Millimetre Wave Scattering from Layers of Spherical and Non Spherical Dielectric Bodies

Dr. KUMAR SANJAY

PhD. (Physics), Babasaheb Bhimrao Ambedkar Bihar University, Muzaffarpur

---***---

Abstract - : *In order to consider the effect of main constituents of Layers spherical and non-spherical dielectric bodies, the profile structure of these particles atmosphere must be taken into account. The length of communication link is assumed to be L which contains the layers of spherical and non-spherical dielectric bodies. The entire section is represented in the form of three layers with spherical and non-spherical dielectric bodies. Further, the layer with sand particle extends from z = 0 to z = 1, the slity particle extends from z = 12 to z = 1,. If ε1,ε2 and ε3denote the ε and E, and permittivity and extension cross section of sand, silt and clay respectively.*

1. INTRODUCTION-

Considerable attention has been devoted to the influence of scattering effect on the propagation of microwave. The scattering dielectric bodies is one of the major problems in the utilization of microwave and millimeter wave bands for terrestrial and space communication. When these waves pass through layers of spherical and non-spherical dielectric media, the signals get attenuated by two phenomena

(a) Absorption cf energy by layers and its conversion into heat

(b) Scattering of energy out of beam by layers. In the present work theoretical investigation has been carried out considering the layers of spherical and non-spherical dielectric bodies.

2. THEORY-

The concept of scattering from dielectric sphere as well as ellipsoids is utilized to quantify the cross section and attenuation due to layers of spherical and non-spherical dielectric bodies de pendent heavily on the frequency visibility and complex dielectric constant. The non-spherical layers exhibit higher attenuation as compared to the spherical particles.

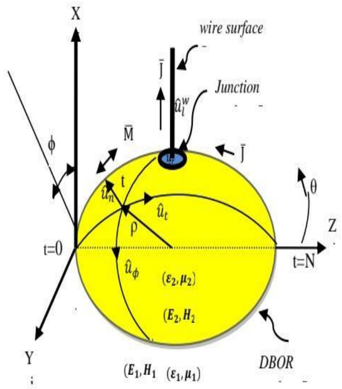


Fig.(1): Homogeneous dielectric object (ε_2, μ_2) embedded in a homogenous medium (ε_1, μ_1) with electric attached wire. $\bar{J}$ and $\bar{M}$ are the equivalent surface electric and magnetic currents for the exterior region.

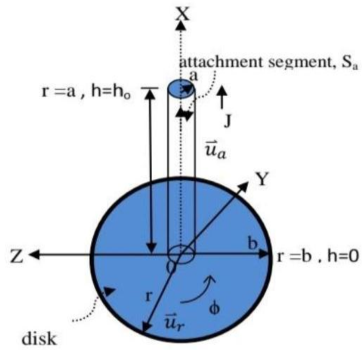


Fig.(2): Attachment region at the wire/BOR surface.

Scattering from dielectric bodies-

In order to study the scattering behaviour of the dielectric particle which is considered to be a dielectric sphere, the concept of energy balance over the surface of surrounding the scattering volume is utilised. E and H denote the incident electric and magnetic field and denote the corresponding scattered fields. The total amplitude of the fields at any point on the surface of the sphere can be given as

$E = E_{inc} + E_{sca}$ ....(1)

$H= H_{inc} + H_{sca}$ ....(2)

As the problem is concerned with the flow of pointing vector must be used. In this case only the radial component of pointing case vector actually crosses the surface of the sphere. In spherical co-ordinate system if E (θ,)and H (θ,ϕ) denote the electric and magnetic fields then the radial component of the average pointing vector will be in the radial direction. The value of which may be given as

S_R =1/2 R_e(Eθ inc H*θ - Eθ inc H*θ) ……………..…………………………….(3)

From the observation of equation (3) is found that the integral of first term on right hand side is zero as it gives the net flow of energy in incident plane wave whereas the second term when integrated gives the total scattered power (P_{sca}) out of the incident wave. The third term, if integrated of yields ($-P_{ext}$) and the integral of (S_R) yields the out flow of energy from the sphere.

Extinction of Cross-Section :

From equation (4) it is evident that to maintain the energy balance the third term of the equation must be equal in magnitude of the sum of the absorbed and scattered energy, one has

$P_{ext}= P_{abs}+ P_s$ ………………(5)

$\sigma_{ext}=-(2\,\pi/k^2)\, R_e\, \Sigma\, (2n+1)(a_n^s+b_n^s)\, Cm^2$ ....(6)

From the observation of equation it is found that the integral of first right hand side is zero as it gives the net flow of energy in incident plane wave whereas the second term when integrated gives the total scattered power out of the incident wave. The third term, if integrated of yields ($-P_{ext}$)

J_n = Bessel function of first kind.

h_n= Spherial Hankel function cf 2nd kind.

m= Complex refractive index.

μ_1= Permeability of internal medium.

μ_0== Permeability of external medium.

In the equation (6) indicate the amplitudes of the field on the surface of the sphere, which are proportional to the amplitude of the magnetic and electric multi-poles induced by incident wave respectively. More specifically a quanties the field distribution corresponding to induced magnetic dipole and a_s is related to magnetic quadrupole. Similarly b_2 signifies the field distribution corresponding to induced electric dipole and b2 S corresponds to electric quadrupole. Under this condition it is quite logical that higher order multiples oscillation will be weakly excited. All the higher order terms could be neglected without significant loss in accuracy, excepting the terms a_1 and b_1.

Since 2πa/λ is small compared to unity, Bessel functions can be expanded in power of (x).

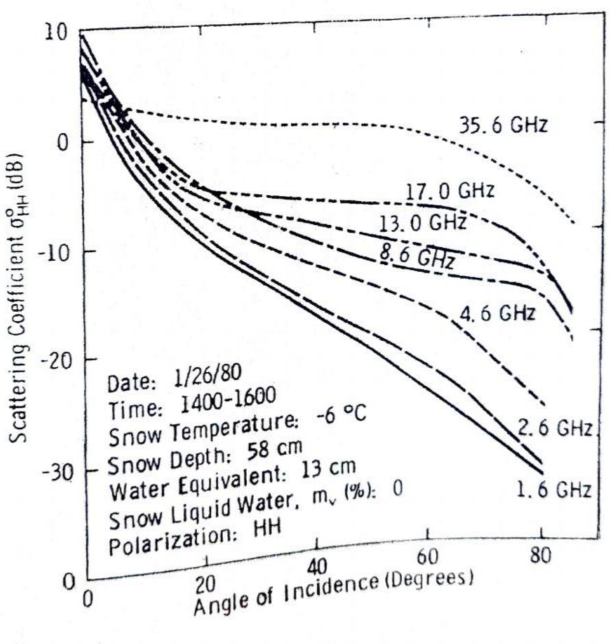
Non-Spherical Particles:

The scattering coefficients and absorption coefficients for small non-spherical dielectric bodies can be calculated using the Scattering amplitude matrix of small ellipsoid which approaches to spheroid under the condition a=b where a, b and c are axes of el lipoid. Scattering and absorption cross section of spherical dielectric bodies are given. During the passage of microwave and illimeter wave through the medium containing sand and dust particles, the waves will be attenuated as a consequence of two phenomena viz. scattering and absorption. Let N (a) da be the number of dielectric bodies per unit volume cf layers with radai in the interval a to a+da. If 6 by the extinction cross section of body then the total power removed from the wave with incident pointing vector S, by the dielectric bodies in volume element of unit cross section area and thickness dl is given as follows

The mathematical description of all classical optics phenomena is based on the Maxwell equations for the macroscopic electromagnetic field (Jackson 1998): ∇ · D = ρ, (1) ∇ × E = −∂B/∂t, (2) ∇ · B = 0, (3) ∇ × H = J + ∂D/∂t, (4) where t is time, E the electric and H the magnetic field, B the magnetic induction, D the electric displacement, and ρ and J the macroscopic charge density and current density, respectively. All quantities appearing in the Maxwell equations are functions of time and spatial coordinates. The vector fields entering (1)–(4) are related by D = ε0E + P, (5) H = B/μ0 − M, (6) where P is the electric polarization, M the magnetization, and ε0 the electric permittivity and μ0 the magnetic permeability of free space. Equations (1)–(6) are insufficient for a unique determination of the electric and magnetic fields from a given distribution of charges and currents and must be supplemented with the constitutive relations J = σE, (7) B = μH, (8) P = ε0χE , (9) where σ is the conductivity, μ the permeability, and χ the electric susceptibility. For linear and isotropic media, σ, μ, and χ are scalars independent of the fields. The field vectors E, D, B, and H may be discontinuous across an interface separating one medium from another. The boundary conditions at such an interface can be derived from the integral equivalents of the Maxwell equations: Electromagnetic Scattering by Nonspherical Particles 79 (D2 − D1) · nˆ = ρS, nˆ × (H2 − H1) = 0 (finite conductivity) (B2 − B1) · nˆ = 0, nˆ × (E2 − E1)=0 , (10) where ˆn is the local normal to the interface separating media 1 and 2 and pointing toward medium 2 and ρS is the surface charge density. The boundary conditions (10) are useful in solving the Maxwell equations in different adjacent regions with continuous physical properties and then linking the partial solutions to determine the fields throughout all space. A fundamental feature of the Maxwell equations is that they allow for a simple traveling wave solution which represents the transport of electromagnetic energy from one point to another and embodies the concept of a perfectly monochromatic parallel beam of light. This solution is a plane electromagnetic wave propagating in a homogeneous medium without sources and is given by E(r, t) = E0 exp(ik · r − iωt), H(r, t) = H0 exp(ik · r − iωt). (11) The vectors E0, H0, and k are assumed to be constant and the wave vector k may, in general, be complex: k = kR + ikI. Hence, E(r, t) = E0 exp(−k1 · r) exp(ikR · r − iωt), (12) H(r, t) = H0 exp(−k1 · r) exp(ikR · r − iωt). (13) E0 exp(−kI · r) and H0 exp(−kI · r) are the amplitudes of the electric and magnetic waves, while kR ·r−ωt is their phase. kR is normal to the surfaces of constant phase, whereas kI is normal to the surfaces of constant amplitude. The electromagnetic wave is called homogeneous when kR and kI are parallel; otherwise it is called inhomogeneous. Surfaces of constant phase propagate in the direction of kR with the phase velocity ν = ω/|kR|. The Maxwell equations for the plane wave take the form k · E0 = 0, (14) k · H0 = 0, (15) k × E0 = ωμH0, (16) k × H0 = −ωεE0, (17) where ε = ε0(1+χ)+iσ/ω is the complex permittivity. The first two equations indicate that the plane electromagnetic wave is transverse: both E0 and H0 are perpendicular to k. Furthermore, E0 and H0 are mutually perpendicular. Equations (11) and (16) yield H(r, t)=(ωμ)−1k×E(r, t). Therefore, a plane electromagnetic wave can always be considered in terms of only the electric field. By taking the vector product of both sides of (16) with k and using (14) and (17), we have k · k = ω2εμ In the practically important case of a homogeneous plane wave, the complex wave vector can be written as k = 80 Michael I. Mishchenko and Larry D. Travis (kR + ikI)ˆn where ˆn is a real unit vector in the direction of propagation and both kR and kI are nonnegative.

Numerical Computation -

In order to obtain the value of extinction cross section, total loss frequency and attenuation constant (u) for spherical and non—spherical dielectric bodies, the computational works were done using equations. The data thus obtained are shown plotted in form of graph.



RESULTS-

The extinction cross section increases with frequency for three constituents. The value of extinction cross section, $\sigma_{ext,}$ for non-spherical dielectric body is found to be higher than the spherical bodies for a given frequency and complex dielectric constant. This is corroborated with the fact that the extinction cross section depends directly on the size of dielectric bodies and most of the small dielectric body suspended in the atmosphere are usually spherical whereas the larger dielectric bodies are ellipsoidal or spheriodal.

In order to find the variation in attenuation with frequency and visibility, some computational works were carried out. The attenuation calculations are based on the Rayleigh scattering, the attenuation increases almost linearly with frequency for and non-spherical dielectric bodies. The magnitude of attenuation increases with decreasing visibility enhances the number of dust particles in the layers.It has also been observed that non-spherical dielectric bodies offer enhanced attenuation as compared to spherical ones.

REFRENCES-

[1] "Andreasen, M. G., 1965,"Scattering from bodies of revolution", IEEE Trans. Antennas Propagat., vol. AP-13, pp. 303 310.

[2] "Harrington, R. F. and Mautz, J. R., 1969,"Radiation and scattering from bodies of revolution", Rep.. AFCRL-69-0305, Syracuse Univ., Syracuse. NY

[3] "Junker, G. P., Kishk, A. A., and Glisson, A. W., 1993,"MoM solution of wire radiators coupled to dielectric bodies of revolution", IEEE Antennas. Propagat. Soc. Int. Symp., pp.40-43, Ann Arbor, MI.

[4] "Kishk, A. A., and Shafai, L., 1986,"Numerical solution of scattering from coated bodies of revolution using different integral equation formulations", IEE Proc. Vol. 133, Pt. H, No. 3, pp. 227- 232