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SATELLITE-EARTH RAIN ATTENUATION PREDICTION IN TROPICAL REGIONS USING TWO-PART MODEL

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ABSTRACT

Two years of rain rate and attenuation measurement in Malaysia is presented. The analysis shows that the attenuation follows the power law and linear law for rain rates below and above a certain cut-off rain rate respectively. A simple Two-Part model is proposed for consideration in the tropical regions.

Keywords: satellite, ku-band, propagation, rain attenuation.

INTRODUCTION

At Ku-band, rain becomes a major constraint in the satellite-earth link in the tropical regions that experiences very heavy rainfall. The ITU rain attenuation model was derived based on data collected predominantly from temperate regions. This causes uncertainties when used in the prediction of rain attenuation in the tropical regions [1]. The one-size-fits-all model proposed by ITU will not yield the best result for tropical regions. The solution will be to propose a more refined model to cater for the tropical regions based on data derived from direct measurements in the tropical regions.

Satellite beacon measurement at Ku-band was initiated at University Science Malaysia (USM) in collaboration with the Ministry of Post and Telecommunications, Japan to study the effects of propagation impairment factors particularly rain on satellite communications in the tropical regions.

MEASUREMENTS

The data collection system was set up in Tronoh, located at 4.367 ^{0}N, 101 ^{0}E which consists of a beacon receiver, two tipping bucket rain gauges and a data acquisition system. The earth station is 100 m above sea level. The tipping buckets were placed at the measurement site and at a distance of 2 km away along the propagation path respectively. The beacon signal level from the satellite (Superbird-C, 144 ^{0}E) at 12.255 GHz at an elevation angle of 40.1^0 was recorded every second. The average value for one minute was stored in the data acquisition system. The uptime of the beacon measurement system for the two years (Dec 1998 to Nov 1999 and Dec 1999 to Nov 2000) was 95.3% and 98.9% respectively. Only attenuation values of 4 dB and above was considered in the attenuation analysis. Attenuation of less than 4 dB is usually caused by other factors such as clouds, gaseous absorption, scintillation and wet antenna loss [2]. The difference between the clear sky beacon level and the beacon level during rain events gives the rain attenuation level. The setup is shown in Figure-1.

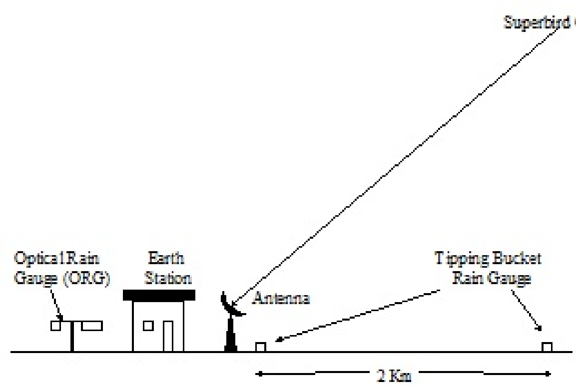

Figure-1. Measurement setup.

The rain rate measurement was made using tipping bucket type rain gauges with one-minute integration time. The bucket size is equivalent to 0.5 mm of rain. The number of tips is counted and stored in a battery operated micro-logger cassette. The complete data logging system consists of a tipping bucket with a power supply, micro-logger cassette, computer interface and software. The micro-logger has a logging capacity in excess of 6000 minutes of measurements. The uptime of the rain gauges for the two years was 99.2% and 98.9% respectively. Only the measurement from the tipping bucket at the antenna is used in the analysis.

RESULTS AND ANALYSIS

Rain attenuation and rain rate for two years at Tronoh was analysed. The attenuation and rain rate plot for the same percentages of time was plotted using the equiprobability method [3]. Figure-2 shows the equiprobability plot of attenuation versus rain rate. A power law relationship was obtained between the attenuation and rain rate as follows:

$$A = 0.1417R^{1.1244} \quad (1)$$

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where A is the attenuation in dB and R is the rain rate in mm/h.

Figure-2 clearly shows that there is a distinct break in attenuation at around a rain rate of 90 mm/h. Taking this into consideration, the attenuation was analysed for rain rates at and below 90 mm/h and at above 90 mm/h. Figure-3 shows the attenuation plot for rain rates at and below 90 mm/h and the attenuation plot for rain rates above 90 mm/h is shown in Figure-4.

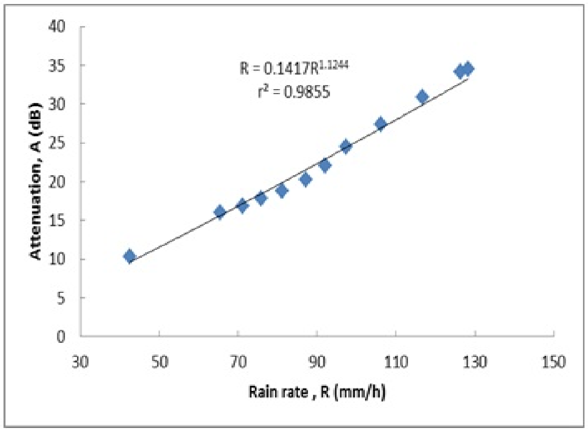

Figure-2. Attenuation versus rain rate.

The attenuation was found to follow a power law for rain rates at and below 90 mm/h, of the form:

$$A = 0.3142R^{0.9325} \ (R \leq 90mm/h) \qquad (2)$$

The attenuation for rain rates above 90 mm/h seems to follow a linear relationship as follows:

$$A = 0.3386R - 8.7549 \ \ (R > 90mm/h) \qquad (3)$$

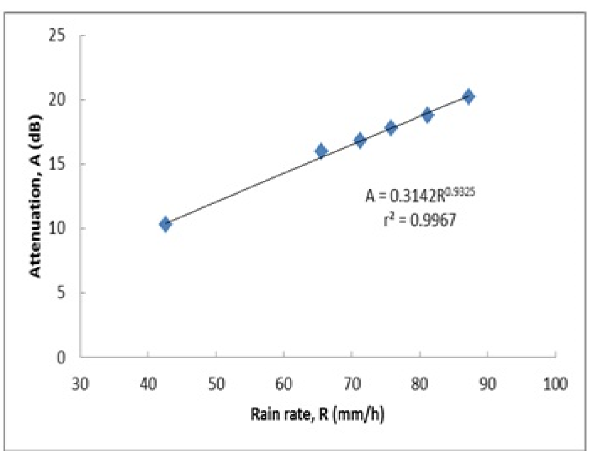

Figure-3. Attenuation for R ≤ 90 mm/h.

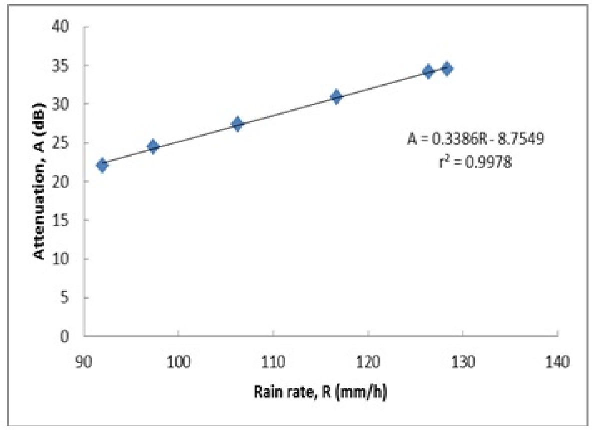

Figure-4. Attenuation for R > 90 mm/h.

The attenuation values derived from the Two-Part model was calculated using equations (2) and (3) for R ≤ 90 mm/h and R > 90 mm/h respectively and compared to the measured attenuation as shown in Table-1.

Table-1. Comparison of attenuation between measured and Two-Part model.

%	R (mm/h)	A (dB)	Two-Part model		% diff
			A for R ≤ 90 mm/h (dB)	A for R > 90 mm/h (dB)	
0.20	42.58	10.29	10.39		+0.97
0.10	65.52	15.94	15.52		-2.63
0.09	71.24	16.79	16.78		-0.06
0.08	75.84	17.76	17.79		+0.17
0.07	81.21	18.75	18.96		+1.12
0.06	87.29	20.19	20.28		+0.44
0.05	92.02	22.06		22.40	+1.54
0.04	97.33	24.46		24.20	-1.06
0.03	106.28	27.32		27.23	-0.33
0.02	116.68	30.92		30.75	-0.55
0.01	126.40	34.10		34.04	-0.18
0.009	128.35	34.45		34.70	+0.72

A comparison between the measured attenuation and Two-Part model indicates that a power law gives a good approximation for rain rate at and below 90 mm/h and a linear law for rain rates above 90 mm/h. The break in attenuation at around 90 mm/h has also been reported earlier for a single year measurement at Tronoh [4]. In other tropical regions, a break in attenuation at higher rain rate has also been reported [5, 6, 7, 8, 9].

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The measured rain rate and attenuation at Tronoh for 0.01% of the time for the two years are 126.4 mm/h and 34.10 dB respectively. Figure-5 shows the comparison between the measured attenuation value at Tronoh to that of ITU-R model [10, 11].

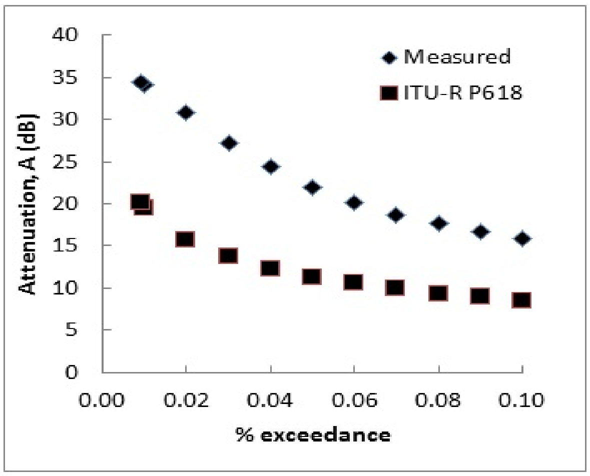

Figure-5. Comparison between measured attenuation to ITU-R model.

CONCLUSION

Since the rain in tropical regions can be characterized into convective and widespread types that have different rain dropsize and rainfall distribution, this factor would contribute to different attenuation distribution for different rain rate ranges as evident in the Two-Part model. Recent research in Malaysia also reaffirms that the attenuation prediction using breakpoint yields a more accurate result [12]. The Two-Part model could be considered as an alternative rain attenuation model in the tropical regions in establishing a reliable satellite-earth link. Furthermore, it is evident that the ITU-R model underestimates the rain attenuation in the tropical regions as shown in Figure-5.

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