PROPAGATION HANDBOOK, FREQUENCIES ABOVE 10 GHz

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Abstract-- The National Aeronautics and Space Administration (NASA) has been involved for nearly a decade in the development and updating of propagation handbooks to document the results of NASA Propagation Program efforts and other related measurements, studies and programs involving earth-space propagation. This paper describes the progress and accomplishments in the development of the Fourth Edition of the NASA Propagation Effects Handbook for Satellite Systems Design, for frequencies from 10 to 100 GHz, NASA Reference Publication 1082(04), dated May 1988, prepared by Westinghouse Electric Corporation for the Jet Propulsion Laboratory, JPL (Ippolito, 1988).

1. Introduction

The NASA Propagation Effects Handbook for Satellite Systems Design was first published in March 1980, and the document has been updated several times. The NASA handbook was conceived as an evolving document and has continually strived to provide relevant information for both the propagation specialist and the satellite systems designer/planner.

The first edition, published as a contractor report (ORI Inc., Technical Report 1905, March 1980), was updated the following year by ORI and published as NASA Reference Publication 1082 (Ippolito, Kaul, and Wallace, 1981). Two years later, the Third Edition was developed for NASA Headquarters by ORI and published as NASA Reference Publication 1082(03), (Ippolito, Kaul and Wallace, 1983). All of the above documents focused on propagation impairments on earth-space links operating in the 10 to 100 GHz frequency bands. A companion handbook, Propagation Effects on Satellite Systems at Frequencies Below 10 GHz (Flock, 1983) was also developed for the lower frequency bands. A Second Edition of that handbook has been published recently (Flock, 1987).

Several hundred copies of the Propagation Handbooks have been distributed by NASA Headquarters, and they have been referenced extensively in numerous government and civil projects. Comments back to the authors indicate that the earlier editions of the Handbook have served as a useful resource to the system designer and planner in the evaluation of propagation impairments on satellite links operating in the frequency bands above 10 GHz.

In the five years since the Third Edition was published, there have been many new developments in the analysis and evaluation of propagation effects on space communications, as well as continuing growth of developmental and operational systems in the K_u, K_a, and EHF frequency bands, for civil, government and international applications. The objective of the development of the Fourth Edition was to document these new developments and incorporate the new technology areas into the Handbook to keep the document up to date and relevant in the rapidly expanding area of communications above 10 GHz.

2. Development of the Fourth Edition

Updating of the Handbook was initiated in January 1988 by a compilation of new reference material and discussions with several of the major propagation experimenters and space communications organizations. Updated reference lists and descriptions of recent work were received from several organizations, including VPI &SU, the U. of Texas, and COMSAT. Their cooperation and help in the development of the Fourth Edition is greatly appreciated.

Since a camera ready copy or an electronic copy of the Third Edition was not available, the first step in the development of the new edition was accomplished by optically scanning clean copies of the earlier edition, utilizing a Kurzweil 4000 optical character reader. An electronic copy of the document was then generated using the Xerox Star 8010 System. This allowed for easier editing as the document revisions were developed.

Major revisions were generated in all seven chapters, with over one hundred and twenty pages of new text and figures produced, in addition to re-writes and text revisions.

The final draft copy of the Fourth Edition was

submitted to JPL on April 29, 1988. Completion of the camera ready copy, originally planned for June 1988, has been deferred pending completion of the draft review by JPL reviewers.

3. Major Revisions and Additions

The handbook is arranged in two parts to facilitate efficient reference and application of the information. Chapters II through V comprise the descriptive part, which describes the propagation effects, prediction models, and available experimental data bases. Chapters VI and VII make up the system design portion of the handbook. In Chapter VI design techniques and prediction methods available for evaluating propagation effects on Earth-space communications systems are presented. Chapter VII addresses the system design process and how the effects of propagation on system design and performance should be considered. Chapter VII also covers several mitigation techniques, such as site diversity and adaptive foward error correction (FEC), useful for overcoming adverse propagation impairments. Figure 1 presents a summary of the major contents of each chapter of the Fourth Edition of the handbook.

Major revisions and additions to Chapters I through VI of the Fourth Edition include:

- updated versions of CCIR prediction models for gaseous attenuation, rain attenuation statistics, and depolarization (CCIR, 1986),
- addition of a new fog attenuation prediction procedure (Altshuler, 1984),
- replacement of the VPI&SU Piecewise Uniform Rain Rate Model with the Simple Attenuation Model (SAM), (Stutzman and Yon, 1986),
- new information on fade duration statistics, low elevation angle effects, and ice depolarization,
- new data measurements and propagation statistics for rain rate, rain attenuation, fade statistics, and rain/ice depolarization, and
- updating of the reference lists through early 1988.

Chapter VII contains extensive new material on new applications, including SS/TDMA, on-board processing satellites, and VSAT systems. Descriptive material on several representative advance satellite systems have been added, including: ACTS, INTELSAT VI, FLTSATCOM, DSCS III, OLYMPUS, ITALSAT, and ATDRSS. New information on rain fade mitigation techniques has been added, including orbit diversity, power control, and adaptive FEC.

Extensive sample calculations and examples are included throughout the handbook to highlight key analysis and prediction procedures. Table 1 summarizes the propagation calculation examples provided in Chapter VI, and Table 2 lists the example system analysis procedures provided in Chapter VII.

Figures 2 through 9 present examples of some of the new material included in the handbook.

4. Summary

The final draft of the Fourth Edition of NASA's Propagation Effects Handbook for Satellite Systems Design, 10 to 100 GHz, has been completed and is now under final review by JPL. This paper has reviewed the development process for the new edition and presented a summary of the major additions and revisions included in the handbook.

Copies of the Fourth Edition will be available through NASA Headquarters, Communications and Information Processing Division, Washington, D.C., at the completion of the review and reproduction process, currently anticipated for the fall of 1988.

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Stutzman, W.L., and K.M. Yon, (1986), "A Simple Rain Attenuation Model for Earth-space Radio Links Operating at 10-35 GHz," Radio Science, Vol. 21, No. 1, pp. 65-72.

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Model	Inputs	Outputs	Comments
Rice-Homberg	Climate or Site-Specific Mean Annual Rainfall plus Ratio of Thunderstorm-to-Total Rain.	Cumulative Time Distribution of Rainfall.	Two Rain Modes Considered: Thunderstorm & Uniform Rains. Probability of Rain Rate Exceedance for Either or Both Modes is Available.
Dutton-Dougherty	Same as Rice-Homberg and Link Parameters (e.g., Frequency, Elevation Angle)	Rain or Gaseous Attenuation Associated with a Given Exceedance Time Percentage.	Utilizes Modified Rice-Holmberg Rain Model. Provides Confidence Limits, Given Two Additional Rain Rate Distributions.
Global	Location and Link Parameters.	Rain Attenuation Associated with a Given Exceedance Time Percentage.	All Rain Attenuation Parameter Values are Selfcontained. Globally Applicable.
Two-Component	Same as Global	Exceedance Time Percentage Associated with a Given Rain Attenuation.	Same Rain Model (& Comments) as for Global Model. Two Rain Modes Considered: Convective Cell and Debris Rains.
CCIR	Same as Global.	Rain Attenuation Associated with a Given Exceedance Time Percentage.	All Rain Attenuation Parameter Values are Selfcontained. Globally Applicable.
Lin	Five Minute Rain Rate and Link Parameters.	Attenuation Associated with a Given Rain Rate.	Simple Extension of Terrestrial Path Rain Attenuation Model.
Simple Attenuation (SAM)	Rain Statistics and Link Parameters.	Attenuation Associated with a Given Rain Rate.	Assumes Exponential Shapted Rain Profile.

Figure 2 Summary of Rain and Rain Attenuation Prediction Models described in Chapter III

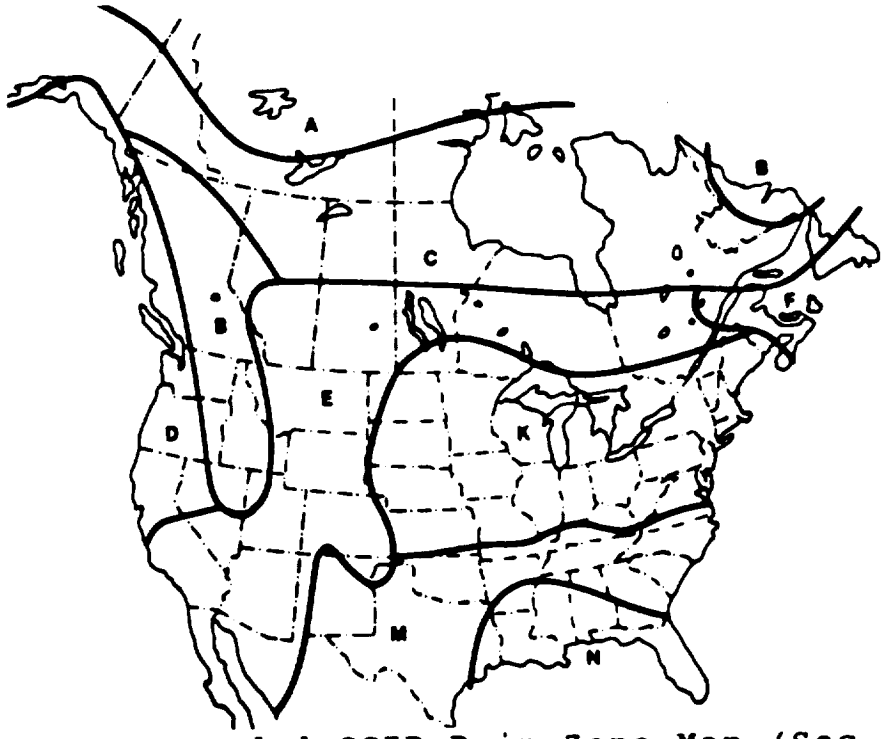


Figure 3 Expanded CCIR Rain Zone Map (Sec. 3.6)

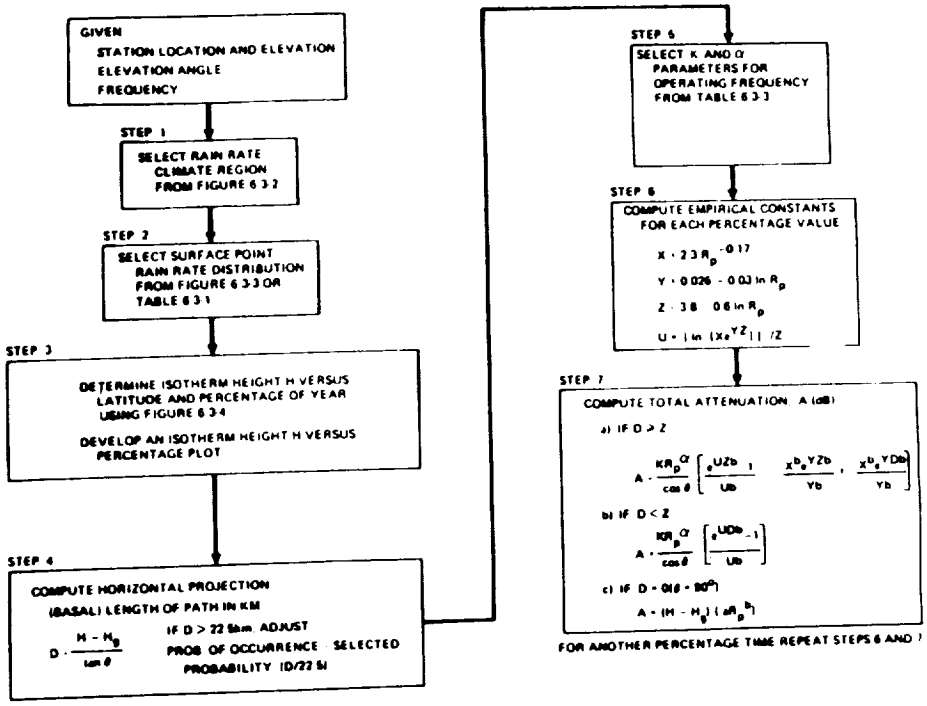
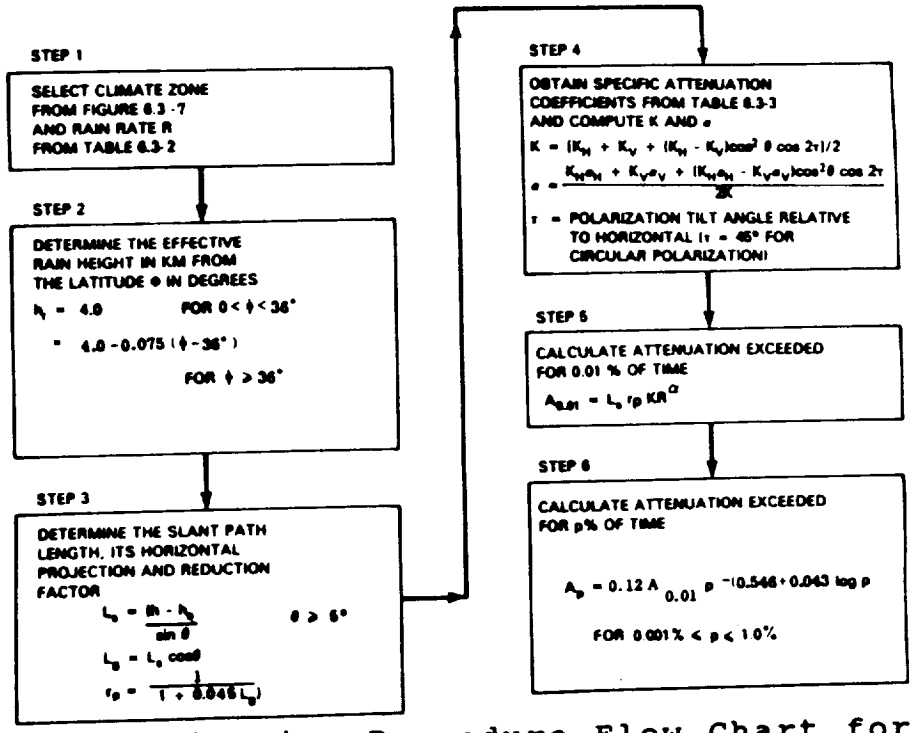


Figure 4 Estimation Procedure Flow Chart for Global Model (Sec. 6.3)



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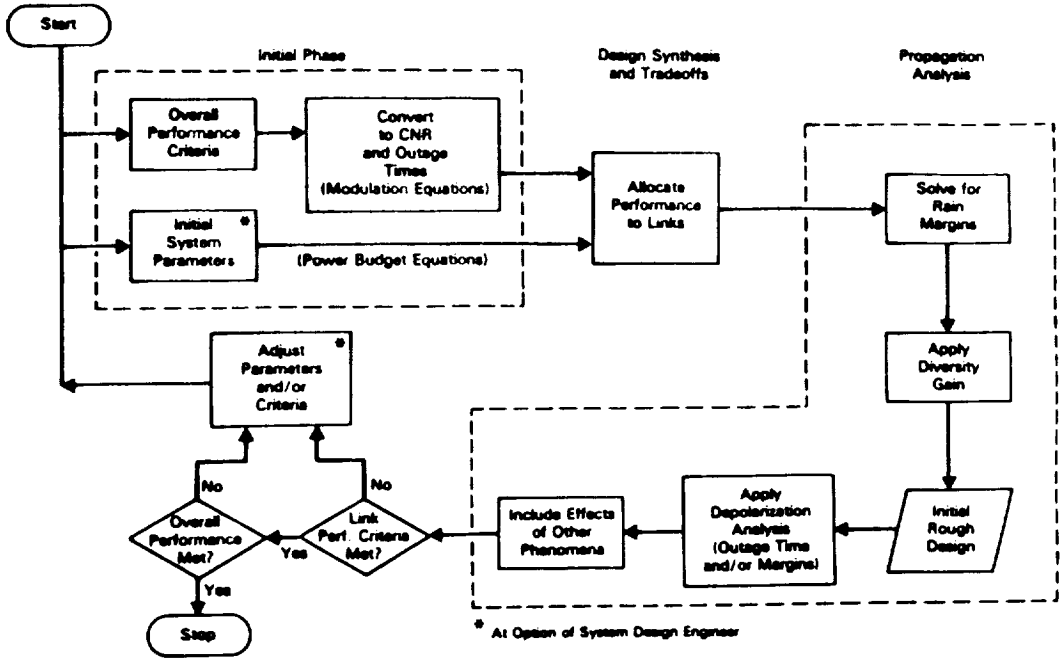

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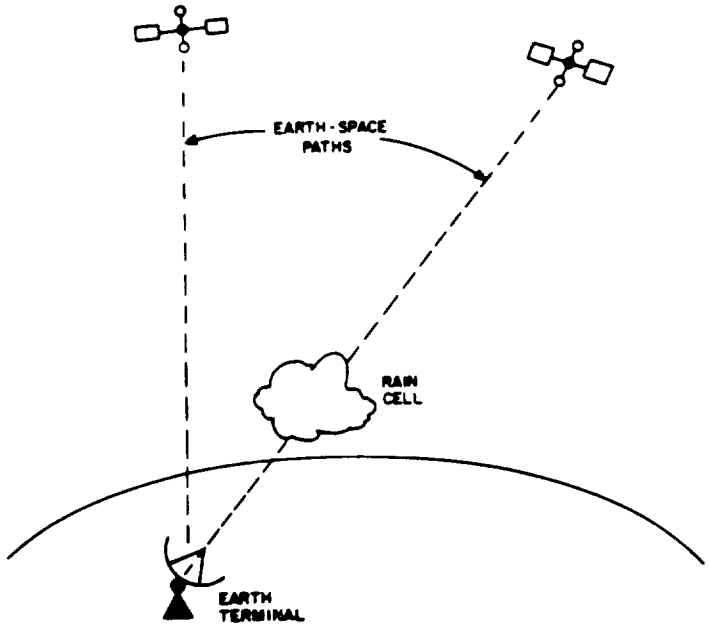

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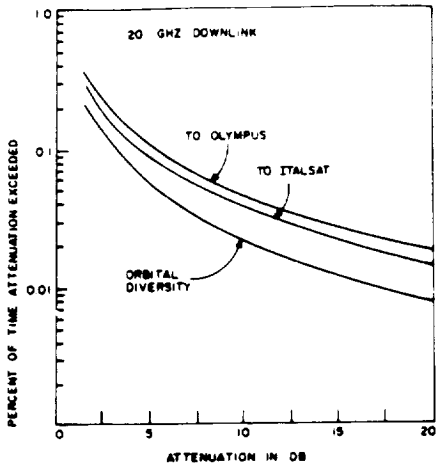

Figure 7.4-13.

Predicted Orbit Diversity Performance at Spino d'Adda, Italy

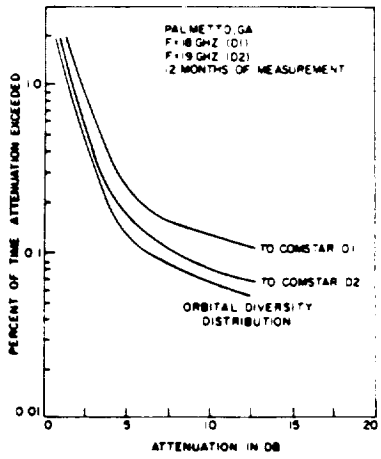

Figure 7.4-14.

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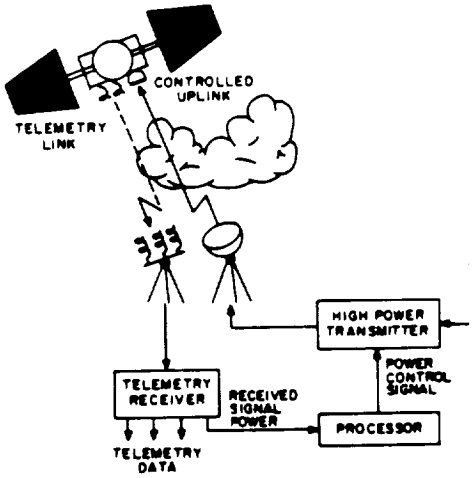

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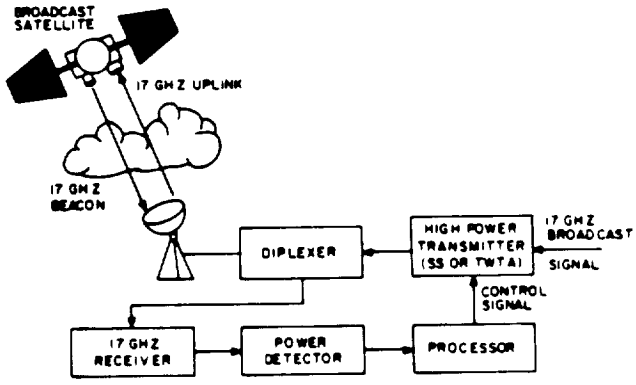

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