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RAINFALL ATTENUATION AT 6.25 MM WAVELENGTH

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1. Introduction

Since 1963, in order to obtain basic data for investigating the possibility of millimeter-wave use, Sophia University in Tokyo has made a propagation experiment at 6.25 mm wavelength (in horizontal polarization) over a 5 km line-of-sight path. This paper describes some of the results of this propagation experiment.

2. Layout of the experiment

The transmitting site was the Research Laboratory of KDD and Sophia University was the receiving site. The parabolic antennas at both sites(120 cm diameter for transmitting and 50 cm for receiving) were placed high enough above any obstacles to obtain good path clearance. The rain gauge used in this experiment was one which, using tipping-buckets and a digital printer controlled by a quartz clock, was able to print out the rainfall intensity for one-minute intervals. We used five rain gauges almost equally spaced at three places along the path and at both ends, in order to obtain data for establishing correlation between mean path attenuation and mean path rainfall intensity. The standard level of attenuation was defined as the signal received in clear and calm weather and rainfall attenuation was calibrated in terms of the comparable attenuation obtained with a millimeter-wave precision variable attenuator inserted into the output waveguide of the receiving antenna.

3. Results

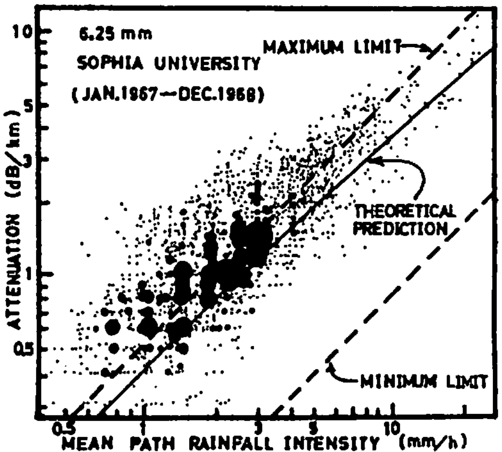

Fig.1. Correlation scatter diagram.

In Fig.1 the data are shown in the form of a correlation scatter diagram between mean path rainfall intensity averaged over one-minute interval and simultaneous signal attenuation due to it. Points plotted in Fig.1 were obtained during two years from Jan.1967 to Dec.1968 and the number of points is more than 5000. In this figure, the theoretical maximum and minimum limits (upper and lower curve) of attenuation and the theoretical predictive curve (inner curve) are quoted from the paper of R.G.Medhurst[1] which is based on the Mie theory of scattering and the Laws and Parsons drop-size distribution. As shown in Fig.1, it is easily seen that there are many measured points above the predicted maximum limit of attenuation and that an agreement between the value of theoretical prediction of rainfall attenuation and the value measured is not always good. This trend is a subject of absorbing interest and has been revived by Medhurst. This deviation is generally considered to result from two classes of causes. One of them consists of various kinds of error arising in the measuring equipment, and the other one seems to be due to the peculiar nature of rainfall phenomena, atmospheric gases and so on, especially to light rainfall, because light rainfall seems to have a great number of very small droplets, giving a drop-size distribution different from the spectra of Laws and Parsons. From the analytical consideration of these two classes of causes, it is found that the absorption caused by the many small droplets becomes considerably larger than other causes, when a great number of very small droplets are contained in light rainfall. In fact, in the paper of Y.Takahashi[2], it is shown that in Japan, in all seasons, especially in spring and autumn there is a kind of rain which contains a great number of very small droplets. He names it "saiu" giving the following example of sizes of droplets in drizzling rain.

rainfall intensity (mm/h)	radius of droplet (cm)
1.86	0.015(mode),0.022(mean)

Therefore, we feel certain that there are very small droplets in space at lower rainfall intensities, but it is impossible to measure these very small droplets with our rain gauges. Fig. 2 shows the theoretical relation between the drop-size and the rainfall attenuation at various wavelengths (per unit intensity of assumed rainfall composed of droplets of equal diameter), in which the values of maximum limit of attenuation are normalized to the value at 6.25 mm wavelength. And here also the attenuation in excess of the maximum limit in the small droplet region comes from absorption by a great number of small droplets. The correlations shown in Fig. 3, are re-plotted after the form shown in Fig.2. The pairs of dot-dash-curves indicate the approximate envelopes including measured points for two wavelengths (6.25 mm and 32 mm) respectively. The envelopes roughly resemble the shape of the curves shown in Fig.2. In the analysis of the data, assuming an empirical expression of the form $A=aR^b$ between the attenuation A (dB/km) and the mean path rainfall intensity R (mm/h), we have obtained a=0.61, b=0.85 by the least squares analysis of the data shown in Fig.1. These values are almost the same as the values given in the NBS Technical Note No.101, vol.1.

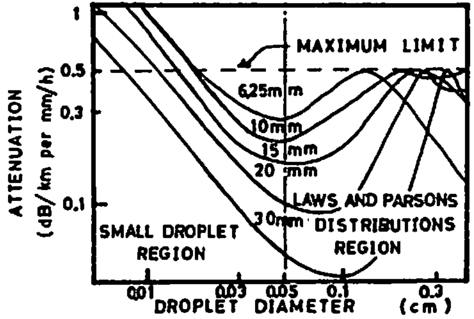

Fig.2. Normalized attenuation vs. drop-size.

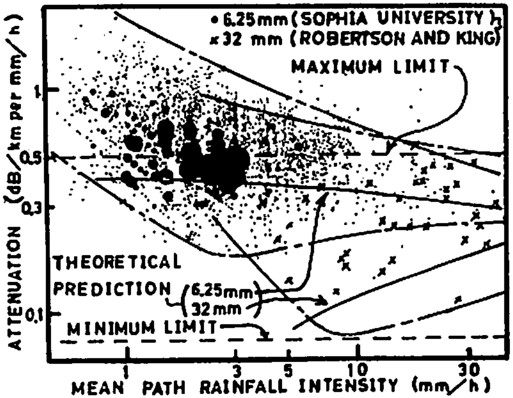

Fig.3. Scatter diagram of normalized measured attenuation vs. rainfall rate.

4. Conclusions

It seems likely that the most of the discrepancy between the theoretical values and the measured ones result from neglecting the existence of very many small droplets. Hence, this may be an explanation of why the attenuation we measured at 6.25 mm or the attenuations reported by others considerably exceed the theoretical values, even the predicted maximum values derived by Medhurst. The prediction formula for a wavelength 6.25 mm given in the NBS Technical Note No.101 has been confirmed by our experiment.

Acknowledgment

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References

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3. Robertson,S.D., and A.P.King, "The effect of rain upon the propagation of waves in the 1- and 3-centimeter regions," Proc. IRE, vol. 34, pp. 178P-180P, Apr. 1946.