The Need for More Measurements in the ACTS Propagation Experiment

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The study of attenuation by rain at frequencies above 10 GHz started more than four decades ago. At first we collected data to size the problem. Then we expanded data acquisition to provide a sufficient data base to describe the problem statistically. The ITU-R (former CCIR) attenuation prediction model is a statistical summary of the data in the data banks. Recently we have tried to quantify the uncertainty that should be attributed to a prediction of the attenuation distribution for a specified path - the risk to be associated with an attenuation distribution prediction.

Attenuation by rain is a random process. The observed cumulative distribution of the time in a month or year an attenuation value is exceeded is a realization of the results of this random process. The distribution observed in one year may be a poor predictor of the distribution to be observed in the next year. We need to quantify the uncertainty to be associated with a prediction based on one or more years of observations. The Crane models for worst-month distribution prediction [Crane, 1996a] and for the risk to be associated with an annual distribution prediction [Crane, 1996b] are based on a simple empirical model for the expected year-to-year variation in an annual attenuation distribution and for the expected seasonal variations in monthly attenuation distributions. These models are based on the extremely limited set of attenuation data that is available from more than a few years of observation on single, fixed propagation paths. For annual variability y, the data were obtained from two 4- and S-year observation sets taken at two different frequencies on two different paths in Italy. For monthly variability, the data were obtained from a single three-year experiment in coastal Virginia.

The goal for the NASA ACTS Propagation Experiment is to expand the data base on "which new attenuation prediction models can be developed or old models can be validated. Seven experiment sites were established, four in climate regions within North America which had not been previously studied, two in regions with insufficient statistical data and one in a region that had been well studied. Figure 1 shows the locations where earlier measurement programs had been conducted and the locations for the ACTS Propagation Experiment. It also indicates the amount of data that had been obtained and the amount of data to be distributed at this meeting. Although the amount of North American data available for application at Ka-band has already been doubled, insufficient data have been collected to provide observation of the annual attenuation distribution within an expected uncertainty of 30% in decibels or of the monthly distribution within an expected uncertainty of 70% in decibels. If the variability y values estimated from the simple model for risk are in error, the uncertainties could be higher.

The locations of the ACTS Propagation Experiment sites were chosen to explore climatological regions that had not been adequately investigated. Two rain-rate climate region maps have been published, one the Global climate zones by Crane [1996c] and the other by the ITU-R [CCIR 1992]. They produce widely varying rain-rate distribution estimates for two of the experiment sites. In addition, two experiment sites within the same climate zone (Global D2) have different seasonal variations in rain occurrence yielding different annual to worst-month distribution transformations and possibly different expected year-to-year variability estimates.

Oklahoma is one of the sites with large differences between the predictions of the two rain-zone climate models and with a seasonal variation different from the site used as the model for worst-month predictions. The differences between the model estimates and two years of measurement are shown in Figures 2 (compare with Global model predictions) and 3 (compare with ITU-R model predictions). From the two figures, it is evident that the ITU-R model produces large prediction errors and does not adequately represent the rain climate in central Oklahoma. The Global model gives a better prediction but still underestimates the attenuation for a given probability y. For attenuation values less than 15 dB, observations for one year are consistent with the model while observations for the second year are not. For the third year, Oklahoma is in the midst of a' major drought and the attenuation for a specified probability maybe significantly lower.

The two annual empirical distribution functions differ by about 50% at 0.1 % of a year, a result larger than expected on the basis of the variability model. At lower attenuation values corresponding to 1 % of a year, the two years of observations are consistent with each other at the level of uncertainty predicted by the variability model. The observations are also consistent with the predictions of the rain climate model if a 1.5 to 2 dB reduction in attenuation is made to compensate for water on the. antenna.

The worst-month attenuation distributions provide a better match to the Global model predictions as illustrated in Figure 4. These results are similar to those presented above with a large difference between the observations for the two years. In this case, both years of observation are within the bounds predicted to be exceeded once in 20 years on average. The data are contradictory with agreement between model and measurement for the worst-month distribution but disagreement for the annual distribution. More observations are needed to resolve this question.

The ACTS Propagation measurement period must be extended to provide observations at each site with small statistical uncertainty sufficient to determine the correct rain climate model and sufficient to establish the variability associated with monthly and annual distribution estimates. Based on the existing model for variability y, five years of observation should be sufficient.

References

CCIR [1992]: Radiometeorological Data, Rcpt 563, CCIR Study Group 5, International Telecommunications Union, Geneva.

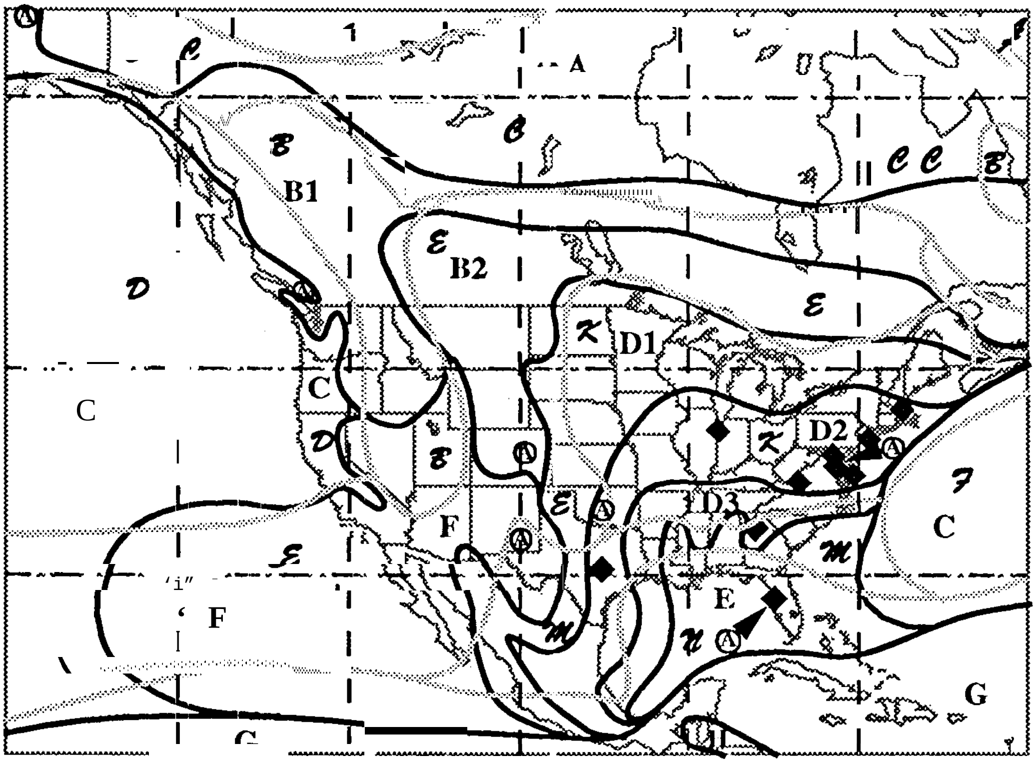
Crane, R. K. [1996a]: *Electromagnetic Wave Propagation Through Rain*, Wiley-Interscience, New York, NY, Chapt. 6.

Crane, R. K. [1996b]: *Electromagnetic Wave Propagation Through Rain*, Wiley-Interscience, New York, NY, Chapt. 7.

Crane, R. K. [1996c]: *Electromagnetic Wave Propagation Through Rain*, Wiley-Interscience, New York, NY, Sect. 3.3.

Crane Global Rain Climate Zones — A

ITU-R (CCIR) Rain Climate Zones



◆ Beacon Observation Sites

12 **GHz: 5** sites and 12 **site years**

19 GHz: 7 sites and 15 site years

29 GHz: 9 sites and 14 site years

Total of 10 sites

Ⓐ ACTS Propagation Experiment Sites

20 GHz: 7 sites and **14** site years

27 GHz: 7 sites and 14 site years

Figure 1

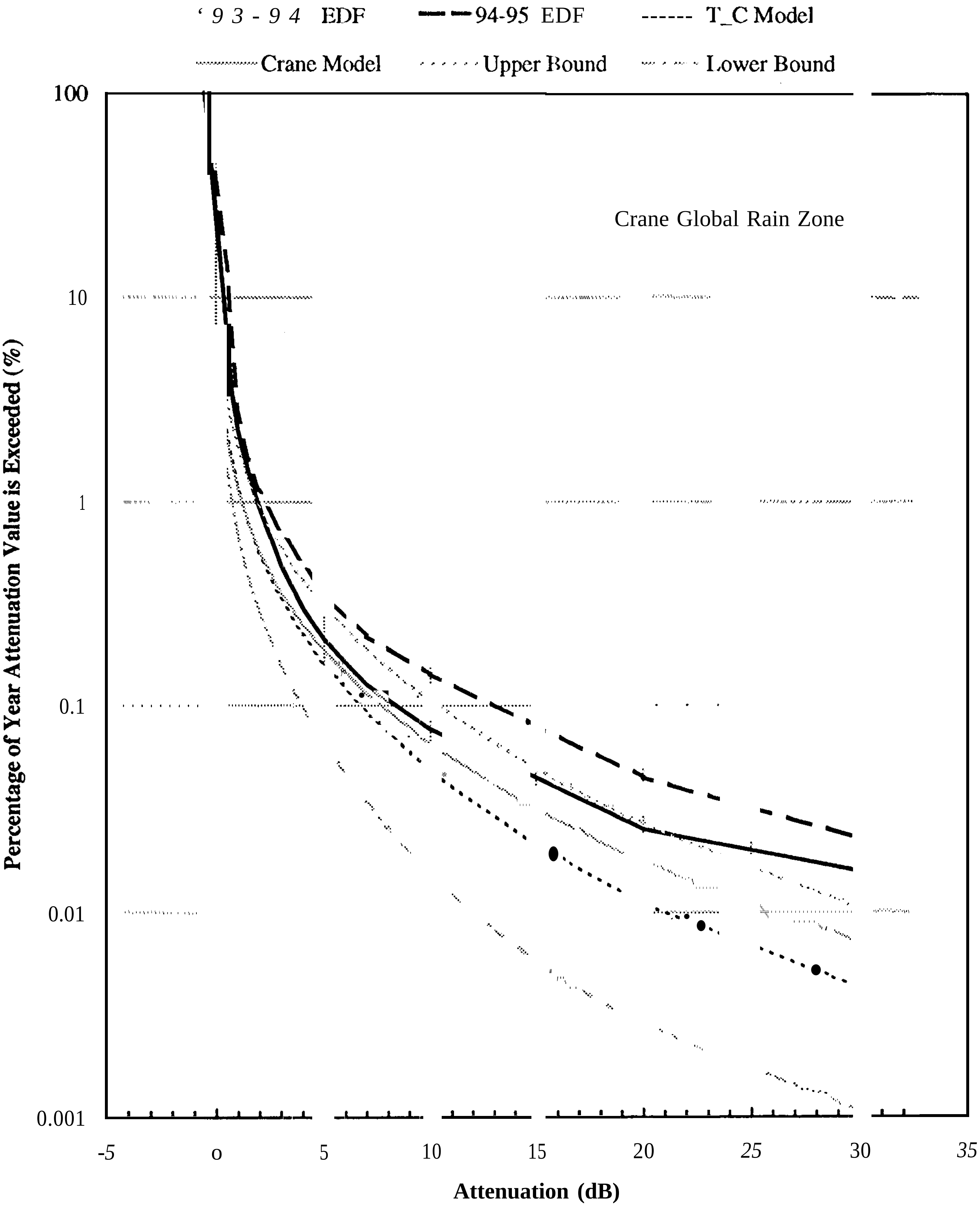
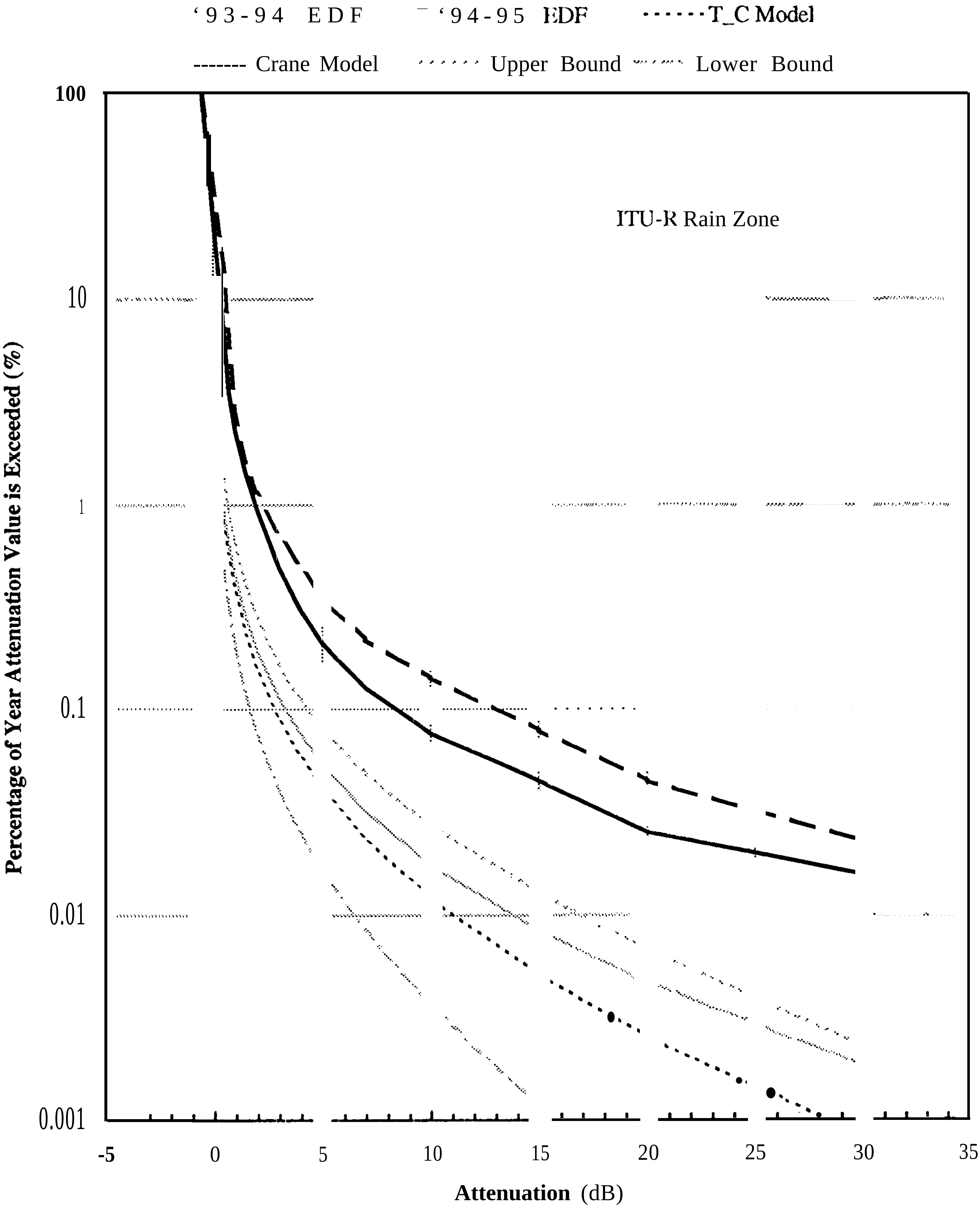

93-94 EDF
94-95 EDF
T_C Model
Crane Model
Upper Bound
Lower Bound
Crane Global Rain Zone
100
10
1
0.1
0.01
0.001
Percentage of Year Attenuation Value is Exceeded (%)
-5
o
5
10
15
20
25
30
35
Attenuation (dB)

Figure 2 95


'93-94 EDF
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T_C Model
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100
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0.1
0.01
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Percentage of Year Attenuation Value is Exceeded (%)
-5
0
5
10
15
20
25
30
35
Attenuation (dB)

Figure 3

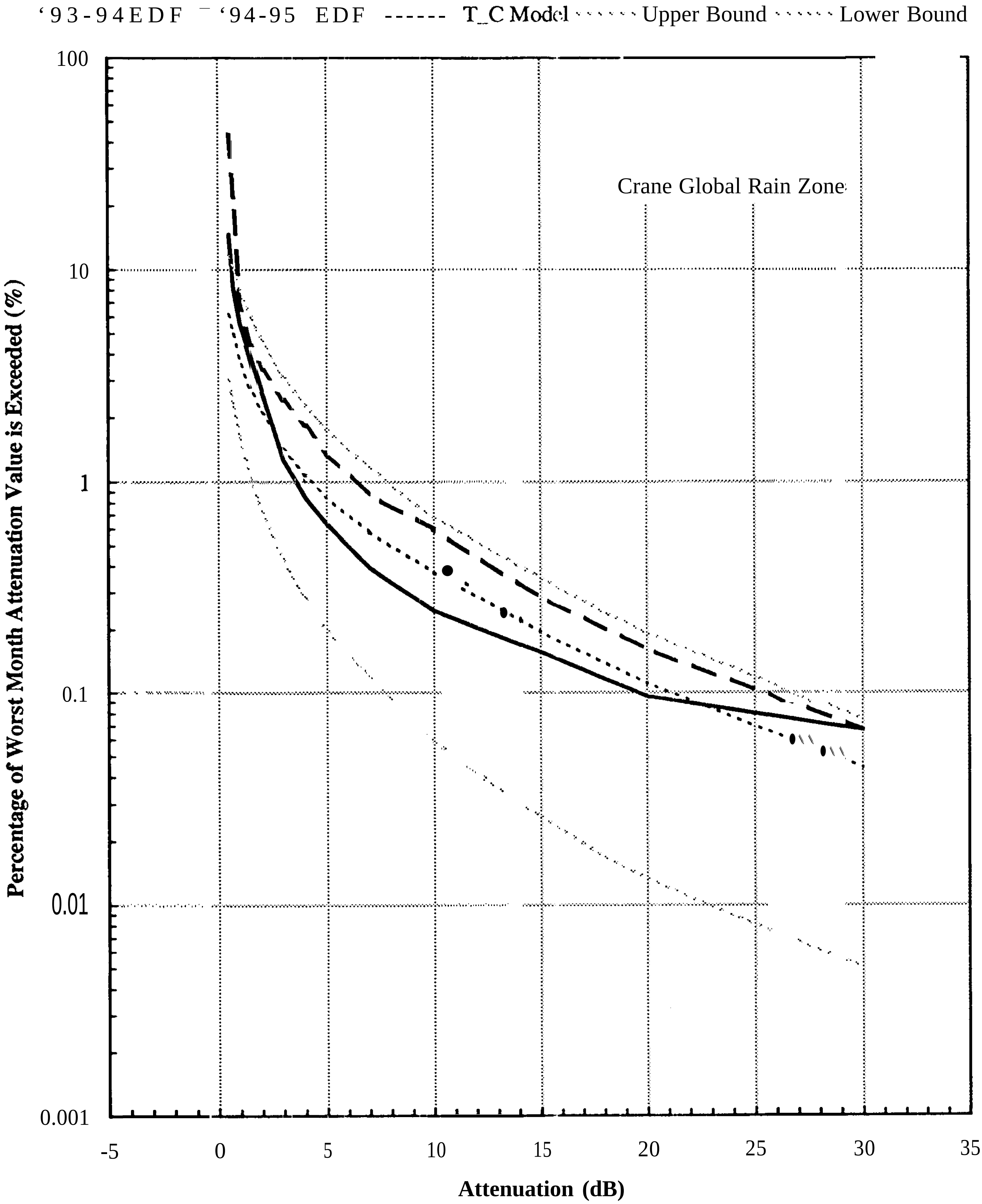
'93-94 EDF
'94-95 EDF
T_C Model
Upper Bound
Lower Bound
Crane Global Rain Zone
Percentage of Worst Month Attenuation Value is Exceeded (%)
100
10
1
0.1
0.01
0.001
-5
0
5
10
15
20
25
30
35
Attenuation (dB)

Figure 4 197