

# Characteristics of Rain Attenuation Time Variation in Ka Band Satellite Communications for the kind of Rain Types in Each Season

# Ryuji Nakajo<sup>1</sup>, Yasuyuki Maekawa<sup>1</sup>

<sup>1</sup>Department of Telecommunications & Computer Network, Osaka Electro-Commun. Univ.,  
18-8 Hatsucho, Neyagawa, Osaka 572-8530, Japan, nakajo@maelab.osakac.ac.jp

## 1. Introduction

The satellite communication links using the frequency of higher than 10GHz are subject to atmospheric effects, such as rain attenuation and scintillation. To mitigate the attenuation effects, various attenuation compensation techniques, for example, site diversity and transmit power control are introduced to the satellite communication systems [1]. The prediction of the attenuation characteristics is very important, to utilize these compensation techniques to a great extent. Up to now, very few studies have been performed in Japan for detailed attenuation characteristics such as fade slope or fade duration, compared to those of overseas researchers, e.g., [2]. This study presents detailed attenuation characteristics of the Ka-band satellite signals observed at 1 sec (partly 0.1 sec) interval, at Osaka Electro-Communication University (OECU) in Neyagawa, Osaka from 1997 to 2006 [3]. In these periods, rain types of all rainfall events are classified into four kinds of rain types, such as warm, cold, stationary fronts, and typhoon or shower that caused the rain attenuation. The comparison of the fade slope and fade duration characteristics is emphasized according to the difference in these rain types during four seasons of spring, summer, autumn, and winter.

## 2. Observation Methods

In this experiment, The Ka-band satellite signal from N-STAR was received with a cassegrain antenna of 5 m diameter. These signal levels were recorded by a personal computer equipped with a 16bit AD converter. The signal levels were originally sampled at 1 sec interval. The sampling intervals have been, however, shortened down to 0.1 sec since March 2003. The fade slope is calculated for the attenuation values that exceed a given threshold level. Also a 5-sec running average filter is applied to remove the noise and scintillation components. Each rainfall event is classified into the four types: warm, cold, stationary fronts and typhoon or shower, using the weather charts published by the Japan Meteorological Agency. Then, the fade slope is calculated using central differentials of the attenuation:

$$FS = \zeta(t) = \frac{A(t+1) - A(t-1)}{2} \quad [\text{dB/sec}] \quad (1)$$

where,  $A(t)$  is the attenuation at a given time.

## 3. Duration time and fade slope

Figure 1 shows cumulative probabilities of the fade duration observed from 1997 to 2006 according to the kinds of rain types, when the threshold is set to be 6 dB. These probabilities are further classified into four seasons such as (a) spring, (b) summer, (c) autumn, and (d) winter, respectively. Also, the black line indicates the ITU-R recommendations [4]. As a whole, the observed cumulative probabilities are found to agree fairly well with the ITU-R recommendations in each season. As for the rain types, however, the observed cumulative probabilities are shown to

be slightly higher than ITU-R recommendations except for the warm front. Specifically, the stationary front may cause longer duration times in (a) spring and (c) autumn seasons, while the typhoon may cause longer duration times in (b) summer and (c) autumn seasons. On the other hand, the longer duration times are caused by the cold front in (d) winter season. Thus, the duration time is considered to become longer than the ITU-R recommendations in (a) summer due to the effects of tropical climate such as the approach of typhoon, while the effects of subtropical climate such as the stagnation of Shurin (Akisame) stationary fronts are considered to be enhanced in (c) autumn. For all seasons, however, the cumulative probabilities of the cold front which is common in Europe and North America actually agree the best with the ITU-R recommendations which may be primarily based on the climate of these mid-latitude areas.

Figure 2 shows the distribution of the fade slope at 0.01 dB/s intervals for the seasons of (a) spring, (b) summer, (c) autumn, and (d) winter, respectively. This figure means that the changing rate of attenuation becomes higher as the fade slope becomes wider. In addition, as for the rain types, the occurrence probabilities of the fade slope show the widest distribution in the cold front events for (a) spring, (c) autumn and (d) winter seasons, indicating that the fluctuation of instantaneous attenuation values is largest. Such a large fluctuation is most likely to affect a quality of satellite communication links. On the other hand, the occurrence probabilities of the fade slope show the narrowest distribution in the warm front events, and they are narrow regardless of seasons.

These differences in the distribution of the fade slope according to the rain fronts seem to be caused by two different kinds of rain types: convective and stratiform types. In general, convective rain has larger rainfall in shorter time and small area than stratiform rain, resulting in larger values and fluctuation of rain attenuation. This may explain that the cold front events primarily composed of convective rain have a comparatively larger fade slope than the others, while the warm front events with a larger proportion of stratiform rain have a smaller fade slope. This nature of convective rain also explains the enhancement of probabilities of fade duration for the cold front events in shorter duration time as was shown in Fig.1.

The model of the fade slope shown in ITU-R recommendations [4] is also plotted by the black line in Fig.2. The observed fade slopes are similarly in fairly good agreement with the ITU-R recommendations in every season. The cold front is, however, found to give slightly wider distributions with faster attenuation variation than the ITU-R recommendations especially in (a) spring season together with other rain types, while the stationary front and typhoon are found to give narrower distributions with slower attenuation variation in (c) autumn season which may correspond to the Shurin (Akisame) season.

## 4. Conclusions

This study discussed detailed characteristics of the rain attenuation, such as the duration time and the fade slope observed on the Ka-band satellite propagation path in Japan, according to the various rain types in each of four seasons that have been rarely considered so far compared to the long-term statistics. This new analysis is enabled by the long-term continuous observations of the Ka-band satellite signal conducted for more than 10 years at 1 sec interval. As a result, the cumulative probabilities of the duration time become comparatively higher in the typhoon and stationary front events as the duration time increases, while the distribution of the fade slope becomes wider in the cold front events. Also, these observational results for both duration time and fade slope are, as a whole, in good agreement with the ITU-R recommendations. In more detail, however, the distribution of the duration time agrees the best in the cold front events which are common in Europe and North America, although that of the fade slope is slightly wider. As for the duration time, the typhoon and stationary front events which are unique in Japanese monsoon climate seem to give longer duration time than the ITU-R recommendations which primarily depend on European or North American climate. As for the fade slope, to contrast, the typhoon and stationary front events seem to give slower changing rate of attenuation. Thus, these characteristics may help to build more appropriate prediction models of fade duration and slope for Japanese original climate in the future.

## Acknowledgments

The authors express deep gratitude to Professor Akio Sato of Tokyo University of Technology who is the chief of Japanese ITU-R SG-3 group for useful comments and discussions.

## References

- [1] T. Iida, "Satellite communication (in Japanese)," Ohmsha, 1997.
- [2] M. M. J. L. van de Kamp, "Statistical Analysis of Rain Fade Slope," IEEE Transactions on antennas and propagation, vol.51, no.8, pp.1750-1759, August 2003.
- [3] K. Sawai and Y. Maekawa, "A study on characteristics of rain attenuation variation for each rain type in Ka-band satellite communication", JC-SAT2009, SAT2009-42, Nara, Japan, 2009.
- [4] Rec. ITU-R, P.1623-1, "Prediction methods of fade dynamics on earth-space paths," Geneva, 2005.

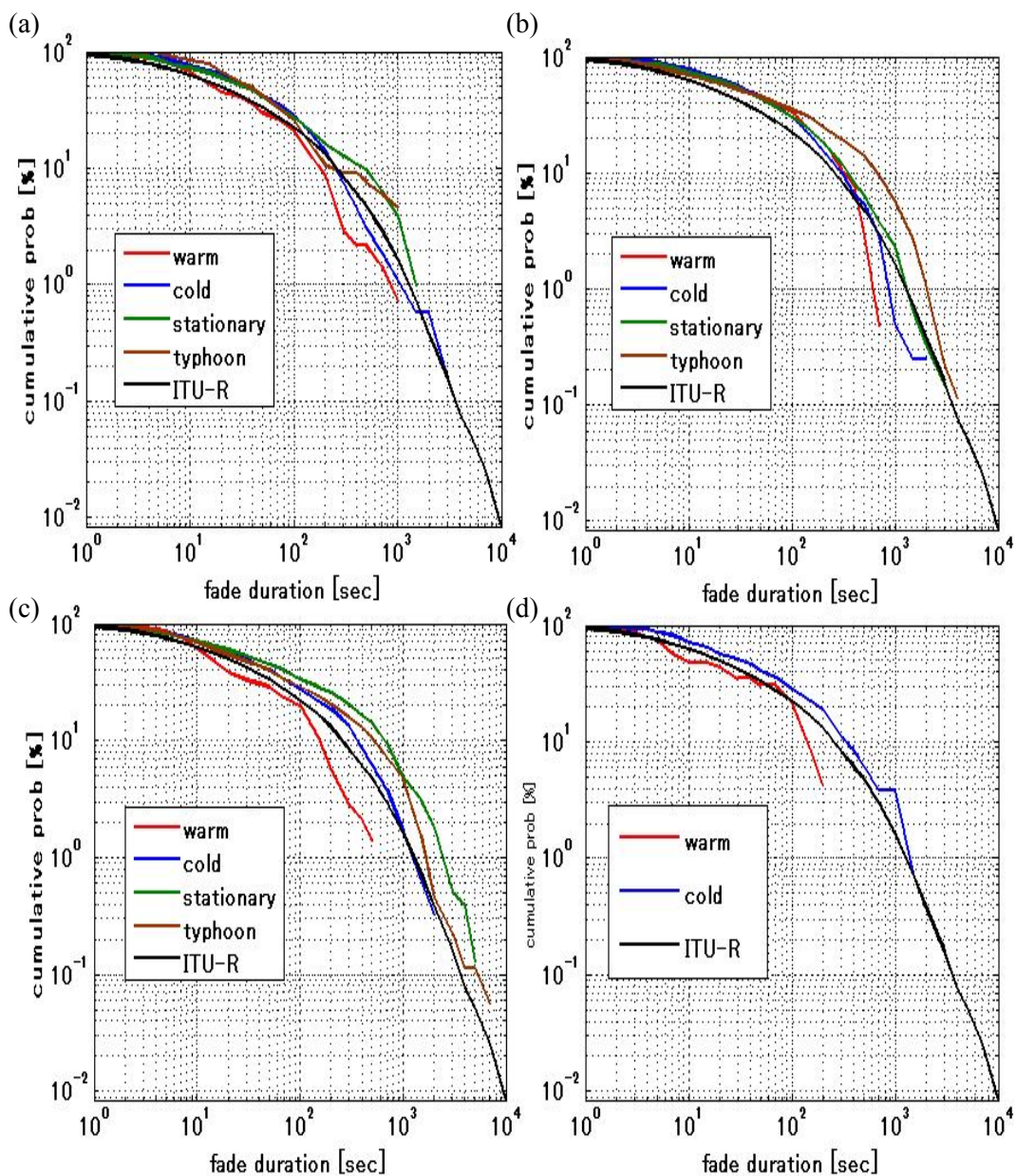


Figure 1: Cumulative probabilities of the fade duration observed from 1997 to 2006 in Osaka, Japan, according to each rain type for (a) spring, (b) summer, (c) autumn, and (d) winter, respectively.

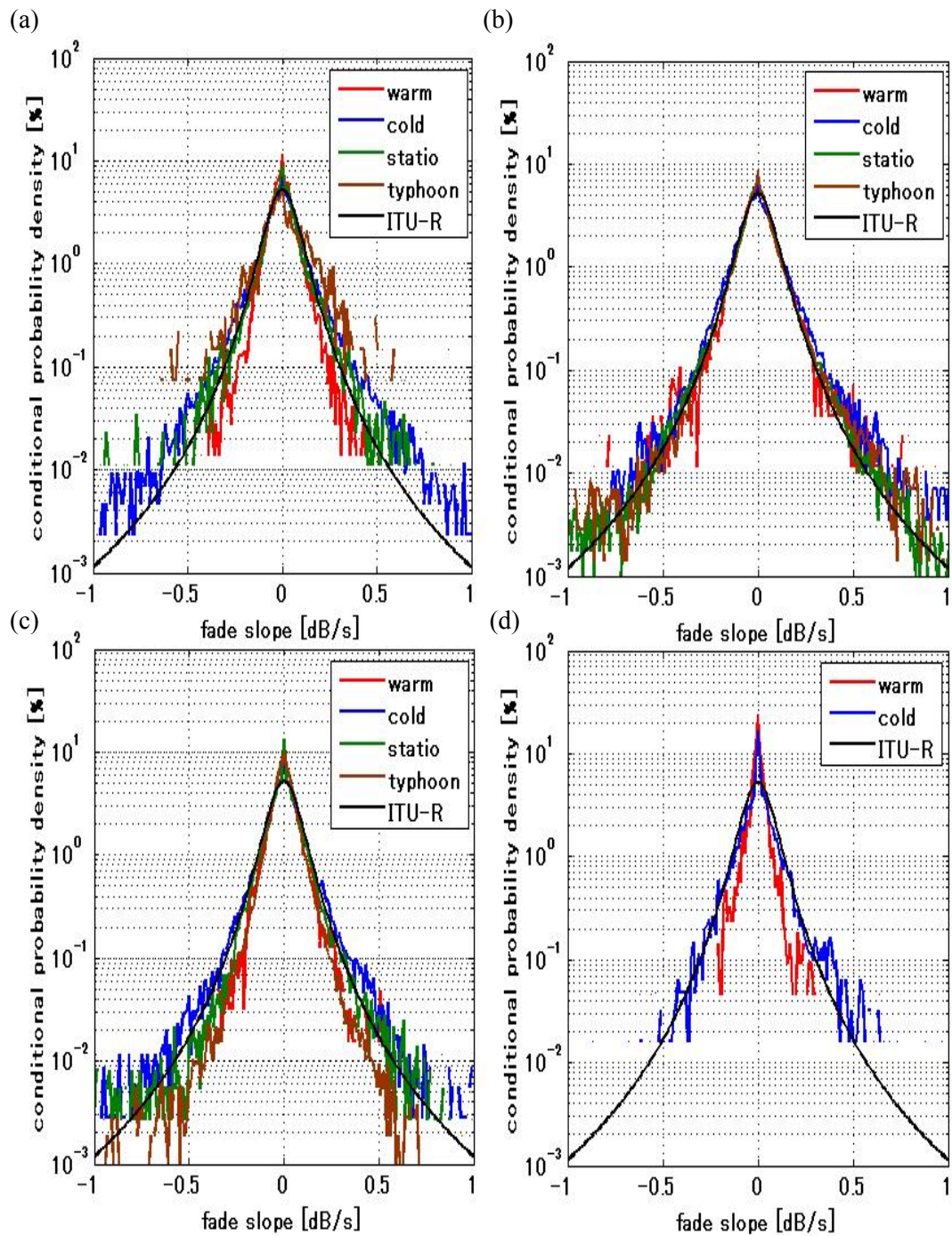


Figure 2: Distribution of the fade slope observed from 1997 to 2006 in Osaka, Japan, according to each rain type for (a) spring, (b) summer, (c) autumn, and (d) winter, respectively.