3D TLM Simulator Application for an Analysis of the EM Field Distribution Inside Metallic Cavity with Real Feed

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Abstract - **In this paper, by using 3D TLM simulator, the analysis of real feed probe influence to electromagnetic field distribution inside the rectangular metallic cavity is examined. According to the wanted type of mode in the cavity, an excitation is achived through a small wire conductor, placed into the cavity on the top wall, along the z-axis, establishing TM_{mnp} modes. In order to investigate the influence of feed and receiving probe to the field distributions in the cavity, field strength versus probe length, are presented.**

Keywords - **TLM method, microwave applicator, cavity, TLM wire node, electromagnetic field distribution**

I. Introduction

Rectangular metallic cavities represent a configuration very suitable for good modeling of some practical heating and drying applicators. The knowledge of the mode tuning behavior has important significance and would help in designing these applicators. For this reason, some researches of the metallic cavities, based on using the different approaches, were presented by a number of authors [1,2,3].

TLM (Transmission Line Modeling) method is a general, electromagnetic based numerical method that has been applied very successfully in the area of metallic cavities modeling [3,4,5]. By using an real feed probe for establishing desired field distribution in the modeled cavity all the deficiencies of impulse excitation could be avoided [6,7]. The difference in the cavity excitation causes that the TLM results in the case of impulse excitation being different from the experimental ones. With some recent improvements in TLM method, it is possible to model a probe inside the cavity using TLM wire node [8] and to investigate the influence of the real excitation to the resonant frequencies and field distributions in the cavity [6,7].

In practice, depending on the position and dimensions excitation, the number of modes will be different [9]. This situation is made worse when many modes are present.

In practical realization of the microwave applicators one of the most important issues is the electromagnetic field distribution inside the metallic cavity, in order to achieve equally material drying. The goal of this paper is to describe the possibilities of TLM method for the analysis of the electromagnetic field distribution inside the metallic cavity for different probe length. TLM method is applied to the rectangular metallic cavity. As an excitation form straight wire conductor loaded in the cavity is used.

Feed probe is connected with voltage source and placed on the top wall along the *z*-axis, establishing TM_{mnp} modes with E_z component. The resonant frequencies and field distribution inside the metallic cavity is analyzed for the excitation probe placed in the middle of the top wall ($a/2$,$b/2$), along the *z*-axis, and for different feed probe length. Also, in the case of both feed and receiving probe presence, field distribution for TM_{mnp} modes for different probe length is analyzed. The analysis is incomplete, as empty cavity only is considered, but some important conclusions can be drawn that are still valid for the loaded cavity.

II. Problem Modeling

In TLM method, an electromagnetic (EM) field distribution in three dimensions, for a specified mode of oscillation in a microwave cylindrical cavity, is modeled by filling the field 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 cavity are modeled by using a network of interconnected nodes (Fig.1), a typical structure being the symmetrical condensed node (SCN). To operate at a higher time-step, a hybrid symmetrical condensed node (HSCN) [10] 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 [11] is implemented to speed up the simulation process.

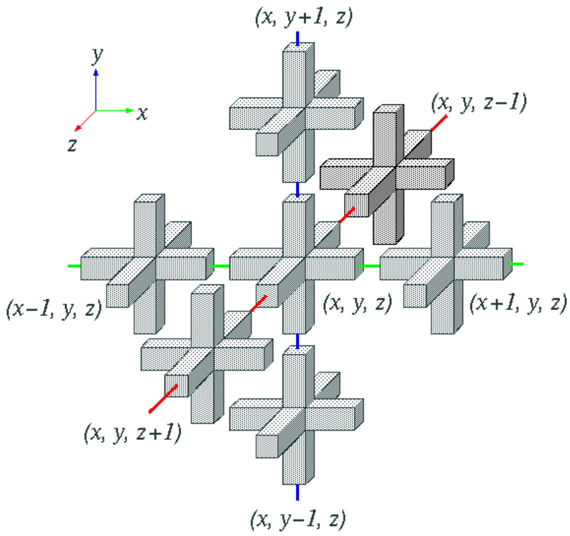

Fig. 1. Network of interconnected TLM nodes

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III. TLM WIRE NODE

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 [12]. 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.

Equivalent radius of fictive cilindre for calculating the capacitance and inductance, r_{Ci} and r_{Li}, respectively, for wire segment spreading along i direction (i $\{x,y,z\}$) are:

$$r_{Ci} = k_{Ci} \;\; i_c \qquad (1)$$

$$r_{Li} = k_{Li} \;\; i_c \qquad (2)$$

where i_c represents mean dimensions of the node cross-section in i direction (for example, x_c=(y+ z)/2), while k_{Ci} and k_{Li} are factors empirically obtained by using known characteristics of TLM network [13].

Distributed capacitance and inductance per unit length, needed for modeling of wire segments, may be expressed as:

$$C_{wi} = \frac{2\pi\varepsilon}{\ln(r_{Ci} / r_w)}, \qquad (3)$$

$$L_{wi} = \frac{\mu}{2\pi}\ln(r_{Li} / r_w) \qquad (4)$$

where r_w is real wire radius.

IV. NUMERICAL ANALYSIS

The numerical results obtained by using 3D TLM software, which illustrate the effect of the real feed probe on the field distribution, are presented for a cavity with rectangular cross-section. Dimensions of the investigated cavity are chosen to be $a=35cm$, $b=37cm$ i $c=26.9cm$. (Fig. 2). As homogeneous lossless dielectric inside the cavity is used air (ε_r $=1$). TLM network with dimensions x y $z=35$ 37 27 nodes is used for modeling considered cavity. Feed probe, with radius r=0.5mm, is placed in the middle of the top wall of the cavity ($x=a/2$, $y=b/2$) along the z-axis. The probe is connected with voltage source V_{source} =1V, R_{source} =50Ω.

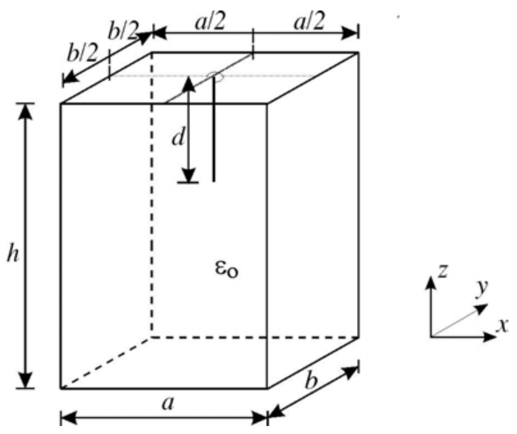
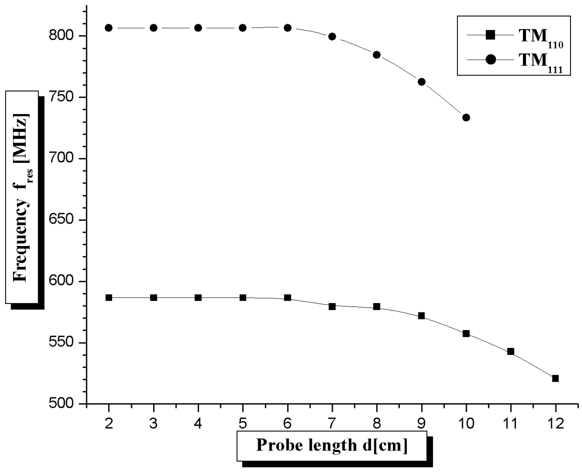
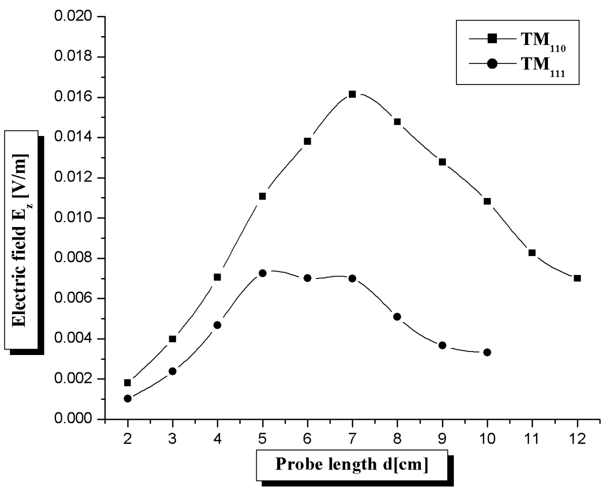


Fig. 2. Rectangular metallic cavity

First, in order to investigate the influence of the feed probe presence to the resonant frequencies and the field strength in the cavity, simulation is done for different probe length in the range d=[2,12] cm. In the Fig. 3. the resonant frequencies and strength of Ez field component in TLM node (18,19,10) versus probe length for TM_{110} i TM_{111} modes is shown.



a)



b)

Fig. 3. *a)* Resonant frequencies, *b)* z component of electric field, versus feed probe length for TM_{110} and TM_{111} modes

As it can be seen from Fig. 3, the results of both resonant frequencies and field strength calculated by using TLM method, where a probe inside the cavity is used as an excitation, significantly depends on the probe length. Due to increasing of wire conductor length, the values of resonant frequencies shift to the lower ones. On the other hand, the strongest electric field for TM_{110} and TM_{111} is obtained for the probe length $d=7cm$ and $d=5cm$, respectively.

Further, for chosen probe length $d=5cm$ and same position of the probe ($x=a/2$,$y=b/2$), electric field distribution is investigated. By using 3D TLM*scn* software [4], *Ez* field component distribution inside the rectangular metallic cavity is analyzed for considered modes. Fig. 4 shows 3D presentation of electric field distribution, as well as corresponding presentation in *x-y* plane for TM_{110}. In similar way, field distribution for TM_{111} mode can be obtained.

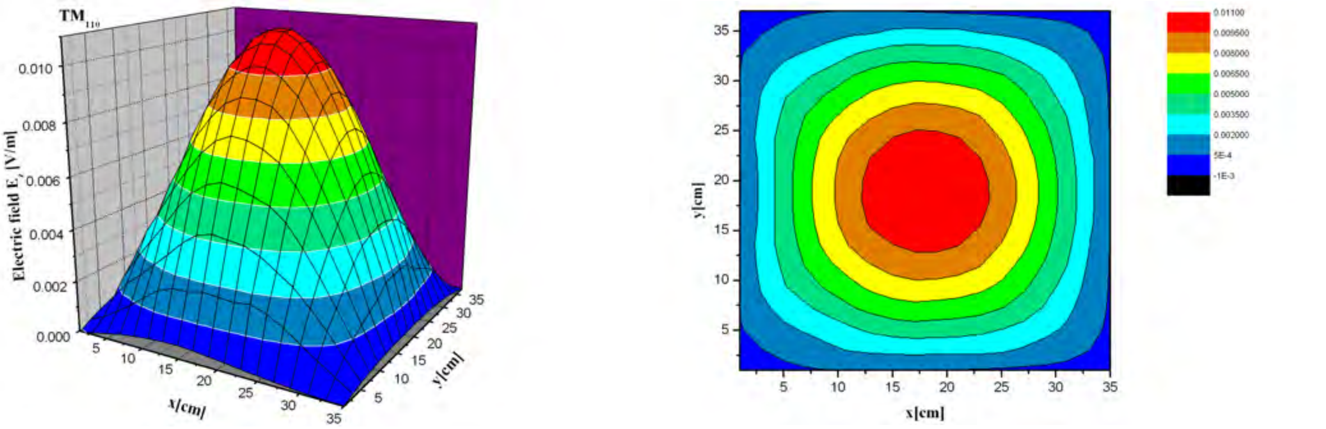
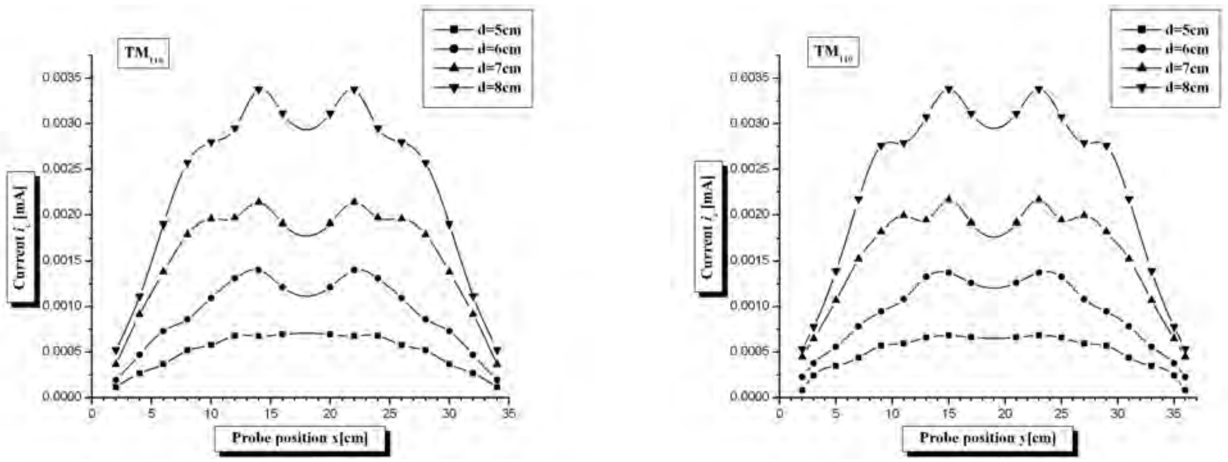


Fig.4. The field distribution of *Ez* component for TM_{110}, mode, for feed probe position (*a/2,b/2*) and probe length *d=5cm*

Also, in the case of both feed and receiving probe presence, field distribution for TM_{110} and TM_{111} modes for different probe length is analyzed. In Fig. 5 distribution of inducted current in the receiving probe $i_c(x,y)$, $x\in(1,35)$, $y\in(1,37)$ for TM_{110} mode versus feed and receiving probe length is shown.

As it can be seen from Fig. 5 values of inducted current in the receiving probe depends on the probe length. In fact, due to increasing probe length, values of the inducted current i_c, determining TM_{110} and TM_{111} modes, increase. Also, deviation of inducted current appears, that is two maximum values in corresponding direction appear instead of one. This deviation is related with the coupling of the probes.

To the aim of illustrating of obtained TLM results, Fig. 6 shows 3D presentation of inducted current distribution, as well as corresponding presentation in *x-y* plane for TM_{110} in the case of probe length of *d=6cm*. As it is shown, the shape of TM_{110} in this case is different from the case shown in Fig. 4. According to the obtained results, influence of the probe presence to establishing modes can be seen.



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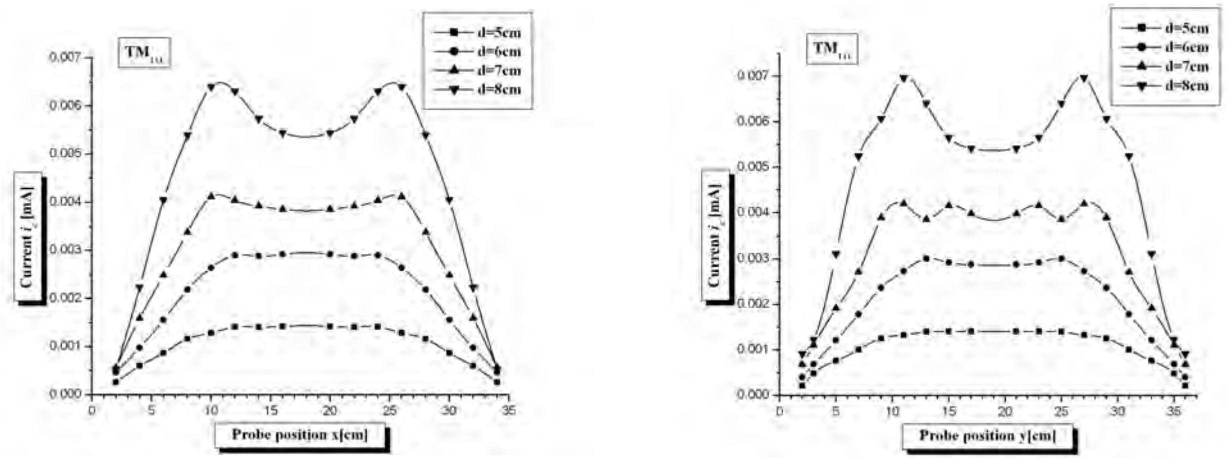

b)

Fig. 5. Inducted current for a) TM_{110} mode b) TM_{111} mode

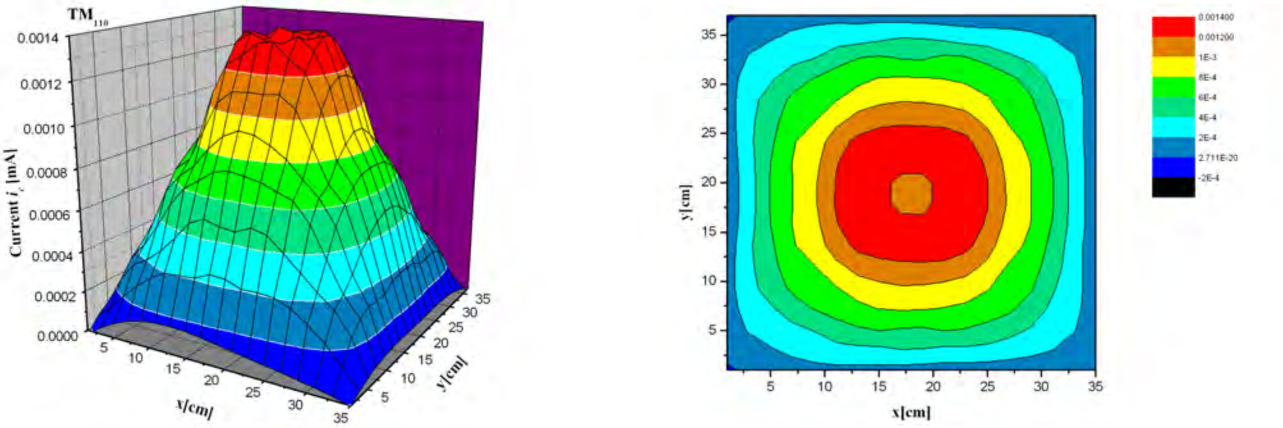

Fig. 5. Inducted current for TM_{110} mode, for probe length d=6cm

V. Conclusion

In this paper, using TLM method, for the example of the rectangular metallic cavity, influence of probe presence to the resonant frequencies and field distribution in the cavity is analyzed. Numerical results of resonant frequencies and field strength calculated by using TLM method, where the probe inside the cavity is used as an excitation, significantly depends on the probe length. The probe presence tends to shift the resonant frequencies of TM_{110} and TM_{111} modes. To the aim of illustrating TLM method application to field strength, distribution of E_z field component for probe length $d=5cm$, is presented.

Further, 3D TLM method is applied to determine field distribution in the real case, when both feed and receiving probe are used. According to the obtained results, influence of the feed and receiving probe presence to establishing modes can be seen. Due to increasing the probe length, values of inducted current i_c, determining TM_{110} and TM_{111} modes, increase. Also, deviation of inducted current is observed, that is two maximum values in corresponding direction appear instead of one. This deviation is related with the coupling of the probes.

Obtained results show possibilities of applying TLM method for analysis of field distribution inside the cavity versus probe dimensions and position.

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