A NEW MODAL APPROACH FOR PLANAR TRANSMISSION LINE TO WAVEGUIDE THREE-PORT TRANSITION

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ABSTRACT

A new modal approach for deriving the admittance matrix of a waveguide to planar transmission line probe transition is presented. The proposed rigorous formulation considerably reduce computation time compared with finite elements method. The junction was fabricated and measured in the case of a waveguide to microstrip line probe transition. Numerical and experimental results are compared with success.

INTRODUCTION

Planar transmission line to waveguide transitions are very useful for circulators, multipliers and particularly for high frequency waveguide mixers [1]-[3]. In these mixers, the RF and LO signals are applied through separate waveguide inputs and are coupled to a transmission planar line.
The available approaches in the literature are experimental investigations [4]-[6] and approximate models which only take into account the effects of probe's lenght and short position and concern particular geometries. Very few rigorous studies [7]-[8] similar to finite elements methods are not suitable since they are too much computation time consuming and give approximate results.
In this paper, a multimodal approach for deriving the admittance matrix of this multiaxial structure (Fig.1.) is proposed [9].
This new approach is based on symmetry considerations and, from the introduction of a particular field excitation source, considers the three-port structure as a simple uniaxial discontinuity. Next, a specific coupling network is elaborated in order to deduce the admittance matrix of the three-port transition. Metallic and dielectric losses are neglected in the formulation.

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FORMULATION

The stucture under study presents a plane of symmetry denoted S in figure 1. By considering perfectly conductive boundary conditions (PCBC) or perfectly magnetic boundary condition (PMBC) on this symmetry plane, only half of the transition can be considered and two configurations are to be studied.

"PCBC on S"

The fundamental mode in the shielded microstrip line can not exist : port 2 is short-circuited. By neglecting the influence of the dielectric substrate in the waveguide, one ends up with the calculation of the normalized input admittance [10] of the waveguide which is shortcircuited at a distance g from port 1 (Fig.2.) :

$$y_1 = \coth(j\beta g) \text{ with } \beta = \sqrt{k_0^2 - (\frac{\pi}{L})^2} \text{ and } k_0 = \frac{2\pi f}{c}$$

where f and c designate the frequency and the light velocity respectively, L is the width of the waveguide and $\mathbf{g} = \frac{\mathbf{a}}{2}$.

"PMBC on S"

A field source denoted e_{01} (tranverse electric field of the TE_{10}-mode of a waveguide with small height δ and width L) is connected far enough away from port 1 so as not to disturb the field in this port (Fig.3.).
The structure can be viewed as cascaded uniaxial discontinuities along z axis, consequently a multimodal approach is applied for deriving admittance matrix seen by e_{01} and port 2. The equivalent circuit of the structure is given in figure 4. Let denote guide I the shielded microstrip-line with smaller transverse section surface. In this equivalent circuit:

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- E_2 and J_2 are respectively transverse electric field of hybrid fundamental mode of guide I and transverse current density at port 2.
- E_1 and J_1 are respectively transverse electric field of excitation source e_{01} and transverse current density.
- $\hat{Y}^1_{ij}, \hat{Y}^2_{ij}$, (i, j =1, 2) are admittance operators of respectively lenghts x_1 and x_2 of guide II (see figure 4).
- E_e is the transverse electric field and J current density of the discontinuity plane.

We then proceed as following:

- First propagation constants of hybrid modes in each guide I and II are calculated by classical approach [11].
- Integral equations obtained by Kirchhoff's laws from the equivalent circuit are transformed into a linear matrix system by Galerkin procdure.
- The boundary condition verified by the current density J on the dielectric part of the discontinuity plane is then written: J= 0.
- The admittance matrix between e_{01} and port 2 is deduced.

Next a two-port network is elaborated [9] to deduce admittance matrix between port 1 and 2 from the preceding one. An equivalent circuit of the two-port network is shown in figures 5a and 5b. In this circuit I_0, V_0 denote mode current and voltage associated with source e_{01}; I'_0, V'_0 denote mode current and voltage associated with TE_{10}-mode at Π_1 -plane. Y and Z are associated with the energy stored by higher-order evanescent modes in the vicinity of the source e_{01}.

Finally admittance matrix of the multiaxial transition is deduced from the contribution of the two configurations : PCBC on S and PMBC on S.

RESULTS

The waveguide of the three-port structure (Fig.1.) has a finite lenght denoted A (A=150 mm). The structure has been fabricated and measurements were performed with a Wiltron 360 network Analyser in Electronic Laboratory of Matra Marconi Space. Its dimensions are L=28.4 mm, h=6.25mm, g=2.25 mm, a=l=4.5mm. Rectangular waveguide cross-section dimensions are (150 mm*28.4 mm). A substrate with a thickness of 0.8 mm and relative permittivity of 2.5 is used. Strip width is 2.3 mm this ensures a characteristic impedance of 50 ohms of the shielded microstrip-line.

Numerical data are obtained for a probe with a lenght of 6.73 mm and for different short positions along the input facing port 3 (Fig.7.). The sliding short in the test structure is used to optimize the transition bandwidth.

Computed results are obtained by taking a height δ of the small waveguide (related to the excitation source e_{01} introduced in the waveguide) such as $\delta = \frac{\lambda_g}{12}$ (λ_g designates guide wavelenght: $\lambda_g = \frac{2\pi}{\beta}$). A good agreement is observed between experimental data and results computed by the proposed theory(Fig.6.).

CONCLUSION

Waveguide to planar transmission line probe transitions have been analyzed by using a new multimodal approach and by taking measurements. This original multimodal approach was chosen for its reduced numerical cost and memory size in analyzing this complex structure. It is based on symmetry considerations and introduction of an original field excitation source in waveguide. The transition was fabricated and measured in the case of a microstrip line to waveguide transition. Good agreement was obtained between the measurements and the present rigorous theory which allows to characterize insertion losses, but not dielectric or metallic losses. It is now of interest to study the effect of lenght's probe on the insertion losses.

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REFERENCES

[1] P.H.Siegel, R.J. Dengler, I. Mehdi, J.E. Oswald, W.L. Bishop, T.W. Crowe and R. Mattauch, ″ Measurements on a 215-
Ghz Subharmonically Pumped Waveguide Mixer Using Planar Back-to-Back Air-Bridge Schottky Diodes ″, IEEE Trans. Microwave Theory Tech., vol.41, No 11, p1913-1920, Nov 1993

[2] Neal Erikson, ″High Efficiency Submillimeter Frequency Multipliers″, IEEE Microwave Theory Tech. Symp. Dig., 1990, p.1301-1304.

[3] Eric R. Carslon, Martin V.Schneider and Thomas F. McMaster, ″Subharmonically Pumped Millimeter-Wave Mixers″, IEEE. Trans. Microwave Theory Tech., vol.M.T.T-26, No10, pp706-715, Oct.1978.

[4] Knerr R. H., ″A New Type of Waveguide-to-Stripline Transition ″, IEEE Trans. Microwave Theory Tech., vol.16, No3, p.192, March 1968.
[5] B.Glance and R. Trambarulo, ″A waveguide to Suspended Stripline Transition″, IEEE Trans. Microwave Theory Tech, vol.21,No2, p.117-118, Feb.1973.
[6] Yi-Chi- Shih, Thuy-Nhung Ton, and Long.Bui, ″Waveguide-to-Microstrip Transitions for Millimeter-Wave Applications″, IEEE Microwave Theory Tech. Symp.Dig., 1988 p.473.
[7] Jan Machac, Wolfgang Menzel, ″On the design of waveguide-to-microstrip and waveguide-to-coplanar line transitions ″ in Proc. of 23th European Microwave Conference, Madrid 1993, pp.615-616.
[8] Robert L. Eisenhart and Peter J. Khan, ″Theoretical and Experimental Analysis of a Waveguide Mouting Structure″, IEEE Trans. Microwave Theory Tech, vol.MTT-19, No.8,p.706-719, August 1971.
[9] B. Storer, H. Aubert, M. Favreau, H. Baudrand ″A New Modal Formulation for Planar Transmission Line to Waveguide Transition″ submitted to IEEE MTT.
[10] R.Collin, Field Theory of Guided Waves. New York : IEEE Press, 1991
[11] R.Sorrentino, T.Itoh, ″Transverse Resonance Analysis for Finline Discontinuities ″, IEEE Microwave Theory Tech., vol.MTT-32, n°12,pp 1633-1638, Dec.1984.

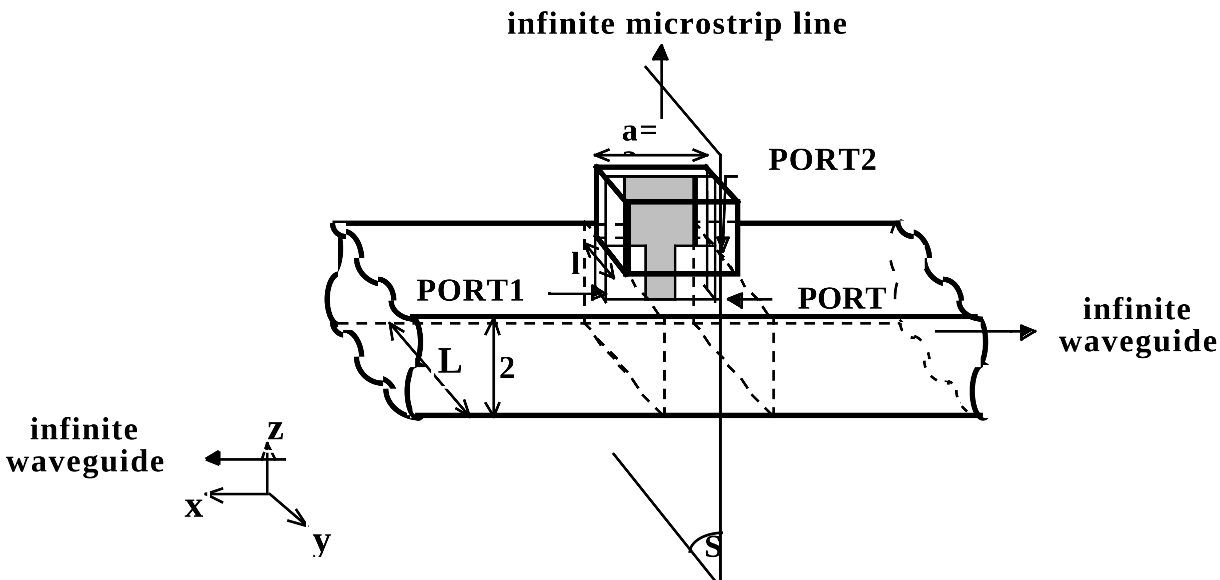

Fig.1. Structure under study

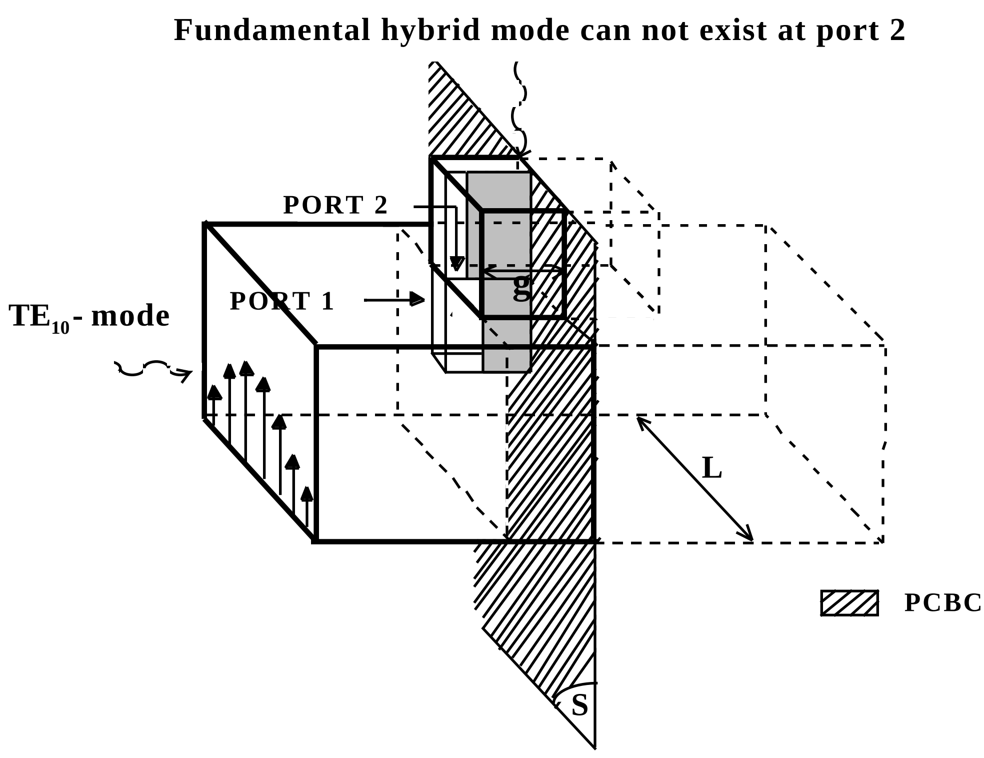

Fig.2. PCBC on S

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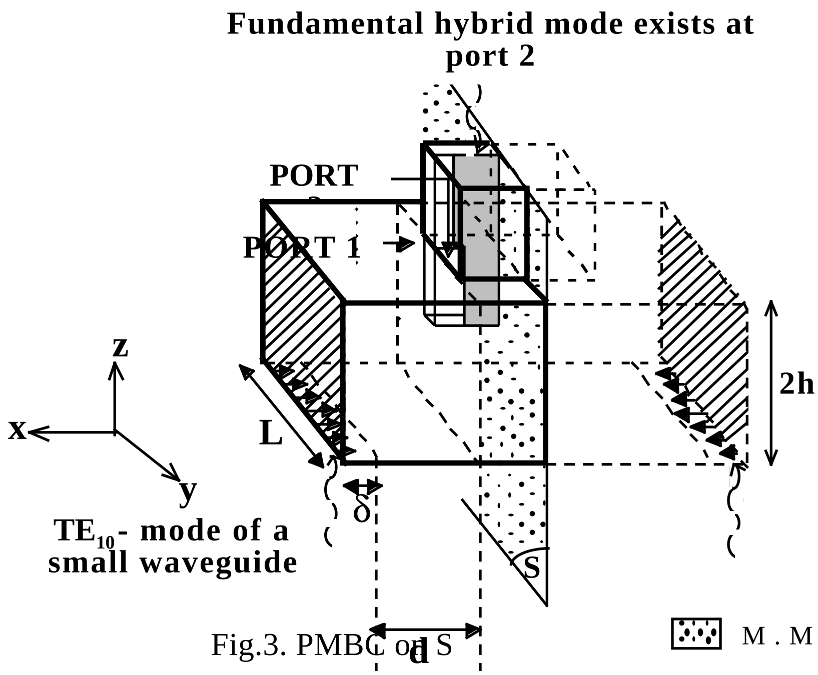

Fig.3. PMBC on S

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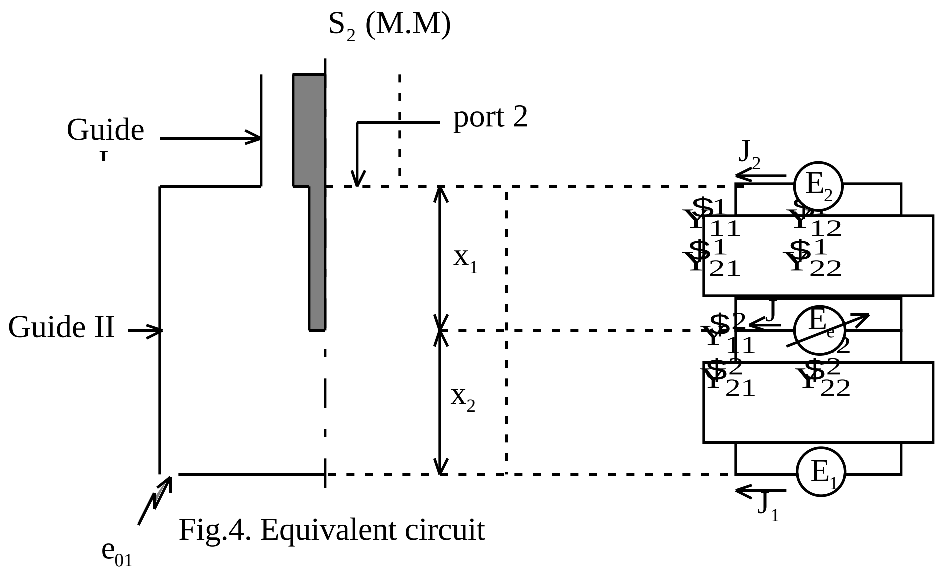

Fig.4. Equivalent circuit

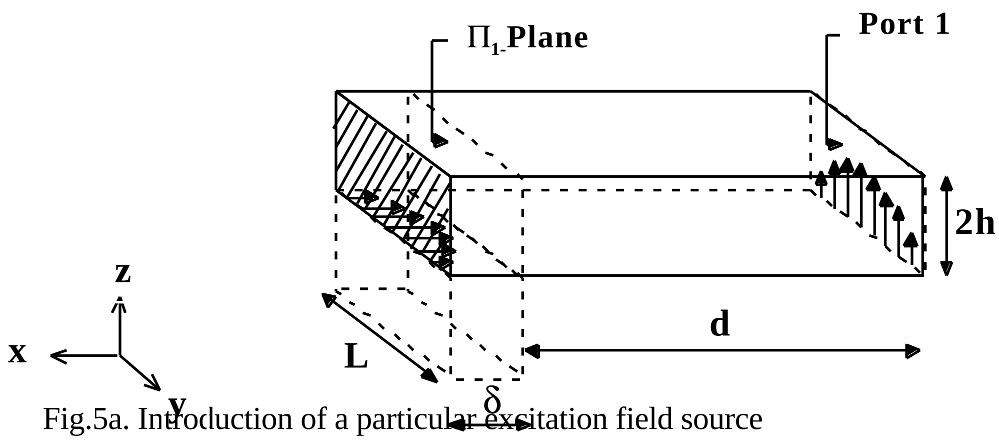

Fig.5a. Introduction of a particular excitation field source

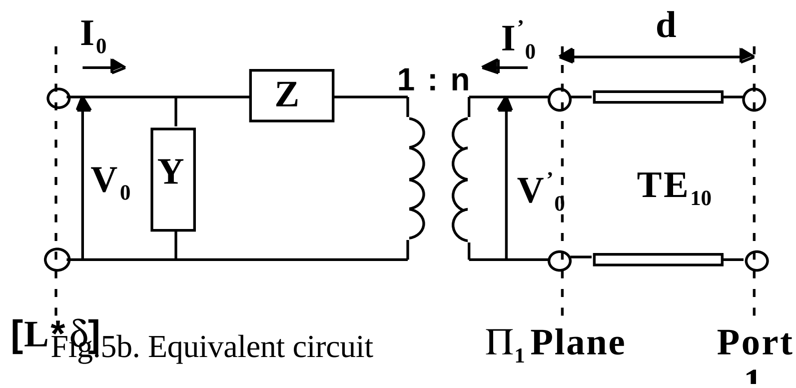

Fig.5b. Equivalent circuit

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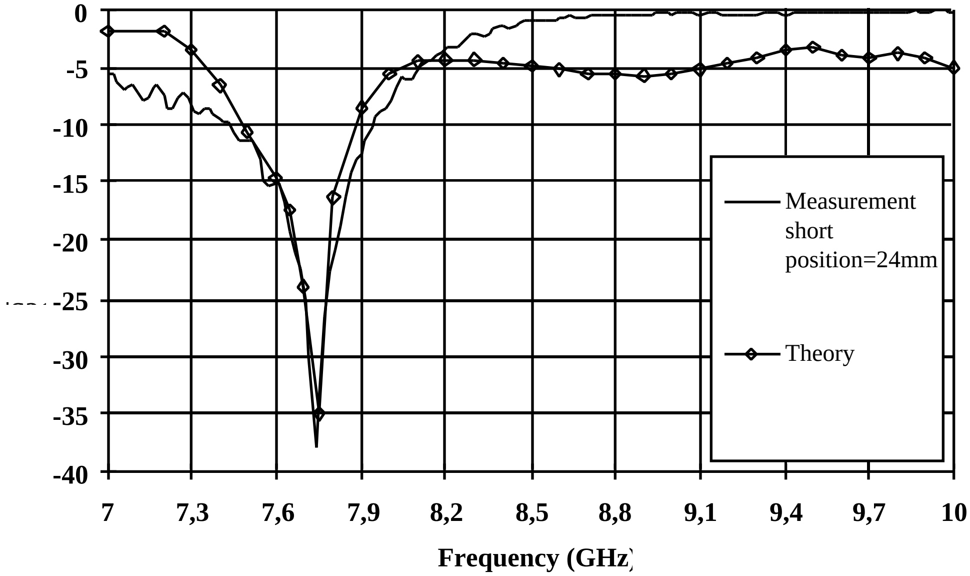

Fig.6. Computed and measured insertion loss in the 7-10 GHz band, strip width in waveguide= 2.3 mm, lenght's probe= 6.73 mm

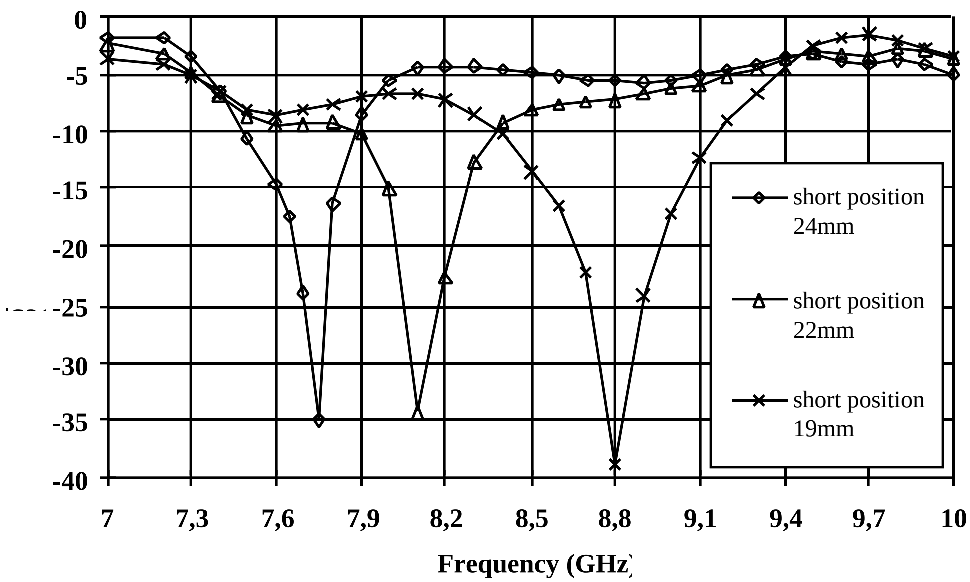

Fig.7. Computed insertion loss in the 7-10 GHz band for different short positions(distance from port3) strip width in waveguide= 2.3 mm, lenght's probe= 6.73 mm

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