Electromagnetic Scattering from Multiple Cylinders

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During the last several decades, electromagnetic scattering from multiple cylinders has been an active research topic of in many areas, such as microwave remote sensing, theory of photonic crystals, atmospheric sciences, and so on. Rigorous theoretical treatment is therefore of critical importance.

A large body of available studies in the literature concerns with two dimensional scattering, such as the scattering matrix method (SMM) [1-2]. The typical treatment is to represent fields (incident, exciting, and scattered) using vector cylindrical harmonic waves, and set up the multi-scatterer equation with the aid of translational addition theorem. For such cases, the circumscribing sphere of each particle is degenerated to a circle, and the mutual exclusive condition of the circumscribing spheres is usually fulfilled. However, when 3-D scattering problems are considered, the issues become more complicated.

The problems of 3-D scattering of multiple spheres can be similarly treated using the multi-scatterer equation, with varying technical delicacy attached to the solution process. Examples include the special cases in the iterative algorithms by Mackowski [3] or the recursive T-matrix algorithm (RTMA) by Chew [4]. Yet regardless of the underlying technical details, several benevolent features hold for such setting, including fulfillment of the mutual exclusive condition of the circumscribing spheres of each scatterer (actually the sphere itself in these cases) and the favorable behavior of the *T* matrix for spheres. It is not the case when scattering from multiple cylinders is considered. One, the mutual exclusive condition of the circumscribing spheres is often found violated (as in the case when any pair of reasonably long cylinders are close to each other), and two, the *T* matrix of a dielectric cylinder of arbitrary length, equivalent volumetric radius, and dielectric contrast with the ambient environment can have poor convergent property or even fail to converge. Partly for these reasons, in [5], the 3D problem was first converted to a 2D problem by assuming infinite length of the cylinders to obtain the exciting fields and then to use the Huygen's principle to bring back the 3D scattering. Yet such convenience for technical treatment may compromise the rigorousness and fidelity of the scattering characterization. Another approach without resorting to the multi-scatterer equation in studying scattering from two scatterers was based on the reciprocity theorem to obtain scatterer coupling up to the second order [6]. Yet this method, an approximated one in its nature, may not be suitable for situations where more rigorous treatment is required.

For electromagnetic scattering from a single dielectric cylinder of finite length, we have recently proposed a new iterative technique with extension to the T-matrix approach [7]. The appealing feature of this approach is its capability of dealing with dielectric cylinder of arbitrary length, hence overcoming the limitation inherent in the conventional T-matrix approach where the algorithm may fail to converge if the length is larger than several times of the radius. In this approach, a long cylinder is divided into a cluster of N identical sub-cylinder, for each the T matrix can be calculated stably in the numerical sense. Special care is then paid to rigorously fulfill the boundary conditions at the hypothetical division interfaces. Coupling among sub-cylinder is also cast into a rigorous formulism.

In this paper we propose to extend the above method to the problem of electromagnetic scattering from a cluster of parallel dielectric circular cylinders. The overall treatment is separated into two stages: at the first stage, scattering from a single cylinder is obtained as the first-order solution; and at the second stage, a recursive process that accounts for multiple scattering, where the scattered field from one cylinder is considered as the illuminating wave for the other cylinder and vice verse, is formed. The procedure is found to converge very fast except for the case when any pair of cylinders is very close to each other. It should be noted that since no approximation is introduced in the procedure, this approach is thus more rigorous. Moreover, the formalism is general and can be readily applied to cylinders with cross section other than circular so long as the T matrix of each sub-cylinder can be accurately obtained.

The validity of the proposed method has been verified by good agreement between model results and numerical simulations. Further verification may be carried out when measurement data are available from our collaborators.

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