SCATTERING FROM LOADED GROOVES

Kasra Barkeshli

Department of Electrical Engineering and Computer Science
The University of Michigan
Ann Arbor, Michigan 48109-2122

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Abstract

Electromagnetic scattering from a two-dimensional groove recessed in an arbitrarily thick conducting screen is studied. The groove may be empty or loaded with a lossy material which may or may not completely fill the cavity. For the partially loaded groove, the filling material is assumed electrically dense so that the standard impedance boundary condition is applicable at the top surface of the material. Employing a full-wave analysis, integral equations are derived for the tangential components of the electric field over the aperture. It is shown that the equations are identical for both partially loaded and completely loaded (or empty) cases provided that the aperture admittance of the groove is treated as the equivalent admittance of the internal medium looking into the aperture, thus simplifying the integral equations.

When the groove is completely filled by a dense material, the formulation reduces to that corresponding to a direct application of the impedance boundary condition over the aperture.

Key words: Electromagnetic scattering and detection, full-wave analysis, impedance boundary condition, cracks and grooves.
Introduction

The study of electromagnetic scattering from filled cavities recessed in ground planes is important in many engineering applications because such cavities can be considered as approximate models for thin cracks in metal surfaces. At millimeter wave frequencies, electromagnetic scattering might be used in non-invasive detection and evaluation of gaps and cracks in structural systems for the purpose of failure prediction. Also, in radar signature analysis of various man-made structures, diffraction from cracks and joint openings can become a dominant mechanism in the bistatic scattering behavior of a target. Therefore, it is important to examine the effect of different geometries and material inserts on the scattering behavior of grooves.

When the operating wavelength, $\lambda_o$ and the aperture width of the groove, $w$ are such that the groove is electrically narrow ($w \ll \lambda_o$), certain approximate solutions have been proposed. These include the transmission line model [1], the narrow resistive strip model based on Babinet's principle [2], and the closed from low-frequency solution [3]. In the latter, analytical expressions were derived for the equivalent magnetic current distribution and over the aperture of the narrow groove based on a quasi-static analysis of the exact integral equations.

In the millimeter wave region, however, the above narrow-width approximations are no longer valid and a more accurate solution is required. In this paper, an exact full-wave formulation is developed for the rectangular groove problem based on the Generalized Network Theory and the equivalence principle [4]. This theory has been applied to a number of related aperture and slot problems in the past [5, 6]. In particular, we will extend the work of Auckland and Harrington who applied this theory to treat the TE transmission through a slit in a thick conducting screen. Employing the equivalence principle, the external fields are expressed in terms of the scattering integral while the fields internal to the cavity are given in terms of appropriate waveguide modes. An integral equation is then formed by enforcing continuity of tangential fields across the interface and is solved numerically via the method of moments. The problem will be formulated for general termination conditions as well as both principle polarizations.

When the groove is fully loaded by a lossy material, the analysis may be simplified by employing the impedance boundary condi-