GENERALIZED SLOT COUPLED COMBLINE FILTERS

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ABSTRACT

The resonant frequency and the slot coupling of combline cavities are analyzed by a rigorous method. The validation and accuracy of the method are confirmed by comparing the numerical results with measured data. It is shown how to achieve both capacitive and inductive coupling and how to realize generalized slot coupled combline filters, with finite transmission zeros. A 6-pole slot coupled combline filter with asymmetrical transmission zeros is designed and tested. Excellent filter response is obtained.

I. INTRODUCTION

With rapid development of mobile communications, the requirement for compact, low-cost, and high performance filters is increasing. One class of filters with these merits is combline filters.

The conventional combline filter consists of a set of metal bars, properly spaced, grounded at one end and loaded by lumped capacitors or open circuit at the other side [1]. The synthesis and design procedures for this kind of filters were studied intensively [1-6]. The comblines are viewed as coupled TEM mode transmission lines. By increasing the electrical length of the resonators, selectivity on the high side of the pass band increases but decreases on the low side.

In some cases, for instance, in design of a combline filter with narrow bandwidth or with transmission zeros to improve the selectivity, irises between resonators may be used. The irises control the couplings which could be magnetic or electric. Some expermental results of slot coupling between 90° combline resonators are shown in [7]. However,there are no accurate modeling of the coupling in the literature.

In this paper, a rigorous method similar to that in [8] and [9] is applied to calculate the resonant frequencies and the slot coupling coefficients of combline cavities. The validation and accuracy of this method is confirmed by comparing the numerical results with the experimental results. As an application, a 6-pole slot coupled combline filter with finite transmission zeros and asymmetric insertion loss response is designed, built, and tested. Excellent filter response is obtained.

II. MODELING OF SLOT COUPLED COMBLINE CAVITIES

The structure of slot coupled combline cavities under consideration is shown in Fig. 1a. This structure can be modeled as a cascade of two cylindrical metal posts and a slot discontinuity in a rectangular waveguide through sev-

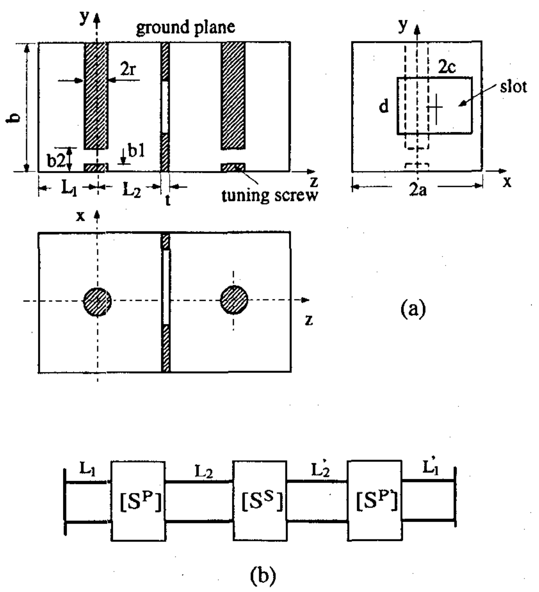

Fig. 1 (a) Configuration of slot coupled combline cavities, (b) S-matrix network representation of the structure eral lengths of the waveguide with the application of the short circuit condition at the two ends (Fig. 1b). The slot discontinuity can be easily modeled by the full wave mode matching technique. Therefore, the key problem of modeling slot coupled combline cavities is to compute the scattering matrix of a cylindrical metal post in a rectangular waveguide $\left[S^P\right]$. To do this, the orthogonal expansion method similar to that used in solving dielectric posts in a rectangular waveguide [8][9] is applied. In this method, an artificial cylindrical boundary at $r = a$ (concentric with the metal post) is introduced. Within the boundary, the radial mode matching method [10] can be used to find the relations among the field coefficients. The fields outside the boundary are linear combinations of the waveguide eigenmodes including both incident and reflected waves. The waveguide eigenmodes are expanded by Bessel-Fourier series. Applying boundary conditions at the artificial boundary and taking proper inner product, one can finally obtain the generalized scattering matrix of the metal post $\left[S^P\right]$.

Once the S-matrices of the posts are known, a cascading procedure of S-matrices [11] may be employed to obtain the eigen equations for the resonant frequencies of a single cavity and slot coupled cavities. When two coupled cavities are identical, PEC and PMC may be used at the symmetrical plane to simplify the coupling computation [12]. Otherwise, a short and an open circuit can be applied at one end of the network successively to obtain two zeros (f_{z1} and f_{z2}) and one pole (f_p) of the transfer function, respectively, from which the coupling coefficient is computed.

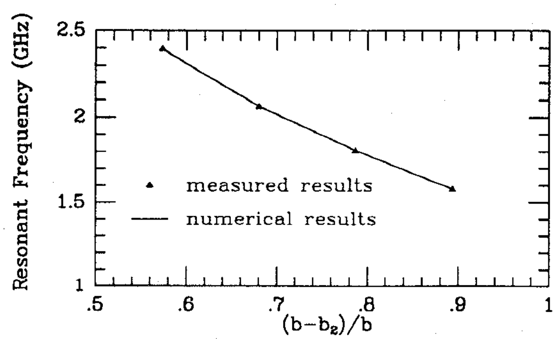

Fig. 2 Resonant frequency of a combline cavity with $2a = 0.872"$, $b = 1.872"$, $r = 0.13"$, $L_1 = L_2 = 0.5"$, and $b_1 = 0.0$

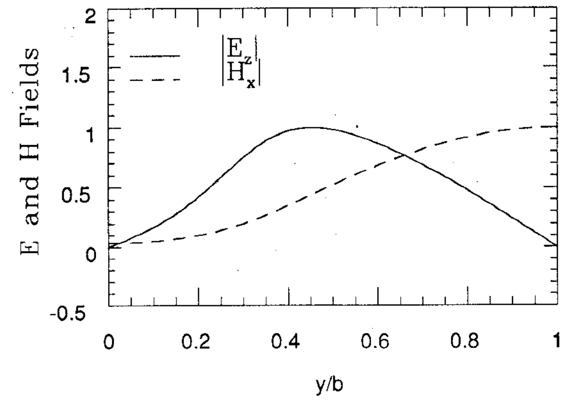

Fig. 3 Field distributions along y at the end wall of a combline cavity with 80^o rod length, the other dimensions same as that in Fig. 2

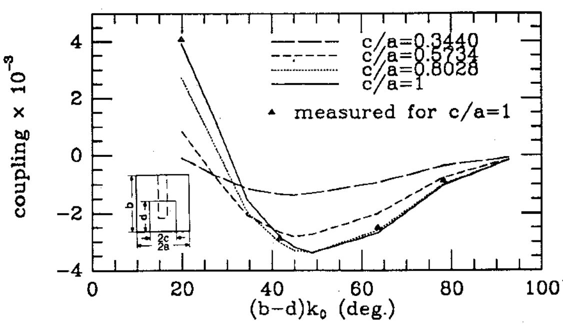

Fig. 4 Slot coupling of two identical combline cavities with slot thickness = 0.052", $b_2 = 0.798"$, the other dimensions same as that in Fig. 2

Fig. 2 shows the numerical and experimental results of the resonant frequencies of a single cavity as a function of the length of the metal rod. Fig. 3 presents the field distributions along y direction at the center of one end wall of a cavity, which indicates where a slot should be located in order to have different coupling. Fig. 4 gives the coupling coefficients of a slot between two identical combline cavities. The figure shows that both magnetic and electric couplings can be realized by changing the dimensions of the slot, but the maximum value of electric coupling is limited. To obtain electric coupling, the length of the metal rod has to be greater than 45^o. Numerical experiments also show that the electric coupling is sensitive to the tuning screw.

III. DESIGN AND REALIZATION OF GENERALIZED SLOT COUPLED COMBLINE FILTER

As an application of the modeling, a 6-pole slot coupled combline filter centered at 915 MHz with 28 MHz bandwidth is designed. The filter is required to meet the specifications of 30 dB rejections beyond 890 MHz and 930 MHz. To satisfy the requirements, a 5-pole Tchebyscheff filter is designed first, then one more resonator is added. By applying the synthesis procedure introduced in [13] in conjunction with optimization, the following coupling matrix to be realized is obtained

$$M = \begin{bmatrix} 0.025 & 0.773 & 0.0 & -0.12 & 0.0 & 0.0 \\ 0.773 & 0.0 & 0.536 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.536 & -0.03 & -0.042 & 0.528 & 0.0 \\ -0.12 & 0.0 & -0.042 & 1.007 & 0.0 & 0.210 \\ 0.0 & 0.0 & 0.528 & 0.0 & 0.0 & 0.767 \\ 0.0 & 0.0 & 0.0 & 0.21 & 0.767 & 0.075 \end{bmatrix}$$

$$R_1 = 0.949, \quad R_6 = 1.002$$

The ideal response of the designed filter is given in Fig. 5.

To realize the design by combline cavities, the schematic configuration shown in Fig. 6 is adopted, where cavity 1, 2, 3, 5, and 6 form a Tchebyscheff filter, and cavity 4 is used to provide the transmission zeros at both sides of the pass band. The lengths of resonator rods are selected around 80^o to ensure enough electric couplings. The slot dimensions are determinated by the method described in the last section to give the required couplings for each slot. The designed filter is built and tested. The measured response of the filter is shown in Fig. 7. Fig. 8 presents the measured Tchebyscheff response of the filter when cavity 4 is detuned completely.

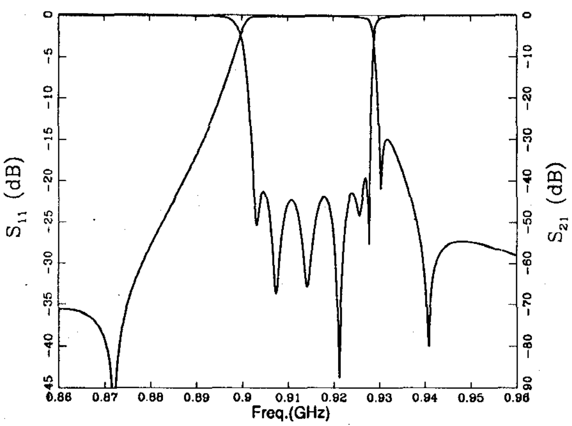

Fig. 5 Ideal response of the designed 6-pole filter

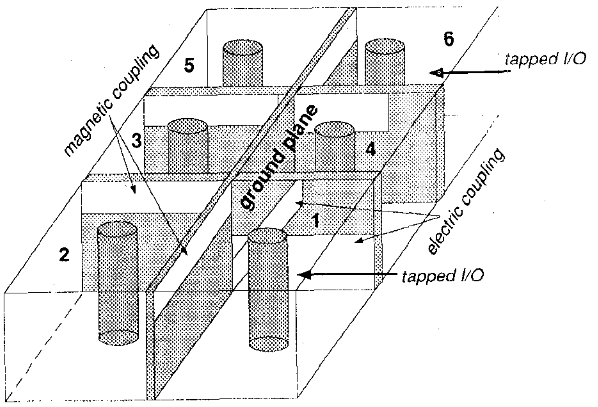

Fig. 6 Schematic configuration of the 6-pole filter realized by slot coupled combline cavities

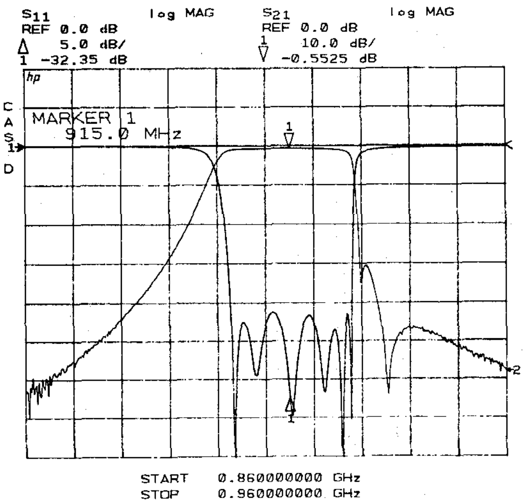

Fig. 7 Measured response of the 6-pole filter

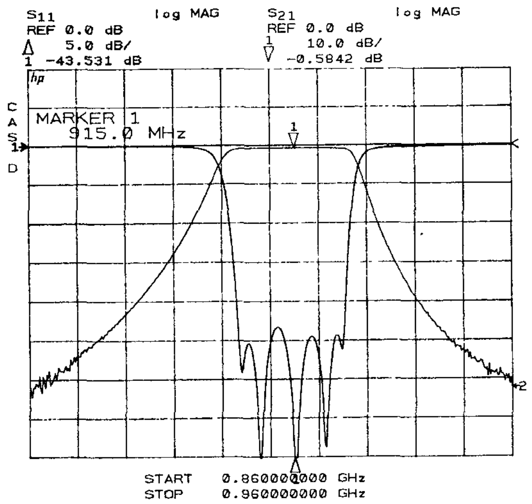

Fig. 8 Measured Tchebyscheff response of the filter when cavity 4 is detuned

IV. CONCLUSION

A rigorous method is applied to model slot coupled combline cavities. Numerical results for both resonant frequency and coupling coefficient of combline cavities agree well with experiment. A 6-pole slot coupled combline filter with asymmetrical transmission zeros is designed and built. Excellent filter responses are obtained.

The modeling methods can be easily applied to analyize the evanescent mode series coupled waveguide filters and waveguide filters using inductive posts.

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