

Effects of combined apertures on the magnitudes of electric coupling coefficients of combline resonators

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Abstract. The effects of differently positioned and combined apertures on the magnitudes of electric coupling coefficients of two identical combline resonators are analysed. Coupling coefficient, k-vertical symmetry provides greater negative coupling for apertures less than 50 % opening on the common wall. Combined apertures do not enhance electric coupling. The Γ aperture annihilates electric coupling, whereas T shaped aperture provides reduced negative coupling coefficients compared to single apertures that make up the combination.

1. Introduction

Conventional combline filters which consist of a set of central metal posts shorted at one end and capacitively loaded at the other end of the enclosure, have been used over the years due to their low insertion loss, low production cost, compact size, relatively high unloaded quality factor and superior spurious free performance [1][2]. The modern wireless systems require miniaturised devices hence dielectric loaded combline filters have been designed and found to be significantly smaller than the equivalent air filled combline filters operating at the same resonant frequency [2]. The presence of the dielectric concentrates the electric fields in itself consequently improving the unloaded quality factor of the filter, although at the detriment of the spurious free bands which become moderate.

Coupling is very important in building filters as it is through it that we control the filter bandwidth and selectivity [3]-[7]. The selectivity of the filter mainly depends on the position of transmission zeros. These transmission zeros are brought about by cross couplings through apertures or coupling through non-resonating modes [5], [6]. The coupling can either be through electric fields, termed electric coupling, or through magnetic fields, termed magnetic coupling [7]. These couplings depend on the size and position of the apertures, the thickness of the coupling wall, the position of the resonators relative to the enclosure walls and the dimensions of the coupling screws [8]. Electric coupling generally poses challenges as it is difficult to effect.

The purpose of the study is to find out the effect of differently positioned coupling apertures (both single and combined) on the magnitudes of the coupling coefficients. A commercial software package CST Microwave studio (CST MWS) was used in the simulations after it was proven to be rigorous. It was established that single apertures provide greater electric coupling compared to combined apertures. The Γ -combined aperture annihilates electric coupling while the T-combined apertures provides a reduced negative coupling compared to the single apertures that make it up.

2. Analysis Technique

A combline resonator designed by Yao et al. [9] was implemented and run in the CST MWS and the coupling coefficients computed. To get f_e and f_m (odd and even mode resonant frequencies of



coupled resonators) two identical and coupled resonators were built and the symmetry option in boundary conditions was used to assign the common wall as electric and then magnetic. The height of the common wall was milled and in each case, f_e and f_m computed. Coupling coefficient for similar resonators can be calculated using the formula 1 [10].

$$k = \frac{f_e^2 - f_m^2}{f_e^2 + f_m^2} \quad (1)$$

Figure 1 is very comparable with that obtained by Yao et al. [9]. Subject to the readability of the Yao et al. graph, the results are very close to those obtained using CST MWS as shown in Figure 2.

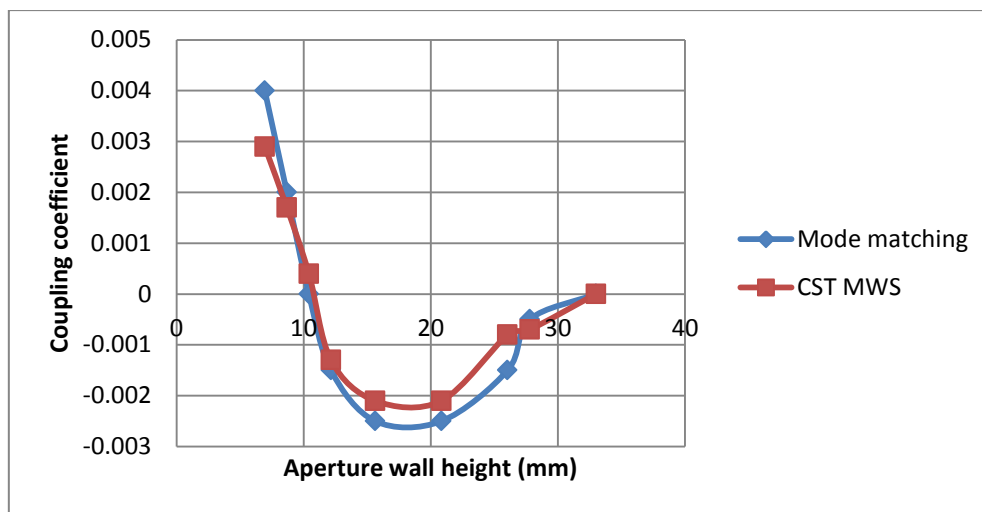


Figure 1. Coupling coefficient against change in the aperture wall height obtained using mode matching method and CST MWS.

3. Effect of size of different aperture openings on the coupling coefficient

CST MWS was used to compare the effect of differently positioned apertures on the coupling coefficients. To study the degree of coupling two identical resonators with a common wall in between were used and a method used in section 2 above was employed. The two identical coupled resonators used for the study is shown in Figure 2.

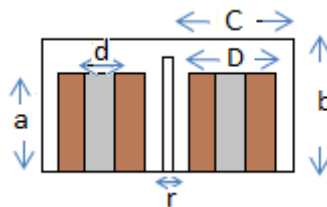


Figure 2. Cross section of coupled identical resonators; width of common wall $r = 2$ mm, height of cavity $b = 23$ mm, height of both dielectric ring and combline post $a = 20$ mm, length and width of cavity $C = 20$ mm, diameter of the post $d = 12.7$ mm, diameter of dielectric $D = 18$ mm. Dielectric constant = 37.

One aperture was opened horizontal from the capacitive side of the combline resonator and the coupling coefficients generated from this are labelled as k -horizontal. The other aperture studied was opened vertical from the side, and the coupling coefficients generated from this aperture were referred to as k -vertical-side. The third aperture studied was opened vertical from the centre of the common

wall, and the coupling coefficients obtained from this were labelled as k-vertical-symmetry. The three cases are represented in Figure 3 as a), b) and c) respectively.

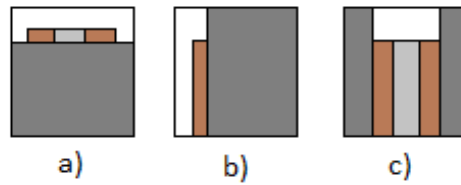


Figure 3. Cross section of horizontal, vertical-side aperture and vertical-symmetric apertures respectively.

It can be observed in Figure 4 that all apertures begin with near null coupling when the apertures are very small, indicating that minimum electric and magnetic fields find their way between the two resonators. K-vertical-symmetry consistently provides superior coupling than the other two aperture positions. The k-vertical-symmetry apertures offer negative coupling for a range of apertures from about 10 % opening to just below 50 % opening on the common wall. A 0.7 ratio of the aperture of k-vertical-symmetry generates magnetic coupling which is 1.5 and 1.7 greater than k-horizontal and k-vertical side respectively. The maximum electric coupling is obtained for the three single apertures when the common walls are opened about 30 %, 40 % and 50 % for k-vertical symmetry, k-horizontal and k-vertical-side respectively. This is attributed to the fact that maximum electric field couple around this region, beyond which the magnetic field begin to dominate hence the coupling coefficients gradually become positive. The maximum electric coupling produced by k-vertical-symmetry is almost equal to that produced by k-horizontal coupling and these two are 1.19 times greater than that generated by k-vertical-side.

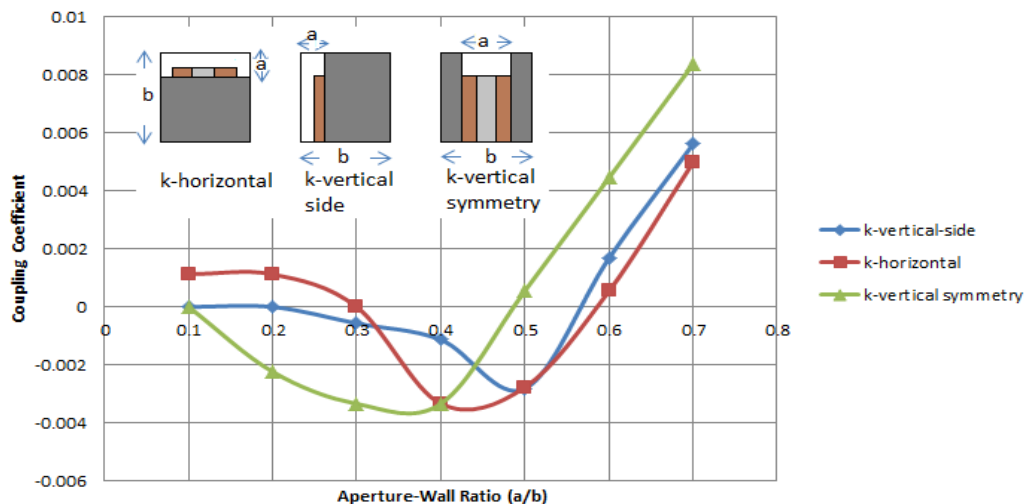


Figure 4. Coupling coefficients for aperture ratio opened horizontal, vertical-side and vertical-symmetry.

4. Combined apertures

The apertures were then milled in a combined way such that they formed the Γ shape which is a combination of the vertical-side and the horizontal aperture, and the T shaped which is a combination of the horizontal and the vertical-symmetry apertures. Simulations were run for these new apertures and f_e and f_m were obtained as was done in section 2 above and coupling coefficients were computed. The results as shown in Figure 5 show that the coupling coefficients for these combinations are not a sum of the combinations. In cases where the apertures are more than 50 % the size of the common wall, the coupling coefficients obtained are greater than the sum of the single apertures that make up the combination. This shows that these combinations do not enhance electric coupling. T

shaped aperture provides a maximum negative coupling coefficient of -0.002223 which is 1.5 times less than the maximum values of the negative coupling coefficients of both the k-vertical-symmetry and k-horizontal, the single apertures that make up the combination.

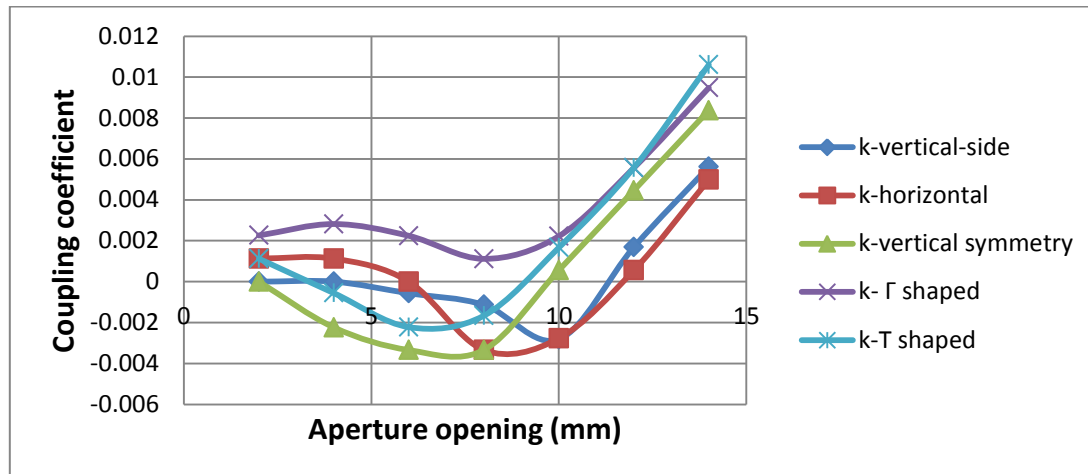


Figure 5. Coupling coefficients for single apertures; vertical-side, horizontal and vertical-symmetry, and combined apertures; Γ shaped and T shaped all against the increasing apertures.

5. Conclusion

CST MWS computed results were compared with mode matching and experimental results obtained by Yao et al. (1995) and the results found to be very comparable. The coupling coefficients of identical coupled combline resonators for k-vertical-symmetry were found to be consistently significant for apertures less than 50 % of the common wall although has the same maximum coupling coefficient as k-horizontal aperture. It was further established that the combined apertures do not enhance electric coupling.

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