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EQUATORIAL RAINFALL MEASUREMENT ON KU-BAND SATELLITE COMMUNICATION DOWNLINK

J. S. Mandeep

School of Electrical and Electronic Engineering
University Sains Malaysia
Engineering Campus
14300 Nibong Tebal, Seberang Perai Selatan, Pulau Pinang, Malaysia

Abstract—Communication systems operating at frequencies above 10 GHz in equatorial climates are subjected to many fade occurrences due to heavy rain. Rain rate analysis using 1-minute data for 10 years (1996–2006) measurements in Penang shows that the rain exceeded 126.8 mm/h for 0.01% of a year ($R_{0.01}$). Simultaneous measurements of Ku-band rain attenuation give $A_{0.01}$ as 22 dB. The rain rate and attenuation are characterized by the presence of breakpoints in the respective exceedance curves. The attenuation exceeds the fade margin for about 8.8 hours in a year.

1. INTRODUCTION

In the design low-margin Ku-band satellite traffic links, such as those for direct-to-home very small aperture terminals (DTH/VSAT) systems, detailed propagation information must be considered that provides insights into performance, availability, and quality of service and customer perceptions. Ku-band TV services are affected by outages for time-critical transmission such as real-time news and sports broadcasting [6]. When the rain rate increases rain attenuation increases, frequently to a point where the communication link fails. DTH/VSAT system, for example, may tolerate a signal 10 dB below its normal signal level for only 0.01 percent of the time dependent on its requirement. For such a system the yearly rain rate statistics must be obtained for every location where a communication link is planned [4]. The effect of rain attenuation on communication systems has been of interest to many researchers but limited investigations in the tropics have been reported [9, 7]. The lack of data for both rain rate and rain attenuation has lead to noticeable deviation of the prediction models for these regions. This paper analyses the rainfall for the past 10 years and compares it with existing models.

2. MEASUREMENT SETUP

The main station for the experiment was located at University Sains Malaysia (USM) (Lat.:5.17°N and Long.:100.4°E) in Nibong Tebal, Penang and is about 7 km from the sea and about 57 m above mean-sea-level. Looking towards the SUPERBIRD–C satellite at 144°E, the elevation and azimuth angle of the receiver antenna are 40.1° and 95.4°, respectively. The downlink frequency is 12.255 GHz. The receiver antenna is an off-centre 2.4 m parabolic dish with an offset angle of 72.5°. The output of the LNB at the dish is connected to a data logger, which is interfaced to a computer by a LABVIEW software. The software was programmed to record the peaks of 60 successive samples each of 1 second duration. The software then calculates the mean of these 60 peak values giving an averaged peak values in 1 min. To account for any variation in the satellite signal strength due to orbital variations, the average clear day signal strengths on the day prior to and after the rainy day(s) were used in computing the rain attenuation [11, 12]. The recordings showed that the mean rate of signal level variations due to rain attenuation is much smaller than that of scintillation [8].

The 1-minute rain gauge has a tipping bucket of 0.5 mm per tip. The aperture area of the collecting surface is 400 cm^2. The accuracy of the gauge is ±1% at 1 liter /hour with a measuring range of minimum 5 mm/h to a maximum of 400 mm/h. The rain gauge is accurate to within 2% up to 200 mm/hr and 3% up to 380 mm/hr. The resolution of the rain gauge is 0.01% and the data logger time stamp resolution is 1 second. The data logger samples the data at one second intervals and averages the data over 1 minute interval.

3. RESULTS AND DISCUSSION

Malaysia experiences heavy rain through out the year and the rainfall distribution is patterned by monsoon activities. The Northeast monsoon (wet season) is from October to March and the Southwest monsoon (dry season) is from April to September [10]. Figure 1 shows the exceeded average of 10 years rain rate and attenuation curves for the two seasons. In the wet season, the rainfall is mainly convectional with strong wind effects. The rain rate and attenuation probability of occurrence for the wet season were higher than for the dry season. The probability of occurrence values for rain attenuation was greater than the rain rate for both the seasons. This is because the frequency of rain in the slant path is higher than the rain measured at site, a point [7]. The maximum rain attenuation and rain rate recorded were 38 dB and 230 mm/h.

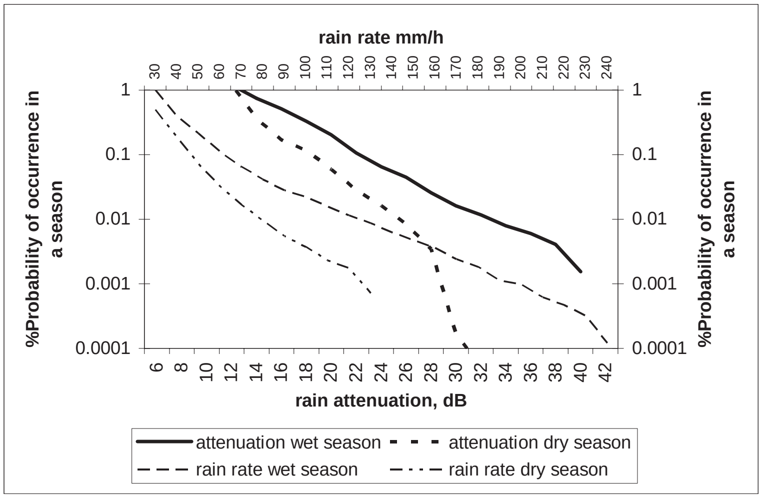

Figure 1. Probability of occurrence of rain rate and rain attenuation for two seasons.

Figure 2 shows the percent of time of the measured rain rate is exceeded computed from 10 years records. The cumulative rain rate at 0.01% of time is 126.1 mm/h. The Crane [1] and ITU-R [2] models places Malaysia in the tropical 'H' and 'P' climate regions, respectively. At 0.01% of time the rain rate for Crane and ITU-R are 209.3 mm/h and 120 mm/h [3], respectively. For comparison, the ITU-R model follow closely to the measured rain rate values until it reaches the breakpoint (the point at which the slope changes), indicating the tendency for saturation. This is because stratiform and convective rainfall was taken into consideration for developing rainfall climate zones. The available measured instantaneous rainfall rate distributions were pooled for each of the climate regions and used to construct a median rainfall rate distribution for the region. The Crane model predicted higher than the measured rain rate at 0.1% of time and lower. This is because the climate region boundaries were set prior to compiling the rain rate statistics for each region. Therefore, for the tropical region 'H' the measured rain rate distributions were pooled based data available from 7 station years. Figure 3 shows the cumulative distributions of the measured and predicted rain

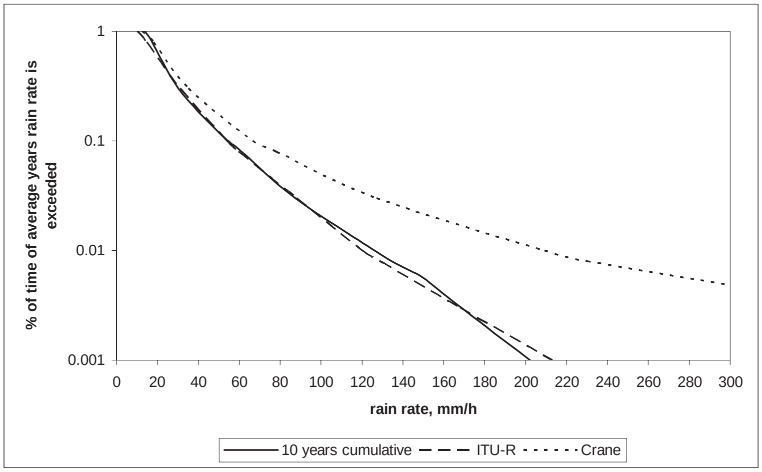

Figure 2. Predicted and measured rain rate cumulative distributions.

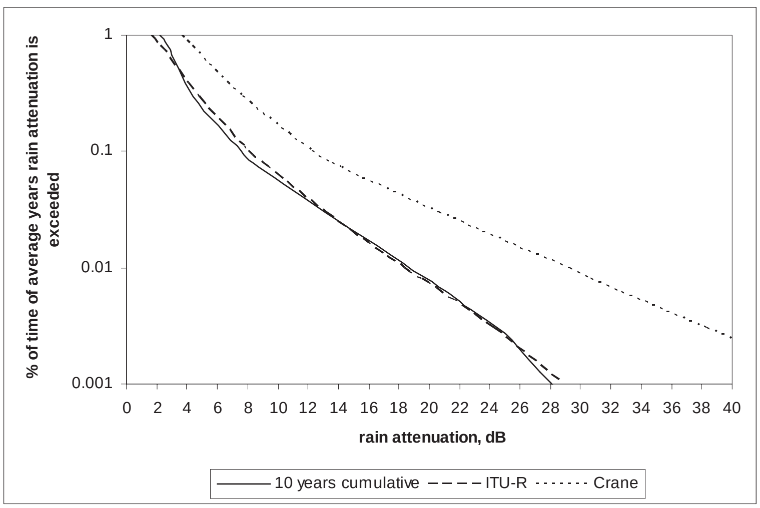

Figure 3. Predicted and measured rain attenuation cumulative distributions.

attenuation exceeded for a given percent of time. The breakpoint is also marked in the attenuation curve at 25 dB. This breakpoint is dependent on the breakpoint in the rain rate exceedence curve. The lower breakpoint occurs when rain changes from stratiform to convective [8]. The one at high rain rate occurs due to saturation of rain. When rain reaches its saturation point, the rain column height is constant and maximum (10 km). However, the rain cell diameter continues to decrease with increasing rain rate [13, 14]. Therefore, at high rain rate, a particular volume of rain that is a combination of rain cell diameter, rain column height and rain rate cannot be exceeded and the rain volume appears to saturate. The ITU-R (2005) model follows the measured rain attenuation closely until it reaches the breakpoint. The Crane (1996) model overestimates the attenuation at low and high rain rates. This is because the model was developed on a large number of rain rate observation that were not taken at either the locations of the attenuation paths or during the measurement periods of the data in the database [1]. For Ku-band satellite services, a threshold of 7 dB is generally considered as the economical limit [5]. From Figure 3, 0.1 % of time of the year, correspond to 8.8 hours, the fade margin is greater than 7 dB.

4. CONCLUSION

The available rain rate and attenuation prediction models are often not suitable for equatorial climates. There is a high correlation between the rain rate and attenuation exceeded values in average years that would be useful in determining the link fade margin. The rain rate and attenuation are characterized by the presence of breakpoints in the respective curves.

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