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TLM Modelling and Analyse of Power Divider Using Linear Electric Probes Coupling Inside Cylindrical Cavity

Jugoslav Joković, Bratislav Milovanović

Abstract – **In this paper, power divider using linear electric probes coupling inside cylindrical cavity is analysed by using 3D TLM software in order to study effects of the feed probe and power dividing probes for determining the maximum power transfer for practical applications. TLM nunerical results of reflection coeficient and standing wave ratio (SWR) of feed probe and dividing probes for various probe length are compared with results obtained using Method of Moments and experimantal ones. In comparison with Method of Moments when probes are considered to be with negligible thickness, TLM results including of modelled probes with real radius shows better agreement with experimental ones.**

Keywords **– Power Divider, Cavity, Electric Probe, TLM Method, TLM Wire Node**

I. INTRODUCTION

Communications systems such as television, radio an mobile phone have been extensively and continuously used for distribution over wide of the service area [1]. The antenna that provides unidirectional beam pattern by using sectoral cylindrical cavity-backed slot antenna excited by probe is attractive candidate for usage [2]. When combining each element to be circular array, omni directional pattern are achieved.

TLM (Transmission Line Modelling) method is a general, electromagnetically 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 [3]. By using a real feed probe for establishing desired field distribution in the modeled cavity, with some improvements in TLM method, it is possible to model a probe inside the cavity using TLM wire node [4] and to investigate the influence of the real feed to the resonant frequencies in the cavity [3, 5].

This paper focuses on the TLM modeling and analyses of characteristics for power divider using probes coupling inside cylindrical cavity [6]. The structure of the power divider is composed of conducting cylindrical cavity of the radius r and the height c. The feed probe is aligned along z direction that is located at the center of the cavity and the length probe is l_f as shown in the Fig. 1.

In this way, it is possible to excite modes having z-component of the electrical field in the cavity (TM modes). The length of the power dividing probes are l_{p1}, l_{p2}, l_{p3} and l_{p4}, respectively. They are aligned along r direction and located at the distance $c/2$ from the bottom of the cavity and the angle between the probe is 90 degrees apart.

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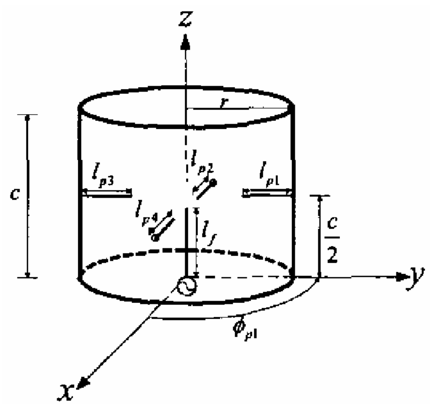


Fig. 1. The structure of power divider using linear electric probes inside cylindrical cavity

In order to investigate the possibilities and effectiveness of TLM method for modelling of power divider with complex geometries that have significant application in modern communication systems, obtained TLM numerical results of characteristics of power divider for various lengths of feed probe and power dividing probes are compared with results obtained using Method of Moments to solve the same problem and experimental results as well [6].

II. TLM MODELLING PROCEDURE

In the TLM time-domain method, an electromagnetic field strength in three dimensions, for a specified mode of oscillation in a cylindrical metallic cavity, is modelled by filling the field space with a network of link lines and exciting a particular field component [7]. Electromagnetic properties of mediums in the cavity are modelled by using a network of interconnected nodes (Fig. 2), a typical structure being the symmetrical condensed node (SCN) [8]. Each node describes a portion of the medium shaped like a cuboid or a slice of cake depending on the applied (rectangular/cylindrical) coordinate system (grid).

TLM wire node is based on SCN with one small modification in the form of additional link and stub lines interposed over the exiting network to account for increase of capacitance and inductance of the medium caused by wire presence [4]. This wire network is usually placed into the centre of the TLM nodes to allow modelling of complex wire structures, e.g. wire junctions and bends (Fig.3). The single column of TLM nodes, through which wire conductor passes, can be used to approximately form the fictitious cylinder which represents capacitance and inductance of wire per unit length. Its effective diameter, different for capacitance and inductance, can be expressed as a product of factors empirically obtained by using known characteristics of TLM network and the mean dimensions of the node cross-section in the direction of wire running.

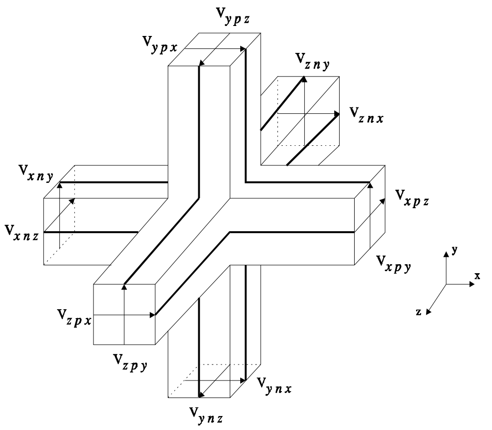


Fig. 2. Symmetrical condensed node

Requirement that the equivalent radius of fictitious cylinder is constant along nodes column can be easily met in a rectangular grid. However, in the cylindrical grid for wire conductor in the radial direction, mean cross-section dimensions of TLM nodes, through which wire passes, are changeable making difficult to preserve distributed capacitance and inductance of wire per unit length. Because of that, a rectangular grid has been chosen for modelling of cylindrical cavity analysed in this paper. At the same time, the numerical errors introduced by describing boundary surfaces of the modelling cavity in a step-wise fashion are reduced applying the TLM mesh higher resolution around cavity walls.

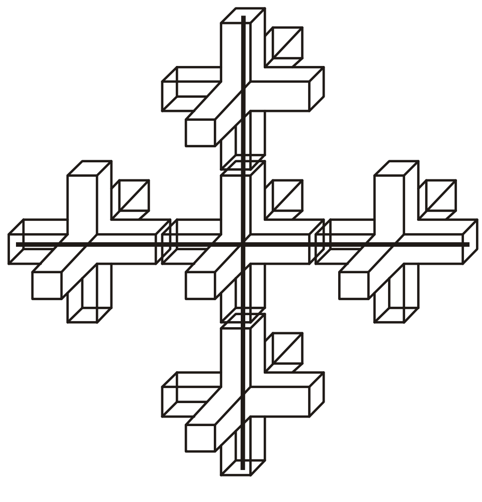
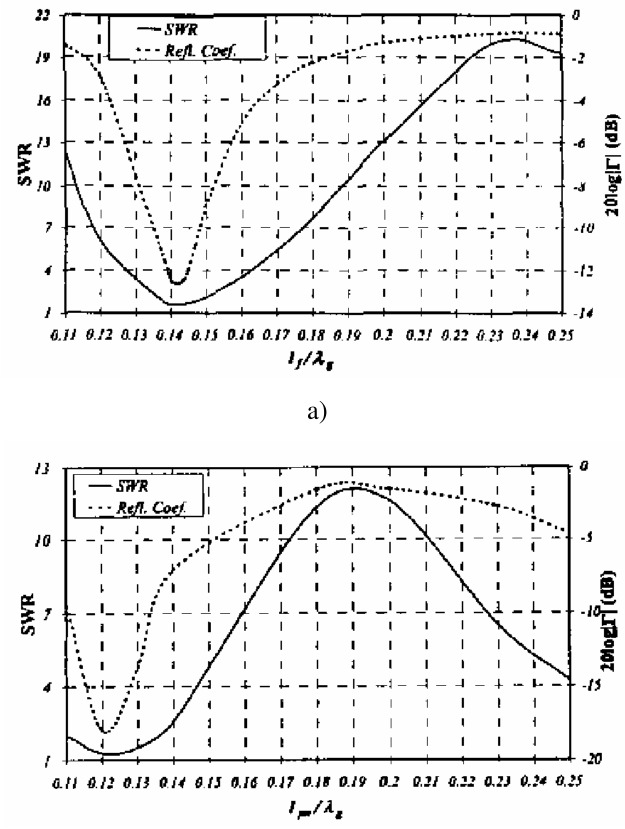


Fig. 3. Wire network embedded within the TLM nodes

III. Method of Moments Results

In the case of Method of Moments applying for study of power divider, analysis is beginning with the integral equations of electric field intensities that can be formulated by applying Field Equivalence Principle together with boundary conditions at all the probes. The dyadic Green function that is the impulse response is derived and Method of Moments is used to solve for unknown current densities in the integral equation [6].

Numerical results based on Method of Moments of reflection coefficient and standing wave ratio (SWR) as a function of probe lengths is presented in the Fig.4. First, the length of feed probe is varied from $0.11\lambda_g$ to $0.25\lambda_g$, at the operating frequency of 2.4GHz. From Fig.4.a. the optimum SWR of 1.62 is realised when the length of feed probe is $0.14\lambda_g$, corresponding the level of reflection coefficient of -12.5dB. Furthermore, for this optimum value of length of feed probe, the length of dividing probes is also varied from $0.11\lambda_g$ to $0.25\lambda_g$. The best of SWR of 1.28 is occurred when the length of probes is $0.12\lambda_g$, the level of level of reflection coefficient of -18dB (Fig.4.b). These optimum values of probe lengths are used as the design parameter. In all calculations based on the applying of Meted of Moments the linear electric probes are considered to be perfect electric conductor and the thickness is negligible [6].



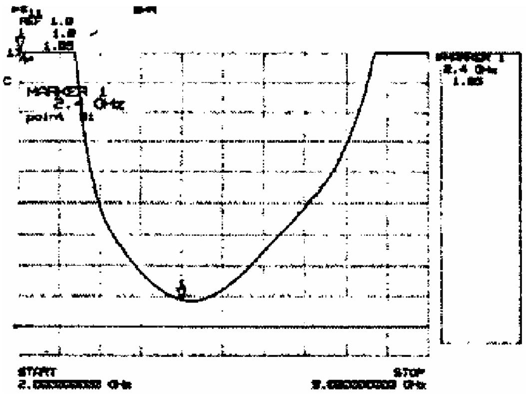
a)

b)

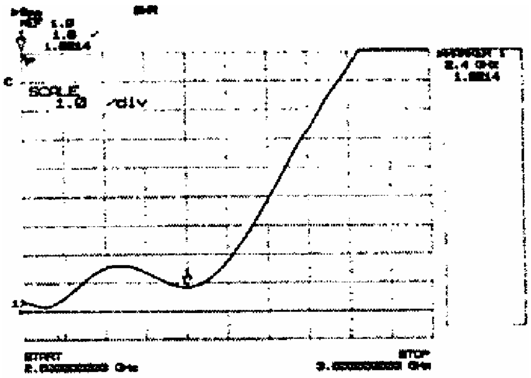
Fig. 4. SWR and reflection coefficient obtained using Method of Moments for: a) feed probe b) dividing probe

IV. Experiment

The prototype of power divider is designed based on TM mode excitation in conducting cylindrical cavity and the length of probes are chosen according to optimum condition as specified is previous section [6]. The Fig 5. illustrates measured SWR of feed probe and dividing probe. Optimum value of SWR on the operating frequency is 1.85 for feed probe, and 1.82 for dividing probe.



a)



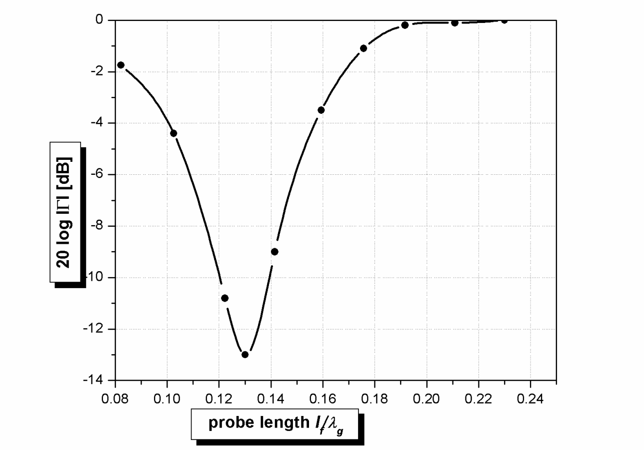
b)

Fig. 5. Measured SWR for:
a) feed probe b) dividing probe

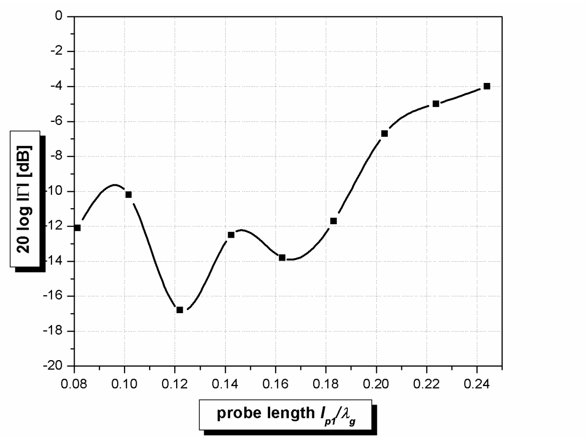
V. TLM NUMERICAL ANALYSIS

The power divider configuration shown in Fig 1 are analysed using 3D TLM software in order to investigate possibilities of TLM method for modelling of power divider structure with excitation in the form of wire probe loaded in the cavity and four dividing probes. Dimensions of the modelled cavity are $2r$=9.25cm and c=7.25cm. For cavity modelling, a non-uniform rectangular TLM mesh was used. The feed and dividing probes are modeled through TLM wire node. The radius of probes are chosen to be r_w =0.5mm, while length is varied to follow the results based on Method of Moments described in previous section.

The numerical results, which illustrate the effect of the feed probe and its length to the reflection coefficient, are presented in the Fig.6.a. The feed probe is used as a receiving probe as well, for resonant frequency detection from the reflection coefficient. From Fig.6.a the level of reflection coefficient of -13dB is realised when the length of feed probe is $0.13\lambda_g$. Corresponding SWR for the level of reflection coefficient of -13dB is 1.58. These results are slightly different from numerical ones based on Method of Moments.



a)



b)

Fig. 6. SWR and reflection coefficient obtained using TLM Method for: a) feed probe b) dividing probe

Furthermore, as in the case of Method of Moments, for this optimum value of length of feed probe, the length of dividing probes is also varied in the same range. The numerical results of power dividing probes are similar for all the probes since the structure of conducting cylindrical cavity is symmetrical. Results, which illustrate the effect of the dividing probe p_1 and its length to the reflection coefficient, are presented in the Fig.6.b. The best level of reflection coefficient of -16.8dB is occurred when the length of probes is $0.12\lambda_g$. Corresponding value of SWR is 1.34.

VI. CONCLUSION

This paper proposes an analysis of characteristics of power divider using linear electric probes inside conducting cylindrical cavity. The power divider configuration with one feed and four dividing probes are analysed by using 3D TLM approach including the wire node for probes modelling. 3D TLM software is applied to study effects of the feed probe and power dividing probes for determining the maximum power transfer for practical applications. The TLM nunerical results of reflection coeficient and standing wave ratio (SWR) of feed probe and dividing probes for various probe length are compared with results obtained using Method of Moments and good agreement has ben achieved. Comparing numerical results with experimantal ones, it has been shown that the application of the TLM method, in comparison with Method of Moments, is more convenient for power divider modelling because alows modelling of wire structures with real thickness.

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