Localization of Rain and Its Effect on Propagation in Tokyo Tech Millimeter-wave Model Network

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Abstract

Evaluation of localized behaviors of rain and its effect on wave propagation in Tokyo Tech millimeter-wave wireless network is presented in this paper. By the statistical analyses based on the collected data up to now, the unique effects due to highly localized behaviors of the strong rain have become clear.

Keywords : Millimeter-wave Localized Rain Critical Rain Rate Rain Attenuation

1. Introduction

Millimeter wave band is still under exploited compared to the microwave band and it can be a potential frequency band for resolving the spectrum congestion. Therefore, millimeter-wave networks are undergoing intensive development to meet the necessity for high speed wireless data transmission. However, millimeter-wave band is largely affected by attenuation due to rain. While calculating link budget for wireless systems using this frequency band, behavior of rain, attenuation due to rain and amount of degradation must be accurately understood.

In the Ookayama Campus of Tokyo Tech, 25GHz and 38GHz band small-scale model network has been operated for testing the broadband (Gigabit) wireless systems. Data about Rain rate, Bit Error Rate (BER) and Rx level are being collected since March 2008. Based on the data, we performed conventional statistical analysis such as measuring rain attenuation constant, cumulative rain rate distribution, relation between availability and path distance. Comparison between rain attenuation of 25GHz and 38 GHz band network has been done. These measurements will be used for link design and also for enhancing the link reliability. Based upon the study up to now, the unique effects due to highly localized/microscopic behaviors of the strong rain have become clear. The cell size of the strong rain frequently becomes smaller than 1km, the size of the campus.

In this paper, evaluation of localized behaviors of rain and its effect on wave propagation is focused upon.

2. Experimental Setup

In the Tokyo Tech millimeter-wave wireless network, Fixed Wireless Access (FWA) equipments are set on the rooftop of 7 buildings of Ookayama campus and the mesh network consists of 11 paths as shown in Figure 1 [1][2].The shortest path is 77m and the longest one is 1020m. However, two extra paths (3500m & 4100m long) have been set up for the 38GHz network. Data for Rain rate, Rx level and Bit Error Rate (BER) are recorded via the millimeter-wave network in every 5 seconds.

The 25GHz band and 38GHz band wireless terminals used in this experiment are shown in Figure 2. The terminals are coated with a water shedding coating. Tipping bucket rain gauge has been used as the rain rate measuring system. The specifications of the 25GHz wireless terminal are as follows: RF 25GHz (BW: 20MHz/ch, 23ch); Antenna Gain 29dBi; Tx Power 0dBm (1mW);

TDD, 16QAM; 80Mbps; Reed-Solomon Code. The specifications of the 38GHz wireless terminal are as follows: RF 38GHz, (BW 60MHz/ch, 5ch); Max Rx Level -30dBm; Transmission speed Max 600Mbps; TDD; Modulation Scheme QPSK/16QAM; Antenna Gain: 32dBi.

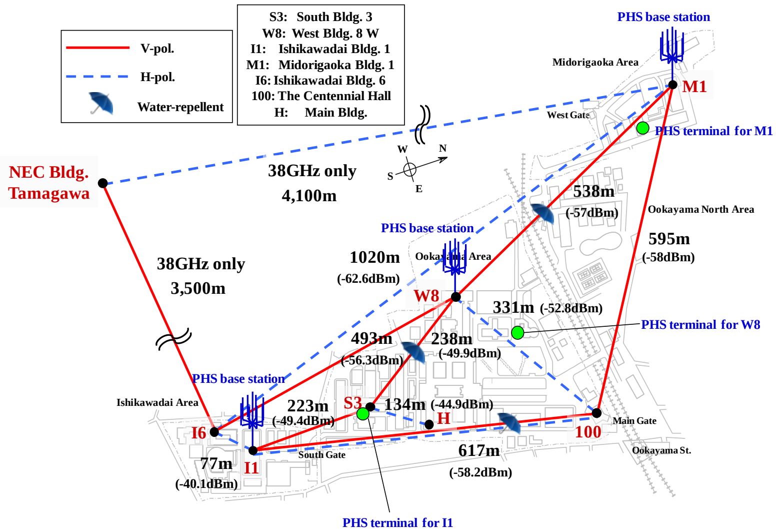

Figure 1: Tokyo Tech Millimeter-Wave Wireless Network

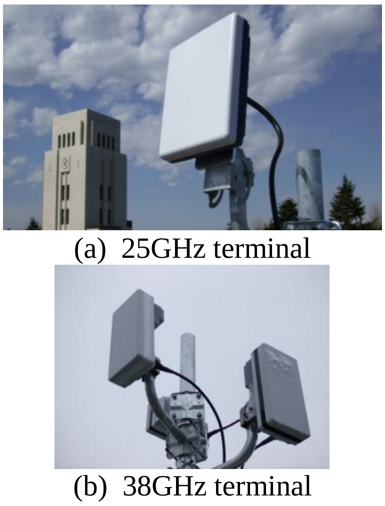

Figure 2: Wireless Terminals

3. Experimental Results

Figure 3 shows the change of Rx level in 25GHz during heavy rain period. Data of December 3, 2010 has been used since it rained more than 250 mm/h that day. As expected, the Rx level decreases when rain rate increases. In fact, couple of links are down during such strong rain.

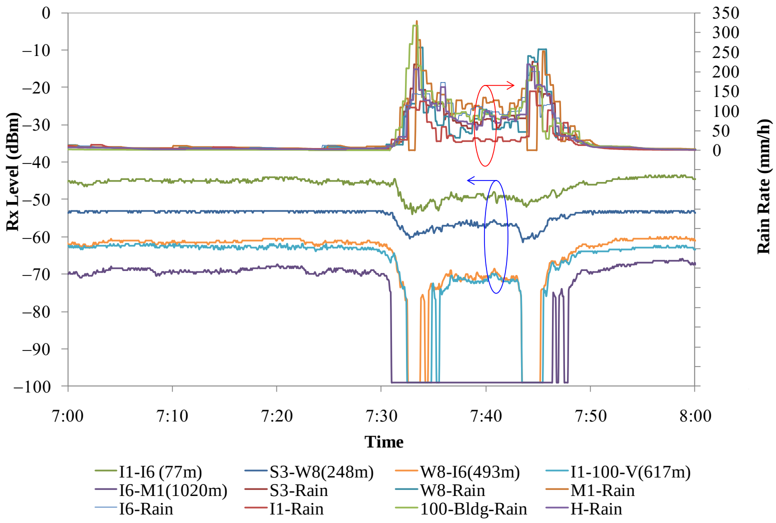

Figure 3: Change of Rx level in 25GHz during heavy rain (December 3, 2010)

Specific rain attenuation γ (dB/km) has frequency dependency and the value of γ increases with the increase in frequency. The theoretical value of γ for our 25GHz and 38GHz network is listed in Table 1[3]. Here, *R* means rain rate (mm/h).

Table 1: Specific Rain Attenuation γ (dB/km)

	25GHz	38GHz
V-pol	$0.113R^{1.03}$	$0.280R^{0.942}$
H-pol	$0.124R^{1.061}$	$0.315R^{0.951}$

Comparison between theoretical and experimental value for both 25GHz and 38GHz network is shown in Figure 4. 2months data (Nov'10 & Dec'10) for H-pol propagation has been used here. As we can see, rain attenuation is larger for the higher frequency and the experimental curves show some deviation from the theoretical curves. It might be due to the localization of rain.

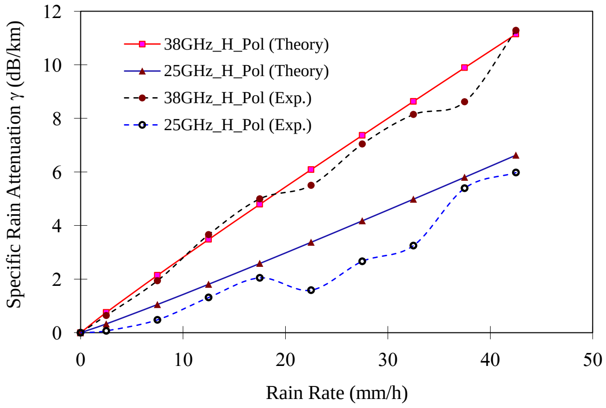

Figure 4: Rain attenuation vs. Rain rate (for 25GHz & 38GHz network)

4. Localized behavior of rain

It has been seen that rain shows localized behaviour [4]. Figure 5 compares rain rates measured at two ends of different links with various path distances (238m~1020m). The deviation from 45deg line can be a good parameter indicating the non-uniformity of the rain. If we define 'Critical Rain Rate' as the rain rate beyond which deviation from 45deg line is large, relation between critical rain rate and path distance are summarized in Figure 6. As the path distance increases, critical rain rate decreases. This phenomenon suggests that the stronger rain has the smaller cell size or the higher locality. Varying the number of days the data were accumulated for, we also get the same tendency.

Since rain tends to show time varying localized behaviour (especially at high rain rates) the rain rate of a path is hard to be estimated, by only knowing the rain rate at the terminals. This affects the rain attenuation calculations, especially when the rain attenuation needs to be expressed as a function of the rain rate. Figure 7 depicts the rain attenuation calculated by the reception level of the path (for 25GHz) that is recorded during different rain rates at the terminals.

It could be seen clearly how the rain attenuation at the same rain rate of the two ends of the path deviates at higher rain rate. The rain rate at which the deviation occurs becomes lower roughly with the increasing path distance. Therefore, it could be said that the localized behavior of rain affects the rain attenuation at higher rain rates especially for longer paths.

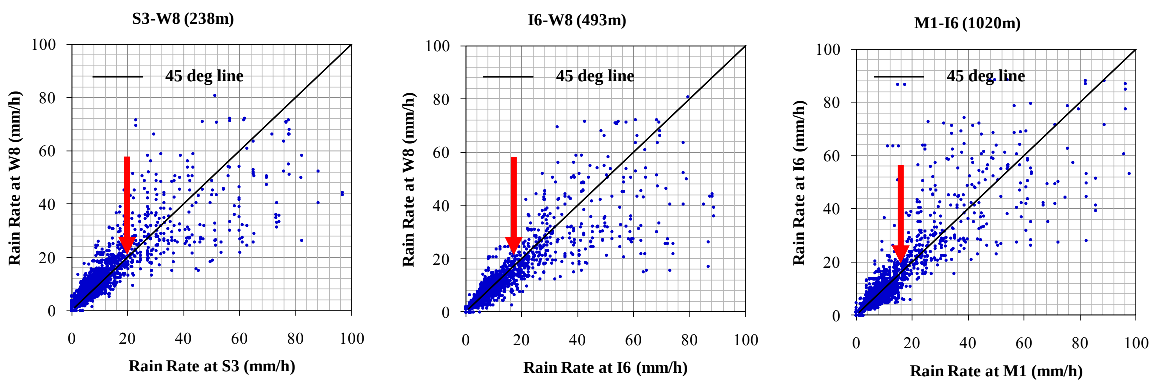

Figure 5: Deviation of rain rates from the 45deg line (5 days data, May'09)

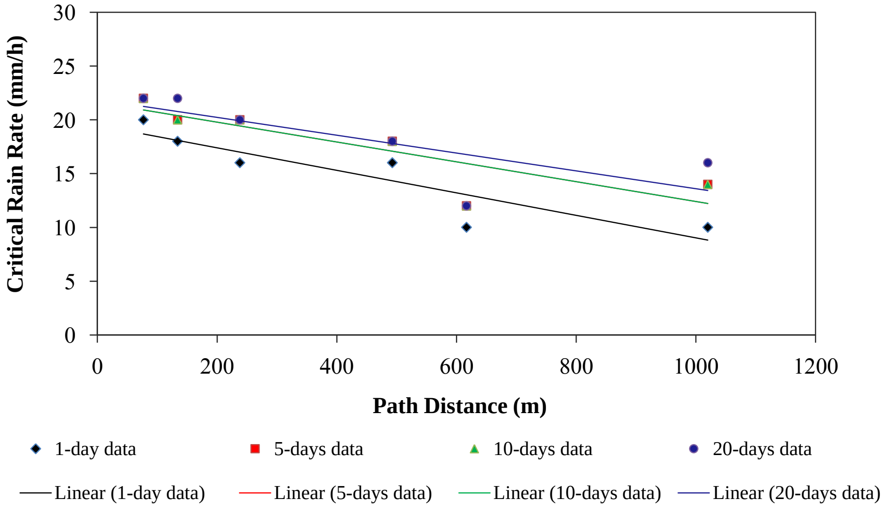

Figure 6: Critical rain rate vs. path distance (Rainy day data: Apr’09~Jun’09)

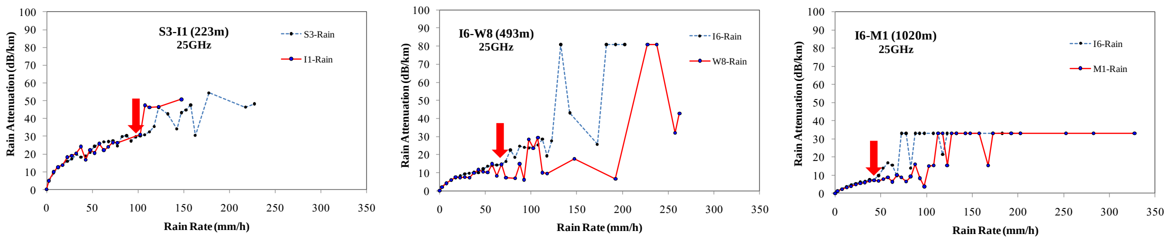

Figure 7: Rain attenuation for different paths against the terminal rain rates
(10 months data (Mar'2010~Dec'2010))

5. Conclusion

Spatial correlations of rain rate as well as rain attenuation characteristics have been investigated to understand its localized behavior. Frequency dependency of the specific rain attenuation γ has been confirmed. A new parameter called “Critical Rain Rate” has been defined to explain the localized behavior of rain.

References

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