International Journal on Emerging Technologies **2**(2): 9-13(2011) **ISSN No. (Print) : 0975-8364**
ISSN No. (Online) : 2249-3255

Performance Improvement in Ku Band Satellite Radar Communication System

Liladhar P. Bhamare, A.P. Abhishek Choubey and Shabahat Hasan
Department of Electronics and Communication, RKDF Institute of Technology, Bhopal, (MP)

(Received 17 August, 2011, Accepted 14 October, 2011)

ABSTRACT : This paper describes a Ka band satellite radar receiver system for measuring both the sky noise and the attenuation caused by rain and water vapor to satellite signals, at the same frequency and look angle. To enable the receiver to stay locked to satellite beacon signals with received power levels between -110 dBm and -170 dBm, a receiver with an ultra low phase noise, an absence of spurious signals and using advanced digital signal processing (DSP) techniques is required. To obtain rain fade statistics, the received signal power of a satellite beacon is recorded continuously at an eight times per second rate.

Keywords: The receiving signal parabolic antenna Ku band, Data Simulation Models for Satellite Communication.

I. 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.

II. 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 cablesusedto connect altogether these components.

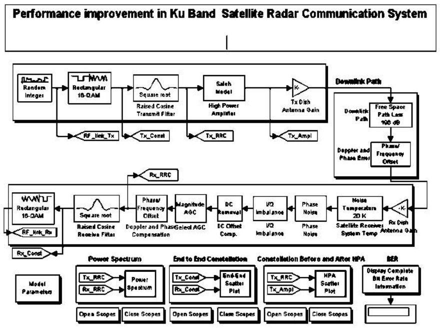

Fig. 1. A Schematic Block Diagram Showing the Main Components of our TX/RX Station.

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

III. EARTH STATION LOCATION

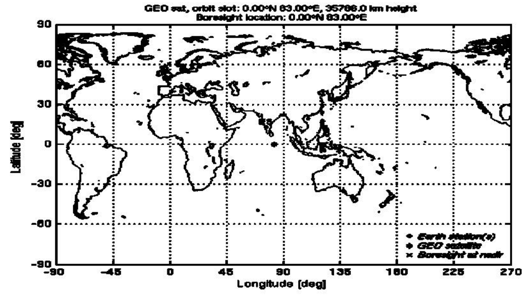

Fig. 2. Earth station location and satellite position.

IV. 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, Troposphere 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].

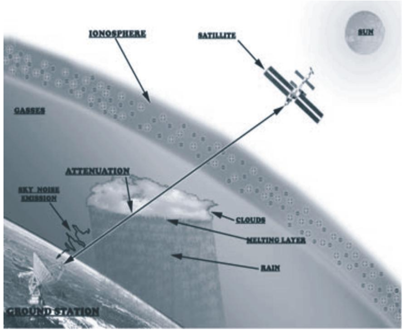

Fig. 3. Propagation Impairments over Earth - Satellite Slant path.

V. 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 region. Data of signal level and intensity during propagate and communication time were collected and analyzed within the 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].

VI. RAINFALL RATE AND RAIN ATTENUATION

The results of satellite signal attenuation ad rainfall rate from this experiment are presented in Fig. 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].

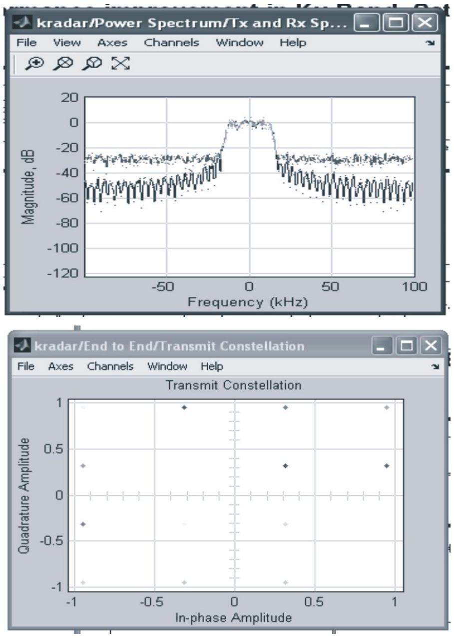

Fig. 4. Variation of Signal Power and Rain rate during.

VII. CUMULATIVE DISTRIBUTION FUNCTION: TYPICAL DAYS

From the days where measurements are taken up at 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.

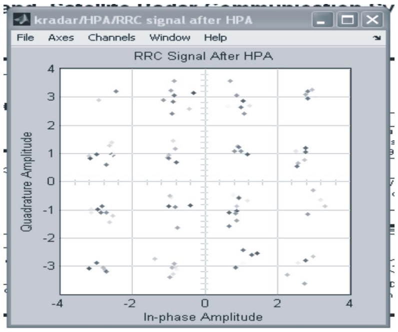

Fig. 5. Cumulative Distributions of High Intense Rainfall rate days and corresponding Rain attenuation compared with models.

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.

VIII. MONTHLY COMULATIVE TIME OF RAINFALL RATE

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.

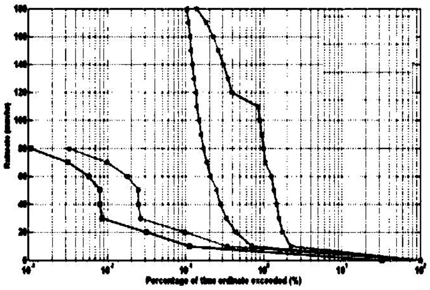

Fig. 6. Cumulative Distributions of Rain rate.

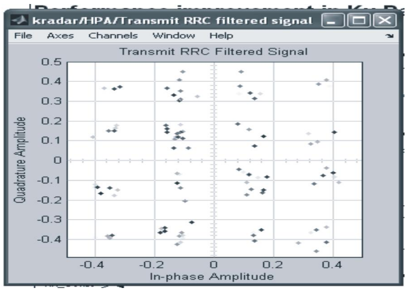

Fig. 7. Cumulative Distributions of Combined Rainrate.

IX. 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 ITUR given values.

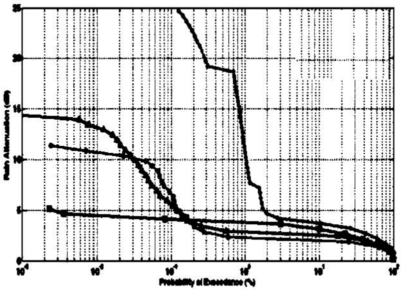

Fig. 8. Cumulative Distributions of Signal Strength.

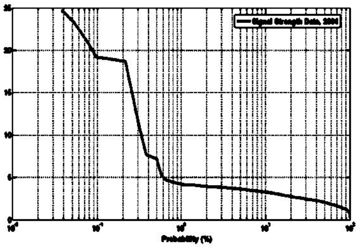

Fig. 9. Cumulative Distributions of Signal Strength.

X. 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 Fig. 10 (*a*, *b*).

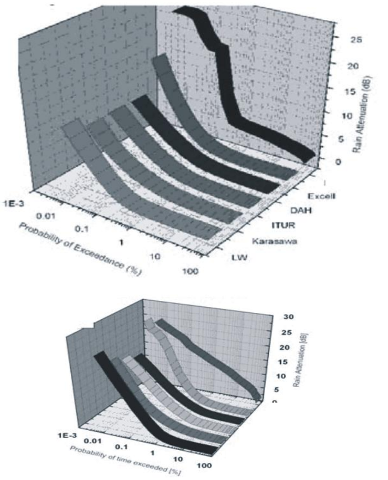

Fig. 10 (*a*, *b*). Comparison plot of Rain Attenuation measured.

XI. 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 Matlab7.8 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 Fig. 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.

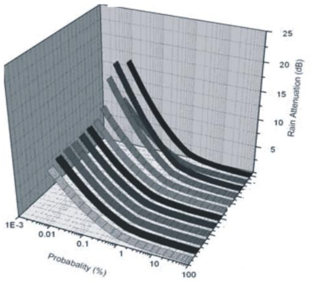

Fig. 11. Predicted Rain Attenuation for different uplink/downlink frequencies between 11-14 GHz.

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.

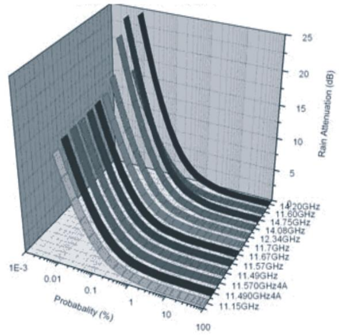

Fig. 12. Expected Rain Attenuation for different uplink/downlink frequencies ranging between 11-14 GHz for INSAT 3A/3B/4A/4B satellites.

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.

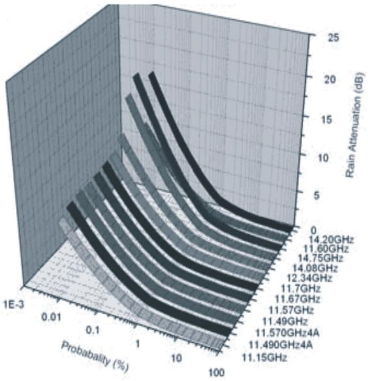

Fig. 13. Simulation plot model for prediction of Rain Attenuation using different uplink/downlink frequencies ranging between 11-14 GHz for INSAT 3A/3B/4A/4B satellites.

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.

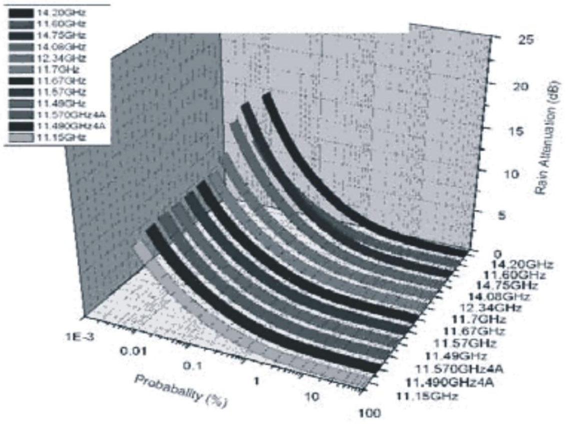

Fig. 14. Plot for predicting the value Rain Attenuation model for uplink/downlink frequencies ranging between 11-14 GHz.

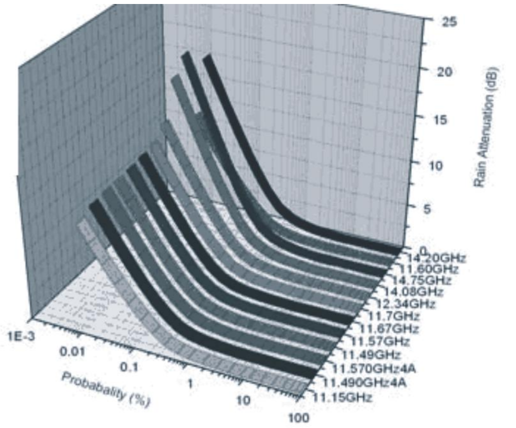

Fig. 15. Using LW model for prediction of Rain Attenuation using uplink/downlink frequencies from 11-14 GHz of various Ku band Geo-Stationary satellites.

XII. SUMMARY AND CONCLUSIONS

Using the experimental data collected at 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 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 radar downlink satellite beacon in India.

REFERENCES

[1] Attasit Datsong, Narong Hemmakom and Nipha Leelaruji The Rain Attenuation in Ku-Band Satellite Signal at Bangkok, ICICS, (2005) 0-7803-9282-5/05 IEEE.

[2] Capsoni C., F. Fedi, C. Magistroni, A. Pawlina and A. Paraboni, "Data and theory for a new model of the horizontal structure of rain cells for propagation applications", R*adio Science*, Vol. **22**, No. 3, pp. 395-404, (1987).

[3] Dissanayake A., Allnutt J., Haidara F., "A prediction model that combines rain attenuation and other propagation that combines rain attenuation and other propagation impairments along Earthsatellite paths", *IEEE Transactions on Antennas and Propagation*, Vol. **45**, No. 10, pp. 1546-1558, 1997

[4] ITU-R P. 618-8 (2004), Propagation Data and Prediction Methods Required for the Design of Earth-Space Telecommunication Systems.

[5] ITU-R: Specific attenuation model for rain for use in prediction methods. Rec. P. 838, ITU-R, (1999).

[6] J.S. Mandeep, S.I.S. Hassan, and K. Tanaka Rainfall effects on Ku-band satellite link design in rainy tropical Climate *JOURNAL OF GEOPHYSICAL RESEARCH*, VOL. **113**, D05107, doi: 10.1029/2007JD008939, (2008).

[7] Maitra, A. (2004), Rain Attenuation Modeling from Measurements of Rain Drop Size Distribution in the Indian Region, *IEEE Trans. On Antennas and Wireless Propag*. Letter., **3**(9), 180- 181.

[8] Maitra, A.K Chakraathy Ku-band rain attenuation observations on an earth-space path in the indian region, *IEEE*, (2005).

[9] Matsudo T. and Karasawa Y., "Characteristics and prediction methods for the occurrence rate of SES in available time affected by tropospheric scintillation," *Electronics and Communications in Japan*, vol. **74**, no. 8, pp. 89-100, (1991).

[10] R.K. Crane, "Prediction of attenuation by rain. *IEEE Transactions on Communications*," Vol. COM-**28**, No.9, pp. 1717-1733, Sep. 1980.

[11] R.K. Crane, Electromagnetic wave propagation through rain. John Wiley & Sons, Inc. pp. 1-4, (1996).

[12] R.L. Olsen, D.V. Rogers, and D.B. Hodge, "The aRb relation in the calculation of rain attenuation," *IEEE Trans. Antennas propagation*, Vol. AP-**26**, pp. 318-329, Mar. (1978).

[13] Ramachandran,V. Kumar (2004), Rain Attenuation Measurement on Ku-band Satellite TV Downlink in Small Island, *Electron. Lett.*, **40**(1), 49-50.

[14] Rachan lekkla* and Prasit prapinmongkolkarn DIURNAL VARIATIONS IN RAIN ATTENUATION ON Ku BAND EARTH-SPACE PATHS *Int. J. Satell. Commun.*, **16**, 219-236, (1998).

[15] ITU-R P. 837, "Characteristics of precipitation for propagation modeling", ITU-R Recommendations ITU, (2001).

[16] Watson P.A., Leitao M.J., Turney O., Sengupta N., "Development of a climatic map of rainfall attenuation for Europe", Postgraduate School of Electrical and Electronic.