A COMPRESSED PLANAR BAND-PASS FILTER USING MICROSTRIP SQUARE RESONATORS WITH INTERDIGITAL CAPACITOR

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Abstract

Decreasing the size and physical dimensions of a planar filter in telecommunication and mobile systems has high importance. Most of the filters with planar structure are designed using electric, magnetic and mixed coupling models. Like as ring resonators, in this paper a new compact planar band pass filter using interdigital capacitor is introduced.

This new filter is compared with a four-pole square open-loop resonators filter. The performance of this filter is comparable to a four-pole square open-loop resonators filter and size of this filter is reduced about 36%.

Index terms- *Inter-digital capacitor, Coupling coefficient, Open-gap*

1. INTRODUCTION

The filters which are manufactured by coupled structures of square open-loop resonators using electric, magnetic and mixed coupling have particular frequency resonance. In [1] all of states to produce different coupling types has been investigated and has been shown that at resonance frequency each of the open-loop resonators has the maximum electric field density at side with on open-gap. The disadvantage of these filters is very large size in printed circuit boards. Recently several methods for size reduction of lines are proposed [4]-[5].

In this investigation open-gaps have been replaced by inter-digital capacitors, so a novel filter has been introduced.

Using full wave advanced design system (ADS) soft ware the filter analysis and simulation was carried out.

2. ELECRIC COUPLING

If a filter would be constructed using what as is shown in fig.1, any open-gap can produce a capacitor itself, which leads to electric coupling between two gaps. (Fig.2)

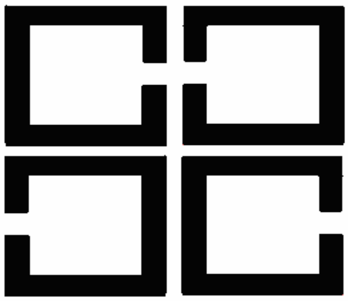

Figure 1. Basic coupling structure of coupled micro-strip square open-gap resonators [1]

Resonance frequencies in electric coupling can be found to be [1]

$$f_e = \frac{1}{2\pi\sqrt{L(C + C_m)}} \qquad (1)$$

$$f_m = \frac{1}{2\pi\sqrt{L(C - C_m)}} \quad (2)$$

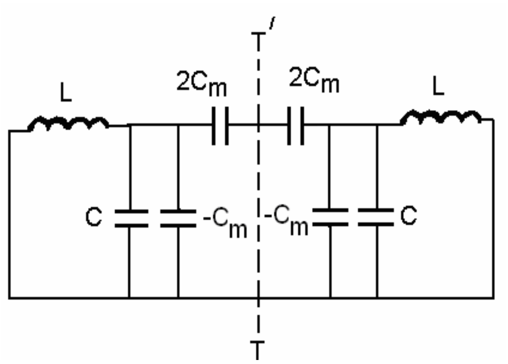

Figure 2. Equivalent circuit of electric coupling [1]

If any open-gap replaced by an interdigital capacitor, then each capacitor in equivalent circuit shown in fig.2 equals to C' capacitor which corresponding to capacitance of interdigital capacitor.

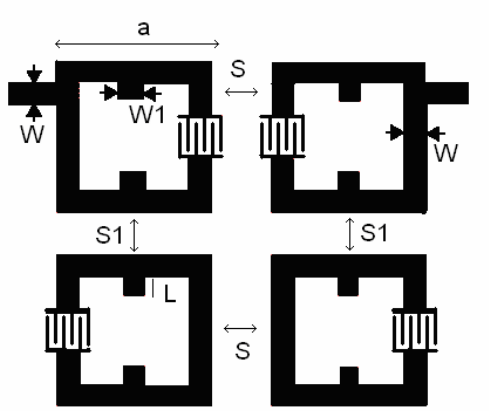

Figure 3. Geometries of the novel filter

Since the interdigital capacitor capacitance is varied with change in its parameters, using this relation it can adjust capacitance of the interdigital greater than capacitance of the capacitor which has been produced by the open-gap.

Since $C' \geq C$ And $C'_m \geq C_m$ Then

$C' + C'_m \geq C + C_m$ and

$$f_e \propto \frac{1}{\sqrt{C + C_m}} \quad (3)$$

And

$$f'_e \propto \frac{1}{\sqrt{C' + C'_m}} \quad (4)$$

$$\Rightarrow f'_e \leq f_e \quad (5)$$

since C and C_m subtraction for f_m and C' and C_m' subtraction for f'_m have been appeared in their equations and both C' and C_m' were increased , therefore $C' - C_m'$ is not much greater than $C - C_m$, then frequency f'_m is not much greater respect to f_m. So

$$f'_m = f_m \quad (6)$$

K_E and K_E' , electric coupling coefficients in equivalent circuits of the two filters can be found to be [1]

$$K_E = \frac{f_m^2 - f_e^2}{f_m^2 + f_e^2} \quad (7)$$

$$K'_E = \frac{f_m'^2 - f_e'^2}{f_m'^2 + f_e'^2} \quad (8)$$

From (3) and (4) can be resulted that

$$K'_E \geq K_E \quad (9)$$

Then, electric coupling coefficient in new state is increased.

3. MACNETING COUPLING

self–inductance (L) and mutual inductance (L_m) perform basic role during changes in magnetic coupling of the filters structure that has been manufactured by coupled structures of square open–loop resonators [1], since in the novel filter's structure using interdigital capacitor only the equivalent circuit's capacitors has been varied, so respect to latter state the magnetic coupling coefficient has no excess change and this can be shown by mathematical relations.

Magnetic coupling frequencies of resonance for reference filter can be found to be [1]

$$f_e = \frac{1}{2\pi\sqrt{(L-L_m)C}} \tag{10}$$

$$f_m = \frac{1}{2\pi\sqrt{(L+L_m)C}} \tag{11}$$

And for the novel filter can be found to be

$$f_e' = \frac{1}{2\pi\sqrt{(L-L_m)C'}} \tag{12}$$

$$f_m' = \frac{1}{2\pi\sqrt{(L+L_m)C'}} \tag{13}$$

In the new state since $C' \geq C$ therefore both

f_e' And f_e have been decreased and from [1]

$$K_M = \frac{f_e^2 - f_m^2}{f_e^2 + f_m^2} \cong K_M' = \frac{f_e'^2 - f_m'^2}{f_e'^2 + f_m'^2} = \frac{L_m}{L} \tag{14}$$

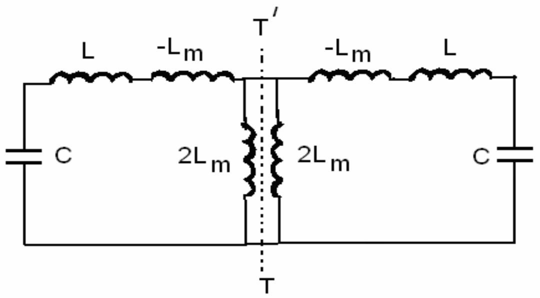

Figure 4. Equivalent circuit of magnetic coupling [1]

4. MIXED COUPLING

In reference filter mixed coupling frequencies are defined by [1]

$$f_e = \frac{1}{2\pi\sqrt{(L-L_m)(C-C_m)}} \tag{15}$$

$$f_m = \frac{1}{2\pi\sqrt{(L+L_m)(C+C_m)}} \tag{16}$$

From (3) and (8) it can result that in this new state f_m' is decreased respect to f_m and f_e' is remains constant respect to f_e approximately. Mixed coupling coefficient is defined by [1]

$$K_B = \frac{f_e^2 - f_m^2}{f_e^2 + f_m^2} \tag{17}$$

$$K_B' = \frac{f_e'^2 - f_m'^2}{f_e'^2 + f_m'^2} \tag{18}$$

Since $f_m' \leq f_m$ and $f_e' \cong f_e$ therefore from (9) in the new case K_B' is increased and

$$K_B' \geq K_B \qquad (19)$$

5. THE STRUCTURE OF COMPRESSED FILTER

In structure of the novel filter from (5), (7), (10) electric coupling coefficient is greater, mixed coupling coefficient is greater and magnetic coupling coefficient is constant approximately respect to former state. Since the purpose is to design a filter which operates in same response frequency, so the coupling coefficient should be adjusted to obtain the desirable results.

The magnetic, electric and mixed coupling coefficients are function of the parameters which have been defined in the filter structure (a, w, s, h) therefore by changing this parameters the desired filter can be designed. Microstrip width decreasing has high effect on increasing of magnetic coupling coefficient K_M and improved the magnetic coupling coefficient.

Decreasing of parameter (a) at a 2 to 1 ratio will decrease electric coupling coefficient K_E and mixed coupling coefficient K_B together respect to magnetic coupling coefficient K_M .

In new state, after creation a good trade off between coupling coefficients the resultant frequency response possessing a frequency shift so the open stub is used to compensate frequency shift.

6.THE INTERDIGITAL CAPACITOR'S STRUCTURE

The interdigital capacitor is an element for producing a capacitor-like [3].

The shape of conductors is defined by the parameters shown in figure.5. The long conductors or "fingers" provide coupling between the input and output ports across the gaps.

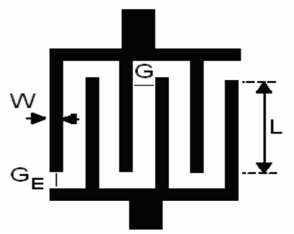

Figure 5. shape of the interdigital capacitor

The produced capacitor by this element is a function as its parameters which have been defined and shown in figure.5. The capacitance increases as the gaps are decreased and increases when the length of the fingers is increased.

In this study the interdigital capacitor has been designed with 6 fingers shown in figure.5 has the following parameters:

W= Width of each finger= 0.1 mm, G= Space between fingers= 0.2 mm, G_E= Space at end of finger= 0.2 mm, L= Length of fingers= 1 mm

N=Number of fingers= 6

7. COMPRATION BETWEEN THE TWO FILTERS

The designed reference filter in [1] has following parameters:

$S_1=S_2=S=$ 2 mm, a= 7 mm, W= 1 mm and G= 0.5 mm

And the novel filter has the following parameters:

$S_1=1.6$ mm, S=2.2 mm, W=0.8 mm,$W_1=1.5$ mm

a=4 mm and L=0.7 mm

With this parameters for two filters the total surface of microstrip for the reference filter is 256 mm^2 however for the novel filter is 171.52 and the total surface has been decreased 36% approximately.

Frequency responses of the two filters shown in figure.6

8. CONCLUSION

In [1] a new type of planar cross-coupled filters using coupled microstrip square open-loop resonators has been proposed. Since decreasing the size and dimensions of a planar filter in telecommunication and mobile systems has high importance, using this proposed filter as reference and interdigital capacitor a novel compressed planar filter has been introduced.

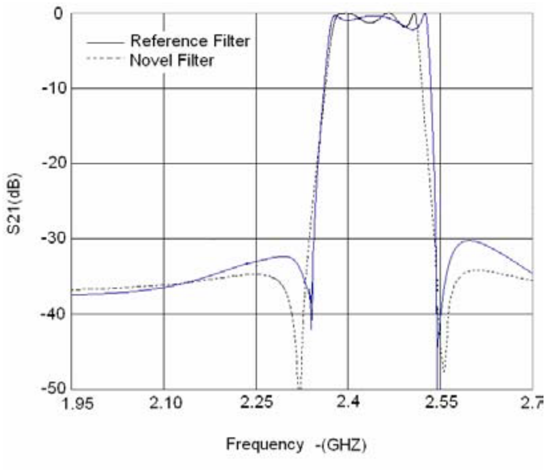

Figure 6.Reference (solid line) and the novel filters (dashed-line) frequency responses

A novel filter has been designed and proposed using the derived equations in [1] and variations in reference filter's parameters.

The filter analysis and simulation has been carried out by full-wave advanced design system (ADS) soft ware and comparison between two frequency responses presented.

Finally in the novel filter the microstrip surface decreased approximately 36% respect to reference filter.

References

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