Modelling of Microstrip Antennas using TLM Method

Tijana Ranđelović, Mila Stojanović, Vera Marković

Abstract - **In this paper, several patch antenna configurations are analyzed by using 3D TLM software in order to investigate possibilities of TLM method for modeling complex structure patch antennas with excitation in the form of wire conductor loaded in the substrate. Good agreement has been achieved between results obtained by using TLM method and those obtained by using the other numerical approaches, which indicates good modeling of antennas using TLM method.**

Keywords - **TLM method, TLM wire node, slotted patch antenna, H-shaped antenna, circular microstrip antenna**

I. Introduction

Microstrip and printed circuit antennas have gained prominence over the past two decades as viable and desirable antenna elements and arrays. The interest in these antennas stems directly from advantages such as low profile, low cost, light weight, conformity to surface, mass production, dual-frequency operation possibilities and direct integrability with microwave circuitry. There are some limitations, however, principally in characteristics such as low gain and narrow bandwidth.

Patch antennas have recently received much attention for application in mobile communication systems since they can provide advantages over traditional whip and helix antennas in terms of high efficiency, low EM coupling to the human head, and increased mechanical reliability. In many applications, the requirements on both bandwidth and physical size are quite stringent, [1].

TLM (Transmission Line Modelling) method is a general, electromagnetic based numerical method that has been applied successfully to the wide range of problems. For example, it has been applied to the modelling of metallic cavities [2]. By using a real feed probe for establishing desired field distribution in the modeled cavity the deficiencies of impulse excitation could be avoided. With some recent improvements in TLM method, it is possible to model a probe inside the cavity using TLM wire node [3] and to investigate the influence of the real excitation to the resonant frequencies and field distributions in the cavity [4, 5].

TLM method has been also successfully applied to the modeling of planar electromagnetic structures. For instance, it has been used for the analysis of a simple rectangular patch antenna [6] and of a U-shaped patch antenna [7].

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The goal of this paper is to investigate the possibilities and effectiveness of TLM method for modelling of up-to-date microstrip antennas with complex geometries that have significant application in modern wireless communication systems. Using TLM wire node it is possible to model coaxial feed and include the influence of the real excitation in the antenna model.

II. Modelling Procedure

In TLM method, a 3D electromagnetic (EM) field distribution in a microwave structure is modelled by filling the space with a network of transmission lines and exciting a particular field component in the mesh by voltage source placed on the excitation probe. EM properties of a medium in the patch antenna are modelled by using a network of interconnected nodes. A typical node structure is the symmetrical condensed node (SCN), which is shown in Fig. 1. To operate at a higher time-step, a hybrid symmetrical condensed node (HSCN) [8] is used. An efficient computational algorithm of scattering properties, based on enforcing continuity of the electric and magnetic fields and conservation of charge and magnetic flux [9], is implemented to speed up the simulation process.

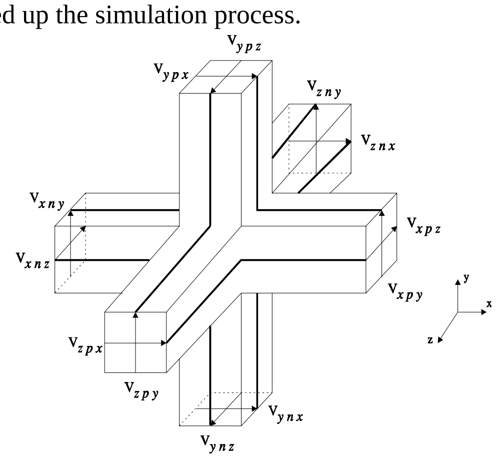


Fig. 1. Symmetrical condensed node

For accurate modelling of this problem, a finer mesh within the substrate and cells with arbitrary aspect ratio suitable for modelling of particular geometrical features are applied.

In TLM wire node, wire structures are considered as new elements that increase the capacitance and inductance of the medium in which they are placed. Thus, an appropriate wire network needs to be interposed over the existing TLM network to model the required deficit of electromagnetic parameters of the medium. In order to achieve consistency with the rest of the TLM model, it is most suitable to form wire networks by using TLM link and stub lines (Fig. 2) with characteristic impedances, denoted as Z_{wy} and Z_{wsy}, respectively.

An interface between the wire network and the rest of TLM network must be devised to simulate coupling between the electromagnetic field and the wire.

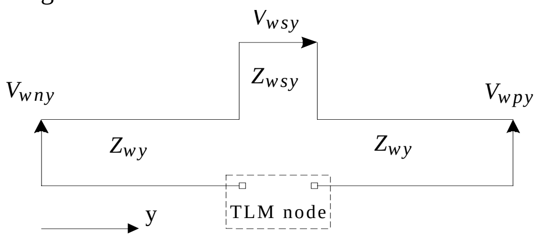


Fig. 2. Wire network

In order to model wire junction and bends, wire network segments pass through the centre of the TLM node. In that case, coupling between the field and wire coincides with the scattering event in the node which makes the scattering matrix calculation, for the nodes containing a segment of wire network, more complex. Because of that, an approach proposed in [10], which solves interfacing between arbitrary complex wire network and arbitrary complex TLM nodes without a modification of the scattering procedure, is applied to the modelling of planar antennas.

III. NUMERICAL ANALYSIS

Different patch antenna configurations are analyzed using 3D TLM software in order to investigate possibilities of TLM method for modelling complex patch antennas with excitation in the form of wire conductor loaded in the substrate.

A. Slotted Patch Antenna

A slotted patch antenna with the possibility to control the input impedance (Fig. 3) is considered first.

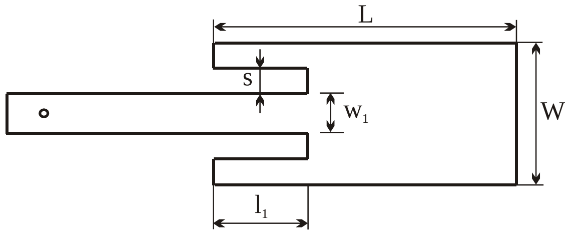


Fig. 3. Slotted patch antenna

Three configurations presented in [11], which have been designed for frequencies 13, 26 and 38GHz, whose dimensions are given in Table 1, are examined.

TABLE I
DIMENSIONS OF THE PATCH ANTENNAS

f [GHz]	*W* [mm]	*L* [mm]	w_1 [mm]	l_1 [mm]	*s* [mm]
13	9.2	7.55	0.5	0.8	0.3
26	4.6	3.6	0.5	0.8	0.4
38	3.1	2.45	0.3	0.825	0.2

The antennas are built on substrate with following characteristics: relative dielectric constant $\varepsilon_r = 2.17$, thickness $h = 0.508$ mm, conductor thickness $T = 0.017$ mm and loss tangent of dielectric $tan\ \delta = 0.002$.

The results for the return losses of these antennas obtained by using 3D TLM method are shown in Fig. 4. A real feed probe loaded in the substrate with radius of 0.05 mm is used as an excitation for all cases.

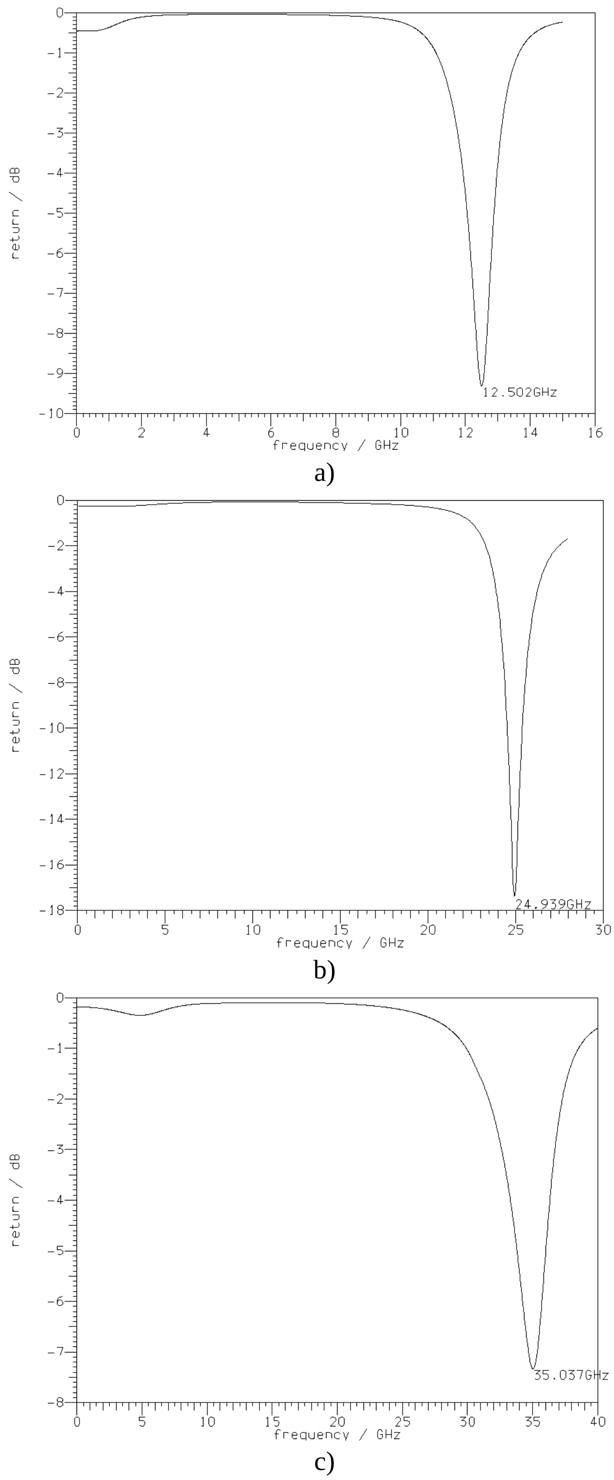


Fig. 4. Results of patch antenna analysis by using TLM for a) 13 GHz, b) 26 GHz, c) 38 GHz

As it can be seen from Fig. 4 resonance frequencies are slightly below the expected ones. This may be caused by the problem of the accurate edge-effects modelling appearing because of slots. The values of resonant frequencies that are somewhat closer to the nominal values can be obtained by using a mesh with smaller TLM nodes, but it increases time of simulation in return.

B. H - Shaped Antennas

Short-circuited H-shaped antennas are very suitable for MMIC active antenna applications because they take only a fraction of the substrate area of conventional patch antennas and have a convenient shape enabling the active circuits to be integrated within the antenna, taking no additional substrate area. In this section, a quarter wavelength H-shaped antenna at 5 GHz [12] is examined by using 3-D TLM method. In that example, the substrate is a glass loaded PTFE substrate with the relative dielectric constant ε_r of 2.2 and with the thickness of 0.508 mm. The length L and the width W of the antenna are 9.5 mm and 11 mm, respectively. The lengths L_1 and L_2 have been chosen to be 2.5 and 2.9 mm, respectively. Ten shorting pins of 0.1 mm thickness are used for making the short to the ground. The substrate and the ground plane size is 50 mm x 50 mm. The antenna layout is presented in Fig. 5.

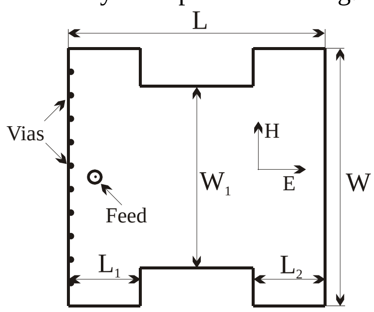


Fig. 5. The layout diagram of short circuit *H*-shaped antenna

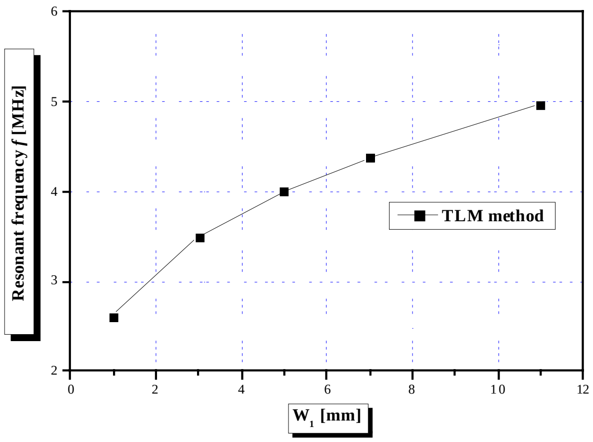


Fig. 6. The resonant frequency of a H-shaped antenna for different values of W_1 (L = 9.5 mm, W = 11 mm, L_1 = 2.5 mm, L_2 = 2.9 mm, substrate ε_r = 2.2 and thickness = 0.508 mm)

The effect of varying the middle width (W_1) on the resonance frequency is investigated by using the above discussed TLM procedure that includes the wire node application. Five antennas with middle width (W_1) of 1, 3, 5, 7 and 11 mm are considered. In all cases, the feed position is chosen to be 0.8 mm from the shorted end.

The results show that the width W_1 has a significant effect on the resonant frequency of the antenna. In Fig. 6, the resonant frequency of the *H*-shaped antenna versus W_1 is presented. It can be seen that the resonant frequency of the antenna reduces by more than 40% when the width W_1 is reduced to 1 mm.

It should be pointed that very good agreement has been achieved between results for the short-circuited H-shaped antennas obtained by using TLM method and those obtained by a FDTD software as well as a commercial HP Momentum electromagnetic simulator [12].

C. Circular Microstrip Antenna

Accurate prediction of input impedance of a coax-fed circular patch antenna is very important for the attempts to improve the antenna performance. In this section, an example of the application of the TLM method to the analysis of circular microstrip antennas is presented. It is investigated how feed position influences resonant frequencies of an circular-shaped antenna built on substrate with relative dielectric constant ε_r = 2.32, loss tangent $\tan\delta$ = 0.001 and with the thickness h = 1.59 mm (Fig. 7). The radius of the circular patch is a = 50 mm. As an excitation, wire conductor loaded in the substrate with diameter d_0 = 1.27 mm is used. The example of antenna is taken from [13].

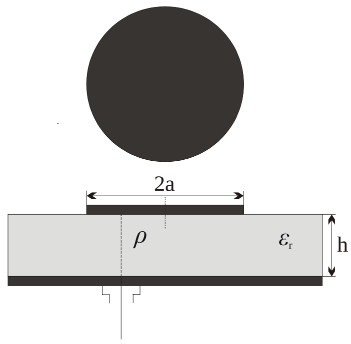


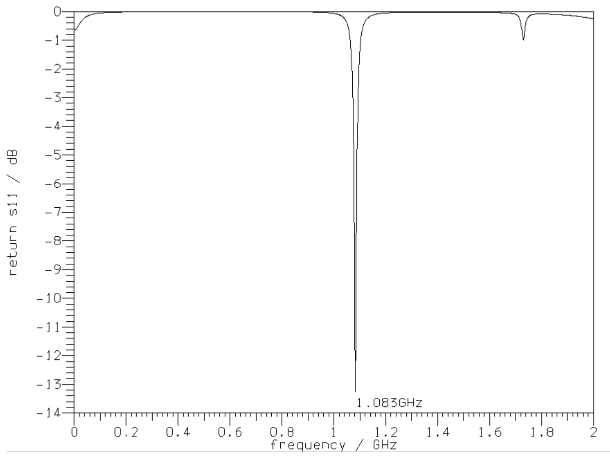
Fig. 7. Coax-fed circular microstrip antenna

TLM analysis has been done for five different feed positions. Normalized feed locations are ρ/a = {0.2, 0.4, 0.6, 0.8, 0.95}. In Fig. 8 the resonant frequencies for two cases, ρ/a = 0.2 and ρ/a = 0.95, are shown. It can be seen that the resonant frequency changed not significantly when the feed location is varied.

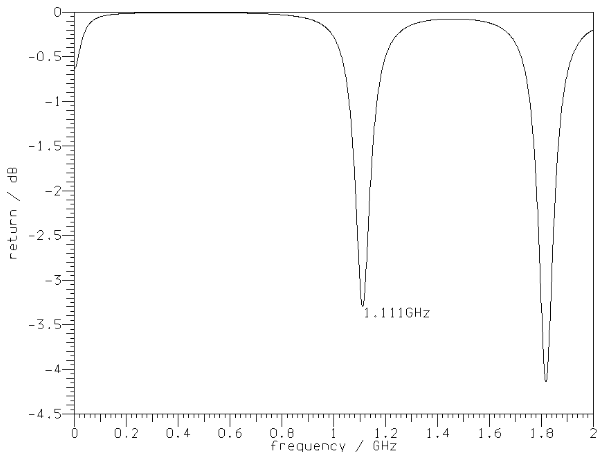
On the other hand, the analysis shows that the influence of the feed location to the reflection characteristics is much more expressed. In Fig. 9 is given the variation of parameter S_{11} of the considered coax-fed circular microstrip antenna as a function of normalized feed position ρ/a.

IV. CONCLUSION

In this paper, several patch antenna configurations are analyzed by using 3D TLM approach. It has been shown that the application of the TLM method including the wire node is very convenient for modelling complex patch antennas with an excitation in the form of wire conductor loaded in the substrate. Three different examples of patch antennas are examined: slotted patch antenna, H-shaped patch antenna and circular microstrip antenna. Good agreement has been achieved between results obtained by using TLM method and those obtained by using the other numerical approaches.



a)



b)

Fig. 8. Resonant frequencies of circular patch antennas for a) ρ/a = 0.2, b) ρ/a = 0.95

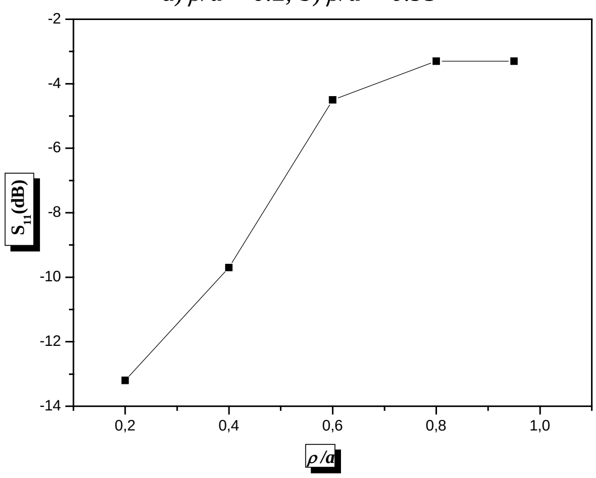


Fig. 9. S_{11} versus normalized feed-location ρ/a

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