Study on Ka band Propagation Effect by Rain

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Abstract

The Ka band satellite system performance describe by the contribute of rainfall rate and rain attenuation.This paper include the comparison of rain attenuation in Ku band and Ka band system caused by rainfall rate in Bangkok area. The experimental results for the 99.99 percent reliability of satellite system, the rain attenuation $A_{0.01}$ on Ka band is 20 dB, while Ku band is about 11 dB when the rainfall rate $R_{0.01}$ is 90 mm/hr.

Keywords — Rain attenuation, Ku and Ka band satellite signal propagation, Yearly cumulative time of rainfall rate, ITU-R model.

1. Introduction

The effects of rain on the transmission path are major problem in space communications. Regarding back ground, satellite communication is considered as the most effective in high frequency bands such as Ka band or millimeter wave band (frequency 30/20GHz).Thailand start to used Ka band in commercial satellite. However, the effect of rain attenuation or fading is more significant than in lower frequency such as Ku band and C band, the fluctuation of received signal level caused by rain is a major problem in radiowave propagation.

Propagation impairments affect on Ka band satellite links include gaseous absorption, cloud attenuation and rain attenuation on troposphere. The rain fade is considered as dominant impairment. The loss of radio signal or attenuation due to rain can degrade the reliability and performance of telecommunication links, especially in the tropical zone such as Thailand which have long period of rainy season in each year. The attenuation due to rain can be predicted by standard model such ITU-R [2],[3],[4], [5], Crane [7].

In this study, rainfall rate and rain attenuation characteristics of Ka band satellite signal, and correlation between rainfall rate and cumulative of time are proposed. The rainfall rate data measured by tipping bucket rain gauge, long term data hourly and annual precipitation data are observed at Bangkok, Thailand and rain attenuation of Ka band provide ITU-R model to predicted rain attenuation and compare with the measuring rain attenuation on Ku band from Thaicom3 and Thaicom5.

2. Experimental methods

The experiment parameters of receiving system in Bangkok are listed in table1.

TABLE 2: PARAMETERS OF RECEIVING SYSTEM AT BANGKOK

Longitude	100.7 ^{O} E
Latitude	13.7 ^{O} N
Azimuth angle (Thaicom3)	239.62 ^{o}
Elevation angle (Thaicom3)	59.81 ^{o}
Azimuth angle (Thaicom5)	125 .62 ^{o}
Elevation angle (Thaicom5)	62.62 ^{o}
Rain guage type	Tipping bucket

Fig.1 is illustrated rainfall rate measurement diagram. The pulse numbers of rain guage is counted to data logger and recorded by the computer. The rainfall amounts are sampled at every 1-second and the resolution of the tipping-bucket type rain gauge for measured rainfall rate is 0.5 mm/tip. This is minimum detectable sensitivity. The total experiment time is one year period from January to December 2005.

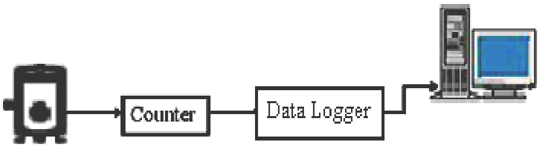

Fig. 1: The experiment block diagram of rainfall rate

3. Experimental Results

A. Rainfall Rate Observation Results

The cumulative time of rainfall rate in monthly with high rainfall rate are investigated. The experimental result from Fig. 2 pointed at 0.01% of cumulative time for the high rainfall rate in November is about 120mm/hr.

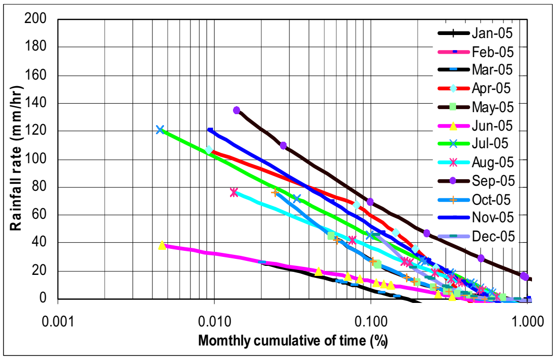

Fig.2: Monthly cumulative of rainfall rate.

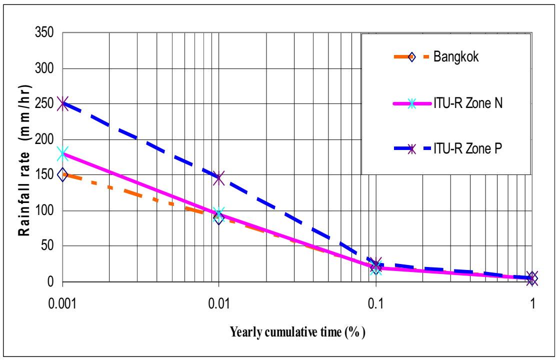

Fig. 3: Comparison between ITU-R zone P, zone N and rainfall rate.

The value of rainfall rate compared to ITU-R Zone N and Zone P are presented in Fig. 3. And yearly cumulative time of rainfall rate in 1 second and 1 minute are indicated in Fig 4. We found that at 0.01% of cumulative time the rainfall rate is about 90mm/hr in 1 minute while in 1 second is 110 mm/hr because of more particulars data.

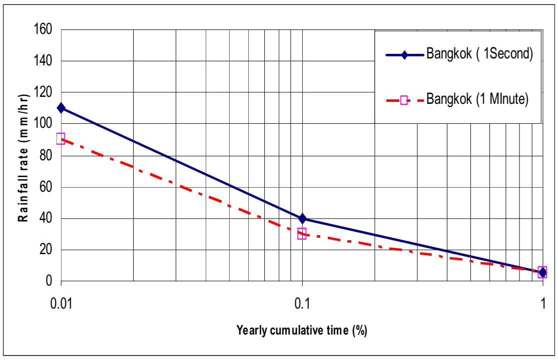

Fig.4: Yearly cummulative time of rainfall rate in 1 Sec. and 1 Min.

4. Rain Attenuation Model on Ka Band

A. Rain attenuation at specific elevation angle.

Attenuation model use for predict attenuation due to precipitation and clouds along slant path. The following procedure provides estimate of the long term statistics of the slant path rain attenuation at giving location. As the result of rain attenuation related to cumulative time of rainfall is indicated. ITU-R model is a standard model used for predict the rain attenuation in global rain zone. This model divides the prediction area in zone N, P…etc, by rainfall intensity at any percentage of time [6].

We used ITU-R model to predict rain attenuation in Ka band from Thaicom5 satellite signal. The general method to predict attenuation due to precipitation and clouds along slant propagation path. The following procedure provides estimates of the long term statistics of the slant path rain attenuation at giving location for frequencies up to 55 GHz. The following parameters are required: point rainfall rate for the location for 0.01% of an average year $R_{0.01}$, height above mean sea level of the earth station h_S, latitude of the earth station φ, the slant path length L_s and specific attenuation γ_R.

For the path length through rain is shown in Fig. 5 where L_s is the effective path length of the signal through the rain. Because the rain density is unlikely to be uniform over the actual path length, an effective path length must be used rather than the actual length. Interpolations formulas on the climatic zone are available for values of percent time of *p*. Because of the path at low elevation angle is longer than at high elevation angle, the rain attenuation values are larger than those values at higher elevation angle.

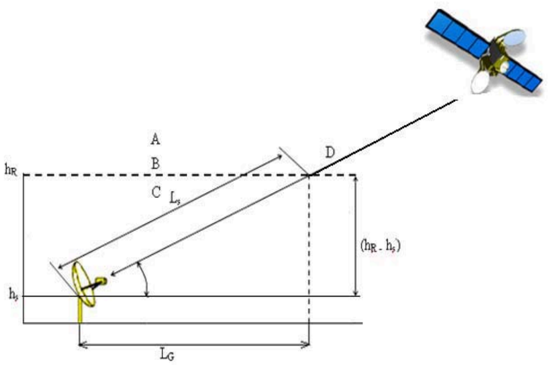

Fig.5 : Path length through rain.

Slant path length L_s is given by:

$$L_s = \frac{(h_R - h_s)}{\sin\theta} \qquad \text{km} \qquad (1)$$

The specific attenuation γ_R is a function of rainfall rate given by:

$$\gamma_R = k(R_{0.01})^{\alpha} \quad \text{dB/km} \qquad (2)$$

Where k and α are coefficient of frequency and polarization parameters. The signal received at 20 GHz, $k = 0.0751$, α = 1.099 which given by ITU-R P.618-7.

For the predicted attenuation exceeded 0.01% of an average year is:

$$A_{0.01} = \gamma_R L_E \qquad (3)$$

Estimated attenuation to be exceeded (P %) for other percentages of an average year is:

$$A_p = A_{0.01}\left(\frac{p}{0.01}\right)^{-(0.655+0.033\ln(p)-0.045\ln(A_{0.01})-\beta(1-p)\sin\theta)} \qquad (4)$$

This method provides an estimate of the long-term statistics of attenuation due to rain. When compared the measured statistics with the prediction, allowance should be given for many years variability in rainfall rate statistics by ITU-R.

The prediction result of ITU-R zone P and N are accurate at 145 mm/hr and 95 mm/hr respectively while data from the site in Bangkok is about 90mm/hr .The comparision of predicted rain attenuation on Ka band at Bangkok is shown in Fig.6.

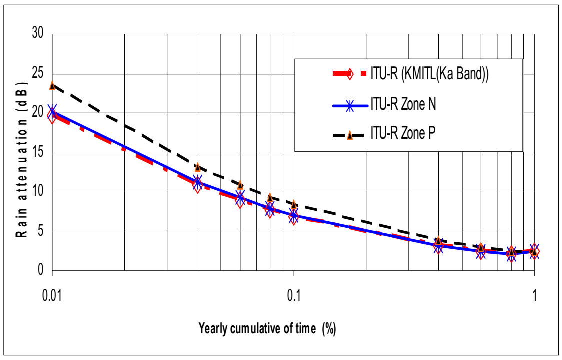

Fig.6: Comparison of rain attenuation between ITU-R Zone N, Zone P and prediction model in Ka band

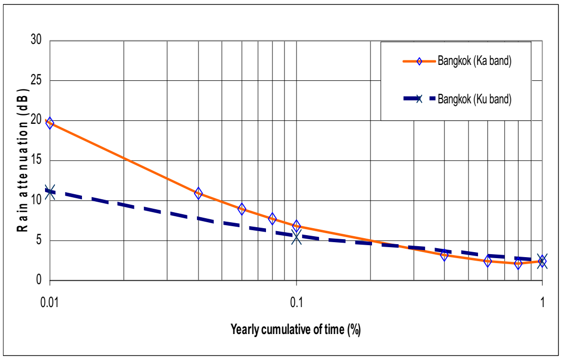

Fig.7: Comparison between Ka band and Ku band rain attenuation.

In addition the measurement of rain attenuation on Ku band from Thaicom 3 satellite is proposed by Fig.7.and compare to the predicted rain attenuation in Ka band.The attenuation result of Ka band is 20 dB at 0.01% of yearly cumulative time which is higher than the rain attenuation in Ku band about 9dB. It's mean that the link of heigher frequency is more effected than lower frequency at the same rain rate.

B. Prediction of rain attenuation at different elevation angle.

Satellite receiving angle is a parameter of rain attenuation as the ITU-R formula. Then the different receiving place will have different rain attenuation under the same rainfall rate.

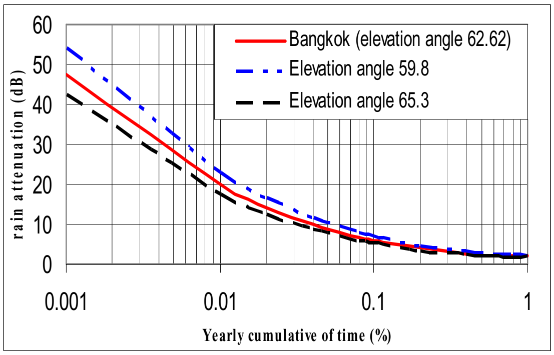

Fig.8: Comparison rain attenuation prediction model in ka band satellite signal at different elevation angle.

We propose the prediction rain attenuation at three elevation angles 59.8 ^{o} , 62.6 ^{o} and 65.3 ^{o} . The result of rain attenuation from prediction model at 0.01% of 59.8 elevation angles is about 23.125 dB, 62.6 ^{o} elevation angles is 19.95 dB and 65.3 ^{o} elevation angles is 17.56 dB. The rain attention at 59.8 ^{o} elevation angle higher than 65.3 ^{o} elevation angles about 5 dB.

5. Conclusion

This paper indicated the effect of rain attenuation in Ka band satellite signal using rainfall rate at Bangkok, Thailand. The monthly and yearly cumulative time of rainfall rate and rain attenuation compare to the ITU-R rain zone model is approach to ITU-R zone N. In addition we use ITU-R model to predict rain attenuation in Ka band and compare to measurement rain attenuation in Ku band in thaicom satellite. From the result, we found that rain attenuation of Ka band exceed 20 dB while the rain attenuation of Ku band is about 11 dB at 0.01% of exceed time and the elevation angle is important factor for satellite receiving signal, the high rain attenuation is depend on elevation angle. From the results of prediction model at different three elevation angles, we found that the lowest elevation angle 59.8 ^{o} attenuation is higher than 59.8 ^{o} elevation angle 5 dB are compared. This summarize that Ka band rain attenuation is strongly effect to satellite communication link for this region.

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References

[1] T.Boonchuk et al "The Rain Attenuation in Ku band Satellite Signal at Bangkok, 2005 fifth international Conference on Information, Communications and Signal Processing: ICICS 2005, 6-9 December 2005, Bangkok, Thailand.

[2] Koji Yasakawa, Matsuichi Yamada, "*The 11.9 GHz rain attenuation and site diversity effect on the earth-space paths of low elevation angles*",Radio Science Volume 20 Number 6 ,1985.

[3] Recommendation ITU-R P.839-3, "*Rain height model for prediction methods*", ITU-R P.839-3, 2001.

[4] Recommendation ITU-R P.838-2, "*Specific attenuation model for rain for use in prediction methods*", ITU-R P.838-2, 2003.

[5] Recommendation ITU-R P.618-7, "*Propagation data and prediction methods required for the design of Earth-space Telecommunication system*", ITU-R P.618-7, 2001.

[6] Recommendation ITU-R P.837-4, "*Characteristics of precipitation for propagation modeling*", ITU-R P.837-4, 2001.

[7] Crane.R.K (1980); "Prediction of Attenuation by rain", IEEE Trans. Commun., COM-28.

[8] Dennis Roddy, "*Rain Attenuation P.92-97*", Satellite Communication, New York: McGraw-Hill, 1996