POLITECNICO DI TORINO Repository ISTITUZIONALE

Surface integral equation method for sharp edge structures with junctions

Original

Surface integral equation method for sharp edge structures with junctions / Lombardi, Guido; Graglia, Roberto. - ELETTRONICO. - unico:(2013), pp. 1554-1556. (Intervento presentato al convegno the International Conference on Electromagnetics in Advanced Applications (ICEAA 2013) tenutosi a Torino, Italy nel September 9-13, 2013) [10.1109/ICEAA.2013.6632513].

Availability: This version is available at: 11583/2518683 since:

Publisher: IEEE - INST ELECTRICAL ELECTRONICS ENGINEERS INC

Published DOI:10.1109/ICEAA.2013.6632513

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)

Surface Integral Equation Method for Sharp Edge Structures with Junctions

G. Lombardi^{*}, R.D. Graglia[†]

Abstract — Complex scattering targets contain metallic structures with junctions and sharp edges that require a special procedure to be analyzed by the Method of Moments. Singular basis functions to mdel junctions with edge profile connected together are considered. At the Conference, we will show how to handle the different geometrical cases together with numerical results that validate the proposed method.

1 INTRODUCTION

In the past, several papers have studied the case of Surface Integral Equations (SIE) modeling surface junctions [1]-[4]. Those papers show how to implement Rao-Wilton-Glisson (RWG) basis functions [5] in Method of Moments (MoM) codes in presence of junctions.

On the other hand, 3D sharp-wedge structures are studied in [6]-[11] by defining singular vector functions for higher-order MoM applications [12].

The interest in junctions come from the observation of real life objects and it is recently demonstrated in [13] where junctions among triangles and wires have been studied.

In this summary we extend the modeling capability of higher-order interpolatory vector bases [12] and singular divergence-conforming vector bases [9] to handle PEC structures with thin joined surfaces in different practical cases. Complex targets exhibit two kinds of junctions: 1) sharp edge plates joined to sharp edge plates, 2) sharp edge plates joined to smooth surfaces.

At the conference, numerical simulation results will be shown to validate the proposed method.

2 SINGULAR DIVERGENCE-CONFORMING VECTOR BASES

Singular divergence-conforming vector bases able to model 3D sharp-wedge structures are described in [9] for triangular and quadrilateral meshes. These elements model the singular charge and current densities near edges and wedges [16], [17].

Without loss of generality let us focus the attention on triangular elements.

The singular elements attached to an edge profile are shown in Fig. 1. In the case of triangular discretization

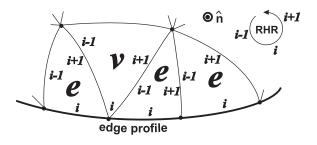


Figure 1: A face of a wedge meshed with edge singular triangles (e) and vertex singular triangles (v). From the reader's viewpoint the figure shows a right-hand-rule (RHR) numbering scheme for the edges i - 1, i, i + 1.

of the geometry, they are of two kinds: edge singular elements or vertex singular elements.

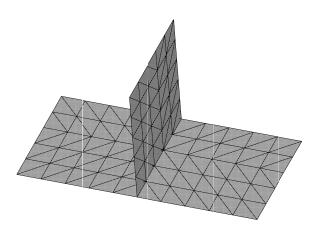
The vertex singular and the edge singular triangles have one vertex and one edge attached to the edgeprofile, respectively. For this property we consider the vertex singular triangles *element fillers* [9]. We recall that all the bases proposed in [12] and [9] are defined in a parent domain using the triangle area coordinates ξ coordinates; the physical modeling properties depend on this definition.

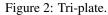
The set of the singular basis functions is complete to an arbitrarily high order s and it is added to the subset of the (high order) polynomial basis functions of order p commonly used in MoM applications [12].

From the reader's viewpoint, Fig. 1 shows a righthand-rule (RHR) numbering scheme for the edges i - 1, i, i + 1 and therefore we obtain an outward normal for the orientation of the element. The choices of RHR and thus of an outward normal are arbitrary but the reciprocal directions of them among elements is an important feature for connection of degrees of freedom in particular in surface junctions. We observe that this orientation property is trivial for simple meshed surfaces since the normals can be swapped to point in the same direction. On the contrary, in junction problems, we have more than two patches attached to a common edge, and each pair of elements might show different hand-rule according to their reciprocal orientation.

^{*}DET, Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy, e-mail: guido.lombardi@polito.it

[†]DET, Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy, e-mail: roberto.graglia@polito.it





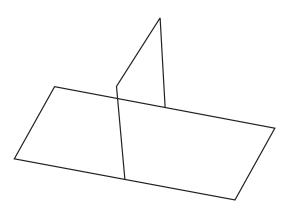


Figure 3: Tri-plate: the fields can be singular along the shown edge-border line.

3 JUNCTIONS IN JOINED ELECTRICALLY CONDUCTING PLATES

Let us consider joined electrically conducting plates. Fig. 2 shows the case of a tri-plate.

With reference to Fig. 2, we focus on the junction region that is constituted by singular elements located only in the region connected to the edge profile, see Fig. 3. Far from the edge profile the junction is modeled only by regular elements. To model the junction we use the Kirchhoff current law (KCL) formulated in terms of current density i.e. with MoM unknowns related to the basis functions. Because of the dependency relation, the KCL requires to discard one of the degrees of freedom. This procedure must be applied to the regular subset as well as to the singular subset of the bases for each interpolation point along the junction profile. Fig. 4 shows the surface junctions among three elements. We recall that the connection among the degrees of freedom (DOFs) is dependent on the relative orientation among the elements (RHR or or opposite to RHR). This feature will affect also the sign of DOFs in each el-

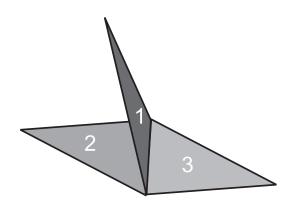


Figure 4: Three triangular patches connected together in a junction.

ement. This scheme is appropriate only for the test case referred to the first kind of junctions (see Section I). The second kind of junctions, i.e. sharp edge plates joined to (merged in) a smooth surface, requires some modeling tool that smooth the properties of singular functions of the edge structure when attached to a surface. Removing of singular dofs and adding new special bases near the attachment profile is considered. At the conference, numerical tests and tool based on singular quadrature [14],[15] will be presented.

4 CONCLUSION

The proposed method will permit to handle junctions of PEC patches with sharp edges. Extension to penetrable wedge structures [18] will be considered in future works.

Acknowledgment

This work was sponsored by the Italian Ministry of Education, University and Research (MIUR) under PRIN grant 20097JM7YR.

References

- J. Shin, A. W. Glisson, and A. A. Kishk, "Modeling of general surface junctions of composite objects in an SIE/MoM formulation," in *Proc. 2000 ACES Conf.*, pp. 683–690.
- [2] M. A. Carr, E. Topsakal, J. L.Volakis, and D. C. Ross, "Adaptive integral method applied to multilayer penetrable scatterers with junctions," in *IEEE Antennas Propagat. Soc. 2001 Int. Symp.*, vol. 4, pp. 858–861.
- [3] M. Carr, E. Topsakal, J.L. Volakis, "A procedure for modeling material junctions in 3-D surface inte-

gral equation approaches," *Antennas and Propagation, IEEE Transactions on*, vol.52, no.5, pp. 1374– 1378, May 2004.

- [4] P. YI-Oijala, M. Taskinen, and J. Sarvas, "Surface integral equation method for general composite metallic and dielectric structures with junctions," *Progress In Electromagnetics Research*, Vol. 52, 81–108, 2005.
- [5] S.M. Rao, D.R. Wilton, A.W. Glisson, "Electromagnetic scattering by surfaces of arbitrary shape," *IEEE Trans. Antennas Propagat.*, vol. AP-30, pp.409-418, May 1982.
- [6] R.D. Graglia, G. Lombardi, "Singular higher order complete vector bases for finite methods," *Antennas and Propagation, IEEE Transactions on*, vol.52, no.7, pp. 1672-1685, July 2004, doi: 10.1109/TAP.2004.831292
- [7] R.D. Graglia, G. Lombardi, "Vector functions for singular fields on curved triangular elements, truly defined in the parent space," *Antennas* and Propagation Society International Symposium, 2002 IEEE, vol.1, no., pp.62,65 vol.1, 2002,doi: 10.1109/APS.2002.1016251
- [8] R.D. Graglia, G. Lombardi, D.R. Wilton, W.A. Johnson, "Modeling edge singularities in the method of moments," *Antennas and Propagation Society International Symposium*, 2005 IEEE, vol.3A, pp. 56- 59 vol. 3A, 3-8 July 2005, doi: 10.1109/APS.2005.1552172
- [9] R.D. Graglia, G. Lombardi, "Singular Higher Order Divergence-Conforming Bases of Additive Kind and Moments Method Applications to 3D Sharp-Wedge Structures," *Antennas and Propagation*, *IEEE Transactions on*, vol.56, no.12, pp. 3768-3788, Dec. 2008, doi: 10.1109/TAP.2008.2007390
- [10] G. Lombardi, R.D. Graglia, "Singular higher order vector bases for wedge-structure MoM-models: The simple recipe," *Electromagnetics in Advanced Applications, 2009. ICEAA '09. International Conference on*, pp.1082-1085, 14-18 Sept. 2009, doi: 10.1109/ICEAA.2009.5297790
- [11] D. Erricolo, R.D. Graglia, G. Lombardi, T. Stoia, P.L.E. Uslenghi, "Benchmark targets for Computational Electromagnetics programs modeling structures with edges," *Antennas and Propagation Society International Symposium (AP-SURSI), 2010 IEEE*, pp.1-4, 11-17 July 2010, doi: 10.1109/APS.2010.5561957

- [12] R. D. Graglia, D. R.Wilton, and A. F. Peterson, "Higher order interpolatory vector bases for computational electromagnetics," *IEEE Trans. Antennas Propag., Special Issue on Adv.Numer. Tech. Electromagn.*, vol. 45, no. 3, pp. 329–342, Mar. 1997.
- [13] F. Vipiana, D.R. Wilton, "Optimized Numerical Evaluation of Singular and Near-Singular Potential Integrals Involving Junction Basis Functions," *Antennas and Propagation, IEEE Transactions on*, vol.59, no.1, pp.162–171, Jan. 2011.
- [14] R.D. Graglia, G. Lombardi, "Machine Precision Evaluation of Singular and Nearly Singular Potential Integrals by Use of Gauss Quadrature Formulas for Rational Functions," *Antennas and Propagation, IEEE Transactions on*, vol.56, no.4, pp.981,998, April 2008, doi: 10.1109/TAP.2008.919181
- [15] G. Lombardi, "Design of quadrature rules for Mntz and Mntz-logarithmic polynomials using monomial transformation," *International Journal for Numerical Methods in Engineering*, pp. 1687-1717, Vol. 80, n.13, 2009, doi: 10.1002/nme.2684
- [16] J. Meixner, "The behavior of electromagnetic fields at edges," *IEEE Trans. Antennas Propagat.*, vol. AP-20, no. 4, pp. 442-446, July 1972.
- [17] J. Van Bladel, Singular Electromagnetic Fields and Sources. Oxford, U. K.: Clarendon, 1991.
- [18] V. Daniele, G. Lombardi, "The Wiener-Hopf Solution of the Isotropic Penetrable Wedge Problem: Diffraction and Total Field," *IEEE Transactions on Antennas and Propagation*, vol.59, no.10, pp.3797-3818, Oct. 2011, doi: 10.1109/TAP.2011.2163780