ANALYSIS OF BRANCH LINE COUPLER IN SUSPENDED STRIPLINE WITH FINITE METALLIZATION THICKNESS

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Abstract

An efficient analysis of branch line coupler in suspended stripline technology is described. The finite metallization thickness of the stripline is fully accounted for by a rigorous full-wave technique. This is based on an improvement of the transverse resonance technique (TRT), which allows a resonator of fixed dimension to be considered. In this manner all the advantages of the TRT are kept (no complex modal spectra to be computed), while repeated field analyses to search for the resonant dimensions of the structure are avoided. The theory has been checked successfully against both experiments and theoretical results based on different numerical methods.

1. Introduction

In the current feed networks for C-Band contoured beam antennas, the dominant technology is based on Square-Coaxial Line (TEM-line) technique [1]. While featuring low loss, relatively simple manufacturing and good electrical performance, the mass of a complex beam forming network manufactured in the TEM-line technology accounts for a significant part of the mass of the complete antenna system. An alternative to the TEM-line technology is the Suspended Stripline (SS) (or Air-Stripline) technology [2]. The loss factor for this type of transmission line is only slightly higher than that of the TEM-line, (tipically 0.3 dB/m at 4 GHz for copper-plated aluminium). The manufacturing of a BFN in the suspended stripline technology employs photo-etching techniques, thus it is much more cost efficient than the fabrication of TEM-line BFN's. The main advantage, however, is the mass reduction of the BFN realized in the suspended stripline technology. Since many of contoured beam antennas require very complex power division networks, the number of components constituting such a BFN is large (e.g. 70-100 hybrid couplers per BFN). The mass savings through the application of the suspended stripline technology instead of the TEM-line are substantial. As opposed to the TEM-line technique, tuning and trimming of components realized in the suspended stripline technology is very difficult. Therefore, the design of the Air-Stripline components should be performed with high accuracy. To this time no comprehensive approach to the full-wave analysis of suspended stripline components has been attempted. This paper presents a formulation based on a recent improvement of the Transverse Resonance Method, i.e. the Impressed Source Technique. The numerical efficiency and the computational accuracy achieved with this method is sufficient to select it as an appropriate design tool for suspended stripline components.

2. Method of analysis

The schematic of the symmetrical suspended stripline is shown in Fig. 1a. After using symmetry and taking into account the enclosing metallic box, the guiding structure becomes that sketched in Fig. 1b, i.e. essentially a (very thick) microstrip line. A branch line coupler in symmetrical suspended stripline technology is shown in Fig. 2a (top view). The device is composed by four T-junctions. In order to achieve the required impedance levels the different branches of the T-junctions have different widths.

Because of symmetry considerations, the structure to be analyzed reduces to that of Fig. 2b, where the walls on the right hand side are either electric or magnetic. To characterize the branch line coupler of Fig. 2a, the analysis of the structure of Fig. 2b has to be repeated four times using the four possible arrangements for the electric/magnetic walls corresponding to even/odd excitations. Since the analysis technique is the same for all cases, let us refer to just one particular example.

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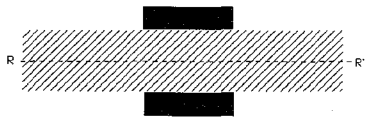

Fig. 1a Cross section of the Suspended Symmetric Stripline.

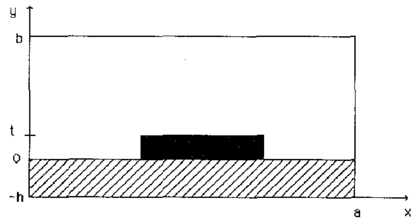

Fig. 1b .Geometry of the boxed suspended stripline after replacing the symmetry plane RR' of Fig. 1a with a metallic wall.

With reference to Fig. 2b it is evident that it is possible to divide our structure into five different regions. Three of them, hereafter denoted as region A, B, and C, are aside the metallic strip; one more region is above the strip (D), and the last one is below the strip (E). Note that all regions are homogeneous, the last one (E) being filled with dielectric. By looking in the z-direction the structure can be seen as a cascade of waveguide sections. All have a rectangular cross-section, except that corresponding to region A which has an L-shaped cross-section. In any case the modes of all waveguides can be easily calculated and, since the waveguides are homogeneous, are independent of frequency.

The application of the mode matching technique to the cascade of waveguides leads to the analysis of the generalized equivalent circuit of Fig. 3 (do not consider for the moment the generator). Each multiport network represents a waveguide section, each port being associated to a mode propagating in one of the central waveguides corresponding to regions A, B, and C. As shown in [3], the admittance matrices are calculated without any matrix inversion and consequently they represent a particularly useful representation for the equivalent circuits.

We can now look for solutions of the above network without the generator. These solutions correspond to resonance conditions and, as such, depend on both the frequency and the cavity dimensions. The parameters of the discontinuity can be extracted using the transverse resonance technique [4,5]. In this case at each frequency point repeated field analyses are performed until the resonant dimensions of the enclosing cavity are found. Notwithstanding the advantage of working with homogeneous regions, and thus with frequency-independent modal spectra, each variation of the cavity size requires a new computation of the modal spectra.

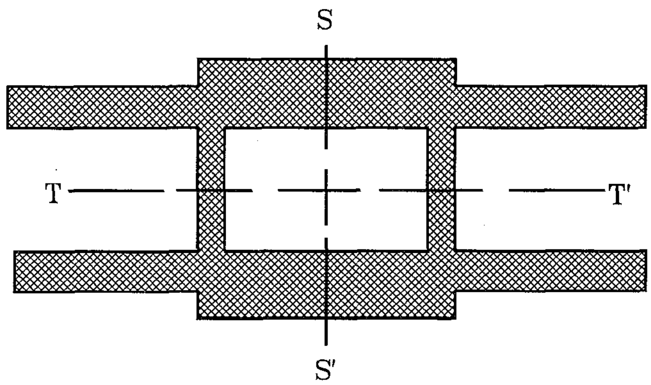

Fig. 2a.Geometry of the branch-line coupler. Symmetry planes SS', TT' can be replaced by electric or magnetic walls

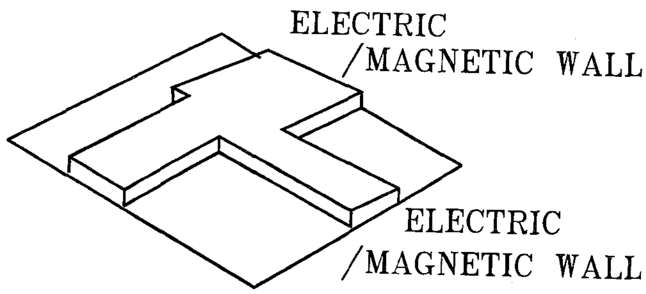

Fig. 2b. Reduced geometry of Fig. 2a after accounting for symmetry.

To reduce the numerical effort, we have applied the Impressed Source Technique (IST) [6]. We consider an aperture produced on the cavity walls, and the cavity feeded by this aperture. This is equivalent to impress a magnetic current source (and therefore a generator) on the cavity wall. In term of the generalized network representation the aperture corresponds to a set of additional ports, where voltage generators, each for one waveguide mode, represent the impressed source. This is shown schematically in Fig. 3. Further details on the IST can be found in [6]. The main advantages of the IST are:

i) only one field analysis is sufficient to determine the unknown complex parameter (e.g. S_{21}) of the discontinuity;

ii) since the enclosing cavity has fixed dimensions, it can be used to simulate the actual package, thus closely modeling the actual operating conditions and accounting for possible package interaction.

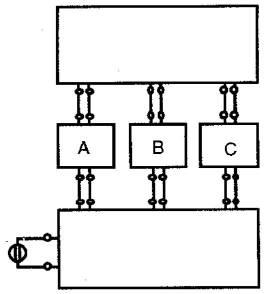

Fig. 3. Equivalent network of Fig. 2b.

Other theoretical simulations using Finite Difference Time Domain and Finite Element techniques have also shown (Fig.4c) a substantially good agreement but at the price of a much higher computational effort.

3. Results

A computer code has been developed according to the previous theory for the analysis of branch line couplers in suspended stripline. The code has been tested against other theories as well as experimental results.

Fig. 4 a shows the geometry of a branch-line coupler fabricated in SS technology. The metallization thickness of the stripline is 0.1 mm, the substrate thickness is 1.016 mm and the dielectric constant is ε_r=3.25. A very good agreement between theory and experiments has been obtained, as shown in Fig. 4b.

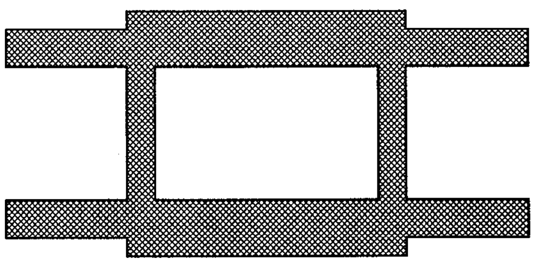

Fig. 4a. Layout of the branch line coupler realized in symmetrical suspended stripline with metallization thickness of 0.1 mm

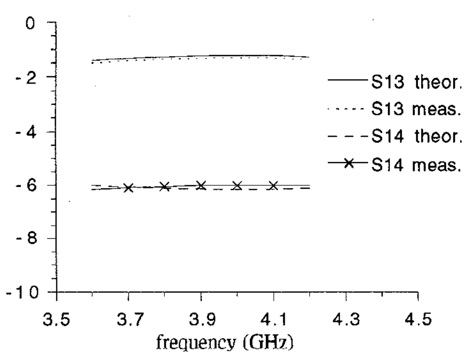

Fig. 4(b) Transmission scattering parameters of the branch-line coupler of Fig. 4a

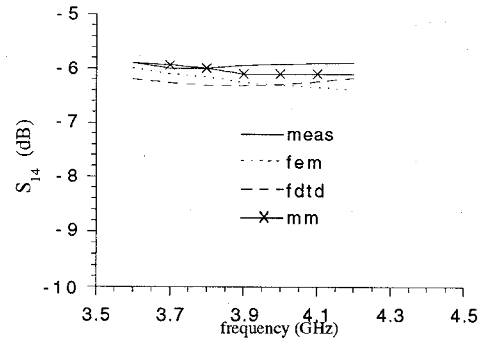

Fig. 4c Comparison of measured data and theoretical simulations using Finite Difference Time Domain(fdtd), Finite Element method (fem) and the present (mm) technique

4 Conclusions

A procedure has been presented for the efficient analysis of branch line couplers realized on symmetrical suspended striplines with thick metallization. The procedure is based on an improvement of the transverse resonance technique (TRT), the so-called impressed source technique (IST), which allows a resonator of fixed dimension to be considered In this manner all the advantages of TRT are kept (no complex modal spectra to be computed), while repeated field analysis to search for the resonant dimensions of the structure are avoided. The theory has been checked successfully against both experiments as well theoretical results based on different numerical methods.

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