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Monthly variation in Rainfall Attenuation for Ka band Satellite Communication for monsoon in Ahmedabad and New Delhi

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ABSTRACT

Rainfall attenuation plays a major role in link failure for Satellite Communication. When Ka band Satellite Communication is used, it becomes worse. India is a tropical country and so experiences heavy rainfall in the season of monsoon. Rainfall attenuation for entire monsoon is estimated for Ahmedabad and New Delhi from database of 64 years (1951 to 2014) taken from IMD. Attenuation for whole monsoon of 122 days is estimated for Ahmedabad and New Delhi locations of India. Coarse data taken from Indian Meteorogical Department is used for estimation. A novel method is invented for estimation which uses Kothyari and Garde equation for obtaining rainfall intensity for 60 minutes integration time. This data is converted to 1 minute integration time using ITU-R P 837.6. This 1 minute integration rainfall intensity is applied to ITU-R P 618.8 for estimation of rainfall attenuation in dBs. The obtained results are also matching with other works for Ka band for India.

Keywords : Ka band, Satellite Communication, India, Rainfall Intensity, Rainfall Attenuation, Kothyari and Garde IDF equation, GSAT-14, ITU R model, ITU-R P618.8 rain attenuation model, ITU-R P837.6, June, July, August, September (JJAS), Indian Meteorogical Department (IMD), Ahmedabad, New Delhi, 122 days long monsoon of 64 years (1951 to 2014), fade mitigation techniques.

I. INTRODUCTION

Satellite communication has grown in leaps and bounds in last few decades. Time has come when only C and Ku band Satellite Communication is not enough for India. India has to go ahead and start looking for Ka band. India has already sent two Ka band beacon signals with GSAT-14, the 23rd geostationary satellite launched by India in January 2014[1]. India is soon going to shift to its new higher band Ka band for Satellite Communication. But unlike other bands, Ka band is far more susceptible to attenuation due to rainfall [2]. GSAT-14 has 20.2 GHz beacon signal which can be used as downlink in future satellite launched. Hence study at this frequency is carried out for Rain attenuation in Ka band. India experiences monsoon from June to September of every year. Hence 122 days long monsoon of 64 years (1951 to 2014) is considered for estimation. Monthly variation of rainfall attenuation is studied for Ahmedabad and New Delhi region. The rainfall attenuation is calculated using ITU-R model P 618.8. The four monthly comparisons are done for Ahmedabad and New-Delhi region individually. Also the inter-monthly comparison is done between both regions. The results obtained will be helpful for application of different fade mitigation techniques during rainfall and hence avoid link failure.

II. STUDY LOCATION AND DATA COLLECTION

GSAT-14 has two beacon signals operating at 20.2 GHz and 30.5 GHz **[1]**, **[3]**. The measurements of these beacons are carried out at different locations of Indian Space and Research Organization. Measurements are carried out Ahmedabad and New Delhi locations. Therefore these are chosen for the estimation of rainfall attenuation and these are the study locations. The downlink frequency of Ka band beacon 20.2 GHz is chosen for the estimation in this work. The Ahmedabad Earth Station (AES) and Delhi Earth Station (DES) used

are having station code ISRO 0303 and ISRO 0463 respectively. The latitude and longitude of AES is 23.02356 °E and 72.515 °N. The latitude and longitude of DES is 28.61 °E and 77.23 °N. The station height and antenna height above mean sea level for AES are 48.77 meters and 49.77 meters respectively. The station height and antenna height above mean sea level for DES are 293 meters and 294 meters respectively. The antenna polarization angle and antenna elevation angle for AES is 21.7° and 63°. The antenna polarization angle and antenna elevation angle for DES is 19.6° and 56.4°. The AES and DES chosen are IRNSS reference stations (IRNES) **[4], [5]**. Indian Meteorogical Department IMD analyses the possible changes in climate and related aspects by keeping records of different atmospheric parameters **[6]**. It has area weighted monthly seasonal and annual rainfall in mm of 36 meteorological subdivision of India starting from 1951. From here the monthly rainfall data of Ahmedabad and New Delhi is collected from 1951 to 2014 and analyzed **[7]**.

III. METHODOLOGY OF ESTIMATION

For estimation of rainfall attenuation, rainfall intensity required is 0.01 % of an average year with 1 minute integration time. Rainfall rate with longer integration time is not used as it cannot capture high intensity short duration rainfall. 1 minute integration time is hence used worldwide in rainfall attenuation predictions. IMD has monthly average rainfall data for many years. India has monsoon from June to September during which it experiences almost all of its total annual rainfall. Hence June to September month rainfall is collected from IMD from year 1951 to 2014. This data is converted to daily data by simple averaging method. This averaged daily data is now used in the Intensity Duration Frequency (IDF) equation for Indian region developed by Kothyari and Garde **[8]**. Kothyari and Garde developed a specific relationship between the rainfall intensity, duration and frequency with the Indian conditions. They developed the equation for IDF curves using the rainfall data of 78 rain gauge stations from all over India considering the value of mean annual rainfall (R) for 24 hr, and two-year rainfall, R_{24}^2 **[9]** . This equation gives the rainfall intensity in mm/hours. IDF is a statistical relationship between the rainfall intensity (i), the duration (d), and the return period (T). This equation is [**8**]:

$$I_t^T = C \frac{T^{0.20}}{t^{0.71}} (R_{24}^2)^{0.33} \quad \ldots\ldots (1)$$

where, I_t^T is the rainfall intensity/ rainfall rate in mm/hr; T return period in years and t duration of rainfall in hr., R_{24}^2 is 24 hr, a two-year return period rainfall in mm. t is chosen be 1 hour as we need 60 minutes integration rainfall data to be applied to Rain rate statistics conversion MATLAB program **[10]** that converts 60 minutes integration rainfall to 1 minute integration rainfall. C is a constant having different value for different part of India. As Ahmedabad is in western India, the value of C can be taken as 8.3 and for New Delhi (northern India) C is chosen as 8.0.

The rainfall intensity obtained from Kothyari and Garde equation is in mm/hour with 60 minutes integration time. To find the rainfall attenuation using ITU-R model P 618.8, we need 1 minute integration rainfall intensity. Hence we need to use Rain rate statistics conversion MATLAB program given by ITU-R P 837.6 **[10]**.

Now, the rainfall intensity with 1 minute integration time obtained from ITU-R P 837.6 is applied to ITU-R P 618.8 model for estimation of Rainfall attenuation in dBs. The ITU-R P.618.8 **[11]** Model-Propagation data and prediction method estimates the rain attenuation for rain rates at 0.01% probability. This model is based on the log-normal distribution as both rainfall intensity and attenuation confirm to the same log-normal distribution. It takes into account the inhomogeneity in horizontal and vertical directions due to rain for 4-55 GHz frequency range and 0.001-5% probability levels.

IV. RESULTS AND DISCUSSION

The one minute integrated rainfall intensity (mm/hr) versus rainfall attenuation (dBs) for Indian monsoon months-June, July, August, September (JJAS) calculated for 64 years for Ahmedabad is shown in figure 1. The figure reveals that for very rare heavy rainfall of 190 mm/hour, the attenuation can reach up to 60 dBs. Figure shows that rainfall intensity and hence the rainfall attenuation is much severe in the month of July for Ahmedabad. Hence monsoon is most intense in the month of July for Ahmedabad. The monsoon is comparatively less intense for the month of June and September. The 0.01 % mean rainfall intensity for 1 minute integration time for Ahmedabad for June, July, August and September is 40.89, 53.21, 46.69 and 44.56 mm/hour respectively. The mean attenuation for June, July, August and September for Ahmedabad is respectively 22.96, 27.03, 24.62 and 24.10 dB

respectively. The mean rainfall intensity during monsoon period is observed to be 41.56 mm/hour for 1 minute integration time for 0.01 % of an average year, which is matching with different rain zones defined by ITU-R for Asia Pacific region [12]. For this mean rainfall intensity of 41.56 mm/hour, the mean rainfall attenuation observed is 23.42 dBs.

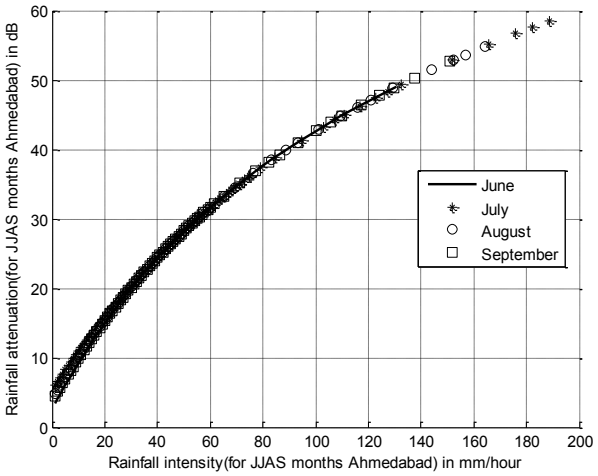

Figure 1: Rainfall intensity vs. rainfall attenuation for JJAS months of Ahmedabad for 64 years (1951-2014)

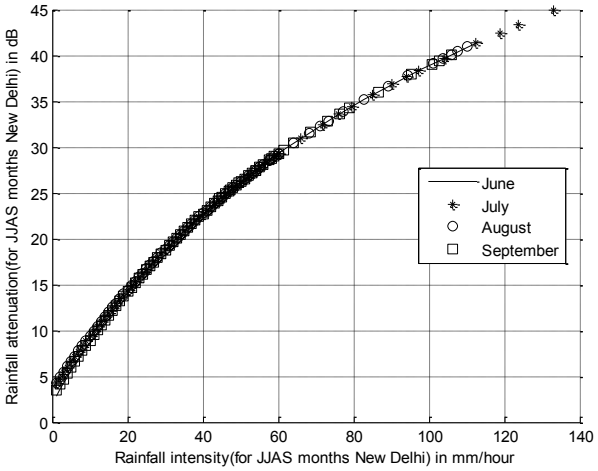

Figure 2: Rainfall intensity vs. rainfall attenuation for JJAS months of New Delhi for 64 years (1951-2014)

The attenuation curve for New Delhi monsoon of 64 years shown in figure 2 reveals that the rainfall intensity and hence attenuation for New Delhi is much lower as compared to Ahmedabad. Here for very rare heavy rainfall of 130 mm/hour, the attenuation can reach up to 45 dBs. From the figure it is observed that rainfall intensity and hence the rainfall attenuation is much severe in the month of July similar to Ahmedabad. It is comparatively low for the month of September. The 0.01 % mean rainfall intensity for 1 minute integration time for New Delhi for June, July, August and September is 38.81, 42.58, 41.26 and 39.19 mm/hour respectively. The mean attenuation for June, July, August and September for New Delhi is respectively 20.75, 21.91, 21.67 and 20.98 dB respectively. The mean rainfall intensity for New Delhi during monsoon period is observed to be 40.92 mm/hour for 1 minute integration time for 0.01 % of an average year. This result is matching with the work done by Shraddha Mohanty et al. **[13]** where they have obtained value of 40.48 mm/hr (attenuation obtained 20.06 dBs). For this mean rainfall intensity of 40.92 mm/hour, the mean rainfall attenuation obtained is 21.54 dBs. The predicted value of 0.01 % exceedance value of rain attenuation for Ka band at 50 mm/hr is found to be 24.6 dBs by M. R. Sujimol et al. **[14]**. In our work also we are obtaining attenuation of around 25 dBs for rainfall intensity of 50 mm/hour, as is observed from figure 2 above.

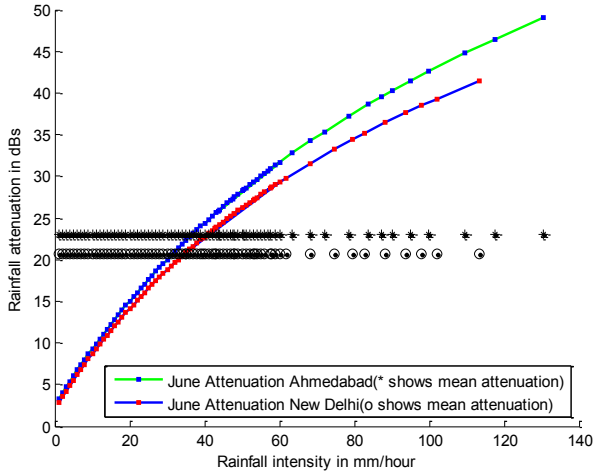

Figure 3: Comparative rainfall attenuation for month of June for Ahmedabad and New Delhi

Figure 3 shows the comparative rainfall attenuation between Ahmedabad and New Delhi in June for 64 years. In the month of June, Ahmedabad experiences more rainfall as compared to New Delhi. Ahmedabad has experienced 8072 mm rainfall in last 64 years as compared to New Delhi which has only experienced 3185 mm in 64 years from 1951 to 2014 **[7]**. Along with this the rainfall intensity for Ahmedabad is also more as compared to New Delhi. Hence, the mean attenuation for New Delhi is less (20.75 dBs) as compared to Ahmedabad (22.96 dBs) as is observed from the figure. Hence the fade mitigation techniques should be designed accordingly for Ahmedabad and New Delhi for the month of June.

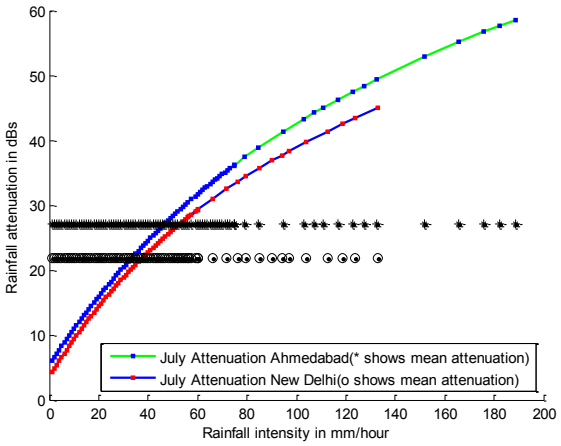

Figure 4: Comparative rainfall attenuation for month of July for Ahmedabad and New Delhi

Figure 4 shows the comparative rainfall attenuation for the month of July for Ahmedabad and New Delhi for 64 years. Ahmedabad experienced a total rainfall of 21395 mm in July for 64 years and New Delhi experienced a total rainfall of 9788 mm **[7]**. From the values it is evident that maximum rainfall is observed in the month of July for both Ahmedabad and New Delhi. But the rainfall and rainfall intensity is much lower for New Delhi as compared to Ahmedabad. From the figure, it is observed that the mean rainfall attenuation in July is 27.03 dBs for Ahmedabad and 21.91 dBs for New Delhi. This suggests that maximum implementation of fade mitigation will be required for both Ahmedabad and New Delhi in the month of July. For other months, it will be less.

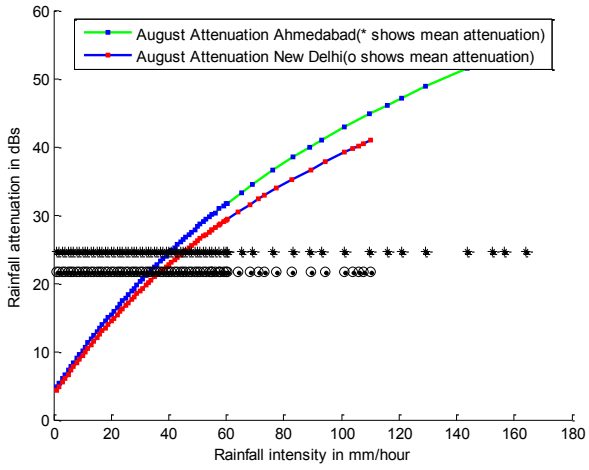

Figure 5 : Comparative rainfall attenuation for month of August for Ahmedabad and New Delhi

In August month, Ahmedabad has experienced a total rainfall of 17962 mm and Delhi has experienced a rainfall of 10567 mm from 1951 to 2014 **[7]**. Figure 5 shows that the mean rainfall attenuation for Ahmedabad is 24.62 dBs and for New Delhi it is 21.67 dBs which is comparatively low as compared to July for both locations.

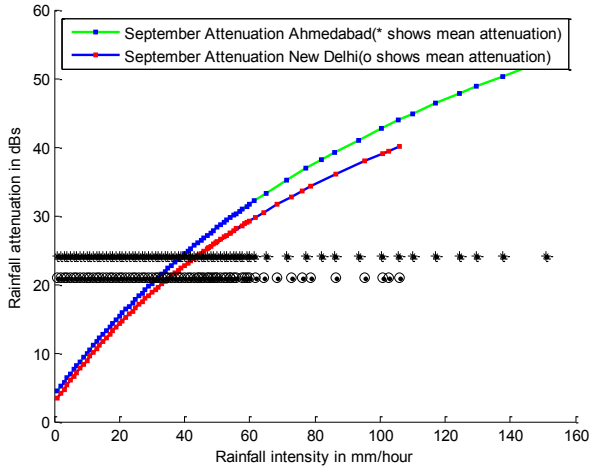

Figure 6 : Comparative rainfall attenuation for month of September for Ahmedabad and New Delhi

Ahmedabad has experienced a total rainfall of 9890 mm in the month of September and New Delhi has experienced a total rainfall of 5274 mm **[7]**. Again the total rainfall and rainfall intensity is almost half in the case of New Delhi as compared to Ahmedabad. The mean attenuation for Ahmedabad is 24.10 dBs and for New Delhi is 20.98 dBs. The fade mitigation required is less in the month of September as compared to July and August.

V. CONCLUSION

Rainfall intensity for 64 years monsoon months is calculated for Ahmedabad and New Delhi. According to different rain climate zones for Asia-Pacific Region suggested by ITU-R [12], New Delhi and Ahmedabad come under region K. For this K region, rain intensity exceeding 0.01% of an average year is 42 mm/hour. The rainfall intensity values obtained in this work is also near 42 mm/hour which proves the authentication of the method invented for estimation. In fact the values obtained are an improvement over ITU-R model, as the estimation is done for 64 years. The other outcome of this work is that it proves that for accurate rainfall attenuation predictions, point rainfall data or fine data is not needed and even the coarse data can be used for accurate rainfall predictions. The work shows that the rainfall intensity and hence the rainfall attenuation is most intense during the month of July for both

Ahmedabad and New Delhi. Subsequently comes the month of August, September and June in decreasing order for both Ahmedabad and New Delhi locations. The rainfall attenuation is less severe in New Delhi as compared to Ahmedabad. This work will be helpful for the application of necessary fade mitigation techniques for both locations. Also it will be helpful to future researchers for estimation of rainfall intensity and rainfall attenuation for other locations.

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