Additional Cross Coupling Coefficient Used as Matching Ladder Network in Coupled Based Band Pass Filters

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Abstract— A coupling coefficient based filter is presented in this paper. The novelty of the proposed design is the introduction of a cross coupling interaction that allows to match the impedance achieving excellent performance, in the transmission and reflection response. Equivalent circuit model is discussed. Clear relation between each component and physical dimensions of the proposed design are established. Measured of a 19.4% band pas filter at 1.6 GHz is reported and compared with EM simulation and equivalent circuit model showing an excellent agreement.

1. INTRODUCTION

Coupling coefficient based design filter is an easy way to synthesize standard filter response [1]. In the design process of this kind of filters it is necessary to use electromagnetic simulators to optimize the filter performance in order to fit the specifications. The designs based on the coupling coefficient exhibit an inherent limitation fixed by the minimal distance allowed by the technology between adjacent resonators. The interaction between resonators and, specially, the interaction between the input-output ports introduces loads in the resonators that affects to the fundamental resonant frequencies as well as to the matching impedance. Therefore, to obtain a good performance it is necessary to go through some optimization process in which the design physical dimensions are modified to balance the resonators resonant frequencies and to achieve the best impedance matching [2]. However, even after this optimization process there is a big gap between the perfect impedance match and the optimized structure. In this paper we propose a small modification of the layout that introduces a cross coupling that can be interpreted as an additional matching ladder network. The proposed equivalent circuit model fits the measured and EM simulated responses. Since it is possible to set up direct relation between the equivalent circuit model parameters and the physical layout parameters, the equivalent circuit model becomes a very useful tool in the optimization stage of the filter design.

2. LAYOUT OF THE PROPOSED DESIGN

Figure 1 shows the layout dimensions of the proposed filter. It has been implemented in a Rogers RO3010 substrate using a laser milling machine. The minimal distance between the resonators is 0.2 mm and the distance between the port line extension and the resonators has been fixed to 0.15 mm which is the more critical distance of the design.

The ports feed the resonators through a capacitive coupling which intensity depends of the proximity to the extreme resonators (1.5 mm). The square shape of the resonators has been chosen to maximize the inter-resonator capacitance coupling, resulting in a final thickness of 3.1 mm, and to maximize the coupling between resonators according with the previous experience with this kind of design [3, 5]. The input and output ports are 50 Ω microstrip lines that, in this substrate correspond to 1.6 mm thick microstrip. Extensions of the ports with a 90° angle following the square resonator profile have been included in order to maximize the coupling with the side resonators.

3. EQUIVALENT CIRCUIT MODEL

The equivalent circuit model of a filter helps to understand the behavior of the design. In this case a clear relationship between the equivalent circuit model and the layout physical dimensions can be set. Fig. 2 shows the equivalent circuit model of the proposed filter. Basically it is composed by three LC tanks which have been modeled as three open rings, and a set of Π model for capacitive coupling networks sketched as the different couplings.

The coupling between resonators is a consequence of the electromagnetic interchange between resonators.

Geometry symmetries are able to force the predominance of one of both magnetic and electric coupling [5]. In our case there are three different kinds of electric coupling, characterized by the

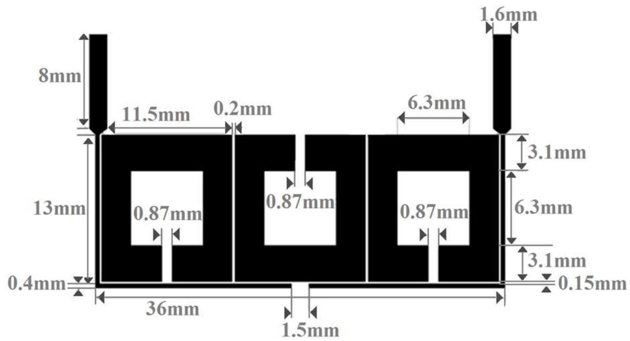


Figure 1: Layout of the proposed coupling coefficient based Chebyshev filter implementation.

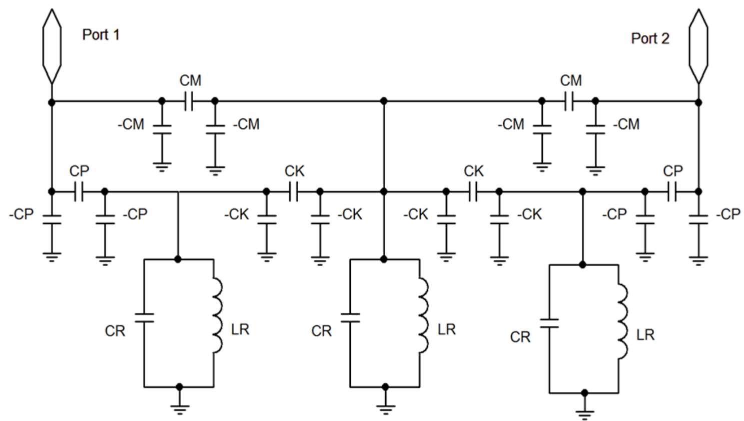


Figure 2: Equivalent circuit model of the proposed filter.

parameters C_P, C_M and C_K. C_P is modeling the coupling between the port extensions and the extern resonators. The value of this parameter can be modified in the layout altering the horizontal distance between the port extension and the adjacent resonator. Also, there is a dependence of this parameter with the side of the adjacent resonator, being possible to modify this coupling using rectangular shape resonators. The C_K parameter models the coupling between adjacent resonators and can be controlled directly with the distance between the resonators. The maximum value of this capacitance is fixed by the minimal distance between metallic layers that the fabrication technology allows. The maximum bandwidth of the filters is bounded to the maximum coupling coefficient [1], and this is the importance of this value. Finally, C_M represents the cross coupling coefficient that represent the novelty of the proposed design. The equivalent circuit model of the capacitive coupling is a Π circuit with two negative capacitors in the parallel branches. Interpreting the negative capacitors as inductors, the structure can be thought as L-C-L matching ladder. Since the value of the C_M can be controlled with the variation of the overlap between the port extension and the central square resonator. This matching ladder can be tuned in a certain range of values. The values of the different parameters can be initially estimated from the physical dimensions, but at the end there will be necessary to optimize them to fit the measured response. Table 1 shows a summary of the equivalent circuit model parameters for the best fit. Work is in progress to improve this fitting and to extend these relations to functions that can link the filter specifications with physical parameters in a useful range for the design process.

4. MEASURED RESULTS

Measures of the fabricated prototype depicted in Fig. 3 shows a band pass between 1.44 GHz and 1.75 GHz performing a 19.4% fractional bandwidth. The return losses are below the −10 dB in all the band pass and the insertion losses oscillate between −1.98 dB and −0.79 dB. The outsideband transmission level stays below −30 dB. The band-pass exhibits a non-symmetrical shape being sharper for the low frequency flank.

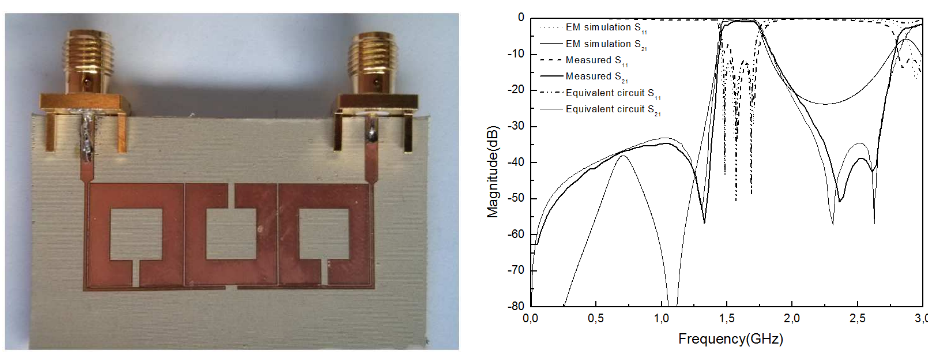
As can be seen in Fig. 3, the measured shows excellent agreement with the electromagnetic simulations and the equivalent circuit response. It is a privileged starting point to develop a robust

Table 1: Summary of equivalent circuit model parameters and geometrical parameters.

Equivalent Circuit parameter	Value		Layout dimensions
Resonant Tank	LR	6.5e-5 nH	External Ring perimeter: 48.13 mm
	CR	219000 pF	Ring: 48.13 mm
			Ring Thickness: 3.1 mm
Coupling	CP	296 pF	Overlap length between Port extension and resonant ring: 23.63 mm
			Distance between port extension and extreme rings: 150 µm
	CK	36505 pF	Distance between adjacent rings: 200 µm
			Side of the rings: 13 mm
	CM	55 pF	Overlap length between port extension and the central ring: 5 mm
			Distance between port extension and central ring: 150 µm

design methodology.

Further work is under development to improve the utilization of designs with small modifications can be extended to wideband-pass filters.



(a) (b)

Figure 3: (a) Picture of the fabricated prototype. (b) Comparison between S_{11}, and S_{21}, measured, electromagnetically simulated and equivalent circuit response.

5. CONCLUSION

The inclusion of the cross coupling in the standard Chebyshev filter supplies an additional matching ladder allowing to match the impedance of the design. The proposed equivalent circuit model based on the capacitance coupling transmission line lets to establish a clear relation between the equivalent circuit model and the layout physical dimensions, therefore establishing a link between the filter specifications and the layout physical dimensions. The designed filter using this cross coupling coefficient has been fabricated and tested. The measured shows and excellent agreement with the electromagnetic simulations and the equivalent circuit response. Work is in progress to extend the technique to match wide band filters through ladder networks with coupling interaction to other filters.

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