Slit-Coupled Ridge Waveguide T-Junctions

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Abstract— **The slit-coupled ridge waveguide T-junction is introduced and modeled using the single-port mode matching technique. The three-port scattering matrix of the T-junction is obtained from nine reflection coefficient computations at the perpendicular arm. Dependance of S-parameters on the slit thickness and width is given. Ridge T-junctions are analyzed as a special case of slit-coupled ridge T-junction and the computed S-parameters are in good agreement with available results.**

I. Introduction

WAVEGUIDE T-junctions play an important role in designing microwave circuits, such as multiplexers used in modern communication systems [1]. Several configurations of the T-junctions can satisfy different specifications. Slit-coupled T-junctions allow the control of the power division between the straight arm and perpendicular arm without having to decrease the width of the perpendicular arm. A recent closed form expression of equivalent network for that T-junction was given in [2]. Ridge waveguide T-junction was proposed [3] for very wide bandwidth applications. It is known that inserting a ridge in an empty guide lowers its cutoff frequency [4] and consequently for the same dimensions of an empty and ridge guide the later will have a wider bandwidth. The drawbacks for using ridge waveguide T-junction is that the structure would be difficult to design for matched input, in addition the power handling capability is reduced.

In this paper we introduce the slit-coupled ridge waveguide T-junction shown in Fig. 1, where we combine advantages of both the ridge and the slit T-junctions. The T-junction is modeled using the single-port mode matching technique SPMMT [5]. Looking at the structure from the top (port 2 with ports 1 and 3 short circuited) we see four cascaded waveguides A, B, C and D. The first three guides are regular waveguides while guide D is a bifurcated guide with a septum of finite thickness. Following [5] in the analysis procedure we evaluate the three-port scattering parameters by computing the reflection coefficients in port 2.

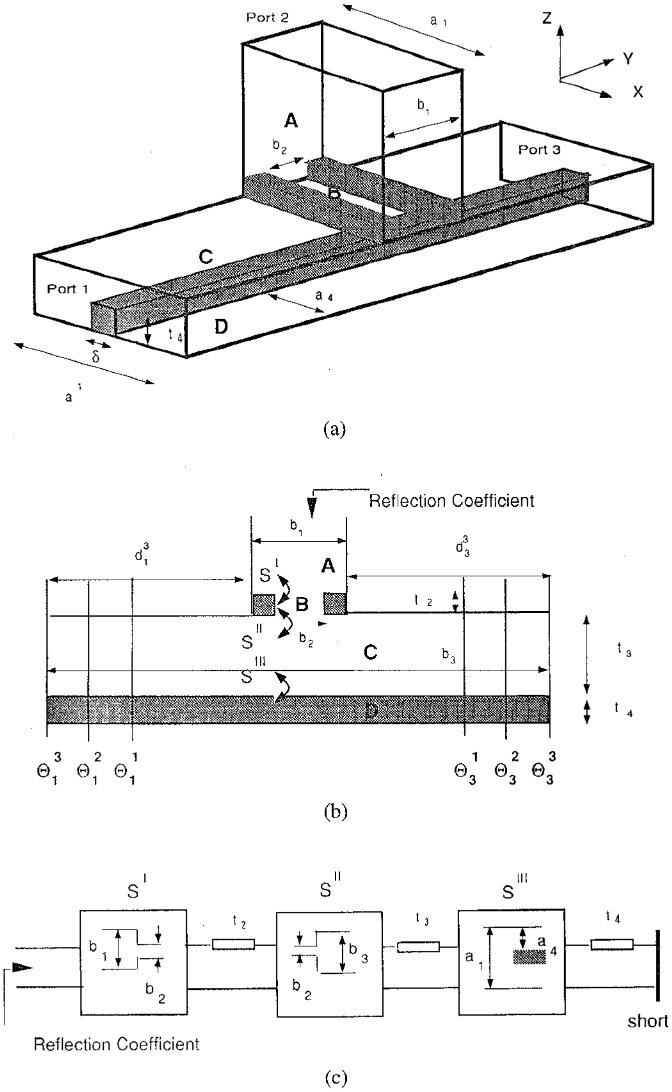

Fig. 1. (a) Slit coupled ridge T-junction, (b) cross-sectional view, (c) equivalent scattering parameter network.

II. Modeling Method and Numerical Results

When ports 1 and 3 are short circuited, the slit-coupled ridge T-junction shown in Fig. 1, is a one port network of four cascaded waveguides A, B, C, and D. Guide A has dimensions $a_1 \times b_1$, guide B has dimensions $a_1 \times b_2$ and length t_2, guide C has dimensions $a_1 \times b_3$ and length t_3 and finally guide D is a bifurcated guide with a septum of finite thickness δ that divides the guide into two halves each has dimensions $a_4 \times b_4$ and length t_4. The reflection coefficient at port 2 is evaluated by assuming a TE_{10} mode incident from region A, expanding the field in terms of waveguide modes of regions A, B, C and D and then matching the transverse fields at the three discontinuities between (A and B), (B and C) and (C and D). The corresponding modal scattering parameter network is given in Fig. 1(c) where the two modal scattering parameter networks S^{I} and S^{II} represent the two junction discontinuities between (A and B) and (B and C) while the modal scattering parameter S^{III} represents the discontinuity from guide C to the bifurcated guide D. The latter discontinuity is analyzed following [6]. By cascading the three networks with the three waveguide lengths t_2, t_3 and t_4 and introducing a short at the output, the reflection coefficient at port 2 is calculated. Although the first two

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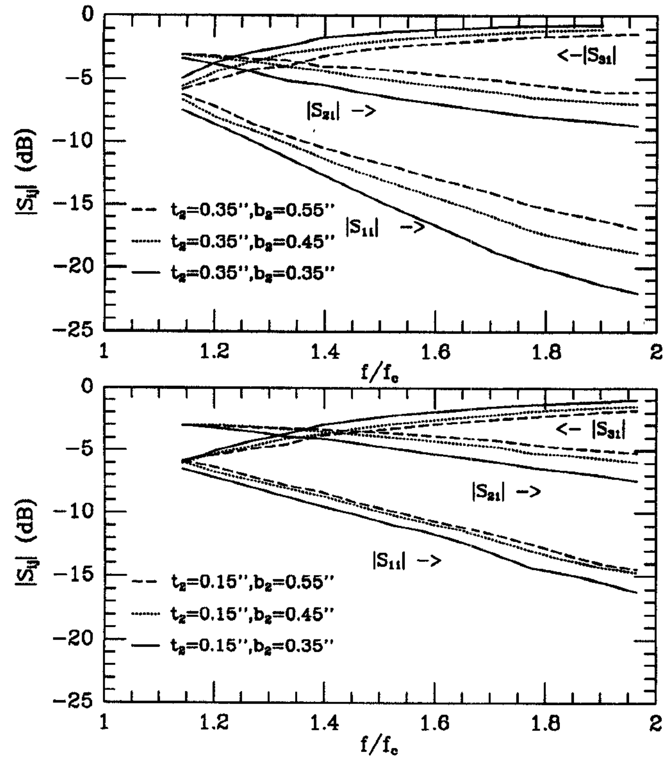

Fig. 2. Computed S-parameters S_{11}, S_{21} and S_{31} of the T-junction as function of frequency with t_2 and b_2 as parameters and $a_1 = 1.872''$, $b_1 = 0.872''$, $t_3 = 0.4''$, $t_4 = 0.472''$, and $a_4 = 0.856''$.

discontinuities are in the y-direction (b changes, a is the same) and the third discontinuity is in the x-direction (a changes, b is the same), each has to be treated as a two dimension problem to take into account all the higher order modes interaction resulting from the cascading of the scattering parameters.

The 3-port scattering parameters of the network can be determined in two steps following [5]. The first step is to get three two-port scattering parameters from nine one port scattering parameters. Then the complete three-port scattering parameters is deduced from that of the three two-port parameters. The width $b_3 = b_1 + d_1^\ell + d_3^i$ where $d_1^\ell, d_3^i, \ell, i = 1, 2, 3$ are the distances from the short as shown in Fig. 1(b). As in [5] the phases $\theta_1^\ell = -2\beta_1 d_1^\ell + \pi$ and $\theta_3^i = -2\beta_3 d_3^i + \pi$, $\ell, i = 1, 2, 3$ where β_1 and β_3 are the propagation constants of the fundamental mode of a ridge wave guide (β_1 and β_3 are equal because of the symmetry of the structure). The distances d_1^ℓ and d_3^i should be long enough (at least equal to $\frac{a_1}{2}$) so that the ridge first higher order mode would decay by a factor of 20 from the vicinity of the T-junction and does not interact with the short circuit.

The main advantage of this technique is that only the fundamental mode of the ridge waveguide needs to be found, and the evaluation of the higher order modes of the ridge are not needed, unlike [3] when using the three plane mode matching technique (TPMMT).

A computer program was developed based on the above model and tested for convergence. Since the discontinuities in this T-junction is two dimensional the S-parameters computations are more complicated. The choice of the number of modes in regions A, B, C and D in Fig. 1 is dependent on the ratio of dimensions [7]. Convergence test of the reflection coefficient on the the shorted T-junction was carried out by varying the N_{xC} and N_{yC} (the mode indices in region C in the x and y direction respectively). The ridge T-junction is a special case of the slit-coupled ridge T-junction in which $b_2 = b_1$. The $[S]$ parameters calculated from this method and [8], are in well agreement both in magnitude and phase.

Fig. 2 shows the effect of slit thickness and width on the S-parameters of the T-junction, where the S-parameters are computed as a function of frequency with b_2 and t_2 as parameters. As the width of the slit b_2 at port 2 is reduced, the reflection coefficient in port 1 decreases, while the transmission to ports 2 and 3 from port 1 become more frequency sensitive and unequal. The slit thickness however have an opposite effect on the S-parameters, decreasing the slit thickness t_2 increases the reflection coefficient at port 1 and S_{21} and S_{31} become less frequency dependent and more equal. At high frequency $\frac{f}{f_c}$ greater than 1.7, the reflection at port 1 is less than 20 dB for narrow slit width $b_2 = 0.35''$ and for $t_2 = 0.35''$. The slit coupled ridge T-junction therefore gives the low reflection property of the ridge T-junction without having to decrease the width of the perpendicular arm and thus combines advantages of both the ridge and the slit T-junctions. Controlling both the slit width and thickness in addition to the main arm dimension can provide freedom for designing almost any T-junction for diplexer application.

III. Conclusion

A new structure the slit coupled ridge waveguide T-junction is introduced and modeled. The single-port mode matching technique is used to obtain the scattering parameters for that structure. Comparison between $[S]$ parameters of a ridge T-junction calculated from that method and the three plane mode matching technique (TPMMT) is performed and excellent agreement was found. Dependance of T-junction S-parameters on the slit thickness and width is calculated showing the flexibility of the structure for diplexer application.

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