C–7–2 MICROWAVE ATTENUATION IN SANDSTORMS

S I Ghobrial
Faculty of Engineering
University of Khartoum
Sudan

I A Ali
Faculty of Engineering
University of Khartoum
Sudan

H M Hussien
Um-Haraz
Earth Station

Introduction

Attenuation of microwaves by rain, fog, snow and the like received considerable attention and interest(1). However, the related problem of attenuation in sandstorms received no consideration. Since the two problems are very similar it follows that the same analytical methods and mathematical techniques may be used for both. Since the linear dimensions of sand particles are small compared with wavelengths at X-band the problem in hand is significantly simplified.

One method for tackling this problem is due to Maxwell Garnett(2). In this method the medium containing the suspending particles is considered to be homogeneous with a permittivity that depends on the permittivity of the material of particles, their radius and density (number of particles per unit volume). From this the propagation constant and hence attenuation may be calculated.

Excellent agreement between this method and more rigorous methods (based on solving Maxwell equations) was obtained for the attenuation of microwaves in rain(3).

Particle Size Distribution

Calculation of attenuation requires knowledge of the radius of the scattering particles. Samples of dust particles were collected during sandstorms that blew over Khartoum (latitude 15 40′N longitude 32 52′E) during the summer of 1974. Analysis of the collected particles revealed the following:
(i) Almost all particles had radii less than 0.15 mm.
(ii) Particles with radii less than 0.005 mm constituted more than 30% of the total number of particles.

Fig 1 shows a typical particle radius distribution curve. It is seen that the distribution is almost exponential and may, therefore, be approximated by

$$p(r) = \beta e^{-\beta r} \qquad (1)$$

with mean

$$\bar{r} = 1/\beta$$

Attenuation Calculation

Using the method of Maxwell Garnett the following expression for the attenuation in dB/Km was obtained

$$\text{Attenuation} = 2.84\text{x}10^7 \left[\left(\frac{e'-1}{e'+2}\right)(N/\lambda^4) \int_0^\infty p(r)r^6\, dr + \left(\frac{0.036Ne''/\lambda}{e''^2+(e'+2)^2}\right) \int_0^\infty p(r)r^3\, dr \right] \quad \text{dB/Km} \qquad (2)$$

where:
p(r) is the particle radius probability density,
N is the total number of particles per cubic meter,
e′ and e″ are the real and imaginary parts of the complex permittivity of the material of which particles are made.

Using equations (1) and (2) and integrating one obtains:

$$\text{Attenuation} = 2.84\text{x}10^7 \left[\left(\frac{e'-1}{e'+2}\right) \frac{\beta^{-6}}{\lambda^{+4}}\; 5! + \frac{0.072e''\beta^{-3}/\lambda}{e''^2+(e'+2)^2} \right] \qquad (3)$$

In equation (3) the first term represents attenuation due to scattering while the second term takes care of absorption.

Fig 2 shows a plot of attenuation versus mean particle radius 1/ß for different e″. The real part of the permittivity, e′, was taken as 3.7, being the average value of e′ for samples of sand collected during actual sandstorms. The imaginary part was observed to vary and is a function of the chemical constituents of the sample. The chemical composition of different samples is not the same being dependent on the geological nature of the land at which the storm originates.

In plotting Fig 2 a wavelength of 3 cm was assumed. It is seen that microwaves at X-band suffer only a negligible attenuation when propagating through a sandstorm. This is attributed to:

(i)The small size of particles in relation to wavelength, (ii) the small loss tangent of sand; however this may vary with the chemical composition of samples.

Conclusions

It may be concluded that attenuation of sandstorms to microwave propagation is negligible at X-band. This is largely due to the low loss tangent of sand. The effect at Q-band and higher frequencies still needs to be investigated.

References

(1) Medhurst R G: "Rainfall attenuation of centimeter waves: Comparison of theory and measurements", IEEE Trans AP-13, pp 550-564, 1965.

(2) Maxwell Garnett J C: "Colours in metal glasses and in metallic films" Phil. Trans. Roy. Soc.;A 203, 1904.

(3) Ghobrial S I: "Electromagnetic properties of hydrometeors at microwave frequncies", Second International Conference of Broadcasting Unions, Rio de Janiero, 2nd-8th November 1973.

Figure Captions

Fig 1 Particle radius distribution.

Fig 2 Attenuation as a function of average particles radius 1/ß.

FIG 1

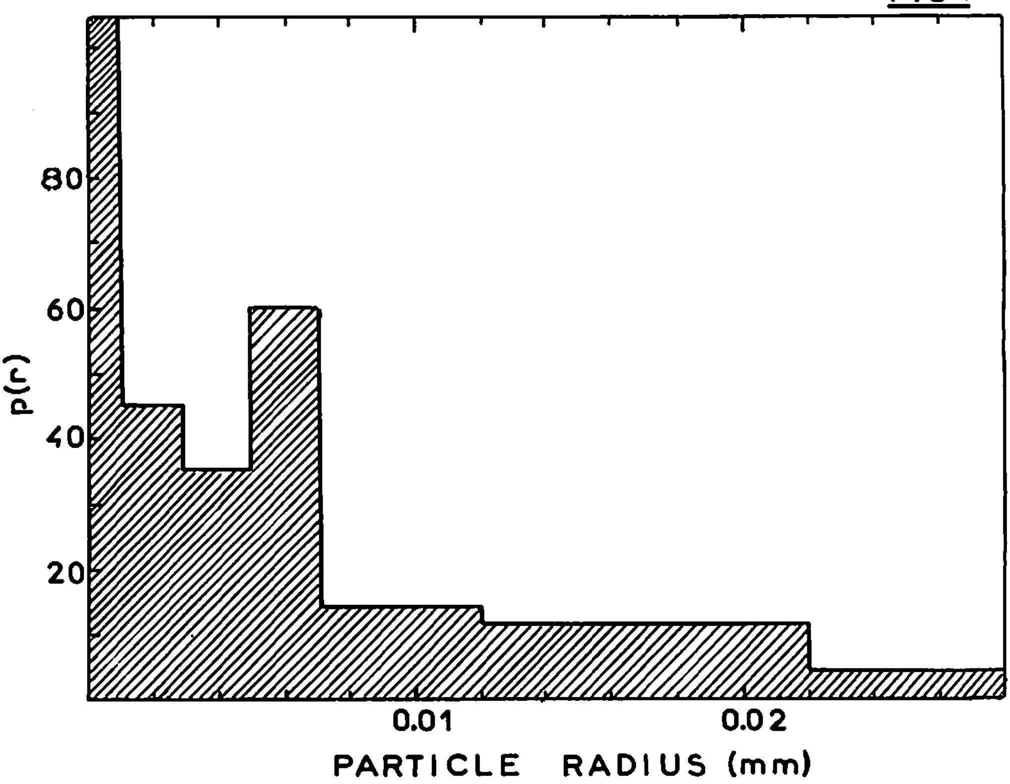
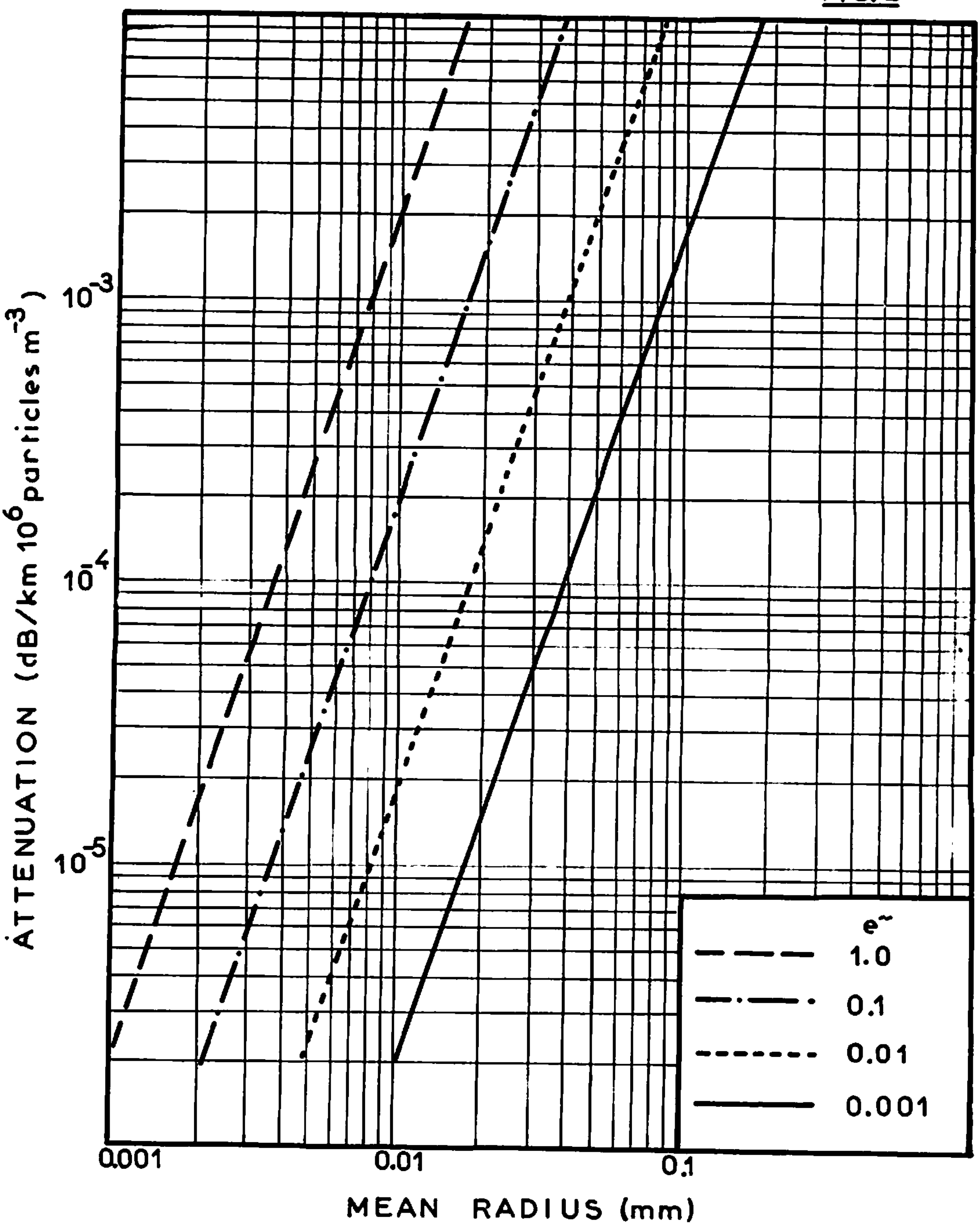


FIG. 2



ATTENUATION (dB/km 10^6 particles m^-3)
10^-3
10^-4
10^-5
0.001
0.01
0.1
MEAN RADIUS (mm)
e~
1.0
0.1
0.01
0.001