Two Year Rain Attenuation Statistics Over a Line of Sight Terrestrial Microwave Link Operating at 30 GHz in Tropical Region Amritsar (India)

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Abstract

The effect of precipitation present in the path of earth-space communication links, in terms of fading of the signal, is well known. The calculation of fade margin required for 99.99 % of the time-availability of such links requires the knowledge of rain rate and attenuation levels for 0.01 % time of the year. The International Telecommunication Union (ITU-R) has given recommendations regarding the estimation of rain rate and attenuation levels but it has been found that the recommendations are not suitable for tropical regions whereas some degree of agreement has been found for temperate regions.

The paper presents the results of two year rain attenuation measurement program conducted in a tropical site Amritsar (India). The results are based upon the rain rate data collected by using a tipping bucket rain gauge and receiver data of LOS link operating at 28.75 GHz. The results presented in the form of cumulative distributions (CD) of rainfall rates and rain attenuation are compared with the calculated ones in accordance with relevant ITU-R recommendations. The experimental results are different from that predicted by ITU-R.

1. Introduction

Satellite communication systems operating at much higher frequencies are subjected to the degradation constituted by the various atmospheric constituents and this degradation is much more severe than that found at lower frequency bands [1-2]. These atmospheric constituents include hydrometers like fog, rain, hail, ice, clouds and moist air. Out of all the hydrometers as listed above, rain is the one, which requires the most serious attention because of the high degree of attenuation that it may cause due its high dielectric constant. It is the rain, which is responsible for the degradation of the performance of a communication system. Thus the knowledge of rain-induced attenuation at the frequency of operation, is a pre-requisite for engineering a reliable communication link, be it a satellite communication systems, a radio link, a radar system or a microwave propagation system. For desired percentage reliability of a satellite communication link, the fade margin due to the rain exceeding that much percentage of time has to be considered. The International Telecommunication Union (ITU-R) has given recommendations [4-5] regarding various above mentioned factors but it has been found that the recommendations are not suitable for tropical regions whereas some degree of agreement has been found for temperate regions [3].

The prediction of rain attenuation on a LOS link required the collection of propagation data over LOS links, radiometric data and meteorological data in the form of rain rate statistics.

The paper presents two year rain attenuation and rate measurement results carried out on a LOS link operating at the frequency of 28.75 GHz. The results are different from that predicted by ITU-R.

2. Experimental Setup

The complete experimental setup is as shown in fig.1.

As shown in the fig.1, the transmitting station has been setup at Village Mallahan and receiving station at top of GNDU library respectively with LOS distance of 2.29 kms. A Tipping rain bucket rain gauge has been installed at receiver site to measure the instantaneous rain rate. The rain gauge is having the accuracy of 0.254 mm.

All the data outputs were directly interfaced with computer by means of Agilent Data Acquisition System which is a serial data acquisition system respectively. The data is monitored during periods of rain for deriving a relation between rain rate and excess attenuation due to rain [6-9].

3. Data Collection

The line of sight data was regularly monitored during rainy events. The receiver was calibrated on regular intervals of time with the standard sources of microwave power. For purpose of calibration; the receiver is disconnected from the antenna and is then connected to a standard signal source along with a variable attenuator. The signal to the receiver can be varied through a variable attenuator, which gives us different output values. Regression analysis over these points gave the best fit equations of the calibration curve of the receiver at 28.75 GHz as given below:

$$S_{28.75} = 11.974 \,.\mathrm{Ln}(V) - 27.851 \quad (\mathrm{dBm}) \qquad (1)$$

Where $S_{28.75}$ and V are received signals in dBm and milli-volts respectively

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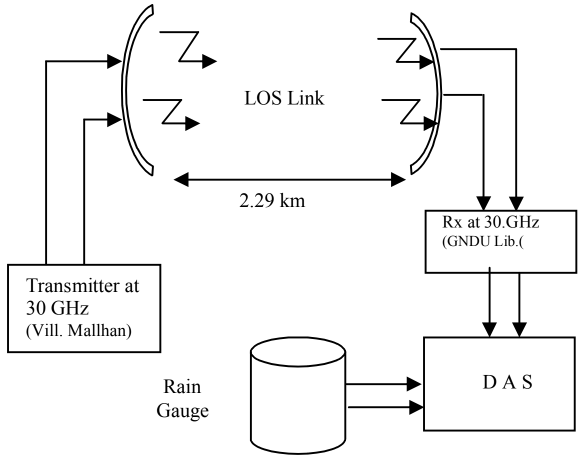

Fig. 1 Block Diagram of Experimental Setup

.The output of the receiver in clear sky conditions was in volts while it reduced to several tenths of volts on several occasion of rainy event. The data was monitored during periods of rain for deriving a relation between rain rate and excess attenuation due to rain.

The data from the receiver was recorded in the form of DC voltage whereas the data from the tipping bucket was recorded in the form of AC voltage which actually represents the charging voltage of a capacitor connected to mercury switch of tipping bucket rain gauge. A typical recording of the data is as shown in the fig 2. After the raw data has been collected, then this data is processed to obtain the rain rates (at the tip point) and corresponding attenuation levels. The rain rate is calculated by the following equation

$$R=0.254/t \qquad (2)$$

Where 't' is the time period between the two consecutive tips in hrs

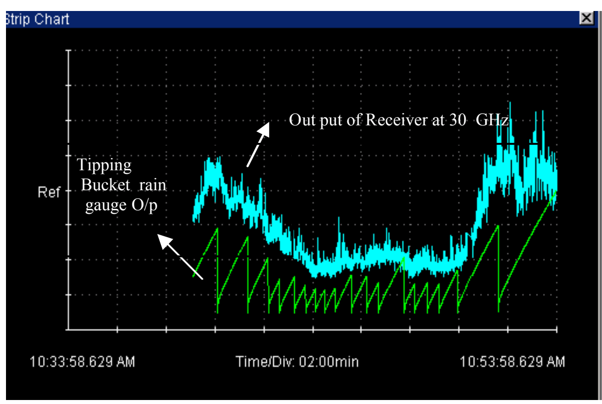

Fig. 2 Snap short depicting attenuation of LOS signal with rain rate

4. Results

The rain rate and corresponding signal attenuation data was collected for a period of two years. All the events were than processed statistically to form cumulative distribution of attenuation. For the purpose of formation of cumulative distribution of rain fall rate, the duration of the each rain rate in the whole year is added , then percentage time, the rain fall rate exceeds a particular rain rate can be calculated by using the formula [3]

$$\frac{\text{Total cumulative rain time exceeding corresponding to rain rate}}{\text{Total Time (Including non-rainy period)}} \times 100 \qquad (3)$$

The formula can be used for formation of year-wise cumulative distribution of rainfall rate for two years time which is as given in fig. 3 and fig. 4 respectively. In the both cases, one can infer that the annual measured rain rate distribution are much lower that those predicted by ITU-R. Since the rain gauge was in operation for both years and not a single event was missed, therefore there is no scope of any kind of ambiguity in the results. Though there were some events with a very little rain fall rate, the events were very low. In the similar manner, cumulative distribution of attenuation for two years is as given in fig. 5 and fig. 6 respectively. The CD of attenuation has also been compared with that predicted by ITU-R.

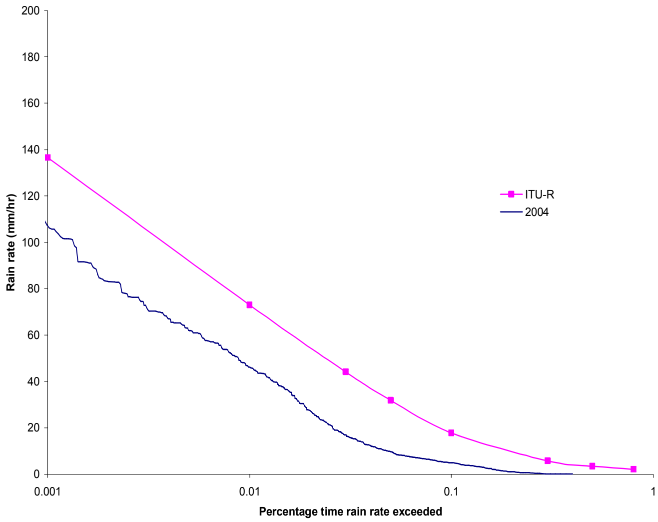

Fig. 3 Yearly Cumulative Distribution of rain rate for 1st year as compared with ITU-R results

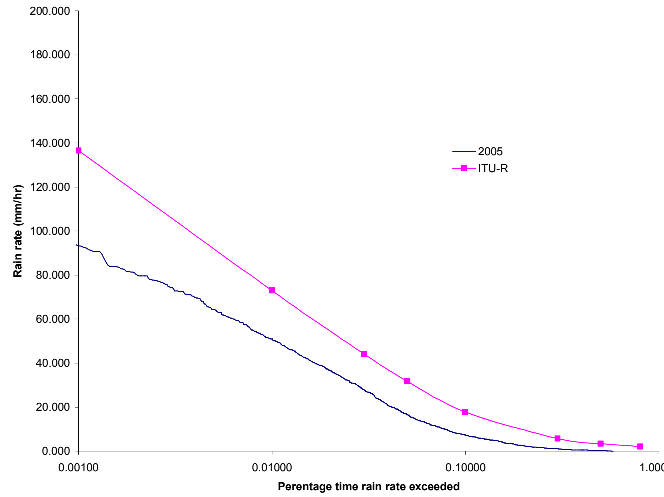

Fig. 4 Yearly Cumulative Distribution of rain rate for 2nd year as compared with ITU-R results

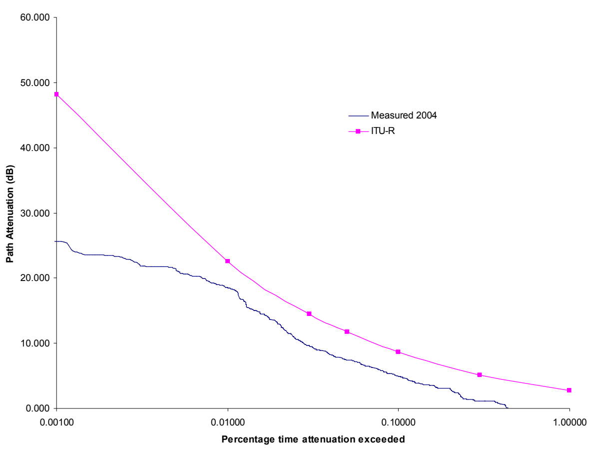

Fig. 5 Yearly Cumulative Distribution of rain attenuation for 1st year as compared with ITU-R results

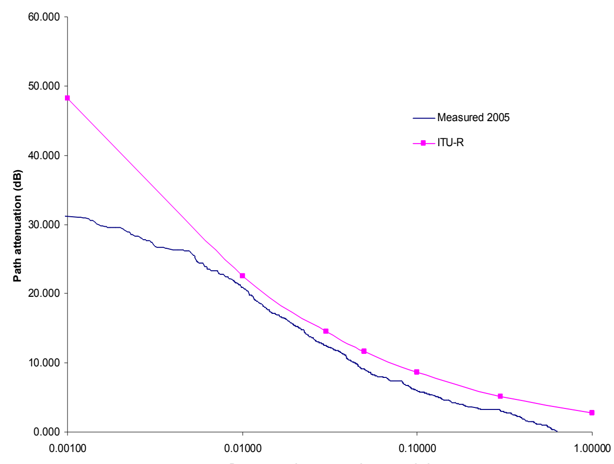

Fig. 6 Yearly Cumulative Distribution of rain attenuation for 2nd year as compared with ITU-R results

The yearly CD's of attenuation levels are also compared with those predicted by using ITU-R Rec. P 530-1 is as given below

$$\frac{A_p}{A_{0.01}} = 0.12\, p^{-(0.546+.043\log_{10} p)} \tag{4}$$

Where Ap, is the attenuation exceeding for the percentages of time 'p' in the range 0.001% and 1%. From fig 5 and 6, It is observed that the there is significant difference between the values predicted by using ITU-R and those predicted, particularly at lower percentage of time which is characterized by higher rain rates.

This can be due to the cell size which decreases rapidly with increase in rain rate. Thus there is a need to revise the existing ITU-R models. This objective can be fulfilled by using cumulative distribution of the full year to form the formulas for deriving the formula for attenuation prediction. Attenuation Ap, exceeded for the percentages of time 'p' in the ranges from 0.001% to 1% may be deduced from the following modified power relation for 1st year.

$$\frac{A_p}{A_{0.01}} = 0.02\, p^{-(1.255 + .225 \log_{10} p)} \qquad (5)$$

The modified formula has been derived to give factors of 4.92 dB, 18.51 dB and 25.60 dB for 0.1%, 0.01% and 0.001% respectively.
Similarly, for the 2nd year, the modified formula is as given below

$$\frac{A_p}{A_{0.01}} = 0.05\, p^{-(0.9 + .18 \log_{10} p)} \qquad (6)$$

The modified formula has been derived to give factors of 5.95 dB, 20.8 dB and 33.56 dB for 0.1%, 0.01% and 0.001% respectively. If the average of two years' is taken, then it is seen that the equation 6 provides the best results and can be used for the prediction of attenuation levels. Using the concept of frequency scaling, the attenuation levels for a link operating at other frequency can also be estimated.

5. Conclusions

In this paper, efforts have been made in the direction to fully study and investigate propagation of microwave signal at 30 GHz at Amritsar. Rain rate has been estimated by measured by using tipping bucket rain gauge. The same has been estimated to form cumulative distribution of rain rates. It has been observed that there is variation between the measured rain rate and those predicted by ITU-R.
The corresponding attenuation levels of the individual rainy events have been statistically processed to form cumulative distribution for the two years, which for the both the two years are lower than the levels predicted by ITU-R. Based upon the results in the form of CD, a new formula has been proposed for the estimation of attenuation levels.

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