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Computations of Multi-Band Electromagnetic Scattering from Non-Conducting Spherical Surfaces

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Abstract— **numerous numerical techniques have been developed in order to model the spread of electromagnetic fields in conducting and dielectric surfaces. These techniques proved themselves for the purposed a computational analysis and numerical solution of well-known, canonical or non-canonical problems. Due to its obvious advantages in complex numerical analysis, matrix calculation, and digital signal processing, the use of MATLAB language programming is a feasible choice when generating significant quantities of data for various processes and processing software. This article's software program aims to provide an educational and verification tool for the physical occurrence of electromagnetic dispersion from a dielectric sphere while also establishing the reality of the Finite-Difference Time-Domain (FDTD).A novel case with different permittivity has been tested and results are comparable with standard results.**

Keywords— **electromagnetic scattering; software verification and validation; boundary value problems.**

I. INTRODUCTION

Various numerical techniques have been developed for modelling electromagnetic field propagation in conducting and dielectric media. The validity of these techniques is usually verified by comparison to the numerical solution of canonical or non-canonical problems of well-known solutions. MATLAB language in complex numerical analysis, matrix computation, digital signal processing has obvious advantages, so in the production needs of large amounts of data for various operations and processing software, MATLAB language programming is a good choice. This a software package designed as an educational and validation tool for the purpose of verifying the availability of Finite-Difference Time-Domain (FDTD) and visualizing the physical phenomena of electromagnetic scattering from a dielectric sphere. A program is constructed to calculate and display the near and far fields due to an excitation from a plane wave using the FDTD method. The basics of electromagnetic scattering theory are frequently taught in electromagnetic education through solutions of

scattering from some canonical objects due to stimulation by incident plane. It can be challenging to extrapolate the physical features of the scattering process from these solutions because they are typically presented in closed mathematical forms, which are frequently difficult to envision. It is crucial to have these canonical solutions coded and set up in an intuitive instrument in order to visualize the physical processes of scattering from these things. Students are therefore given a better grasp of electromagnetic scattering theories thanks to the availability of such tools that resolve these kinds of standard issues on the commonly used personal computers and laptops.

A. Finite-Difference Time-Domain with CPML

Based on FDTD computations with convolution using a precisely matched layer from a dielectric sphere, time-domain extrapolation to the far field (CPML).

$$E_x^{n+1}(i,j,k) = C_{exe}(i,j,k)\, E_x^n(i,j,k) +$$
$$C_{exhz}(i,j,k)[H_z^{n+0.5}(i,j,k) -$$
$$H_z^{n+0.5}(i,j\_1,k)] +$$
$$C_{exhy}(i,j,k)\big[H_y^{n+0.5}(i,j,k) -$$
$$H_y^{n+0.5}(i,j,k\_1)\big] +$$
$$C_{\mathcal{P}exy}(i,j,k)\; \mathcal{P}_{exz}^{n+0.5}(i,j,k) +$$
$$C_{\mathcal{P}exz}(i,j,k)\,\mathcal{P}_{exy}^{n+0.5}(i,j,k)\dots\dots\dots\dots\dots\dots\dots$$
$$\dots\dots(1)$$

B. Scattered-field Formulation for FDTD

The central finite difference estimate is used in the scattered-field version, and the FDTD form is obtained:

$$E^{s,n+1} = A1 E^{s,n} + A2\,(\nabla X H^{s,n+0.5}) +$$
$$A3\, E^{i,n+1} + A4\, E^{i,n}$$

$$H^{s,n+0.5} = B1 H^{s,n-0.5} + B2\,(\nabla X E^{s,n}) +$$
$$B3\, H^{i,n+0.5} + B4$$
$$H^{i,n-0.5}\dots\dots\dots\dots\dots\dots\dots\dots\dots(2)$$

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Where A ,B are functions in ε , μ and σ .

As an example of the coordinate mapping of curved subdivisions, we look at a dielectric sphere; its shape and computation region are shown in Fig. 1.
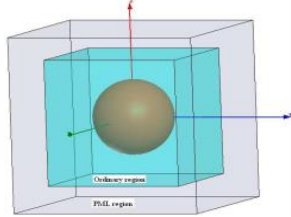

Fig. 1 Geometry and computation domain of a spherical problem.

By contrasting the findings with Mie-series conventional analytical solutions, validation is carried out to verify the RCS calculation's correctness. In Figs. 2 and 3, respectively, the co-polarized biostatic radar cross-sections in the xz plane (E-Plane) and the yz plane (H-Plane) are displayed. It has been demonstrated that the FDTD-developed model produces excellent outcomes for dielectric sphere. They show electromagnetic scattering issues that are well-aligned with those based on precise mathematical answers.
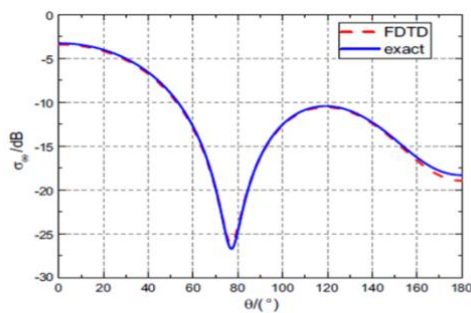
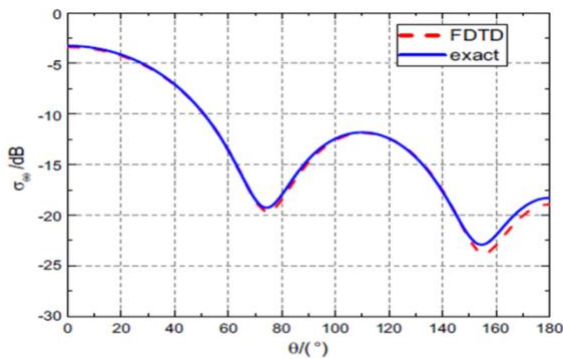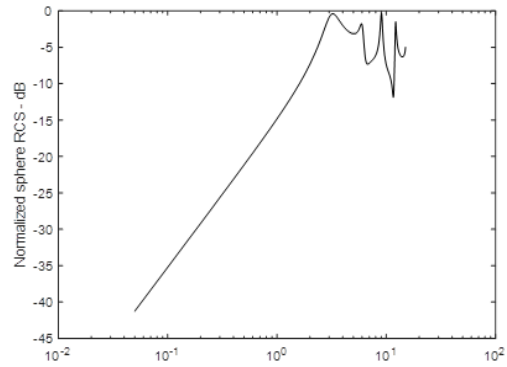

Figure 2. Bistatic cross-section at **1 GHz** in the **xy** plane.

Figure 3. Bistatic cross-section at **1 GHz** in the **xz** plane.

II. OPERATING SOFTWARE

Scattering from a sphere due to an incident plane wave is calculated based on the FDTD method. The sphere's material can be a dielectric or a conductor. For this module, the input parameters that the user can change

and tweak are the simulation step, the operating frequency, the dielectric sphere radius, the dielectric

Figure 4. Bistatic cross-section at **1 GHz** in the **xy** plane.

sphere's relative permittivity, the relative permeability, the incident theta and phi. When we press clear push button, the input parameters can be the default value show in Fig. 3. Polarized radar cross sections can be plotted and saved to a file. A snapshot of the module is shown in Figs. 2 and 3 with the model, the Electric field the polarized scattering cross section and Cartesian scattering cross section of a dielectric sphere.

III. RESULTS

Practical examples has been concentrated on 1GHz and 9GHz to examine the resultant behaviours of the radar cross section (RCS) from the proposed dielectric surface at different band.

RCS values, as depicted from figures 4-6 and figures 7-9 shows dependency of the incident plane of the wave on the scatterer. For. Figure 3. Bistatic cross-section at **1 GHz** in the **xz** plane

Example for X-Y plane RCS start from smaller value at the low edge of angle range and reaches its maximum at the upper range. For x-z plane RCS value fluctuates nearly periodically through the directional range. On the other hand results at Y-Z plane behaves in like domes. As a comparison between resulting figures it

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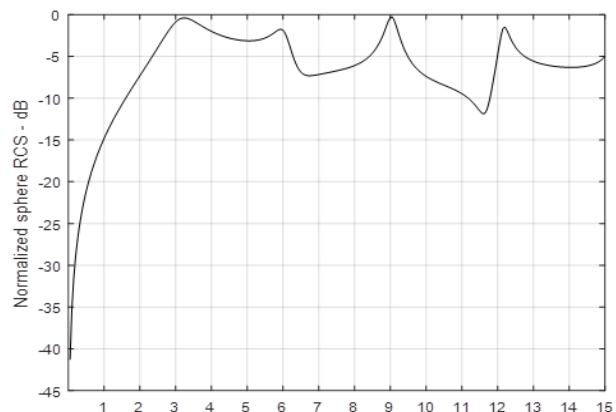
can be noticed that more details results are obtained with ascending manner in frequency

Figure 5. Bistatic cross-section at **1 GHz** in the **xz** plane.
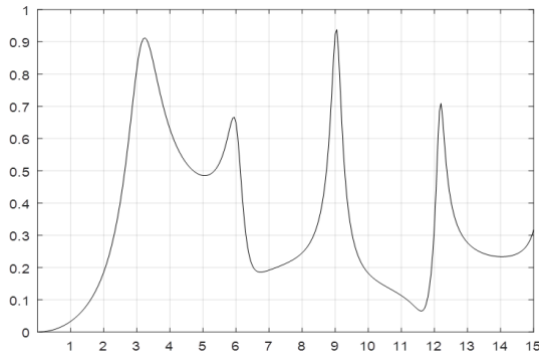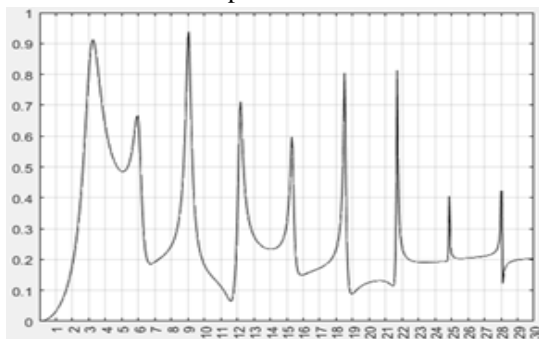
Figure 6. Bistatic cross-section at **1 GHz** in the **yz** plane.

Figure 7. Bistatic cross-section at **9 GHz** in the **yz** plane.
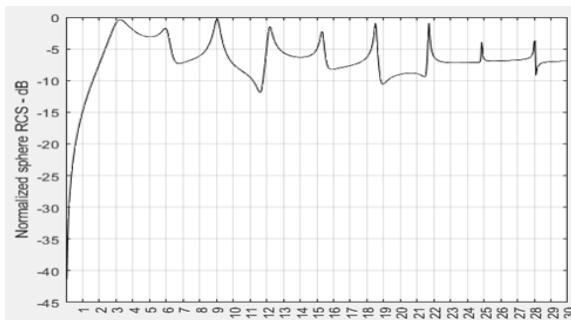

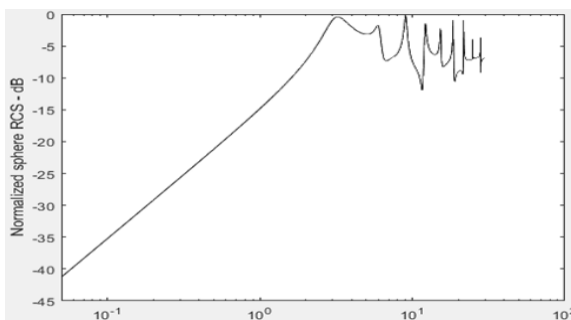Figure 8. Bistatic cross-section at **9 GHz** in the **xz** plane.

Figure9. Bistatic cross-section at **9 GHz** in the xy plane.

The sampled electric field at the origin and the cross-section images are acquired after the algorithm has completed 2,000 time steps. Figure 2 displays the waveform of the incoming plane wave along with the sampled dispersed electric field that was recorded at the origin. The cross-sections of the dielectric sphere in the **xy**, **xz**, and **yz** planes are depicted in Figures 4, 5, and 6, respectively.

IV.   CONCLUSIONS

The dispersion from a dielectric sphere has been created with a graphical user interface (GUI) . Specifically finite difference method has been used for simulating the results. Depending of the incident plane, RCS manifests its self in nearly doming behaviors with directional range. Moreover, the analyses of the paybacks of the dielectric is scattered by increase of frequency.

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