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Rigorous RCS Analysis of a Finite Parallel-Plate Waveguide Cavity with Perfect Electric Conductor Loading

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In the field of target identification using radar, the study of electromagnetic diffraction and scattering by cavities formed by open-ended waveguides remains a critical area of research. Historically, radar cross-section (RCS) analyses have been extensively conducted for various two- and three-dimensional cavities using high-frequency ray techniques and numerical methods. However, the solutions derived from these approaches often lack uniform validity across arbitrary cavity dimensions. The Wiener-Hopf technique, recognized as a powerful method, offers rigorous solutions applicable to arbitrary target dimensions. In our previous work, we have analyzed the case of a semi-infinite parallel-plate waveguide with partial material loading [1]. In this paper, we focus on a finite parallel-plate waveguide cavity with perfect electric conductor loading, which serves as a cavity-like geometry, and rigorously solve the E-polarized plane wave diffraction problem using the Wiener-Hopf method.

The geometry of the waveguide is shown in Figure 1, where the waveguide plates are perfectly conducting, infinitely thin, and uniform in the y-direction. In the figure, f^i is the incident field of E polarization, and PEC is loaded in the region $D_2 < z < D_1$. Introducing the Fourier transform for the unknown scattered field and applying boundary conditions in the transform domain, the problem is reduced to the simultaneous Wiener-Hopf equations satisfied by unknown spectral functions. The Wiener-Hopf equations are then solved via the factorization and decomposition procedure leading to an exact solution. The solution obtained is formal, as it involves an infinite number of unknowns. Then, we shall develop approximate methods to determine the unknowns. Taking the inverse Fourier transform of the solution in the transform domain, the scattered field in real space is derived. In particular, the field inside the waveguide is expressed in terms of the TE modes, whereas the field outside the waveguide is evaluated asymptotically with the aid of the saddle point method. In Figure. 2, we present the RCS oscillation curves at four different frequencies. The blue line corresponds to $kb = 1.57$, the orange line represents $kb = 3.14$, the green line represents $kb = 15.7$, the purple line represents $kb = 31.4$. Finally, numerical examples of the RCS will be presented for various physical parameters and backscattering characteristics of the waveguide will be discussed. Main results of this paper are published in our paper [2].

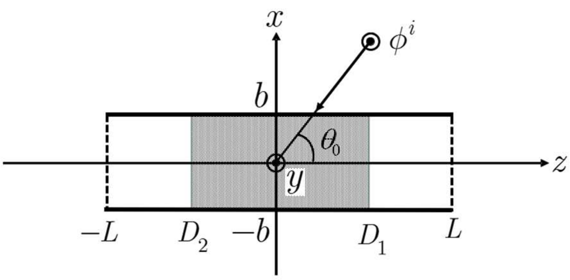

Figure 1. Geometry of the waveguide.

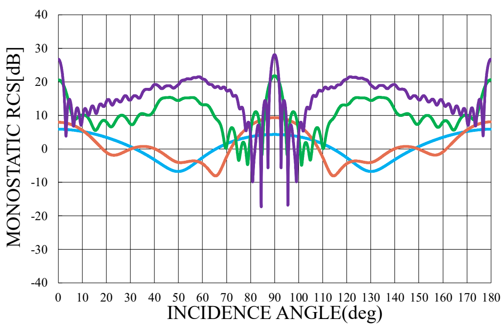

Figure 2. RCS of $L/b = 1.0$, $D_2 = -0.5L$, $D_1 = 0.5L$.

References

[1] T. Zhang, and K. Kobayashi, "Diffraction by a Semi-Infinite Parallel-Plate Waveguide with Partial Material Loading: A Combined Wiener-Hopf and MRCT Solution," *IEICE Trans. Electron*, **E108-C**, 5, May 2025, doi:10.1587/transele.2024ECP5041. (in press)

[2] T. Zhang, and K. Kobayashi, "Diffraction by a Finite Parallel-Plate Waveguide Cavity with Perfect Electric Conductor Loading: The Case of E Polarization," *IET Microw. Antennas Propag.* (accepted for publication)