ATTENUATION OF 3CM MICROWAVES DUE TO ARTIFICIAL RAIN

J. K. SINGH

Radio and Electronics Research Laboratory, Engineering College, Banaras Hindu University, Banaras

(*Received* 3 *April*, 65; *revised* 12 *Oct.*, 65)

Observations to study the variation of attenuation of 3 cm waves due to falling of water or artificial rain are confined to the high rates of precipitation and short distance between the transmitter and receiver, due to low power of the microwave generator. A comparison of these observations and those recorded by others shows that the attenuation increases non-linearly with the intensity of artificial rainfall which is generally assumed to be linear for the observations at lower rates of precipitation.

The effect of meteorological conditions of the atmosphere on the propagation of microwaves is of great consequence for successful operation of communication systems operating on centimetre wavelengths. Out of the various meteorological factors, the effect of rain drops on the absorption of microwaves is, however, found to be more pronounced [1,2]. Although some observations have been made by previous investigators [3—5] on the attenuation of microwaves due to lower rates of precipitation as generally available during natural rainfall, such data for higher rates of precipitation are lacking even for very short duration. An effort has, therefore, been made to study the variation of attenuation at higher rates of precipitation with artificial rainfall produced within a limited space in the laboratory. The observations have been compared with those at lower rates of precipitation for finding the mode of variation of attenuation of these waves due to water drops, which may satisfy the lower as well as higher rates of precipitation.

When an electromagnetic wave passes through a medium containing precipitation particles, the energy from the incident beam is attenuated both by absorption and scattering. The absorbed energy is transformed into heat in the particle while the scattered energy appears in the form of radiation propagated in the various directions around the source of scattering. The total attenuation [6] of the wave per unit time by a single spherical drop of radius a, for the wave length λ, is given by

$$W = S\ Q\ (a, \lambda) \tag{1}$$

where S is the magnitude of the incident energy per unit volume present in the beam and $Q(a, \lambda)$ is the total cross-section, which includes the scattering and absorption cross sections. The decrease in the magnitude of the incident energy, after passing through a layer of precipitation dl in thickness, is given by

$$-dS = S\ dl \int_0^\infty n(a)\ Q(a, \lambda)\ da \tag{2}$$

where $n(a)\,da$ gives the number of drops per unit volume (cubic metre) with radius a in range da. Integrating equation (2) we get the attenuation formula as

$$S=S_{0}\,e^{-\int \alpha\, dl} \tag{3}$$

where S_0 represents the total energy present in the beam before entering the medium containing precipitation particles or rain drops, and α is the attenuation constant given by

$$\alpha = \int_{0}^{\infty} n(a)\; Q(a, \lambda)\; da \tag{4}$$

In (4), if Q be in sq. cm. and a in cm., the attenuation in decibels is given by

$$\gamma = 434\ \alpha \quad db/km. \tag{5}$$

It may, however, be mentioned that in general $n(a)$, and hence, α and γ are functions of the distance l along the path length. From the above equations we observe that the attenuation can be readily calculated if the drop-size distribution is known. But the methods of determination of the drop-size distribution are fairly elaborate and, therefore, the attenuation is generally related to the easily measurable meteorological parameter, the rate of precipitation, which is defined by the volume of water reaching the ground per unit time per unit area. Now, the total rate of precipitation p is given by the equation

$$p=15{\cdot}1 \int_{0}^{\infty} n\ (a)\ v\ (a)\, a^{3}\, da \tag{6}$$

where $v(a)$ is the terminal velocity of the water drops in m./sec. and the rate of precipitation is given in mm/hr.

It may be mentioned that a linear relation between the attenuation of the microwave and the rate of precipitation is generally assumed from the observed results at lower rates of precipitation. But on comparing equations (4) and (6), it is found that this relation does not hold good in general for all the rates of precipitation. This has been experimentally verified from the observations as shown below.

EXPERIMENTAL PROCEDURE

A 2K25 Klystron tube was used as the transmitter and a pyramidal horn fed by a rectangular waveguide as the transmitting antenna. An identical horn with waveguide was used as the receiving antenna system as shown in Fig. 1. A 1N60 crystal diode detector connected to a suspended coil galvanometer with lamp and scale arrangement, and with a high resistance in series, was used to detect the received signal. It will be mentioned here that the characteristic of the detector used was of square law type and hence the deflection

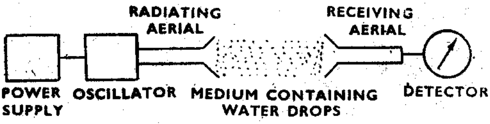

Fig. 1—Block diagram of experimental arrangement.

of the galvanometer was taken as directly proportional to the power received by the aerial system. A rectangular water shower connected to an elevated water tank was used to produce artificial rain in the space of about 1 m. in length between the transmitting and receiving horns. For recording the observations, the transmitter was switched on and the galvanometer deflections were noted with and without the water drops present in the space between the transmitting and receiving horns. From these observations the attenuation in *db/km.* was claculated as shown below.

CALCULATIONS

Let θ_1 and θ_2 be the galvanometer deflections without and with the water drops respectively and L be the path length in cm between the transmitting and receiving horns. The attenuation will be given by

$$\gamma = 10^5 \times 10 \log \frac{\theta_1}{\theta_2} \Big/ L \; db/km \tag{7}$$

It may be mentioned that the size of the water drops was assumed to be constant throughout the experiment. Only the rate of precipitation was changed by regulating the flow of water from the elevated water tank. From the various readings of the galvanometer deflections θ_2, corresponding to the different rates of precipitation of the water drops, attenuation was calculated from equation (7), the results of which are shown in Table 1. The high rates of precipitation shown in column 1 of Table 1 may not continue for a long period during natural rainfall yet they may interrupt communication systems even if they occur for a very short duration.

TABLE 1

VARIATION OF ATTENUATION OF 3 CM MICROWAVES WITH RATE OF PRECIPITATION

Rate of artificial rainfall cms./min	Galvanometer deflection (cms.) Without rain θ_1	Galvanometer deflection (cms.) With rain θ_2	Attenuation db/km
0·60	59·0	58·8	14·7
0·95	59·0	58·6	29·5
1·20	59·0	58·4	44·4
1·41	59·0	58·2	59·3
1·57	59·0	58·0	74·2
1·74	59·0	57·8	89·3
1·80	59·0	57·7	96·7

The values of attenuation given in column 4 of Table 1 have been shown with continuous line in Fig. 2 along with the attenuation obtained by other investigators for lower rates of precipitation in actual rainfall as shown by the dotted line at the bottom end of the curve. The dash and dot portion of the curve shows the extrapolation which fits in with the lower portion of the curve. As it was not possible to take observations with lower rates of precipitation of the drops, dash and dot portion of the curve has been drawn by extrapolation.

DISCUSSION

It will be observed from the curve given in Fig. 2 that the results obtained for artificial rainfall with higher rates of precipitation are in continuation of the increase of attenuation found at lower rates of precipitation by other investigators shown by the dotted line at the lower end of the curve. It will be further observed that the rate of increase of attenuation is not linear as generally assumed at low rates of precipitation. An empirical relation between the rate of precipitation and attenuation has, therefore, been derived from the curve in Fig. 2, which can be represented by a cubic equation

$$Y = aX + bX^2 + cX^3 \qquad (8)$$

where Y represents the attenuation in *db/km* and X represents the rate of precipitation in cm/min. The values of the coefficients a, b, and c have been calculated by taking any three arbitrary values for the rate of precipitation and the corresponding attenuation from the experimental curve as shown with triangles on the curve. On substituting the numerical values of a, b and c in (8) we get the empirical relation

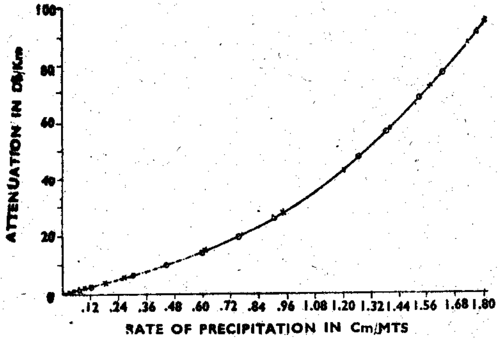

Fig. 2—Variation of attenuation of 3 cm microwaves with rate of precipitation.

$$Y = 15\cdot 94X + 11\cdot 81X^2 + 4\cdot 92X^3 \qquad (9)$$

As a check for (9), the attenuation for various values of the rate of precipitation was calculated and plotted as shown with the points within the circles in Fig. 2. It will be observed that these points lie very close to the experimentally observed curve shown in Fig. 2. It is, therefore, concluded that although for very low rates of precipitation the attenuation of 3 cm waves due to rain drops may appear to be linear, the attenuation increases rapidly with the increase of rate of precipitation and is expected to be very high as the rate of precipitation approaches 2 cm/min even for a very short duration[7].

CONCLUSION

The total variation of attenuation is found to be non-linear unlike the variation observed with lower rates of precipitation.

ACKNOWLEDGEMENTS

My grateful thanks are due to Dr. S. S. Banerjee for his continuous guidance during the above investigations and my sincere thanks are also due to the Ministry of Defence, Government of India, for financial assistance and premission to publish the above results.

REFERENCES

1. Ryde, J. W., "Meteorological Factors in Radio Wave Propagation" (Physical Society, London) 1946, p. 169.
2. Saxton, J.A. & Hofkins, H. G., *Proc. Inst. Elect. Engrs.*, **98** III (1951), 27.
3. Anderson, L. J., Day, J. P., Freres, C.H. & Stokes, A.P.D., *Proc. Inst. Radio Engrs.*, **35** (1947), 351.
4. Robinson, N. P., *Proc. Inst. Elect. Engrs.*, **102** B(1955), 709.
5. Nourse O. and Nicholls, S. G., *ibid.*, **111**, (1964), 1523.
6. Goldstein, H., "Propagation of Short Radio Waves" edited by Donald E. Kerr, Radiation Laboratory Series (Pub. by McGraw Hill Book Co.), 1951, p. 671.
7. Tonnehill, I. R., "Weather Around the World" (Princeton University Press, Princeton), 1952.