Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article
Special Issue

DETERMINATION OF FADE MARGIN FOR KA BAND OPERATING IN EQUATORIAL REGION

N. H. S. Suhaimi[1,*], K. Badron[2], A. F. Ismail[2], Y. A. Ahmad[2] M. R. M. Yassin[2] and M. H. Rahmat[2]

[1]Science and Technology Research Institute for Defence (STRIDE)
[2]International Islamic University Malaysia (IIUM)

Published online: 01 February 2018

ABSTRACT

Reliability of satellite-Earth communication links can be improved by ensuring the availability of adequate fade margin. Fade margin can be established from prediction methods and also determined from quantitative analyses. Malaysia is located in the equatorial region, where Ka band link experiences high attenuation due to rain. Most existing prediction methods were developed in temperate climate region and therefore might not be applicable for conditions in Malaysia. In this paper, study on the effect of rain on Ka-band satellite signals has been carried out. Ka band transmissions operating at frequency of 20.199 GHz from the MEASAT 5 satellite are being monitored at MEASAT Cyberjaya ground station. It has been observed that rain attenuations experienced by the Ka band link vary from 6 to 34 dB. The determined fade margins for 99.97% availability, typical quality of service (QoS) standard for communications and 99.7% availability, conventional (QoS) criterion for broadcast are 31 dB and 27 dB respectively.

Keywords: Ka band, satellite-earth communication, fade margin, rain attenuation, equatorial region

Author Correspondence, e-mail: sabrina.suhaimi@stride.gov.my

doi: http://dx.doi.org/10.4314/jfas.v10i2s.19

1. INTRODUCTION

Fade margin is a design provision that facilitates sufficient system gain or sensitivity to overcome expected fading hence ensuring that required quality of service can be maintained. Fade margin can be acquired through data analytics performed at the set of rainfall rate and rain attenuation data. Information provided by the data analyses will help system designers to determine reliable fade margin required in setting up the best communication link or delivering broadcasting system. The analyses of a long-term data can produce a reliable fade margin [1]. Fade margin is important in order to ensure the required threshold of the received signal power can be maintained during temporary attenuation or fading. The understanding about the fade margin is essential in order to design the system that can reduce the losses of service due to rain maintaining the required link availability percentage [2]. Fade margin value for a specific satellite link should be deliberated in detail in order to offer reliable services [3]. In general, reliability of a satellite link for a period of time can be defined as percentage of time for which satellite link can work sufficiently when associated to the total time.

As lower frequencies bands are already congested, the communication systems now have to move to higher frequencies. Higher frequencies offer higher channel capacities, more spectrum availability, and reduced chance of interference or noise and reduced equipment size. However, satellite signals at higher frequencies especially above 10GHz are certainly challenged by propagation impairments during signal transmissions between the satellite and Earth stations which can severely degrade service quality. In many instances, the low received signal due to heavy rainfall cannot be differentiated from noises from receiver itself. Atmospheric effect especially rain is a main cause of attenuation in satellite-to-Earth link operating at higher frequencies above 10GHz. The outcome is more severe for extremely high frequencies (EHF) that have wavelength in the range of 1mm to 10mm,also known as millimeter wave.

Malaysia is located in equatorial regions between 5°-10° north and south latitudes of the equator as illustrated in Figure 1. Malaysia can also be regarded as experienced wet equatorial climate as Malaysia is subjected to average humidity up to 95% and sometime remains high for an extended period due to high temperature and enormous sea surface that caused higher evaporation. The precipitation in Malaysia is also very high where the average rainfall spread uniformly about 250 centimeters (98 in) throughout the year.

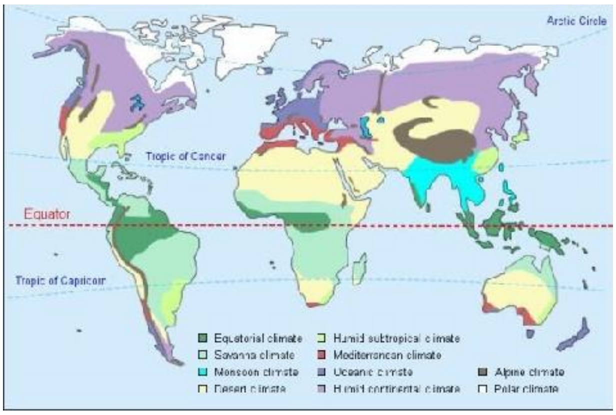


Fig.1. Map of equatorial of the world [4]

Due to limited amount of reliable long term rain attenuation statistic in equatorial region for higher frequencies, estimations of attenuation statistics had been proposed in the attempt to identified relevant fade margin to ensure the best possible service quality. It had been proposed that an estimation of fade margin at desired frequency can be acquired from attenuation values measured at another frequency; which is called as the frequency scaling method. As most availablerain attenuation prediction models had been developed for/in temperate region, their application is still subjected for verification for condition in Malaysia. A comprehensive full-fledged rain attenuation studiesare required to validate all existing prediction models. To achieve this, an extensive study needs to be conducted in order to improve the statistical model applicable for the equatorial region. On such note, Ka-band beacon signals from a geostationary satellite acquiredata ground station had been analyzed in order to comprehensively understandthe effect of rain on Ka-band frequency. This study hopes to offer anew input concerning the fade margin models and helps in understanding of the rain fade characteristics endured by higher frequencies satellites operating in equatorial regions.

2. MEASUREMENT SETUP

The signal receiver is located at MEASAT Cyberjaya ground station (2° 56' 42.94'' N latitude, 101° 40' 4.71''E longitude)at above sea level height of 20 m.The 20.199 GHz Ka band beacon is being transmitted by the MEASAT 5 satellite and also known as IPSTAR (Thaicomm-4) located at 119.5° E. The receiver is connected to an 8m horizontal linear polarization antenna with elevation angle of 68.8° and azimuthangle of 99°. The receiver sampled the data at an interval of

10 seconds which are later averaged over 1-minute distribution for further statistical analyses. The rainfall ratesfor the area have been recorded using a tipping bucket rain gauge with0.1 mm resolution installed at business premise of Puncak Niaga, Malaysia (2˚54’40”N latitude, 101˚41’50”E longitude) about 5km away from Cyberjaya ground station. Figure 2 illustrated location of MEASAT 5 satellite with respect to its ground station in Cyberjaya.

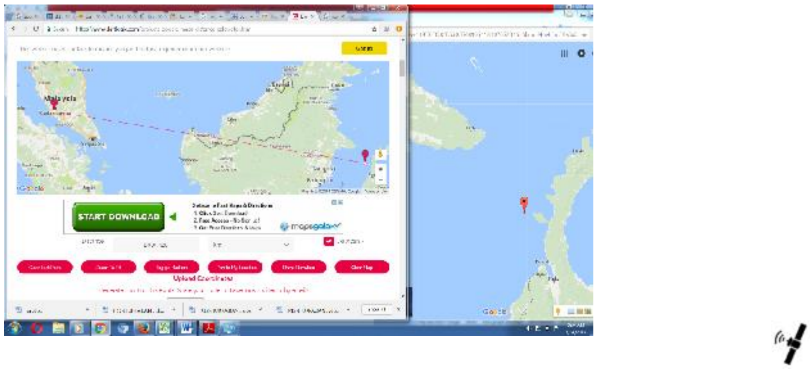


Fig.2. Measat 5 location with respect to Cyberjaya

The schematic for the measurement setup is as shown in Figure 3 below. Measurements were made for 10 months in the year 2016 (January 2016 to October 2016). Throughout the 10 months period, 60 days were identified to experience rain event. The collected attenuation data which the beacon receiver data and the meteorological data which arethe rainfall rate data were synchronized and common time stamps had been acquired. Partially missing and invalid data were removed from the preprocessed data. The clear sky reference level of the beacon data was established from after and before rain event information using the averaging method. Then, Cumulative Distribution Functions (CDF) for rainfall rate and rain attenuation at Ka band were then generated.

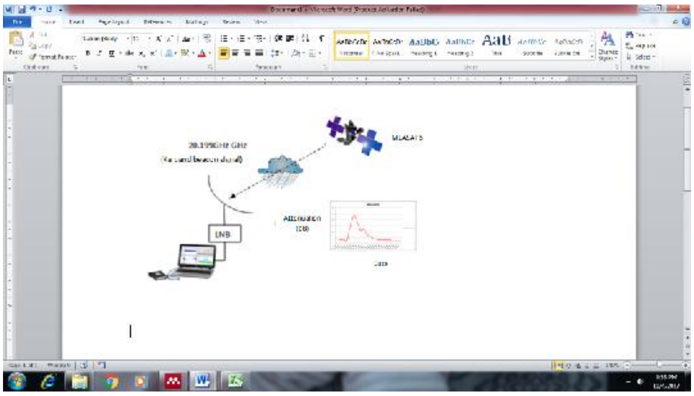
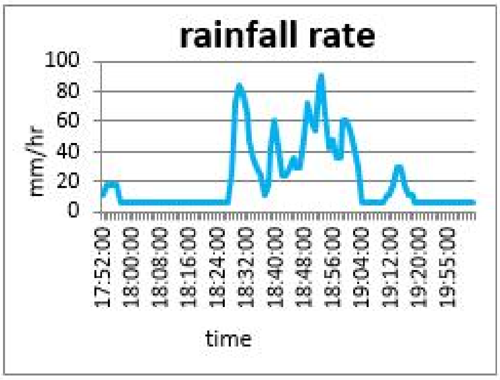


Fig.3. Measurement setup to collect rain attenuation data

3. RESULTS AND DISCUSSION

Figure 4 and Figure 5below are examples of time-series plot of rainfall intensity and attenuation as observed on the space-Earth link created using MEASAT databases. From the Figure 4below, it can be observed that heavy rainfall occurred during the evening. From the analysis carried out using rainfall rates data obtained from Jabatan Pengaliran dan Saliran (JPS) Malaysia,it had been identified that November experienced the most number of rainy days when compared to other monthswithin 1 year observation period. However, the heaviest rainfall rates had been detected to take place in the month of April, 2016.



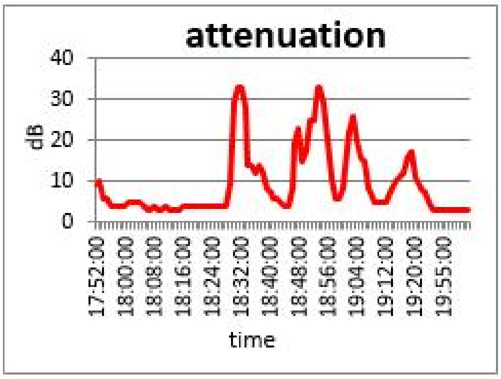


Fig.4. Rainfall rate on 19th June 2016Figure 5: Rain attenuation on 19th June 2016

The analysis discovered that Ka-bank link experienced higher attenuation during daytime rather that at nighttime. In general, a good correlation between fading and the intensity of the rainfall can be observed in the time-series plots as shown in Figure 6below. Several fades that exceeded the 30 dB level were also recorded. Rainfall intensity as high as 180 mm hr^{-1} was detected on three days which are 29th April 2016, 30th April 2016 and 31st December 2016. This Figure 6 below indicates that there is a definite correlation between the rain rate and rain attenuation.

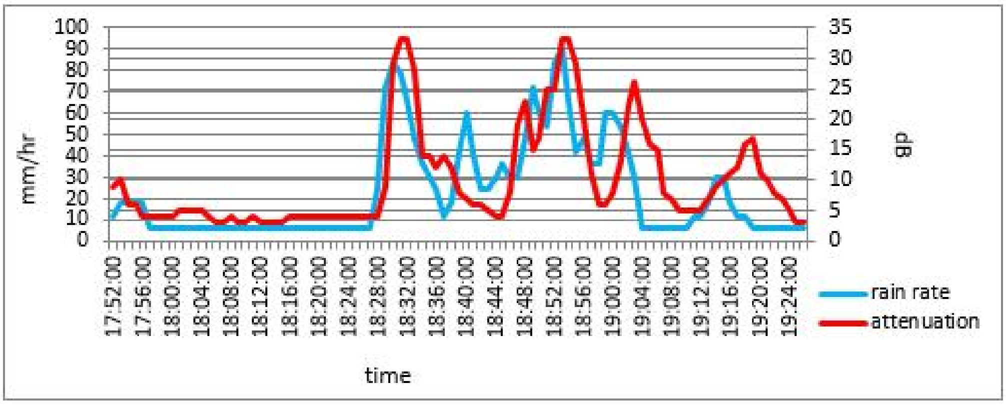


Fig.6. Combined rain attenuation and rainfall rate graph

The attenuation data measured at Cyberjaya ground station, Malaysia were compiled into each individual month. Since attenuation data is only available from January 2016 to October 2016, attenuation data for month of November 2016 and December 2016 had been extrapolated in order to produce annual cumulative distributions. The annual cumulative distributions will be changed accordingly when measured data of November and December are made available. Figure 7 below shows the cumulative distributions for measured beacon attenuation on a monthly basis and the monthly cumulative distributions for 12 consecutive months were compiledto produce one-year observation. From Figure 7, within the period of the twelve months, the measured attenuation in January 2016substantially exceeded all measurements observed in other months at all percentages of time.

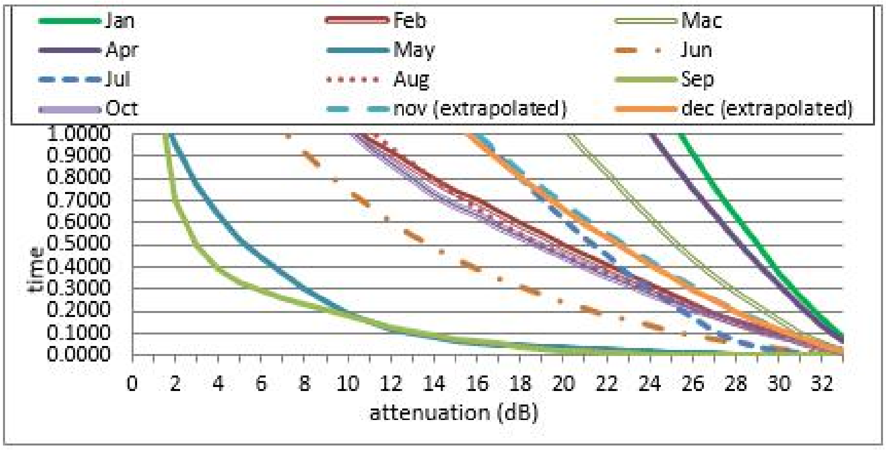


Fig.7. Monthly distribution of attenuation (01/2016-12/2016)

One of the most suitable presentation formats for satellite link designers or engineers are the cumulative distributions. From the annual cumulative distribution, an exceedance at a specific point or link availability can be determined. Thus, in order to attain the desired link performance, rain attenuation values can be inferred as the system fade margin. The annual cumulative distribution of attenuation due to rain measured at 20.199 GHz of the MEASAT 5 satellite beacon signal is presented in Figure 8 below. This cumulative distribution is very essential in order determine information regarding the estimation of rain attenuation margins required for a given link reliability. Basically, the distribution is expressed in percent and it is equivalent for a given link reliability expressed in minutes. For instance, at 0.0217% of the time, 1-minute rain rate and attenuation values are taken for about 114(((365∗24∗60∗0.001)/100) = 114.055 ≈ 114) instances. Therefore, from Figure 8 below, for 2 hour per year, 0.0217% link outage, equivalent to 99.98% link availability, approximately 34 dB margins would have been required. Similarly, margins of 31 dB and 33 dB would have been required for outages of 10 hours (0.1174%) and 4 hours (0.0495%) respectively.

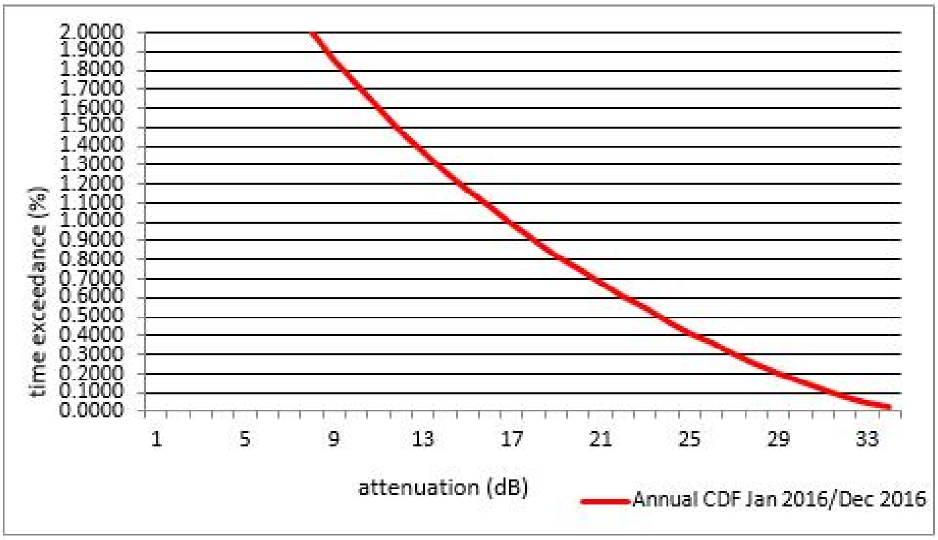


Fig.8. Annual cumulative distribution of beacon attenuation

The attenuations exceeded for 99.7%, 99.9% and 99.97% of the average year are listed in Table 1. Table 1 outlines that in order to achieve 99.7%, 99.9% and 99.97% availabilities, 27dB, 31dB and 34dB rain margins are required in order to deliver expected service. However, a more completed data are required for the development of satisfactory physically based models for prediction with the variety of rain event to be characterised.

Table 1. The attenuations exceeded for 99.70%, 99.9% and 99.98% of the average year

Link availability	Margin required
99.70%	27 dB
99.9%	31 dB
99.98%	34 dB

4. CONCLUSION

The rain attenuations experienced by the Ka-band beacon signals from MEASAT 5 were analyzed to quantify the statistical characteristicsin the effort to determine required fade margin for links operating in equatorial region.Particular considerationshave been made for link availabilities from 99.98% up to 99.9% of the time. For better broadcasting application, the requirement of availability is 99.70% meanwhile for communications services is 99.97% availability. From the study involving Ka-band link analysis, it had been determined that for 99.9% availability is the fade margin is 31dB and for 99.7% availability is 27dB. Evidently, as the availability increases, the required rain fade margin also increased. A long term data is a requirement in order to produced high accuracy analysis regarding attenuation during rain in tropical region at higher frequencies. In the future Ka band applications, these fade margin values are needed to be embedded in the design consideration to mitigate rain attenuation.Such analyses will provide wide-ranging ideas of rain attenuation to communication engineers and designers to facilitate a more relevant link budget for an improved signal propagation.

5. REFERENCES

[1] Afahakan, I. E., Udofia,K. M., & Umoren, M. A. (2016). Analysis Of Rain Rate And Rain Attenuation For Earth- Earth - Space Communication Links Over Uyo - Akwa Ibom State, 35(1), 137–143.

[2] Sujimol, M. R., Acharya, R., Singh, G., & Gupta, R. K. (2015). Rain attenuation using Ka and Ku
band frequency beacons at Delhi Earth Station. Indian Journal of Radio and Space Physics, 44(March), 45–50.

[3] Ghasemi, A., Abedi, A., & Ghasemi, F. (2013). Propagation engineering in radio links design. Propagation Engineering in Radio Links Design (Vol. 9781461453). https://doi.org/10.1007/978-1-4614-5314-7

[4] https://iasmania.com/hot-wet-equatorial-climate/

[5] Kamruzzaman, M., & Islam, M. S. (2014). Rain attenuation prediction for satellite communications link at Ku and Ka bands over Bangladesh. In 1st International Conference on Electrical Engineering and Information and Communication Technology, ICEEICT 2014. https://doi.org/10.1109/ICEEICT.2014.6919092

[6] Magdum, D. and J. A. (2003). Ka-band rain attenution over major indian cities. Design, (1), 2–5.

[7] Shrestha, S., & Choi, D. (2017). Characterization of Rain Specific Attenuation and Frequency Scaling Method for Satellite Communication in South Korea, 2017.

[8] Semire, F. A., Ismail, W., Mohamad, N., & Mandeep, J. S. (2015). Modeling of rain attenuation and site diversity predictions for, 321–331. https://doi.org/10.5194/angeo-33-321-2015

[9] Malinga, S. J. (2014). Determination of Millimetric Signal Attenuation Due To Rain Using Rain Rate and Raindrop Size Distribution Models for Southern Africa, (March).

[10] Christensen, J., & Ph, D. (2012). ITU Regulations for Ka-band Satellite Networks, 1–8.

[12] Cuervo, F., Schonhuber, M., Capsoni, C., Yin, L. H., Jong, S. L., Din, J. Bin, & Martellucci, A. (2016). Ka-band propagation campaign in Malaysia - First months of operation and site diversity analysis. 2016 10th European Conference on Antennas and Propagation, EuCAP 2016. https://doi.org/10.1109/EuCAP.2016.7481248

[13] Ezeh, G. N., Chukwuneke, N. S., Ogujiofor, N. C., & Diala, U. H. (2014). EFFECTS OF RAIN ATTENUATION ON SATELLITE COMMUNICATION LINK, 8(22), 1–11. https://doi.org/10.12913/22998624.1105138

[14] Kestwal, M. C., Joshi, S., & Garia, L. S. (2014). Prediction of rain attenuation and impact of rain in wave propagation at microwave frequency for tropical region (Uttarakhand, India). International Journal of Microwave Science and Technology, 2014. https://doi.org/10.1155/2014/958498

[15] Yeo, J. X., Lee, Y. H., & Ong, J. T. (2014). Rain Attenuation Prediction Model for Satellite Communications in Tropical Regions, (c). https://doi.org/10.1109/TAP.2014.2356208

[16] https://www.mapsofworld.com/lat_long/asia.html

How to cite this article:
Suhaimi N H S, Badron K, Ismail A F, Ahmad Y A, Yassin M R M, Rahmat M H. Determination of fade margin for ka band operating in equatorial region. J. Fundam. Appl. Sci., 2018, *10(2S), 229-238.*