

GENESYS-Compatible Models for Two-Dimensional Circuit Analysis in Frequency Domain

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Abstract – In this paper new multi-port models convenient for two-dimensional (2D) electrical circuit analysis are suggested. These models are implemented in the known program GENESYS. Microwave transmission lines can be efficiently analyzed by the suggested procedure. A microstrip lowpass filter is analyzed. The results obtained by 2D analysis are compared with the ones obtained by 1D analysis and 3D electromagnetic analysis.

I. Introduction

Electrical circuits containing microwave lines can be modelled by one-dimensional (1D) circuits composed of transmission lines. Analysis of such circuits in frequency domain is simple and very fast. Sometimes, the results of analysis differ very much from the desired exact results. This is happening due to appearance of discontinuities that are results of different physical dimensions and shapes of line. Because of that, more exact, but also more complex methods, based on two-dimensional (2D) and three-dimensional (3D) approaches to the analysis of circuits containing microwave lines, are used. For that purpose, a number of approaches is developed, and some of them are given in the papers [1-7]. Also, a number of software packages is developed, such as ADS [9], GENESYS [10-11], FAMIL [3-4], and etc.

DC and frequency analyses of complex circuits can be done with software package GENESYS [10-12]. It unites many simulators, such as synthesis of active and passive filters, fast linear 1D analysis of active and passive circuits, 3D electromagnetic analysis, nonlinear harmonic analysis, spectral analysis of systems, drawing of circuit schemes and layouts, and etc. Its platform is projected in the manner that different modules can work together, it can analyse many different circuits at the same time, and it can easily count different output parameters and clearly show them on different graphics.

An approach to the analysis of 2D circuits in the software package GENESYS, based on new models for multi-port networks, is proposed in this paper. Existent models of multi-port networks are here modified, so they can be simple and uncomplicated used for analysis of 2D electrical circuits. The approach has general character, and the verification is done on microstrip lowpass filter which is modelled with 2D complex circuit composed of lumped elements. The same filter is then analysed as 1D circuit with transmission lines, and 3D electromagnetic analysis is also done.

II. New Multi-Port Models

A 2D electrical circuit with lumped LC elements, which is very suitable for modelling of microwave transmission lines [1-4], is shown in Fig.1. In the case of uniform microwave lines, complex network consists of large number of simple networks, as shown in Fig.2a), which inductances and capacitances can be obtained by relations given in the reference [3]

$$L_1 = L_2 = \frac{Z_c d \sqrt{\epsilon_r^{eff}}}{2c_0} \cdot \frac{nu}{nk}, \quad (1)$$

$$L_3 = L_4 = \frac{Z_c w^2 \sqrt{\epsilon_r^{eff}}}{2c_0 d} \cdot \frac{nk}{nu}, \quad (2)$$

$$C_1 = \frac{Z_c \sqrt{\epsilon_r^{eff}}}{c_0 Z_c} \cdot \frac{1}{nk \times nu}. \quad (3)$$

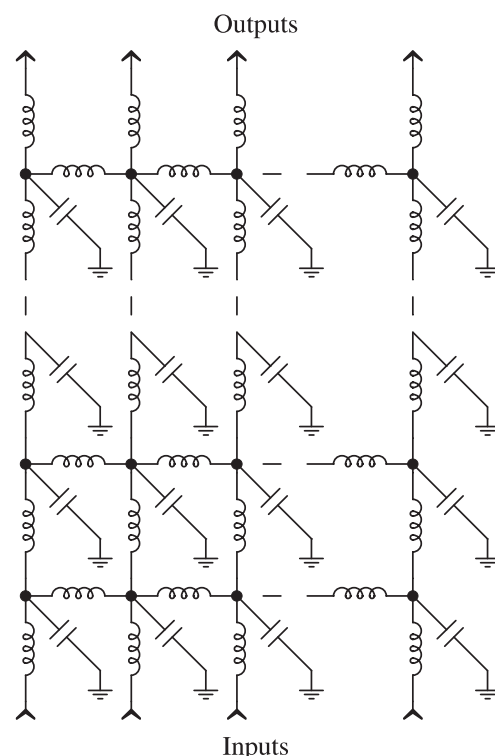


Fig. 1. A 2D electrical network.

The parameters in the previously given relations are: d - length and w - width of line, nu - number of 2D network inputs, nk - number of cascade-connected networks, c_0 - speed of the light in vacuum, Z_c - line characteristic impedance

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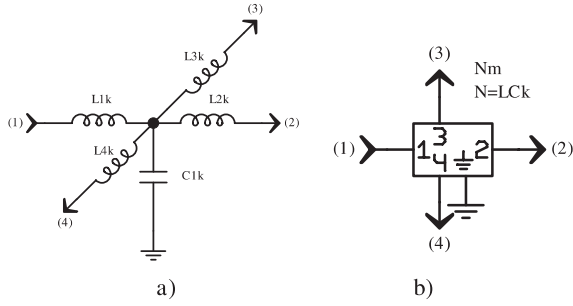


Fig. 2. a) LC node and b) its equivalent 4-port network.

and ε_r^{eff} - effective dielectric constant. Formulas for and are known and given in the paper [8]. In the program *GENESYS*, one part of the analysed network can be replaced with multi-port network. For example, a part of LC network shown in Fig. 1, with 5 inputs and 5 outputs, can be replaced with network which symbol is given in the Fig. 3a). Now, whole network can be represented by a large number of such constituent networks, which are connected between them. How all ports in this symbol are putted at one side, connection of constituent networks is very difficult and whole network is very confused. In order to simplify replacement of 2D electrical network, which is very complex in its nature, with equivalent multi-port networks, new models are suggested. New symbols for the case of network with 10 ports are given in Fig. 3b) and c). Network shown in Fig. 3c) is used only in the case of cascade connection, ports 1-5 and 6-10. Network shown in Fig. 3b) is used for cascade connection, ports 1-4 and 6-8, and for side connection, ports 9 and 10. Now, networks of such shapes can be connected very easily. The resulting equivalent network has simple shape; it is also very clear and easy for controlling.

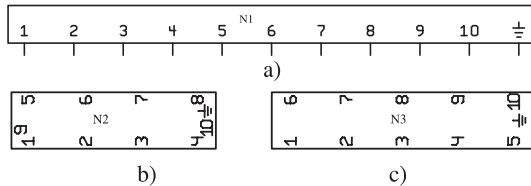


Fig. 3. a) Original symbol of 10-port network, b) and c) new equivalent symbols.

III. Forming of Networks by Using New Models

Procedure of forming equivalent network by using new models of multi-port networks will be explained on an example of microstrip lowpass filter, which layout is shown in Fig. 4. It is a 7th order filter with a cutoff frequency of 900 MHz and 50 Ohm terminations, which is taken from the reference [10] and analysed in the paper [4]. The filter parameters are: $d_1 = d_9 = 2540\mu\text{m}$, $d_2 = d_8 = 13385.9\mu\text{m}$, $d_3 = d_5 = d_7 = 2873.93\mu\text{m}$, $d_4 = d_6 = 30022.8\mu\text{m}$, $w_1 = w_9 = 932.59\mu\text{m}$, $w_2 = w_4 = w_6 = w_8 = 465.19\mu\text{m}$, $w_3 = w_7 = 15679.79\mu\text{m}$, $w_5 = 18016.59\mu\text{m}$, $\varepsilon_r=6.0$, $h=635$ and $t=18.03\mu\text{m}$. Chosen segmentation for the lines 1 and 9 is $nu=4$ and $nk=8$, for the lines 2 and 8 is $nu=2$ and

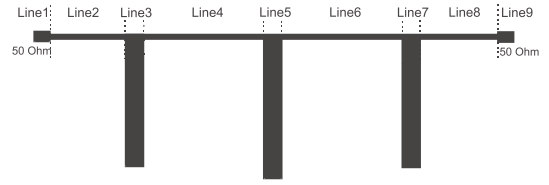


Fig. 4. A layout of microstrip lowpass filter.

$nk=40$, for the lines 4 and 6 is $nu=2$ and $nk=100$, for the lines 3 and 7 is $nu=45$ and $nk=9$, and for the line 5 segmentation is $nu=54$ and $nk=9$.

At the beginning, numerical values of the physical dimensions of microstrip filter, data about substrate and data about a number of line segments in transverse direction, nu , and in longitudinal direction, nk , are assigned in the *Equations* option by using program statements which are accessible in the program *GENESYS*. Then, the characteristic impedance, Z_c , and effective dielectric constant, ε_r^{eff} , are counted by using program statements for the formulas given in the reference

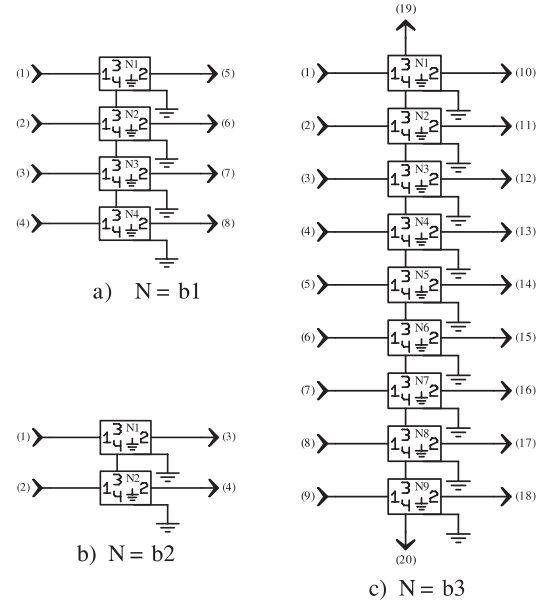


Fig. 5. a) 8-port network, b) 4-port network and c) 20-port network.

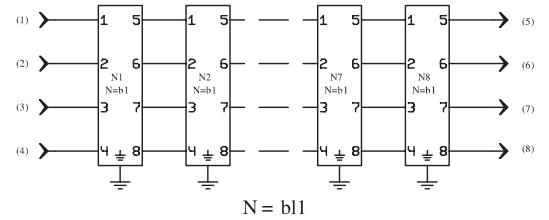


Fig. 6. Cascade connection of eight 8-port networks.

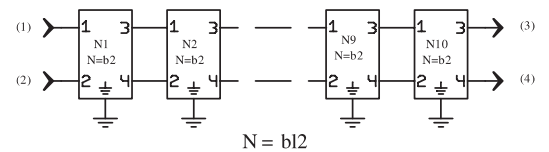


Fig. 7. Connection of ten 4-port networks.

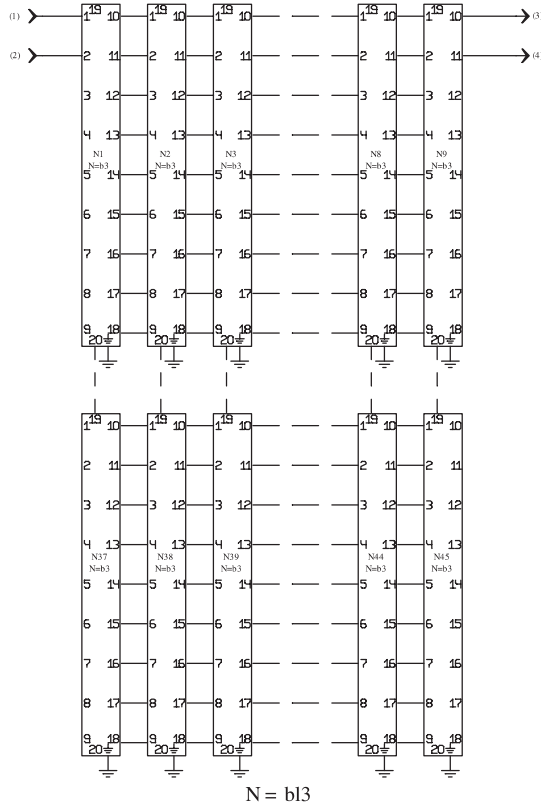


Fig. 8. Connection of forty five 20-port networks.

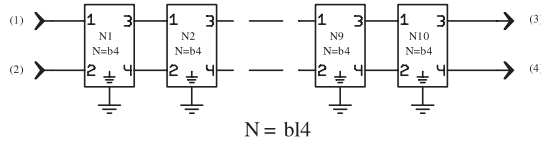


Fig. 9. Connection of ten 4-port networks.

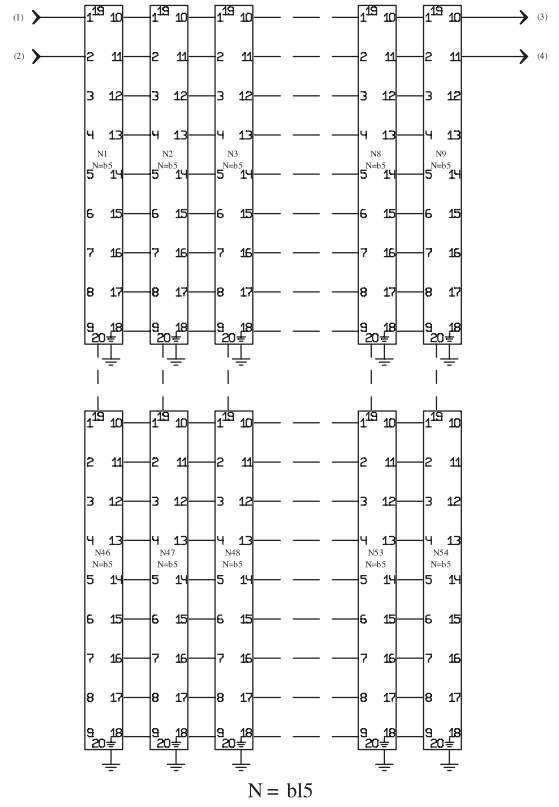


Fig. 10. Connection of fifty four 20-port networks.

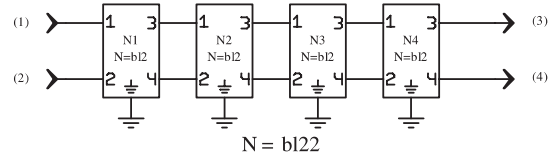


Fig. 11. Cascade connection of four 4-port networks.

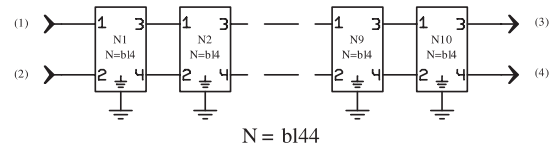


Fig. 12. Cascade connection of ten 4-port networks.

[8]. The inductance and capacitance values shown in the network given in Fig. 2a), for the lines 1 to 5, are counted by using the relations (1-3).

Now, it walks up to drawing the needed multi-port electrical circuits and networks. Because of the symmetrical analysed filter, only the networks for the approximation of the lines 1 to 5 are formed. Five separated electrical schemes, $N = LCk$, $k = 1, \dots, 5$, are drawn in the *Workspace*. Their inductance and capacitance values are automatically taken from the option *Equations*, and they depend on the physical dimensions of the corresponding lines and the segmentations in transverse and longitudinal directions. These networks are replaced with 4-port networks given in the Fig. 2b) and then, next multi-port networks are drawn, Fig. 5. The first line is simulated by network given in Fig. 6, where the network assigned by $N = b1$ is given in the Fig. 5a). The second one is simulated by network shown in the Fig. 11, where the network assigned by $N = bl2$ is shown in the Fig. 7. The network assigned with $N = b2$ is given in Fig. 5b). Because the third line is very wide, for its simulation are used 20-port networks as shown in Fig. 8, where the network assigned by $N = b3$ is given in Fig. 5c). The fourth and fifth networks are simulated as the second and third ones, respectively. The

complete network used for simulation of microstrip lowpass filter is shown in Fig. 13. The input lines are simulated by 3-port networks, and terminated impedances are $Z_{cl} = 50\Omega$.

IV. Analysis Results

In the software package *GENESYS*, microstrip lowpass filter is analyzed by using three different procedures: 1) simulation of the filter by 1D circuit with transmission lines, 2) 3D electromagnetic simulation of the filter and 3) simulation of the filter by 2D circuit consisting of lumped *LC* elements according to the suggested procedure. Response results of the transmission parameter S_{21} are shown at the same graphic in Fig. 14. From this graphic it can be concluded that results obtained by suggested procedure are nearer to the val-

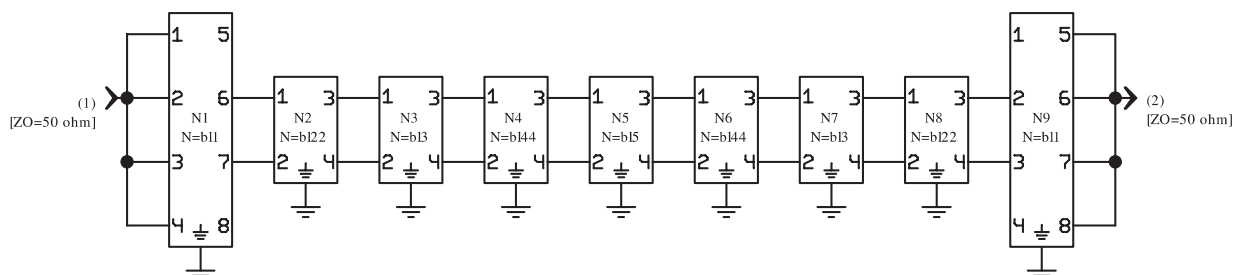


Fig. 13. Microstrip lowpass filter simulated by cascade connection of nine complex multi-port networks.

ues obtained by 3D electromagnetic simulation in whole frequency band than to the ones obtained by 1D simulation. The same microstrip filter is analyzed in the paper [4] by using ETS (Equivalent Thevenin Source) method incorporated in the software package FAMIL. Counted values are in full agreement with the ones counted by procedure suggested in this paper.

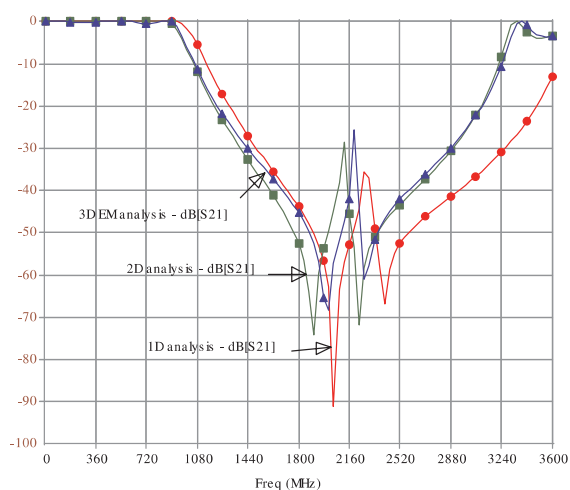


Fig. 14. Frequency response of the microstrip lowpass filter.

V. Conclusion

In this paper, simple procedure for frequency analysis of complex 2D circuits with lumped LC elements by using program GENESYS, is given. Electrical circuits, formed in this way, are using very successfully for modelling of microwave transmission lines. In order to analyze such circuits by program GENESYS, new models of the multi-port networks are formed. The schedule of forming electrical circuits and multi-port networks is shown on example of microstrip lowpass filter. The analysis results obtained by filter simulation with 2D circuit with lumped LC elements are in better agreement with results of 3D electromagnetic simulation than with the ones obtained by filter simulation with 1D circuit with transmission lines.

The suggested procedure is simple, has general character and can be applied to microwave circuits with both uniform and nonuniform transmission lines of complex configuration. Choosing different segmentation solves the discontinuity problem, i.e. changes of line widths.

Acknowledgment

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