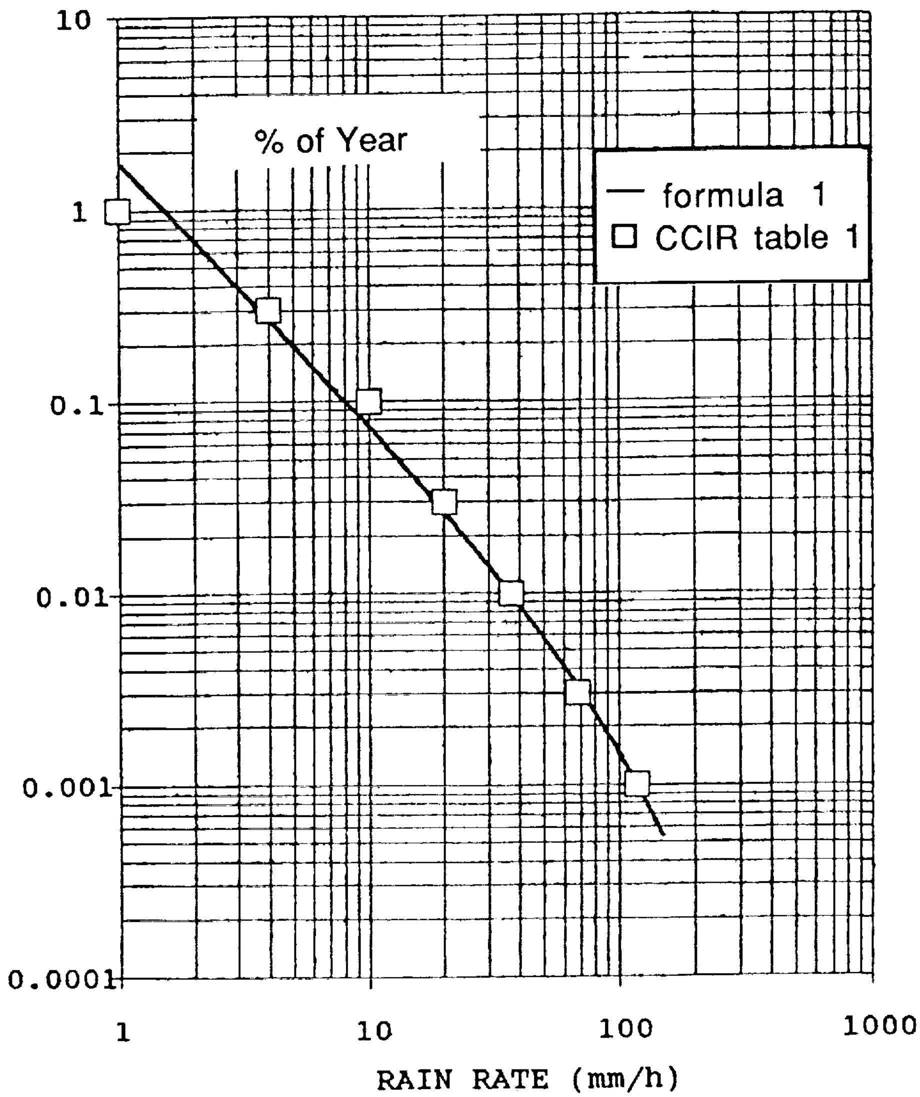

Figure 3 Analytical vs Experimental Results (CCIR region E)

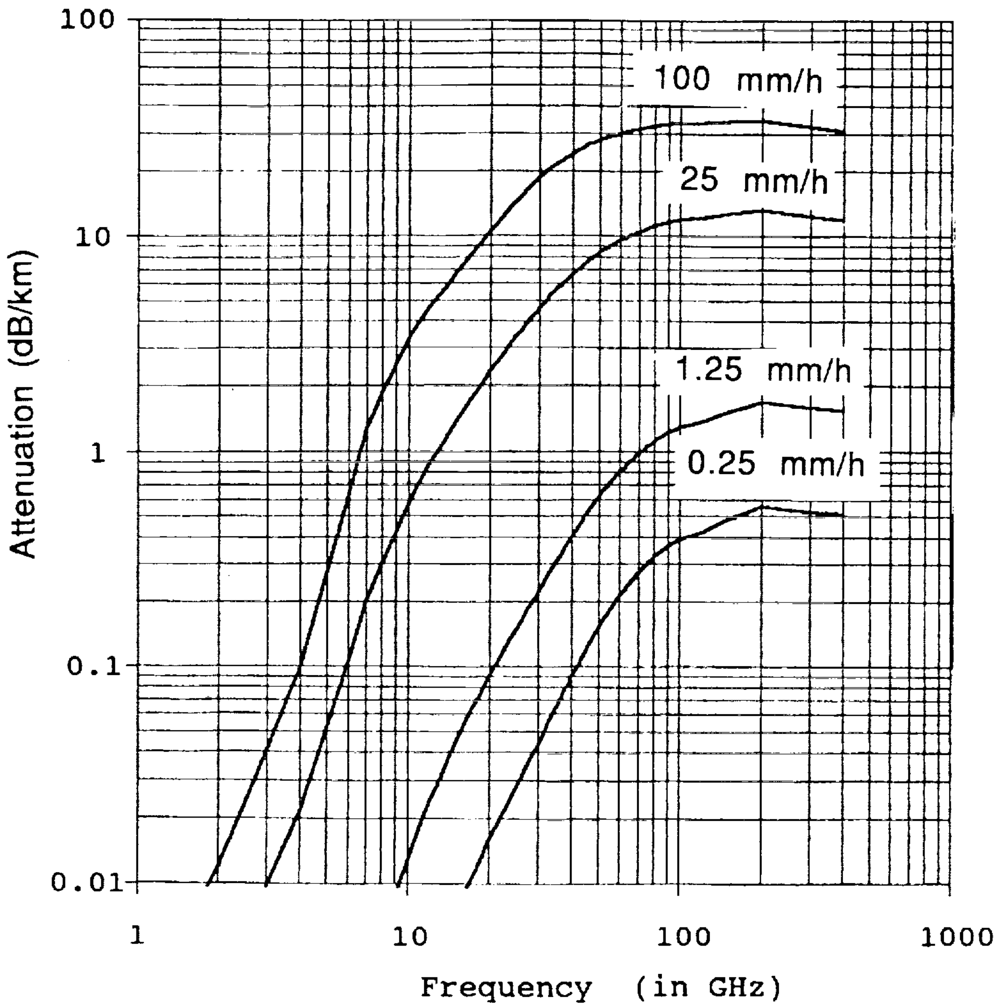

Figure 4 Specific Attenuation γ_r Due to Rain

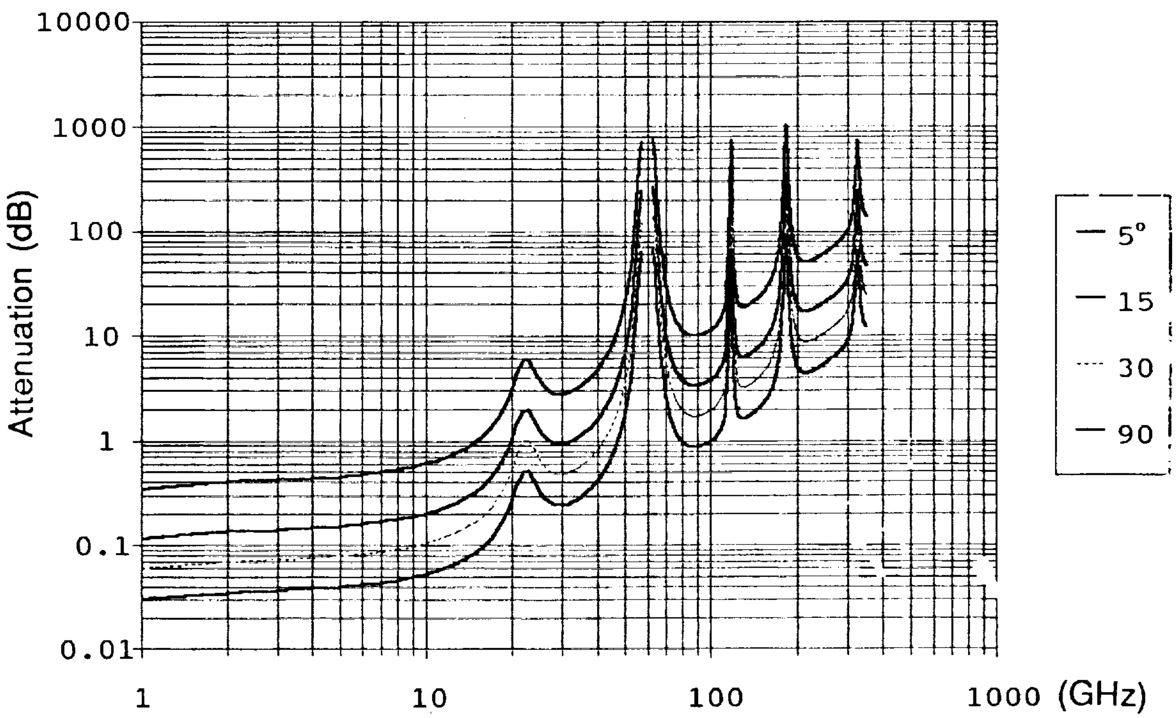

Figure 5 Gaseous Attenuation Transiting the Atmosphere
(pressure 1013 mb, temperature 15o C, Water Vapor 7.5 g/m3)

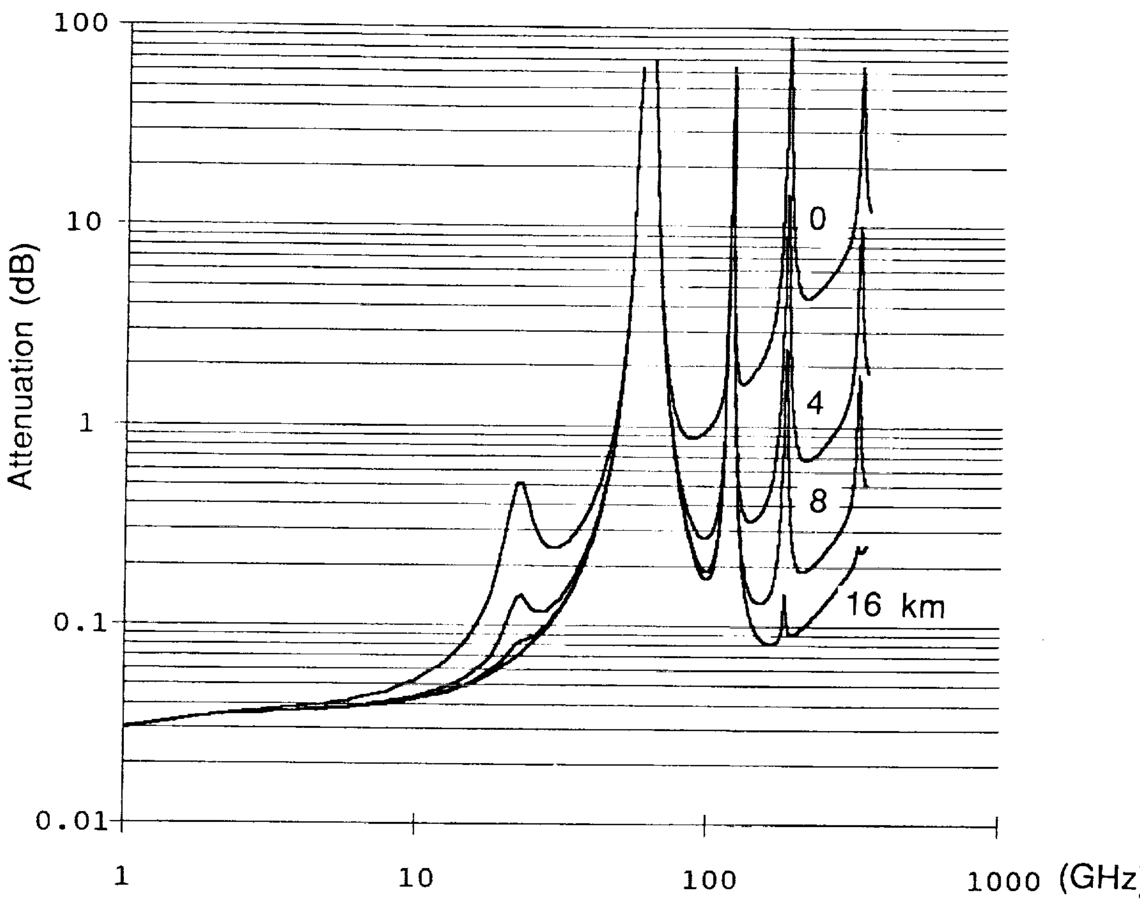

Figure 6 Zenith Gaseous Attenuation at Different Heights

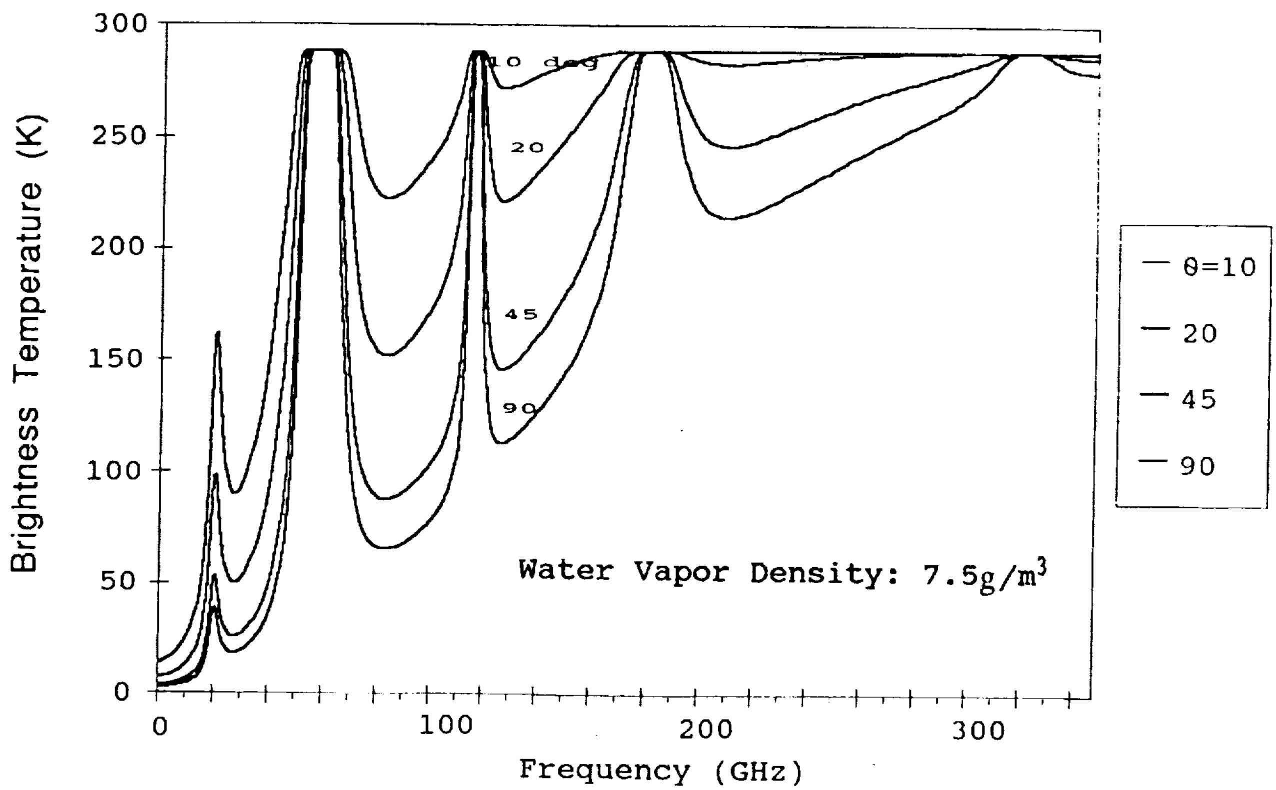

Figure 7   Brightness Temperature at Different Elevation Angles

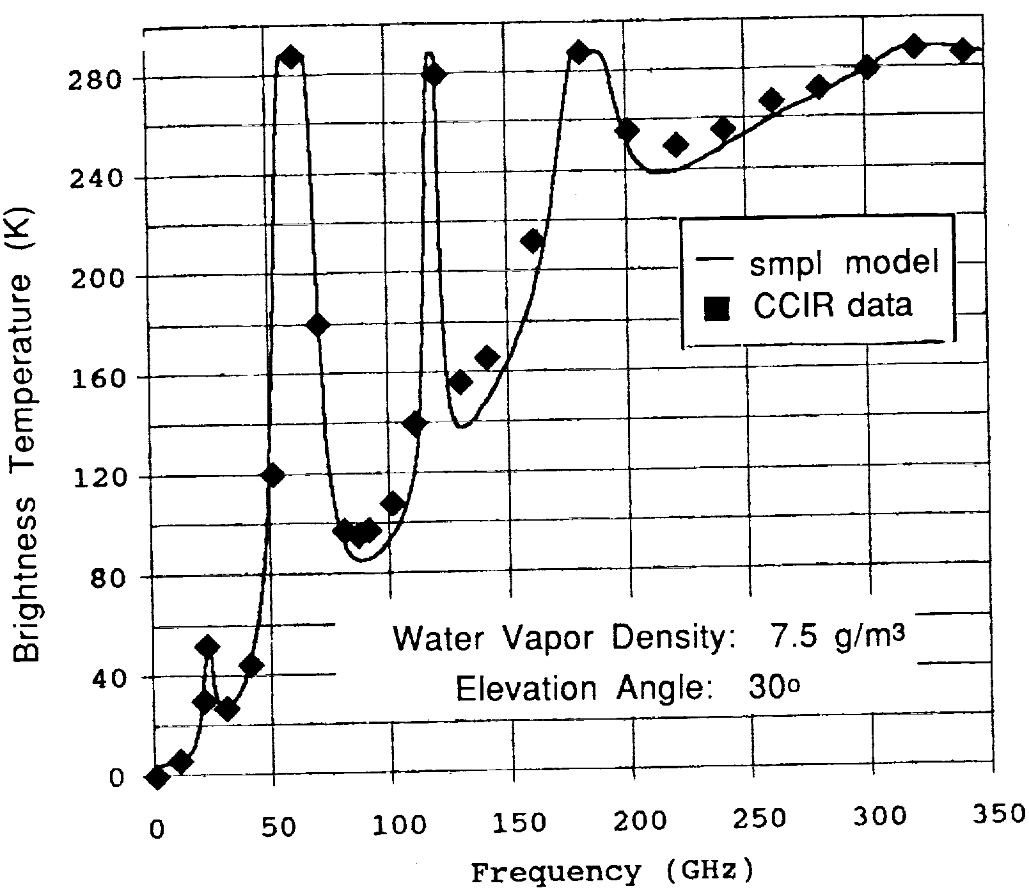

Figure 8 Brightness Temperature Comparison of the Simple Model and the CCIR Radiative Transfer Model

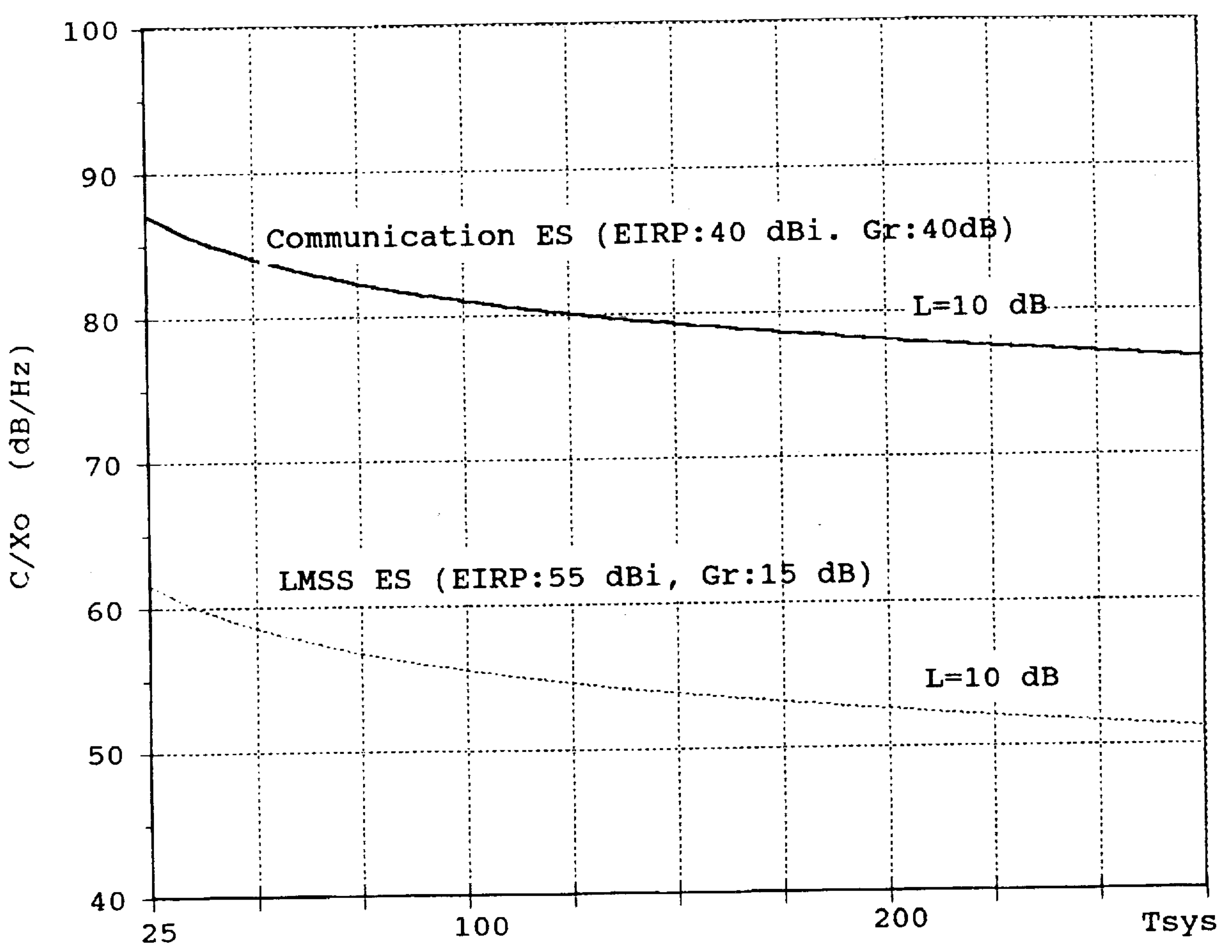

Figure 9 Two Examples of C/Xo as Received at Earth Stations
(—1.6 GHz, ... 30 GHz)

C-3

The program takes about 2-5 minutes to run for each application, depending on the parameters given. The program can be totally customized or manually controlled. In the former case, the program can open, run, and close automatically; the only thing needed to do is to input your options and answer questions asked.

References:

[1] CCIR [1990] Recommendations and Reports of the 1990 Plenary Assembly, Dusseldorf (taken from pink documents), Reports 563, 564, 719, 720, 721.

[2] Smith, E.K. [1982] "Centimeter and Millimeter Wave Attenuation and Brightness Temperature due to Atmospheric Oxygen and Water Vapor", Radio Science, vol.17, No.6, pp 1455-1464.

[3] Waters, J.W. [1976] "Absorption and Emission by Atmospheric Gases", in Methods of Experimental Physics, vol. 12B, edited by M.L. Meeks, Chapter 2.3, Academic Press, N.Y.

[4] Moupfouma F. [1985] "Model of Rainfall Rate Distribution for Radio System Design", IEE Proceedings, Vol.132, Pt. H, No 1.

[5] Moupfouma F. [1987] "More about Rainfall Rates and Their Prediction for Radio System Engineering", IEE Proceedings, Vol.134, Pt. H, No 6.

Software for Propagation
by W. Vogel, U. of Texas, Austin

1. Choice of Hardware and Software Platform
2. Selection of Problems To Be Coded
3. Coding & Solicitation of Contributions
4. Testing & Documentation
5. Dissemination to Users
6. Technical Support
7. Revisions/Expansion

1. <u>Hardware and Software Platform</u>

- IBM/PC + Macintosh
- Spreadsheet: 1-2-3, EXCEL, QUATTRO...
- Math: MATHCAD
- Special Purpose: EE-PAC
- Language: Quick, FORTRAN
- Survey Users
- User Modifiable

2. Problem Selection

- CCIR Greenbook
- NASA Handbook
- Books: P+B, Ippolito...
- Models
- Orbits
- Footprints
- Propagation Database
- Call for Contributions

3. Coding & Solicitation of Contributions Standards

4. Testing & Documentation

Operation, Logical Errors, ß-Testing

Easy To Use, Built-In Help, Example

User Knowledgeable

5. Dissemination

To Anybody

Mail, BBS

6. Technical Support

   BBS, FAX

7. Revisions/Expansion

   Useful Lifetime...

   Enhance Functionality

   Include New Developments

   Advisory Panel