Modeling of Strip Conductors Centered between Ground Planes

Sarhan M. Musa[1], Matthew N. O. Sadiku[2]

Abstract – **In this paper, we introduce the modeling of thin coplanar structures by finite element method (FEM). We present the quasi-static computational of capacitance coefficients and potential distribution for several configurations of coplanar strip conductors centered between ground planes. Excellent agreement was demonstrated by comparing our results with integral equation method, conformal mapping method and variational technique.**

Keyword s– **Coplanar conductor, capacitance, finite element method.**

I. Introduction

Computation of capacitance of multistrip transmission lines is one of the essential parameters in designing of microwave circuits. Therefore, the improvement of accurate and efficient computational method to analyze the modeling of multistrip transmission lines structure becomes an important area of interest.

Previous attempts at the problem include using integral equation method [1], variational technique [2], conformal mapping method [3], analytical method [4], Fourier transform method [5], and spectral domain method [6]. We illustrate that our method using FEM is suitable and effective as other methods for modeling of strip conductors centered between ground planes.

In this work, we design single, two, three, four and five strip conductor systems between two parallel ground planes using finite element method (FEM) with COMSOL multiphysics package to calculate the capacitance and the potential distribution of the configurations. We use finite-element method (FEM) in modeling the transmission lines structure, because FEM is especially suitable for the computation of electric and electromagnetic fields in strongly inhomogeneous media. Also, it has high computation accuracy and fast computation speed.

II. Discussion and Results

Using COMSOL for modeling and simulation of the strip conductors centered between ground planes involves taking the following steps. We develop the geometry of the line and take the difference between the conductor and dielectric material. We select the relative permittivity as 1. For the boundary, we select the outer conductor as ground and inner conductor as port. We generate the finite element mesh, and then solve for the potential. As postprocessing, we select Point Evaluation and choose capacitance element to find the capacitance per unit length of the line.

In any electromagnetic field analysis the placement of far-field boundary is an important concern, especially when dealing with open solution regions. It is necessary to take into account that the natural boundary of a line at infinity and the presence of remote objects and their potential influence on the field shape [7]. In all our simulations, the coplanar structures is surrounded by a w X h shield, where w is the width and h is the thickness of the shield. In all models, the strip lines are equally spaced with 0.01 mm thickness centered between the ground planes with each strip having width 0.2 mm and with a strip-to-strip spacing distance of 0.1 mm. We use the permittivity ε_r = 1 for all models.

Figure 1 shows the cross section for single conducting strip between two ground planes.

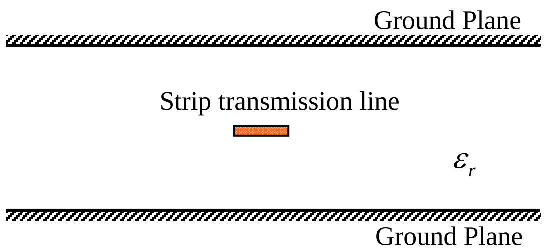

Fig. 1. Cross-section of single strip conductor between two ground planes.

The geometry is enclosed by a 2 X 1 mm shield. Fig. 2 shows the potential distribution from (0, 0) to (2, 1) mm.

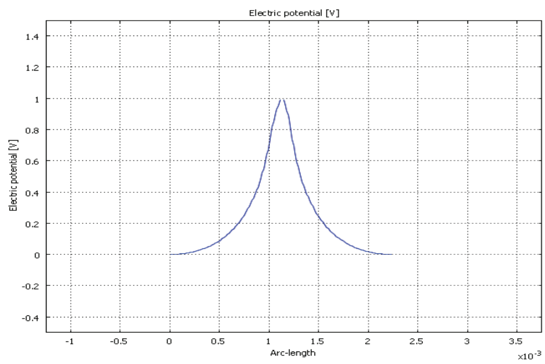

Fig. 2. Potential distribution of single strip conductor between two ground planes.along the line from (0, 0) to (2mm, 1mm).

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Table I shows the finite element results for the capacitance of single strip conductor between two ground planes. The results in Table I are compared with the work of previous investigations. They are in good agreement

TABLE I
VALUES OF THE CAPACITANCE (IN F/M) COEFFICIENTS FOR SINGLE STRIP CONDUCTOR BETWEEN TWO GOUND PLANES

Capacitance matrix ($C_{ij} = C_{ji}$)	Reference [1]	Reference [2]	Our Work
C_{11}/ε_o	2.4618	2.4617	2.5745

Figure 3 shows the cross section for two-strip conductors between two ground planes.

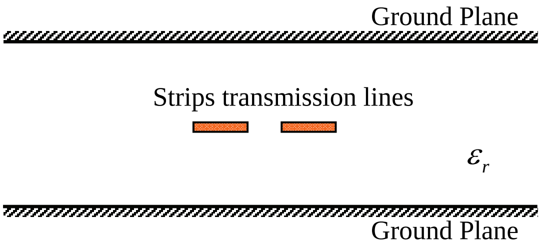

Fig. 3. Cross-section of two- strip conductors between two ground planes.

The geometry is enclosed by a 4 X 1 mm shield. Fig. 4 shows the potential distribution along a line from (0, 0) to (4, 1) mm.

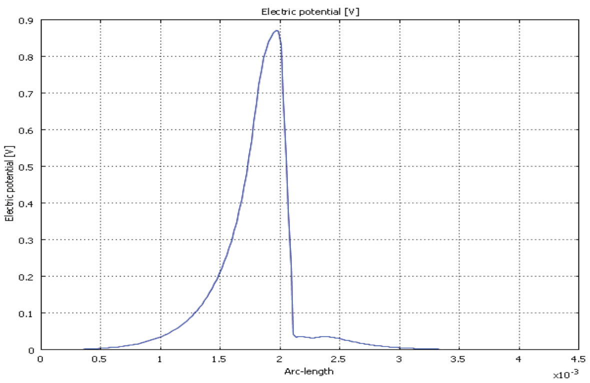

Fig. 4. Potential distribution of two-strip conductors between two ground planes along a line from (0, 0) to (4mm, 1mm).

Table II shows the finite element results for the capacitance of two-strip conductors between two ground planes. The results in Table II are compared with the work of previous investigations. They are in good agreement.

TABLE II
VALUES OF THE CAPACITANCE (IN F/M) COEFFICIENTS FOR TWO-STRIP CONDUCTORS BETWEEN TWO GOUND PLANES

Capacitance matrix ($C_{ij} = C_{ji}$)	Reference [1]	Reference [2]	Our Work
$C_{11}/\varepsilon_o = C_{22}/\varepsilon_o$	2.8888	2.8878	3.0868
$C_{12}/\varepsilon_o = C_{21}/\varepsilon_o$	-1.0379	-1.0372	-1.1684

Figure 5 shows the cross section for three conducting strips between two ground planes.

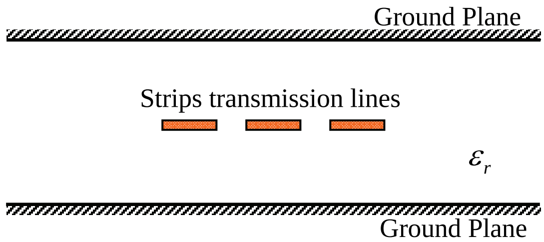

Fig. 5. Cross-section of three- strip conductors between two ground planes.

The geometry is enclosed by a 6 X 1 mm shield. Fig. 6 shows the potential distribution along a line from (0, 0) to (6, 1) mm.

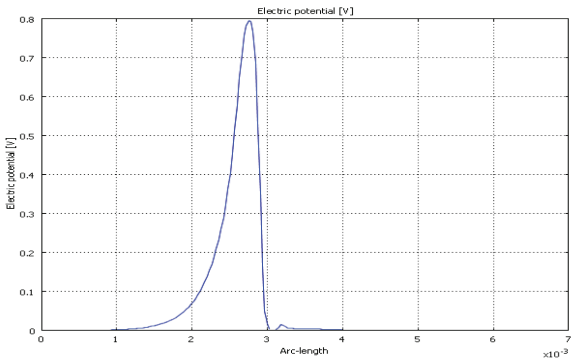

Fig. 6. Potential distribution of three- strip conductors between two ground planes along a line from (0, 0) to (6mm, 1mm).

Table III shows the finite element results for the capacitance of three conducting strips between two ground planes. The results in Table III are compared with the work of previous investigations. They are in good agreement.

Figure 7 shows the cross section for four conducting strips between two ground planes.

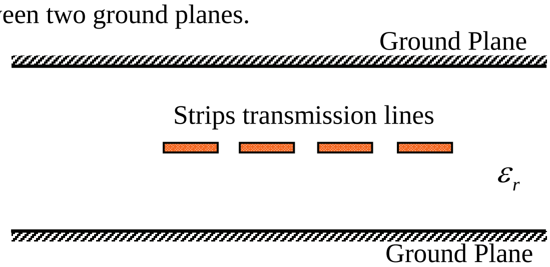

Fig. 7. Cross-section of four- strip conductors between two ground planes.

TABLE III

VALUES OF THE CAPACITANCE (IN F/M) COEFFICIENTS FOR THREE-STRIP CONDUCTORS BETWEEN TWO GOUND PLANES

Capacitance matrix ($C_{ij} = C_{ji}$)	Reference [1]	Reference [2]	Our Work
$C_{11}/\varepsilon_o = C_{33}/\varepsilon_o$	2.8914	2.8903	3.082
$C_{12}/\varepsilon_o = C_{21}/\varepsilon_o = C_{23}/\varepsilon_o = C_{32}/\varepsilon_o$	-1.0064	-1.0060	-1.1352
$C_{13}/\varepsilon_o = C_{31}/\varepsilon_o$	-0.0841	-0.0834	-0.0844
C_{22}/ε_o	3.2915	3.2908	3.566

TABLE IV

VALUES OF THE CAPACITANCE (IN F/M) COEFFICIENTS FOR FOUR-STRIP CONDUCTORS BETWEEN TWO GOUND PLANES

Capacitance matrix ($C_{ij} = C_{ji}$)	Reference [1]	Reference [2]	Our Work
$C_{11}/\varepsilon_o = C_{44}/\varepsilon_o$	2.8914	2.8903	3.0820
$C_{12}/\varepsilon_o = C_{21}/\varepsilon_o = C_{34}/\varepsilon_o = C_{43}/\varepsilon_o$	-1.0061	-1.0057	-1.1347
$C_{23}/\varepsilon_o = C_{32}/\varepsilon_o$	-0.9767	-0.9766	-1.1037
$C_{22}/\varepsilon_o = C_{33}/\varepsilon_o$	3.2938	3.2921	3.5679
$C_{13}/\varepsilon_o = C_{31}/\varepsilon_o = C_{24}/\varepsilon_o = C_{42}/\varepsilon_o$	-0.0795	-0.0788	-0.0797
$C_{14}/\varepsilon_o = C_{41}/\varepsilon_o$	-0.0125	-0.0124	-0.0121

TABLE V

VALUES OF THE CAPACITANCE (IN F/M) COEFFICIENTS FOR FIVE-STRIP CONDUCTORS BETWEEN TWO GOUND PLANES

Capacitance matrix ($C_{ij} = C_{ji}$)	Reference [1]	Reference [2]	Reference [3]	Our Work
$C_{11}/\varepsilon_o = C_{55}/\varepsilon_o$	2.8914	2.8904	2.8914	3.0822
$C_{22}/\varepsilon_o = C_{44}/\varepsilon_o$	3.2939	3.2921	3.2939	3.5682
C_{33}/ε_o	3.2961	3.2943	3.2961	3.5701
$C_{12}/\varepsilon_o = C_{21}/\varepsilon_o = C_{45}/\varepsilon_o = C_{54}/\varepsilon_o$	-1.0061	-1.0057	-1.0061	-1.1349
$C_{23}/\varepsilon_o = C_{32}/\varepsilon_o = C_{34}/\varepsilon_o = C_{43}/\varepsilon_o$	-0.9764	-0.9763	0.9764	-1.1033
$C_{13}/\varepsilon_o = C_{31}/\varepsilon_o = C_{35}/\varepsilon_o = C_{53}/\varepsilon_o$	-0.0794	-0.0789	-0.0794	-0.0796
$C_{24}/\varepsilon_o = C_{42}/\varepsilon_o$	-0.0751	-0.0745	-0.0751	-0.0752
$C_{14}/\varepsilon_o = C_{41}/\varepsilon_o = C_{25}/\varepsilon_o = C_{52}/\varepsilon_o$	-0.0117	-0.0117	0.0117	-0.0114
$C_{15}/\varepsilon_o = C_{51}/\varepsilon_o$	-0.0020	-0.0020	-0.0020	-0.0019

The geometry is enclosed by a 8 X 1 mm shield. Fig. 8 shows the potential distribution along a line from (0, 0) to (8, 1) mm.

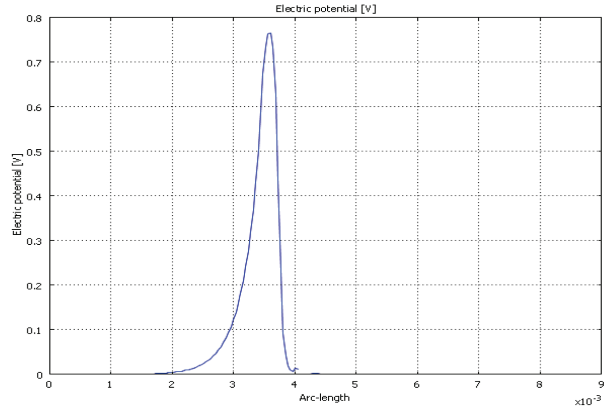

Fig. 8. Potential distribution of four- strip conductors between two ground planes along a line from (0, 0) to (8mm, 1mm).

Table IV shows the finite element results for the capacitance of four-strip conductors between two ground planes. The results in Table IV are compared with the work of previous investigations. They are in good agreement.

Figure 9 shows the cross section for five conducting strips between two ground planes.

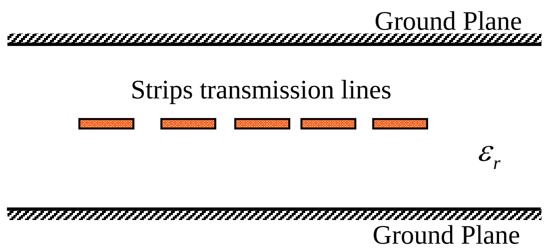

Fig. 9. Cross-section of five- strip conductors between two ground planes.

The geometry is enclosed by a 10 X 1 mm shield. Fig.10 shows the potential distribution along a line from (0, 0) to (10, 1) mm.

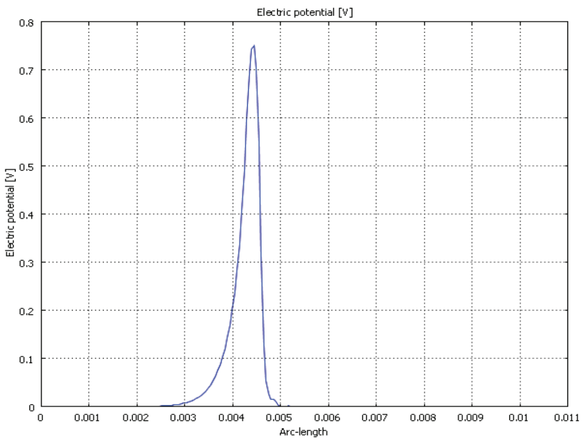

Fig. 10. Potential distribution of five- strip conductors between two ground planes along a line from (0, 0) to (10mm, 1mm).

Table V shows the finite element results for the capacitance of five-strip conductors between two ground planes. The results in Table V are compared with the work of previous investigations. They are in good agreement.

Figs. 2, 4, 6, 8, and 10 present the potential distributions of single, two, three, four and five strip conductors between two parallel ground planes, respectively. These potentials are not mentioned or studied by other researchers; hence they can not be verified with other approaches. The potential distributions show how the potential become smaller when we get farther from the selected input port/conductor.

Tables I, II, III, IV, and V present the comparison of the computation of capacitance matrix of single, two, three, four and five strip conductors between two parallel ground planes, respectively. These tables can help the improvement of accurate and efficient computational method of capacitance matrix in designing of microwave circuits. All methods considered and referred to in this paper are numerical solutions and there is no exact, analytical solution to compare with.

III. Conclusion

In this paper, we have presented modeling of coplanar structures in homogeneous dielectric medium between two parallel ground planes. We computed the capacitance matrix and identified the potential distribution of single-, two-, three-, four- and five-strip conductor systems between two ground planes. The results obtained efficiently using finite element method (FEM) for the capacitance agree well with those found in the literature.

References

[1] D. W. Kammler,"Calculation of characteristic admittances and coupling coefficients for strip transmission lines", IEEE Transmissions on Microwave Theory and Techniques, Vol. 16, No. 11, November 1968, pp. 925-937.

[2] F. Medina and M. Horno," Capacitance and inductance matrices for multistrip structures in multilayered anisotropic", IEEE Transmissions on Microwave Theory and Techniques, Vol. 35, No. 11, November 1987, pp. 1002-1008.

[3] D. Homentcovschi, A. Manolescu, A. M. Manolescu and L. Kreindler, "An analytical solution for the coupled stripline-like microstrip line problem", IEEE Transmissions on Microwave Theory and Techniques, Vol. 36, No. 6, June 1988, pp. 1002-1007.

[4] M. K. Amirhosseini and A. Cheldavi," Time domain analysis of circulant symmetric coupled transmission lines", IEE Proceedings of Microwaves, Antennas and Propagation, Vol. 150, No.5, October 2003, pp. 325-31.

[5] S. Voranantakul, J. L. Prince and P. Hsu," Crosstalk analysis for high-speed pulse propagation in lossy electrical interconnections", IEEE Transactions on Components, Packaging, and Manufacturing Technology, Vol. 16, No. 1, February 1993, pp. 127-136.

[6] R. Schwindt and C. Nguyen, "Spectral domain analysis of three symmetric coupled lines and application to a new bandpass filter", IEEE Transmissions on Microwave Theory and Techniques, Vol. 42, No. 7, July 1994, pp. 1183-1189.

[7] Y. R. Crutzen, G. Molinari, and G. Rubinacci (eds.), Industrial application of electromagnetic computer codes. Norwell, MA: Kluwer Academic Publishers, 1990, p. 5.