60-GHz Short-range Terrestrial Rainfall Attenuation Compared with K-band Long-distance Satellite Link

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***Abstract* - In order to clarify rainfall attenuation of millimeter-wave terrestrial and satellite links, rainfall attenuation of a 60-GHz short-range terrestrial link was measured and compared with those of K-band long-distance satellite links. Cumulative probability distribution of 60-GHz rainfall attenuations was slightly larger than that estimated from Morita and Higuti's prediction method. Availability of 60-GHz terrestrial link was also evaluated by duration time and compared with K-band satellite ones. 60-GHz availability was nearly constant with the duration time although K-band satellite availability was changed by the duration time.**

***Index Terms* — Rainfall attenuation, millimeter-wave, 60 GHz, terrestrial link.**

I. Introduction

Satellite diversity techniques have been studied to compensate degradation of the satellite communication quality due to rainfall attenuation and to realize wideband millimeter-wave satellite communications. One technique is orbital diversity that utilizes multiple geostationary satellites and works because of rain area migration [1] and the other is frequency diversity that utilizes dual frequencies and improves satellite availability [2] both to overcome rainfall attenuation. In the study, millimeter-wave rainfall attenuation was estimated from measured Ku- or Ka-band attenuation based on ITU-R P.838-3 model. However, since millimeter-wave rainfall attenuation is slightly different from Ku- or Ka-band ones, modified Morita and Higuti's prediction method has been studied [3], [4]. In this presentation, in order to investigate exactly the millimeter-wave rainfall attenuation, 60-GHz short-range terrestrial rainfall attenuation were measured for almost two and a half years and compared with those of Ku- and Ka-band long-distance satellite links.

II. Measurement System

Figure 1 shows configuration of the measurement system for 60-GHz short-range terrestrial-link and Ku- and Ka-band satellite-link attenuations located at NICT Kashima Space Technology Center, Japan. 60-GHz terrestrial link is 150 meters long in a north-south direction. Ku-band satellite links, JCSAT3A and AsiaSat3S, are towards 128 and 105.5 degrees east longitude, respectively. Ka-band satellite link, WINDS, is towards 154 degrees east longitude. All received signals were sampled at intervals of a second. Rain intensity was sampled at intervals of a minute by a rain-intensity gauge.

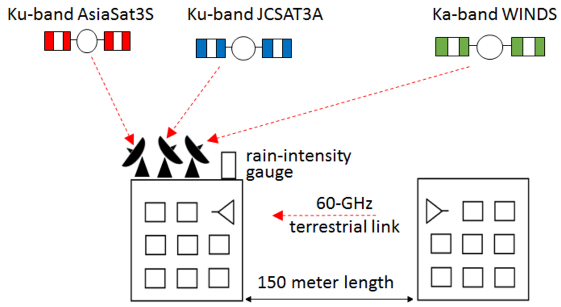


Fig. 1. Measurement system for 60-GHz short-range terrestrial-link and Ku- and Ka-band satellite-link attenuations.

III. Cumulative Probability Distribution

Rainfall attenuation of 60-GHz terrestrial link was measured for almost two and a half years from August, 2011 to December, 2013. Among the received signals, we analyzed the attenuated signal when the rainfall intensity exceeded 10 mm/h.

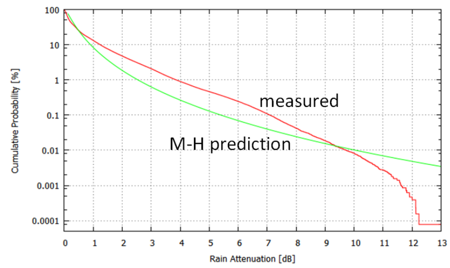
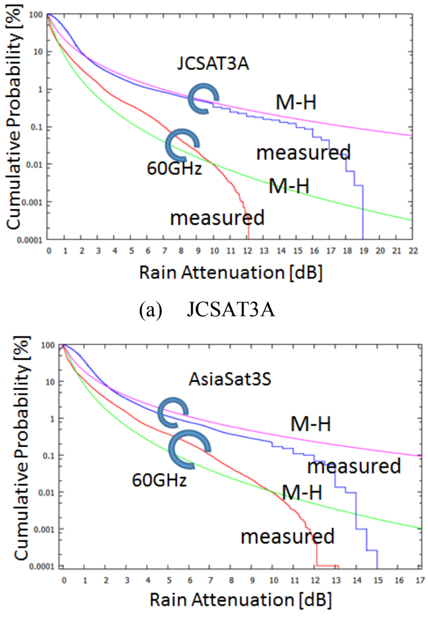


Fig. 2. Cumulative probability distribution of 60-GHz short-range terrestrial rainfall attenuations.

Figure 2 shows cumulative probability distribution of 60-GHz rainfall attenuations. Measured attenuation is compared with Morita and Higuti's prediction method (M-H) [3]. Measured attenuation tends to be slightly larger than M-H prediction. In order to clarify the cause of disagreement between the measured and predicted, we compared 60-GHz terrestrial rainfall attenuation with Ku- and Ka-band satellite-link ones. Figure 3 shows cumulative probability distribution of Ku-band satellite-link rainfall attenuations located at different longitude. Both measured attenuations coincide relatively well with the M-H predicted one and are only slightly lower than the predicted.



(a) JCSAT3A

(b) AsiaSat3S

Fig. 3. Cumulative probability distribution of Ku-band satellite-link attenuations.

Figure 4 shows cumulative probability distribution of Ka-band, WINDS satellite-link rainfall attenuation. Also measured attenuation coincides relatively well with the M-H predicted and is only more slightly lower than the predicted.

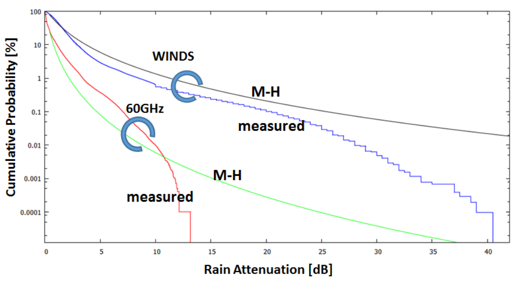
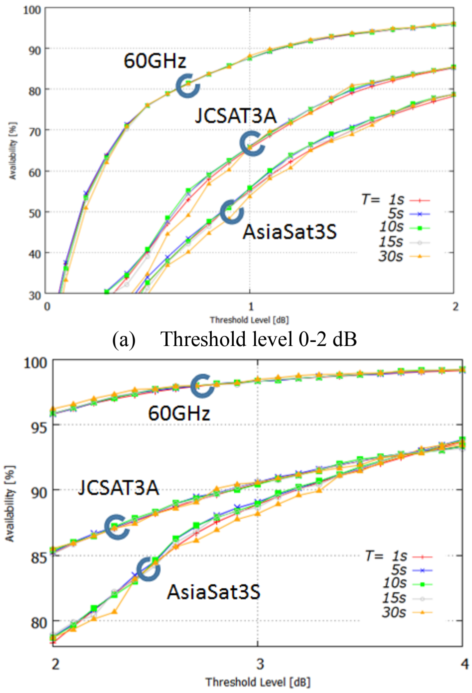


Fig. 4. Cumulative probability distribution of Ka-band, WINDS satellite-link attenuations.

The comparison of rainfall attenuations between 60-GHz terrestrial link and Ku- and Ka-band satellite links shows that millimeter-wave rainfall attenuation is slightly different from Ku- and Ka-band ones and needs to precisely consider the spatial correlation function of specific attenuation for conditional time by using modified Morita and Higuti's prediction method [4].

IV. Link Availability

In order to clarify time-series characteristics of 60-GHz terrestrial link, availability of the 60-GHz link was evaluated by duration time *T* and compared with Ku-band satellite ones [5]. Figure 5 shows comparison of the link availability evaluated by the duration time *T* when threshold for rainfall attenuation is defined. Although variation in availability by the duration time is small, difference in availability of Ku-band satellite-link for different duration times is larger than 60-GHz terrestrial one. Availability of the 60-GHz short-range link is almost constant with the duration time. This could be mainly due to difference in propagation distance between the satellite and terrestrial links.



(a) Threshold level 0-2 dB

(b) Threshold level 2-4 dB

Fig. 5. Link availability vs. threshold evaluated by duration time *T*.

V. Conclusion

60-GHz short-range terrestrial-link rainfall attenuation was measured and compared with K-band satellite-link ones. Difference in cumulative probability distribution found that measured attenuation tends to be slightly larger than M-H prediction at 60 GHz. Availability analysis by duration time found that availability of the 60-GHz short-range link is almost constant with the duration time.

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