Absorption of 30 and 20 GHz Microwave Communication Signal as a Function of Rain Rate

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Abstract— The attenuation of Microwave communication signals operating at 30 GHz and 20 GHz has been measured as a function of rain rate. The line of sight distance between the transmitters and receivers was 2.3 km. It is experimentally observed that as the rain starts falling the signal received by the receivers at both the frequencies starts decreasing and as the rain rate starts increasing, the signals received by both the receivers starts decreasing and reaches to a minimum value when the rain rate is highest and as the rain rate starts decreasing the signal received at both the frequencies starts increasing and reaches the previous maximum value when the rain stops. This shows that microwave signal is absorbed by water contents of rain and we must transmit more power during rain to get the same power at the receiver. However, the increase in power at the transmitter end will depend on the rain rate. It is observed that the attenuation of microwave signal operating at 30 GHz and 20 GHz follow the same pattern. Line of sight path attenuation as a function of rain rate has also been experimentally measured at these frequencies. It is observed that the rain induced attenuation increases at both the frequencies as the rainfall rate increases. It is observed that the rain induced attenuation at 30 GHz is higher than at 20 GHz for the same rainfall rate. Specific rain induced attenuation has also been calculated using Medhurst technique and compared with Marshal and Palmer and International Telecommunication Union Models.

Rain attenuation parameters as a function of rainfall rate obtained in this experimental study can be used for designing efficient and reliable terrestrial and satellite communication systems.

1. INTRODUCTION

Absorption of Microwave Communication signal is one of the most important constraints in the performance of microwave communication system. The knowledge of absorption of microwave signal at the operating frequency is very useful for designing of reliable communication system, particularly in tropical climates where high rainfall occurs. Microwave links operating above 10 GHz are severely impaired by the presence of rain on the path link. The absorption of signal also takes place by atmospheric gases, scattering, clouds and absorption and depolarization by rain. Out of all these factors, absorption by rain is the most dominant. The loss factor of water is very high and hence rain absorbs microwave signal. The signal is absorbed over the entire path link over which it is raining and the cumulative attenuation becomes quite significant and deteriorates the received signal. Hence it is highly desirable to experimentally measure the signal absorbed by rain as a function of rain rate, so that a signal fade margin can be added in the transmitter signal power.

2. EXPERIMENTAL SET UP

Two CW transmitters operating at 20 GHz and 30 GHz were installed in an air conditioned hut to maintain constant temperature. Two receivers corresponding to each transmitter and operating at 20 GHz and 30 GHz were installed in another air conditioned hut located at a distance of 2.3 km from the transmitters. These huts were made on the roofs of two houses, one window was made in the transmitter hut and another in the receiver hut. Both these windows were covered with perspex sheet 3 mm thick. The transmitter antennas and receiver antennas were placed behind these perspex sheets. The transmitter Antennas were facing the receiver antennas as shown in the Fig. 1.

The receivers were calibrated by standard signal sources. The received signal by the receivers were recorded on strip line chart as shown in Fig. 2 and further analyzed for excess attenuation due to rain.

3. RAIN DATA COLLECTION

The rain-rate data was collected using a tipping bucket rain gauge installed at the experimental site as shown in Fig. 3.

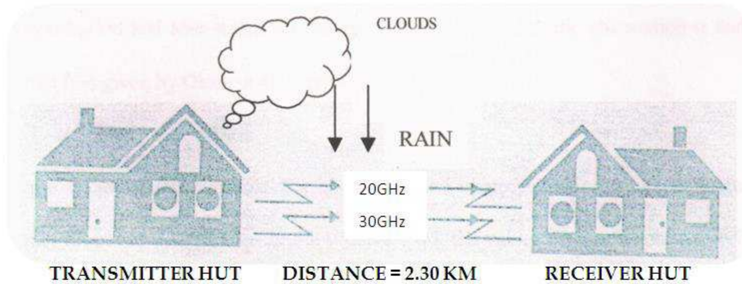

Figure 1: Line of sight link operating at 30 GHz and 20 GHz.

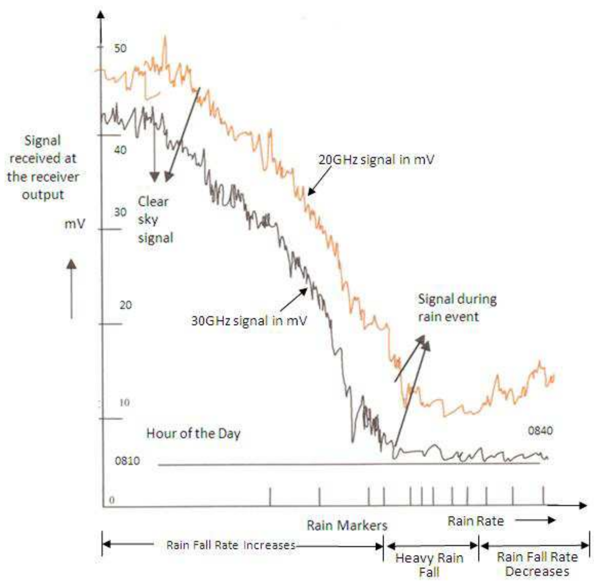

Figure 2: Signal output at 30 and 20 GHz as a function of rain rate.

Figure 3: Tipping bucket rain gauge.

The bucket is calibrated to mark one tip for each 0.254 mm of rainfall. The tipping event was recorded using strip line chart recorder as shown in Fig. 2. The rain rate (mm/hr) at a particular instant is calculated by measuring the distance between the two tips as follows:

$$R\,(\mathrm{mm/hr}) = (0.254 * x)/d$$

where d is the distance between two tips in mm and x is the speed of the chart in mm per hour.

4. MEASUREMENT OF RAIN INDUCED ATTENUATION

The attenuation induced by rain on the microwave signal propagating at 20 GHz and 30 GHz over 2.30 km line of sight link was measured as a function of rainfall rate. The rain induced attenuation continuously increased at both the frequencies as the rainfall rate increased. Fig. 4 shows a plot of rain attenuation versus rate of rainfall at 20 GHz and 30 GHz together with the best-fit curve equation as given below:

$$A_{20} = 1.0278 R^{0.8556} \text{ dB} \quad (1)$$
$$A_{30} = 2.9006 R^{0.6149} \text{ dB} \quad (2)$$

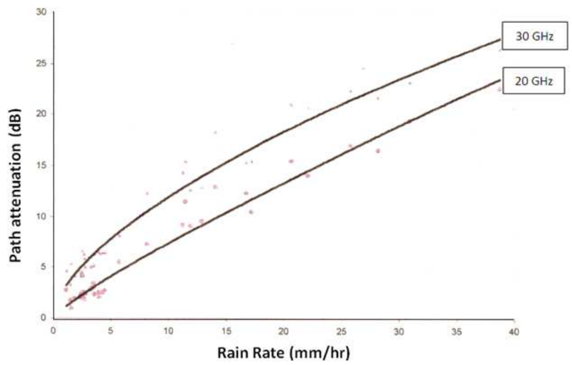

Figure 4: Plot of measured rain attenuation as a function of rainfall rate at 20 GHz and 30 GHz.

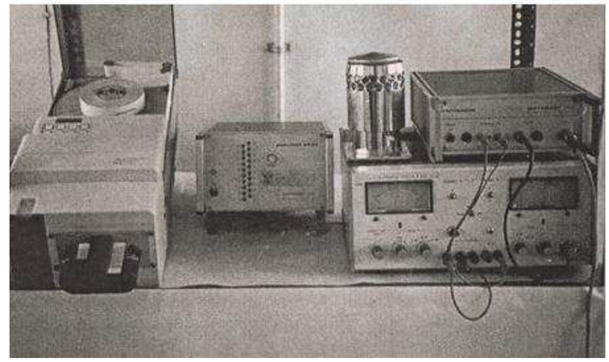

Figure 5: Experimental arrangement for measuring drop size distribution using disdrometer and paper tape puncher.

5. MEASUREMENT OF SPECIFIC ATTENUATION

It is the attenuation due to rain expressed in dB/km. Mathematically:

$$A = \int \alpha \mathrm{d}x \, \mathrm{dB} \tag{3}$$

where α is the specific attenuation of the rain volume expressed in dB/km and integration is taken along the extent of the propagation path from $x = 0$ to $x = L$. The Equation (1) can be written as:

$$A = \alpha L \text{ dB} \tag{4}$$

$$\alpha = \frac{A}{L} \text{ dB} \tag{5}$$

The specific attenuation α (dB/km) is a fundamental quantity in the calculation of rain attenuation for terrestrial path and can be calculated using rain drop size distribution (RDSD) and

Table 1: Comparison of coefficients a and b calculated as a function of Raindrop size distribution.

RDS Distribution	***a***		***b***	
	20 GHz	**30 GHz**	**20 GHz**	**30 GHz**
Experimental	0.071	0.186	1.31154	1.0478
MP RDSD	0.0751	0.191	1.103	1.032
ITU-R RDSD	0.0721	0.177	1.0827	1.01109

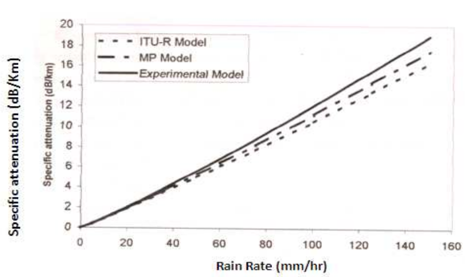

Figure 6: Comparison of specific attenuation at 20 GHz calculated by experimental model with existing models.

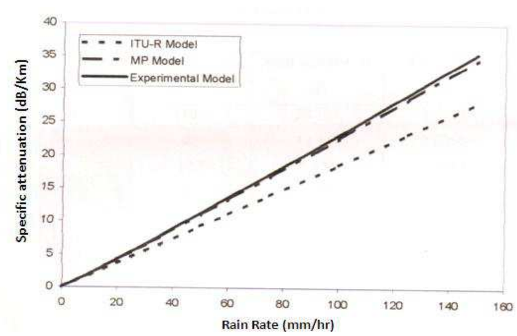

Figure 7: Comparision of specific attenuation at 30 GHz calculated by experimental model with existing models.

Mie-scattering theory. The relation of specific attenuation α and rain rate R is given by Olsen et al. [1] as

$$\alpha = aR^b \text{ dB/km} \tag{6}$$

The values of co-efficient a and b depend upon frequency, rain temperature and rain drop size distribution. In this present work the values of co-efficient a and b based on MP drop size distribution model as suggested by Olsen et al. [1] has been taken.

In the present study Medhurst [2] technique has been used for the evaluation of specific attenuation based on rain drop size data collected by disdrometer. The experimental arrangement made for measuring rain drop size distribution using disdromter and paper tape puncher is shown in the Fig. 5. The method is based on the proportion of the total volume of water reaching the ground which consists of drops of different diameters interval. Using this technique the specific attenuation at 20 and 30 GHz has been evaluated at different rain rates based on 1 minute integration time data collected by disdrometer. An empirical relation obtained from the regression analysis over specific attenuation values calculated at various rain rates has resulted in the following models:

$$\alpha_{20} = 0.071R^{1.1154} \tag{7}$$

$$\alpha_{30} = 0.186R^{1.0478} \tag{8}$$

The values of co-efficient a and b as obtained analytically [1] for various drop size distributions, are given in Table 1 along with our calculated values for comparison. The raindrop temperature was assumed to be 20°C. The values for refractive index required for calculations were also taken at temperature of 20°C.

Based on experimental models, the specific attenuation values at 20 and 30 GHz have been evaluated for different rain rates and compared with those based on LP-RDSD, adopted by CCIR and MP-RDSD given by Olsen et al. [1] as shown in Figs. 6 and 7.

6. CONCLUSION

It has been experimentally observed that the absorption of microwave communication signal depends on the rain rate and the operating microwave frequency. In the Fig. 2 it can be seen that in clear sky maximum signal is obtained by both the receivers, i.e., operating at 20 GHz and 30 GHz. However, as the rain starts, the signal received by both the receivers starts decreasing as shown in the Fig. 2. The absorption of microwave signal goes on increasing as the rainfall rate increases and reaches to a maximum when the rain rate is highest. As the rain rate starts decreasing the signal being received by the receivers again starts increasing and will attain the same value when rain stops and there is no moisture in the air and the sky is clear. Therefore for line of sight communication to remain uninterrupted during rain we should transmit higher signal corresponding to the signal absorbed by the rain. The results of these experimental measurements can be used for designing efficient and reliable terrestrial and satellite communication systems.

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