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Comparison of Rain Prediction Models to be Used in the Equatorial Region

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ABSTRACT

Rain will cause serious attenuation on microwave signals transverse in the atmosphere. Rain attenuation strongly depends on rain attributes. This paper reports the comparison of three models of 1-min. rain rate cumulative distribution for estimating signal attenuation due to rain in the equatorial region. The models are Rice-Dutton (RHDD) model, Tattelman-Scharr (TS) model and Moupfouma model.

ABSTRAK

Hujan menyebabkan pelemahan tenaga isyarat gelombang yang merambat di ruang angkasa. Pelemahan ini ada hubungkaitnya dengan sifat-sifat hujan. Kertas ini melaporkan perbandingan tiga model ramalan taburan longgok kadar hujan 1-min. bagi ramalan di kawasan khatulistiwa. Ketiga-tiga model tersebut adalah model Rice-Dutton (RHDD), model Tattelman-Scharr (TS) dan model Moupfouma.

INTRODUCTION

Signal degradation due to rain, known as rain attenuation, for gigahertz frequencies propagation in the atmosphere, especially frequencies above 10 GHz, is not negligible. Rain attenuation strongly depends on rain attributes such as rain rate, drop size and other microstructures (CCIR Plenary 1990). The relationship between rain attenuation (A) and rain rate (r) can be expressed as an equiprobable equation as shown in equation 1 (Moupfouma 1987). According to this equation, the probability of A exceeding attenuation level A_p is equal to probability of r exceeding rain rate level R_p at same precentage of occurrence P.

$$P(A > A_p) = P(r > R_p). \tag{1}$$

This equation also implies that if we know the probability of rain rate then we can estimate the probability of rain attenuation. For that purpose, many researchers recommended their empirical models which hopefully can estimate the probability of rain at any location. This paper reports studies and comparison of three prediction models of 1-min. rain rate cumulative distribution to be used in the equatorial region. The models are RHDD model, TS model and Moupfouma model.

INTEGRATION TIME AND RAIN RATE

The term rain rate usually referred to in communication studies is different from the definition by meteorologist. Meteorologists define rain rate as amount of water collected over one hour interval. This definition omits the variation of rain intensities which may happen within one hour interval. In communication studies, however, instantaneous changes of rain rate at certain level will attenuate signal energy transmitted through the atmosphere. Therefore in communication studies, the term rain rate is always associated with integration time τ. For example, τ equals to 60, 10 or 1 minute (s) or even shorter. With this new definition, rain rate is defined as τ-min. rain rate with the unit in mm/h.

ONE-MIN. RAIN RATE CUMULATIVE DISTRIBUTION

We can produce any τ-min. rain rate if we have appropriate rain records. Then using this τ-min. rain rate we can plot the τ-min. rain rate cumulative distribution. However, according to several researchers and recommendations by CCIR (1990) and Watson et al. (1982), 1-min. rain rate cumulative distribution is the most important data and is directly applicable in rain rate attenuation calculation. Obviously, direct measurement is the best way to obtain 1-min. rain rate cumulative distribution. But to have good results we need at least 10 years continuous rain records. If such records, however, are not available then prediction models are required as an alternative method to obtain 1-min. rain rate cumulative distribution.

PREDICTION MODELS OF ONE-MIN. RAIN RATE CUMULATIVE DISTRIBUTION

Several researchers recommended a number of prediction models for 1-min. rain rate cumulative distribution. Most of these models are derived using rain data collected at a certain location over a certain period. Three prediction models were studied and compared to be used in the equatorial region.

Rice-Dutton (RHDD) model This model has two different equations. The first equation predicts the percentage of average year that τ-min. rain rate is expected to be exceeded for τ less than or equal to 60 minutes. The second equation is for τ greater than 60 minutes (Watson et al. 1982), (Rice et al. 1973). Inputs of this model are average annual rain (M) in millimeter, ratio of thunderstorm rain to total rain (β) and average annual number of day (D) for which precipitation is equal or greater than 0.25 mm. Most meteorological records or rain data achievers have records on parameters M and D, while parameter β is neither a climatic nor an atmospheric parameter. Nevertheless, Rice et al. (1973) provided a global β contour map. But the derivation of the map was not explained. Alternatively, Dutton et al. (1978) recommended a better empirical equation to determine the value of β. In addition to the meteorological data described above, RHDD model also requires another six regression coefficients which were provided in form of a table (Watson et al.

1982). The table was regressed using rain data collected in the temperate region but no table for the equatorial and tropical regions were presented.

Tattelman-Scharr (TS) model This model consists of six equations which estimate 1-min. rain rate cumulative distribution that are equal or exceed six percentage level (p) where p are 0.01, 0.05, 0.10, 0.50, 1.0 and 2.0 percent of time during a month (Tattelman et al. 1983). This model requires four climatological input and four regression coefficients. The four climatological inputs are mean monthly temperature (T) in ^{0}F, number of day with measurable precipitation, total monthly precipitation (mm) and latitude of location. The four regression coefficients are Ap, Bp, Cp and Dp (Tattelman et al. 1983). These regression coefficients are for three threshold amounts, 0.25 mm, 1.0 mm and 2.54 mm. It is should be noted that these coefficients are regressed using rain data collected in the tropical and extra-tropical regions. Two new terms are defined using the four climatological inputs. The first term is called precipitation index (I), defined as a ratio of total monthly precipitation to number of days with precipitation. The second term is a product of latitude (L) and monthly mean temperature. This product is an additional independent variable to establish transition from latitude region: $L \leq 23.5^{0}$, $23.5^{0} < L \leq 40^{0}$ and $L > 40^{0}$. The product has zero value for latitude below 23.5^{0}. Tattelman et al (1983) reported some shortcomings in this model. This model is invalid if any of the following conditions happen in a specific month: (a) monthly temperature less than 23^{0} (0^{0}C), (b) precipitation index less than 2 mm/day, and (c) number of rainy days less than 1 day.

Moupfouma model This model is a single empirical equation to predict one-min. rain rate cumulative distribution (Moupfouma 1989). It was derived using rain data collected from various regions. It has a behavior of a log-normal distribution at low rain rate and a gamma distribution at high rain rate. Inputs of this model are constants a, b and u. The constants a and b are derived from the 1-min. rain rate ($R_{0.01}$) which exceeding 0.01% of time. Moupfouma provided two regression equations that relate the rain rate $R_{0.01}$ with the values of a and b. The rain rate $R_{0.01}$ is directly obtainable from 1-min. rain rate records. The CCIR report (1990), alternatively, also provided a global table of $R_{0.01}$ for various regions. The constant u is a parameter describing the slope of the cumulative distribution curve. This constant is climatic and geographical features dependent. Moupfuoma proposed two methods in order to determine the correct value of u. The first method is using an equation and the second method is using a table (Moupfouma 1989). However, the first method is preferable if appropriate rain data are available.

COMMENTS

Three prediction models of 1-min. rain rate cumulative distribution were studied and compared. Below are some comments to the prediction models.

RHDD model This model is relatively more complex compared to the other models. Inputs to the model are standard annual rain records. The model also need some non climatological standard inputs that are tediously prepared. Four regression coefficients are also required by this model. Unfortunetly, coefficients for the temperate regions are given but none are available for the equatorial region.

TS model. This model consists of six empirical equations. These equations cover only six discrete percentage of exceeding levels. All inputs are standard monthly rain records. It also requires four regression coefficients that were regressed for the tropical and extra tropical regions. Furthermore, one of these coefficients is zero in the equatorial region.

Moupfouma model This model is single empirical equation. It requires only 1-min. rain rate ($R_{0.01}$) that exceeding 0.01% of time. No regression coefficients needed by the model. It considers geographical and climatic features.

CONCLUSION

One-min. rain rate cumulative distribution is an essential data for rain attenuation calculations. Whenever records on 1-min. rain rate is not available then we need prediction model to predict 1-min. rain rate cumulative distribution. For that purpose, three prediction models of 1-min. rain rate cumulative distribution have been compared. The RHDD model is relatively more complex model with some of its input are tediously prepared. The TS model has six empirical equations and all its inputs are available at any existing rain records. Furthermore, the regression coefficients for the RHDD and TS models are not available for the equatorial region. Finally, the Moupfouma model is an empirical equation. It requires only the 1-min. rain rate ($R_{0.01}$) exceeding 0.01% of time. This model is more applicable in the equatorial region because its considers all climatological and geographical features.

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