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PERFORMANCE EVALUATION OF AN IMPROVED ITU-R RAIN ATTENUATION PREDICTION MODEL OVER MALAYSIA EQUATORIAL REGION

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***Abstract*:**

Attenuation due to rainfall is one of the most fundamental constraints on the performance of satellite links above 10 GHz. This work presents the results of rain attenuation measurement using radar data collected from MMD and DIDM Malaysia. The results were compared with newly improved ITU-R P530-16 and four other selected tropical rain attenuation prediction models. The statistical analysis showed that ITU-R P 530-16 has significantly addressed the problem of rain attenuation underestimation prediction as presented by older version of the recommendation.

Key words: Radar data; Satellite signal; Rain attenuation; Standard deviation; Equatorial region

I. INTRODUCTION

The performance of radio communication system in term of reliability and availability of any radio link depends majorly on the propagation medium between the transmitter and the receiver (Omotoso and Oluwafemi(2009a,b). Satellite signal propagation above 10 GHz in free space is not only adversely affected by rain but also impaired by other natural phenomena such as gaseous attenuation, cloud and fog attenuation, and scintillation. As the frequency increases, so does the impact of atmospheric conditions on the radio wave propagation (Ippolito, 2008; MMD, 2012 a,b; Ito and Hososya,1999) which causes reduction in the quality of signal in the case of analogue transmission, and an increase in the bit error rate (BER) in the case of digital transmission. It is therefore very imperative when planning for both earth-to-space and terrestrial line-of-sight system links; to make an accurate prediction of rain rate and the corresponding induced rain attenuation along the propagation paths.

The International Telecommunication Union-Radio Sector (ITU-R) has made several research efforts to develop and ratify a global model suitable for rain attenuation prediction both at line of sight and slight path for the two major rainfall regions of the world: temperate and tropical region. However, several ample of research findings in tropical and equatorial regions have been reported to yield low performance while applying ITU-R global model (Semire, 2013; Ito and Hosoya, 2002; Semire et al., 2015). Meanwhile, the latest version of ITU-R 530-16 recently released is yet to be validated using measured rain attenuation data from equatorial and tropical region (Green, 2004). Hence the need to carry out this performance analysis using rain radar data from Malaysia.

The radar data employed were obtained from Meteorological Department of Malaysia (MMD) while rain rate data were collected from Department of Irrigation and Drainage Malaysia (DIDM) (ITU-R. 2009). The result is compared with five selected tropical rain attenuation prediction model. In brief, this paper is arranged as follows: section II describes the experimental procedures and data collection. Section III presents the results and performance evaluation of the new ITU-R model. Finally, the conclusion is given in Section IV.

II. EXPERIMENTAL PROCEDURES AND DATA COLLECTION

In this study, four month radar data from November, 2008 to February, 2009 were obtained from MMD, from which, data from the Butterworth, Subang and kuching radar stations were employed. The details of Malaysia radar parameters can be accessed from Goddard and Thurai (1997) and Yagasena et al. (2000). The radial lines exploited in this study were selected based on the virtual link concept employed by Semire et al., (2015) and Ong et al. (1995). Goddard used both links along the radial lines and orthogonal to the scanning radar. The angles for virtual paths links were selected based on ITU-R recommendation on worst month concept (ITU-R, 2009. The virtual link selection was based on worst case scenario, in which the angles with better rain rate readings or where rain is likely to occur are selected. Aside radar data, rainfall data of ten years collected from DIDM were also employed for rain rate distribution analysis. The measurement site parameters are as shown in Table I.

Table I: Measurement Site parameters

Location	Longitude (^{0} E)	Latitude (^{0} N)	Frequency(GHz)	Annual rainfall (mm)	Path length (km)
Kuching	110.35	1.48	12.255	2204.3	5.0
Subang	101.55	3.12	12.255	2882.5	6.0
Butterworth	100.38	5.47	12.255	2581.6	10

III. RESULTS AND PERFORMANCE EVALUATION

The cumulative distributions function (cdf) of the measured rain rate and rain attenuation are as shown in Figure 1 (a) and (b). The cdf revealed highest distribution pattern in Butterworth followed by Subang. The reason attributed to this is the location of the station. Butterworth is located in the island of Penang State, where frequent and high rainfall occurrence is expected which could be due to conventional type of rainfall. Lowest pattern is observed in Kuching. The average of ten years annual rain accumulation is as shown in Table 1.

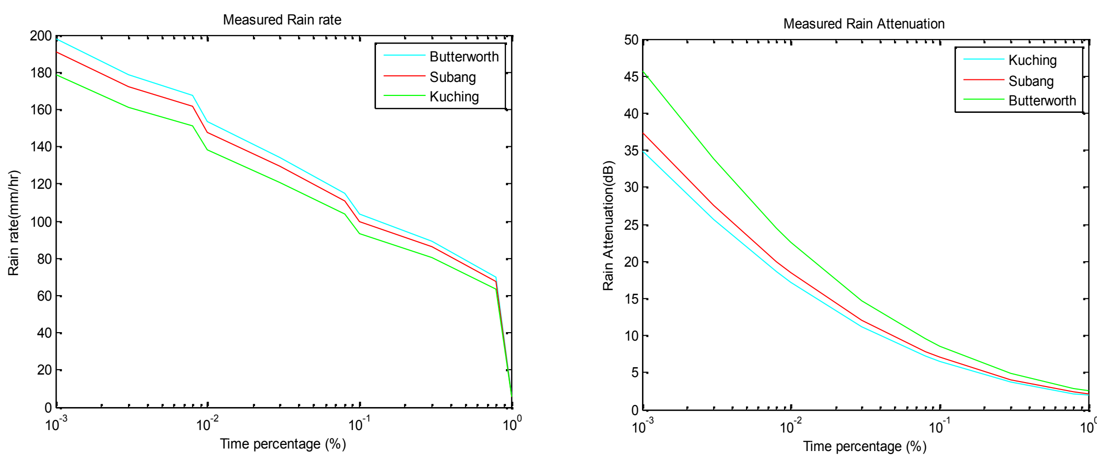
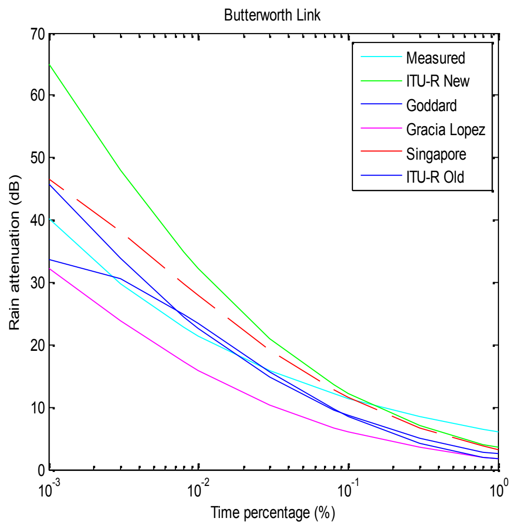
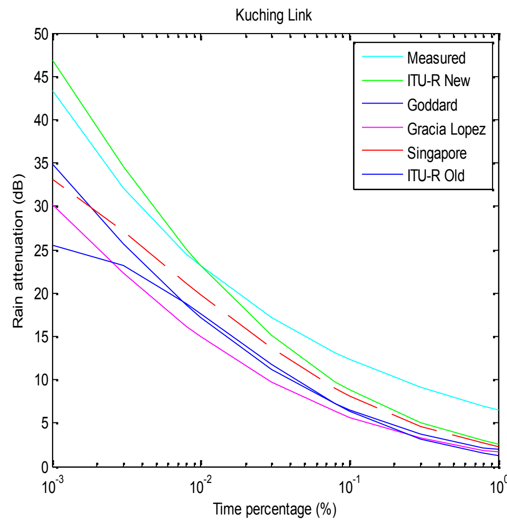


Figure 1 (a) and (b): Measured rain rate and rain attenuation distribution

The comparison of measured and the predicted rain attenuation is as shown in figure 2 (a)-(c). The results revealed that out of five selected models considered, two models overestimated rain attenuation for Butterworth station with the new ITU-R model having the highest attenuation value at higher unavailability time. This is followed by Singapore model with 27.89dB at 0.01 percentage time. ITU-R new and Singapore model overlapped below 0.1 percentage of time. The result also showed slight underestimation between 0.1 and 1.0%. Underestimation was observed throughout the percentage of time for Gracia Lopez, Goddard and ITU-R old model. Similar trend was observed on Subang link. On the contrary, Kuching link showed overlapped of the predicted and measured attenuation at 0.01 percentage of time. Down the line, the trend showed sharp deviation between 0.03 and 1.0

percent of unavailability.





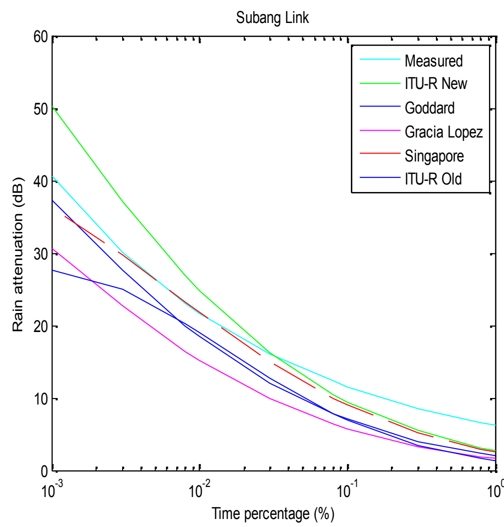


Figure 1I (a) and (c): Comparison of measured and predicted rain attenuation

Further comparison was statistically evaluated using the ITU-R P 311-13 recommendation ITU-R (2015), the results showed that Gracia Lopez has the highest mean error (μ) at Kuching link together with root mean square (rms) and standard deviation (σ) which shows high disagreement as compared with measured data. The ITU-R P 530-16 has significantly addressed the problem of rain attenuation underestimation prediction.

Table II: Statistical comparison at 0.01% for the selected locations

Location	Parameters	ITU-R new Model	Goddard Model	Gracial Lopez Model	Singapore Model	ITU-R old Model
Kuching	μ	0.03	-0.33	-0.50	-0.21	-0.38
	σ	0.04	0.02	0.02	0.04	0.09
	rms	0.05	0.33	0.50	0.21	0.39
Subang	μ	0.19	-0.17	-0.04	-0.02	-0.02
	σ	0.04	0.03	0.02	0.03	0.08
	rms	0.20	0.17	0.40	0.03	0.22
Butterworth	μ	0.51	0.09	-0.33	0.29	0.05

	σ rms	0.06 0.52	0.04 0.10	0.02 0.33	0.02 0.30	0.07 0.09

IV. CONCLUSION

The results of statistical analysis of rain rate and rain attenuation measurement using radar and rain gauge data collected from MMD and DIDM have been presented and compared with five tropical rain attenuation prediction models. The result in the selected links showed great improvement in rain attenuation prediction of the ITU-R P 530-16. Although, point accuracy is far fetch in reality, however more improvement is needed on the model as to address its insufficiency in tropical and equatorial rain attenuation estimation.

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