Real Excitation Modeling in a Cylindrical Metallic Cavity with Circular Cross-section Using 3-D TLM Method

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Abstract - **In this paper, the real excitation modeling, using TLM wire node for the example of the cylindrical metallic cavity with circular cross-section, will be presented. The small wire conductor, as an excitation form, is used according to the wanted type of mode in the cavity. The modeling process is described and the obtained TLM numerical results are compared with the experimental results. Also, in order to investigate the influence of length and radius of real excitation to the resonant frequencies of TM_{010}, TM_{011}, TE_{111} and TE_{211} modes, TLM results are compared with results calculated by using the theoretical approach that not include real excitation, and the appropriate conclusions are given.**

Keywords – **TLM method, microwave applicator, cavity, real excitation, wire node, resonant frequency**

I. INTRODUCTION

Cylindrical metallic cavities represent a configuration very suitable for good modeling of some practical heating and drying applicators. The knowledge of the mode tuning behavior under loading condition has important significance and would help in designing these applicators. For this reason, some researches of the cylindrical cavities, based on using the different approaches, were presented by a number of authors [1,2,3]. Also, some experimental work has been done in order to investigate the mode tuning behavior experimentally [1,2].

TLM (Transmission-Line Modeling) method is a general, electromagnetic based numerical method that has been applied very successfully in the area of cylindrical metallic cavities modeling [3,4,5]. In all this applications, an impulse excitation was used to establish desired field distribution in the modeled cavity. However, this way of enhancing the wanted TE or TM mode is different from the experimental case where a small probe inside the cavity is used as an excitation.

This difference in the cavity excitation causes that the TLM results in the case of impulse excitation being slightly different from the experimental ones. With some recent improvements in TLM method, it is possible to model a small probe inside the cavity using TLM wire node [6] and to investigate the influence of the real excitation to the resonant frequencies of the cavity.

The goal of this paper is to describe the possibilities of TLM method for modeling of real excitation in the form wire conductor loaded in the cylindrical metallic cavity with circular cross-section. In order to verify TLM method the obtained numerical results of resonant frequencies for TM_{010}, TM_{011}, TE_{111} and TE_{211} modes are compared with the experimental ones. Experimental set up for resonant frequencies measurement is shown on the Fig.1.

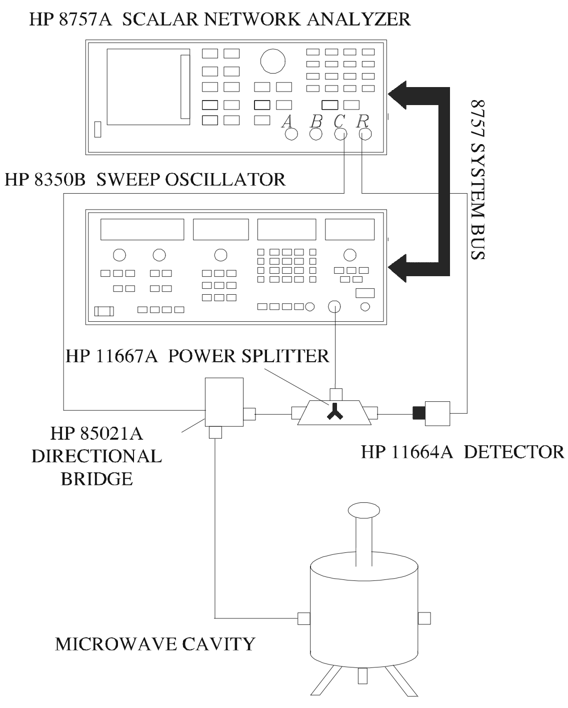

Fig.1. Experimental set up for resonant frequency of the cylindrical metallic cavity with circular cross-section measurement

Also, on this way, it is possible to investigate the influence of the real excitation, i.e. length and radius of wire conductor, to the resonant frequencies of the cavity. In this paper obtained TLM results for resonant frequencies in the case of cavity with real excitation are compared with results calculated by using the theoretical approach, i.e. impulse excitation.

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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, a typical structure being the symmetrical condensed node (SCN), which is shown in Fig.2. To operate at a higher time-step, a hybrid symmetrical condensed node (HSCN) [7] 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 [8] is implemented to speed up the simulation process.

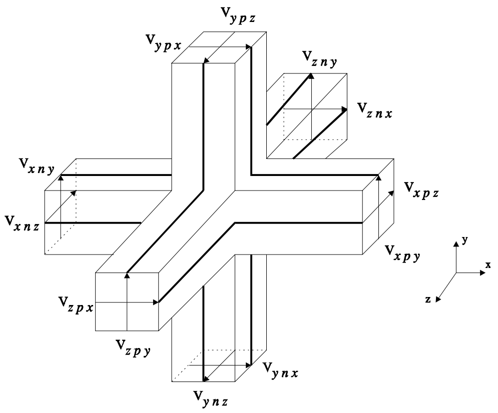

Fig.2 Symmetrical condensed node

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. 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. 3) with characteristic impedances, denoted as Z_{wy} and Z_{wsy}, respectively.

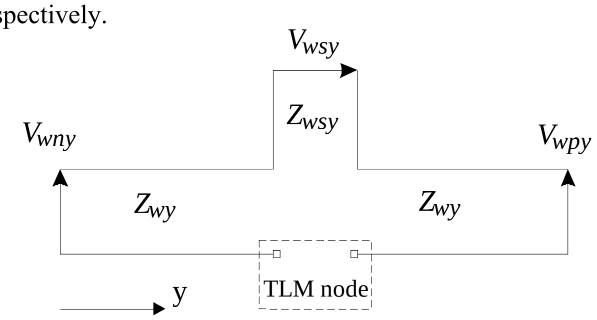

Fig. 3. Wire network

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. In order to model wire junction and bends, wire network segments pass through the center 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, a simple and elegant approach is developed [6], which solves interfacing between arbitrary complex wire network and arbitrary complex TLM nodes without a modification of the scattering procedure.

IV. NUMERICAL ANALYSIS

The numerical results, which illustrate the effect of the real excitation probe on the resonant frequency, are presented for a cavity with circular cross-section, without dielectric sample. Dimensions of the investigated cavity are chosen to be a=7 cm and h=14.24 cm, starting from the example from [3].

For modeling of this cavity uniform TLM mesh with 45x45x32 nodes was used. At the same time, a real excitation in form of small straight wire conductor is modeled by using TLM wire node. An excitation probe is located in the middle of the cavity, on the height l=7.24 cm from bottom on the cavity, in the r direction (Fig.4.). In this way, it is possible to excite modes having r-component of the electrical field in the cavity.

The radius of the excitation probe is r=0.5 mm and length d is variable in order to investigate the influence of the real excitation, i.e. length of wire conductor, to the resonant frequencies of the cavity. At the center of the real excitation probe, voltage source V_{source} =1 V, as an excitation, was applied. The same probe is used as a receiving probe, therefore it is possible to give reflection characteristic and determine the resonant frequencies for TM_{010}, TM_{011}, TE_{111} and TE_{211} modes.

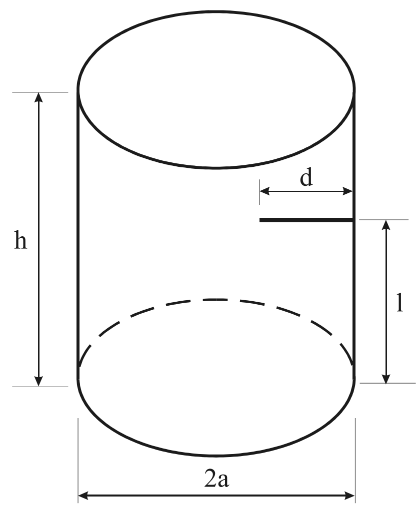

Fig. 4. Real excitation loaded in a metallic cavity with circular cross section (*a=7 cm, h=14.24 cm, l=7.24 cm*)

The obtained TLM numerical results and experimental results of resonant frequencies TM_{010}, TM_{011}, TE_{111} and TE_{211} modes, for different values of length of the real excitation probe *d*, are shown in TABLE I.

Length of the real exci-tation d[cm]	Resonant frequencies f_{res} [MHz]					
	TM_{010}, TE_{111} Theoretical value =1640 MHz		TM_{011} Theoretical value =1950 MHz		TE_{211} Theoretical value =2334 MHz	
	TLM	exp.	TLM	exp.	TLM	exp.
1,55	--	--	--	--	2309	--
1,86	1630	1634	1943	1947	2304	2309
2,18	1620	1621	1943	1946	2291	2297
2,49	1618	1620	1939	1940	2269	--
2,8	1607	1611	1928	1940	2223	--
3,11	1597	1607	1924	1936	2148	--
3,42	1579	1595	1906	--	2067	--
3,73	1549	--	1870	--	2013	--
4,05	1508	--	1825	--	--	--

TABLE I. The resonant frequencies of TM $_{010}$, TM $_{011}$, TE $_{111}$ and TE $_{211}$ modes versus length of excitation probe, calculated by using theoretical approach and TLM method, respectively

As it can be seen from TABLE I, there is very good agreement between TLM and experimental results, which indicates good TLM modeling of the real excitation probe.

Besides, in order to investigate the influence of the length of real excitation to the resonant frequencies of the cavity the resonant frequencies f_{res} of TM_{010}, TM_{011}, TE_{111} and TE_{211} modes versus length of real excitation probe *d*, are shown in the Fig. 5. The triangle symbols indicate the results obtained by using TLM method with real excitation and rectangular indicate experimental ones. In the same figure circle symbols with straight lines present the values of resonant frequencies calculated by using the theoretical approach, i.e. impulse excitation.

The Fig.5. shows that the values of resonant frequencies f_{res} for TM_{010} , TM_{011} , TE_{111} and TE_{211} modes depend of the length of the real excitation probe *d*. The results calculated by using TLM method and experimental ones, where a small probe inside the cavity is used as an excitation, are different from the results calculated by using the theoretical approach where an impulse excitation was used to establish desired field distribution in the modeled cavity

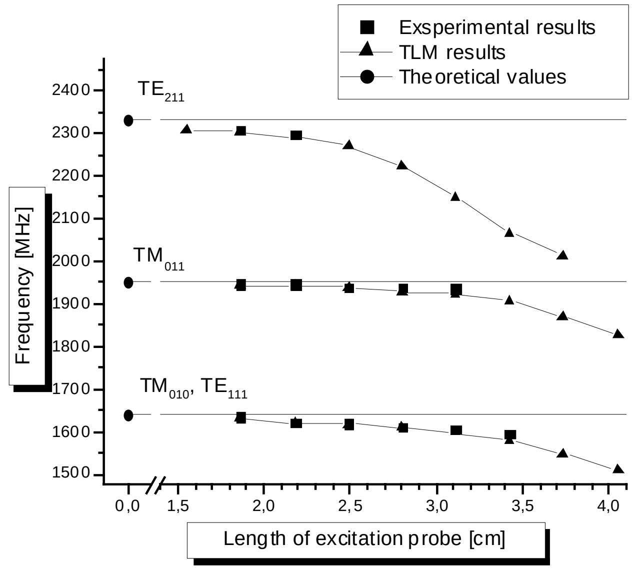

Fig. 5. The resonant frequencies of TM $_{010}$, TM $_{011}$, TE $_{111}$ and TE $_{211}$ modes versus length of excitation probe, calculated by using theoretical approach and TLM method, respectively

Further, in order to investigate the influence of the radius of wire conductor to the resonant frequencies of the cavity, TLM model is applied for the constant value of length of real excitation probe *d*=2.8 cm as a parameter, and different values of the radius of excitation probe *r* in the range *r*= (0,005-0,5) mm. Obtained TLM results for TM_{010}, TM_{011}, TE_{111} and TE_{211} modes are shown in TABLE II.

Radius of the real exci-tation r[mm]	Resonant frequencies f_{res} [MHz]		
	TM_{010}, TE_{111} Theoretical value =1640 MHz	TM_{011} Theoretical value =1950 MHz	TE_{211} Theoretical value =2334 MHz
0.005	1622	1942	2278
0.01	1621	1941	2274
0.02	1620	1940	2269
0.05	1618	1939	2262
0.1	1617	1937	2253
0.2	1613	1935	2243
0.3	1612	1932	2235
0.4	1608	1930	2229
0.5	1607	1928	2223

TABLE II The resonant frequencies versus radius of excitation probe, calculated by using TLM method, for TM $_{010}$, TM $_{011}$, TE $_{111}$ and TE $_{211}$ modes, respectively

The Fig.6. and Fig.7. show dependence of resonant frequency for TM_{010}, TM_{011} and TE_{111} modes versus radius of excitation probe: due to reducing of the radius of wire conductor the values of resonant frequencies decrease and tend toward theoretical value.

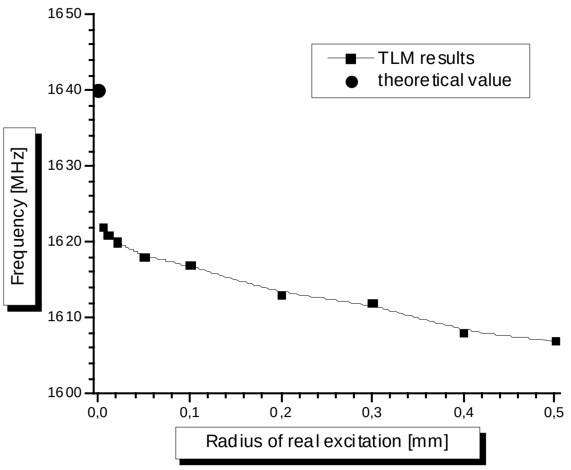

Fig. 6. The resonant frequencies for TM_{010} and TE_{111} modes versus radius of excitation probe, calculated by using TLM method and theoretical approach

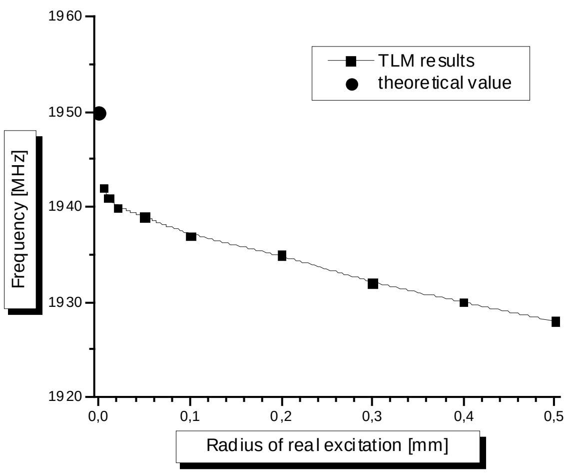

Fig. 7. The resonant frequency for TM_{011} mode versus radius of excitation probe, calculated by using TLM method and theoretical approach

V. Conclusion

Real excitation modeling in a microwave applicator represented in the form of cylindrical metallic cavity with circular cross section is presented in this paper. TLM numerical technique has been implemented in the appropriate software and applied to the problem of determining resonant frequencies as important information in the microwave applicator designing.

In comparison with results calculated by using the theoretical approach where an impulse excitation was used, the obtained TLM numerical results in the case of real excitation show a much better agreement with experimental ones, which indicates good TLM modeling of the real excitation probe.

Also, in this paper, the influence of the length and radius of real excitation to the resonant frequencies of the cavity for TM_{010}, TM_{011}, TE_{111} and TE_{211} modes are investigated. The obtained results where a small probe inside the cavity is used as an excitation show that values of resonant frequencies depend on both length and radius of wire conductor.

In this paper, for the first time, real excitation in a circular cylindrical metallic cavity without dielectric sample is modeled by using TLM method. According to previously showed results a general conclusion can be derived that TLM approach gives valid result. Therefore it is expected that these resonant structures can be successfully modeled by TLM method, independently of probe location and dimensions, dielectric sample location in the cavity and its losses.

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