Fade Slope Comparison between Thailand and Japan for Ka band Rain Attenuation

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Abstract: Fade slope can be expressed the localized rain behavior using attenuation beacon data. This paper used Thaicom 2 and 3 beacon received in Thailand to represent rain occurrence in tropical areas and CS beacon received in Japan represents for temperate areas. Thaicom 2, 3 and CS beacon operated different frequency, the scaling formula from the International Telecommunications Union (ITU) R P.618-12 [1] standard is used for the comparison. Thaicom beacon frequencies from 12.57 (Thaicom 2) and 12.59 (Thaicom3) GHz in the Ku band are scaling up to the similar of CS beacon at 19.45 GHz. Moreover, we derived the indicators such as standard deviation and skewness obtained from fade slope to confirm rain attenuation activities in both regions.

Keywords—**Fade slope, Frequency scaling, Tropical attenuation, Temperate attenuation**

1. Introduction

Research on technology for mitigating the effects of rain attenuation in satellite communications is a high priority. The demands on communication networks around the world are increasing rapidly. As well as the increasing volume of information, there is demand for faster and higher quality communication links. To meet these requirements, it is necessary to expand the bandwidth used in satellite communications from the existing C- and Ku-bands to the Ka-band and above. Many countries would also like to use the C-band for ground level mobile communication networks. It is well known that rain attenuation presents a serious problem in satellite communications. In particular, rain attenuation can degrade higher frequency satellite signals. Tropical areas with high volumes of rainfall will be unable to use Ka-band satellite communications without mitigation technology [2].

Fade slope is a one of significant information to determine and predict the rain attenuation countermeasure as proposed by Van de Kamp [3], Dao [4] and others [5]-[9]. It is well known that fade slope is difference in which places are difference because it depends on rain type, rain drop size distribution, path length or even attenuation level in each observation areas.

In this paper, we investigated Ka-band rain attenuation in a tropical region using satellite data from the Thaicom 2 and 3 satellites, via King Mongkut's Institute of Technology Ladkrabang (KMITL) in Bangkok, Thailand. For non-tropical regions, we used satellite data from the Communication Satellite (CS) program via the Kashima Space Technology Center (KSTC) operated by the National Institute of Information and Communications Technology (NICT) at Kashima, Japan. These datasets were used to investigate the differences in rain fade duration and rain fade slope between temperate and tropical regions. The frequency of the datasets was standardized with the International Telecommunications Union (ITU) scaling formula, ITU-R P.618-12. The implications of these dynamic properties in the development of rain attenuation mitigation technologies for satellite communication are then considered

2. Data Used

Fade slope are calculated based on the received beacon data. This paper used two different sites in different rerions, one in a tropical area and another one in a non-tropical area. The parameters involved are listed in Table 1. In the case of the tropical zone, the beacon reception site was located at KMITL and receives transmissions from the Thaicom 2 beacon at an operating frequency of 12.57 GHz with vertical polarization, and the Thaicom 3 beacon operating at a frequency of 12.59 GHz with horizontal polarization. These satellites are co-located at 78.5°E longitude in geostationary orbit.

Table 1. Beacon received parameters.

	CS	Thaicom2	Thaicom3
Frequency	19.45 GHz	12.57 GHz	12.59 GHz
Polarization	circular	vertical	horizontal
Elevation angle	48°	59.83°	
Place	Kashima, Japan	Bangkok, Thailand	
Duration	2 years (Apr 1981-Mar 1983)	1 year (2006)	
Interval	1 sec		

For the temperate areas, we used the beacon data of CS operating at frequency of 19.45 GHz with circular polarization. We could only obtain 1 year (2006) of Thaicom 2 & 3 beacon received data at 1-second time intervals, but obtained 2 years of CS beacon received data covering the period between Apr 1981 and Mar 1983, also at 1-second time intervals.

3. Frequency Scaling

As previously mentioned, the signal obtained from Thaicom 2 and 3 beacons both operate in the Ku-band at frequencies of 12.57 and 12.59 GHz, respectively. In order to evaluate and compare Thaicom 2 and 3 rain attenuation behavior with that of the CS beacon, which is operating in the Ka-band at 19.45 GHz, it was first necessary to set up a scaling frequency in order to boost the Thaicom beacon up to the CS beacon level. The Thaicom 2 and 3 attenuation data set was estimated by using the ITU R. P.618-12 frequency scaling formula from the Ku- to Ka-band as the following equation below:

$$A_2 = A_1 (\varphi_2 / \varphi_1)^{1-H(\varphi_1,\varphi_2,A_1)} \quad (1)$$

$$\varphi(f) = \frac{f^2}{1+10^{-4} f^2} \quad (2)$$

$$H(\varphi_1,\varphi_2,A_1) = 1.12\times10^{-3} (\varphi_2 / \varphi_1)^{0.5} (\varphi_1 A_1)^{0.55} \quad (3)$$

where A_1 and A_2 are the equiprobable values of the excess rain attenuation (dB) at frequencies f_1 and f_2 (GHz), respectively.

Figure 1 shows attenuation of Thaicom 2 beacon increasing to 19 dB at 19.45 GHz from 9 dB at 12.57 GHz of the existing attenuation data set with vertical polarization and attenuation of Thaicom 3 beacon increasing to 25 dB at 19.45 GHz from 12 dB at 12.59 GHz with vertical polarization, after the appropriate attenuation formula is applied in the Ka-band. Thus, a significant rain attenuation difference of 10 dB and 13 dB of Thaicom 2 and 3 respectively when is observed as a Ka-band characteristic at 19.45 GHz.

4. Fade Slope Result

Fade slope is determined as the speed of change of attenuation with respect to time in dB/s. Fade slope can calculate from the consequence state of attenuation before and after as shown in Equation (4). For time interval can be used from 1 second. The distribution of fade slope is shown general symmetry around zero for positive and negative slope. The positive slope corresponds to the attenuation state due to the attenuation of *(i+1)* is higher than the attenuation of *(i-1)*. Alternatively, the negative values represents the recovery state due to the attenuation of *(i+1)* is lower than the attenuation of *(i-1)*. There are two parameters to express the behavior of rain attenuation derived from fade slope which are standard deviation (σ_ζ) and skewness *(S)*. However, if the skewness shows positive values, it is meant that the attenuation state is much occurred than recovery state, or represents the occurrence of convective rain in a tropical area. In the other hand, if the skewness shows negative slope, it is evidence of widespread rain happened or no suddenly change of attenuation. Fade slope formula from ITU R. P.1623 [10] is given by:

$$\zeta(i) = \frac{A(t+1) - A(t-1)}{2} \quad (4)$$

where A is the attenuation in dB and t is the time in second.

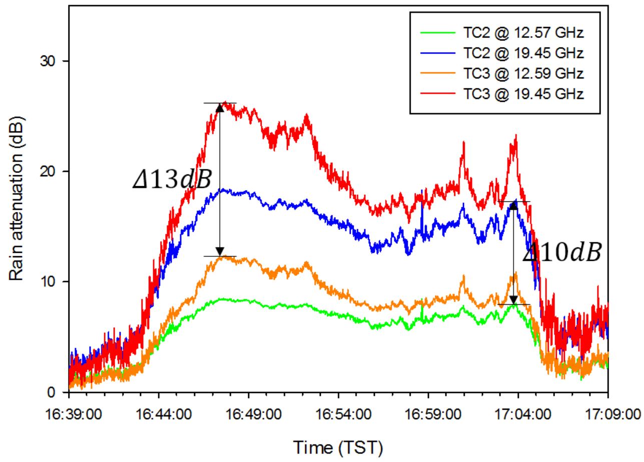
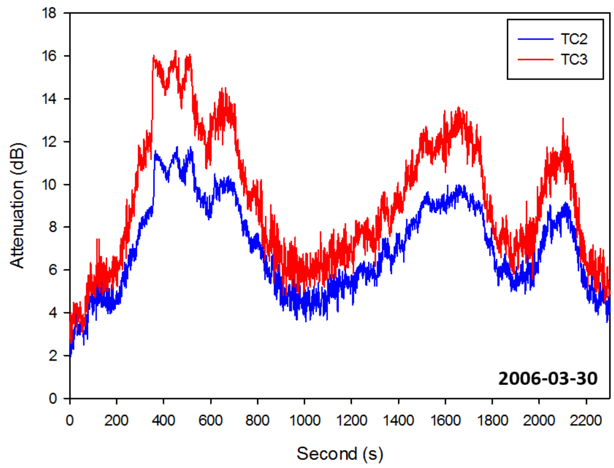
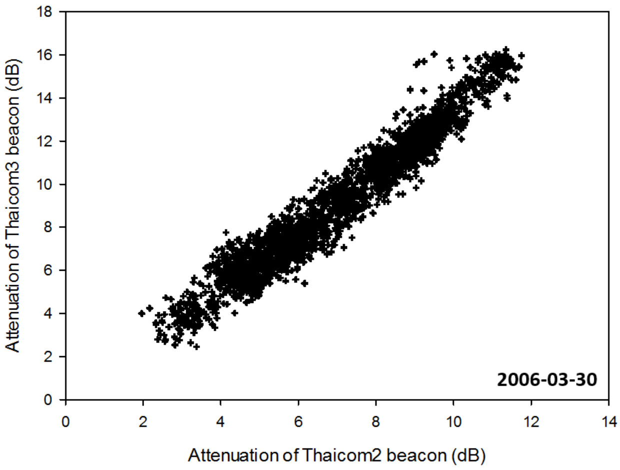


Figure 1. Sample of rain attenuation between Ku-band and Ka-band of Thaicom 2 and 3.

In this paper, we derived the fade slope using the CS, and the Thaicom 2 and 3 satellite datasets with time intervals of 1 second. To reduce noise from ground equipment or other unknown interferences, a minimum attenuation threshold of 2 dB at 19.45 GHz was selected for the calculations. The observation period for the CS (Thaicom 2 and 3) data was two (one) years. The Thaicom 2 and 3 satellites were located at a longitude of 78.5 °E in orbit and used the same receiver station but different polarizations. Figure 2 shows a comparison of the attenuations for the Thaicom satellites.



(a)



(b)

Figure 2. Rain attenuation comparison of Thaicom2 and 3. (a) sample of consideration period, (b) scatter plot of attenuation.

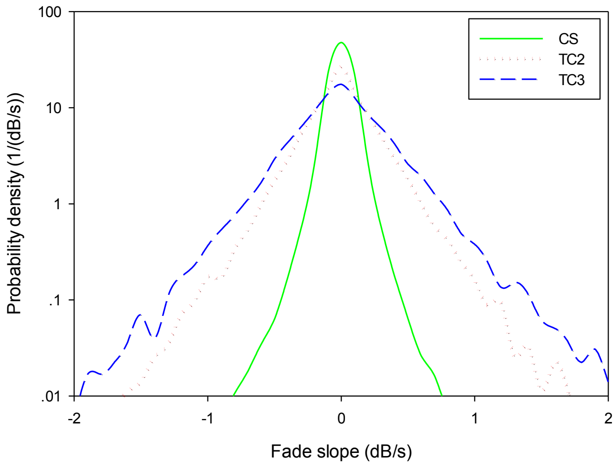


Figure 3. Fade slope comparison of Thaicom 2, 3 and CS.

Table 2. Indicatior describes the rain attenution behavior.

	Standard deviation (σ_ζ)	Skewness (S)
CS	0.09065	-0.11783
Thaicom2	0.26721	0.12172
Thaicom3	0.36103	0.09379

Figure 3 shows the distribution of fade slope of CS, Thaicom 2 and 3 beacon. The indicator that can expresses the behavior of rain attenuation are standard deviation *(σ_ζ)* and skewness *(S)* shown in Table 2. For standard deviation considering here, if the value of σ_ζ is small, the narrow band of fade slope is happened. It is also meant slow attenuation rate of change or represents the behavior of rain attenuation in a temperate areas. In the other hand, if the value of σ_ζ is large, the wide band of fade slope will be appeared. It is evidence of fast attenuation rate of change or represents the behavior of rain attenuation in a tropical areas. Moreover, to confirm the difference rain attenuation both tropical and temperate areas, shewness values is another one indicator to express this behavior trends. Table 2 shows negative value of *S* calculated from fade slope of CS beacon, it is confirming well with widespread rain happened in a non-tropical areas. The positive values of *S* obtained from Thaicom 2 and 3 beacon, it can be seen as evidence confirming the frequent apparent of attenuation state in tropical areas.

5. Conclusion

Dynamic properties is a valuable factor in order to determine and predict the efficiency of the rain attenuation mitigation methods. This paper presented the results of fade slope derived from satellite beacon compared between tropical and temperate areas. For tropical areas used the beacon signal from Thaicom 2 & 3 received in Thailand at 12.57 and 12.59 GHz respectively. Then Thaicom 2 & 3 beacon were scaled up to 19.45 GHz as same frequency as beacon signal received in Japan represents for temperate area. The frequency scaling was performed based on ITU R. P.618-12 and the results were used to calculate fade slope to consider the behavior and effect of rain attenuation in the Ka band at 19.45 GHz

Fade slope can expresses well the behavior of rain attenuation in both regions by derived some factors which are standard deviation and skewness. The standard deviation of fade slope is presented the speed of change of attenuation. The narrow band of fade slope of CS beacon is describe as rain attenuation changed slowly. But for the wide band of Thaicom 2 & 3 beacon can be expressed that the rain attenuation changed rapidly in tropical areas than CS beacon in temperate areas. The skewness factor can be presents the type of rain by the derived values. The Thaicom 2 & 3 and CS beacon shows clear the different values to confirm the different type of rain occurred between tropical and non-tropical areas.

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