

# Effects of Integration Time on Rainfall Intensity and Rain Attenuation Cumulative Distributions

Shuhei Kaneko and Hajime Fukuchi

Department of Aerospace Eng., Tokyo Metropolitan University  
6-6 Asahigaoka, Hino, Tokyo 191-0065, Japan  
kaneshu88@gmail.com

## 1. Introduction

Now, we use satellite communication. When we use satellite communication, we need to consider how we use effectively finite resources such as frequency spectrums. But as the demands of satellite communication and the launch of stationary satellites increase, frequency spectrums will be almost fully used. Then, we need to develop new one due to increasing demands of satellite communication and broadcasting in the world.

Now, we should research and develop high frequency bands such as 20, 30 and 40GHz. However, we have big problems when we use the higher frequency band. The problems are especially rain-induced attenuation. In order to countermeasure rain-induced attenuation, it is important for us to know the property of rainfall. To know the property, we need the information of rainfall rates time series with short measuring interval.

In this research, we measured rainfall rate every 1 second with the device and got the information on rainfall rate time series with 1 second measurement. Then, we calculated rainfall intensity and dependence on integration time of cumulative distribution. Furthermore, this time we got the dependence of integration times on rain-induced attenuation statistics at 19.5GHz measured in Japan and at 12GHz measured in Thailand. In this paper, we discuss rainfall intensity and rain-induced attenuation with 1 second measuring integration time and consider integration time dependence.

## 2. Rainfall intensity statistics

We use the device to measure rainfall rate with a 1 second measuring integration time. This device is called Compact Weather Station and the type is WS600-UMB. We show the appearance of the device in Fig.1. We measured rain at Tokyo Metropolitan University from July the 22nd 2011 to October the 31st 2011. Fig.2 shows the time-series of rain-fall rate on September the 21st 2011. It is noted that we got very heavy rain in this day up to 500 mm/h.

Fig.3 shows the effect of integration time on rainfall intensity cumulative distribution. We tried the average from 1 second data to 10, 30 and 60 seconds. This device has threshold value. When we measure rainfall by 1 second, the threshold is 0.06 mm. So, this corresponds to 36 mm/h when we calculate rainfall intensity.

Fig.4 shows the following percentage deviation from the case of 1 second integration time;

$$\left(\frac{P_n}{P_1} - 1\right) \times 100 \quad (\%) \quad (1)$$

where the  $P_n$  and  $P_1$  denote cumulative time percentages with integration times of  $n$  and 1 second, respectively. As this figure shows, the longer the integration time is, the bigger the difference is as compared with 1 second when the integration time is changed from 1 second to 10, 30 and 60 seconds, respectively.

## 3. Rain attenuation statics at 20 GHz in Japan [1]

We discuss the integration time effect on attenuation statistics based on rain-induced attenuation time series measured at 19.5 GHz with an elevation angle of 48 degrees. It was measured from April 1981 to March 1983 and the interval was 1 second.

Fig.5 shows a comparison of two years cumulative distribution of attenuation with integration time ( $T_i$ ) of 1, 60 and 120 seconds. We can see the cumulative time percentage decreases as integration time increases in a large attenuation region. In order to consider this more clearly, we derived percentage deviation in Fig.6. This is calculated with the above-mentioned function (1). This figure shows that the percentage deviation decreases at most about 40 %, 25 % and 8% when the integration time is changed from 1 second to 120, 60 and 20 seconds when attenuation becomes about 30 dB. However, when cumulative time percentage is larger than 0.01 %, percentage deviation remains 0 to -5 %.

#### **4. Rain attenuation statistics at 12GHz in Thailand**

Fig.7 shows time-series of received power level from Thaicom-2 and 3 at Ku-band. From this figure, rapid decrease of power level is clearly observed. These power levels were obtained in every 1 second. By using those data, we derive cumulative distributions of attenuations with several integration intervals at Ku-band in Bangkok.

Fig.8 shows the cumulative distribution based on one year measurements of rain-induced attenuation events with attenuation larger than 5 dB in 2006 by using Thaicom-3. This figure shows no clear difference among integration time of 1, 30 and 60 seconds as far as attenuation below 10 dB is concerned.

Fig.9 shows relative cumulative time percentage deviation similar to Fig.6. And it shows above observation more clearly. Regarding cumulative time percentage larger than 0.1 %, cumulative time percentages differ less than 2 % due to integration time difference from 1 to 60 seconds. This shows that even in tropical area, integration time dependence on cumulative distribution of attenuation is not significant in the region time percentage larger than 0.1 %. In other words, if one wants to design satellite link budget with availability less than 99.9 %, cumulative distribution of attenuation derived from 1 minute integration time can be used even in tropical Asian area.

#### **5. Conclusion**

In this paper, we discuss integration time dependence on rainfall rate and rain-induced attenuation statistics measured by 1 second. According to our analysis using rainfall rate time series in Japan and rain-induced attenuation time series in Japan and Thailand all measured with 1 second measuring integral, we noticed no significant difference between 1 second data and 60 second data as far as cumulative time percentage larger than 0.1 % is considered. In other words, if one wants to design satellite link budget with availability less than 99.9 %, cumulative distribution of attenuation derived from 1 minute integration time can be used even in tropical Asian area.

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#### **References**

- [1] H. Fukuchi, "Effects of Integration Time on Rain Attenuation Statistics at 20 GHz", IEICE TRANS. COMMUN., VOL. E76-B, NO. 12, pp. 1590-1592, 1993.



Fig.1 Compact Weather Station

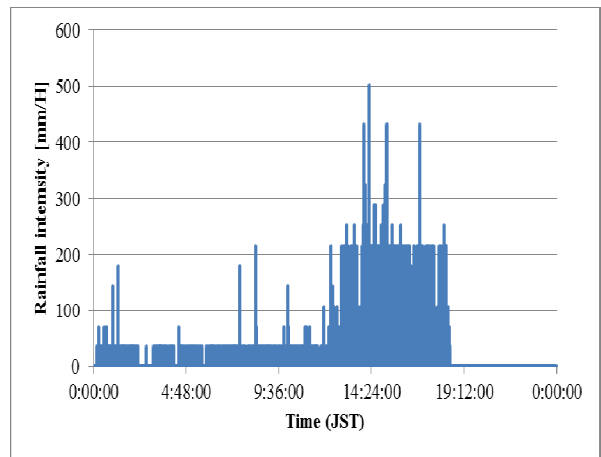


Fig.2 Time-series of rainfall intensity in September the 21<sup>st</sup> 2011.

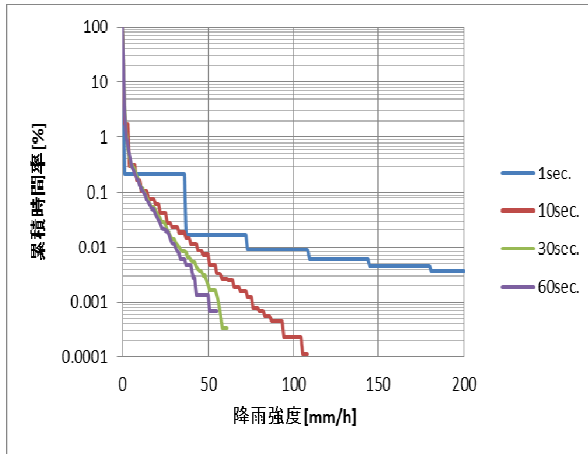


Fig.3 Dependence on integration time of rainfall rate cumulative distribution.

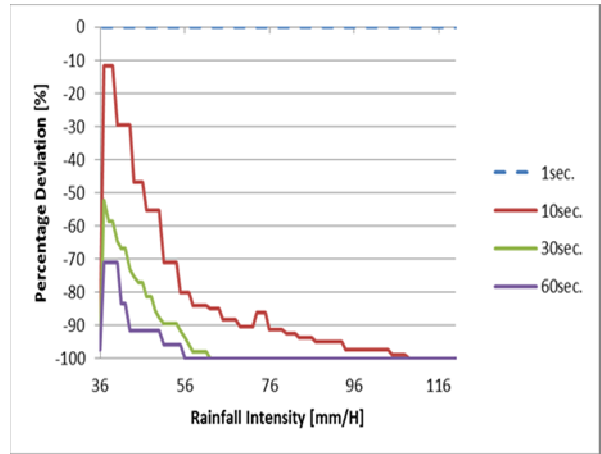


Fig.4 Percentage deviation relative to statistics with integration time of 1 second.

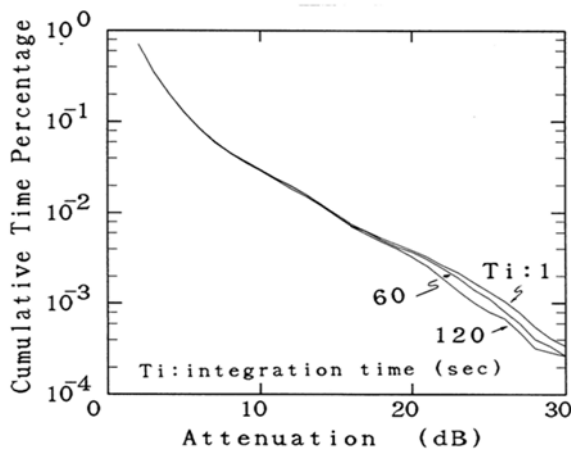


Fig.5 Effect of integration time ( $T_i$ ) on annual attenuation statistics.

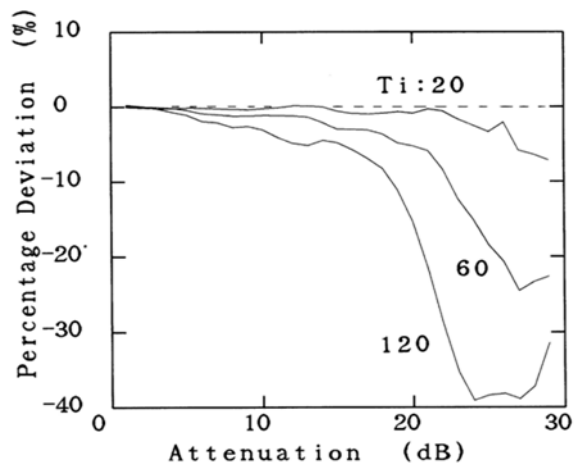


Fig.6 Percentage deviation relative to statistics with  $T_i$  of 1 second.

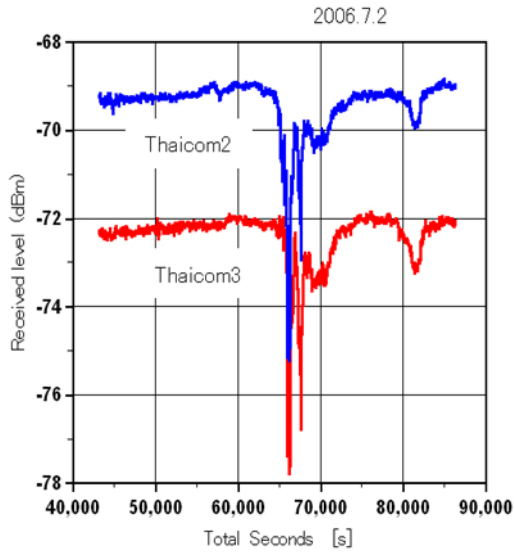


Fig.7 Time-series of received power level from Thaicom-2 and 3 at Ku-band.

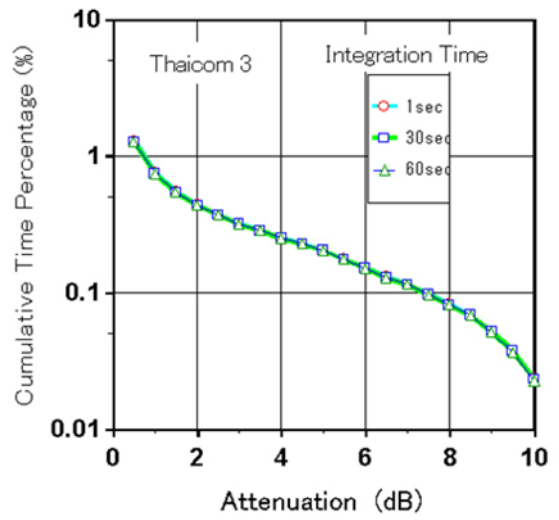


Fig.8 Cumulative distribution of Ku-band attenuation based on one year in 2006.

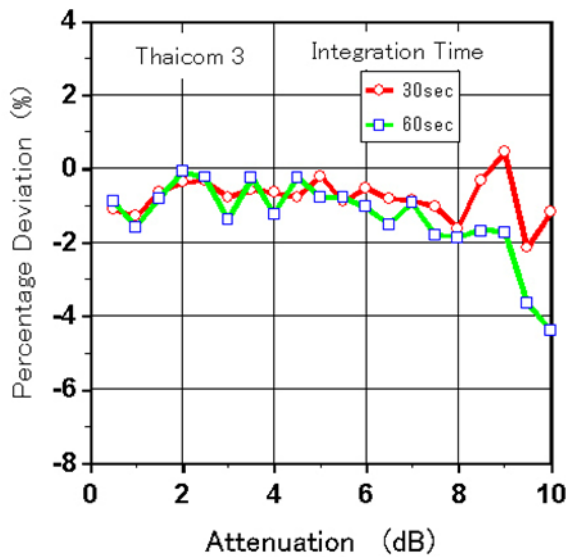


Fig.9 Percentage deviation relative to statistics with integration time of 1 second.