TARGET RECOGNATION FROM MULTILAYERED DIELECTRIC SPHERES

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Abstract

This thesis presents electromagnetic target recognition technique in far field region based on use of a new algorithm for calculation the far scattering field of an electromagnetic linearly polarized plane wave by a multilayered sphere. This algorithm is more elegant for the general problem of scattering from a sphere with any number of layers, and to obtain the solution to scattering from a homogeneous sphere or a sphere with a single coating as special cases.

Introduction

- In 1871, Lord Rayleigh (1842–1919) was interested in the scattering of light by particles in the earth's atmosphere, and conceived of as phere as being the simplest model for such scatterer. First, the most important calculation details are the 1908 Gustav Mie article. Robert A. Shore did broadcast the IEEE Antennas and Propagation magazine in 2015 analyzed scattering of an electromagnetic linearly polarized plane wave by a multilayered sphere.
- Rainbow theory is important for understanding spherical scattering and the parameters of reflection, refraction and

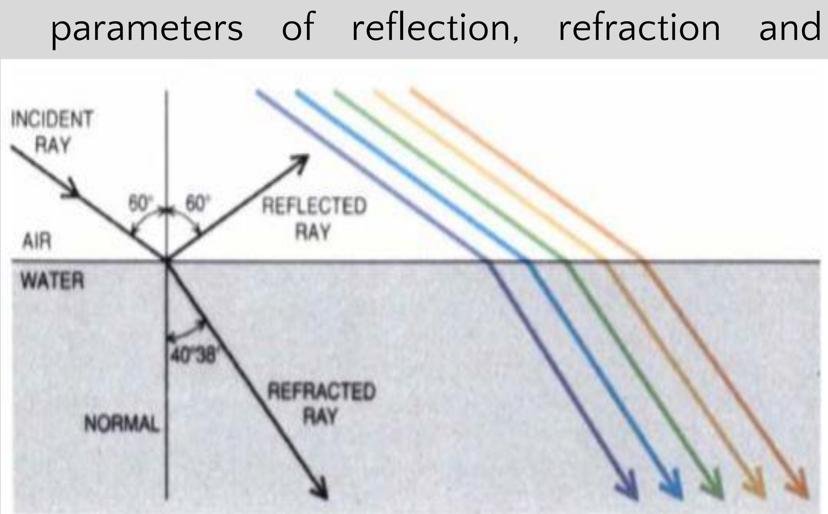

Fig.1: Reflection and Refraction of light at boundaries between air.

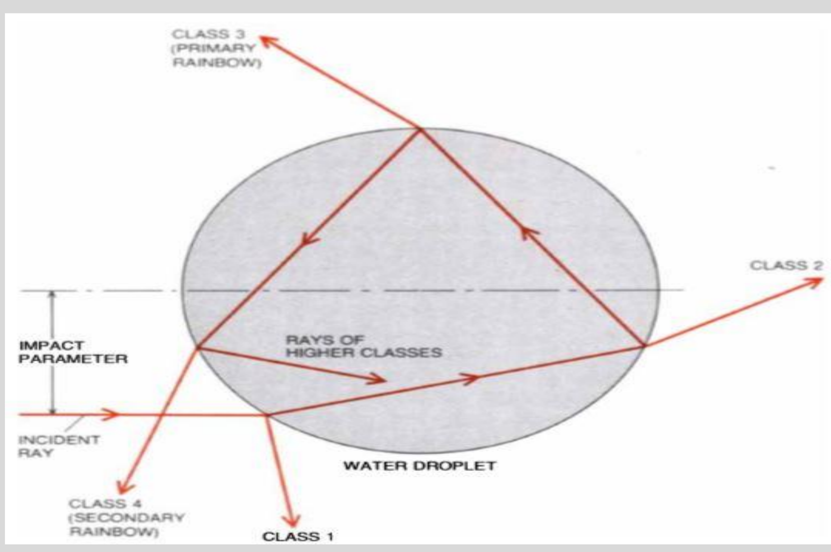

Fig.2: Light path in a droplet .

- The aim of this project is to recognize the target from multilayer dielectric spheres.
- It is to analyze the scattering field of an electromagnetic linear polarized plane wave by a multilayered sphere for classification of objects.

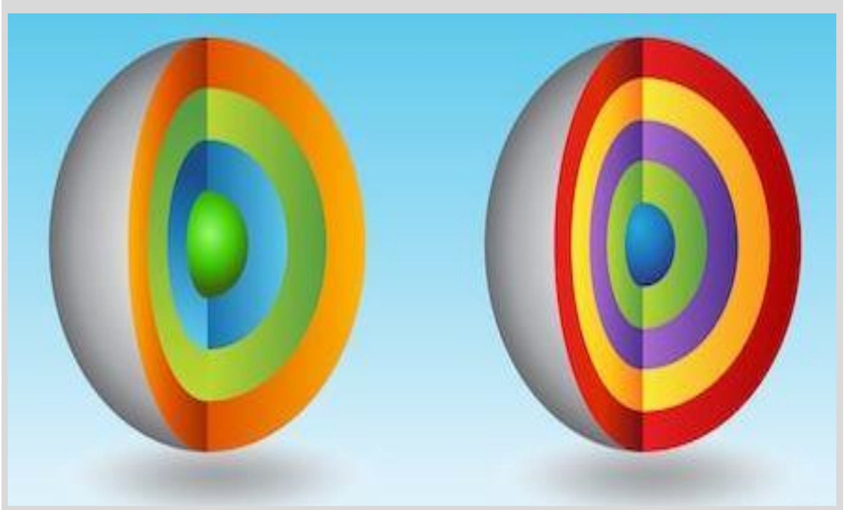

Fig.3: Multilayer dielectric spheres

Methodology

Scattering Framework:

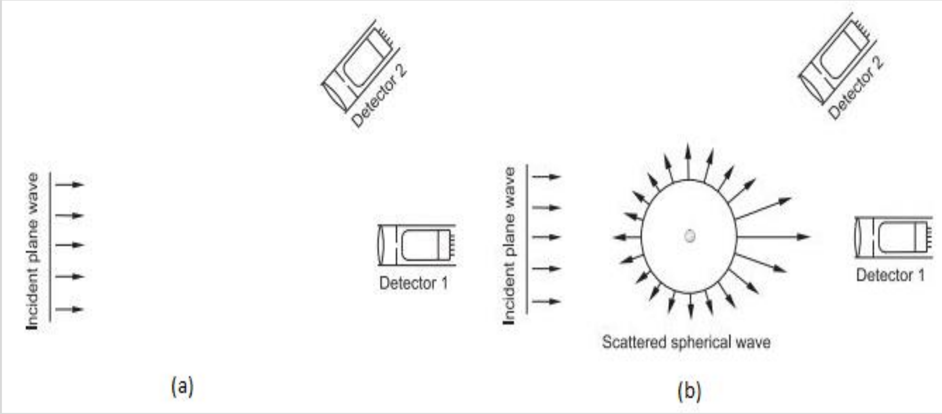

Fig.4: Reading of electromagnetic energy detectors in the presence of a particle.

$$[E(r), H(r)] = [E_{inc}(r), H_{inc}(r)] + [E_{sca}(r), H_{sca}(r)] \qquad (1)$$

Derivation Of The Mie Scattering Coefficients In A Nonabsorbing Medium:

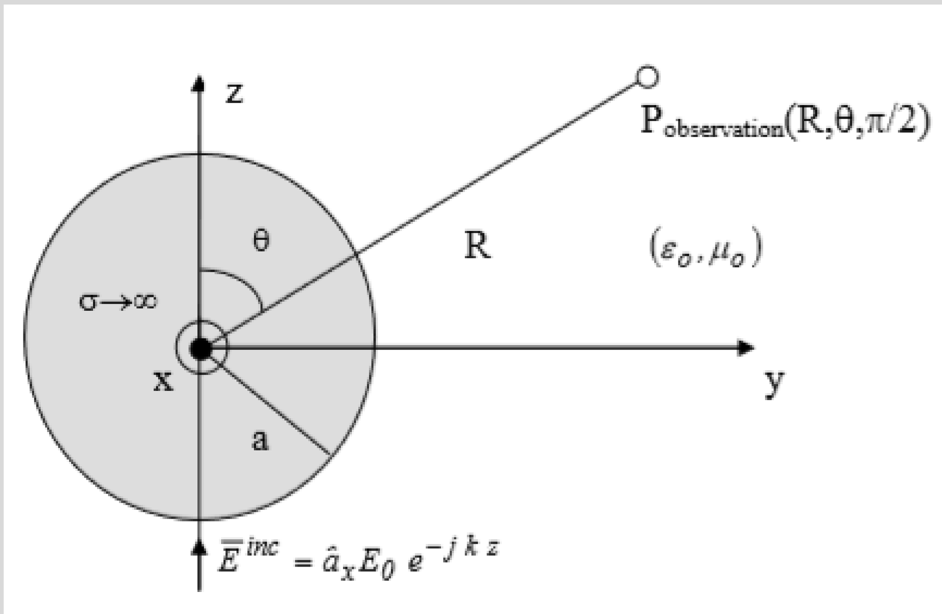

Fig.5: The problem geometry used to generate electromagnetic signals scattered from the spherical targets.

Calculation of a_n and b_n mie coefficient.

$$a_n = f_n(v_L)\frac{u_L A_n(v_L) - \left(\frac{\mu_L}{\mu_{L+1}}\right) v_L F_{S,n}^{(L)} + n\left(\left(\frac{\mu_L}{\mu_{L+1}}\right)\left(\frac{v_L}{u_L}\right) - \left(\frac{u_L}{v_L}\right)\right)}{u_L B_n(v_L) - \left(\frac{\mu_L}{\mu_{L+1}}\right) v_L F_{S,n}^{(L)} + n\left(\left(\frac{\mu_L}{\mu_{L+1}}\right)\left(\frac{v_L}{u_L}\right) - \left(\frac{u_L}{v_L}\right)\right)}$$

$$b_n = f_n(v_L)\frac{\left(\frac{\mu_L}{\mu_{L+1}}\right) v_L A_n(v_L) - u_L F_{T,n}^{(L)} + n\left(1 - \left(\frac{\mu_L}{\mu_{L+1}}\right)\right)}{\left(\frac{\mu_L}{\mu_{L+1}}\right) v_L B_n(v_L) - u_L F_{T,n}^{(L)} + n\left(1 - \left(\frac{\mu_L}{\mu_{L+1}}\right)\right)}$$

For complex argument the individual Riccati–Bessel functions and their derivatives can become extremely large in magnitude with associated overflow problems. The expressions is derived in a form suitable for practical computation, using ratios of Riccati–Bessel functions.

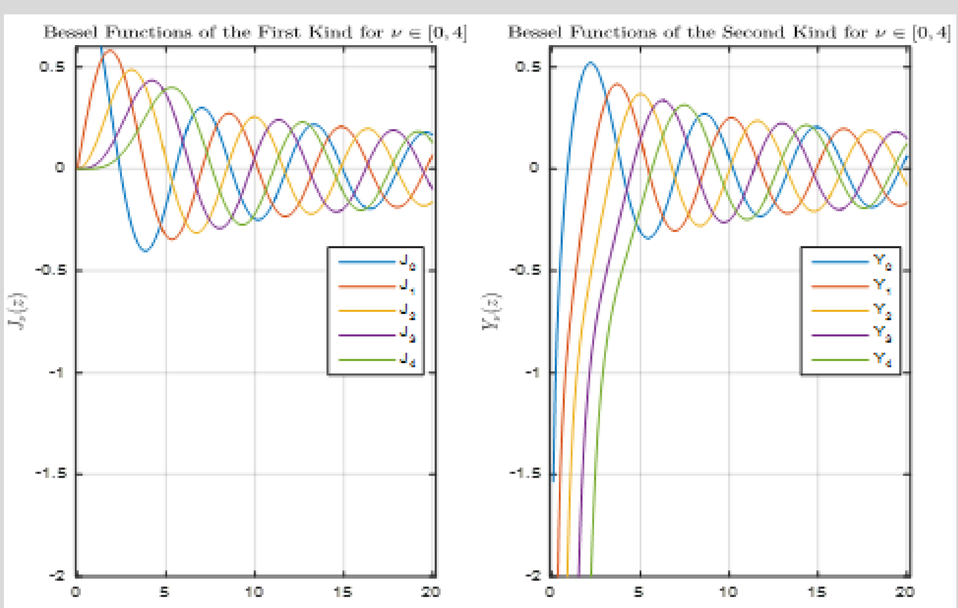

Fig.6: First five Bessel functions of the first and second kind.

The Scattered Field: The far scattered field equations

$$E_{sca} = E_0\frac{e^{ikr}}{-ikr}[\cos\phi\, S_2(\theta)\hat{e}_{s\parallel} + \sin\phi\, S_1(\theta)\hat{e}_{s\perp}], \qquad kr \gg 1$$

$$H_{sca} = \frac{(k_{L+1})}{\omega\mu_{L+1}}E_0\frac{e^{ikr}}{-ikr}[\cos\phi\, S_2(\theta)\hat{e}_{s\parallel} + \sin\phi\, S_1(\theta)\hat{e}_{s\perp}], \qquad kr \gg 1$$

with

$$S_1(\theta) = \sum_{n=1}^{M}\frac{2n+1}{n(n+1)}[a_n\pi_n(\cos\theta) + b_n\tau_n(\cos\theta)]$$

$$S_2(\theta) = \sum_{n=1}^{M}\frac{2n+1}{n(n+1)}[a_n\tau_n(\cos\theta) + b_n\pi_n(\cos\theta)]$$

Results

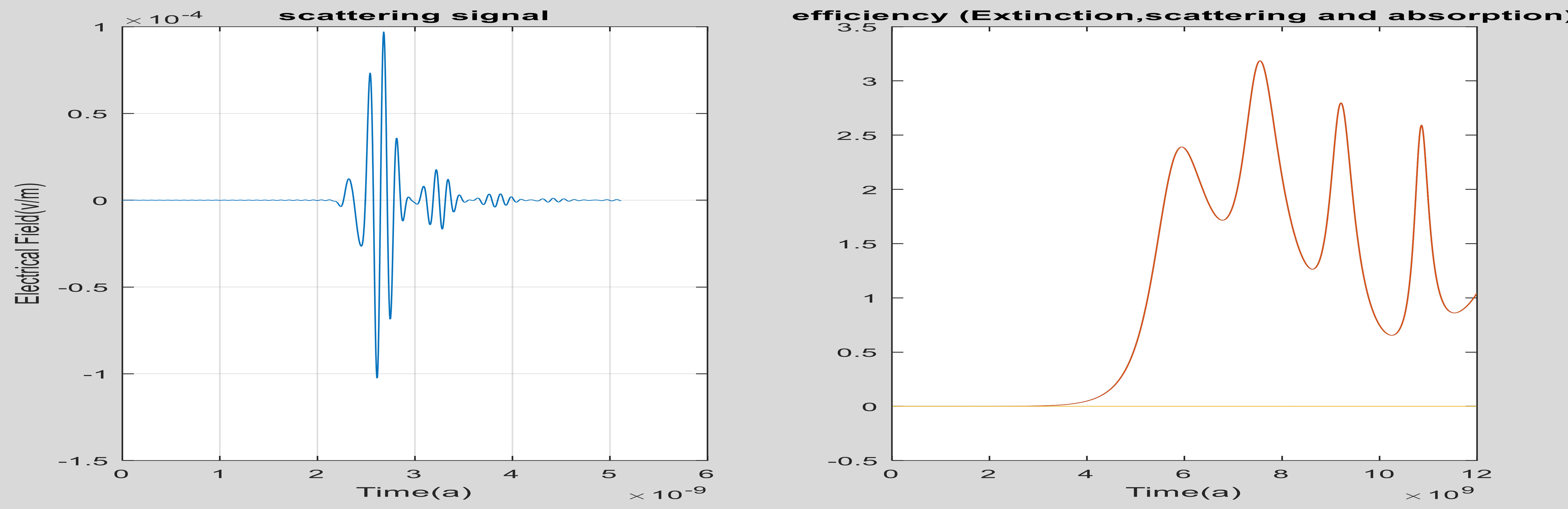

Fig.7: For single-layer sphere, Scattered signals (a) and cross section efficiency (b) for the dielectric sphere of $\boldsymbol{\varepsilon}_r = 4$ and radius 1.8 cm at θ values of 120°.

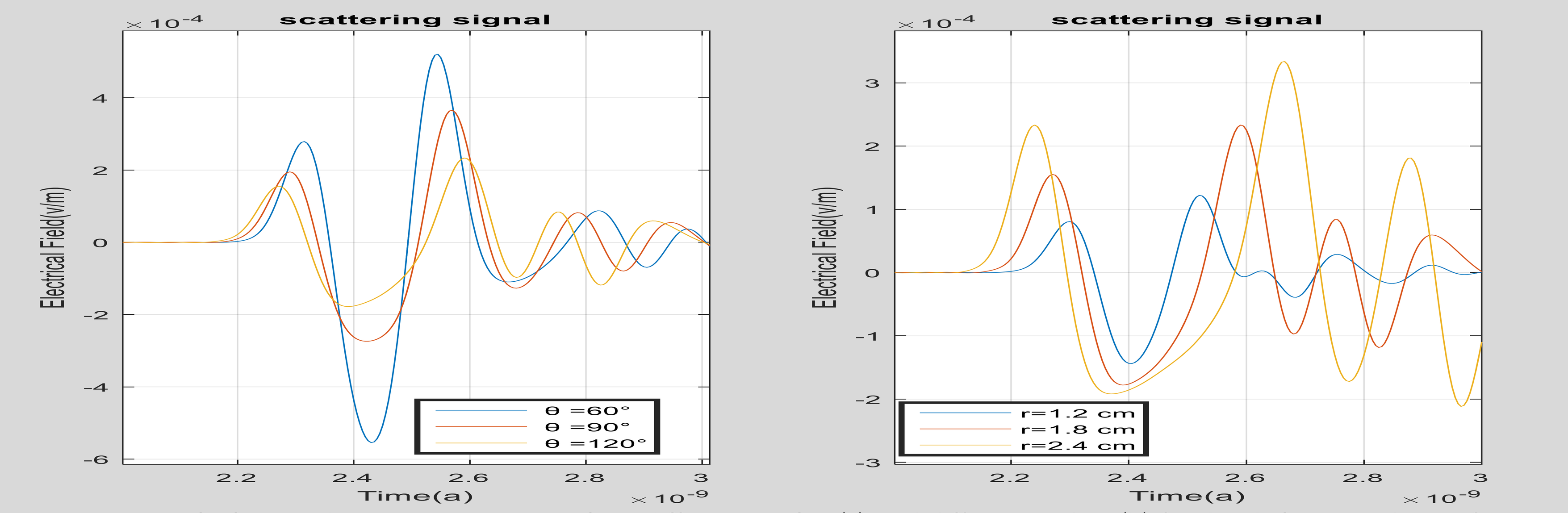

Fig.8: For single-layer sphere, Scattering signals at different angles (a) and different radius (b) for the dielectric sphere of $\boldsymbol{\varepsilon}_r = 4$

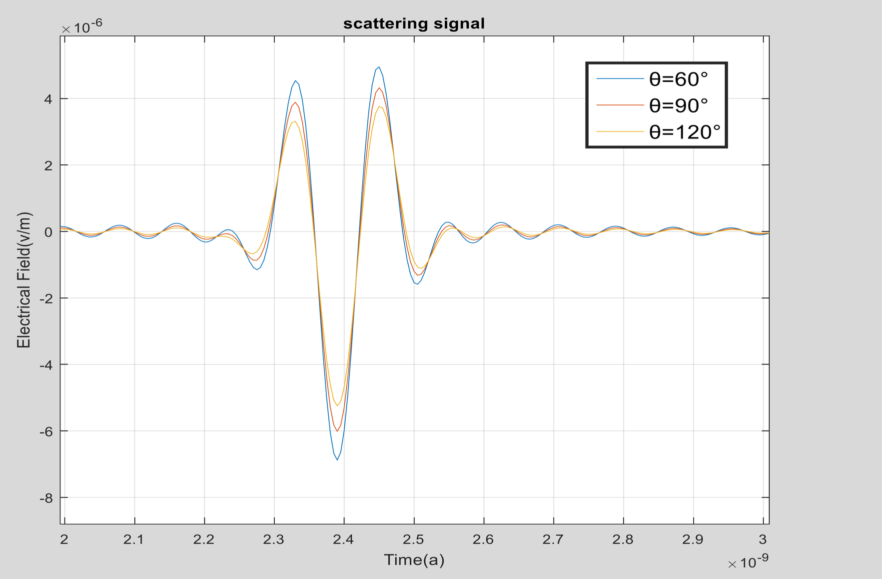

Fig.9: For two-layer sphere, Scattered signals for the dielectric sphere of $\boldsymbol{\varepsilon}_{r1} = 4$, $\boldsymbol{\varepsilon}_{r2} = 2$ and inner radius r1=0.9 cm and outer Radius r1=0.9 cm at θ values of 60°, 90°, and 120°.

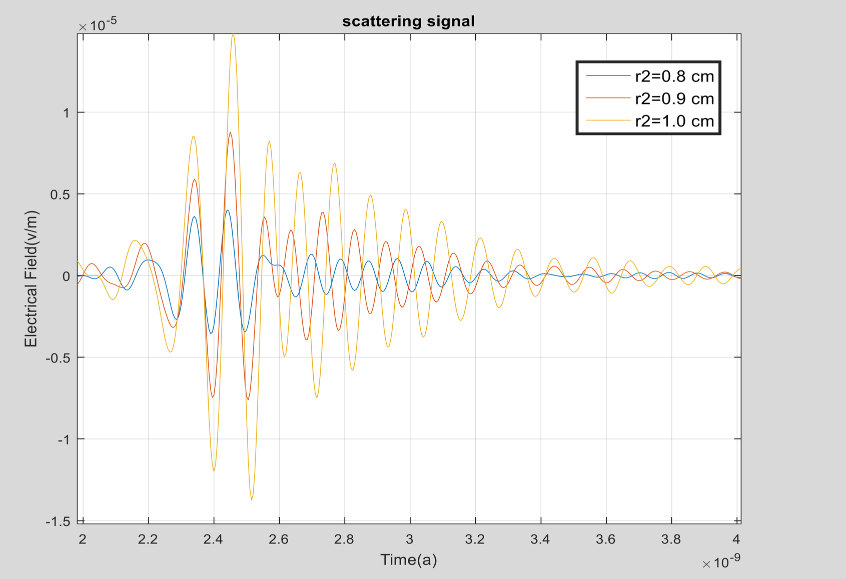

Fig.10: For two-layer sphere, Scattered signals for the dielectric sphere of $\boldsymbol{\varepsilon}_{r1} = 4$, $\boldsymbol{\varepsilon}_{r2} = 4$ and inner Radius r1=0.9 cm outer Radius r2=0.8, 0.9 and 1 cm at θ values of 120°.

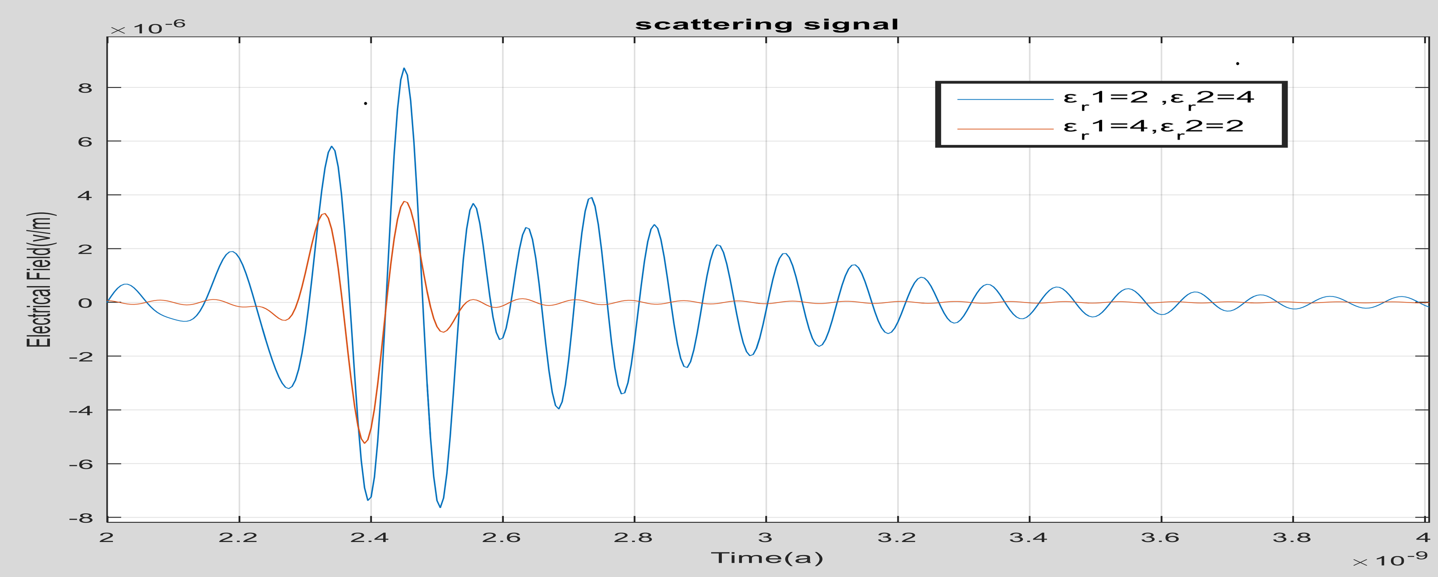

Fig.11: For two-layer sphere, Scattered signals for the dielectric sphere of $\boldsymbol{\varepsilon}_{r1} = 4$, $\boldsymbol{\varepsilon}_{r2} = 2$ and $\boldsymbol{\varepsilon}_{r1} = 2$, $\boldsymbol{\varepsilon}_{r2} = 4$ and inner Radius r1=0.9 cm outer Radius r2=0.9 cm at θ values of 120°.

Conclusion

These results show that, this target recognition system is sensitive to the differences in the scattered signals caused by the sizes and refractive indices of the targets. The internal structure and thicknesses of the layers play an extremely important role in the scattering behavior of the sphere, and even small changes can significantly change the scattered field. In addition to this, if there is a strongly absorbing layer within the sphere, then the scattering behavior of the sphere is determined by this layer and the layers external to it.

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References

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