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Rain Attenuation for 5G Network in Tropical Region (Malaysia) for Terrestrial Link

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Abstract—Millimeter wave (mm-Wave) is today's breakthrough frontier for emerging wireless mobile cellular networks, wireless local area networks, personal area networks, and vehicular communications. In the near future, mm-Wave products, systems, theories, and devices will come together to deliver mobile data rates thousands of times faster than today's existing cellular and Wi Fi networks for an example from the era of 3G, 4G towards 5G mobile communication in near future. This paper presents studies on rain attenuation at 6 GHz and 28 GHz, which is widely used for local multipoint distribution service deployment by using the measured and prediction methods for terrestrial microwave links point to point in tropical regions. Besides this, discussion and comparison of five different reduction factor models have been presented. Several models have been proposed by researchers to account for the horizontal variation of rainfall. Five rain attenuation prediction models in the tropical region are analyzed. The models are ITU-R model, revised Moupfouma model, revised Silva Mello model, Abdul Rahman model, and Lin model which have been analyzed. The objective of these studies is to identify rain attenuation using a prediction model for 5G networks in tropical regions for a country like Malaysia. This study has been carried out with the setting of an experimental testbed. A link to the path length of 0.2 km was set up in Johor Bahru, Malaysia. Both the transmitter and receiver operate at frequencies of 6 GHz and 28 GHz. A tipping bucket rain rate is used, and all the data have been recorded using a data logger. At the end of the analysis, it is found that all the five models predict rain attenuation at less than 1 dB and 11 dB for operating microwave frequency at 6 GHz and 28 GHz for 5G Network. This findings will be useful for future 5G network designers to consider the effect of rain impairments especially in tropical region.

1. INTRODUCTION

Generally at frequencies below 5 GHz, excess attenuation due to rainfall and atmospheric gaseous, frozen particles such as snow, ice crystals are very small and can be neglected in radio system design. However at frequencies above 5 GHz, liquid rain drops in the form of absorption and scattering do become serious which contribute to transmission losses [1–3]. The attenuation on any given path depends on the value of specific attenuation, frequency, polarization, temperature, path length, and latitude [4]. For mobile communication designers in microwave system need to consider rain attenuation factors as one of the criteria. Revolution and evolution took place in mobile communication industries from starting 1G, 2G, 3G, 4G, and 5G in near future. The increasing demand for high speed wireless communication systems has motivated the research in 5G cellular system. Due to the large bandwidth requirement and the scarcity of frequency spectrum under 5 GHz, a millimetre wave (mm-Wave) spectrum has been

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proposed for 5G system. In 5G networks, the designers will be using small cells with short distance using lower and higher band operating frequencies in a microwave system to cater higher demand. In other words, the capacity of the link will be increased tremendously [5]. However, impairments due to rain need to be considered too, especially tropical region like Malaysia. There are various models on rain attenuation prediction [6]. Most common and widely used models are ITU-R, revised Moupfouma, revised Silva Mello, and Lin model. However, Revised Moupfoma, Revised Silva Mello and Lin model prediction data still look good for low and high operating frequencies especially in the tropical region.

2. RAIN ATTENUATION PREDICTIONS OVER TERRESTRIAL LINKS

Rain attenuation limits the availability and performance of the system, and in order to develop an adequate link margin, the rain attenuation expected for a given time percentage needs to be calculated [7, 8]. There are three steps; determination of the rain fall rate (mm/h) for the time percentage of interest, calculation of the specific attenuation of the signal at this rainfall rate in dB/km, and careful estimation of the effective length of the path.

Attenuation can be accurately predicted if the rain can be precisely described all the way along the path. Most prediction models used semi-empirical approaches, which calculate an effective path length through the rain, L_{eff}, over which the rain fall rates are assumed to be constant for long term. A power law equation describes the relationship between point rainfall R and specific attenuation over 1 km. If the rain fall rate were constant along the path calculating the total attenuation for a given rain rate would be simple; the physical length through rain would be the same as the effective path length and total attenuation [9–15]. Total attenuation is the product of specific attenuation and the physical path length in rain. Since the path encounters highly variable drop sizes and rain fall rates, the physical length L has to be replaced by an effective length, L_{eff}, an estimate of path attenuation with rain rate exceeded for 0.01% of time given by:

$$A_{0.01} = \gamma \cdot L_{eff} = k \cdot R_{0.01}^{\alpha} \cdot r \cdot d \quad \text{(dB)} \tag{1a}$$

Hereby, γ is specific attenuation, and k and α are the regression coefficients. r — path reduction factor, and d — link distance.

$$\gamma = k \cdot R_{0.01}^{\alpha} \quad \text{(dB/km)} \tag{1b}$$

3. EXPERIMENTAL SET-UP

A link of path length 0.2 km was set up in Johor Bahru, Malaysia. Both the transmitter and receiver operate at frequencies of 6 GHz and 28 GHz. The received signal levels were sampled every minute. One year precipitation data with 95% of validity of all time were collected from the tipping bucket rain gauge model TB 3 installed at the measurement site (June 2012–May 2013). These data have been used to investigate the link. The precipitation data and rain attenuation data were recorded at the same period of time. The rain gauge used is a tipping bucket type, and it has sensitivity of 0.2 mm. It records the total rainfall occurring in each minute without recording non-rainy events; therefore, the rain rate is recorded as an integral multiple of 12 mm/h or 0.2 mm/min. Table 1 shows the measured cumulative distributions of rain rate, while Figure 1 shows the experimental test bed setup. Figure 2 shows the monthly distribution of rain fall rate throughout the period while Figure 3 presents the complementary cumulative distribution function (CCDF) of the rainfall rate for an average of one year in Johor Bahru and shows the monthly distribution of rain fall rate throughout the period of measurement. It was observed at 0.01% of time that the rain rate was 120 mm/h.

Table 1. Measured cumulative distributions.

Probability Level (%)	0.2	0.1	0.05	0.03	0.02	0.01	0.005	0.003	0.001
Rain rate (mm/h)	20	48	62	83	96	120	132	144	168

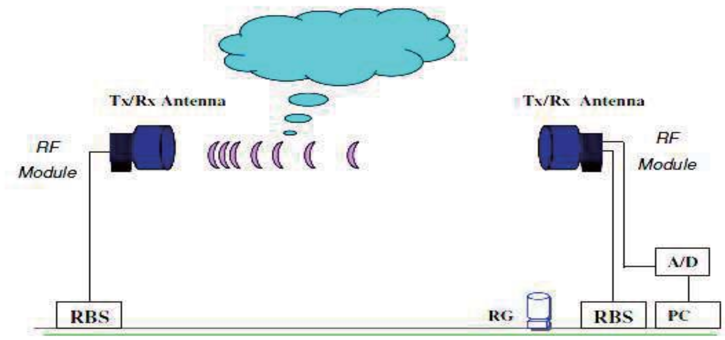

Figure 1. Diagram of experimental setup and rain rate measurement.

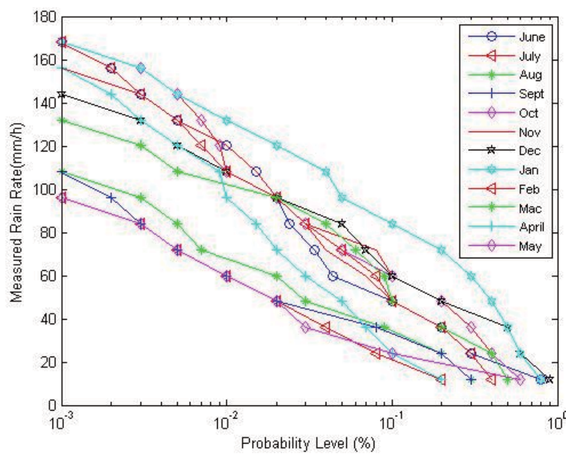

Figure 2. Monthly CCDF rain rate for the period of June 2012–May 2013.

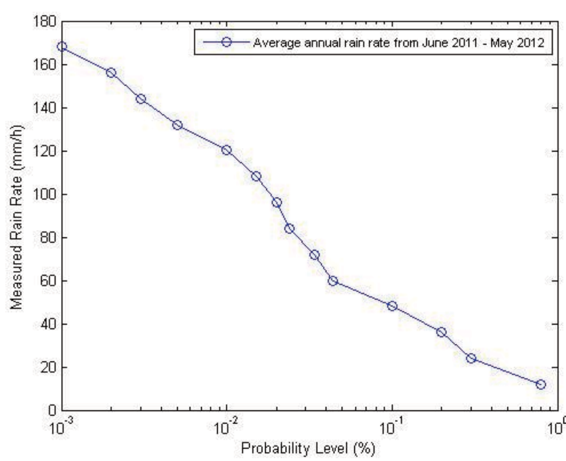

Figure 3. Rainfall rate CCDF for Johor Bahru (1 year).

By using MATLAB simulation, all the five predictions models, rain attenuation prediction for 5G network for lower, 6 GHz, and higher 28 GHz operating frequencies have been predicted, and Figures 4 and 5 show the rain attenuation predictions.

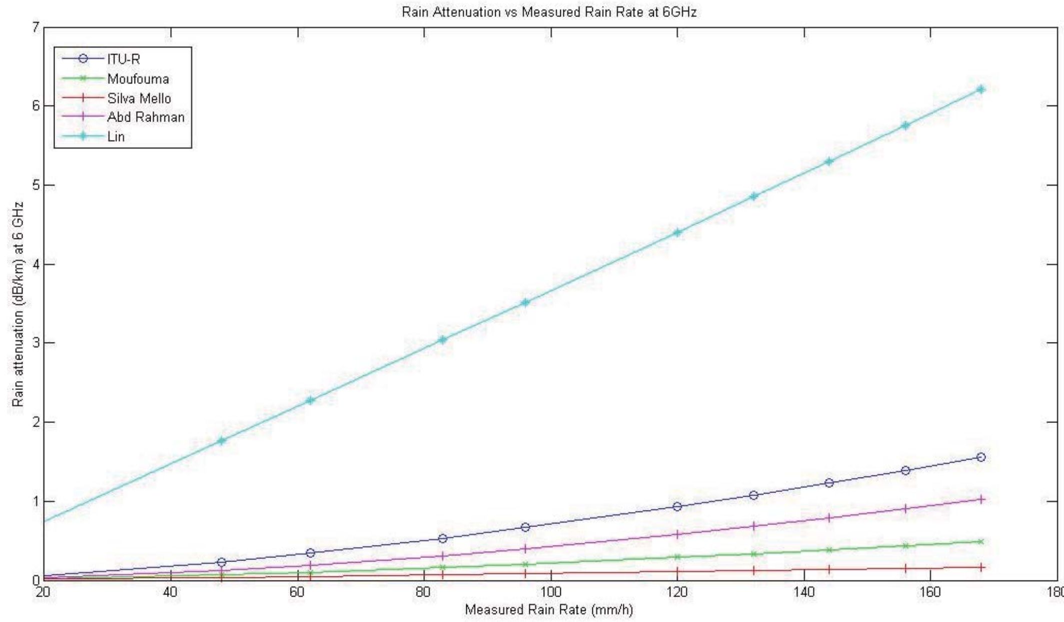

Figure 4. Rain attenuation using the prediction model for the 5G network for lower operating frequency at 6 GHz.

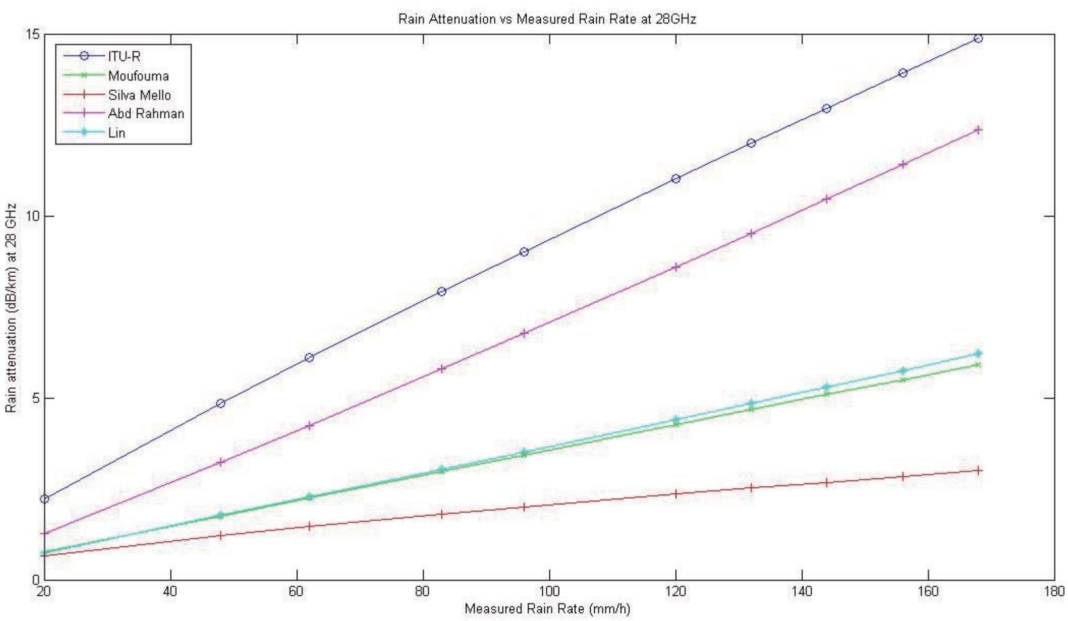

Figure 5. Rain attenuation using the prediction model for the 5G network for higher operating frequency at 28 GHz.

4. RESULTS AND DISCUSSIONS

The measured rain data at 6 GHz and 28 GHz are used to compare rain attenuation using the predictions models of ITU-R, Revised Moupfouma, Revised Silva Mello, Abdul Rahman, and Lin at different probability levels. As seen in Figures 4 and 5, the predicted rain attenuation data at operating frequencies 6 GHz and 28 GHz at 0.1% and 0.01% using ITU-R, Revised Moupfouma, Revised Silva Mello, Abdul Rahman, and Lin models respectively are presented in Table 2. It was observed at 0.1% that the rain attenuation at lower operating frequency at 6 GHz predicted rain attenuation for all the prediction models more or less the same except for Lin model; however, at 0.01% the rain attenuation varies for prediction model. Lin model predicts more followed by ITU-R, Abdul Rahman, Revised Moupfouma, and Revised Silva Mello. It was observed that Revised Silva Mello model predicted lower rain attenuation for lower operating frequency compared to all the other models. Moreover, for operating frequency at 28 GHz, the predicted attenuations at 0.1% and 0.01% for ITU-R, Revised Moupfouma, Revised Silva Mello, Abdul Rahman, and Lin models respectively are presented in Table 3. It is observed at 0.1% and 0.01% rain attenuation at higher operating frequency 28 GHz that the rain attenuations for all the prediction models vary. ITU-R model recorded the highest rain attenuation followed by Abd Rahman, Revised Moupfouma, Lin, and Revised Silva Mello. It is observed that Revised Silva Mello model predicts lower rain attenuation for higher operating frequency too than all the other prediction models.

Table 2. Rain attenuation data using the prediction model at rain rate exceed 0.1% for operating frequency at 6 GHz.

SEQ	PREDICTION MODEL	A (0.1%) dB	A(0.01%) dB
1.	ITU-R	0.20	4.86
2.	REVISED MOUFOUMA	0.08	1.77
3.	REVISED SILVA MELLO	0.04	1.22
4.	ABDUL RAHMAN	0.01	3.22
5.	LIN	1.77	1.76

Table 3. Rain attenuation data using the prediction model at rain rate exceed 0.01% for operating frequency at 28 GHz.

SEQ	PREDICTION MODEL	A (0.1%) dB	A(0.01%) dB
1.	ITU-R	0.90	11.04
2.	REVISED MOUFOUMA	0.30	4.30
3.	REVISED SILVA MELLO	0.10	2.30
4.	ABDUL RAHMAN	0.60	8.60
5.	LIN	4.40	4.40

5. CONCLUSIONS

Rain rate was measured for one year over 6 GHz and 28 GHz microwave links in Malaysia. It was observed that Revised Silva Mello model predicted lower rain attenuation for lower and higher operating frequencies followed by Revised Moupfouma, Abd Rahman, and ITU-R models. However, Lin model predicted rain attenuation more or less similar for both lower and higher operating frequencies at both probability levels. Based on the comparison done, it is found that Revised Silva Mello prediction model is a suitable choice for tropical region for 5G networks. However, model validation method needs to be studied further to conclude the findings.

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