Non Adjacent Resonators Effects on Coupling and Resonant Frequency in Combline Filters

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Abstract— **Resonant frequencies and coupling coefficient between two combline cavities, in the presence of other cavities, are obtained accurately using mode matching technique. The effect of iris dimensions and position on the electric and magnetic coupling is rigorously investigated. The corresponding data for two isolated cavities are included for comparison.**

I. Introduction

The conventional combline filter consists of a set of metal bars, spaced, grounded at one end and loaded by lumped capacitors or open circuited at the other side [1]. To design combline filters with narrow bandwidth, transmission zeros to improve the selectivity, small spacing between resonators to miniaturize the dimensions then irises between resonators are needed. Accurate determination of coupling between two isolated combline cavities has been reported [2], [3], [4]. However, there are no accurate modeling of the coupling between two cavities in the presence of other couplings. In this paper, a rigorous method implemented using mode matching technique is applied to calculate the resonant frequency and the coupling coefficient between two combline cavities in the presence of other couplings.

II. Modeling of Iris Coupled Combline Cavities in the Presence of Other Couplings

The structure of iris coupled combline cavities under consideration is shown in Fig. 1. The structure can be modeled by cascading the building blocks shown in Fig. 2. The generalized scattering parameters of the 4-ports junction (Fig. 2a) $\left[S_4^G\right]$ has been computed using mode matching technique [5]. The generalized scattering matrix of the T-junction $\left[S^T\right]$ and the right angle bend $\left[S^B\right]$ are obtained from $\left[S_4^G\right]$ by placing short circuits at one or two ports respectively. Fig. 3 shows the model of the structure of Fig. 1 using the building blocks of Fig. 2.

In the model shown in Fig. 3, a perfect electric wall (PEW) or perfect magnetic wall (PMW) is placed only between the two combline cavities required to compute their coupling. The other two cavities are detuned off resonance. The two resonant frequencies f_e and f_m (corresponding to PEW and PMW respectively) are computed. The coupling is obtained in terms of f_e and f_m by using (1) [4].

$$k = \frac{f_e^2 - f_m^2}{f_e^2 + f_m^2} \tag{1}$$

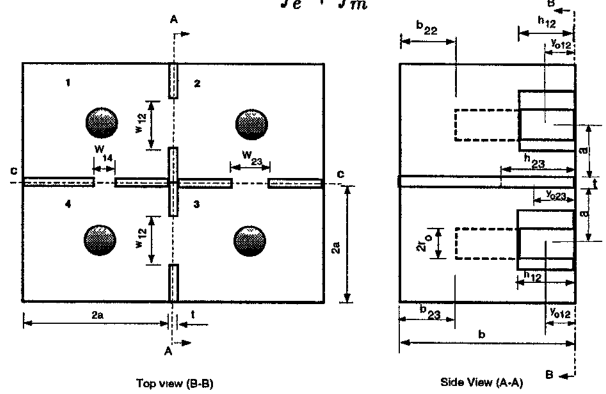

Fig. 1. Top and side views of four combline cavities. Dimensions in this figure: $2a = 0.75''$, $b = 1.315''$, $r_o = 0.115''$, $t = 0.1''$

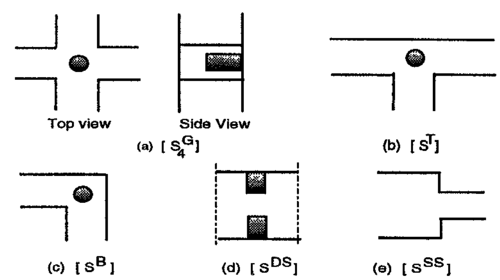

Fig. 2. Building blocks. (a) Four port junction $\left[S_4^G\right]$, (b) T-junction $\left[S^T\right]$, (c) Right angle bend $\left[S^B\right]$, (d) Double step in rectangular waveguide $\left[S^{DS}\right]$, (e) Single step in rectangular Waveguide $\left[S^{SS}\right]$.

III. Numerical Results

A. *Effect of Iris Height on Coupling*

The effect of iris height (h) on the coupling and resonant frequency is investigated. The iris is either placed

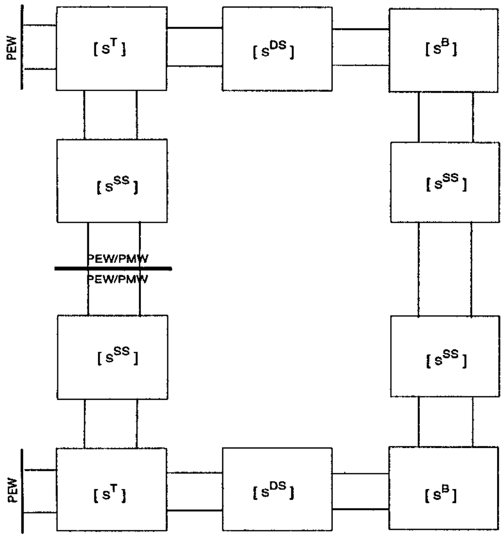

Fig. 3. S-matrix representation of the structure of Fig. 1

at the short circuit end giving the positive coupling (magnetic coupling) or placed at the open end giving the negative coupling (electric coupling). The results obtained from the model proposed in Fig. 3, taking into account the adjacent irises effect, are compared to those obtained for two isolated cavities. Fig. 4 shows the effect of iris height on the positive coupling. The curve shows an increase of the coupling up to a maximum value at $h_{12}/b = 0.395$ then decreases with further increase of height. The figure also shows that the coupling obtained when taking adjacent irises effect is larger in value than the one obtained between two isolated cavities. Fig. 5 gives the variation of resonant frequency with iris height. The resonant frequency is decreasing up to a minimum resonant frequency at $h_{12}/b = 0.395$ and then starts to increase again with further increase of iris height. The figure shows that the loading effect of adjacent irises decreases the resonant frequency by $38.6MHz$ from that of two isolated cavities. In the design of narrow band filters, this shift of resonant frequency must be taken into account. The effect of iris height on the negative coupling is shown in Fig. 6 where the negative coupling increases as the iris height increases. The coupling has its maximum value at $h_{14}/b = 0.513$ and then decreases until it becomes positive coupling at $h_{14}/b = 0.67$. The coupling for two isolated cavities is close to the one obtained when taking adjacent irises effect into account. The corresponding resonant frequency curve is shown in Fig. 7 where the resonant frequency is increasing with the increase of iris height up to a maximum value at $h_{14}/b = 0.557$ then it starts to decrease again. The resonant frequency when taking adjacent couplings effect is reduced by $42.3MHz$ from that between two isolated cavities.

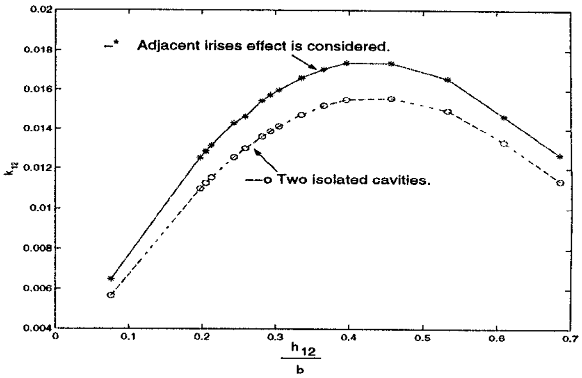

Fig. 4. Effect of iris height on magnetic coupling. Dimensions as in Fig. 1: $b_{22} = 0.3439''$, $W_{12} = 0.435''$, $h_{12} = h_{12}$, $y_{o12} = b - h_{12}/2$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = 0.75''$, $h_{14} = 0.54''$, $y_{o14} = 0.27''$.

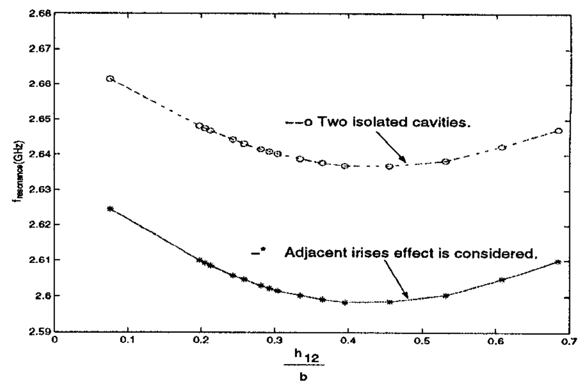

Fig. 5. Effect of iris height on the resonant frequency. Dimensions as in Fig. 1: $b_{22} = 0.3439''$, $W_{12} = 0.435''$, $h_{12} = h_{12}$, $y_{o12} = b - h_{12}/2$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = 0.75''$, $h_{14} = 0.54''$, $y_{o14} = 0.27''$.

B. Effect of Iris Width on Coupling

The results obtained from the accurate model in Fig. 3, taking into account the adjacent irises effects, are compared to those obtained for two isolated cavities. Fig. 8 shows the variation of the magnetic coupling (positive coupling) with iris width. Fig. 9 shows the variation of the resonant frequency versus iris width. The loading effect when taken into account shows a difference of $40MHz$ from that of two isolated cavities. Fig. 10 shows the effect of iris width on the electric coupling (negative coupling). For very small

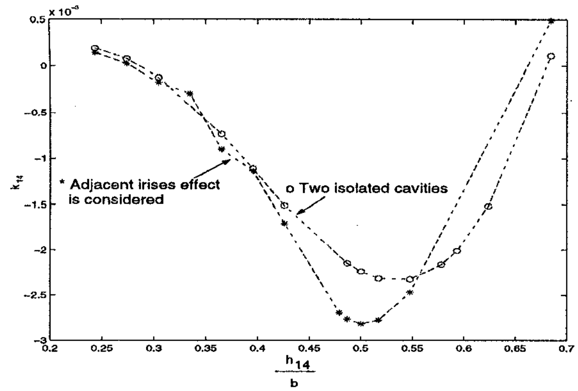

Fig. 6. Effect of iris height on electric coupling. Dimensions as in Fig. 1: $b_{22} = 0.3439''$, $W_{12} = 0.435''$, $h_{12} = 0.385''$, $y_{o12} = 1.1225''$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = 0.75''$, $h_{14} = h_{14}$, $y_{o14} = h_{14}/2$.

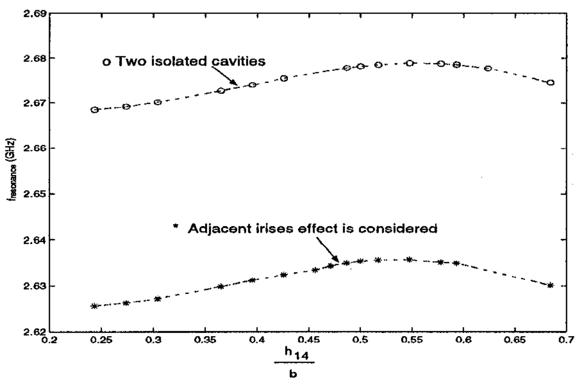

Fig. 7. Effect of iris height on the resonant frequency. Dimensions as in Fig. 1: $b_{22} = 0.3439''$, $W_{12} = 0.435''$, $h_{12} = 0.385''$, $y_{o12} = 1.1225''$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = 0.75''$, $h_{14} = h_{14}$, $y_{o14} = h_{14}/2$.

width, the coupling is almost zero. As the width increases the coupling increases up to a maximum value at $W/2a = 0.6$ after which the coupling decreases with further increase of the iris width. Fig. 11 shows the variation of resonant frequency, for the case of negative coupling, versus the iris width. The resonant frequency increases with the increase of width up to a maximum value at $W/2a = 0.6$ after which the resonant frequency decreases with further increase of the iris width. Also, the curves show that the loading effect due to adjacent irises effect is about $41MHz$ different from the case of two isolated cavities.

C. Effect of post gap on Negative Coupling

The effect of post gap variation on the electric coupling is investigated. The variation of the post gap is inversely related to the variation of the post length which controls the resonant frequency. Fig. 12 shows

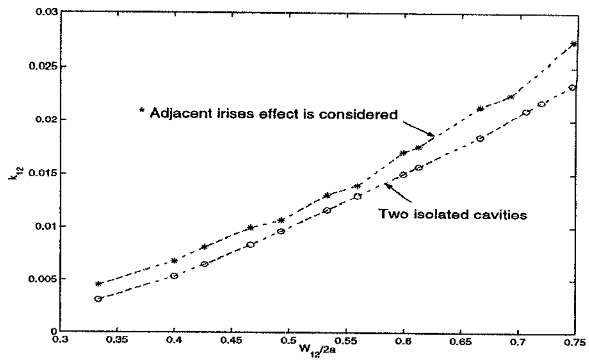

Fig. 8. Effect of iris width on magnetic coupling. Dimensions as in Fig. 1: $b_{22} = 0.3439''$, $W_{12} = W_{12}$, $h_{12} = 0.385''$, $y_{o12} = 1.1225''$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = 0.75''$, $h_{14} = 0.54''$, $y_{o14} = 0.27''$.

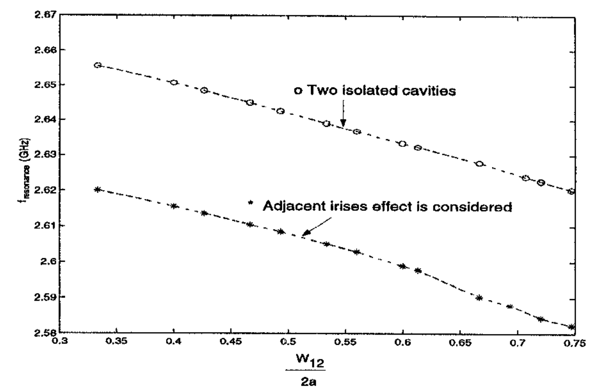

Fig. 9. Effect of iris width on the resonant frequency. Dimensions as in Fig. 1: $b_{22} = 0.3439''$, $W_{12} = W_{12}$, $h_{12} = 0.385''$, $y_{o12} = 1.1225''$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = 0.75''$, $h_{14} = 0.54''$, $y_{o14} = 0.27''$.

the effect of post gap on the negative coupling where the coupling increases as the post gap increases up to a maximum value for $b_{21}/b = 0.25$ after which the coupling decreases as the post gap increases. The negative coupling, when adjacent irises effect is considered, is larger than the one obtained from two isolated cavities. Fig. 13 shows the variation of resonant frequency for the case of negative coupling as a function of the post gap. The resonant frequency increases with the post gap. Fig. 14 shows an optimized response of a typical 4-pole elliptic function filter obtained by using the data presented above.

IV. CONCLUSION

Accurate coupling between combline cavities in the presence of other couplings is investigated. The effect of changing iris dimensions and position on the coupling and resonant frequency values is obtained. A comparsion is done between values obtained for two isolated cavities and two cavities in presence of other couplings. Numerical results show that the resonant frequency when the adjacent couplings effect is considered has a large variation from that of two isolated cavities.

References

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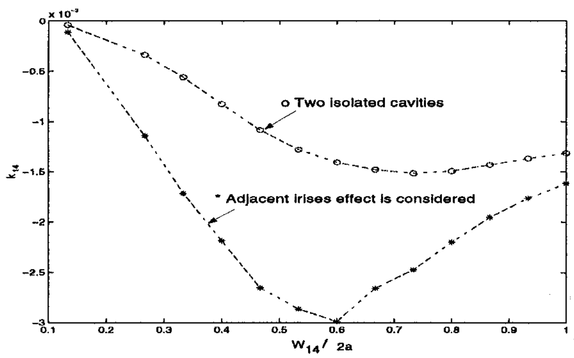

Fig. 10. Effect of iris width on electric coupling. Dimensions as in Fig. 1: $b_{22} = 0.3439''$, $W_{12} = 0.435''$, $h_{12} = 0.385''$, $y_{o12} = 1.1225''$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = W_{14}$, $h_{14} = 0.54''$, $y_{o14} = 0.27''$.

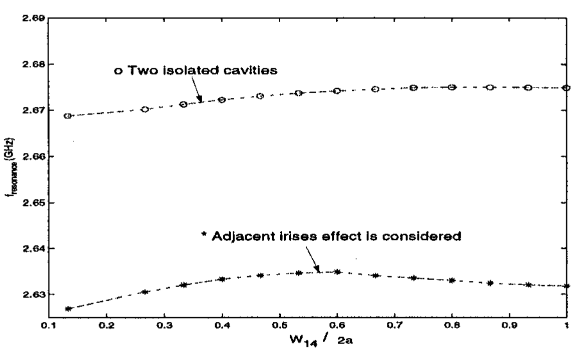

Fig. 11. Effect of iris width on the resonant frequency. Dimensions as in Fig. 1: $b_{22} = 0.3439''$, $W_{12} = 0.435''$, $h_{12} = 0.385''$, $y_{o12} = 1.1225''$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = W_{14}$, $h_{14} = 0.54''$, $y_{o14} = 0.27''$.

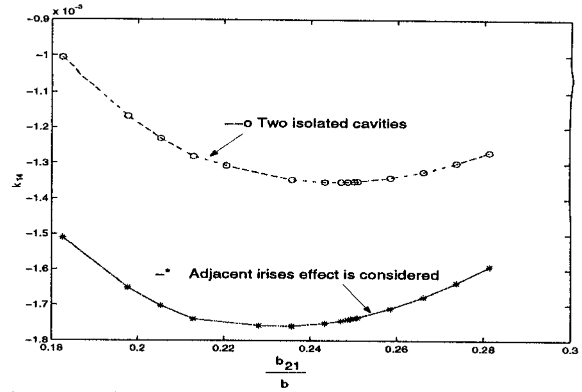

Fig. 12. Effect of post gap on electric coupling. Dimensions as in Fig. 1: $W_{12} = 0.435''$, $h_{12} = 0.385''$, $y_{o12} = 1.1225''$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = 0.75''$, $h_{14} = 0.54''$, $y_{o14} = 0.27''$.

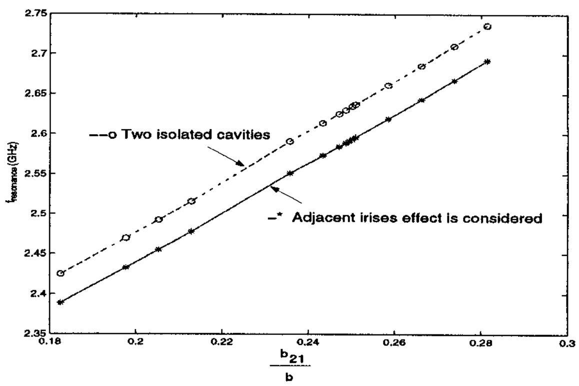

Fig. 13. Effect of post gap on resonant frequency. Dimensions as in Fig. 1: $W_{12} = 0.435''$, $h_{12} = 0.385''$, $y_{o12} = 1.1225''$, $W_{23} = 0.4''$, $h_{23} = 0.271''$, $y_{o23} = 1.1795''$, $W_{14} = 0.75''$, $h_{14} = 0.54''$, $y_{o14} = 0.27''$.

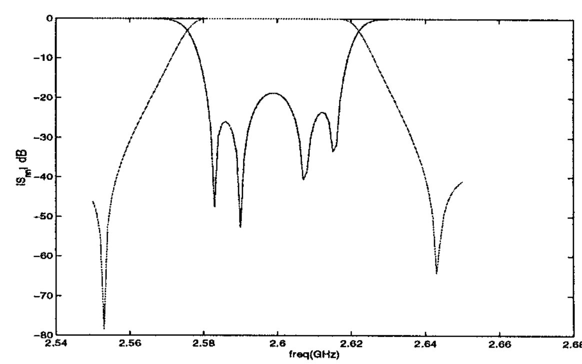

Fig. 14. Four pole elliptic filter frequency reponse. Dimensions as in Fig. 1: $W_{12} = 0.435''$, $h_{12} = 0.385''$, $y_{o12} = 1.1225''$, $W_{23} = 0.4''$, $h_{23} = 0.27''$, $y_{o23} = 1.18''$, $W_{14} = 0.75''$, $h_{14} = 0.541''$, $y_{o14} = 0.2705''$, $2a = 0.75''$, $b = 1.315''$, $t = 0.1''$, $r_o = 0.115''$, $b_{21} = 0.32''$, $b_{22} = 0.3439''$.