Rain Attenuation Modeling

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Background

* Rain attenuation is a key limiting factor in the introduction of higher frequency bands into satellite and terrestrial microwave systems.

* Limited knowledge of the rain process makes it difficult to come up with accurate predictions of rain attenuation .

* An average prediction accuracy better than 2570 appears difficult to achieve; higher accuracies are desirable for communication system design purposes.

DAH Model

* A need for an improved propagation model was identified to facilitate:
  - introduction of higher frequency services into tropical areas
  - reliable attenuation prediction for low elevation angle links
  - design of low availability services.

* This resulted in the development of the DAH model.

DAH Model

* DAH model contains methodologies to predict
  - rain attenuation,
  - cloud attenuation,
  - melting layer attenuation, and
  - low angle fading.

* These are combined with the ITU prediction methods for
  - gaseous absorption and
  - tropospheric scintillations

to predict combined attenuation along satellite paths.

Model Components

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* Rain attenuation: empirical approach based on statistical models and available measured path attenuation data.

* Cloud attenuation: makes use of long term observations of cloud cover data with average cloud properties

* Low angle fading: extension to the ITU tropospheric scintillation model based on low-elevation angle measurements on satellite links.

Rain Attenuation Prediction

* Input parameters:
  System related - frequency, polarization, elevation angle
  Rain related - rain rate distribution or rain rate at
  a given probability, rain height,
  drop size distribution, temperature,
  spatial correlation of rain intensity,
  year to year variability of rainfall.
* Output: attenuation exceeded for a given
  percentage of time
* Requirements: easy access of input parameters,
  applicability across a wide range of
  inputs

Log-normal Model

* Both rain rate and path attenuation can be adequately described in terms of log-normal statistics (three parameter distribution)

$$P\,(r > R) = PO\,/2\ \mathrm{erfc}[(\ln r - \ln \mu_R)/(\sqrt{2}\,\sigma_R\,)1$$
$$P\,(a > A) = P_L\,/2\ \mathrm{erfc}[(\ln a - \ln \mu_A\,)/\sqrt{2}\,\sigma_A\,)]$$

PO - probability of rain falling at a point;
P_L - probability of rain falling on the path

* P_L is a function of Po . path length, and rain climate

$$P_L\ = f(P_o\,, L, R\,)$$

Path Averaged Rain Rate

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* Path averaged rain rate is a useful concept in developing rain attenuation prediction methods.

* Conversion of point rain rate statistics to path averaged statistics through spatial correlation function: p(L).

* p(L) can be established using radar or rain gauge network data

* Spatial correlation modeled as a function of distance and rain climate using:

$$\rho(L) = \exp(-\alpha\sqrt{L})$$

$$\alpha = 0.007\ R_{0.01}$$

Simplified Prediction Model

* Log-normal model requires full rain rate distribution including the probability of rain falling at a point.
* To simplify the attenuation prediction, a model centered around the 0.0170 rain rate (similar to the ITU model) was devised by introducing:
  - a horizontal path adjustment factor to account for horizontal inhomogeneity of rain and
  - a vertical adjustment factor to account for vertical inhomogeneity
* Both factors applicable at the probability level of 0.01%.
* Attenuation distribution approximated by a power-law model.

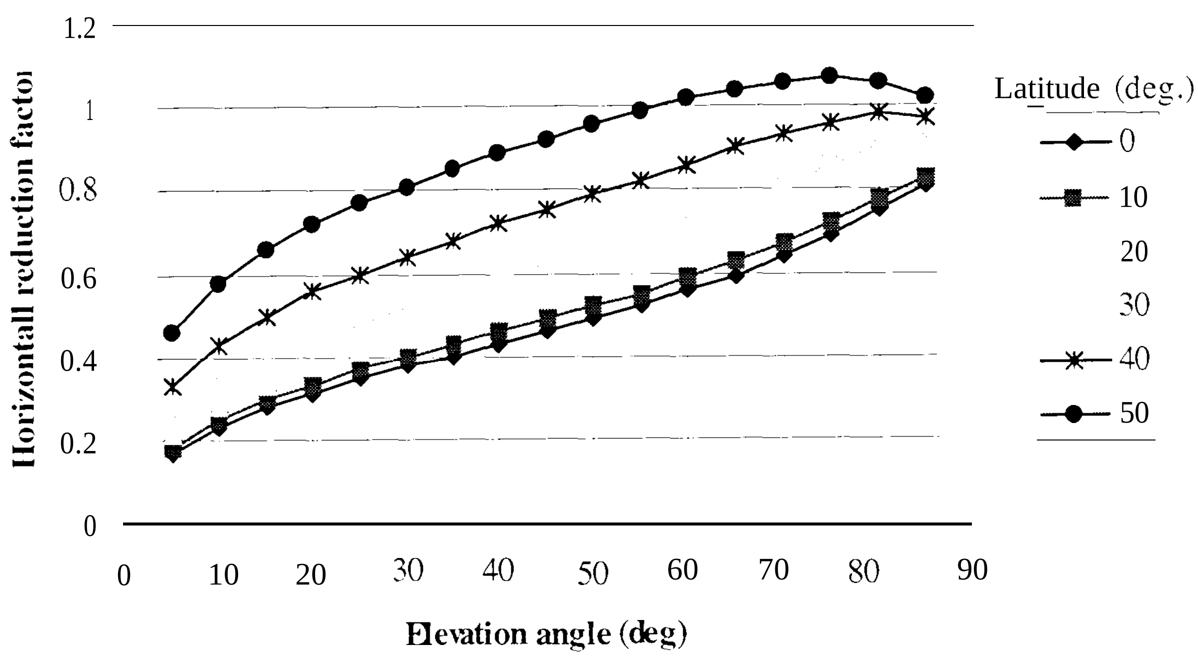
Horizontal Path Adjustment Factor

* Horizontal path adjustment factor best described as a function of specific attenuation, frequency, and the horizontal projection of the rainy path length.

* Shape of the path adjustment factor derived using the statistical model and the parameters describing the shape derived from the terrestrial attenuation database.

* Horizontal projection of the path is multiplied by the adjustment factor to obtain the effective horizontal path length.

Horizontal path adjustment factor at 20 GHz



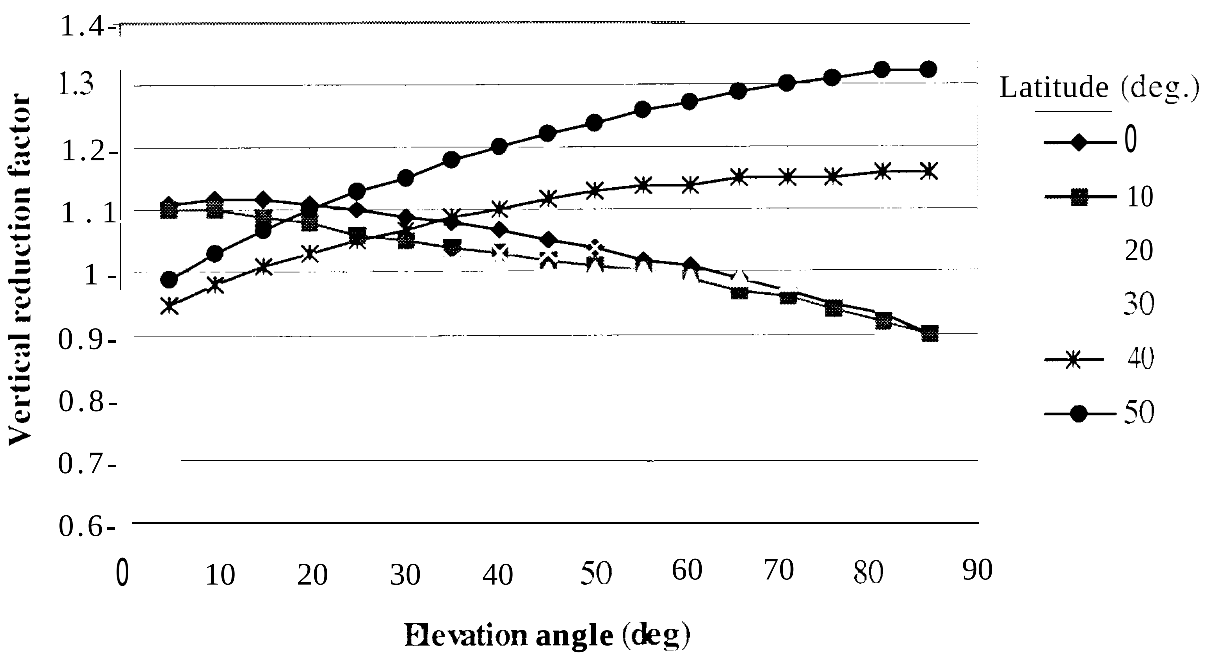
Vertical Path Adjustment Factor

* Vertical adjustment factor applied to 0° C isotherm height: based on measured slant path attenuation data.

* Vertical adjustment factor is a function of frequency, specific attenuation, elevation angle, latitude, and the horizontally adjusted path length.

* After applying the two adjustment factors, effective path length is the distance across the box defined by the adjusted horizontal and vertical path lengths.
A constant specific attenuation along the effective path length assumed.

Vertical path adjustment factor



Rain Model

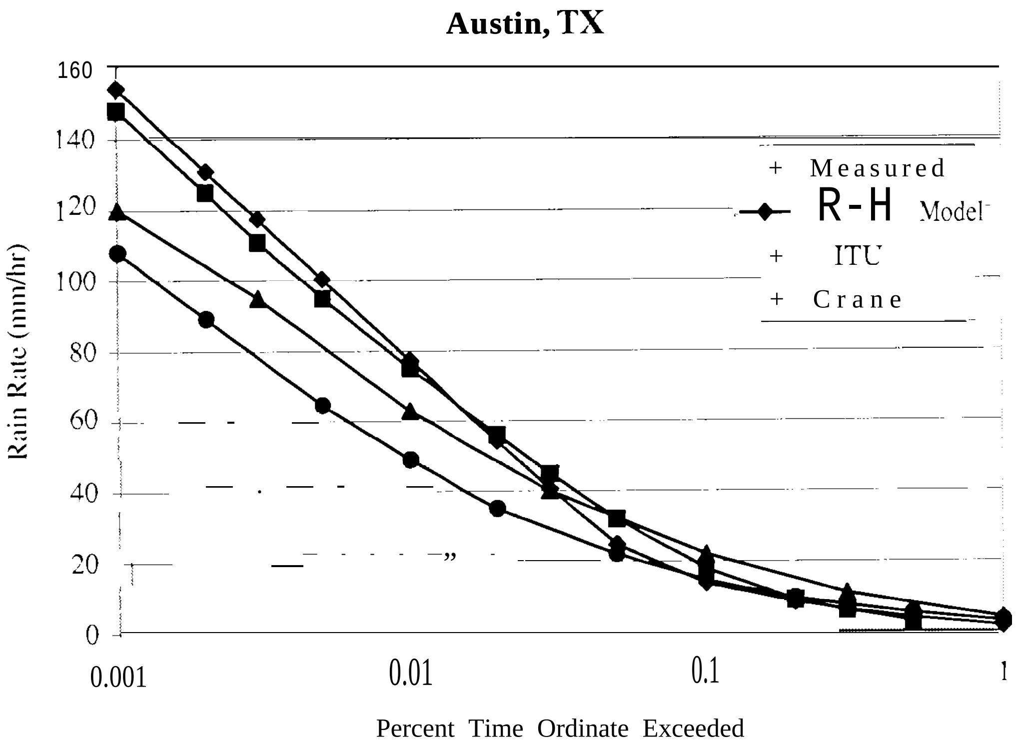
* For satellite link design a rain model based on local rain data is preferred.

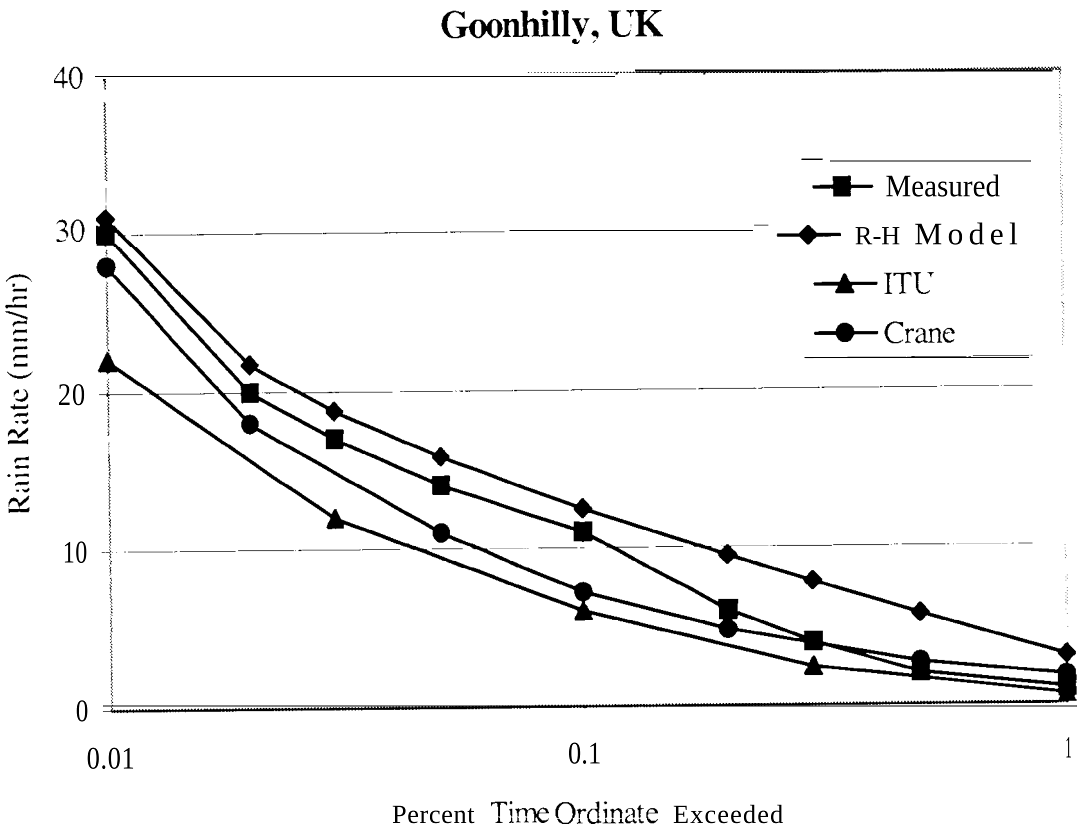
* Zonal descriptions are appropriate for planing and coordination purposes.

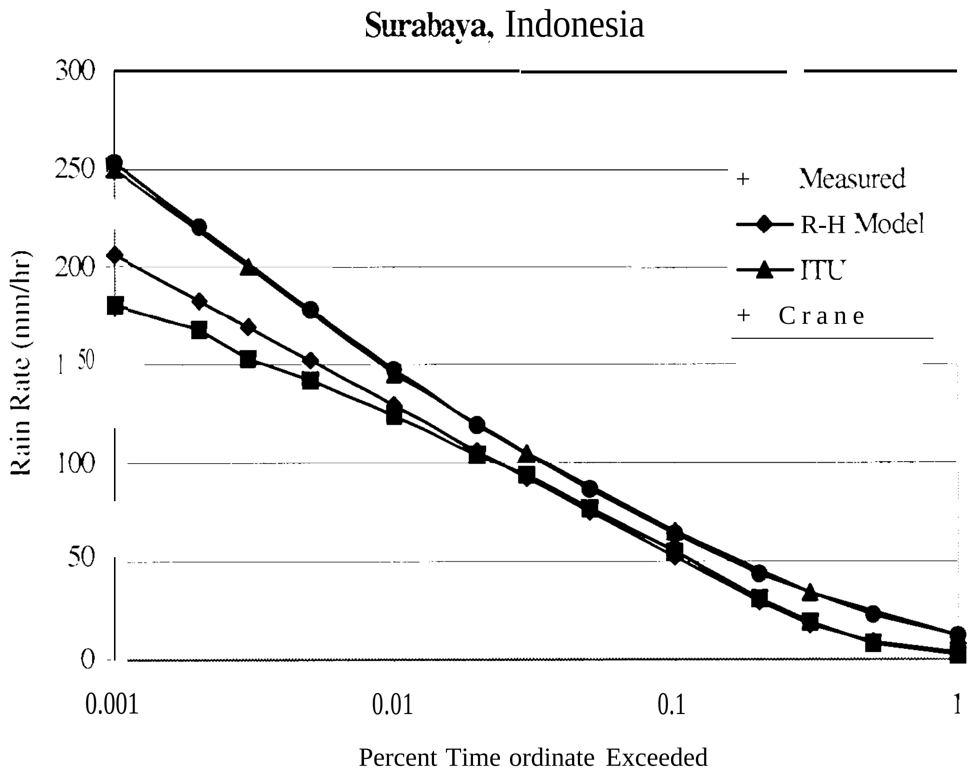
* DAH model appears to provide reasonable predictions when used with the Rice-Holmberg rain model.

* Parameters for the Rice-Holmberg model (annual rain accumulation and thunderstorm factor) can be easily obtained from climatological data archives.

Rain Model Comparisons




Goonhilly, UK
40
30
20
10
0
Rain Rate (mm/hr)
Measured
R-H Model
ITU
Crane
0.01
0.1
1
Percent Time Ordinate Exceeded



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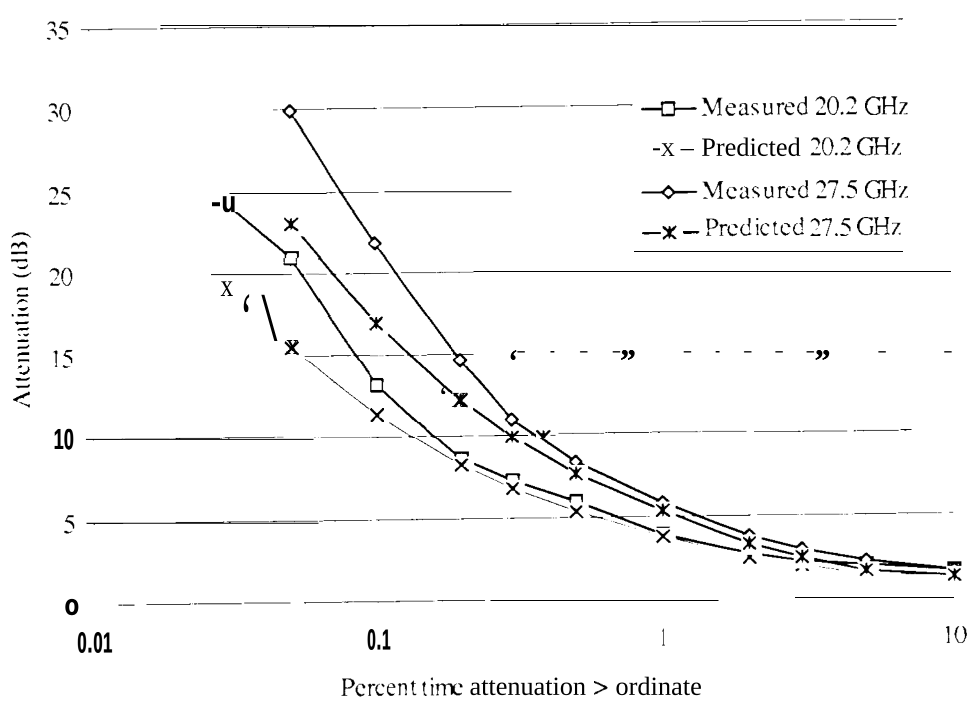
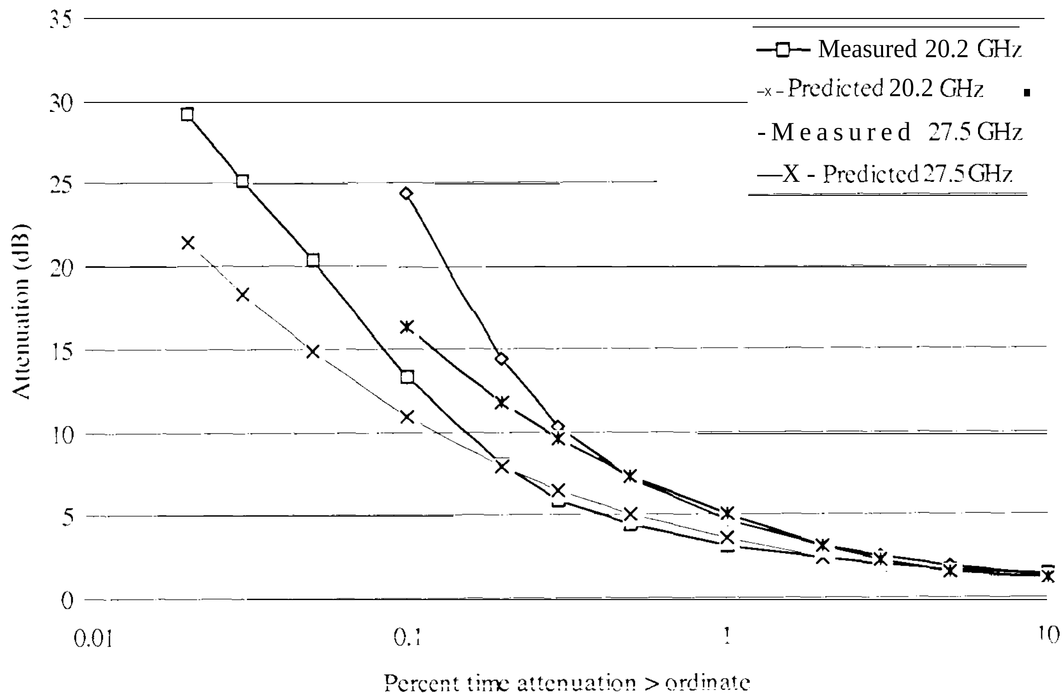
Attenuation Model Comparisons

- Combined attenuation for Clarksburg, MD



- Combined attenuation for Reston, VA



Conclusions

* A simple rain attenuation prediction model based on the log-normal hypothesis developed.

* Slant-path case is treated as an extension to the terrestrial path prediction.

* Prediction accuracy depends on the availability of representative rain intensity data.

* DAH model provides a method of combining different propagation impairments.