Noval Approaches and Investigation of Electromagnetic Wave Propagation in Random Media

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Abstract:
When a wave propagates through this medium, random scattering occurs and scattered fields intermingle in a very complex manner. The resulting field also becomes random. The problem of wave propagation in a random medium is the study of the statistical characteristics of a wave. This work presents a new approach to resonating interactions between light and matter. A novel approach and investigation of electromagnetic wave propagation in random media is presented. Numerical simulations of the extinction rate of electromagnetic radio wave propagation in the presence of a large number of point scatter are randomly distributed and are based on multiple scattering theory. The results show that, the attenuation rate increases as the realization increases but remains independent for a large number of point scatter in the cluster. We have developed a model for electromagnetic wave propagation in and scattering from random media. The boundaries introduce scattering capability for reflection and refraction. The differential cross section for the backscatter is calculated in the Kirchhoff approximation. We find that, in single scattering processes, polarizations of differential cross sections are conserved and independent of differential cross section polarization. Cross-polarized differential cross sections are responsible for symmetric and fully multi-scattering processes. Our results are in good agreement with experimental measurements.

Keywords: *Random, Rate, Large, Scatters, Random*

1. Introduction

Electromagnetic [EM] wave returns from ocean surfaces have long been considered, as Bragg is isolated from rough surfaces in both experimental and theoretical investigations. Typically, such studies have a welded boundary between air and water, and one can calculate EM fields with suitable boundary conditions in different approximations. However, recent experiments have led to unexpected results. The most important example of micro-scale interactions is the scattering phenomenon. For example, much has been learned about the structure of the nucleus, in fact its discovery was also the result of scattering experiments. Similarly, most of our current particle physics knowledge has been gained from the analysis of scattering. Compton scattering of x rays by electrons is often cited as experimental evidence for the particle nature of photons. An early example of scattered studies was that of light scattered by the atmosphere, which was studied by Tandall, Rayleigh, and others in the late nineteenth century. The problem of light scattering from random media is an important research topic for both fundamental research and application. Theoretical analysis of the process of scattering light in a densely filled middle cone makes the task more difficult. The transport of waves through random media is a matter of interest in daily life. Examples are light through fog, clouds, milky liquids, white paint, paper, and porcelain, as well as electromagnetic waves transported through stellar atmospheres and interstellar clouds. Studies on electromagnetic wave scattering in geophysical and biological media have become an essential topic for developing remote sensing and radar engineering. Sensing techniques based on wave scattering are considered to be the keys to future progress in materials and environmental sciences, physics, astronomy, communications, medical electronics and civil engineering, and so on. The effects of wind-blowing sand movement and dust storms on electromagnetic wave propagation are important in a variety of scientific and engineering research and applications. It is necessary to study multiple scattering in a system of densely packed particles. Therefore, this thesis investigates scattering from a system of densely packed particles. The effect of electromagnetic wave propagation was randomly distributed in the presence of point scatter which was studied using the principle of multiple scattering and numerical simulations. We consider an HDWSL that consists of air bubbles and water droplets with random shapes and sizes. Applying the EM wave on HDWSL will cause phenomena with different reflection and refraction amplitudes at different boundaries in the target region depending on the geometry of the event. To account for contributions from all possible boundaries, an individual may consider each boundary to be pieced together by several small patches. Without loss of pervasiveness, we can assume that the patches are smaller disks with an average radius. We also believe that the radius is much larger than the wavelength so the Kirchoff approximation can be applied.

2. Multiple Scattering Theory

Putting the light on random media will cause multiple scatter. Multiple scattering typically means a thousand to a few thousand times more. What is Random Media? Suppose that we are interested in the propagation characteristics of a small pulse through turbulent environments. As far as the propagation of the wave is concerned, turbulence is characterized by a randomly refractive index in space and time and therefore turbulence is a random medium. In a random medium, scattering is caused by particles that can be located in a random state or scatter with random efficiency. Scattering occurs because the signs of refraction of transparent materials are different and have many scattering because the average distance between two scattering events is much shorter than the dimensions of the medium. If one of the materials absorbs light or the absorption is limited to a particular wave length range, the medium will be colored. Radiation transport can be described at approximately three length scales: Macroscopic: The average intensity at a much larger scale than the average free path satisfies a diffusion equation. The diffusion coefficient DP enters as a system parameter that has to be calculated on the mesoscopic length scale.

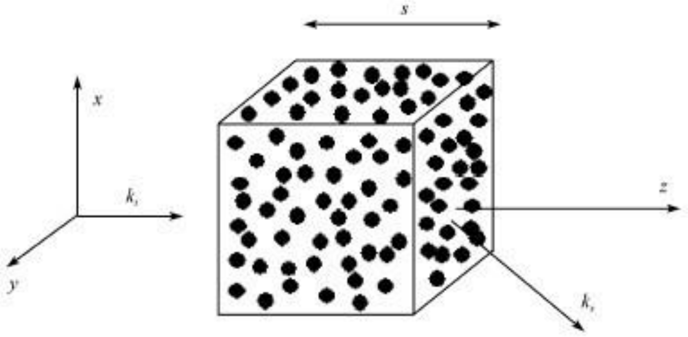
3. Scatering from a Cluster

Consider a plane electromagnetic wave incident on half-space with N spheres of radius a and permittivity εs and centered at $r_1, r_2,$ rN. The back ground medium has permittivity ε. Then the incident wave vector can be expressed as

$$E^{inc}(r) = \sum_{l} a_l^{inc} Rg\psi_l(kr)$$

Where Ψ stands for spherical vector wave function.

$E^{E(\beta)}$



(3)

The exciting field of scatterer α is the sum of the incident field and the scattered field from all the particles except its self and can be expressed as

$$E^{E(\alpha)}(\bar{r}_\alpha) == E^{inc}(\bar{r}_\alpha) + \sum_{\beta=1,\beta\neq 1}^{N} E^{s(\beta)}(\bar{r}_\alpha) \qquad (1)$$

We use T (r_j) to denote the T matrix of the jth scatterer and the scattered field of scatterer β can be expressed as

$$E^{S(\beta)}(r) = T\left(r_\beta\right) * E^{S(\beta)}(r) \qquad (2)$$

Introducing eq.(1) in to eq.(2) to calculate exciting field EE(β)(r) yields
The field exciting the βth scatterer can be expressed as

$$E^{E(\beta)}(\bar{r}_\alpha) = \sum_l W_l^\beta \, Re\psi_l\left(k\bar{r}_\alpha \bar{r}_\beta\right) \qquad (4)$$

Where $\Psi l(kr_\alpha r_\beta)$ denotes spherical wave functions centered at r_β and with field point at r_α,the scattered field will be the sum of scattered field from all scatterers:

$$E^s(r) = \sum_{\beta=1}^{N} E^{S(\beta)}(r) = \sum_l \left[\sum_{\beta=1}^{N} W_l^\beta \bar{T}(r_\beta)\right] * Re\psi_l\left(kr_\alpha r_\beta\right) = \sum_l a_l^{S(\beta)} \psi_l\left(kr_\alpha r_\beta\right) \qquad (5)$$

$$a_l^\beta = \bar{T}\left(r_\beta\right) * W_l^\beta \qquad (6)$$

Maxwell's equations cast into the Foldy-lax multiple scattering equations can be expressed in matrix notation as

$$W^\alpha = \sum_{\beta=1,\beta\neq 1}^{N} \sigma\left(kr_\alpha r_\beta\right) T^\beta W^\beta + e.x.p(ik_i.r_\alpha).a_{inc} \qquad (7)$$

where

$$\alpha = 1,2,3, \ldots \ldots \ldots .. N$$

W^α is the coulmn matrix that represents the exciting field of the scatterer α .The final exciting scatterer includes α includes the multiple scattering effects. a_{inc} is a column matrix that contains the coefficients of the incident wave. T^β is the T matrix that represents scattering from β and $\sigma(kr_\alpha r_\beta)$ is a vector spherical wave transformation matrix that transforms spherical waves of multipole fields centered at r_β to multipole spherical waves centred at r_α. The physical interpretation of Eq.(7) is that the field exciting scatterer α is the sum of the incident field and the scattered field from all other particles except from itself. Note that in Eq.(8),the exciting field $W^{(\alpha)}$ depends on the exciting field $W^{(\beta)}$ on the right hand side. The multiply scattered field $a^{s(\alpha)}$ of particleα is

$$a^{s(\alpha)} = \bar{T}^{(\alpha)}.\bar{W}^{(\alpha)} \qquad (8)$$

The final scattered field by the N spheres in direction k_S,with at an observation point R is given by

$$k_s = \sin\theta_s \cos\emptyset_s x + \sin\theta_s \cos\emptyset_s y + \cos\theta z \qquad (9)$$

$$E_S(\bar{r}) = \frac{e^{ikr}}{kr}\sum_{mn}^{N}\gamma_{mn}\left[\bar{a}_{mn}^{s(M)} C_{mn}(\theta_s,\emptyset_{s,}) i^{-n-1} + \bar{a}_{mn}^{s(N)} B_{mn}(\theta_s,\emptyset_{s,}) i^{-n}\right] \qquad (10)$$

Where K is the wave number of the backgroung media ,B_{mn} and C_{mn} are the vector spherical wave functions and γ_{mn} is a coefficient. We can combine Eq.(9) and Eq.(10) to calculate directly the multiply scattered field coefficients $a^{s(\alpha)}$ by calculating the solution of the following equation:

$$a^{s(\alpha)} = \sum_{\beta=1,\beta\neq 1}^{N} \bar{T}^{(\alpha)}\bar{\sigma}(kr_\alpha r_\beta)a^{s(\beta)} + e.x.p(ik_i r_a)\bar{T}^{(\alpha)}.a_{inc} \qquad (11)$$

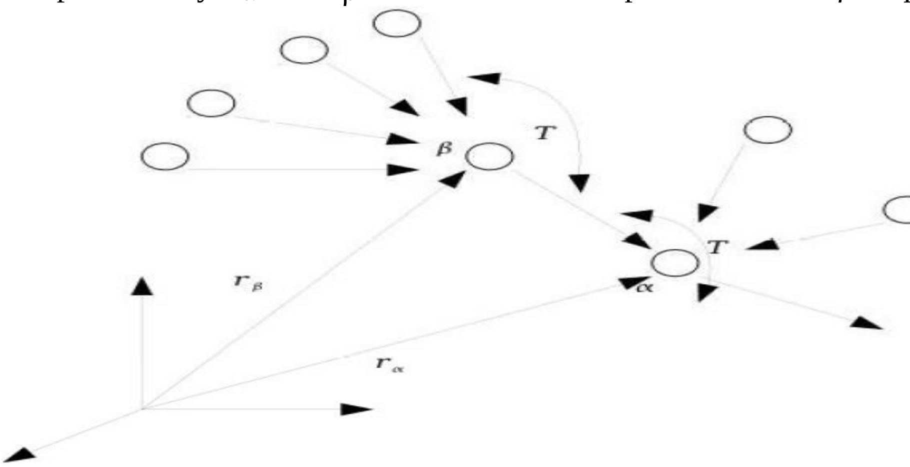
$$\alpha = 1,2,3, \ldots \ldots . . N$$

with

Where

$a^{s(\alpha)}$:is the vector of coefficients for spherical wave harmonics of the multiple scat- tered field for the particle. a_{inc}:is the coefficient of the incident wave. k:is the wave number of of the background media. k_i: is the wave number of the incident wave.
N: is the number of spheres in the containing volume.
$\sigma(kr_\alpha r_\beta)$: is the vector spherical wave transformation matrix.

$T^{(\beta)}$: is the T matrix for for scatterer β which depends on the permittivity and radius of β ,as well as the background permittivity. r_α and r_β : are the center of particles α and β respectively.



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Equation (11) can be solved by iteration. The result for the (ν+1) iteration is

$$a^{s(\alpha)(\nu+1)} = e.x.p(ik_{i,}r_{\alpha})\bar{T}^{(\alpha)}.a_{inc} + \sum_{\beta=1,\beta\neq 1}^{N} \bar{T}^{(\alpha)}\bar{\sigma}(kr_{\alpha}r_{\beta})a^{s(\beta)} \qquad (12)$$

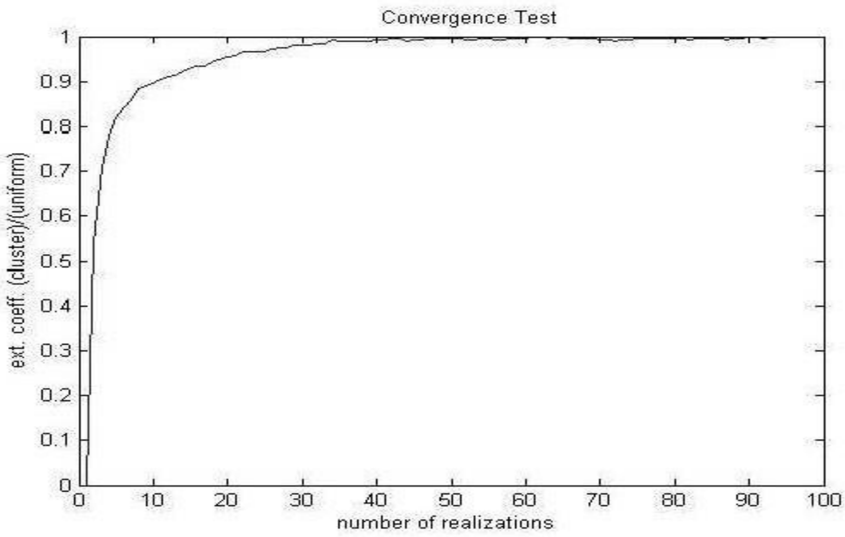
Where ν denotes the ν-th iterated solution .The intial solution of the $a^{s(\alpha)(1)}$ is just the first term on the right hand side of Eq.(12).

In the simulaton ,for a fixed N and a given realization,the position of the are randomly generated in a cubic box with out allowing interpenetration.For a given realization, $a^{s(\alpha)}$ is calculated. The procedure is repeated for N_r realizations, and calculated fields are averaged over N_r realizations.Under the classical assumption of independent scattering ,the extinction rate of coherent wave is,for nonabsorptive scatterers, $(k_e)_{ind} = n_0\sigma_s$,where is the scattering crossection of one sphere and is in terms of of Mie scattering coefficients, $n_0 = {}^N$ is the number of particles per unit volume.

4. Numerical Computation

Input Parameters For Extinction Coefficients : Number Of Clusters:1
Number Of Point Scatterers Per Cluster:250 Incident Wavelength (Meter):50
Length Of Cubic Box (Of Wavelengths):50
Length Of Cluster (Of Wavelengths):50
Real Part Of Scattering Amplitude0.008905
Polar Incidence Angle (Degree):45
Azimuthal Incidence Angle (Degree):0
Number Of Realizations:100
Seed For Random Numbers:123456

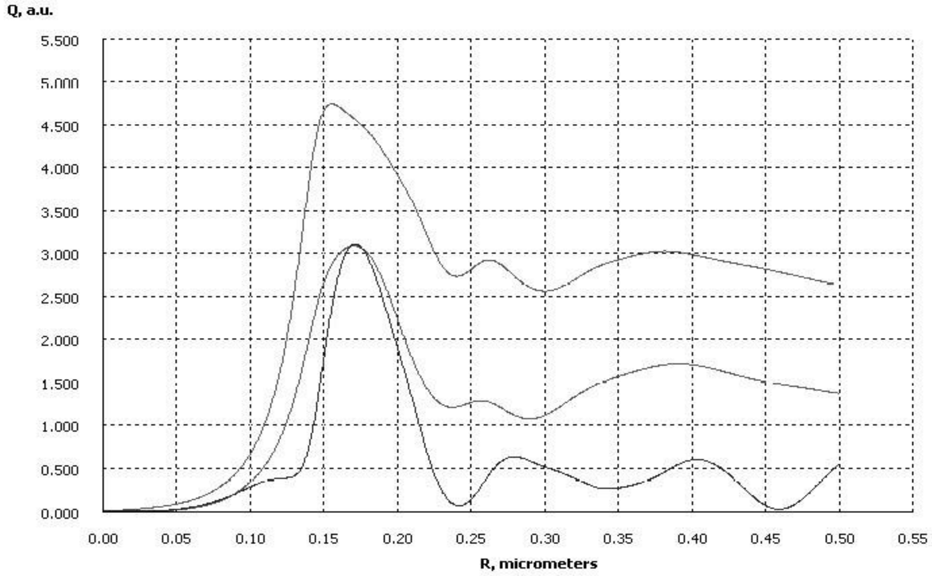
Extinction Rate Versus The Number Of Realizations



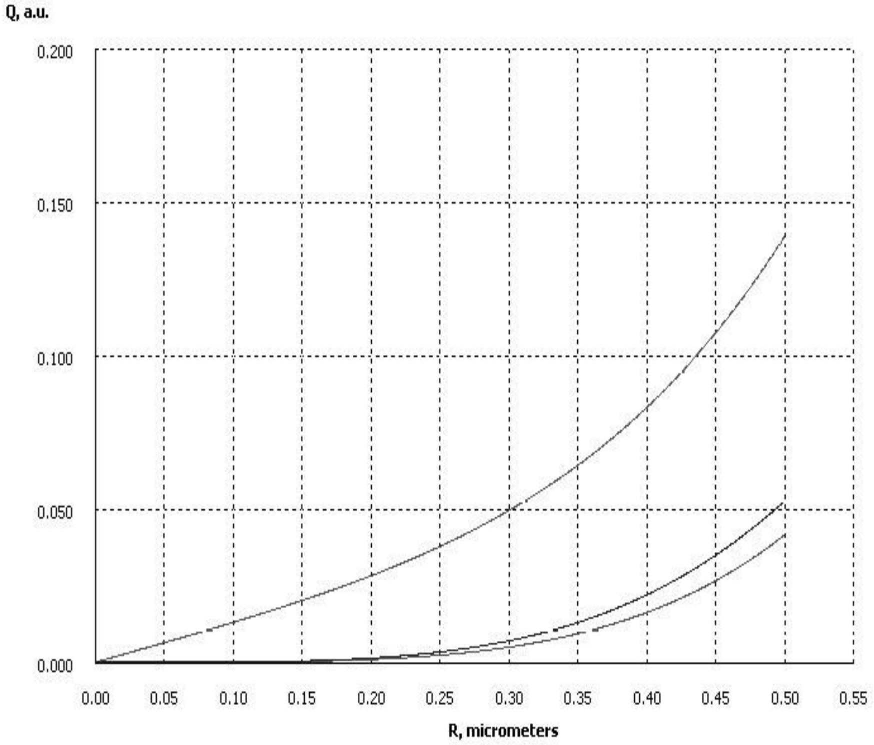
1. Input for Mie Scattering Crossection: Particle Radius in Micrometers: 3.00
Real Part of Environment Refractive Index:1.00
Imaginary Part of Environment Refractive Index: 0.00
Real Part of Particle Refractive Index:3.200
Imaginary Part of Particle Refractive Index:0.3200
Incident Light Wavelength In Micrometers: 0.800

2. Input For Rayleigh Scattering Crossection: Particle Radius In Micrometers: 5
Real Part Of Environment Refractive Index:1.00
Imaginary Part Of Environment Refractive Index: 0.00
Real Part Of Particle Refractive Index:3.200
Imaginary Part Of Particle Refractive Index:0.3200
Incident Light Wavelength In Micrometers: 8

MIE Scattering Crossection



Rayleigh Scattering Cross Section



5. Results and Discussion

We wanted to show in the present paper that the approximations commonly employed in calculating the average Green's methodology are not associated with any customary assumptions, either having a normal distribution of potential V (x) or that the scattering centers are independent. We were able to generalize these estimates to include arbitrary distributed random potentials. It turns out that the number of correlation groups, largely denoted by individual approximations M1, is based on the single-group term of the extension of the operator M. The obtained applicability conditions do not have limitations on the individual terms of the series representing M1, and therefore accept cases in which the effects of high correlations are not small. We hope that in the future, through very simple models, it will be shown that such a situation is indeed possible.

In this section we present results from numerical simulations of scattering by point scatter. Numerical convergence of the extinction coefficients with the number of realizations is performed. We calculate the extinction coefficient for the case of a clustered random distribution. The extinction rate is normalized to the case of independent scattering. In different realizations, we only change the position of the particle. The position of 250 scatter is generated randomly and the result is calculated for 100 realities. We found that the extinction coefficient increases with increase without any increase and attains a saturation value. The extinction coefficient is independent of large realizations for large numbers of particles. Next we calculated the scattering crossing for a spherical particle using the Me and Rayleigh principle of scattering. We found that the ME scattering crossing increases with an increase in the size parameter, obtains a maximum value and then decreases with an increase in the size parameter. However, size increases in Rayleigh crosses. The crossection calculations were made taking sour-rounding medium as air and particle permitivity ọp = 3.2(1 + i0.1)ọ. The dense media were prepared by embedding a circular dielectric scatter in a homogenous background medium: the size and volume fraction of the scatter were the controlling parameters. A network analyzer-based system operating in the frequency domain was used to measure the electric field reflected and transmitted by slab-shaped samples of dense media as large as 26.5 to 40 GHz in the source region. An inverse Fourier transform was used to convert the frequency domain response into time domain pulse waves. The time domain response was then used to obtain the pulse propagation velocity and attenuation in the controlled samples. The experimental results are shown in general agreement with the dense medium principles. The fluctuations are weak, but they cause significant cumulative scattering over long distances of the propagation of the waves. We perform the propagation of waves with random amplitudes to propagate and transform electric and magnetic modes that encode the cumulative scattering effect. They satisfy a coupled system of stochastic differential equations driven by random fluctuations of electrical permeability. We analyze the solution of this system with the diffusion approximation theorem, under the assumption that the fluctuations converge rapidly in the direction of the range. The result is a detailed characterization of the transport of energy in the waveguide, loss of coherence of modes, and depolarization of waves due to cumulative scattering.

References

1. Anderson, P.W. The Question of classical Localization: A theory of white Paint ? Philosophical Magazine B ,1985, vol.
2. Hulst, (1981). Ligh Scattering by Small Particles (Dover, New York).
3. Max, Born, Emil Wolf (2006). Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light (Cambridge University Press).

4. Mishchenko, Multiple Scattering, Radiative Transfer, Weak Localization in Discrete random media:Unified Microphysi- cal Approch, Reviews of Geophysics 46,RG2003/2008.
5. Mishchenko, Travis, Lacis, Scattering (2002). Absorption and Emission of Light by Small Particles (Cambridge University Press).
6. Shivamoggi, Andrews, Phillips Nonliner Wave propagation in Random Medium, Physica A,275(2000) 86-98
7. Tsang, Kong, Ding (2001). Vol-3, Scattering of Electromagnetic waves: Advanced Topics, (John Wiely and Sons).
8. Tsang, Kong, Ding (2001).Vol-2,Scattering of Electromagnetic waves: Numerical Simulations, (John Wiely and Sons)
9. Tsang, Kong, Ding, (2000).Vol-1,Scattering of Electromagnetic waves: Theories and Application, (John Wiely and Sons).
10. Van, M. C. W. Rossum and Th. M. Nieuwenhuizen (1999). Multiple Scattering of Classical Waves: Microscopy, Mesoscopy and Diffusion, Reviews of Morden Physics, vol.71, No.1, January
11. Wiersma DS, Bartolini P, Lagendijk A, Righini R. Nature 1997;390:671-3.
12. Zheng,Qin,Guang.Rayleigh, (2009). Mie and Tyndall Scatterings of Polystyrene microspheres in water:Wavelength,size and an- gle dependances.Journal of Applied optics 105,023110