# RAIN ATTENUATION IN TERRESTRIAL PATHS

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## 1. INTRODUCTION

In the last years the use of short terrestrial links in urban areas is increasing fastly. As most of these links operate at frequencies above 10 GHz, an important issue for system planning refers to the effect of rain attenuation in radio path availability. To solve this problem it is fundamental to have in hands an accurate mathematical model for evaluating rain attenuation. The model currently adopted by CCIR, in spite of its simplicity, seems to be inadequate for low latitude regions. A roll-over phenomenon is observed when the precipitation rate is higher than about 100 mm/h. The rain attenuation model proposed in this paper is capable to overcome this unlike behaviour. On the other hand, this model presents a good performance independent of the rain climate area where the radio path is located.

## 2. CCIR MODEL BEHAVIOUR AT HIGH RAINFALL RATES

The CCIR model has as basic reference the precipitation rate exceeded for 0.01% of an average year ($R_{0.01}$). For a terrestrial path, the corresponding rain attenuation exceeded for the same percentage of time ($A_{0.01}$) is given by

$$A_{0.01}\ (\mathrm{dB}) = \gamma\, r d \tag{1}$$

where $\gamma = k\, R_{0.01}^{\alpha}$ is the specific attenuation in dB/km, k and $\alpha$ are primarily functions of frequency and polarization, d is the path length in km, and r the reduction factor defined by

$$r = \frac{1}{1 + d/d_o} \tag{2}$$

where $d_o = 35 \exp(-0.015\, R_{0.01})$.

For other percentages of time (p), rain attenuation ($A_p$) is given by

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

The reduction factor given by (2) collapses when the rainfall rate is higher than about 100 mm/h. This behaviour is due to the exponential variation of r that causes an unexpected decrease of attenuation for high precipitation rates. The result of this collapse is a roll-over in the curve attenuation vs. rainfall rate. As most of CCIR data arise from measurements carried out in temperate locations (low to moderate rainfall rates), only recently this improbable result was observed when applying the model to evaluate rain attenuation in tropical locations [1]. As a preliminary measure to avoid the roll-over phenomenon in regions where $R_{0.01} > 100$ mm/h, it was approved by the CCIR Study Group 5 that the parameter $d_o$ in (2) must be given by [2],

$$d_o = 35 \exp(-0.015\ R_{max}) \tag{3}$$

where $R_{max}$ = 100 mm/h.

## 3. PROPOSED MODEL

The mathematical representation of the path length reduction factor proposed by Assis [1] is given by,

$$r = \frac{1}{y}\,[1 - \exp(-y)] \tag{4}$$

or, in a series form,

$$r = \frac{1}{1 + \frac{y}{2} + \frac{y^2}{12} + \ldots} \tag{5}$$

where $y = \frac{\alpha d}{2\rho}$, being $\rho$ the distance at which the rain rate decays by a factor of 1/e in a exponential rain cell model.

The major difficulty in (4) and (5) is to relate the parameter $\rho$ with the precipitation rate. This problem is mainly due to the variability and inaccuracy of the experimental data. In order to select the most accurate data, the following procedure is recommended:

i) only measurements where concurrent rainfall rate and rain attenuation are available must be taken into account to fit (4) to the experimental data;

ii) to avoid the effect of more than one rain cell in this analysis, a maximum path length of about 20 km must be used;

iii) experimental measurements corresponding to a reduction factor equal to or greater than 1 must be neglected.

A power-law function is proposed to relate the rainfall rate to the parameter $\rho$, i.e.,

$$\rho = a\ R^{-b} \tag{6}$$

where, to avoid the roll-over phenomenon described in the previous section, particularly when $y \gg 1$, the constant b in (6) must satisfy the condition

$$b < \alpha$$

By using the CCIR data bank, a preliminary analysis has indicated

$$a = 65.4 \text{ and } b = 0.695$$

On the other hand, for $y < 1.5$, with a maximum error of about 10%, the series in (5) can be approximated by its first two terms. In this case it is easy to show that the CCIR model is a particular case of (4).

## 4. RAIN ATTENUATION PREDICTION

The reduction factor given by (4) was derived without reference to any particular value of percentage of time. Consequently, the rain attenuation at a given percentage of time ($A_p$) can be calculated by

$$A_p = k\ R_p^{\alpha}\ rd \qquad (7)$$

where $R_p$ is the precipitation rate exceeded at the same percentage p.

This procedure seems to be more appropriate than the one adopted in the CCIR model, at least for high rainfall rates. Figure 1 shows the rain attenuation distribution predicted by the above method together with experimental measurements carried out in a terrestrial link, 8.6 km long, operating at 11 GHz and located in Rio de Janeiro, Brazil (tropical climate). To the effect of comparison, the distribution corresponding to CCIR model is also included in this figure.

A good agreement is observed between the proposed prediction method and the experimental data. The CCIR model agrees also for percentages higher than 0.01% (although the rain attenuation is slightly higher than the corresponding to the proposed method). However, for percentages below 0.01% the attenuation differs considerably from the experimental measurements.

## 5. CONCLUDING REMARKS

The rain attenuation prediction method described in this document uses a path length reduction factor, which avoids the roll-over phenomenon observed in the CCIR model. On the other hand, this reduction factor permits to evaluate rain attenuation as a function of precipitation rate in a point-to-point basis. Preliminary results, including other terrestrial links not shown here, are promising enough. It remains, however, to investigate eventual limitations of this method, as well as, its performance against experimental data available in the CCIR data bank.

## 6. REFERENCES

1. ASSIS, M.S., "Path length reduction factor for tropical regions", URSI Commission F Open Symposium on Regional Factors in Predicting Radiowave Attenuation Due to Rain", Rio de Janeiro, Brazil, December 1990.

2. CCIR, Draft Revision of Recommendation 530-3, Doc. 5C/TEMP/15, Geneva, December 1991.

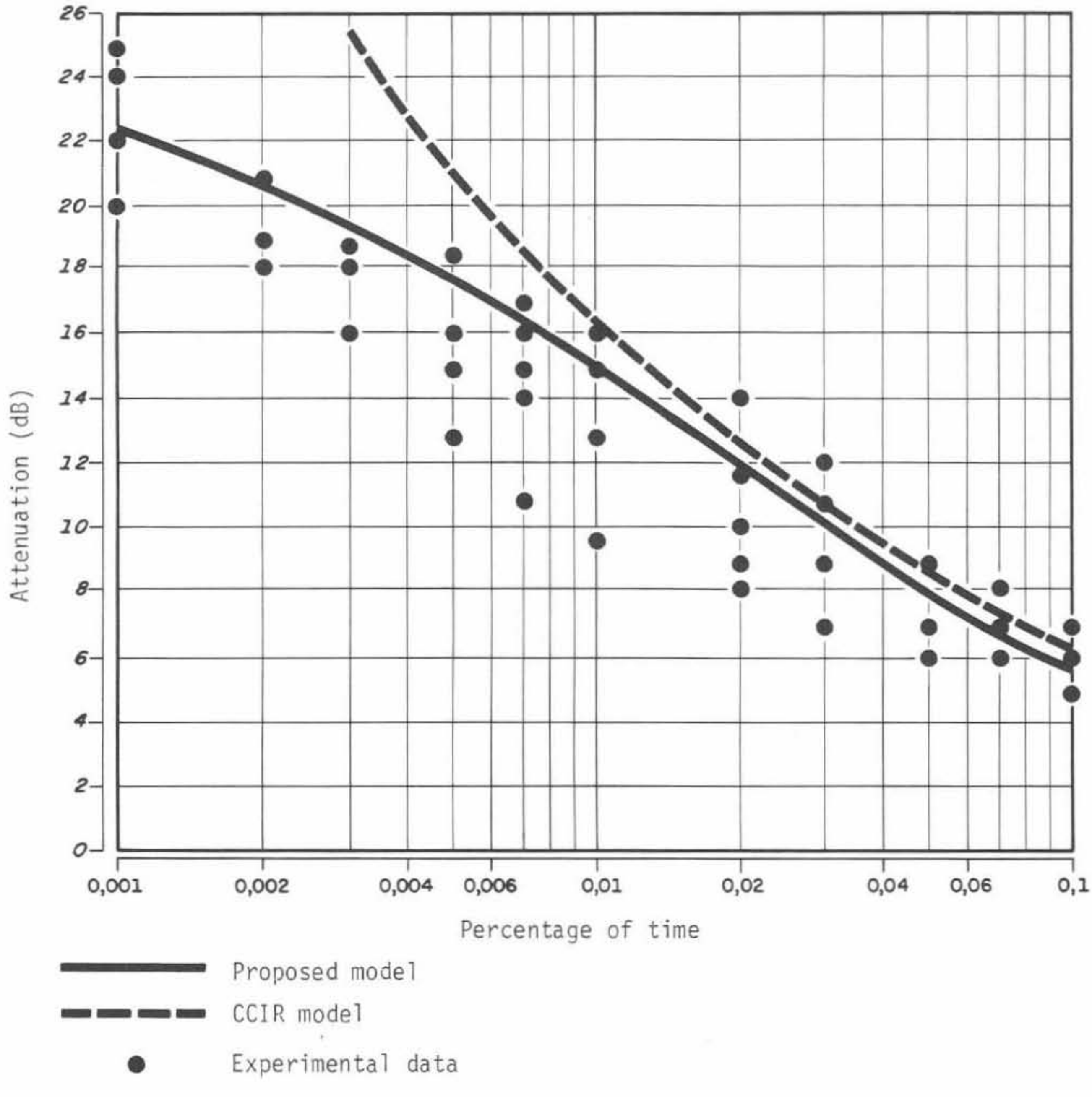


Fig. 1 - Rain attenuation in a terrestrial path - comparison between theoretical and experimental results.