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An Analysis of Cylindrical Posts of Arbitrary Convex Cross Sections Located in Waveguide Junctions with the Use of Field Matching Method

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Abstract—**A problem of electromagnetic wave scattering from cylindrical posts of arbitrary cross section located in waveguide junction is presented. The method of analysis is based on the direct field matching technique. Multimode scattering matrices of every section of waveguide junction are calculated and cascading procedure is utilized to investigate the whole structure. The results are verified by comparing them with those obtained from the mode matching method analysis as well as commercial software calculations.**

I. Introduction

The accurate analysis of electromagnetic wave scattering in waveguide junctions is one of the most important issues, which is crucial to the design of microwave devices. There are numerous analytical and numerical techniques, which allow to find the solution to the problem with different efficiency and effectiveness. The proper choice of the method is closely dependent on the complexity of the structure geometry. For structures with simple geometries, which can be described by constant coordinates of orthogonal systems, the analytical methods can be applied, which give accurate results with notably low numerical cost, if the correct basis functions are used. For complex shapes the analytical descriptions are often impossible, and the hybrid or space discretization techniques become handy. However, their accuracy strongly depends on the used mesh density, as a result their efficiency is low for complex structures.

Recently, the semi-analytic method for electromagnetic wave scattering from cylindrical objects with arbitrary convex cross section has been developed [1]. It allows to investigate both open and closed problems as the procedure is divided into two independent stages. In the first stage the sole scatterer is modeled in isolation from external stimulation. The result of this modeling is an multimode impedance matrix, which relates the total electric and magnetic fields (both incident and scattered) on the cylindrical artificial surface describing the object. Such description allows to match the object with any known external excitation, e.g. plane wave illuminating the object or waveguide fields in which the investigated object is located. The method is based on the direct field matching

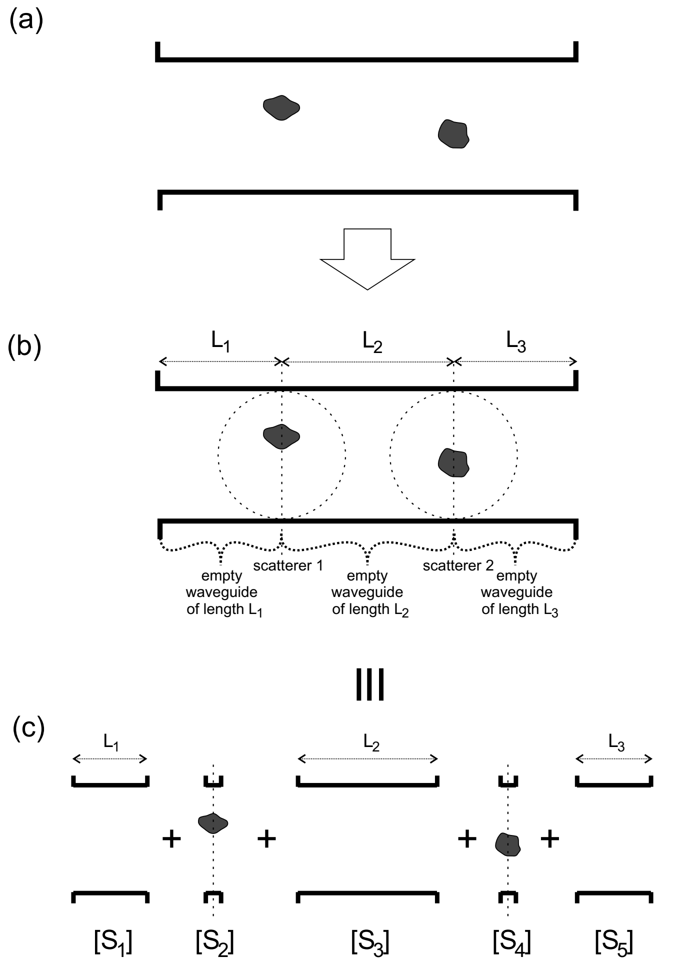

Fig. 1. Investigated structure. (a) Waveguide junction with two post of arbitrary geometry. (b) Decomposition of the structure into three waveguides of fixed lengths and two posts enclosed in cylindrical regions. (c) Cascade of five subsequent sections described by their multimode scattering matrices.

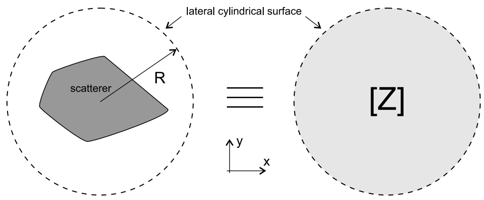

Fig. 2. The geometry of an scatterer and its impedance matrix representation.

technique involving the projection of the fields at the boundary on a fixed set of orthogonal basis functions, and the main idea of the analysis is based on decomposition of the obstacles' fields into Fourier-Bessel series with unknown coefficients. In order to analyze several objects, which are in close proximity with each other, the iterative scattering procedure [2] can be utilized. For objects located at greater distances their description by multimode scattering matrices and the utilization of the cascading formula is a better choice.

In this paper the field matching method [1] is investigated for the posts or arbitrary cross section located in a waveguide junction. Such structures find application in microwave filters [3], [4]. The investigated examples show the possibility of use of cascading formula for several sections of waveguide junctions and the accuracy of the approach. The results are verified by calculations performed with the use of mode matching method and commercial software based on finite element method.

II. Formulation of the problem

The investigated structure is composed of two cylindrical posts of arbitrary cross section located within the waveguide junction as depicted in Fig. 1(a). In order to calculate the scattering parameters of the entire junction with the use of the procedure described in [1] this structure needs to be decomposed into five separate segments: three waveguides of fixed lengths and two posts enclosed in cylindrical regions (see Fig. 1(b)). The procedure [1] allows to replace the object of arbitrary cross section by a circular cylinder described by its multimode impedance matrix $\mathbf{Z}$ as illustrated in Fig. 2.

In further stages of the procedure the circular cylinder is matched with the external excitation, i.e. the waveguide fields, on the cylinder surface (see Fig. 3), which allows to calculate the multimode scattering matrix of the waveguide section defined on the cylinder symmetry axis. The calculated matrices of subsequent sections (see Fig. 1(c)) allow to derive the scattering parameters of the entire waveguide junction with the use of simple cascading formula.

III. Results

The numerical tests were performed for the structure presented in Fig. 4. Two rectangular metal posts of dimensions 3 mm $\times$ 6 mm and full height were located inside a standard WR90 waveguide ($a = 22.86$ mm $b = 10.16$ mm).

The first tests concerned the obstacles located in the symmetry axis of the waveguide $h_1 = h_2 = a/2$ and four different distances d (15 mm, 12 mm, 9 mm, 6 mm). The results obtained

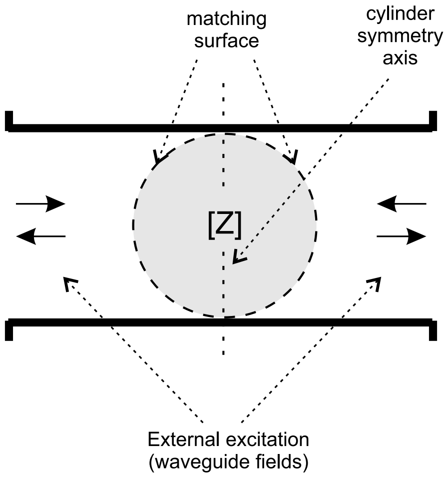

Fig. 3. Matching the external excitation with the cylindrical area described by matrix $\mathbf{Z}$.

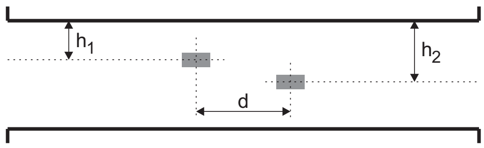

Fig. 4. The geometry of the analyzed structure: two rectangular metal posts of dimensions 3 mm $\times$6 mm (full height) located inside a standard WR90 waveguide.

from the field matching technique (FM) were compared with the ones from the mode matching method (MM) and from commercial software [5], [6] based on finite element method (FEM) - see Fig. 5 and Fig. 6. An excellent agreement was obtained even for the last case ($d = 6$ mm) when the posts are in contact.

Similar tests were performed for the obstacles located closer to the waveguide wall (parallel to its symmetry axis) $h_1 = h_2 = a/5$. Also in this case four different distances d (15 mm, 12 mm, 9 mm, 6 mm) were analyzed. The results obtained from all three methods are presented in Fig. 7 and Fig. 8. As can be observed the agreement is also very good for all distances d.

For the final analysis the obstacles were located in different distances from the wall $h_1 = a/5$ and $h_2 = 2a/3$. As in the previous cases the same distances d between the posts were assumed. The results obtained from the proposed technique are in excellent agreement with the alternative methods used for comparison - see Fig. 9 and Fig. 10.

The investigation of posts, which overlap with each other (for distances $d < 6$ mm for the considered cases) did not provide satisfactory agreement, which is a limitation of the method. This could results from the influence of higher modes, which are excited in the discontinuity. The maximum number of waveguide modes, which can be taken into account in the analysis is 20 (for the considered cases). Higher number of modes should not be used to avoid the ill conditioning of the problem, which can result in incorrect results.

The cascading procedure can be utilized to investigate filter-

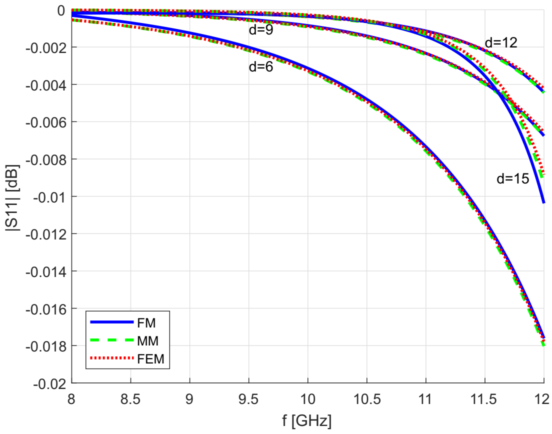

Fig. 5. Scattering parameters S_{11} for $h_1 = h_2 = a/2$ and different values of d (in millimeters).

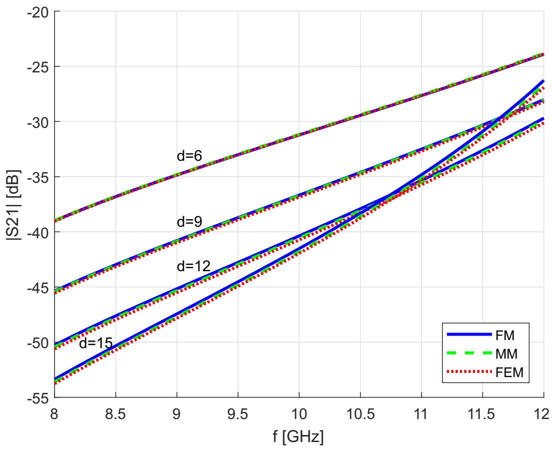

Fig. 6. Scattering parameters S_{21} for $h_1 = h_2 = a/2$ and different values of d (in millimeters).

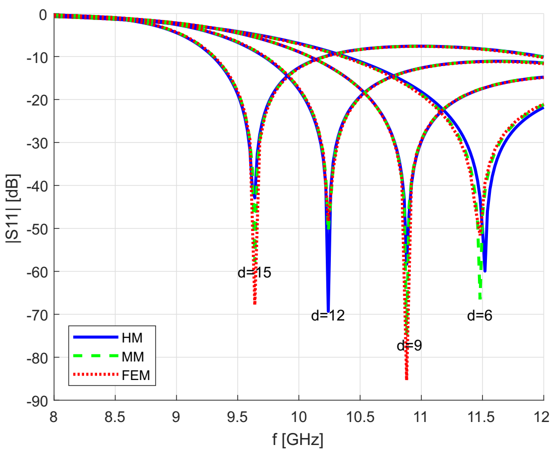

Fig. 7. Scattering parameters S_{11} for $h_1 = h_2 = a/5$ and different values of d (in millimeters).

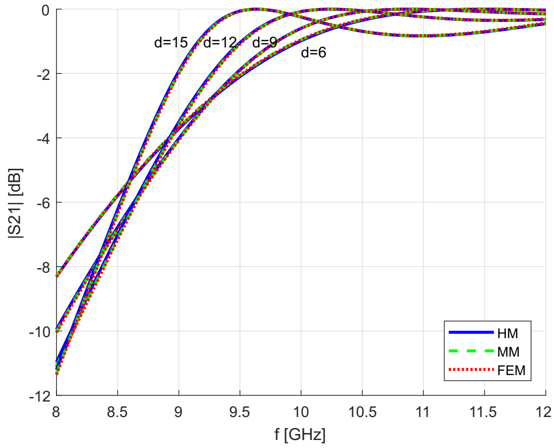

Fig. 8. Scattering parameters S_{21} for $h_1 = h_2 = a/5$ and different values of d (in millimeters).

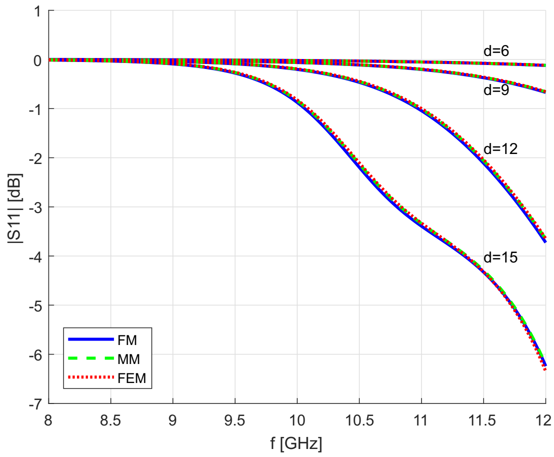

Fig. 9. Scattering parameters S_{11} for $h_1 = a/5$, $h_2 = 2a/3$ and different values of d (in millimeters).

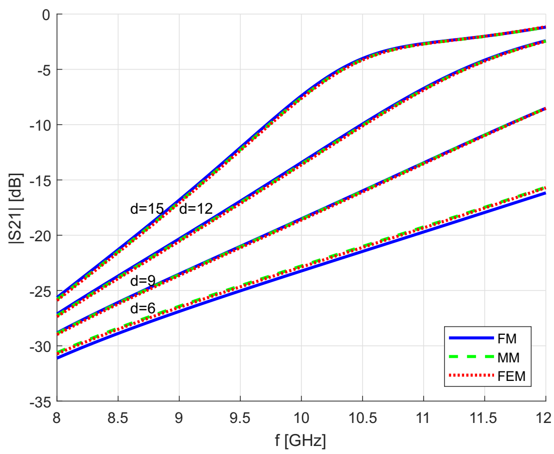

Fig. 10. Scattering parameters S_{21} for $h_1 = a/5$, $h_2 = 2a/3$ and different values of d (in millimeters).

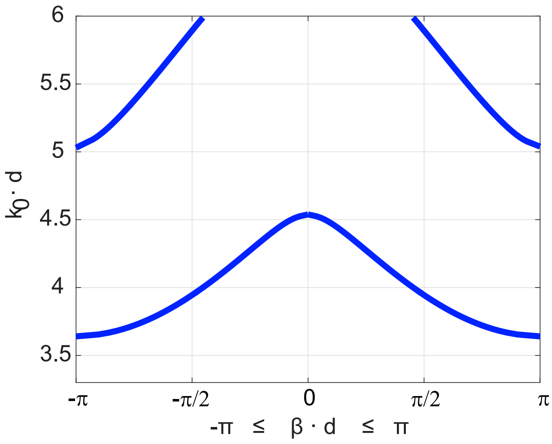

Fig. 11. $k_0 - \beta$ diagram for periodic structure composed sections of rectangular posts located at $h = a/5$ form the waveguide wall with period $d = 22$ mm.

ing periodic structures composed of posts periodically arranged in the waveguide junction. An example of such structure composed of rectangular posts, with dimensions from previous examples, was analysed. The posts are located at $h = a/5$ from the waveguide wall with the period (distance between the sections) $d = 22$ mm. The dispersion diagram [7] of the periodic structure is illustrated in Fig. 11, which represents the plot of propagation constant βd as a function of $k_0 d$ (k_0 is a wavenumber in vacuum). The results show passbands and stopbands formed in the periodic structure. The scattering parameters for the finite periodic structures containing five, ten and fifteen sections of rectangular posts were calculated and presented in Fig. 12. It can be seen that even for a small number of sections the bands shown in dispersion diagram are visible.

IV. Conclusion

The semi-analytic technique based on field matching methods was used to investigate scattering in waveguide from cylindrical posts with arbitrary convex cross section. The cascading formula was utilized to calculate scattering parameters of waveguide junction with multiple posts. The procedure was verified for different distances of objects and the correctness of the results was confirmed by the calculations of alternative methods. The methods limitation occurs for close proximity of the posts i.e. when the posts overlap in the junction.

Acknowledgment

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References

[1] R. Lech, P. Kowalczyk, A. Kusiek, "Scattering from a cylindrical object of arbitrary cross section with the use of field matching method," IEEE Trans. Antennas Propag., vol. 64. no. 11, pp. 4883–4887, Nov. 2016.

[2] M. Polewski, R. Lech, and J. Mazur, "Rigorous modal analysis of structures containing inhomogeneous dielectric cylinders," IEEE Trans. Microw. Theory Techn., vol. 52, no. 5, pp. 1508–1516, May 2004.

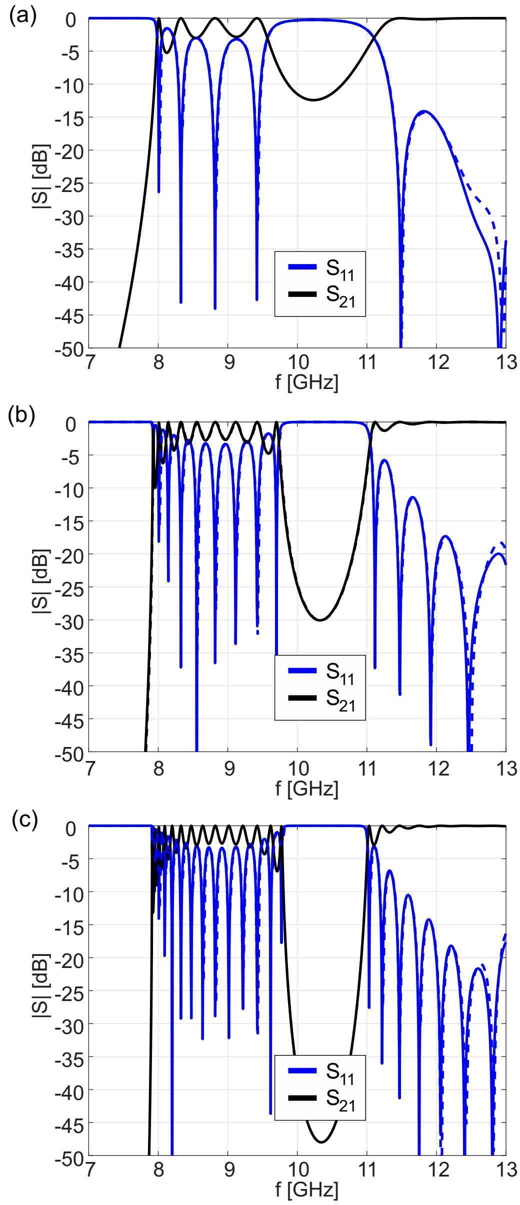

Fig. 12. Scattering parameters for finite periodic structure from Fig. 11 composed of (a) five, b ten and (c) fifteen sections. Solid line - this method; dashed line - FEM.

[3] R. Coccioli, A. Morini, G. Pelosi and T. Rozzi, "Design of tolerance-corrected filters employing half-cylinder posts," IEEE Trans. Microw. Theory Techn., vol. 46, no. 1, pp. 116–118, Jan 1998.

[4] R. Lech and J. Mazur, "Tunable waveguide filter with bow-tie metallic posts," IEE Proceedings - Microwaves, Antennas and Propagation, vol. 151, no. 2, pp. 156–160, Apr 2004.

[5] A. Lamecki, L. Balewski, M. Mrozowski, "An Efficient Framework For Fast Computer Aided Design of Microwave Circuits Based on the Higher-Order 3D Finite-Element Method," Radioengineering, Vol. 23, 2014.

[6] [Online]. Available: www.eminvent.com

[7] R. Lech, J. Mazur, "Propagation in Rectangular Waveguides Periodically Loaded with Cylindrical Posts," IEEE Microwave and Wireless Components Letters, Vol. 14, Issue: 4, April 2004, pp. 177–179.