Monthly and Diurnal Variability of Rain Rate and Rain Attenuation during the Monsoon Period in Malaysia

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Abstract. *Rain is the major source of attenuation for microwave propagation above 10 GHz. In tropical and equatorial regions where the rain intensity is higher, designing a terrestrial and earth-to-satellite microwave links is very critical and challenging at these frequencies. This paper presents the preliminary results of rain effects in a 23 GHz terrestrial point-to-point communication link 1.3 km long. The experimental test bed had been set up at Skudai, Johor Bahru, Malaysia. In this area, a monsoon equatorial climate prevails and the rainfall rate can reach values well above 100 mm/h with significant monthly and diurnal variability. Hence, it is necessary to implement a mitigation technique for maintaining an adequate radio link performance for the action of very heavy rain. Since we now know that the ULPC (Up Link Power Control) cannot guarantee the desired performance, a solution based on frequency band diversity is proposed in this paper. Here, a secondary radio link operating in a frequency not affected by rain (C band for instance) is placed parallel with the main link. Under no rain or light rain conditions, the secondary link carries without priority radio signals. When there is an outage of the main link due to rain, the secondary link assumes the priority traffic. The outcome of the research shows a solution for higher operating frequencies during rainy events.*

Keywords

Rainfall rate, rain distribution, rain attenuation, diurnal variability, monthly variability, power control, frequency diversity, radio link, system availability.

1. Introduction

The evaluation of system availability due to rain attenuation in a line-of-sight radio link is normally based on the annual cumulative distribution of precipitation rate for terrestrial and earth-to-satellite link [1]-[3]. However, in equatorial climates the monthly and even the diurnal variability of rain must be taken into account. This problem is particularly critical in regions where the rainfall can reach higher levels during the monsoon season. In this context, it must be pointed out that Malaysia is located in the equatorial region and is surrounded by extensive amount of water with heavy rainfall through-out the year and the precipitation distribution is patterned by monsoon activities. During the monsoon period, the rain is characterized by a sequence of bands of intense convective precipitation followed by intervals of stratiform precipitation. As a consequence, besides the monthly variability, a concentration of intense rain is also observed at specific hours of the day. Keeping in mind the need for solutions to improve the performance of radio systems in monsoon climate environment, this paper deals with the analysis of the variability of rainfall rate and rain attenuation in the equatorial monsoon climate of Malaysia.

2. Experimental Set-up

A 23 GHz radio link, 1.3 km long, was set up in Skudai, Johor Bahru, Malaysia. The received signal level was observed simultaneously with precipitation rate measurements using a 0.2 mm tipping bucket rain gauge placed in an open area near the experimental site. Rain measurements were collected for thirteen months from June 2011 till June 2012 with one minute interval for each day using data logger. Fig. 1 shows the block diagram of this experimental set-up.

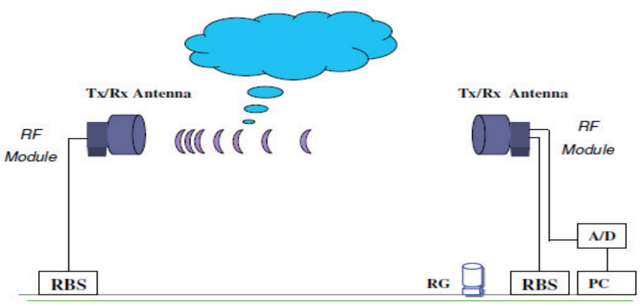

Fig. 1. Block diagram of the experimental set-up (test bed).

3. Characterization of the Monsoon Period

From the analysis carried out here, the rain shower can be classified according to its rate of fall as shown in Tab. 1. The Malaysian meteorological department recommendation has been used for this classification. Tab. 2 displays the recorded precipitation intensity in percentage for various rain types from June 2011 to June 2012. Clearly the monsoon period is between October and December with a maximum rainfall in the latter month. A pictorial view of the rain behavior in this period is illustrated in Fig. 2.

Rain type	Precipitation rate R (mm/h)
Slight rain	$R < 2$ mm/h 2 mm/h $\le R \le$ 10 mm/h
Moderate rain	10 mm/h $\le R \le$ 50 mm/h
Heavy rain	50 mm/h $\le R \le$ 100 mm/h

Tab. 1. Rain types.

Month	< 2 mm/h (Very slight rain)	2-10 mm/h (Slight rain)	10-50 mm/h (Moderate rain)	> 50 mm/h (Heavy rain)	>100 mm/h (Very heavy rain)
JUNE'11	10.8	16.0	3.3	2.2	0
JULY'11	7.5	6.7	6.3	1.8	0
AUG'11	8.1	9.1	8.2	1.5	0
SEPT'11	15.5	19.1	10.5	3.3	0
OCT'11	10.5	7.8	15.7	21.2	20.6
NOV'11	23.0	16.3	38.1	44.7	35.3
DECE'11	24.6	25.1	17.8	25.3	44.1
JAN'12	18.5	16.0	14.5	10.5	20.0
FEB'12	15.0	11.0	10.0	5.5	12.0
MAR'12	11.0	10.5	8.0	3.0	5.0
APR'12	12.2	8.5	6.5	2.5	0
MAY'12	10.0	9.5	7.0	1.5	0
JUNE'12	9.5	15.0	4.0	2.0	0

Tab. 2. Recorded rain fall intensity in percentage from June 2011 to June 2012.

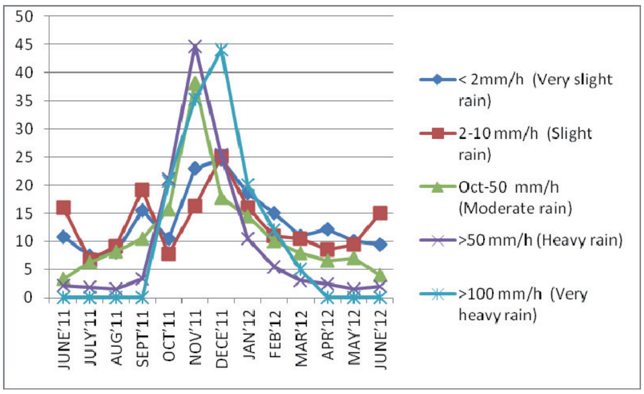

Fig. 2. Recorded rainfall trend in percentage for various rain types.

4. Results and Discussion

4.1 Seasonal Variability

The rainfall rates exceeding 0.1% and 0.01% of time will be used as a reference in the analysis that is carried out in this section. The monthly cumulative distribution of the rainfall rate from June 2011 to June 2012 is presented in Fig. 3. The rain rate values corresponding to the month of December and the average distribution can be derived from this figure. These values are shown in Tab. 3 together with four years measurements carried out at the same location [4]. It is observed in Fig. 3 that the annual average distribution practically coincides with the average values from June 2011 to June 2012.

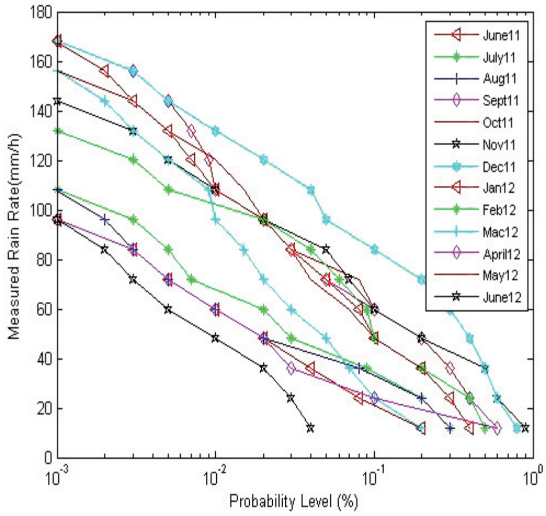

Fig. 3. Monthly rainfall rate cumulative distribution for Johor Bahru.

Period of reference	Percentage of time % the rain rate (mm/h) exceeds	
	0.1	0.01
December 2011	84	144
Average distribution (June 2011 to June 2012)	60	120
Four years distribution	59	125

Tab. 3. Quantiles distribution of rain rate [6].

The rain attenuation for the same periods referred to in Tab. 3 was evaluated, taking as a reference a model recently derived by Assis [5]. The results are shown in Tab. 4. On the other hand, a preliminary evaluation of rain attenuation for the precipitation rates of 60 mm/h and 90 mm/h has shown values of 15 dB and 30 dB. These values are in tandem with the theoretical evaluation for the last two lines in Tab. 4. Additionally, it is observed that there is a difference of 5 dB ~ 6 dB with the corresponding attenuation values for December.

Period of reference	Percentage of time % the rain attenuation (dB) exceeds	
	0.1	0.01
December 2011	23.7	37.1
Average distribution (June 2011 to June 2012)	17.8	31.9
Four years distribution	17.5	33.0

Tab. 4. Rain attenuation after Assis model [5].

As a consequence of the above results, it is clear that there is a pivotal need of an engineering solution to overcome the higher attenuation during the worst monsoon month. Two solutions can be considered:

(i) Up-link power control (ULPC) [7] – possibly the most adequate for case in question once a margin of 5 dB is not excessive. However, it must be pointed out that, this technique is not viable for higher margins;

(ii) Frequency band diversity (FBD) – a solution which is currently being developed by the first author in his doctoral thesis at University Technology Malaysia (UTM).

In the FBD solution a parallel radio link operating in a frequency not affected by rain (5.8 GHz in the case of UTM development) is placed in parallel with the main link. When there is an outage of the main link due to rain, the secondary link assumes the priority traffic. Although more expensive than the ULPC, it has an inherent advantage of having free channel when there is no critical rain effects. Hence, this channel can be used for secondary transmissions without priority.

4.2 Diurnal Variability

Tab. 5 shows a summary of the hourly distribution of rain intensity during the day in the monsoon period. The time period with average rain fall rate for a day in a monsoon period been shown in Tab. 5. It is observed in this case that, rainfall rates higher than 100 mm/h must be taken into account in the period between 1 p.m. and 7 p.m. From a commercial point of view, this period covers important office labor hours from 1 p.m. to 5 p.m. and the beginning of prime time period from 6 p.m. to 7 p.m. As a reference to highlight rain effect in these hours, it must be pointed out that a rainfall rate of 160 mm/h corresponds to an attenuation of 40.4 dB in the 23 GHz link used in this paper [8], [9]. The margin relative to the maximum monthly attenuation evaluated previously was around 7 dB ~ 8 dB. Clearly the ULPC solution cannot be used. Consequently, the frequency band diversity described earlier becomes the most indicated solution to overcome the problem of rain attenuation. It should be pointed out that the worst period in the afternoon hours was also observed in the Amazon region of Brazil [6].

Time	Intensity of rain	Percentage
1.00 – 7.00 pm	50 ~ 160 mm/h	70 %
Breakdown		
1.00-3.00 pm	50 ~ 80 mm/h	15%
3.00-4.00 pm	>100 mm/h	30%
5.00-6.00 pm	Maximum ~ 160 mm/h	25%
Other periods	< 100 mm/h	30%

Tab. 5. Diurnal variability.

5. Conclusions

The study carried out in this paper has evidenced the importance of taking into account the rainfall behavior during the monsoon period in Malaysia. Both the monthly and diurnal variability were considered. Engineering solutions which are considered adequate to solve this problem is the well-known ULPC and the frequency band diversity (FBD) as proposed here. It should be noted that the ULPC solution is not viable to compensate a rain margin higher than 5 dB ~ 6 dB above the attenuation values based on the annual distribution [10]. In such a case, the FBD appears as a better solution [11]. Of course, this problem is also observed in other countries where the monsoon equatorial climate prevails. It is hoped that the proposed FBD solution would also help them to improve the performance of their radio links.

Acknowledgments

The authors would like to acknowledge and express their sincere appreciation to the Technology University of Malaysia (UTM) and the Ministry of Higher Education (MOHE) for financing the research project under the Research University Grant (RUG), title: Rain propagation studies and mitigation technique at 5.8 GHz and 26 GHz for point-to-point application, vote no. Q. J130000.7123. 01H05.

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Kesavan ULAGANATHEN was born in Malaysia. He obtained his bachelor's and Master's degree from the University Technology Malaysia in 1997 and 2005, respectively. He is currently a full-time PhD research student at the Wireless Communication Centre (WCC), Faculty of Electrical Engineering, University Technology Malaysia (UTM), Malaysia. His research interests include radio-propagation and rain-attenuation studies in tropical regions. Kesavan is currently working on development of 5.8 GHz links as redundancy for 26 GHz links for terrestrial point-to-point microwave links in tropical regions.

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