Ka-Band Space Diversity Study by Using TRMM Nasa Data in Tropical Region for Satellite Communication.

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Abstract : Commercial exploitation of the Ka-Band for satellite communications is in the development stage, while V-band services have been planned, to access the large bandwidths allocated at these frequencies for satellite communication and other applications. Better understanding of the propagation characteristics in these bands is desirable, both to develop and validate models to predict propagation impairments, and for development of technique to mitigate the propagation impairments. One impairments mitigation technique that offers potential for many applications is space diversity. This technique is very effective for satellite communication in tropical regions, because these regions always experience heavy rainfall and relatively bigger raindrop compared to the temperature regions.

The objectives of this study are to determines the vertical rain profile such as rain rate, rain attenuation, and single site diversity gain for space diversity in satellite communication operating in tropical region. Vertical rain profile will be determined from NASA Precipitation Radar (PR) data from Tropical Rainfall Measuring Missions (TRMM). Comparison with weather radar and rain gauge data will be carried out.

1.0 Introduction

The three types of data used in this project are TRMM data, weather radar data and rain gauge data. The specification of the data was covered in the first paper [1]. The TRMM precipitation radar (PR) is the first spaceborne rain radar that has been develop by NASDA and Communications Research Laboratory of Japan (CRL), and is able to directly observe the vertical distributions of rain. The PR has 128 element active phased array to measure 3-D rain distribution over the swath width of 215km with horizontal resolution (footprint size) is 4.3 km at nadir and range (vertical) resolution of 250m [2].

File 1C-21 (PR radar reflectivity) was selected to analyze rain profile in this study. The 1C-21 calculates the effective radar reflectivity factor at 13.8 GHz without any propagation loss (due to rain or any other atmospheric gas) correction (Zm). Therefore, the Zm value can be calculated by just applying a radar equation for volume scatter with PR system parameters. The empirical relation between radar reflectivity, Z(dBZ) and rain rate,R (mm/h) is Log-Normal KL [3]. The relation between power reflectivity and rain rate as below,

$$Z=320R^{1.4} \text{ (dBZ)} \qquad (1)$$

where Z is power reflectivity in dBZ and R is rain rate in mm/h.

The empirical relation between specific attenuation, A_s (dB/km) and rain rate, R (mm/h) is

$$A_s = aR_{0.01}{}^{b} \text{ (dB/km)} \qquad (2)$$

where parameter a and b is regression coefficients for estimating specific attenuation. A_s and R_s is specific attenuation and rain rate at 0.01 percentage.

2.0 Space Diversity

Space diversity is the technique to improve the overall link performance by taking advantages of finite size of rain cell or the spatially inhomogeneous nature of rain [4]. Through space diversity, two or more earth stations are deployed to establish more than one propagation paths from a satellite. Assuming that impairments on the different paths are usually decorrelated, traffic can be then either be switched between the paths, or the multiple signals might be combined. The benefits of space diversity, such as preservation of traffic for many paying customers and bandwidth protection can be worth substantial investment in duplicate earth station facilities and necessary terrestrial interconnection. Space diversity is generally more viable for downlink protection, unless some form of information recovery is available. This space diversity study is based on two models, the Hodge model and ITU-R model (Rec.P.618-5, 1997) [5].

3.0 Result & Analyses

3.1 Comparison Cumulative Distribution between MMSR(Kluang), TRMM PR and Rain Gauge.

The rain rate, R (mm/h) was calculated from Eq. 1 using KL-Log Normal. Figure 2(a) and figure 2(b) show the relationship between % probability of occurrence and rain rate for PR TRMM for a nine- month period and MMSR (Kluang) for a six -month period. Figure 2(c) is a cumulative distribution for rain gauge at Labis for a period of nine years and Segamat for seventeen years.

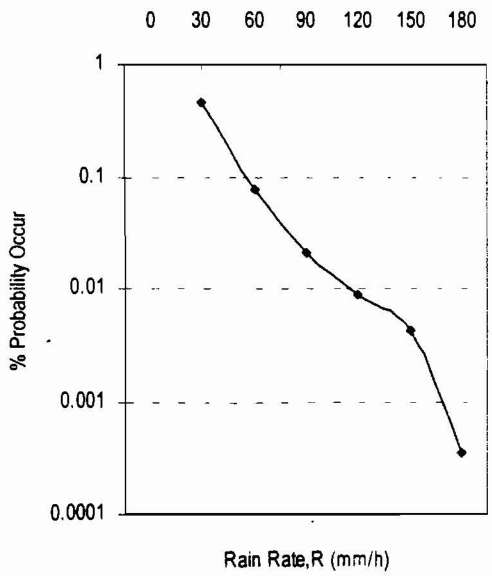


Figure 2(a) : Cumulative Distribution for TRMM PR at Kluang.

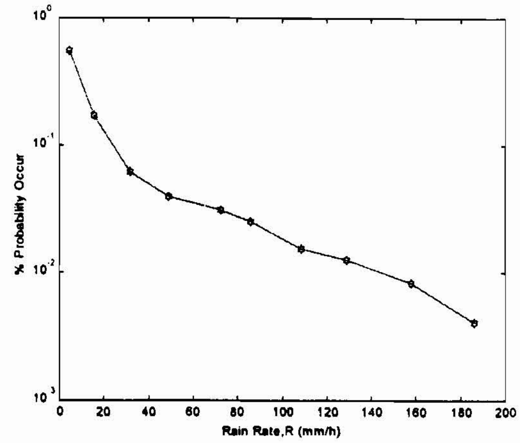


Figure 2(b) : Cumulative Distribution for MMSR at Kluang

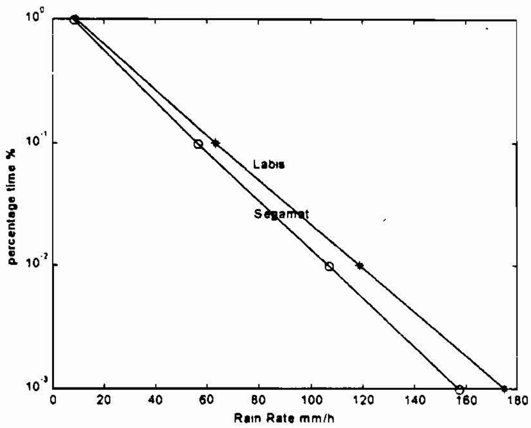


Figure 2(c): Cumulative Distribution for Rain Gauge at Labis and Segamat

The comparison of $R_{0.01}$ between the measured and proposed by ITU-R and MMSR (KL)[2] is shown on Table 1.

Table 1 : Comparison $R_{0.01}$ Between PR TRMM, MMSR, ITU-R and KL

Type	$R_{0.01}$ (mm/h)
PR TRMM (Kluang)	120
MMSR (Kluang)	142.7
ITU-R (P-Region)	145
MMSR(KL)	141
Rain Gauge(Labis)	119
Rain Gauge (Segamat)	107

The radar rain rate data obtained (a few months), as shown in Table 1 is lower than the rain rate proposed by ITU-R and MMSR (KL). This is because the radar data is limited.

3.2 The comparison of Specific Attenuation, As between MMSR (Kluang), TRMM PR, ITU-R and Rain Gauge.

The specific attenuation, A_s (dB/km) was calculated from Eq. 2 for frequency 10 GHz, 15 GHz, 20 GHz, 25 GHz, 30 GHz, 35 GHz and 50 GHz. Figure 4 shows the specific attenuation, A_s (dB/km) versus frequency, f from 10 to 40 GHz.

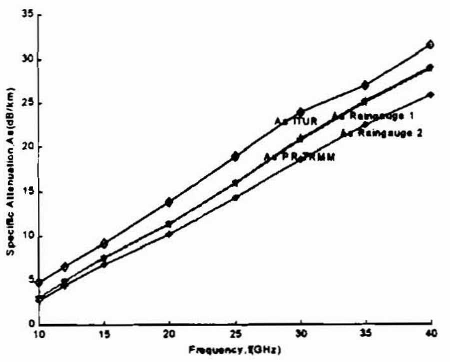


Figure 4: Comparison specific attenuation , A_s (dB/km) for PR TRMM(Kluang), MMSR(Kluang),RainGauge 1&2 (Labis/Segamat)and ITU-R.

Figure 4 shows that both the attenuation for PR TRMM and MMSR (Kluang) is lower than that of the ITU-R and rain gauge. This is because the radar data (only a few months) is not available for cumulative distribution.

3.3 Space Diversity Gain

The comparison of rain rate for PR TRMM and rain gauge are shown in Table 2.

Table 2: Comparison Rain Rate, R (mm/h) for PR TRMM and Rain Gauge at Labis and Segamat.

Type	$R_{0.01}$ (mm/h)
PR TRMM	
Labis	104.60
Segamat	100.07
Rain Gauge	
Labis	119
Segamat	107

The specific attenuation (A_s) and total single site attenuation (A) of the two locations, namely Labis (103.03E, 2.38N) and Segamat (103.08E, 2.27N) are:

As (Labis) = 13.9448 dB/km

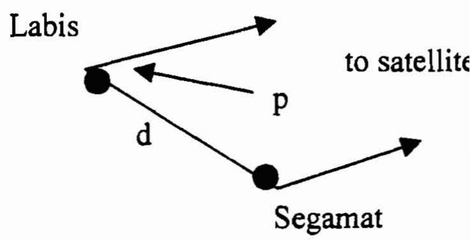
As (Segamat) = 13.3316 dB/km

A (Labis) = 62.7141 dB

A (Segamat) = 60.9798 dB

The diversity gain was calculated based on the Hodge Model [4] and is found to have the values below:

Site separation, d = 13.41 km
Baseline orientation, p = 67.53°



Thus,

G_D = **40.9029**

This suggests that, an improvement of 40.9029 dB will take place if the site diversity method is to be implemented. In other words, the average attenuation that will take place in the system will only be around 21 dB if the space diversity approach is applied.

4.0 Conclusion and future works

From the results shown above, we can conclude that the attenuation suffered by the satellite receivers can be reduced through the application of the space diversity method. The data that was being used in this paper was the TRMM and rain gauge data. However, the TRMM data was incomplete because only a period of nine-month data was collected. It is therefore, an essential step to verify the validity of the TRMM data. The rain gauge data was then used to verify the TRMM data. It is found that the difference in the TRMM data and the rain gauge data was very small. Thus, the TRMM data is proved to be valid.

The future works will mainly be focusing on more analysis of the TRMM data. Once the TRMM data is able to characterize the slant path rain profile of satellite receivers, it will be used in the calculations of the space diversity gain, instead of the ITU-R recommendation. The TRMM data is a more suitable approach because it can characterize the actual slant path attenuation.

Acknowledgments

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