4D2-1

Assessment of Seasonal Asia Monsoon Rain Impact on the Earth-Space Propagation in Equatorial Kuala Lumpur

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1. Introduction

Future satellite communication systems are moving towards high operational frequencies, typically in the Ka band (18 to 30 GHz) to deliver wider bandwidths and higher data rates in response to the increasing demand for broadband communication services and the congestion of Ku band (11 to 18 GHz). As well known, signal degradation due to rain can be a main limiting factor in this frequency band, especially in tropical and equatorial regions [1]. Equatorial regions are characterized by wet months throughout the whole year and there is no alternation of summer and winter as in temperate regions. However, the climate in South East Asia, where Kuala Lumpur is located, is strongly seasonal because of the different monsoons caused by the changes in the direction and speed of airstreams [2]. Hence, it is worthwhile to further assess the impact of this monsoon variation on the Earth-space propagation in this specific equatorial location.

In this work, we present an extensive analysis of long-term rain attenuation statistics, focusing on seasonal variations for a Ka band satellite communication system whose ground station is located in Kuala Lumpur, Malaysia. Results are analyzed from the local drop size distribution (DSD) measurements collected by a disdrometer in the 1992-1994 periods and the usage of Synthetic Storm Technique (SST). The details on the DSD databank and on the seasonal variation of rainfall rate are briefly presented in Section 2. Afterwards, rain specific attenuation inferred from DSDs is discussed in Section 3. In Section 4, long-term rain attenuation statistics (Ka band) are predicted by means of the SST and focusing on the seasonal variation. Finally, Section 5 draws some conclusions.

2. Disdrometer Data and Monsoon Seasonal Variation

Three-year DSD measurement campaign has been carried out from January 1992 to December 1994 employing Joss-Waldvogel disdrometer (RD-69), installed inside the University of Technology Malaysia Campus (101.42º E, 3.08º N), Kuala Lumpur, Malaysia (UTM). The disdrometer provided about 100512 minutes of rainy time with 60-second integration time T, from which 781 rain events were classified by considering a dry period of at least 1-hour between an event and the following one. The availability of the recorded data for the complete three-year period is larger than 98% for all months.

Kuala Lumpur characterized by an equatorial climate, which exhibits two monsoon seasons, named North-East monsoon (December to March) and South-West monsoon (June to September), and two Inter-monsoon seasons (April to May and October to November) [2] as evidenced on monthly basis in Fig. 1.

Based on such climatology characteristics, we investigate the rain rate seasonal variation by considering three different seasons: i) North-East, ii) South-West and iii) Inter-monsoon. Fig.2

shows the seasonal complementary cumulative distribution functions (CCDFs) relative to the whole three-year period, together with recommendation ITU-R P.837-6 [3]. We can observe considerable differences between the South-West season and the other two seasons at high rain rates (i.e. approximately higher than 70 mm/h).

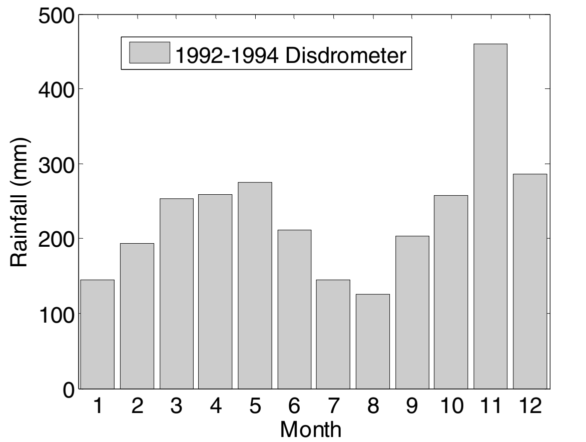

Fig. 1. Monthly variation of rainfall accumulation in Kuala Lumpur.

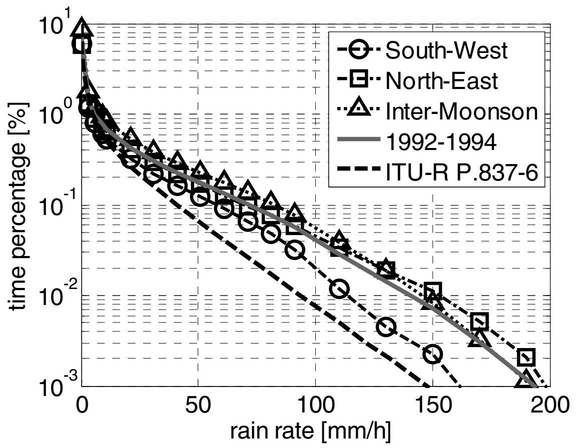

Fig. 2. Seasonal variation of rainfall rate in Kuala Lumpur, compared with recommendation ITU-R P.837-6.

3. Specific Attenuation from Disdrometer data

The prediction of rain attenuation depends on the specific rain attenuation γ defined as the attenuation per unit distance, usually expressed in dB/km. This quantity can be easily estimated from rain rate by using the power law relationship $\gamma = kR^{\alpha}$, whose coefficients can be extracted from recommendation ITU-R P.838-3[4] or calculated using local DSD data coupled with classical techniques aimed at estimating the scattering and absorption properties of hydrometeors. Fig.3 illustrates the average drop size distribution as a function of the average rain rate and 20 different bins corresponds to the drop diameter ranging from 0.3 mm to 5 mm.

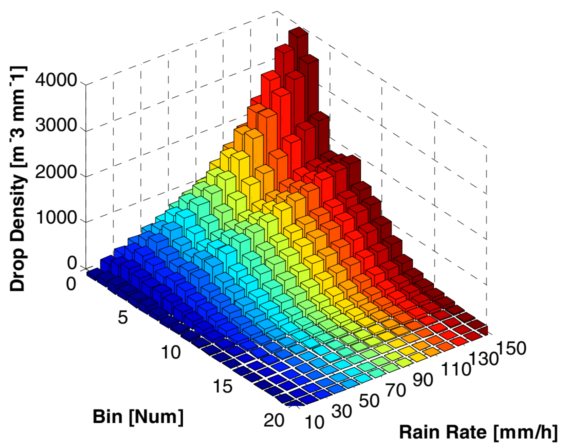

Fig. 3. Average drop size distribution as a function of rain rate

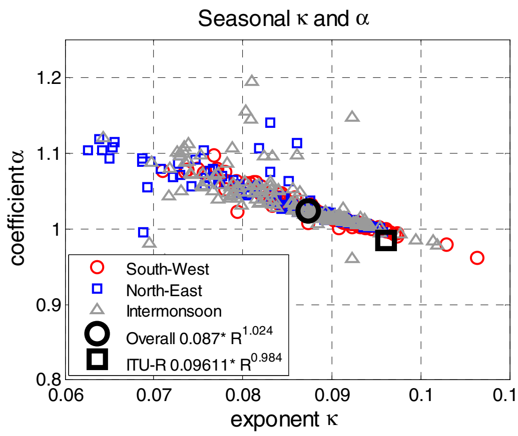

Fig. 4. Scatter plot of power law curve-fitted coefficient k and α for estimating specific attenuation of each rain events on a seasonal monsoon basis.

In the present work, we focused on a frequency in the Ka band (20 GHz) and employed the point matching technique to calculate the extinction properties of rain drops. In order to deeply investigate the rain attenuation process, the coefficient of the $\gamma = kR^{\alpha}$ relationship where calculated from rain rate and specific attenuation values both on event basis and on overall basis. Fig.4 shows the scatter plot of coefficients k and α as extracted from 781 rain events. The figure also reports the average fitting coefficients regardless of the rain event classification. The variability of the $\gamma = kR^{\alpha}$ clearly emerges from the marked dispersion of the points, which means that the average k and α coefficients might not always be representative of the specific attenuation affecting Earth-space link. The probability density distributions for coefficients k and α are presented separately in Fig. 5 and Fig. 6 to provide an indication of the spread of the coefficients considering all events. It is also worth mentioning that the coefficient of determination R^2, which indicate the representativeness of the power law relationship between specific attenuation and rain rate, is higher than 99.9% for all the events. This implies that the $\gamma = kR^{\alpha}$ relationship is representative of the whole event, or, in other words, that no strong variation of the rain attenuation process can be noticed within the same event. Fig. 7 and Fig. 8 clearly confirm the above statements by showing the two events with the best and worst R^2.

Fig.9 shows the comparison between the CCDFs of specific attenuation calculated using each one-minute sample of disdrometer data and calculated from using the $\gamma = kR^{\alpha}$ relationship (overall coefficient indicated in Fig. 4)..

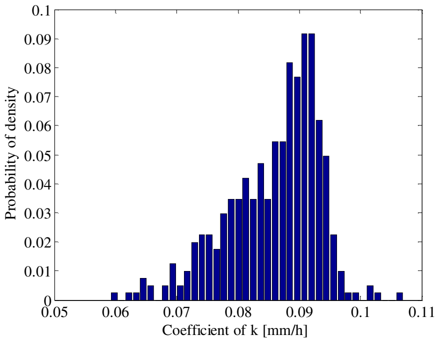

Fig. 5. Probability density distribution of power law curve-fitted coefficient k

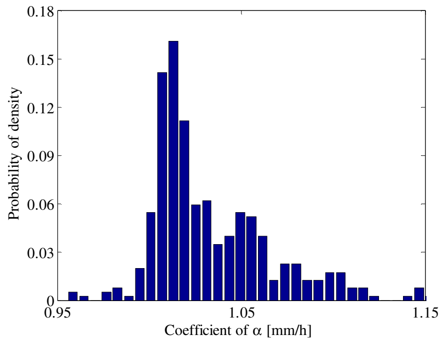

Fig. 6. Probability density distribution of power law curve-fitted coefficient α

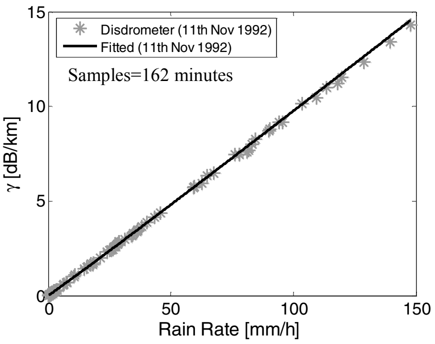

Fig. 7. Event with the best coefficient of determination R^2 (25th December 1994).

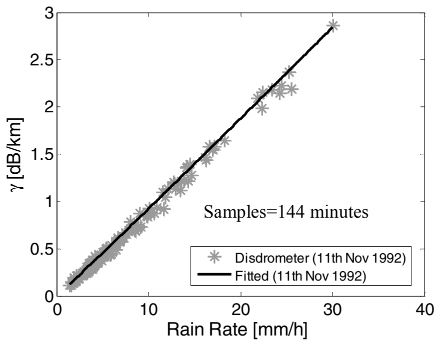

Fig. 8. Event with the worst coefficient of determination R^2 (11th November 1992).

4. Seasonal Variation of Rain Attenuation on Earth-Space Link

In this section, we extended the analysis in Section 3 to obtain seasonal slant-path rain attenuation statistics using the available DSD data and the SST [5]. In the absence of experimental beacon data, SST is a useful tool to convert one-minute integrated rain rate time series into rain attenuation time series. A comprehensive explanation on the SST model can be found in [5]. The Earth-space link considered in this work has the following characteristics: downlink from the MEASAT-3 satellite, frequency 20 GHz (vertical polarization), elevation angle of 77.43°, (ground station located in Kuala Lumpur (101.42° E, 3.08° N)).

As shown in Fig. 10, the South-West monsoon appears as the season that experience lower attenuation compared to the Inter-monsoon and North-East seasons. For example, a 28-dB fade margin would have been sufficient in this season to achieve a link availability of 99.9% during the

South-West season, while the necessary margin would be 33 dB and 37 dB in the North-East and Inter-monsoon seasons respectively. Fig. 10 also point out that the prediction from recommendation ITU-R P.618-10 significantly underestimates the statistics for the inter-monsoon season and North-East seasons, but agrees quite well with those relative to the South-West season. Overall the results in Fig. 10 point out the needs of smart strategies such as Propagation Impairment Mitigation Techniques (PIMTs) to achieve higher link availability (i.e. 99.99%), since such large signal fades can no longer overcome by static power margins. As an example, diversity schemes, such as site diversity, might be the appropriate choice to decrease the required fade margins for high availability systems.

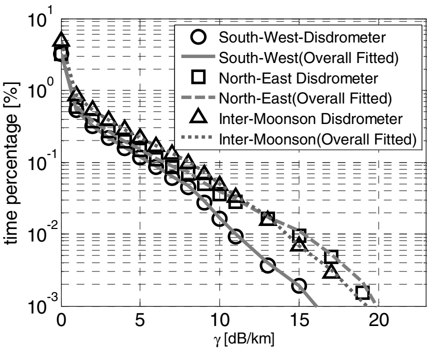

Fig. 9. Seasonal CCDFs of specific attenuation at 20 GHz derived from power law curve-fitted coefficients and DSD measurement.

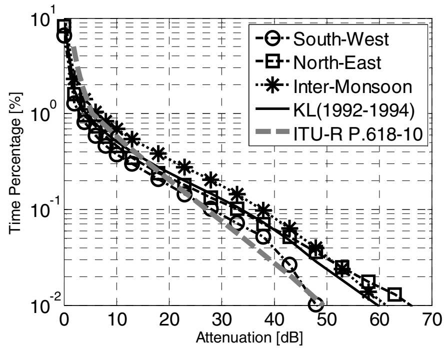

Fig. 10. Seasonal CCDFs of rain attenuation at 20 GHz in Kuala Lumpur : comparison between the predictions using the SST and recommendation ITU-R P.618-10.

5. Conclusions

This work investigated the impact of Asian monsoon seasons on the rain attenuation experienced by a Ka band Earth-space link in Equatorial Kuala Lumpur. To this aim, local DSD data have been exploited to estimate specific attenuation and the SST model has been employed to predict long term rain attenuation statistics. Results show that during the South-West monsoon season, the system would require a lower rain attenuation fade margin with respect to the North-East monsoon and Inter-monsoon season (for the same link availability target). Moreover, such results represent useful information for planning appropriate PIMTs for high availability systems.

References

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