ELECTROMAGNETIC WAVES IN RANDOM MEDIA

A Dissertation Submitted in partial fulfillment

FOR THE DEGREE OF MASTER OF SCIENCE IN PHYSICS

Under Academic Autonomy

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

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CERTIFICATE

This is to certify that the thesis entitled **"Electromagnetic Waves in Random Media "** submitted by Mr.Satya Narayan Tripathy in partial fulfillment of the requirements for the award of Master of Science in Physics at National Institute of Technology,Rourkela is an authentic work carried out by him under my supervision. To the best of my knowledge,the matter emboidied in this thesis has not been submitted to any other institute for the award of any degree.

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ABSTRACT

This work presents a new approach towards resonant interaction between light and matter . An 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 large number of point scatterers distributed randomly is presented and is based on the multiple scattering theory. The results obtained shows, the attenuation rate increases as realizations increases but remains independent for large no of point scatterers in the cluster.

SYNOPSIS

This thesis entilted " **ELECTROMAGNETIC WAVES IN RANDOM MEDIA**" is submitted by Satya Narayan Tripathy to the Department of Physics, National Institute of Technology ,Rourkela in partial fulfillment of the requirments of the M.Sc degree.

In the chapter I We discuss the the past theoretical works concering scattering of light from a random medium and the application of wave transport through the random medium.

In the chapter II we discuss the basic theory multiple scattering , Phenomenon of localization , closed paths and backscatter cone. we also study propagation of radiation in microscopic ,mesoscopic and macroscopic scale leading to Maxwll Equation ,Radiative transfer Equation and Diffusion Equation respectively.

In the chapter III we discuss about Mie and Rayleigh Scattering theory and find a basic formula for scattering crossection for both theory.The Scattering of a single spherical particle is well understood .

In the chapter IV we discuss the the propagation of light in the presence of a large number of point scatterers. The interaction of light with random media is presented by Foldy-Lax equation of multiple scattering and the theory for calculating extinction is discussed.

In the chapter V and VI the numerical simulations and results are discussed.The result shows the attenuation rate increases as realizations increases but remains independent for large no of point scatterers in the random media.The extinction rate is normalised to the independent scattering case. In different realization ,we only change the position of the particle. Next we calculate the scattering crossection for a spherical particle by using Mie and Rayleigh theory of scattering. We found that mie scattering crossection increases with increase in size parameter ,attains as maximum value and then decreases with increases in size parameter.But, Rayleigh crosssection increases with increase in size parameter.

CONTENTS

1 INTRODUCTION

One of the most important examples of interaction at the microscopic scale is the phenomenon of scattering. For example, much of what has been learned about the structure of the nucleus, indeed even its discovery, was the result of scattering experiments. Similarly, the analysis of scattering has yielded most of our present knowledge of elementary particle physics. Compton scattering of x rays by electrons is often cited as experimental evidence for the particle nature of the photon. One of the earliest examples of scattering to be studied was that of light scattered by the atmosphere, which was studied by Tyndall, Rayleigh, and others at the end of the nineteenth century. The problem of light scattring from a random media is an important research subject for both fundamental research and application.The theoretical analysis of light scattering process in a densely packed medium constitutes a much more difficult task .Transport of waves through random media is a subject of interest in daily life. Examples are light transported 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 subject for developing remote sensing and radar engineering .Sensing technology based on wave scattering is considered to be a key to future progress in material and environmental science,physics, astronomy,communication , medical electronics and civilgineering, and so on. The effects of wind-blown sand movement and duststorm 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 the scattering from the system of densely packed particles. The effect of electromagnetic wave propagation in the presence of point scatterers distributed randomly was studied using the theory of multiple scattering and Numerical simulation.

2 MULTIPLE SCATTERING THEORY

Light impinging on a random media will be multiple scattered.Multiple scattering means more than one thousands to a few thousand times typically. What are random media? Suppose we are interested in the propagation characteristics of a short pulse through the turbulent atmosphere . As far as wave propagation is concerned, the turbulence is characterized by the refractive index randomly varying in space and time and therefore the turbulence is a random medium.In a random medium the scattering is caused by particles that can be located at a random position or scatter with a random efficiency.Scattering occurs because of indices of refraction of the transparent materials differ and multiple scattering occurs because the avrage distance between two scattering events is much smaller than the dimensions of the medium.if one of the material absorbs the light or the absorption is restricted to a particular wave length range, then the medium will be coloured . The description of radiation transport can occur on roughly three length scales:

Macroscopic: On scales much larger than the mean free path the average intensity satisfies a diffusion equation. The diffusion coefficient D enters as a system parameter that has to be calculated on mesoscopic length scales.

Mesoscopic: On length scales of the mean free path l, the problem is described by the radiative transfer equation or Schwarzschild-Milne equation. This is the Boltzmann-type equation for the system. At this level one needs as input the mean free path l and the speed of transport v, which should be derived from microscopics. In the diffusive regime this approach leads to the diffusion coefficient$D = \frac{vl}{3}$.

Microscopic: The appropriate wave equation, such as Maxwell's equations, the Schordinger equation, or an acoustic wave equation, is used on this length scale. The precise locations and shapes of scatterers are assumed to be known. Together with the wave nature they determine the interference effects of scattered waves. In light-scattering systems the scatterers often have a size in the micron regime, comparable to the wavelength λ, which could lead to important resonance effects. The mesoscopic or Boltzmann description follows by considering the so-called ladder diagrams. The drawback of the microscopic approach is that it is too detailed. In practice the precise shape and positions of the scatterers often are not known and a mesoscopic or macroscopic description is necessary.

Localization ,Closed paths and Backscatter Cone: The diffusion equation is a classical equation that fully neglects interference effects inherent to wave propagation. At this level of description there is no difference between diffusion of particles and of wave intensity. Whereas a transmission pattern of monochromatic (laser) light through an opaque medium is known to consist of speckles (bright spots on a dark background), the diffusion equation and the radiative transfer equation only describe the average intensity.

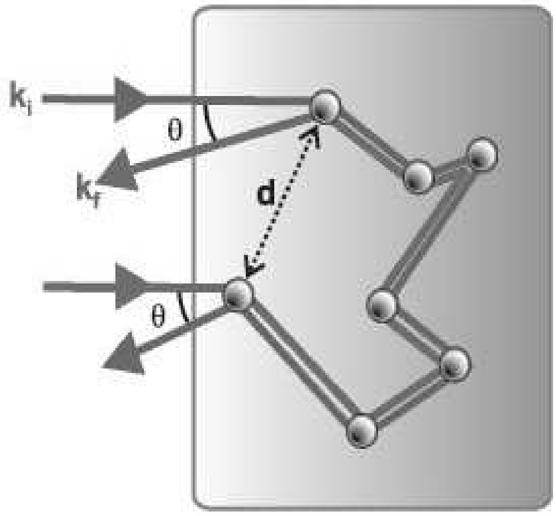
The wave nature of light immediately leads to a reduction in transmission due to interference effects. Following Rayleigh (1880) we suppose that the transmission amplitude E for a certain experiment is composed of many terms C_p arising from physically different interference paths p.

Some paths have closed loops, i.e. loops that return to the same scatterer. When such loops contain two or more common intermediate scatterers, they can be traversed in two directions. Let us consider one of such loops C_p , and denote the contribution of the second, reversed loop byD_p . Summing over all paths we have

$$E = \sum_p (C_p + D_p) \tag{1}$$

The intensity is given by

$$E^2 = \sum_p ({C^*}_p C_p + {D^*}_p D_p) + \sum_p ({C^*}_p D_p + {D^*}_p C_p) + \sum_{p' \neq p} ({C^*}_p + {D^*}_p)(C_{p'} + C_{p'}) \tag{2}$$



When applied to electrons, quantum mechanics tells us that the C^*C and D^*Dterms are probabilities, while C^*D and D^*C terms are interference contributions. Naively, one expects the second and third term to be small. Thus in Boltzmann theory only probabilities are taken into account, that is to say, the first term.

However, if there is time-reversal invariance, the second term $\Sigma_p({C^*}_p D_p + {D^*}_p C_p)$ will be equally large: there is a factor of 2 for each closed loop. As a result, for the wave intensity there is a larger probability of return. In optics there is a simply measurable effect due to this, namely the enhanced backscatter cone. When the incoming and outgoing light are in exactly the same direction, the light path may be considered closed. As predicted by Barabanenkov (1973) and detected by several groups (Kuga and Ishimaru, 1985; van Albada and Lagendijk, 1985; Wolf and Maret, 1985) the average intensity in the backscatter direction has a small cone of height almost one and angular width $\delta\theta \approx \frac{\lambda}{l}$ .This observation has given an enormous push to the research of weak localization phenomena in optics.

This effect is a so-called weak localization effect. These effects occur if $\frac{\lambda}{l} \ll 1$ and are precursor of the so-called strong localization effects which occur if $\frac{\lambda}{l} \approx 1$ These effects are also known as mesoscopic, indicating length scales between macroscopic (the diffusion equation) and microscopic (individual scattering events). Indeed, in electron systems these effects only show up in rather small samples due to inelastic scattering.

3 SCATTERING FROM SPHERICAL PARTICLE

3.1 BASIC SCATTERING PARAMETERS

Consider an electromagnetic plane wave impinging upon a particle which has prmitivity $\varepsilon_p(r)$ that is different from the background permitivity ε .

The electric field of the incident wave is given by

$$E_i = \hat{e}_i E_0 e^{ik\hat{k}_i \cdot r} \tag{3}$$

In the far field,the scattered field is that of a spherical wave with dependance e^{ikr}/r,where r is the distance from the particle .In general ,the particle scatters wave in all directions .The far scattered field in the direction of $\hat{k}_s$ is given by

$$E_s = \hat{e}_s f(\hat{k}_s, \hat{k}_i) E_0 \frac{e^{ikr}}{r} \tag{4}$$

The proportionality $f(\hat{k}_s, \hat{k}_i)$ is called the scattering amplitude from direction $\hat{k}_i$ in to direction $\hat{k}_s$.

The pointing vectors for incident wave and scattered wave is given by

$$S_i = \frac{|{E_0}^2|}{2\eta} \hat{k}_i \tag{5}$$

$$S_s = \frac{|{E_0}^2|}{2\eta} \hat{k}_s \tag{6}$$

Using Eq.(4) in Eq.(6)

$$S_s = \frac{|f(\hat{k}_s, \hat{k}_i)|^2}{r^2} \frac{|{E_0}^2|}{2\eta} \hat{k}_s \tag{7}$$

At a distance r,the surface area subtended by the differential solid angle dΩ_s is

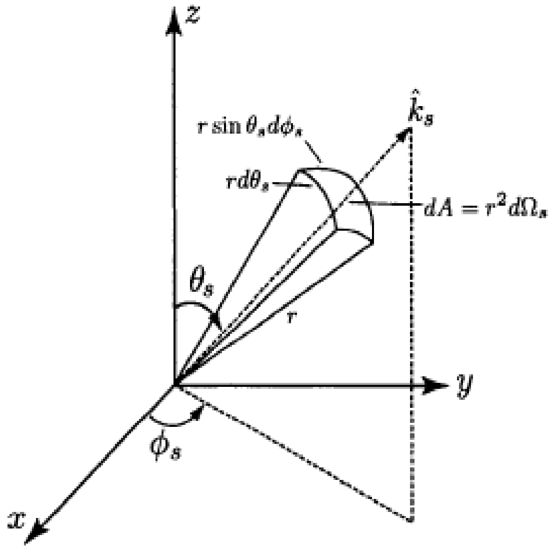
$$dA = r^2 sin\theta_s d\theta_s d\phi_s \tag{8}$$

Then the differential scattered power dP_s through dA is

$$dP_s = |S_s| dA = |S_s| r^2 d\Omega_s \tag{9}$$

Putting Eq.(7) in Eq.(9)

$$dP_s = |f(\hat{k}_s, \hat{k}_i)|^2 \frac{|{E_0}^2|}{2\eta} d\Omega_s \tag{10}$$



Using the poynting vector of the incident wave from Eq.(5),we have

$$\frac{dP_s}{|S_i|} = |f(\hat{k}_s, \hat{k}_i)|^2 d\Omega_s \tag{11}$$

The dimension of the Eq.(11) is area .It is convenient to define a differential scattering crossection $\sigma_d(\hat{k}_s, \hat{k}_i)$ by

$$\frac{dP_s}{|S_i|} = \sigma_d(\hat{k}_s, \hat{k}_i) d\Omega_s \tag{12}$$

Comparing Eq.(11) and Eq.(12) gives

$$\sigma_d(\hat{k}_s, \hat{k}_i) = |f(\hat{k}_s, \hat{k}_i)|^2$$

Integrating Eq.(11) over scattered angles gives

$$\frac{dP_s}{|S_i|} = \int d\Omega_s |f(\hat{k}_s, \hat{k}_i)|^2$$

Thus the scattered power is given by

$$dP_s = \sigma_s |S_i|$$

Where σ_s is the scattering crossection which is

$$\sigma_s = \int d\Omega_s |f(\hat{k}_s, \hat{k}_i)|^2 = \int d\Omega_s \sigma_d(\hat{k}_s, \hat{k}_i) \tag{13}$$

It is important to remember that the scattering crossection σ_s also depends on the constrast between ϵ_p and ϵ.

In case of weak scatterers when $\epsilon_p = \epsilon$,we have

$$\sigma_s proportional to |\frac{\epsilon_p}{\epsilon} - 1|^2$$

This is a result of Born approximation.

The particle can also absorb energy from the incoming electromagnetic wave. The absorption crossection can be defind as

$$\sigma_a = \frac{P_a}{|S_i|}$$

The total crossection of the particle is

$$\sigma_t = \sigma_a + \sigma_s$$

The albedo of the particle is

$$\varpi = \frac{\sigma_s}{\sigma_t}$$

The albedo is a measure of the fraction of scattering crossection in the total crossection.

3.2 MIE SCATTERING CROSSECTION OF A DILETRIC SPHERE

The scattering from molecules and very tiny particles less than $\frac{1}{10}$ wavelength is predominantly Rayleigh scattering. For particle sizes larger than a wavelength, Mie scattering predominates. This scattering produces a pattern like an antenna lobe, with a sharper and more intense forward lobe for larger particles.Mie scattering is not strongly wavelength dependent and produces the almost white glare around the sun when a lot of particulate material is present in the air. It also gives us the the white light from mist and fog.

The light scattering crossection of an individual diletric sphere suspended in a homogenous medium can be expressed as

$$\sigma_{mie} = \frac{{\lambda_l}^2}{2\Pi} \sum_{n=1}^{\infty} (2n+1)(|a_n|^2 + |b_n|^2) \tag{14}$$

Here n is a positive integer and a_n and b_n are two complex coefficients defined by

$$a_n = (-1)^{(n+1/2)} \frac{S_n(\alpha)\tilde{S}_n(\beta) - mS_n(\beta)\tilde{S}_n(\alpha)}{\tilde{S}_n(\beta)\phi_n(\alpha) - mS_n(\beta)\tilde{\phi}_n(\alpha)} \tag{15}$$

$$b_n = (-1)^{(n+3/2)} \frac{mS_n(\alpha)\tilde{S}_n(\beta) - S_n(\beta)\tilde{S}_n(\alpha)}{m\tilde{S}_n(\beta)\phi_n(\alpha) - S_n(\beta)\tilde{\phi}_n(\alpha)} \tag{16}$$

Where $m = \frac{n_2}{n_1}$,n_1 andn_2 are the refractive indices of the sourrounding medium and the sphere, respectively, and

$$S_n = (\frac{\pi z}{2})^{1/2} J_{n+1/2}(z)$$

$$\tilde{S}_n(z) = \frac{dS_n(z)}{dz}$$

$$\phi_n = S_n(z) + iC_n(z)$$

$$\tilde{\phi}_n(z) = \frac{d\phi_n(z)}{dz}$$

$$C_n = (-1)^n(\frac{\pi z}{2})^{1/2} J_{-n-1/2}(z)$$

Where $J_{n+1/2}(z)$ and $J_{-n-1/2}(z)$ are Bessel functions of half integral order and z takes on the values od α or β, $\alpha = 2\pi r/\lambda$,$\beta = m\alpha$.

Here r is the radius of the sphere ,$\lambda_1 = \lambda/n_1$ is the wavelength of the incident beam in the sourrounding medium and λ_0 is the wave length is the wavelength of the incident beam in the vaccum.

From Eqs.(14)-(16) one can see that the scattering crossectionis a function of α , β and m or in other words ,a function of r,n_1, n_2 andλ_0.

3.3 RAYLEIGH SCATTERING CROSS SCETION FOR SPHERICAL PARTICLE

The Rayleigh cross section is valid for spherical particles that have radii small compared to the wavelength of the scattered light. Rayleigh scattering can be considered to be elastic scattering since the photon energies of the scattered photons is not changed. For the Rayleigh approximation the cross section can be written as the analytic function

$$\sigma_{ray} = \frac{8\pi}{3}(\frac{2\pi n_{med}}{\lambda_0})^4 a^6 (\frac{m^2-1}{m^2+2})^2 \tag{17}$$

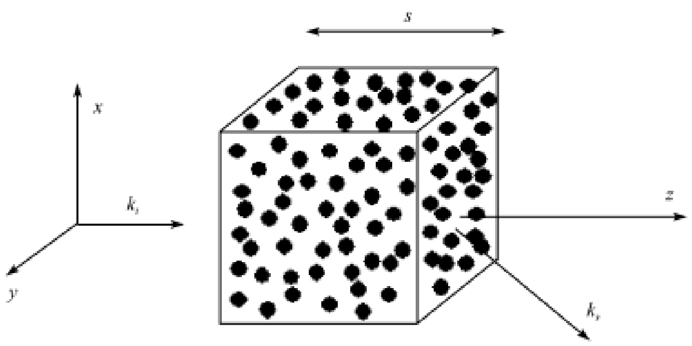
Where λ_0 is the wave length in the free space,a is the particle radius. m is the ratio of refractive index of particle to that of sourrounding medium.Rayleigh scattering crossection is directly proportional toλ^{-4}.

4 SCATERING FROM A CLUSTER

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

$$\mathbf{E^{inc}}(\mathbf{r}) = \sum_l a_l{}^{inc} Re\Psi_l(kr) \tag{18}$$

Where Ψ stands for spherical vector wave function.



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

$$E^{E(\alpha)}(r_\alpha) = E^{inc}(r_\alpha) + \sum_{\beta=1,\beta\neq\alpha}^{N} E^{S(\beta)}(r_\alpha) \tag{19}$$

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

$$E^{S(\beta)}(r) = T(r_\beta) * E^{E(\beta)}(r) \tag{20}$$

introducing eq.(20) in to eq.(19) to calculate exciting field $E^{E(\beta)}(r)$ yields

$$E^{E(\beta)}(r_\alpha) = E^{inc}(r_\alpha) + \sum_{\beta=1,\beta\neq\alpha}^{N} \bar{T}(r_\beta) E^{S(\beta)}(r_\beta) \tag{21}$$

The field exciting theβth scatterer can be expressed as

$$E^{E(\beta)}(r_\alpha) = \sum_l {W_l}^\beta Re\Psi_l(kr_\alpha r_\beta) \tag{22}$$

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:

$$\mathbf{E^s}(\mathbf{r}) = \sum_{\beta=1}^{N} E^{S(\beta)}(r) = \sum_l [\sum_{\beta=1}^{N} {W_l}^\beta \bar{T}(r_\beta)] * Re\Psi_l(kr_\alpha r_\beta) = \sum_l {a_l}^{S(\beta)} \Psi_l(kr_\alpha r_\beta) \tag{23}$$

$${a_l}^\beta = \bar{T}(r_\beta) * {W_l}^\beta \tag{24}$$

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

$$\mathbf{W}^{\alpha} = \sum_{\beta=1,\beta\neq\alpha}^{N} \sigma(kr_{\alpha}r_{\beta})T^{\beta}W^{\beta} + exp(ik_i.r_{\alpha}).a_{inc} \tag{25}$$

where

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

$\mathbf{W}^{\alpha}$ 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 coulmn 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.(25) is that the field exciting scatterer α is the sum of the incident field and the scattered fieldfrom all other particles except from itself. Note that in Eq.(25),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

$$a^{s(\alpha)} = \bar{T}^{(\alpha)}.\bar{W}^{(\alpha)} \tag{26}$$

The final scattered field by the N spheres in direction k_s,with

$$k_s = sin\theta_s cos\phi_s \mathbf{x} + sin\theta_s cos\phi_s \mathbf{y} + cos\theta_s \mathbf{z}$$

at an observation point R is given by

$$E_s(r) = \frac{e^{ikr}}{kr}\sum_{mn}\gamma_{mn}[\alpha_{mn}^{s(M)}C_{mn}(\theta_s,\phi_s)i^{-n-1} + \alpha_{mn}^{s(N)}B_{mn}(\theta_s,\phi_s)i^{-n}] \qquad (27)$$

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.(25) and Eq.(26) to calculate directly the multiply scattered field coefficients $a^{s(\alpha)}$ by calculating the solution of the following equation:

$$a^{s(\alpha)} = \sum_{\beta=1,\beta\neq\alpha}^{N}\bar{T}^{(\alpha)}\bar{\sigma}(kr_\alpha r_\beta)\alpha^{s(\beta)} + exp(ik_i.r_\alpha)\bar{T}^{(a)}.a_{inc} \qquad (28)$$

with

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

Where

$\mathbf{a^{s(\alpha)}}$:is the vector of coefficients for spherical wave harmonics of the multiple scattered field for the particle.

$\mathbf{a_{inc}}$:is the coefficient of the incident wave.

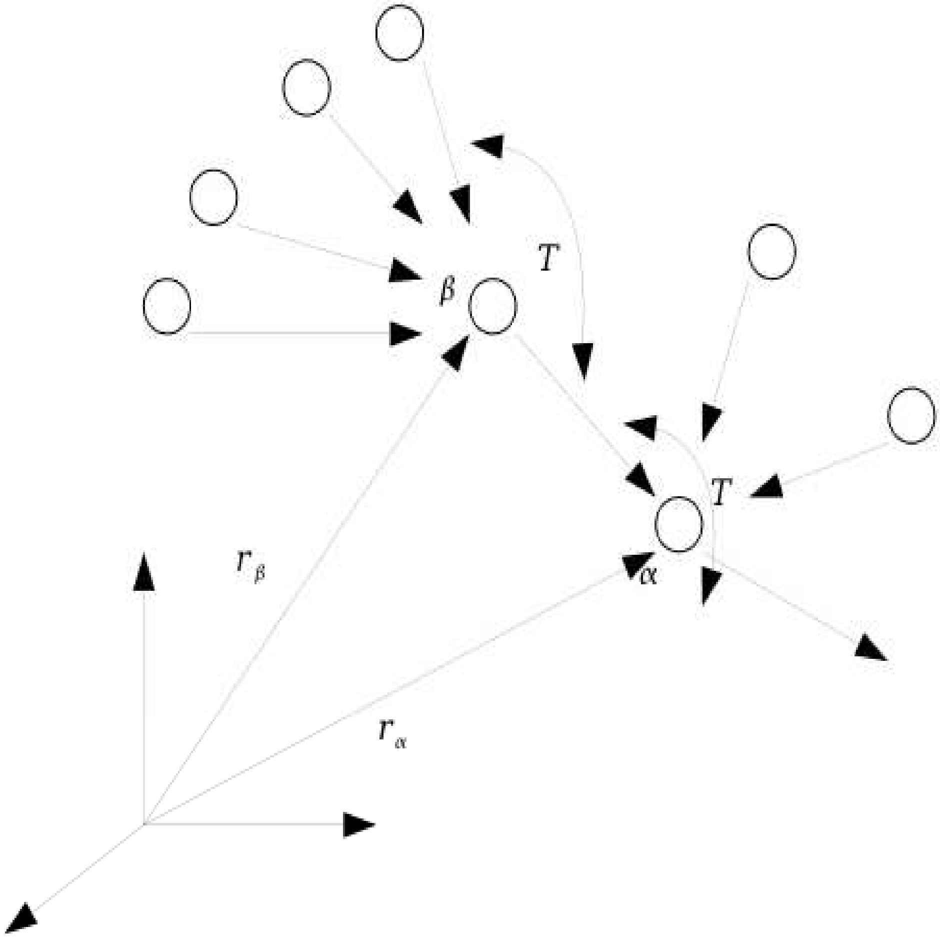
k:is the wave number of of the background media.

$\mathbf{k_i}$: is the wave number of the incident wave.

N: is the number of spheres in the containing volume.

$\sigma(\mathbf{kr}_\alpha\mathbf{r}_\beta)$: is the vector spherical wave transformation matrix.

$\mathbf{T}^{(\beta)}$: is the T matrix for for scatterer β which depends on the permitivity and



radius of β ,as well as the backgroung permitivity.

$\mathbf{r}_\alpha$ and $\mathbf{r}_\beta$: are the center of particles α and β respectively.

Equation (28) can be solved by iteration . The result for the (ν+1)iteration is

$$a^{s(\alpha)(\nu+1)} = exp(ik_i.\alpha)\bar{T}^{(\alpha)}.a_{inc} + \sum_{\beta=1,\beta\neq\alpha}^{N} \bar{T}^{(\alpha)}\bar{\sigma}(kr_\alpha r_\beta)\alpha^{s(\beta)(\nu)} \tag{29}$$

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.(29).

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, $n_0 = \frac{N}{V}$ is the number of particles per unit volume.

5 NUMERICAL COMPUTATION

INPUT PARAMETERS FOR EXTINCTION COEFFICIENTS :

NUMBER OF CLUSTERS:1

NUMBER OF POINT SCATTERERS PER CLUSTER:250

INCIDENT WAVELENGHT (METER):50

LENGTH OF CUBIC BOX (OF WAVELENGTHS):50

LENGTH OF CLUSTER (OF WAVELENGTHS):50

REAL PART OF SCATTERING AMPLITUDE0.008905

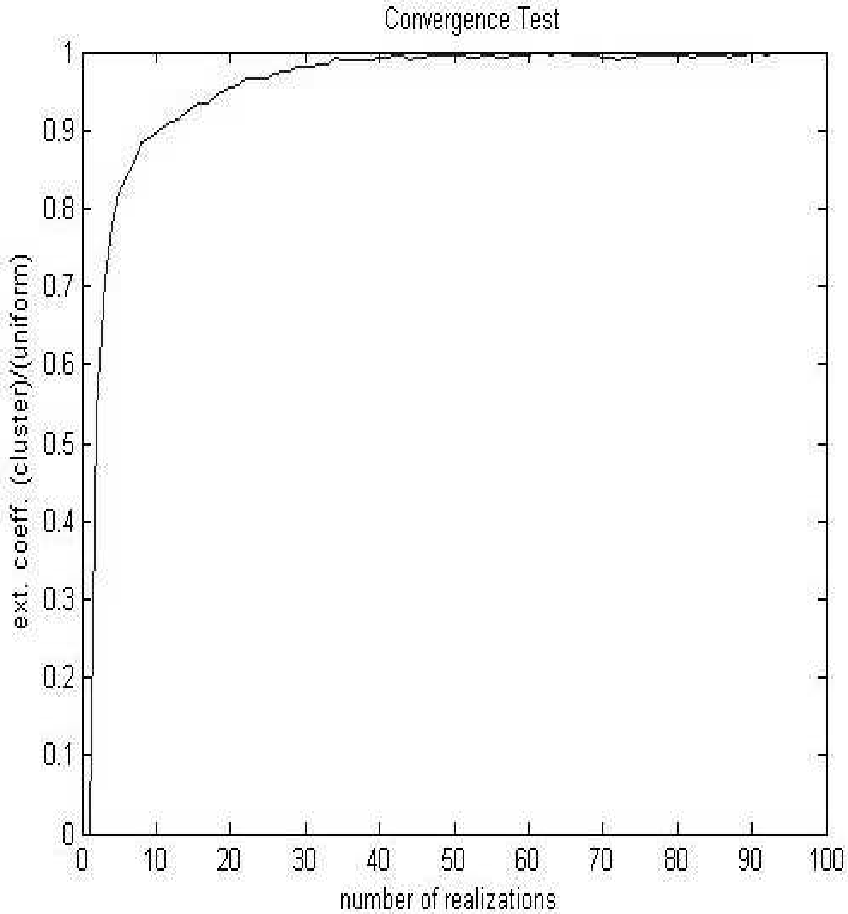
POLAR INCIDENCE ANGLE (DEGREE):45

AZIMUTHAL INCIDENCE ANGLE (DEGREE):0

NUMBER OF REALIZATIONS:100

SEED FOR RANDOM NUMBERS:123456

EXTINCTION RATE VERSUS THE NUMBER OF REALIZATIONS



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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

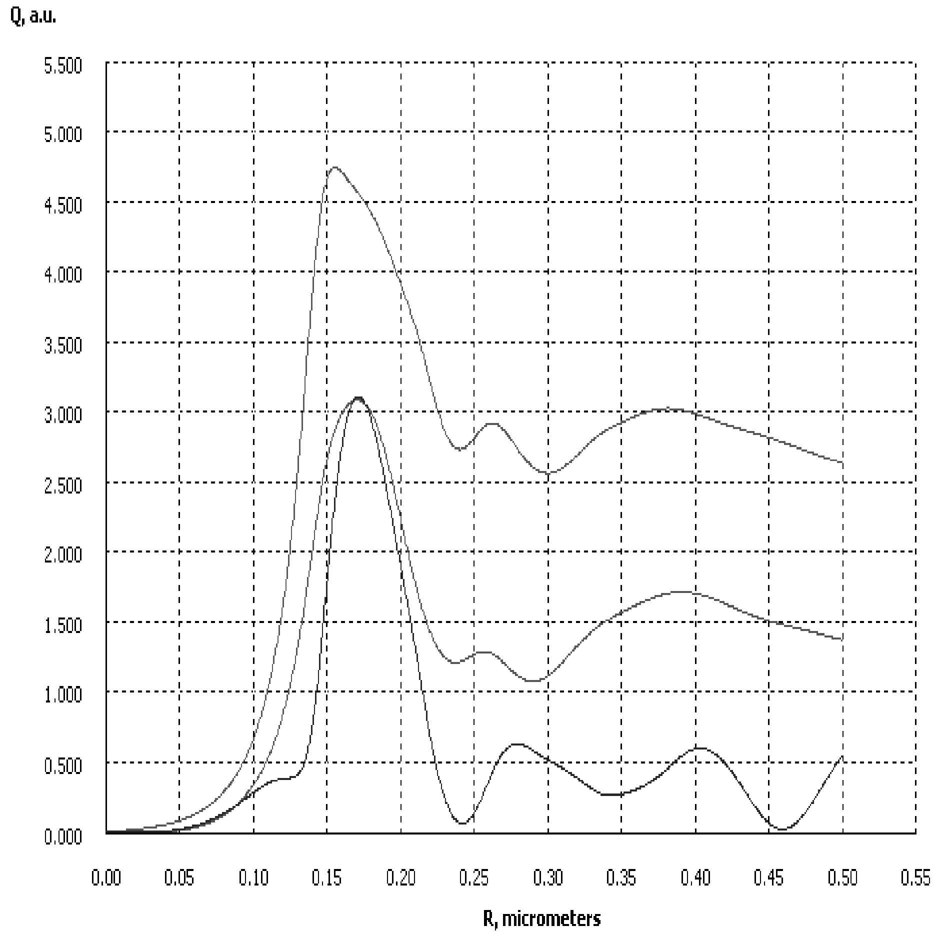
IMAGINARY PART OF ENVIRONMENT REFRACTIVE INDEX: 0.00

REAL PART OF PARTICLE REFRACTIVE INDEX:3.200

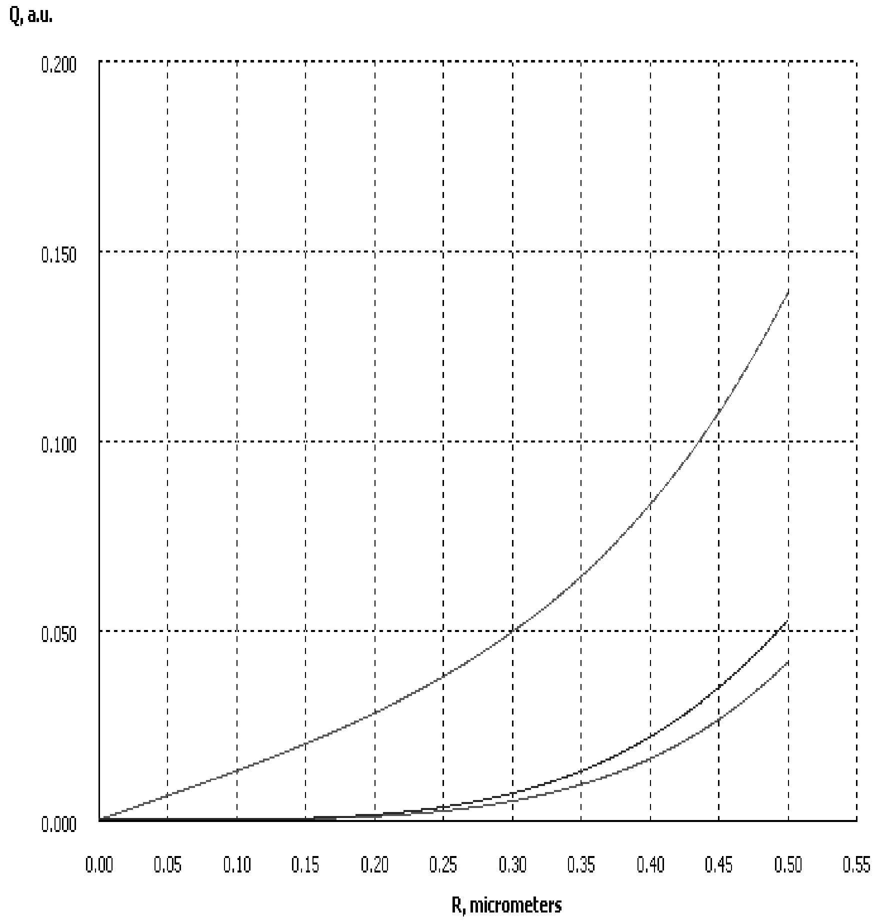
IMAGINARY PART OF PARTICLE REFRACTIVE INDEX:0.3200

INCIDENT LIGHT WAVELENGTH IN MICROMETERS: 8

MIE SCATTERING CROSSECTION



RAYLEIGH SCATTERING CROSS SCETION



6 RESULTS AND DISCUSSION

In this section we present results from numerical simulation of scattering by point scatterers. Numerical convergence of the extinction coefficients with number of realization is demonstrated . We calculate the extinction coefficients the for the case of clustered random distribution .The extinction rate is normalised to the independent scattering case. In different realization ,we only change the position of the particle.The positions of the 250 scatterers are generated randomly and the result is calculated for 100 realizations .We found that with increasing of no of realizations extinction coefficient increases and attains a saturation value .The extinction coefficient is independent of large realization for large no of particles .

Next we calculated the scattering crossection for a spherical particle by using Mie and Rayleigh theory of scattering.We found that mie scattering crossection increases with increase in size parameter ,attains a s maximum value and then decreases with increases in size parameter.But, Rayleigh crosssection increases with increase in sizeparameter.The crossection calculations were made taking sourrounding medium as air and particle permitivity $\epsilon_p = 3.2(1 + i0.1)\epsilon$.

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