THE EFFECT OF HEAVY RAINFALL ON ATTENUATION OVER TERRESTRIAL LOS LINK AT 28.75 GHZ

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1.Introduction

Recent advances in civil and military communication systems require the use of higher frequencies for terrestrial & satellite communication links in the millimeter wave range. The reliability of such systems may be severely degraded due to rain-induced attenuation. Many methods proposed for predicting rain-induced attenuation make use of the rainfall cumulative distribution measured at point. International Radio Consultative Committee (CCIR) [1] has suggested the use of report 338 to calculate the cumulative distribution of rain attenuation. In this experiment Rain induced attenuation at 28.75 GHz over a terrestrial line-of-sight link of 2.29 km was measured for the period of one year in Amritsar (31° $36'$ N 74° $52'$E) environment. An empirical model for predicting rain-induced attenuation on terrestrial path link is proposed and compared with the recently prediction method proposed by the International Radio Consultative Committee (CCIR). It is found that our experimental results differ from those obtained using CCIR equation for the rain rates occurred during this period.

2.Experimental set up

The experimental site in India (Amritsar) is at Lat.31°36′N & Long.74°52′E and about 229.4m above sea level. The line of sight link consists of CW transmitter and corresponding receiver at 28.75 GHz. The link has been set up between Guru Nanak Dev University, Amritsar and the nearby village Mallahn. The distance between the transmitter and receiver is 2.29 km. The transmitters and receivers are housed in air-conditioned huts to keep the temperature constant. System setup for the rain attenuation measurement is shown in fig.1. This arrangement provides a dynamic range of about 47 dB at 28.75 GHz of excess attenuation, which is adequate for our purpose. The transmitter consists of Phase Locked Oscillator (PLO) to provide stable source for transmission.

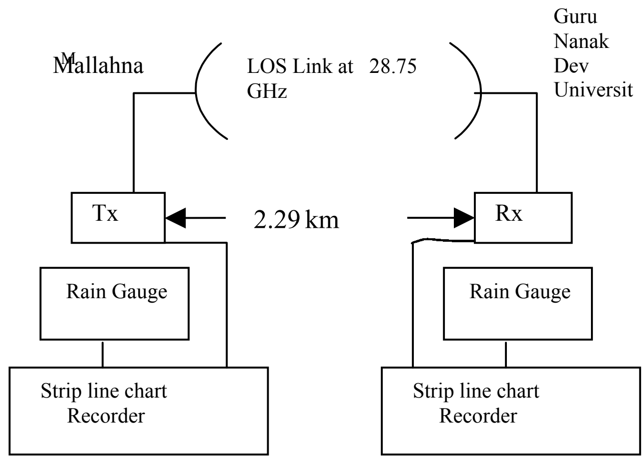

Fig.1 Experimental setup for rain attenuation Measurement

Tipping bucket rain gauges of 0.254 mm sensitivity are co-located near the receiving and transmitting sites to measure average point rainfall rates. The rain gauge uses a 12-inch diameter orifice and a tipping bucket mechanism coupled to a mercury switch. The buckets are calibrated to make one tip for each 0.01 inch of rainfall. As one-bucket fills and tips, the second bucket starts collecting water. At the time of tip a magnet moves and momentarily closes the mercury switch that is connected to an event marker of the strip line chart recorder where each event is recorded.

3. Measurement Procedures

The rain attenuation data collected over line of sight (LOS) link have been analyzed for cumulative attenuation statistics. Data collection started on 1st January 2001 and we present one-year statistics from Jan to Dec 2001. Experimental results have been compared with that of predicted by CCIR. The CCIR prediction is determined as given below.

3.1 CCIR Prediction:

The rain-induced attenuation on a line of sight (LOS) path can be expressed as

$$A = \alpha L_{eff} = \alpha L r \quad (dB) \qquad \ldots\ldots..(1)$$

The effective path length L_{eff} can be computed by multiplying the actual path length L (2.29 km for our LOS link) with a reduction factor r, given by [1]

$$r = 1/(1 + L/L_0), \text{ where } L_0 = 35 \exp(-0.015 R) \qquad \ldots\ldots\ldots(2)$$

The specific attenuation α (dB/km) and rain rate R (mm/hr) are related by [2]

$$\alpha = a R^{b} \quad (dB/km) \qquad \ldots\ldots\ldots(3)$$

where a & b are co-efficients that depend upon frequency, rain temperature and rain drop size distribution. The values of a & b can be found in table1 of CCIR report 721 for 28.75 GHz [3]. The corresponding specific attenuation calculated from equation (3) for 22mm/hr rain rate with a probability of occurrence stated as 0.01 % (for rain zone E of reference [4] which includes Amritsar) is 4.36 dB/km with a probability of occurrence stated as 0.01 %.

The total attenuation exceeded for 0.01% of an average year may then be obtained from equation given below and is 9.13 dB.

$$A_{0.01} = \alpha_{0.01} L r_{0.01} \quad (dB) \qquad \ldots\ldots\ldots.(4)$$

Attenuation exceeded for other percentages of time p in the range 0.001% to 1% may be deduced from the following power law [1]

$$Ap / A_{0.01} = 0.12\, p^{-(0.546 + 0.043 \log p)} \qquad \ldots\ldots(5)$$

where as $A_{0.01}$ = 9.13 dB as calculated above.

3.2 Measured Prediction

The data on rain attenuation have been recorded on strip line chart in the form of slow varying DC voltage and then converted back into received power in dBm available at the input of the receiving antenna by using calibration curve of the receiver given as

$$S = 4.4293 \mathrm{Ln}(V) - 13.53 \quad (dBm) \qquad \ldots\ldots.(6)$$

where S & V are received signal strength in dBm and in millivolt respectively.

During rain, the attenuation is estimated by measuring the excess attenuation over clear weather attenuation values, for vertically polarized received signal at various rain rates.

A software program was developed for deriving annual cumulative distribution statistics from the collected data on rain attenuation.

3.2 Rain Rate Statistics

As already discussed that each rain event marked a tip on strip line chart. The rain rate (mm/hr) at a particular instant is calculated, by measuring the distance between the two tips, as follow:

$$R\ (mm/hr) = (0.254 * x)/\ d \qquad \ldots\ldots\ldots(7)$$

where d is the distance in mm, between the two tips and x is the speed of the chart in mm/hr.

For studying the cumulative distribution of rainfall rate, the duration of each rain rate is estimated from the chart recorder. The total duration of each rain rate in the whole year is estimated by adding such duration for that particular rain rate. Table 1 summarizes the data on rate of rainfall exceeding various percentage of time for rain zone E (which include Amritsar) as given by CCIR [4] with measured values.

Table 1 – Rain Climate Zone E and measured Rain Intensity exceeded (mm/hr)

%time rain rate exceeded	Measured (mm /hr)	CCIR E
0.001	110.5	70
0.003	88.5	41
0.01	62	22
0.03	39.70	12
0.05	29.5	8.5
0.08	16.3	7
0.1	12.6	6
0.3	2	2.4
0.5	0.75	0.9

4.Results

Annual cumulative distribution statistics from the data on rain attenuation collected over LOS link for vertical polarization has been obtained. The data for vertical polarization has been recorded for 2632 minutes. Fig. (1) shows the annual cumulative distribution of attenuation at 28.75 GHz. The best-fit curve based on regression analysis over the measured points has been plotted in fig. 1 and compared with that predicted by CCIR [1].

It is observed that measured cumulative statistics of rain attenuation overestimates the statistics predicted by the CCIR. Based on these results, we propose a modification to the prediction formula used in the CCIR report [1] for predicting the rain attenuation statistics.

For predicting the percentage of time (p) for which attenuation Ap is exceeded for this location, we propose

$$Ap\ /A_{0.01} = 0.12\ p^{-(0.6023 + 0.073 \log p)} \qquad \ldots(8)$$

Where $A_{0.01}$ is the path attenuation for 0.01% of time, which is estimated to be about 25.5 dB.

Monthly cumulative percentage time at which rain attenuation exceeded 5dB, 10 dB, 15dB, 20dB, and 25 dB are given in fig. 2 with plotted values.

5.Conclusion

The results of one-year measurement of rain attenuation of microwave signal propagating at 19.4 GHz have been presented in this paper. The annual statistics of rainfall rate and rain attenuation have been derived from the measured experimental data and compared with those predicted by CCIR. It is observed that CCIR predictions underestimate the measured rain attenuation statistics. Based on our experimental results we have proposed an empirical formula for predicting the rain attenuation statistics for Amritsar Latitude.

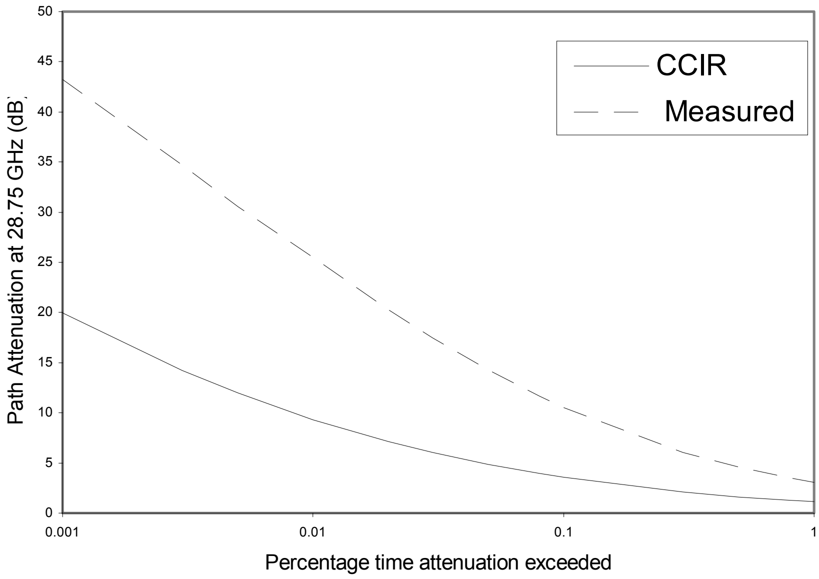

Fig. 1 Annual cumulative percentage of time for path attenuation exceeding preset level.

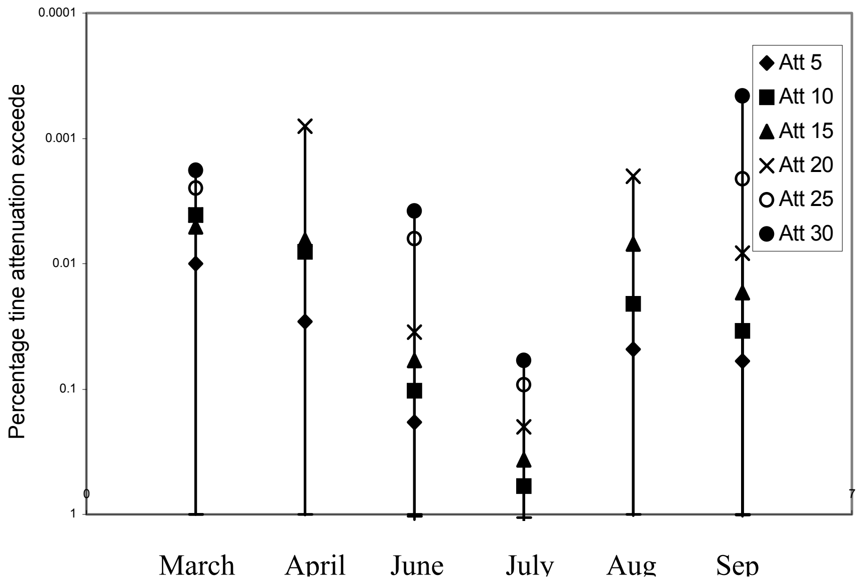

Fig. 2- Monthly cumulative percentage of time for path attenuation exceeding 3 dB, 5dB, 10dB, 15dB, 20dB, 25dB and 30dB.

References

[1] International radio Consultative committee "Propagation data and prediction methods required for terrestrial line of sight systems," *Recommendations and Reports of the CCIR*, Vol. 5, Rep. 338-6, XVIII Plenary Assembly, Geneva, 1990, pp. 355-420.

[2] R. L. Olsen, D. V. Rogers and D. B. Hodge, "The aR^b relation in the calculation of rain attenuation," *IEEE Trans. Antennas Propagation*, Vol. 26, 1978, pp.318-329.

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[4] International radio Consultative committee 'Effects of the atmosphere (Radiometeorology)', *Recommendations and Reports of the CCIR*, Vol. 5, Rep. 563-4, XVIII Plenary Assembly, Geneva, 1990, pp. 105-148.