

**Modifications in Rainfall Intensity values suggested by ITU-R model and
Estimation of Rainfall Attenuation for Ka band for India**Alpesh H. Dafda¹, Dr. Kishore G. Maradia²¹ Research Scholar, Gujarat Technological University,² Professor in Electronics and Communication Engineering, Government Engineering College, Gandhinagar,

Abstract — Estimation of rainfall attenuation is very critical parameter when the Ka band is used for Satellite Communication. It becomes more important when the estimation is to be done for tropical country like India. The present work verifies the Rainfall Intensity values suggested by ITU-R model and also the Rainfall Attenuation estimation is done for Ka band downlink frequency 20.2 GHz for Ahmedabad and New Delhi using ITU-R P618-8 rain attenuation model. The rainfall intensity values are estimated for 64 years long monsoon duration from 1951 – 2014 using Kothyari and Garde IDF equation. The 1 hourly rain rate values obtained using Kothyari and Garde equation are converted to 1-minute integration time using ITU-R P837-6, before being used in the attenuation model. The study suggests modifications in the rainfall attenuation values suggested by ITU-R model for India by 1 to 3%. Also Rainfall Attenuation for Ka band for India has been calculated for Ahmedabad and New Delhi.

Keywords- Ka band, India, Modifications in 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, 64 years monsoon, 122 days long monsoon.

I. INTRODUCTION

Communication services have experienced a substantial growth in past few decades. The available radio spectrum is congested to such an extent that there is a need to go beyond and look for newer frequency band above 20 GHz [1]. At these higher radio band frequencies, the signal will be affected by many propagation impairments such as rain attenuation, cloud attenuation, tropospheric attenuation, scintillations etc. Among all impairments for higher frequencies, the rain attenuation is the most crucial and important parameter [2]. Rain attenuation results in outage that severely affects the signal quality and link availability that makes it a prime factor in designing satellite links [3]. The knowledge of rain attenuation is extremely important for tropical countries like India that experiences heavy rainfall. If the proper prediction of rain attenuation can be made, suitable fade mitigation techniques can be employed for avoiding link failure. India has launched GSAT 14 with Ka band beacons and is soon going to launch full Ka band Satellites to enhance bandwidth capacity which also makes the work of this paper interesting and important.

II. RAIN ATTENUATION MODELS

Due to the importance of rain attenuation in defining link availability, numerous efforts have been carried out in past several years to develop reliable techniques for its predictions. Most of these predictions and models are statistical in nature. Some popular models are Crane model (1980), ITU-R model (1982), Moupfouma-Martin model (1984), and Dissanayake, Allnutt and Haidara - DAH model (1997) [4]. India is planning to launch Ka band satellite in near future, but for Indian region very less work has been done for Ka band. So it is necessary to study propagation effects at Ka band for Indian climate. This paper applies ITU-R model because it is globally accepted and is continuously being updated as rain attenuation modelling is better understood [5]. Also as major of the predictions of rain attenuations are performed along the slant path, rather than along the nadir, the ITU-R model [6] provides the best estimate.

In present work, Ka band downlink satellite communication has been considered for the purpose of estimation of attenuation due to rain. The corresponding Ka band downlink microwave frequency is 20.2 GHz. The proposed study area is Ahmedabad and New Delhi. The ITU model P618.8 is used for the calculation of rain attenuation predictions for the Indian monsoon for 64 years from 1951 – 2014. For precise calculations of rainfall attenuation the rain data collected should be as long as possible. Keeping in mind this fact the rain attenuation prediction is done from 64 years (1951-2014)

data for India. The proposed work will be helpful to predict signal loss due to rain rate and adopt necessary fade mitigation technique for the future Indian Ka band satellite communication. The work also suggests an improvement in the rain rate suggested by global ITU-R model.

III. DATA SET USED AND THE AREA OF PREDICTIONS

Rainfall data of 64 years from 1951-2014 are obtained from IMD Indian Meteorological Department website. The data used are monthly average rainfall for 64 years available on IMD website. Monthly rainfall data for 4 months long Indian monsoon is obtained for 64 years of time period starting from 1951-2014. ITU-R P.837-6 [7] is used for the calculation of the rainfall rate exceeding 0.01% of an average year in mm/hr. Apart from the primary inputs to the ITU-R P.618-8 model [6], for ancillary data, we have provided the following station details for Ahmedabad and New Delhi as these are IRNSS reference stations (INRES) [8]:

Table 1: Site parameter details
 (Courtesy: www.mosdac.gov.in [9] and www.dishpointer.com [10])

STATION PARAMETER	AHMEDABAD STATION(AES)	EARTH DELHI STATION(DES)
Station Code:	ISRO0303	ISRO0463
Latitude(degree)	23.02356 °E	28.61 °E
Longitude(degree)	72.515 °N	77.23 °N
Station height above MSL(m)	48.77	293
Antenna height above MSL(m)	49.77	294
Antenna Polarization angle(degree)	21.7°	19.6°
Antenna Elevation angle(degree)	63°	56.4°

IV. ANALYSES OF DATA AND METHODOLOGY USED

4.1 Rainfall Rate Calculation

For rainfall rate calculation, first the monthly rainfall data obtained from IMD is converted to daily data by simple averaging method. This data is used in the IDF equation for Indian region developed by Kothyari and Garde [11]. 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 [11]:

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

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 [7] 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.

4.2 Rain Attenuation Calculations

The rainfall intensity obtained from Kathyari and Garde [11] equation for 64 years is applied to ITU-R model for estimation of Rainfall attenuation in dBs. The ITU-R P.618.8 [6] Model-Propagation data and prediction methods estimates the rain attenuation for rain rates at 0.01% probability. The 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.

V. RESULTS AND DISCUSSIONS

Figure 1 shows different rain climate zones for Asia-Pacific Region. India comes under rain zone K and N. New Delhi and Ahmedabad comes under region K. For rain intensity exceeding 0.01% of time, the rain intensity is 42 mm/hour for Ahmedabad and New Delhi as shown in Table 2 suggested by ITU-R.



Figure 1: Different Rain Zones defined by ITU-R in Asia Pacific Region [12].

Table 2: Rain intensity exceeded (mm/hr) for Indian Rain climate zones [12]

Percentage of time (%)	Region K	Region N
1.0	15	5
0.1	12	35
0.01	42	95
0.001	100	180

Figure 2 shows the overall rain intensity and attenuation for 122 days long monsoon (June, July, August and September) for Ahmedabad for 64 years from 1951-2014. Results show that the rainfall attenuation varies from 12.67 to 34.17 dB on average during monsoon period in Ahmedabad. 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. ITU-R specifies that for K region the 0.01 % of average time rainfall intensity is 42 mm/hour (Source ITU-R). Ahmedabad and New Delhi comes in the K region of ITU-R. A deviation of 1.047 % is obtained for Ahmedabad region as compared to ITU-R standard model. For this mean rainfall intensity of 41.56 mm/hour, the mean rainfall attenuation observed is 23.42 dBs.

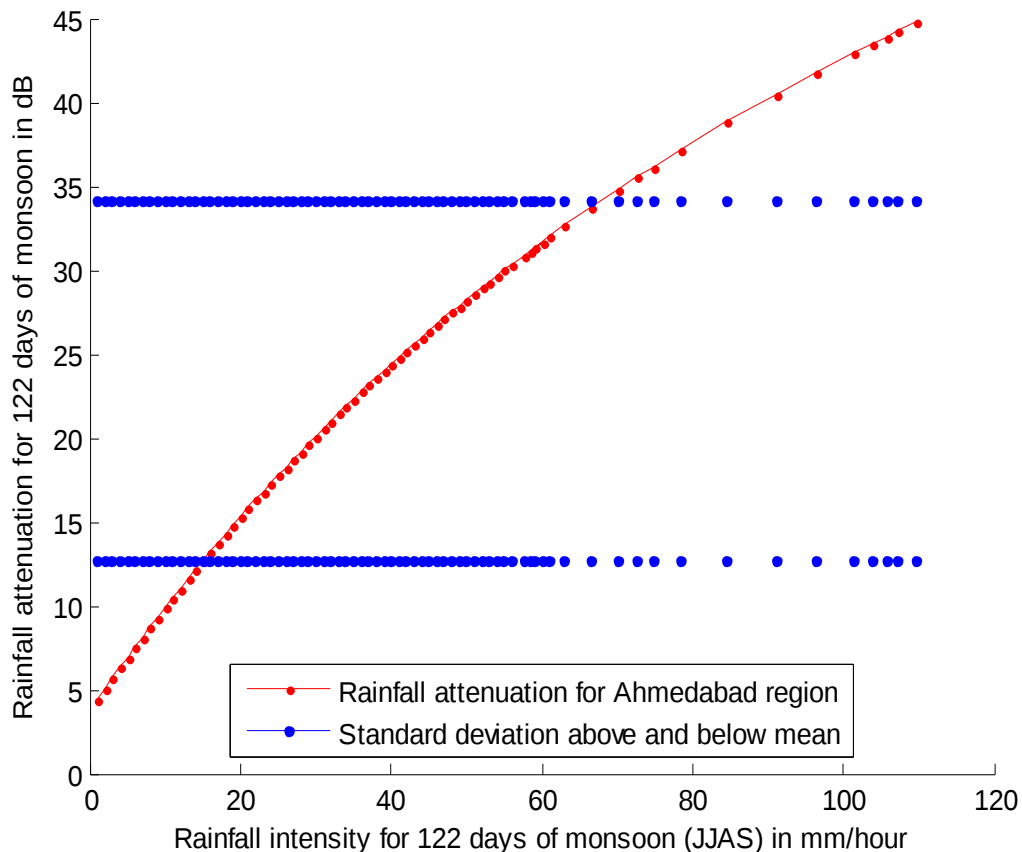


Figure 2: Overall rain intensity vs. attenuation for monsoon in Ahmedabad

Similarly for New Delhi, the mean rainfall intensity 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. For this mean rainfall intensity of 40.92 mm/hour, the mean rainfall attenuation obtained is 21.54 dBs. A deviation of 2.57 % is obtained for Delhi region as compared to ITU-R standard model. Figure 3 shows the overall rain intensity and attenuation for 122 days long monsoon for Delhi region for last 64 years. It shows that the rainfall attenuation varies between 11.94 to 31.14 dB on average during monsoon period in Ahmedabad. This leads to conclusion that the rain attenuation for Ka band is lower for Delhi as compared to Ahmedabad. Also around 1 to 3 % accuracy is obtained in rainfall intensity prediction. This improvement has occurred due to the fact that we have made predictions from the data of last 64 years.

Figure 4 shows the Overall rain intensity vs. attenuation for monsoon in Ahmedabad and New Delhi. It also shows Mean attenuation for both locations. Figure reveals that the rainfall intensity and hence the rainfall attenuation is less for New Delhi as compared to Ahmedabad. The mean attenuation for Ka band due to rainfall for Ahmedabad is 23.42 dB whereas for New Delhi it is 21.54 dBs.

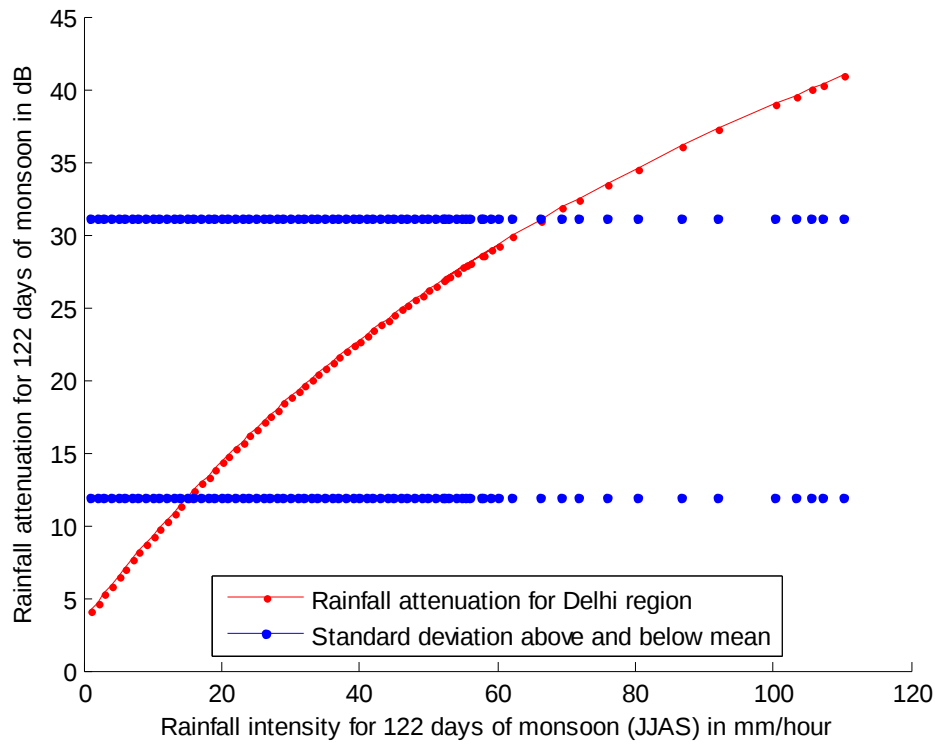


Figure 3: Overall rain intensity vs. attenuation for monsoon in Delhi

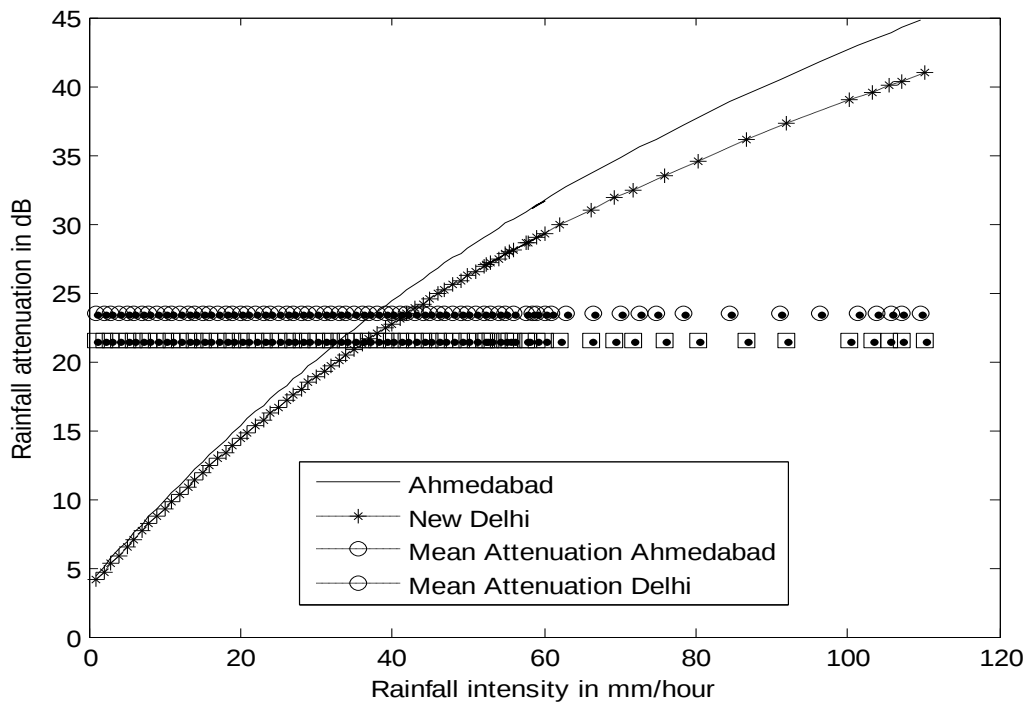


Figure 4: Overall rain intensity vs. attenuation for monsoon in Ahmedabad and New Delhi. Figure also shows Mean attenuation for both locations

VI. CONCLUSIONS

Rainfall intensity for 0.01% integration time is calculated for Ahmedabad and New Delhi for 64 years using Kothyari and Garde equation and 1 to 3 % improvement is observed as compared to the values suggested by ITU-R. These improvements in ITU-R predictions will be very helpful for future researchers. This improvement results as the

prediction duration chosen is very large. As large is the prediction duration, the more accurate the predictions are obtained. For the Ka band Satellite communication downlink of 20.2 GHz, the attenuation predictions have been carried out using the ITU-R 618.6 model. The calculations show that the attenuation increases rain rate. The same method can be used for predictions of other locations in India. This work also 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. In the present study the ITU-R 618.6 model has been implemented which is best suited for the tropical countries. This study finally suggests modifications in the existing ITU-R model rainfall intensity values for India by 1 to 3%.

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