MICROWAVE PROPAGATION IN SAND AND DUST STORMS

Safa Haddad, M.J.H. Salman and R.K. Jha* Electrical Engineering Department, U.O.T., Baghdad, Iraa.

ABSTRACT

With a view to examine the effects of sand and dust storm on the propagation of microwaves, several parameters, such as attenuation, phaseshift, scattering and absorption were investigated. Both natural and simulated sand and dust samples were studied with varying degree of moisture contents, particle size distribution and visibilities. Scattering and absorption of microwave are found to depend heavily on the moisture content. The dependence of attenuation and phaseshift on visibilities is also studied. Experimentally measured and calculated values of attenuation and phaseshift of microwave in simulated dust storms with particle size distributions are compared for the first time in this paper.

I. INTRODUCTION

Propagation of microwave through sand and dust storm has received considerable attention 1-5. The dependence of attenuation and phase on moisture is already reported 3. To the best of authors knowledge, comparison of calculated and experimentally measured attenuation in the sand and dust storm having distribution of particle sizes are not reported so far. Neither the calculated phase shifts are compared with experimentally obtained results in the simulated dust storms. In the present work therefore, effects of visibilities on attenuation and phase shift of microwave, propagating in sand and dust storm are studied. Experimentally measured and calculated values of attenuation and phase shift are compared for the first time, Further scattering and absorption of microwave propagating in sand and dust storms are studied with varying moisture content and particle size distribution.

2. ATTENUATION COEFFICIENT

Considering a linearly polarized plane wave incidence and applying Ray-leigh approximation, the intensity of the scattered radiation for an arbitrary particle shape can be written as, with spherical co-ordinates $(\gamma, \theta, \emptyset)$

 $I = \frac{\{(1 + \cos^2\theta) \ K^4\alpha^2/2r^2\} \text{ Io}}{\text{where } K = 2\pi/\lambda \text{ and } \alpha \text{ is scalar polarizability for isotropic particle which is given as$

cle which is given as $\alpha = \{3(m^2-1)/4\pi(m^2+2)\} V$... (2) where m is the refractive index of the particle and V is the volume $\pi d^3/6$. The scattering efficiency factor without absorption is given as

Q scat = $(8/3)X^4 \{(m^2-1)/(m^2+2)\}^2$... (3) while the scattering efficiency of a small spherical absorbing particle is given by

Q scat = $(8/3)X^4$ Re $\{(m^2-1)/(m^2+2)\}^2$... (4)

^{*}Professor of Electronics Engineering, Institute of Technology, Banaras Hindu University, Varanasi (India)-5.

where $X = \pi dp/\lambda$ is a dimensionless optical size parameter. The

absorption efficiency is expressed as $Q abs = -4X Im \{(m^2-1)/(m^2+2)\}$... (5)

If there are dN particles in size range dp to dp + d(dp) per unit volume of the storm, this corresponds to a total particle cross-section area of ($\pi d^2/4$) dN dz over the wave path length, dz,per unit area normal to the beam. Microwave attenuation coefficient, then is given by the relation 6 , 7 Att.=(-dI/Idz)= $\int (\pi d^2/4) \operatorname{Qest}(X,m) n_d(d_p) d(d_p) 8.68 \times 10^5 dB/Km$ where dN = $n_d(d_p) d(d_p)$, ... (6) and Q ext = Q scat + Q abs ... (7)

SCATTERING AND ABSORPTION COEFFICIENTS

and absorption coefficient is given as

b abs=8.6x10⁵
$$\int_{dp}^{d_p+d(d_p)} (\pi d_p^2/4) Q$$
 abs $n_d(d_p) d(d_p) dB/Km$... (9)

where $n_d(d_p)=(N/\bar{d}_p)$ exp (d_p/\bar{d}_p) since the distribution of the particle follows an exponential form in the storm where \bar{d}_p is the mean diameter and N=no of particles/cm³ = $(15/\vec{d}_p)/(\pi v_b)$

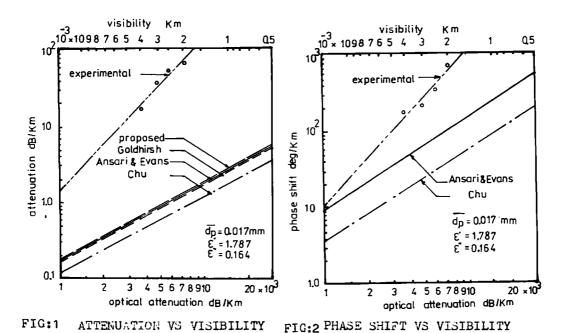
DISCUSSION OF RESULTS

Microwave attenuation (9.35 GHz) in storm with dry dust concentrations are shown in Fig. 1, against visibility and optical attenuation alongwith the results obtained using Goldhirsh⁵, Chu² and Ansari and Evans⁴ formulas. There is an excellent agreement for spherical particle of given size distribution (62.5-31;31-15.6; 15.6-7.8; 7.8-3.9; 3.9-2; 2-0.98 and 0.98-0µm) except the case of Chu since in this work uniform distribution is assumed. The measured attenuation in the simulated dry dust storm shows large deviation from the theoretical values. This is attributed to the fact that the shape of the particle, nonuniformity in the volume of storm and reflection etc. are not taken into account.

Variation in the phase shift is shown in Fig.2. It may be noted that the experimental curve is closer to the theoretical results obtained using Ansari and Evans expression. This is because they have taken into account the size distribution of particles. Results using Chu's experession deviate to a great extent from the practical values。

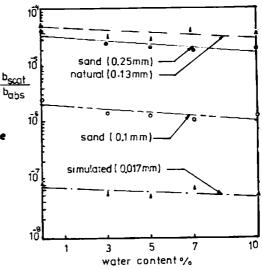
Natural and simulated dust particles have diameters in the range 500-2.00 and 62.5-0.98µm respectively while sands have uniform diameters. It may be mentioned that the natural sample was collected at the height of 3m. The variation in dielectric constant as reported by Haddad etal³ were used to calculate the various parameters.

The scattering and absorption coefficients are plotted as a function of visibility and optical attenuation in Figs.3 and 4 for various moisture contents. It has been found that (i)scattering and



visibility Km 210 × 10 98 76 5 4 sand(0.25mm) — natural(0.13mm) — sand(0.10mm) — simulated(0.017mm) visibility Km 10 × 1098 7 6 -3 10 **Q**5 1 10 9,3564z scattering coefficient dB /Km atural (0.13mm sand (0.10mm) 9,35GHz absorption coefficient dB/Km simulated (0.017mm) 10 10 10 10 H₂0: 0% -3% -5% 7% 10% -6 10 H₂0: 0% 10 3°/0 5°/0 7°/0 10°/0 10 0.1 2 4 5 6 7 8 9 1 0 $20 - 10^3$ 2 3 4 5 6 7 8 9 10 20 optical attenuation dB /Km optical attenuation de IKm FIG: 3 SCATTERING COEFFICIENT VS FIG4 ABSORPTION COEFFICIENT VS VISIBILITY VISIBILITY

absorption coefficients of microwave in sand and dust storm depend directly on its moisture content. The scattering and absorption of microwave are found to be considerably higher in sand and dust storm with moisture as compared to dry samples. The scattering of microwave is insignificant as compared to absorption. Large size particles in the storm exhibit higher scattering and absorption. The scattering and absorption of the microwave increase with increasing particle concentration i.e. decreasing visibility. Scattering to absorption ratio is found to decrease with increasing moisture content and is independent of visibility (Fig.5).



CONCLUSION

FIG: 5 Experimentally measured and RATIO OF SCATTERING TO ABSORPTION COEFFICIENT VS / WATER CONTENTS . galculated values of attenuation and phase shift of microwave in simulated dust storm with particle size distribution are compared in this paper. They are found to depend on visibility. Further, scattering and absorption of microwave are observed to depend very much on the moisture content and consequently their values are considerably higher in sand and dust storm with moisture as compared to dry samples.

REFERENCES

- 1. Ghobrial, S.I., 'The effect of sand storms on microwave propagation' Proc. Nat. Telecom.Conf., Houston TX, Vol.2, No. CH 1539-6/ 80/0000-0216, 1980, pp.43.5.1-43.5.4.
- 2. Chu, T.S., 'Effects of sand storms on microwave propagation', Bel Syst. Tech. J., Vol.54, No.2, Feb. 1979, pp 549-555.
- 3. Haddad, S, Salman, M.J.H. and Jha, R.K., 'Effect of sand/dust storms on some aspects of microwave propagation' Published in URSI Commission F, Symposium, Belgium, June 1983.
- 4. Ansari, A.J. and Evans, B.G., Microwave propagation in sand and dust storm', IEEE Proc. Vol. 129, Pt.F. No.5, Oct. 1982, pp 315-322.
- 5. Goldhirsh, J., A param ter review and assessment of attenuation and back scatter properties associated with dust storm over desert region in the frequency range of 1 to 10 GHz', IEEE Trans. Ant. and Prop. Vol. AP-30, No.6, Nov. 1982, pp 1121-1127.

 6. Friedlander, S.K., 'Smoke, Dust and Haze', Fundamentals of Aerosol Behaviour', John Wiley Publ. 1977.
- 7. Van De. Hulst, H.C., 'Light scattering by small particles, John Wiley Publ. 1957.