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Effects of Thickness of Hollow Centre Conductor on Different Parameters of Coupled combline Resonators

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ABSTRACT

The effect of the thickness of the hollow centre conductor in a combline resonator on the resonant frequency, coupling coefficients and spurious performance are analysed. It is shown that both the electrical and magnetic couplings are not significantly affected by the size of the thickness of the hollow centre conductor, while the resonant frequency and spurious free band both change. When the thickness of the hollow centre conductor reduces the spurious free band deteriorates while the resonant frequency increases.

Index Terms-combline resonator, coupling coefficient, spurious free band.

I. INTRODUCTION

Filters are used in telecommunication systems to allow a certain range of frequencies to pass with minimum or no loss. The frequency spectrum is a finite scarce resource hence the need to design filters with elliptic function response. Filters with elliptic function response have sharp roll off (skirts), hence the frequency band is efficiently used. In order to implement a filter with elliptic function response, the design has to offer both positive (magnetic) and negative (electric) coupling. It has been reported that for a filter to have negative coupling it has to meet certain conditions in its design parameters. For a combline filter, the ratio g/d (see figure 1) should be greater than 1.3 and its electrical length should be at least 80˚ in order for electric coupling to occur [1]. A combline filter has over the years been used as it offers these advantages, including the fact that it has superior spurious free response, compared to dielectric loaded cavity filters [2][3][4]. Both positive and negative coupling are achieved by milling apertures in the common walls between the combline resonators. Electric coupling is realised when the aperture is milled from the open circuit end, and greater magnetic coupling obtained when the aperture is milled from the short circuit end [1][5].

Telecommunication systems have over the years increased in complexity and the need to reduce their sizes have become even more necessary. This need to miniaturise also contributes in reducing the prices of these devices as less material is used. Some researchers have lately designed filters that employ single cavity with two inner conductors (the intermediate and the central post) to get a dual band combline filters response [6]. This arrangement is better than the other ones where two combline filters are designed separately and then combined using multiband combiners.

In this paper we study the intermediate hollow combline resonator introduced by Ruiz-Cruz et al. [6] and apply the findings of Chuma [1] to realise electric coupling. This takes away the need to use probes in order to realise electric coupling hence reduce the complexity of the design. We further study the effect of the thickness of the hollow inner conductor on the coupling coefficients. The use of hollow conductor saves the material used, hence reduces costs. Our results show that the Ruiz-Cruz design could not realise electric coupling as the g/d ratio was barely greater than 1.3 and its electrical length was less than 80˚. The dimensions were adjusted to get g/d ratio of 2.56 and an electrical length of 80.7˚. The results also show that the thickness of the hollow inner conductor does not significantly affect the magnitudes of both the electric and the magnetic coupling. We also studied the effect of the thickness of the hollow centre conductor on the spurious performance and resonant of the combline resonators.

II. ANALYSIS TECHNIQUE

Two-coupled identical hollow centre conductor combline resonators are shown in Figure 1. Each resonator consists of a rectangular cavity, and a hollow rectangular centre conductor, both made of aluminium. The two resonators are coupled through an aperture of thickness x. The coupling between these two-coupled resonators can be either electric or magnetic. The aperture was milled from the short-side end and the resonant frequency referred to as f_m, and when milled from the open-side end they were referred to as f_e. A Finite Integration technique in the CST Microwave package was used to analyse a hollow centre conductor combline resonator filter. This software package provides auto-mesh which has proven to give results comparable to those obtained experimentally and those using mode matching methods [11].

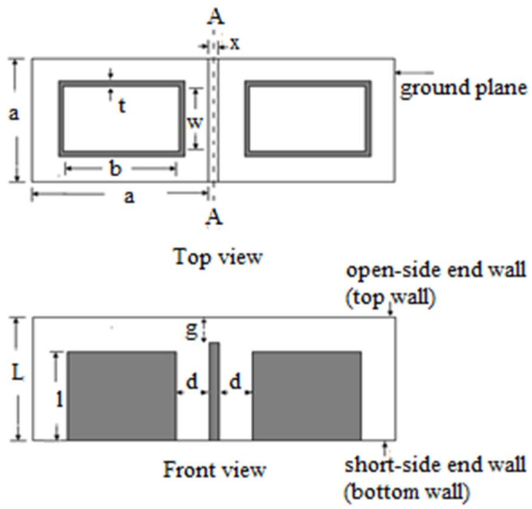

Figure 1: Configuration of two coupled identical combline resonators

The dimensions of each resonator are a = 26 mm, b = 14.8 mm, w = 13.9 mm, L = 42 mm, l =33 mm, d = 3.06 mm, g = 9 mm, x = 4 mm, t= 2.54 mm, f_0 = 2.039 GHz

Two resonators with their fundamental modes near resonance being coupled have an equivalent lumped-element circuit of the form shown in figure 2 (a) [7]-[9]. This circuit consists of two series resonant circuits coupled by a mutual inductance M. L and C are the self-inductance and self-capacitance so that

$$f_o = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

where f_0 is the resonant frequency of the uncoupled resonators.

The coupling coefficient k between the resonators is defined in terms of the equivalent circuit element,

$$k = \frac{M}{L} \quad (2)$$

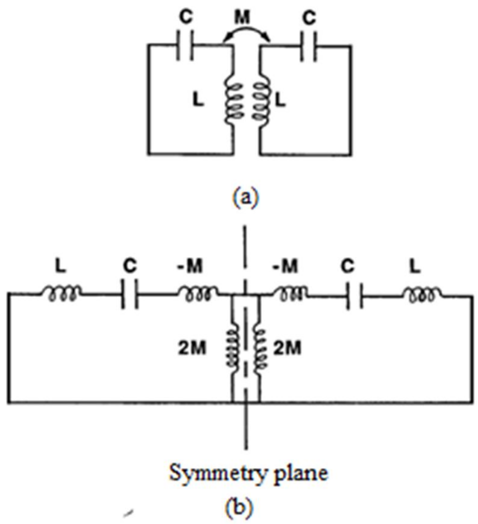

Figure 2: Two forms of the equivalent lumped-element circuit of the coupled resonator [10]

An alternative form of the equivalent circuit is shown in figure 2(b). This form yields two-port parameters that are identical with those of the circuit of figure 2(a). If the symmetry plane in figure 2(b) is replaced by an electric wall (or a short circuit), the resultant circuit has a resonant frequency [10] of,

$$f_e = \frac{1}{2\pi\sqrt{(L-M)C}} \tag{3}$$

And if the symmetry plane is replaced by a magnetic wall (open circuit), the resultant circuit has a frequency of,

$$f_m = \frac{1}{2\pi\sqrt{(L+M)C}} \tag{4}$$

Equations (2), (3) and (4) can be solved for the coupling coefficient:

$$k = \frac{f_e^2 - f_m^2}{f_e^2 + f_m^2} \tag{5}$$

III. RESULTS

First the dimensions of the intermediate resonator designed by Ruiz-Cruz et al. [6] were adjusted such that the ratio g/d was 2.56 and the electrical length was 80.7˚ as in figure 1. The effect of the thickness of the hollow centre conductor on its coupling coefficients, spurious performance and resonant were studied.

A. The effect of the dimensions of the inner conductor on the coupling coefficient of a combline resonator

A combline resonator shown in figure 1 was implemented and run in the CST Microwave [11] and the coupling coefficients computed. To get the resonant frequencies f_e and f_m (when the symmetry wall is assigned electric and magnetic respectively) of two coupled combline resonators was built and the symmetry option in boundary conditions was used to assign the symmetry plane as electric and magnetic respectively. 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 equation 5.

The results in Figure 3 show that the electric coupling cannot be realised when both the conditions, ratio g/d >1.3 and electrical length greater than 80˚ are not meet. The adjusted dimensions meet these conditions hence electrical coupling is realised. Electric coupling (for an aperture milled from the open-side end wall) occurs for a limited range of values from aperture height of 12 mm to 28 mm, while magnetic coupling (for an aperture milled from the short-side end wall) occurs for all aperture heights. Maximum magnetic coupling is obtained when the aperture milled from the bottom has a height of 16 mm, and maximum electric coupling is obtained when the aperture milled from the top has a height of 20 mm.

B. The effect of the thickness of the inner conductor on the coupling coefficient of a combline resonator

In this section we study the effect of the thickness of the inner hollow conductor on the coupling coefficient of a combline filter. The other dimensions of the structure studied are as in Figure 1. The thickness of the inner hollow conductor was initially kept at 0.635 mm while the height of the aperture was changed and both f_e and f_m were computed as under sub-section *A*. Coupling coefficient was calculated using equation (5). The procedure was repeated for inner hollow conductor of 1.27 mm, 2.45 mm, 5.08 mm, 7.62 mm and lastly when the inner conductor had no hole (the post usually used). The results in figure 4 show that the thickness of the inner conductor does not significantly affect both the electric and magnetic coupling coefficients as the values slightly vary in the order of 1000th. This is explained by the fact that the skin depth of aluminium at 2 GHz is 1.821×10^{-6} m [12], which means that thicknesses much greater than this figure will not results in the fields being disturbed. The thicknesses of the hollow conductor studied in this paper are all much greater than the skin depth. The smallest thickness of the hollow conductor studied here is about 348.7 greater than the skin depth of aluminium.

C. The spurious performance and resonant frequency against the thickness of a hollow centre conductor of a combline resonator

The spurious performance which shows how far the unwanted mode is from the operating mode, deteriorates as the thickness of the hollow conductor reduces. A combline resonator with a centre conductor without a hole has spurious free band of 2.135 GHz, while a combline resonator with a hollow centre conductor with a thickness of 0.635 mm has a spurious free band of 2.036 GHz, constituting a difference of 99 MHz for the two resonators. On the other hand, the resonant frequency of the hollow centre conductor increases with reducing thickness of the hollow centre conductor of a combline resonator as shown in figure 5. A combline resonator with a centre conductor without a hole has a resonant frequency of 2.027 GHz, while a combline resonator with a hollow centre conductor with a thickness of 0.635 mm has a resonant of 2.060 GHz, making a difference of 33 MHz.

IV. CONCLUSION

A Finite Integration technique in the CST Microwave package was used to analyse a hollow centre conductor combline resonator filter. The results show that the thickness of the hollow conductor does not affect the coupling coefficients but only slightly affect the resonant frequency. In designing a combline filter, one may use a hollow conductor to save some material, but at the expense of the spurious free band. The spurious free band deteriorates as the thickness of the hollow conductor reduces. This calls for a trade-off between saving material used in the resonator and other design parameter like spurious free.

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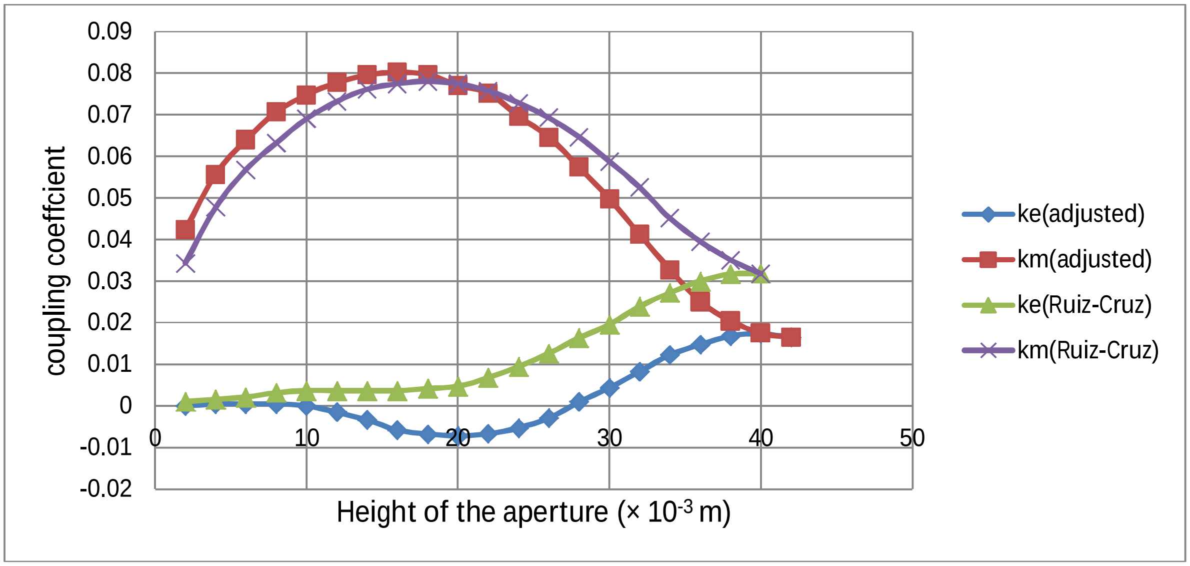

Figure 3: Coupling coefficient of a hollow inner conductor of two coupled combline resonators against the height of the aperture

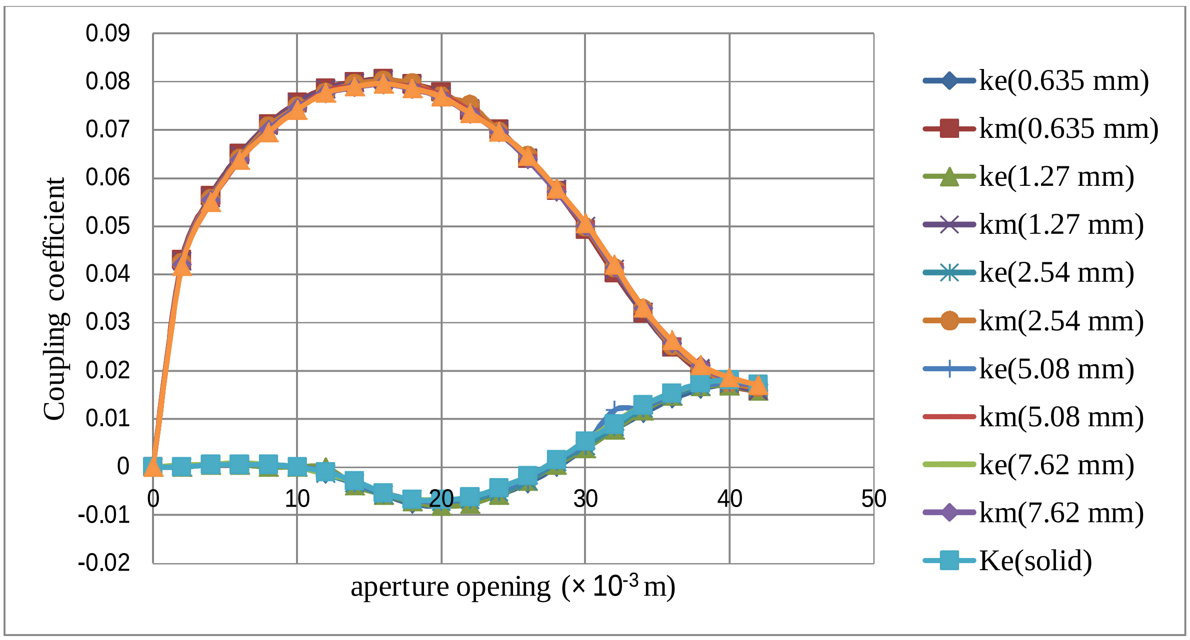

Figure 4: Coupling coefficients of a hollow inner conductors of thickness 0.635 mm, 1.27 mm, 2.54 mm, 5.08 mm, 7.62 mm and solid (without a hole) of two coupled combline resonators against the height of the aperture opening

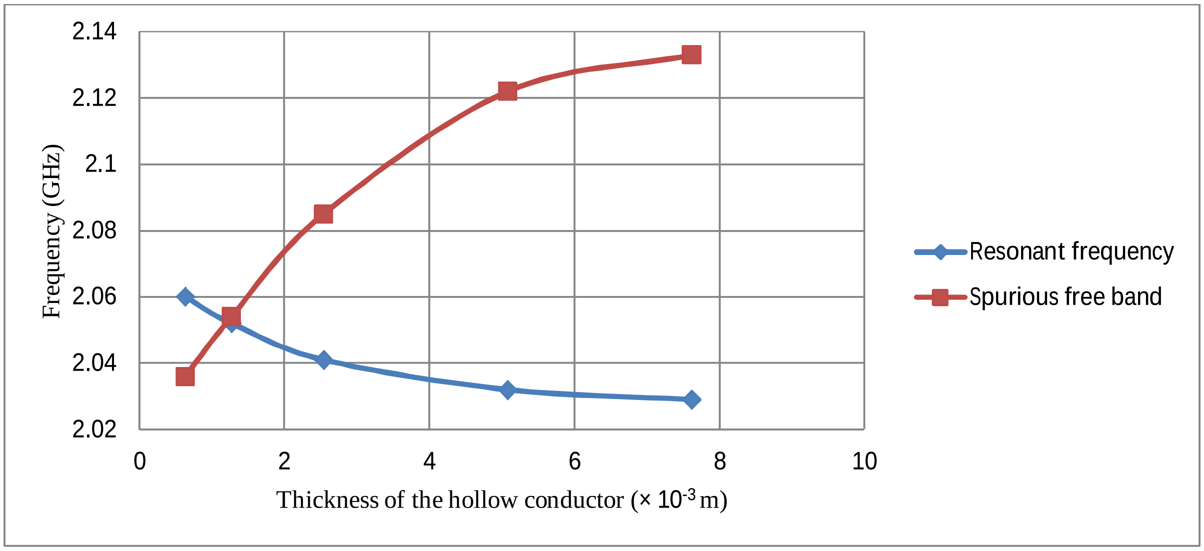

Figure 5: Thickness of hollow conductor varies with resonant frequency and spurious free band of a combline resonator