Prediction of Ku Band Rain Attenuation Using Experimental Data and Simulations for Hassan, India

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Summary

In this paper, the results of rain attenuation experiment conducted at Master Control Facility, Hassan, India (13.07^0 N, 76.08^0 E) at a downlink operating frequency of 11.544 GHz in Ku-band was presented and the measurements are compared with several rain attenuation models. Also, typical frequencies in Ku bands which are in operation for different applications in India were chosen for obtaining the expected rain attenuation statistics using simulations and results are compared with ITU-R, Excell, Karasawa, Leitao-Watson and DAH models. The data collection period is from August-November 2004.

Key words:
Rain Attenuation, Ku band, Prediction Models, Satellite Communications,

1. Introduction

Utilization of higher frequency bands such as the Ku band for satellite communications provides a number of important benefits. It relieves congestion in the lower frequencies which are shared with terrestrial links; it exploits the larger bandwidths available at higher frequencies, and provides cheaper implementation of spectrum conservation techniques and a more efficient use of the geostationary arc. However, the severity of atmospheric impairments (especially due to rain) on radio wave propagation increases markedly with the increase in frequency. Therefore, extensive knowledge of the propagation phenomena affecting system availability and signal quality in these bands are required

Although theoretical and experimental studies of rain attenuation can be found in many literatures, the measured rain attenuation data is still insufficient in order to estimate the link within the individual spot beam. Most of the studies been performed in developed countries using satellite beacon experiments, whereas in tropical regions, studies were still needed to be pursued which may leads to new prediction model. Based on this reason it is proposed to conduct these experiments to study the effect of rainfall and other hydrometeors impact on INSAT series which are providing number of services operable in Ku band. In the present experimental study INSAT 3B satellite link was used and the simulations are performed by using DTH application frequencies of INSAT 3A/3B/4A. All these are communication satellites owned by Indian Research Space Organisation.

2. Experimental Setup Details

The main components used in the construction of the receiving station were a offset parabolic antenna of approximately one meter in diameter, a Block Down Converter (LNB) connected at the front of the antenna a rotor connected to the antenna that improves the pointing accuracy when tracking GEO-satellites, a spectrum analyzer with multiple different digital measuring functions, a laptop PC computer used for saving and expanding the measured spectrums and coaxial cables used to connect all together these components.

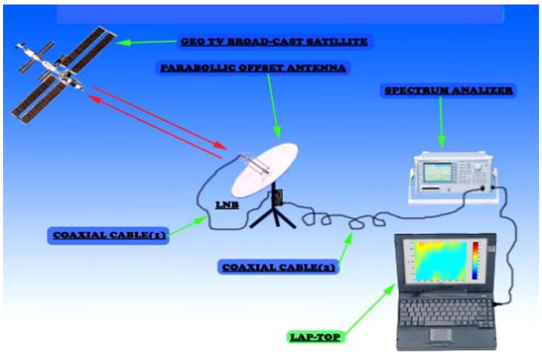

Fig 1: A schematic block diagram showing the main components of our receiving station

The above system was proposed be used for the propagation of signal over Earth-Satellite path using geo stationary downlink satellite beacon [1] operating at Ku-band frequency. The obtained parameters like signal strength with time during clear air and also precipitation events can be recorded and analyzed. Rain rate data is collected using rapid response rain gauge with 5 second integration at the same place where beacon signal is monitored. The outcome of the experimental

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measurements is Signal Strength (in dB) with a sampling time of 5 seconds and maximum of 17,280 samples per day along with Rainrate (mm/hr) values. [13]

3. Earth Station Location

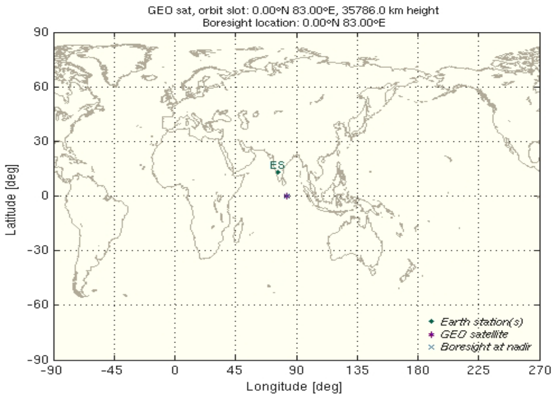


Fig 2: Earth Station Location and Satellite Position

4. Possible Propagation Impairments

The phenomena that lead to signal losses on transmissions through the earth atmosphere are: **Atmospheric absorption**: due to gaseous affects such oxygen and water vapor, **Cloud attenuation**: involve aerosol and ice particle effects that form part of the clouds, **Tropospheric scintillation**: due to the change of refractive indexes of the different gaseous and rain masses in this part of the atmosphere, **Rain attenuation**: is by far the most important attenuation factor at Ku-band frequencies, **Rain and ice depolarization:** due to rain drops shapes and sizes and ice particles content in clouds .[8],[10], [11], [12]

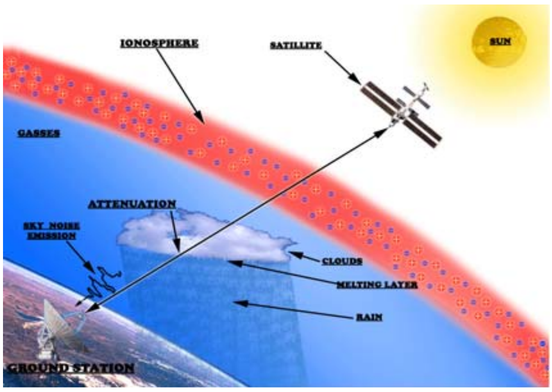


Fig 3: Propagation Impairments over Earth - Satellite Slant path

4. Received Signal Level and Rain Intensity

It has been seen that the signal level is at a level of -80 dB with a fade from 1 to 2 dB under clear air conditions. The communication link used to exhibit substantial loss of signal during rainy condition. The analysis of experimental results on signal levels and rain rates has yielded the percentage of time for which the communication link does not serve the purpose under rainy conditions during monsoon months, August to November over the Hassan region. Data of signal level and rain intensity during propagation and communication time were collected and analyzed within the period of August to November 2004. Rain attenuation is obtained by subtracting a reference level from the measured received signal level. The reference level is obtained by averaging the entire received signal level data on data on each month and at each place during no rain term. [7]

5. Rainfall Rate and Rain Attenuation

The results of satellite signal attenuation ad rainfall rate from this experiment are presented in figures 4. From the figures, it can be seen that the duration time of intense rain is shorter than the duration time of the rain attenuation. The figures below show the high intense rainfall events from the experimental results. [6]

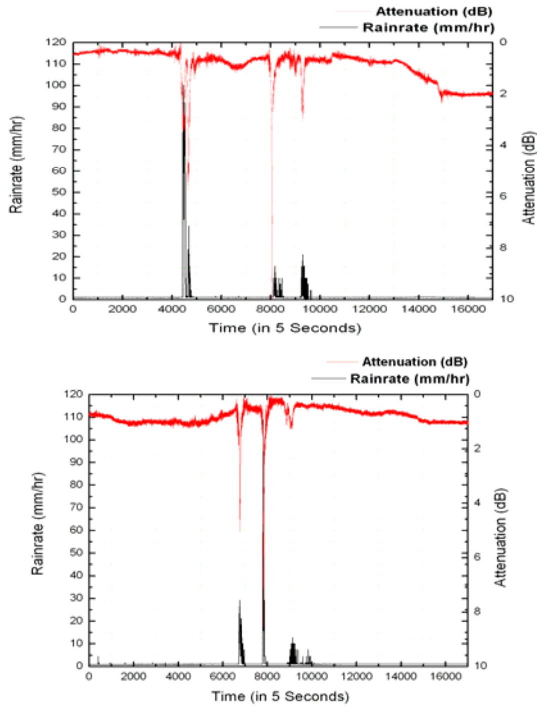


Fig 4: Variation of Signal Power and Rain rate during September 13, 2004 and October 02, 2004

6. Cumulative Distribution Function:Typical Days

From the days where measurements are taken up at Hassan location during August – November 2004, typical days are chosen for analysis. The selection of days depends on the information of heavy Rain rate (mm/hr) and corresponding attenuation (in dB) observed in the signal during the reception using the experimental antenna receiver setup described above.

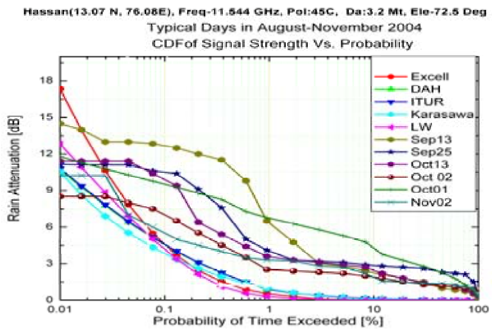


Fig 5: Cumulative Distributions of High Intense Rainfall rate days and corresponding Rain attenuation compared with models

In the plots shown here cumulative distribution function of Signal Strength vs Rain Attenuation the curve is not smoother, because of the number of samples are less, considered for one day only

7. Monthly Cumulative Time of Rainfall Rate

Monthly cumulative time in Hassan during August-November 2004 was shown in figure below. It can be seen that during the monsoon season for the months, September and October Rain rate is almost reached a value of 180 mm/hr for 0.1 % probability of time, and during the August month the maximum Rain rate observed was 60 mm/hr for 0.001% and for November it is of 80 mm/hr for 0.01 % probability of time

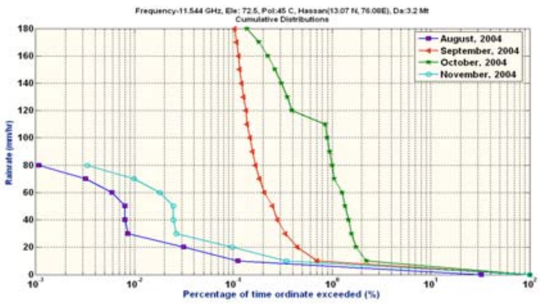


Fig 6: Cumulative Distributions of Rain rate Individual for the four months August-November in 2004

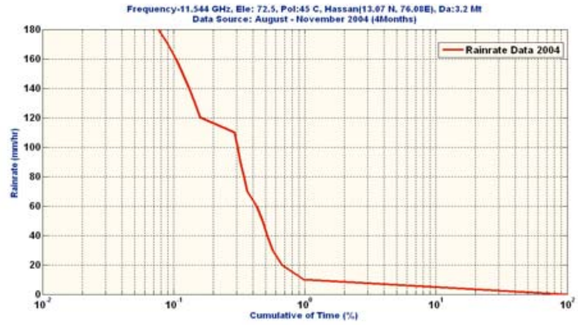


Fig 7: Cumulative Distributions of Combined Rainrate of the four months August-November 2004

8. Monthly Cumulative Time of Rain Attenuation

The rain attenuation observed from measurements varies from month to month because of variation in rainfall intensity. Four months CDF shows that for a probability of 0.01 the attenuation observed was about 24 dB which is considered to be more than actual ITU-R given values

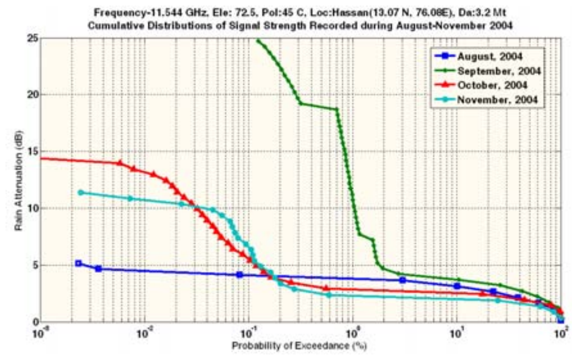


Fig 8: Cumulative Distributions of Signal Strength Variation (Monthly) for the four months August-November in 2004

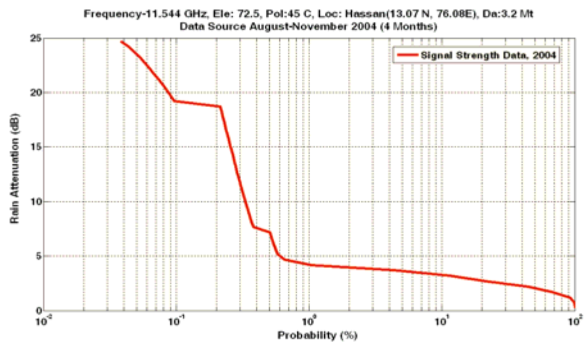
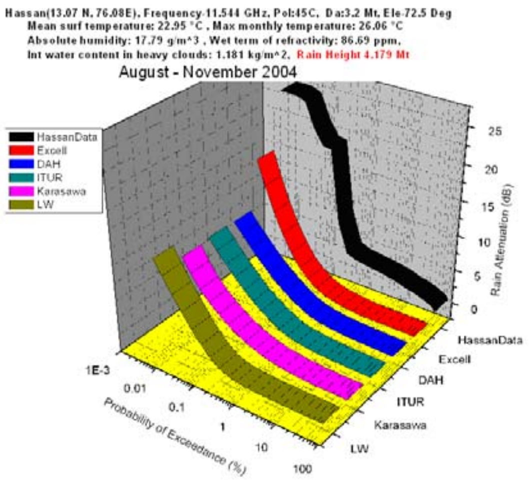


Fig 9: Cumulative Distributions of Signal Strength Variation (Seasonal) for the four months August-November in 2004

9. Comparison with Models

From the comparison plot it was observed that the Rain Attenuation (in dB) is approximately 24 dB where as from all the models it ranges in between 5-15 dB. This is because the input parameters like Station height, Mean temperature at ground level, Maximum monthly surf temperature, Absolute humidity, Integrated water-vapor content statistics, Integrated reduced liquid water content statistics, **Rain height**, Rainfall rate statistics, Rain intensity exceeded for 0.01 % of the year, Wet part of surface refractivity are chosen low value in the models. Also one of the reason is the measurement time is too low. Attempt has been made to compare the observed rain attenuation with number of models [4], [5], [14] by varying parameters mentioned above which are shown in the figure 10 (a, b)



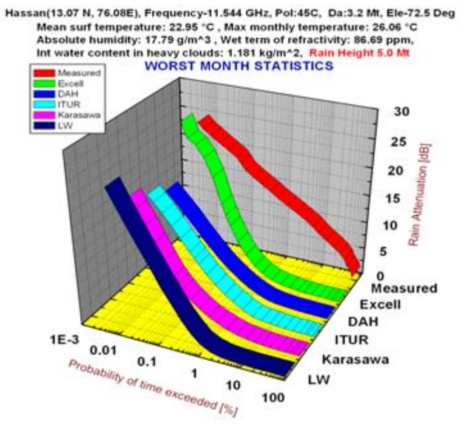


Fig 10(a, b): Comparison plot of Rain Attenuation measured at Hassan location with worldwide accepted models, considering the Worst Month Statistics.

10. Rain Attenuation Prediction for INSAT 3A/3B/4A Ku Band Frequencies

As the most important factor, the Rainfall Rate data is needed for determining the degree of rain attenuation in the Ku-band satellite communication system. Field measurements and recordings for long time periods are the best (empirical) method to know the rainfall rate in a country. Such data can then be used for various calculations concerning signal attenuation caused by rain. The input requirements to run the simulations are frequency, latitude, longitude, polarization, elevation angle, station height, antenna diameter, and other meteorological parameters along with the ITU-R data base files. Most of the input values used in simulation are taken from the ECMWF data. A Matlab program was developed to predict the rain attenuation, the output of the program was the CDF of Rain attenuation by the providing the required inputs.

The figure 11 shows the Rain Attenuation versus Probability of exceedance for different frequencies ranges in between 11-14 GHz. All the frequencies considered for simulation based on the application frequencies of DTH Services which are in operation over Indian region. From the above maximum attenuation was observed using DAH model for the frequency 14.75 GHz is 16 dB and the minimum for 11.15 GHz which is about 4 dB. The value of rain rate considered is 90 mm/hr

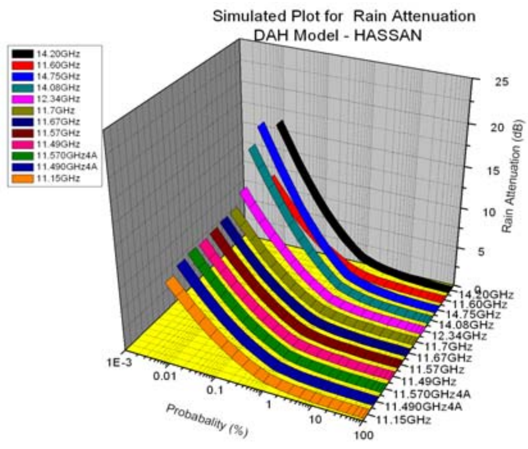


Fig 11: Predicted Rain Attenuation for different uplink/downlink frequencies between 11-14 GHz

Using the input considerations same as in DAH model the simulations are performed for Excell [2] model and the estimated value of attenuation is about 23 dB for the frequency of operation 14.75 GHz where maximum value estimated and minimum value of 11 dB for the frequency 11.15 GHz

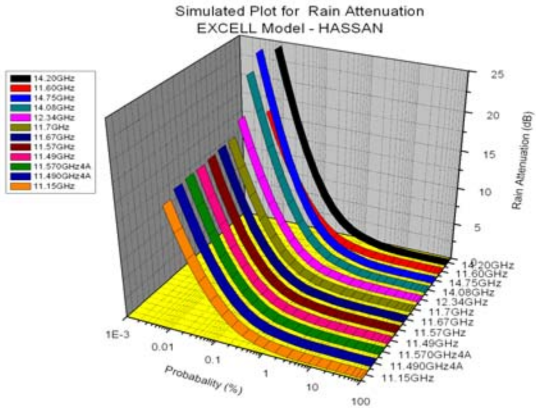


Fig 12: Expected Rain Attenuation for different uplink/downlink frequencies ranging between 11-14 GHz for INSAT 3A/3B/4A/4B satellites

From the figure 4.12 the predicted values of rain attenuation using ITU-R method was provided for number of application frequencies. The maximum and minimum values of attenuation are 16 dB and 4 dB for the frequencies 14.75 GHz and 11.15 GHz respectively.

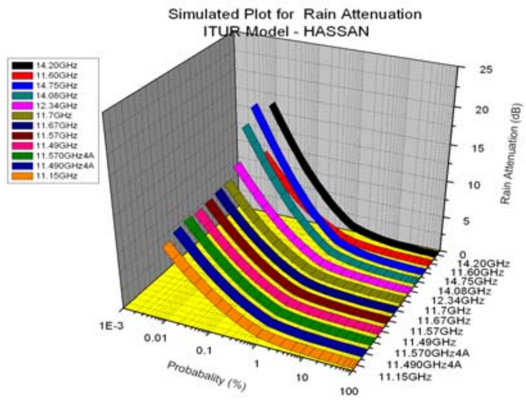


Fig 13: Simulation plot using ITU-R model for prediction of Rain Attenuation using different uplink/downlink frequencies ranging between 11-14 GHz for INSAT 3A/3B/4A/4B satellites

The predicted values of attenuation for the frequencies 14.75 GHz and 11.15 GHz are 8 dB and 4 dB, the results are obtained using the Karasawa model. Using the models DAH [3], ITU-R, Karasawa[9] the difference in predicted attenuation is not more than 20 % each other.

From the Leitao-Watson model [16] the rain attenuation predicted for a Hassan location was given as 17 dB for 14.75 GHz and 6 dB for 11.15 GHz. The simulations are run by considering the required input values for predicting the rain attenuation in dB.

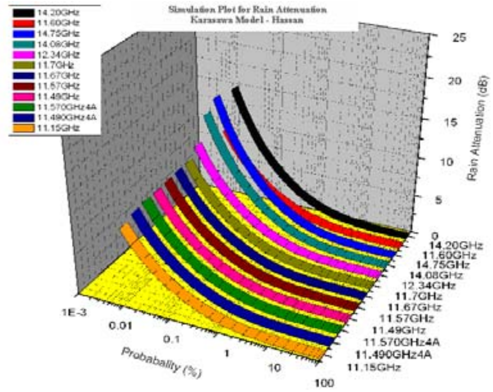


Fig 14: Plot for predicting the value Rain Attenuation using Karasawa model for uplink/downlink frequencies ranging between 11-14 GHz

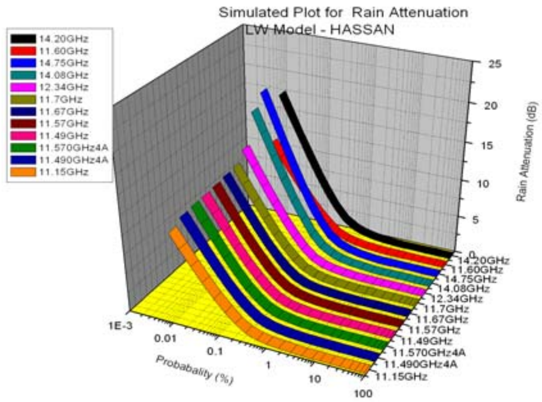


Fig 15: Using LW model for prediction of Rain Attenuation using uplink/downlink frequencies from 11 -14 GHz of various Ku band Geo-Stationary satellites.

11. Summary and Conclusions

Using the experimental data collected at Hassan, the cumulative distribution function of the rain rate and rain attenuation was plotted and is compared with number of models. Also number of frequencies which are in operation for different application in India was chosen to predict the rain attenuation which will be useful for propagation engineer for the effective estimation of link availability during the rainy days. The world wide used ITU-R method underestimating the rain attenuation for a Hassan location, showing a difference about 10 dB.

It is well known fact that long term experimental data is very much required to predict the rain attenuation of the desired location, and the data considered is only 4 months may not provide accurate results. And the measurements made for a location Hassan are been compared with the world wide used propagation prediction models resulting either underestimating or overestimating the observed measurements. This is because of most of the models are developed and are valid in mid latitudes or temperate regions are considered to be estimation on global means. Attempt has been made to predict the rain attenuation using the INSAT Ku band downlink satellite beacon in India.

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