LIGHT SCATTERING BY THIN CURVED DIELECTRIC SURFACE AND CYLINDER

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Abstract

Different disciplines are interested in different scattering properties of the dielectric objects, and many published papers about this topic are found in literature. The electromagnetic scattering of plane waves by arbitrary shaped objects has been widely studied for several decades. Several authors had offered different models for electromagnetic scattering from arbitrary shaped objects [1-3].

This paper presents a quasi-static approximate solution in order to determine light scattering from dielectric thin curved surface and cylinder. A cylindrical shell is firstly considered to illustrate the validity of the method which is then extended to derive a formula for more arbitrary shapes. There is no existing solution method in the literature for scattering from lossy dielectric curved surface and cylinder. This method is valid only when curved surface or cylinder is small compared to wavelength in one direction. If this criteria is satisfied, the results are valid in all frequency regions.

Techniques described in the literature were used to determine the scattering fields ($E_S = f.\frac{e^{ikR}}{R}$) and scattering amplitudes scattered by a thin plate and cylinder in the far-field zone.

After determining the scattering amplitudes, the scattering amplitudes of curved surface and cylinder is obtained as;

1. The arbitrary shape is divided into N small approximately element (curved surface and cylinders are divided as small plate and cylinder), each of which has a center described by x_c, y_c, z_c. For each element, the normal vector ($\mathbf{n_c}$) is determined ($c = 1, 2, ...N$).
2. The scattering amplitudes of each element $\mathbf{f}^{(c)}(\mathbf{o,i})$ are determined [2].
3. Each scattering amplitude is added coherently in order to obtain scattering amplitude of total object as

$$\mathbf{f(o,i)} = \sum_{c=1}^{N} \mathbf{f}^{(c)}(\mathbf{o,i})\, e^{jk_0 \gamma_c \cdot \mathbf{r}_c} \; , \qquad (1)$$

with propagation constant γ_c and $\mathbf{r}_c$. Here, $\mathbf{r}_c$ is the position vector to the center of the c^{th} element.

The bi-static RCS, the scattering field intensity and the scattering power flux density are obtained in terms of the scattering amplitude as follows,

$$\sigma_{pq} = 4\pi \mid f_{pq}(\text{o},\text{i}) \mid^2$$
$$|E_s|^2 = \frac{\sigma_{pq}}{4\pi R^2} \quad , \tag{2}$$
$$S_s = |E_s|^2 / 2\eta_0$$

where f_{pq} depends on the shape function and the dielectric properties of scatterer and $\eta_0 = 377\Omega$. The scattering amplitudes are found as:

$$f_{pq} = \frac{k_0^2}{4\pi} \left\{ \begin{array}{l} \mathbf{p}\cdot\mathbf{q} \sum_{c=1}^{N} K_1 \, e^{j\,k_0\,\boldsymbol{\zeta}\cdot\mathbf{r_c}} V_c \\ + \sum_{c=1}^{N} K_2 \, (\mathbf{p}\cdot\mathbf{n_c})\,(\mathbf{n_c}\cdot\mathbf{q})\, e^{j\,k_0\,\boldsymbol{\zeta}\cdot\mathbf{r_c}} V_c \end{array} \right\}, \tag{3}$$

with $K_1 = \varepsilon_r - 1$, $K_2 = -(\varepsilon_r - 1)^2 / \varepsilon_r$ for plate, $K_1 = 2\,(\varepsilon_r - 1)/(\varepsilon_r + 1)$, $K_2 = (\varepsilon_r - 1)^2 /(\varepsilon_r + 1)$ for cylinder, $\boldsymbol{\zeta} = \mathbf{i} - \mathbf{o}$, the inner radius ($a$) of the cylinder, the angle (ϕ) which is measured from x axis, the number of element (N), and the volume shape function,

$$V_c = \begin{cases} L\cdot T \cdot \Delta s & \text{for plate} \\ \dfrac{\pi D^2}{4}\cdot \Delta s & \text{for cylinder} \end{cases}$$

and L, T, Δs are side lengths of plate, D is the diameter

The several results of numerical calculations and their validity are studied by comparison with Ansoft HFSS simulation program . The excellent agreement were found for both Horizontal and Vertical polarizations. **This work is the generalization of the theoretical work of ref [4, 5].**

The advantage of using our method is that it takes less calculation time than HFSS. For instance, the CPU time for our method is four minutes, however, the CPU time for HFSS is more than one hour, even for more complex shapes, or at high frequencies, this CPU time becomes a couple of hours. In addition, minimum 2 GB of RAM is necessary for HFSS simulations. In contrast, the same simulations with our method can run with a basic PC. The developed model also has the following advantages: The structures are formed by arbitrary lossy dielectric materials. Most of the previous works in wave propagation have focused on specific frequency ranges. The developed model is applicable for a broad band of frequencies. The model can be extended to more complicated configurations easily.

References

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