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Wiener-Hopf Modelling of Cylindrical Structures with Polygonal Cross Sections

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***Abstract*— This paper outlines a self-consistent spectral-domain methodology for the electromagnetic analysis of diffraction by cylindrical structures having polygonal cross-sections. The proposed methodology broadens the applicability of the Wiener-Hopf (WH) methodology beyond the canonical geometries traditionally considered in the literature. Both finite and infinitely extended polygonal geometries are described through Generalized Wiener-Hopf equations and then by their integral equation representations in the spectral domain, from which a systematic equivalent-network representation can be derived. The methodology allows the investigation of novel complex canonical electromagnetic problems, useful for applications involving guided and radiated structures, radar, and electromagnetic compatibility. In addition, the obtained solutions can serve as reliable reference results for assessing and validating fully numerical computational techniques.**

***Index Terms*— Electromagnetic diffraction, electromagnetic scattering, wave propagation, near field interactions, Wiener-Hopf method, spectral domain, Green's function, integral equations, regularization, Fredholm factorization.**

I. INTRODUCTION

SPECTRAL techniques are well-established tools for the analysis of wedge diffraction, including the Sommerfeld-Malyuzhinets (SM) method that takes origin from [1], the Kontorovich-Lebedev (KL) transform method [2], with excellent ongoing developments of the techniques till now in practical applications, and the Generalized Wiener-Hopf Technique (GWHT) [3-7].

Building on previous extensions of the Wiener-Hopf method to non-standard geometries and complex linear media [8-11], this work further develops the GWHT for diffraction by polygonal cylindrical scatterers made by arbitray linear media. Alternative techniques to obtain solutions for infinite polygonal profiles with impedance boundary conditions made immersed in isotropic media are proposed by SM researchers such as Bernard, Budaev, and Lyalinov [12-16].

II. THE PROPOSED METHODOLOGY

Assuming cylindrical configurations and time-harmonic electromagnetic fields, after decomposing the original configuration into canonical sub-regions, among which finite or unbounded rectangular and angular subdomains, Maxwell's equations are enforced in transverse form within each sub-region, following an approach analogous to that adopted for stratified media [17]. Cartesian coordinates are employed for rectangular regions, whereas oblique Cartesian coordinates are introduced for angular ones. Despite the different coordinate systems, both formulations lead to differential systems of similar structure [10].

Applying a spectral transform along one of the coordinates lying on the interface bounding each subdomain converts the governing equations into a first-order system of ordinary differential equations (ODEs) in the spectral domain. These equations are solved through the characteristic Green's-function technique, which expresses the solution as the sum of a homogeneous contribution and a particular integral. Both terms are constructed by exploiting the eigenvalues and eigenvectors of the ODE system matrix. Evaluating the resulting field representation at the two boundaries of each sub-region and projecting it onto the reciprocal eigenvector basis produces a set of spectral functional relations connecting the field quantities on opposite boundaries.

The same procedure can be applied to all subdomains. The resulting functional relations admit an equivalent network interpretation, providing a systematic formulation in which generalized voltages and currents correspond to spectral transforms of tangential electromagnetic-field components [18], [5-9].

In the general case, this formulation leads to Generalized Wiener-Hopf equations (GWHEs), whose plus and minus unknowns are analytic in distinct, although mutually related, complex spectral planes. For impenetrable wedge configurations embedded in isotropic media, only two such planes are involved, and an appropriate mapping transforms the GWHEs into classical Wiener-Hopf equations (CWHEs) [6-7].

For more complex structures or in problem with linear arbitrary media with multiple propagation constants, however, the number of interconnected complex planes is in general more than two. In this situation, the direct Fredholm factorization approach, based on Cauchy-type representations, can be used to reformulate the problem as spectral-domain integral equations defined on a single complex plane [11]. This unified representation enables Fredholm factorization [19] to be applied directly to general GWHEs, without first converting them into CWHEs. We recall that Fredholm factorization eliminates one kind of unknowns (either plus or minus) when applied to CWHEs by transforming the problem into Fredholm integral equations (FIEs) of second kind. The final formulation

consists of a system of FIEs whose unknowns are the tangential spectral field components of one WH type along the interfaces of the different sub-regions, all represented in the same complex plane and whose kernel contains the Cauchy type integral representation.

Once the FIE system is solved with simple numerical procedure due to fast convergence if the integral equations [20], approximate spectral-domain expressions for the relevant physical quantities are obtained. The corresponding electromagnetic fields can then be reconstructed through inverse spectral transformations, suitable asymptotic techniques and Kirchhoff-type relations when multiple complex domains are involved.

Figure 1 summarizes the main steps of the formulation and solution strategy described above.

Practical applications will be shown during the presentation at the conference.

III. Conclusions

This work outlines a unified and self-consistent generalized Wiener-Hopf methodology for the analysis of diffraction by structures with finite or infinite polygonal cross-sections, including configurations embedded in or composed of arbitrary linear media.

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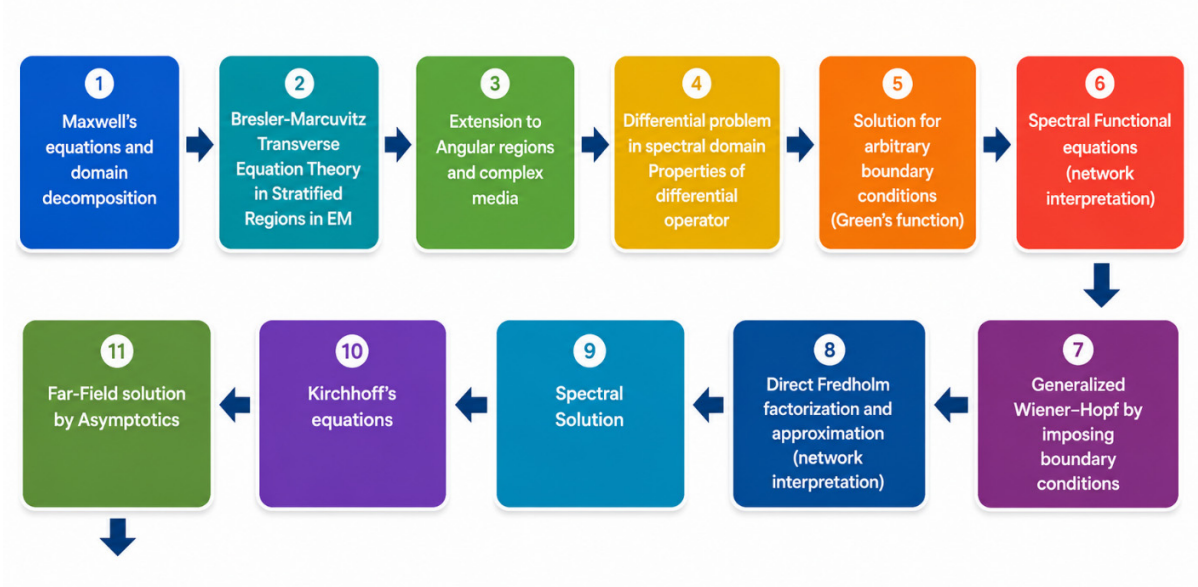


Fig. 1. Schematic overview of the methodology and solution procedures outlined in this work.