Radar Cross Section Analysis of a Finite Parallel-Plate Waveguide with Material Loading: A Rigorous Wiener-Hopf Approach

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The analysis of electromagnetic scattering by open-ended metallic waveguide cavities is an important subject in the prediction and reduction of the radar cross section (RCS) of a target. This problem serves as a simple model of duct structures such as jet engine intakes of aircrafts and cracks occurring on surfaces of general complicated bodies. Some of the diffraction problems involving two- and three-dimensional cavities have been analyzed thus far based on high-frequency techniques and numerical methods. It appears, however, that the solutions due to these approaches are not uniformly valid for arbitrary dimensions of the cavity. Therefore it is desirable to overcome the drawbacks of the previous works to obtain solutions which are uniformly valid in arbitrary cavity dimensions. The Wiener-Hopf technique is known as a powerful, rigorous approach for analyzing scattering and diffraction problems involving canonical geometries. In this talk, we shall consider a finite parallel-plate waveguide with four-layer material loading as a geometry that can form cavities, and analyze the plane wave diffraction rigorously using the Wiener-Hopf technique. Both E and H polarizations are considered.

Introducing the Fourier transform of the scattered field and applying boundary conditions in the transform domain, the problem is formulated in terms of the simultaneous Wiener-Hopf equations. The Wiener-Hopf equations are solved via the factorization and decomposition procedure leading to an exact solution. However, this solution is formal since infinite series with unknown coefficients and infinite branch-cut integrals with unknown integrands are involved. For the infinite series with unknown coefficients, we shall derive approximate expressions by taking into account the edge condition. For the branch-cut integrals with unknown integrands, we assume that the waveguide length is large compared with the wavelength and apply a rigorous asymptotics. This procedure yields high-frequency asymptotic expressions of the branch-cut integrals. Based on these results, an approximate solution of the Wiener-Hopf equations, efficient for numerical computation, is explicitly derived, which involves a numerical solution of appropriate matrix equations.

The scattered field in the real space is evaluated by taking the inverse Fourier transform and applying the saddle point method. Representative numerical examples of the RCS are shown for various physical parameters, and the far field scattering characteristics of the waveguide are discussed in detail. The results presented here are valid over a broad frequency range and can be used as a reference solution for validating other analysis methods such as high-frequency techniques and numerical methods.