STRONG FEM ANALYSIS OF THE MULTILAYERED ANISOTROPIC STRIPLINES

Žaklina J. Mančić[1], Vladimir V.Petrović[2]
Faculty of Electronic Engineering, Niš[1]
School of Electrical Engineering, Belgrade[2]

Abstract *–In this paper with the use of the strong FEM formulation, a quasistatic analysis of shielded striplines with multilayer anisotropic dielectric and conductive strip of the finite thickness was performed. For this structure it was determined how the parameters of the line depend on the position of the conductive strip. Also, a three-layer shielded microstrip line was analyzed and the influence of the order of layers on the line parameters was studied.*

1. INTRODUCTION

The Finite Element Method (FEM) is a well established numerical method in Electromagnetics [1,2]. However, practically all the work in this field is dedicated to the so-called weak FEM formulation. In recent years, the strong FEM formulation for the closed two-dimensional quasistatic problems was introduced and applied to several EM problems [3-6]. Strong basis functions are hierarchical and linearly independent functions [7]. Between the elements, continuity of both the (scalar) function value and its first derivative is provided. In this paper we will apply the Galerkin variant of the strong FEM formulation. The detailed description of the procedure is shown in [3-5]. A computer program was made to calculate quasistatic parameters of shielded (i.e., closed) structures with multiple conductors and layered isotropic, anisotropic and biizotropic dielectric [5,6]. Conductive strips can be of a finite or zero thickness. The symmetry can also be taken into account. In order to improve the quality of approximations the order of the approximation can be arbitrarily increased. Minimum order of strong basis functions is $n=3$.

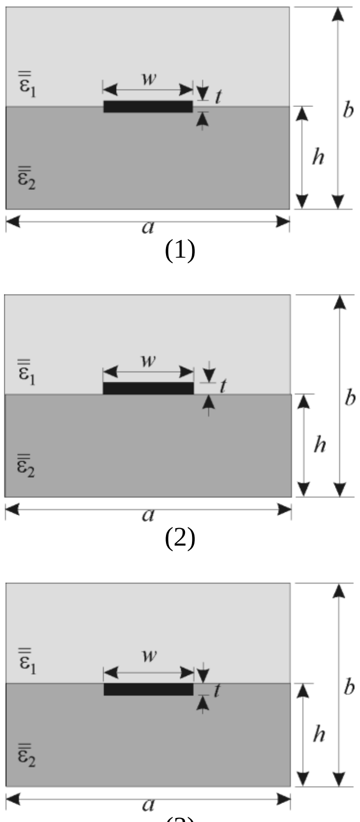
2. STRIPLINE IN THE MULTILAYERED ANISOTROPIC DIELECTRICS

First example is a shielded stripline with double-layer dielectric in Figure 1., $a/b=1, h/b=0.5, t/b=0.1$, $n=3$, analyzed the influence of the position on the conductive strips in relation to cross-cut to the surface of two dielectric quasistatic parameters. There were chosen three typical cases:

(1) when the conductive strip in the layer 1 (dielectric constant $\overline{\overline{\varepsilon}}_1$) of one and the bottom surface is lying on the surface of cross-cut,

(2) when the conductive strip is up to a half of the one and the other layer,

(3) when the conductive strip is in the layer 2 (dielectric constant $\overline{\overline{\varepsilon}}_2$) and with its upper surface is lying on the surface of the cross-cut. In the case of Figure 2. the change of the quasistatic parameters when the strip moves continuously from position (1) to position (3) in its top surface lying on the surface cross-cut was analyzed. The third case is the calculation of quasistatic parameters of a three-layer dielectric stripline in Figure 3., where the order is changed but not the thickness of the dielectric layers. When $\varepsilon_1=\varepsilon_0$, observed structure is a shielded microstrip line.



(1)

(2)

(3)

Figure 1. Striplines with double-layer anisotropic dielectric with three different strip positions with respect to the surface cross-cut.

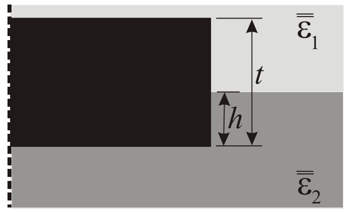


Figure 2. Conductive strip on the surface between layer.

3. NUMERICAL RESULTS

We first calculate parameters of the line with microstrip conductive strip of finite thickness on Sapphire, which is the relative dielectric constant $\varepsilon_r=\mathrm{diag}\left[9.4 \quad 11.6\right]$.

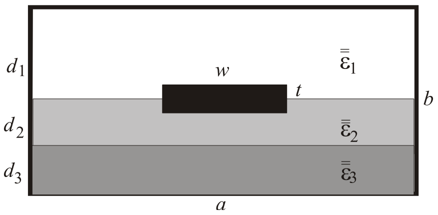


Figure 3. The three-layer dielectric stripline environment, $d_2 = d_3 = b/4$.

In Figure 4. and Figure 5. is shown the relative effective dielectric constant and characteristic impedance for all three cases as a function of w/a. It is noted that the position of the conductive strips is much more influential to the effective relative dielectric constant and is the greatest in the case of 3 and the characteristic impedance the smallest. Figure 4. shows that the curve bends upward or downward, depending on whether the conductive strips have a larger or smaller share in the Sapphire or in the air.

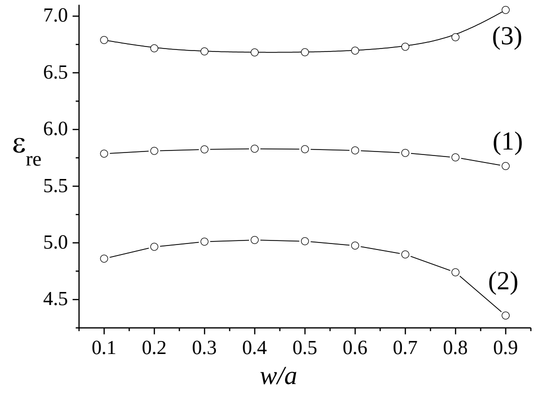


Figure 4. Variation of effective microstrip permittivity with w/a, for $\varepsilon_{r1} = 1$, $\bar{\bar{\varepsilon}}_{r2} = \mathrm{diag}[9.4 \quad 11.6]$.

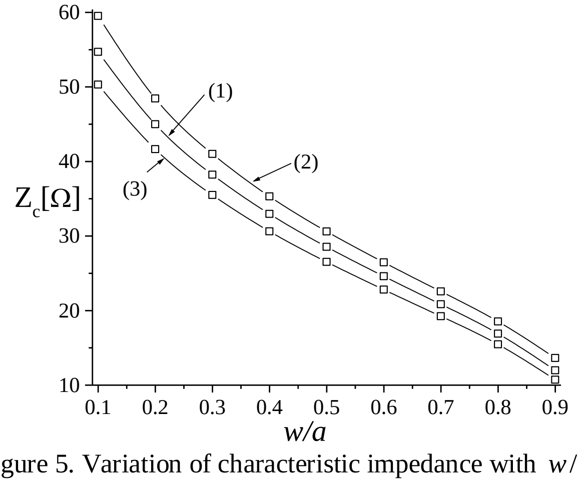


Figure 5. Variation of characteristic impedance with w/a for $\varepsilon_{r1} = 1$, $\bar{\bar{\varepsilon}}_{r2} = \mathrm{diag}[9.4 \quad 11.6]$.

Next, we calculate parameters of the line, with a conductive strip on the Sapphire-BN interface. Several results in Figure 6. are compared with results from CST program [8]. An excellent agreement is observed. In the third case, Figure 8. and Figure 9., there are the conductive strips of finite thickness at the interface two isotropic dielectrics - air and the dielectric with $\varepsilon_r = 4$. When the height h to which the conductive strips in the lower dielectric continually change, Figure 2., then the quasistatic parameters are changed by a linear law as shown in Figure 10. and Figure 11. and here are considered cases with a two-layer dielectric stripline.

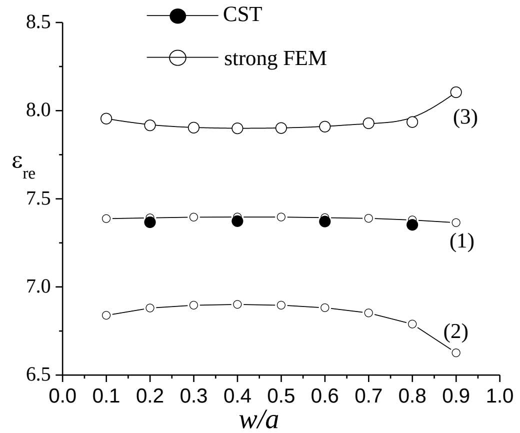


Figure 6. Variation of effective stripline permittivity with w/a, for $\bar{\bar{\varepsilon}}_{r1} = \mathrm{diag}[5.12 \quad 3.4]$, $\bar{\bar{\varepsilon}}_{r2} = \mathrm{diag}[9.4 \quad 11.6]$.

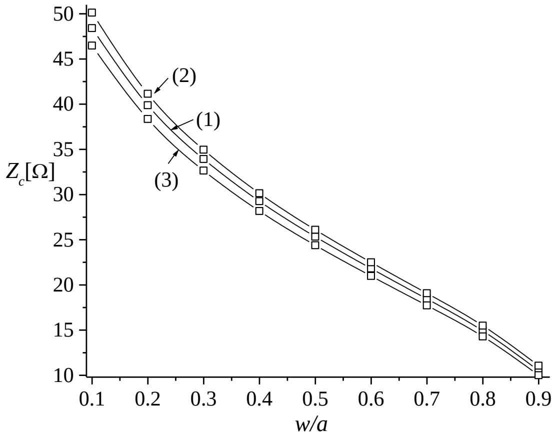


Figure 7. Variation of characteristic impedance with w/a for $\bar{\bar{\varepsilon}}_{r1} = \mathrm{diag}[5.12 \quad 3.4]$, $\bar{\bar{\varepsilon}}_{r2} = \mathrm{diag}[9.4 \quad 11.6]$.

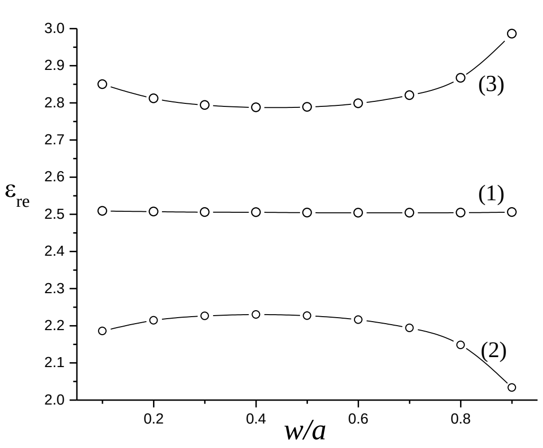


Figure 8. Variation of effective microstrip permittivity with w/a, for $\varepsilon_{r1} = 1$, $\varepsilon_{r2} = 4$.

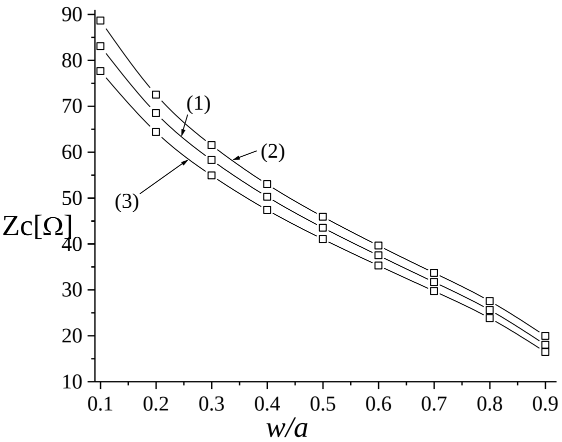


Figure 9. Variation of characteristic impedance with w/a for $\varepsilon_{r1}=1,\ \varepsilon_{r2}=4$.

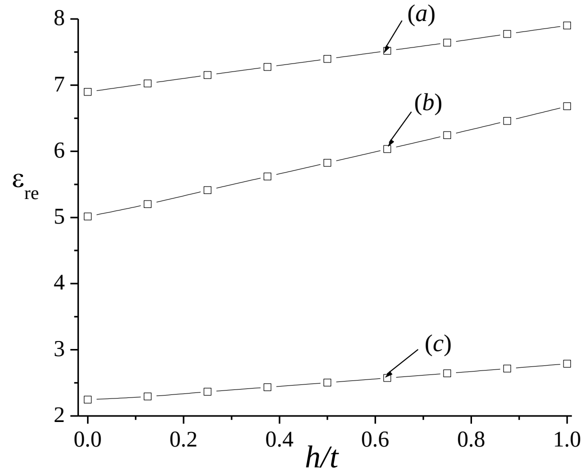


Figure 10. Variation of effective permittivity with h/t for (*a*) anisotropic two-layer dielectric (Sa- Bn), (*b*) Air-Sapphire, (*c*) Air–homogeneous dielectric, $\varepsilon_r=4$.

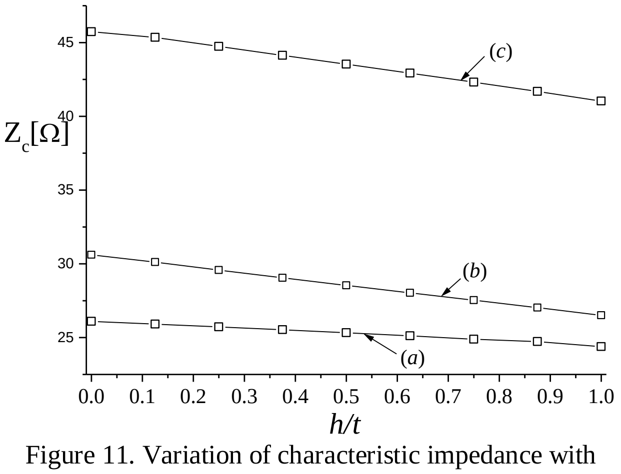


Figure 11. Variation of characteristic impedance with h/t for (*a*) anisotropic two-layer dielectric (Sa-Bn), (*b*)Air-Sa, (*c*) Air–homogeneous dielectric, $\varepsilon_r=4$.

Figure 12. and Figure 13. show the quasistatic parameters for microstrip with a three-layer dielectric anisotropic when the conductive strip is to the middle of the layer 1, Figure 3. The order of dielectric layers is changed. Figure 13. and Figure 14. show the characteristic parameters in the case when (1) the air layer 1, layer 2 is a Sapphire layer 3 which is BN. In case (2) the layer 1 and layer 3 is a air and layer 2 is a Sapphire. Case (2) shows a suspended stripline.

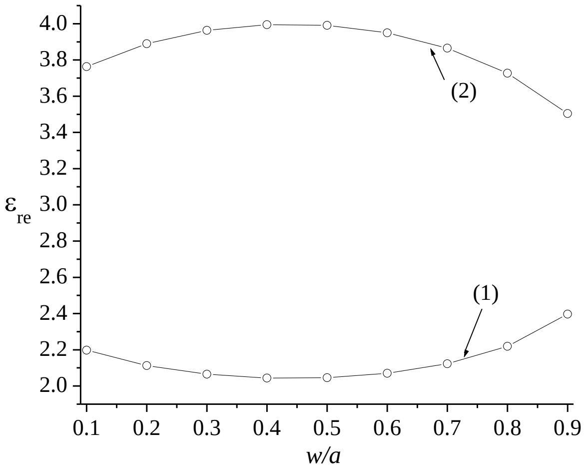


Figure12. Variation of effective microstrip permittivity with w/a for

$$(1)\ \varepsilon_{r1}=\varepsilon_{r3}=1,\overset{=}{\varepsilon}_{r2}=\mathrm{diag}[5.12\quad 3.4]$$

$$(2)\ \varepsilon_{r1}=1,\overset{=}{\varepsilon}_{r2}=\mathrm{diag}[5.12\quad 3.4],\ \overset{=}{\varepsilon}_{r3}=\mathrm{diag}[9.4\quad 11.6]$$

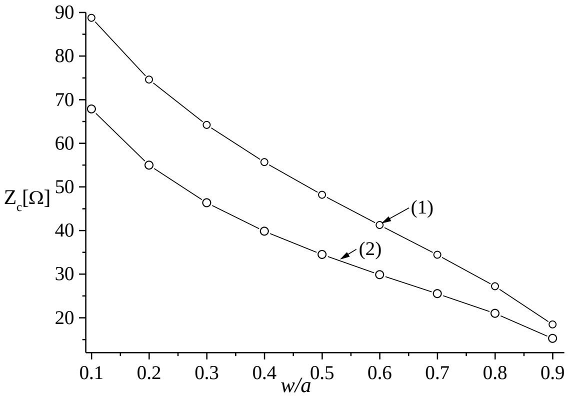


Figure 13. Variation of characteristic impedance with w/a for $(1)\ \varepsilon_{r1}=\varepsilon_{r3}=1,\overset{=}{\varepsilon}_{r2}=\mathrm{diag}[5.12\quad 3.4]$, $(2)\ \varepsilon_{r1}=1,\overset{=}{\varepsilon}_{r2}=\mathrm{diag}[5.12\quad 3.4],\overset{=}{\varepsilon}_{r3}=\mathrm{diag}[9.4\quad 11.6]$

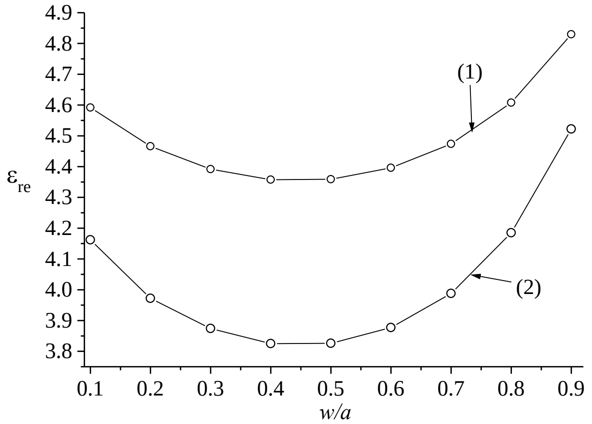


Figure 14. Effective microstrip permittivity for

$$(1)\ \varepsilon_{r1}=1,\overset{=}{\varepsilon}_{r2}=\mathrm{diag}[9.4\quad 11.6],\overset{=}{\varepsilon}_{r3}=\mathrm{diag}[5.12\quad 3.4]$$

$$(2)\ \varepsilon_{r1}=\varepsilon_{r3}=1,\overset{=}{\varepsilon}_{r2}=\mathrm{diag}[9.4\quad 11.6].$$

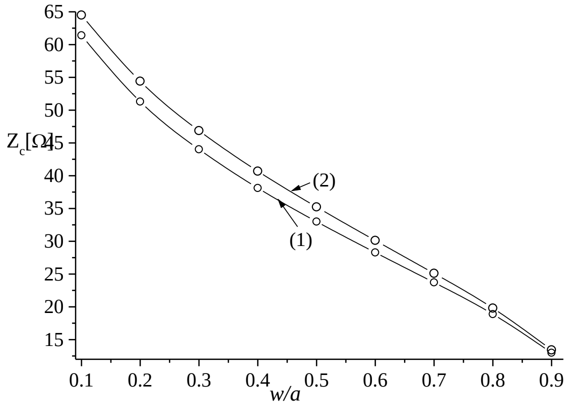


Figure 15. Characteristic impedance for

$$(1)\ \varepsilon_{r1}=1, \bar{\bar{\varepsilon}}_{r2}=\mathrm{diag}\begin{bmatrix}9.4 & 11.6\end{bmatrix}, \bar{\bar{\varepsilon}}_{r3}=\mathrm{diag}\begin{bmatrix}5.12 & 3.4\end{bmatrix}$$

$$(2)\ \varepsilon_{r1}=\varepsilon_{r3}=1, \bar{\bar{\varepsilon}}_{r2}=\mathrm{diag}\begin{bmatrix}9.4 & 11.6\end{bmatrix}.$$

4. CONCLUSION

In the first part of this paper, using the strong FEM formulation the analysis of shielded microstrip line with finite thickness of the conductive strips in multilayered anisotropic substrate was performed. The influence of the strip position is analyzed. In the second part of this paper, a three-layer dielectric microstrip is analyzed. The suspended stripline case was also considered. For a two-layer dielectric it was found that the line quasistatic parameters significantly depend on the order of layers. The second part of paper is also a demonstration of our computer program that is able to analyze multilayer anisotropic dielectric.

REFERENCES

[1] J. Jin, The Finite Element Method in Electromagnetics. New York: Wiley, 1993.

[2] P. P. Silvester, *Finite Elements for Electrical Engineers*. Cambridge University Press, 3rd Ed., 1996.

[3] Mančić, Ž. J. and Petrovic, V. V., "Strong and Weak FEM Formulations of Higher Order for Quasi-Static Analysis of Shielded Planar Transmission Lines", Microwave and Optical Technology Letters (MOTL), Vol. 53, No. 5, pp. 1114-1119, May 2011. (DOI 10.1002/mop.25917, online ISSN 1098-2760.

[4] Mančić, Ž. J. and Petrovic, V. V., "Strong FEM Formulation for Quasi-Static Analysis of Shielded striplines in Anisotropic Homogeneous Dielectric", Microwave and Optical Technology Letters (MOTL), Vol. 54, No. 4, pp. 1001-1006, April 2012. (DOI 10.1002/mop.26676.

[5] Petrovic, V. V and Mančić, Ž. J., "Strong FEM Formulation for Quasi-Static Analysis of Shielded Planar Transmission Lines in Anisotropic Media", ECCSC2010, Belgrade.

[6] Mančić, Ž. J. and Petrovic, V. V., "Strong FEM Calculation of the Influence of the Conductor's Position on Quasi-Static Parameters of the Shielded Stripline With Anisotropic Dielectric", Proc. of the ICEST 2011 conference, pp. 191-194, Niš, 2011. (ISBN 978-86-6125031-6).

[7] Petrovic, V. V and Popovic B. D., "Optimal FEM solutions of one-dimensional EM problems," *International Journal of Numerical Modelling: Electronic Networks, Devices and Field,* vol. 14, no. 1, pp. 49–68, Jan.-Feb. 2001.

[8] CST Studio Suite, version 2010, CST—Computer Simulation Technology AG, Darmstadt, 2010.

ACKNOWLEDGMENTS

The presented work is supported by the Serbian Ministry for Science under grant TR-32052.