Comparison of the Rain Drop Size Distribution Model in Tropical Region

M.A. Awang[1] and J.Din[1]

[1]Wireless Communication Center (WCC)
Faculty of Electrical Engineering
Universiti Teknologi Malaysia
81310,UTM Skudai, Johor, Malaysia.

Abstract - Information of raindrop size distribution (DSD) is important for prediction of the microwave signal attenuation due rain, especially for high microwave frequency applications. The modeling of the raindrop size distribution in temperate and tropical region is different because tropical region has experiences heavy rain rate compared to temperate region. This paper reports the comparison of the rain attenuation measurements from 38 GHz microwave links conducted at Wireless Communication Center, Universiti Teknologi Malaysia (UTM) with the DSD model from Malaysia (KL-Lognormal), Singapore, Brazil and Nigeria using lognormal distribution model. The lognormal parameters are determined by the predicted result from those countries. Thus, direct comparison of the rain attenuation measurement with the various DSD models could be made. The use of DSD establishes for another climate and countries may result in prediction error.

1.0 Introduction

The rapid growth of telecommunication services, both in satellite and terrestrial links using higher frequency bands is above 10 GHz has highlighted need for estimating the effect of hydrometeors such as rain, clouds, fog and gaseous. The presence of hydrometeors in radio wave propagation, particularly rain, can produce major impairments to microwave propagation. Raindrops can be absorbed and scattered radio wave energy in signal attenuation, which can degrade the reliability and performance of the communication links [1].

Rain attenuation can be obtained through measurement or predicted from knowledge of rain rate and drop size distribution. The modeling of the raindrop size distribution in temperate and tropical region is different. It is because tropical region has experiences heavy rain rate compared to temperate region. In temperate region, Law and Parsons Model [2] or negative exponential function as proposed by Marshall and Palmer [3] and gamma distribution model usually characterizes modeling of raindrop size distribution. While mean, in tropical region, researchers from Brazil [4], Malaysia [5,6], Singapore [7] and Nigeria [8] have conducted raindrop size measurements and proposed raindrop size distribution models.

However, the negative exponential is not appropriate for use in tropical regions and gamma model distribution must be too modified [7]. Thus, lognormal raindrop size distribution models are suitable, used to estimate rain attenuation and compared to rain attenuation measurements from microwave links installed at Wireless Communication Centre (WCC), Universiti Teknologi Malaysia, UTM Skudai, Johor. Microwave links is operating at frequency 38 GHz and distance between transmitter and receiver about 301.3 meters.

2.0 Rain Attenuation

The rain attenuation can be express as below:

$$A(dB) = As \; x \; r \; x \; L \qquad (1)$$

where A is the rain attenuation in dB, As is the specific attenuation in dB/km, L is the path length between transmitter and receiver and r is the reduction factor [9].

Specific attenuation, A_s (dB/km) for an electromagnetic wave that propagates through rain which is depended upon the drop size distribution is given by the equation

$$As = 4.34x10^3 \frac{\lambda^2}{\pi} \sum \mathrm{Re}\left[S_{H,V}(0)\right] N(D)\Delta D \qquad (2)$$

where, λ is the wavelength in meter, $S_{H,V}(0)$ is the forward scattering amplitude (FSA) for horizontal and vertical polarization, $N(D)\Delta D$ is the drop size distribution per cubic meter and $R_e[\chi]$ is the real value for χ [10].

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Equation (1) is called the classical method. The lognormal raindrop size distribution can be expressed as:

$$N(D) = \frac{N_t}{\sigma D\sqrt{2\pi}} EXP\left(\frac{-[In(D)-\mu]^2}{2\sigma^2}\right) \quad (3)$$

where, μ is the mean of In (D), σ is the standard deviation, N_t is the total number of drops per cubic meter per mm. The parameters N_t, σ and μ are related to the rain rate, R as:

$$N_t = a_o R^{b_o} \quad (4)$$

$$\mu = A_\mu + B_\mu In(R) \quad (5)$$

$$\sigma^2 = A_\sigma + B_\sigma In(R) \quad (6)$$

where, the coefficients of a_o, b_o, A_μ, B_μ, A_σ and B_σ can be determined from the measured rain drop size distribution by A.R Tharek and J.Din for Malaysia [5], J.T Ong and Y.Y Shan from Singapore [7], Ajayi and Olsen at Ile-Ife, Nigeria and Maciel [8] and Assis at Sau Paulo, Brazil [4].

3.0 Result and Comparison

In this section, the comparison of the raindrop size distribution models with rain attenuation measured is presented. The cumulative distribution function (CDF) for microwave links data at frequency 38 GHz on year 1999 as shown in Figure 1. The Figure 1 is show that rain attenuation measured at 0.01 percentages of time about 16.8 dB.

The calculation of raindrop size distribution is using equation in (3), (4), (5) and (6). The coefficients of the DSD from measured data at Malaysia, Singapore, Nigeria and Brazil as shown in Table 1.

Table 1: Log Normal coefficients for Malaysia, Singapore, Nigeria and Brazil.

Coefficients	Malaysia	Singapore	Nigeria	Brazil
a_o	45.325	276.18	108	0.859
b_o	0.6703	0.3815	0.363	1.535
A_μ	-0.39141	-0.4286	-0.195	-0.023
B_μ	0.18734	0.14577	0.199	0.116
A_σ	0.40723	0.1564	0.137	0.805
B_σ	-0.05862	0.00913	0.013	-0.150

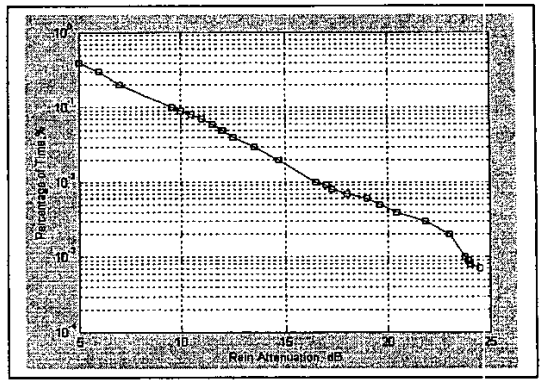

Figure 1: CDF of measured data at frequency 38 GHz from Microwave Links on 1992.

Figure 2 shows the comparison models of the raindrop size distribution for Malaysia, Singapore, Nigeria and Brazil at rainfall rate of 100 mm/h. It is show that models are quite similar for the drop diameter greater than 1.5 mm for Malaysia, Singapore and Brazil but the raindrop size distribution for Nigeria is lower.

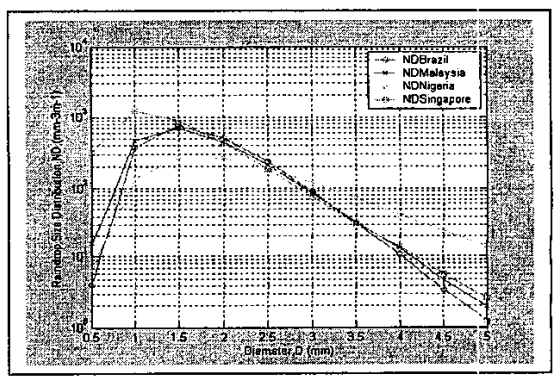

Figure 2: Comparison models of the raindrop size distribution for Malaysia, Singapore, Nigeria and Brazil at rainfall rate of 100 mm/h

Equation in (1) and (2) are used to calculate the specific rain attenuation, As in dB/km and rain attenuation, A in dB. Figure 3 shows the comparison of rain attenuation using log normal distribution and measured data from microwave links. It is show that rain attenuation using Brazil Log Normal model and Malaysia Log Normal model are closer to the measured data compared to Singapore Log Normal model and Nigeria Log Normal model at rainfall rate greater than 120 mm/h. However, at

rainfall rate less than 100 mm/h, Nigeria Log Normal model is close to measured data. This is due to the different fitting of rainfall rate is used in the DSD models.

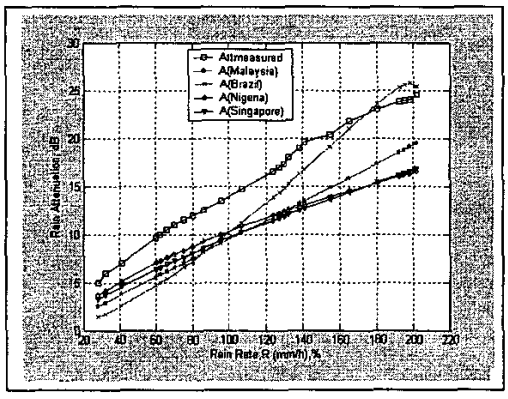

Figure 3: Comparison of rain attenuation using log normal distribution models and measured data.

4.0 Conclusion

The comparisons of rain attenuation using different lognormal models from tropical region with measured data are presented. The use of drop size distribution established for other countries may result in the prediction error when applied. An extensile study is currently conducted at WCC, UTM. Thus, a suitable model for Malaysia climate could be obtained.

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