UNIFORM THEORY OF DIFFRACTION ANALYSIS FOR CONDUCTIVE STRIPS WITH CONSTANT AND TAPERED RESISTIVE LOADS

Mark C. Heaton and Philip J. Joseph
Department of Electrical and Computer Engineering
Air Force Institute of Technology
Wright-Patterson Air Force Base OH 45433

Randy L. Haupert
Department of Electrical Engineering
United States Air Force Academy CO 80840

I. INTRODUCTION

Resistive edge loading of perfectly conducting surfaces can reduce the backscattering sidelobe levels from those surfaces with little increase to the main backscattering lobe. A constant resistive load provides some control over the backscattering sidelobes, but a tapered resistive load provides significantly improved performance. Traditionally, these geometries have been analyzed using integral equations and physical optics (PO). The integral equation approach limits calculations to electrically small or mid-sized objects, while the physical optics approach has limited accuracy.

This paper explores the use of a uniform theory of diffraction (UTD) approach to the analysis of conductive strips with constant and tapered resistive loads. UTD diffraction coefficients are found for resistive edges and junctions using the geometrical optics (GO) reflection and transmission coefficients of resistive strips. The UTD radar echo-length predictions for edge-loaded strips agree well with moment method (MM) predictions and with measurements.

II. UTD DIFFRACTION COEFFICIENTS FOR RESISTIVE LOADS

Figure 1 illustrates the more general case of a conductor with tapered resistive loads. The taper is approximated by a sequence of constant resistive loads (typically 10 per wavelength), as shown. Diffraction coefficients are thus needed for resistive edges and junctions (the conductor/resistive junction is treated as a special case of the resistive junction).

The GO reflection and transmission coefficients for a resistive sheet are derived in [1] using the resistive boundary condition. These determine the GO field discontinuities associated with the resistive edge and junction geometries. The needed diffraction coefficients are found by scaling the UTD solution for the perfectly conducting case according to the GO field discontinuities (analogous to the approach of [2] for a dielectric half-plane), then empirically modifying the scaled result.
Figure 2 shows the model of the junction of two resistive half planes, or of the edge of a single resistive half plane if material B is ignored. The diffraction coefficient for resistive edge diffraction is given by

\[ D_h^{(1)} = (1 - T_s^h) D(\phi - \phi') + R_s^h D(\phi + \phi') \]  

while the diffraction coefficient for the resistive junction is given by

\[ D_h^{(2)} = \begin{cases} (R_s^h - R_B^h) D(\phi + \phi') & \text{if } (0 < \phi, \phi' < \pi) \text{ or } \pi < \phi, \phi' < 2\pi \text{ or } \pi < \phi < \phi' < 2\pi \\ (T_s^h - T_B^h) D(\phi - \phi') & \text{if } 0 < \phi < \pi < \phi' < 2\pi \end{cases} \]  

where

\[ R_s^h = \left\{ \begin{array}{ll} \frac{1 + 2\eta \cos \theta}{\cos \theta + 2\eta} & \text{for backscatter} \\ 1 & \text{for transmission} \end{array} \right\}, \quad T_s^h = 1 \pm R_s^h \]  

The subscripts s and h indicate soft and hard boundary conditions, respectively. R and T are the (modified) GO reflection and transmission coefficients, respectively; the superscripts A and B differentiate between materials A and B, when necessary. \( \eta \) is the sheet resistivity normalized to that of free space. Finally, \( \theta = \theta^s = \theta^h \) for backscatter while \( \theta = (\theta^s + \theta^h)/2 \) for bistatic scatter, where \( \theta^s \) and \( \theta^h \) are the angles made by the incident and scattered rays with respect to the surface normal. Note that the angles \( \phi, \phi' \) are measured from material A.

III. RESULTS

UTD calculations are compared with MM and PO calculations, and with experimental results. Figure 3 shows the E-polarized (electric field parallel to the edge of the strip) backscattering patterns from a 4A strip with the center 2A highly conductive and 1A resistive loads (\( \eta = 0.320 \pm 0.120 \)) on either edge. The resistivity value was determined through waveguide reflection measurements with a network analyzer. Calculations and measurements show very good agreement.

Figure 4 shows the E-polarized backscattering patterns from a 4A strip with an x^2 taper 1A from either edge. The MM and PO solutions differ from the UTD solution in the null and far-out sidelobe regions. Similar comparisons made for H-polarized scattering and bistatic scattering yield like results.

IV. CONCLUSIONS

This paper presents a UTD approach for calculating the scattering patterns of resistively edge-loaded conducting strips. The approach shows good agreement with method of moments calculations and with measurements.
References


Figure 1: Loaded strip and quantized model of resistive taper.

Figure 2: UTD geometry for resistive junction (also for resistive edge if material B is ignored).
Figure 3: E-polarized backscattering patterns of a 2λ conducting strip with 1λ resistive edge loads (η=0.320+j0.120). (measurement —, MM - - , UTD ...) 

Figure 4: E-polarized backscattering patterns of a 2λ conducting strip with 1λ resistive edge loads, x^2 taper. (MM —, UTD - - , PO ...)