Training Program : Point-to-Point Radio Link Design

Course : Rain Attenuation

COMPLEMENTS to Lesson 2 : Prediction Models

Crane Model

The Crane "Rain Attenuation Model" has been presented in different versions, to be applied both to terrestrial links and to earth-to-satellite links [1].

The last version is known as the "Global Model". Rain attenuation is computed according to different formulas, depending on hop length and rain rate. Let us define :

L = Hop length [km] R = Rain intensity [mm / h]

$Lo = 3.8 - 0.6 \cdot \ln(R)$ Intermediate distance [km]

k and α = as in ITU-R Rec. P.838 [2] (depending on frequency and polarization)

Then :

$$Atten = k \cdot R^{\alpha} \left(e^{y \cdot Lo} - 1 \right) / y \qquad \text{if } 0 < L < Lo$$

$$Atten = k \cdot R^{\alpha} \left\{ \left[\left(e^{y \cdot Lo} - 1 \right) / y \right] + \left[\left(e^{z \cdot L} - e^{z \cdot Lo} \right) \cdot e^{0.83 - 0.17 \cdot \ln(R)} \cdot (1/z) \right] \right. \qquad \text{if } Lo < L < 22.5 \text{ km}$$

where :

$$y = \alpha \cdot \{ [0.83 - 0.17 \ln(R)] \cdot (1 / Lo) + 0.26 - 0.03 \cdot \ln(R) \}$$

$$z = \alpha \cdot [0.026 - 0.03 \cdot \ln(R)]$$

It appears from the above equations that the Crane model is only validated for distances up to 22.5 km, while the ITU model is validated for links as long as 60km.

A useful comment on ITU and Crane models can be found in [3]. In summary, it is noted that "... the Crane models tend to produce higher attenuation than the ITU model. But the uncertainty of either of these models or alternatively the short-term expectation of fade is quite large". However, comparison is made with reference to a previous ITU model version, not to the last one.

Depolarization associated to Rain Attenuation

Signal depolarization caused by rain contributes to rain unavailability by reducing the discrimination to a cross-polar interfering signal. Typically, the problem arises in radio systems using a co-channel frequency plan (same radio channel used on both polarizations).

A step-by-step procedure is given by ITU-R Rec. P.530 [4]:

1) Computation of the "reference attenuation" A_P : $A_P = 10^{[U - (C/I)] / V}$

   where $U = 15 + 30 \cdot \mathrm{Log}_{10}(F)$

   $V = 12.8 \cdot F^{0.19}$ if $8 \leq F \leq 20$ GHz $V = 22.6$ if $20 < F \leq 35$ GHz

   C/I = threshold level of the Carrier-to-Interference ratio

2) Computation of parameter $m = \min \{ 23.26 \cdot \mathrm{Log}_{10} [(A_P / (0.12 \cdot A_{0.01})], 40 \}$

   where $A_{0.01}$ is the rain attenuation exceeded for 0.01% of the time.

3) Estimate of Outage Probability due to cross-polar interference : $P_{XPR} = 10^{n}$

$$n = -4.35 + \sqrt{(40.3 - m)}$$

Reliable P_{XPR} estimates are in the range 10^{-2} to 10^{-5}. The overall Outage due to rain can be estimated as the larger of P_{XPR} and Outage due to rain attenuation.

Useful References

[1] Seydol J.S., "Introduction to RF Propagation", Wiley, 2005

[2] ITU-R Rec. P.838-3, "Specific attenuation model for rain for use in prediction methods'", 2005

[3] Myers W., " Comparison of Propagation Models", IEEE P802.16 Broadband Wireless Access Working Group, 1999

[4] ITU-R Rec. P.530-18, "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems", 2021