A Compact Microstrip Two-layers Bandpass Filter Using Improved Interdigital-Loop Resonators

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***ABSTRACT* —In this paper we present a new compact two-layers microstrip bandpass filter using multilayer cross-coupled improved interdigital-loop resonators. The filter structure consists of four resonators placed on two microstrip stack layers. The coupling between the resonators on the upper layer and the lower layer is obtained by using three coupling apertures on the common ground plane. The full-wave simulator IE3D has been employed to design the interdigital-loop resonators and to calculate the coupling coefficients between resonators of the filter. Finally, the filter has been optimized, resulting to low passband insertion loss (less than 3 dB) and high return loss (higher than 20dB) at the center frequency. By using this two-layer technique in the microwave filter design, a filter size reduction of about 50% is obtained. These features make the proposed structure suitable for compact and high-performance circuit component designs in microwave integrated circuit (MMIC).**

***INDEX TERMS* — microstrip filter, size reduction, Bandpass filter**

I. Introduction

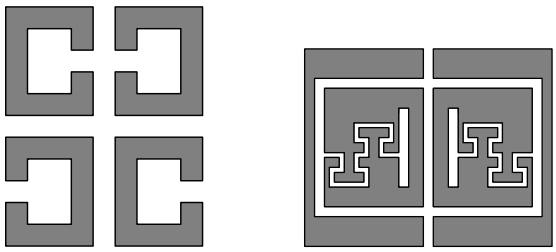
In modern communication systems, a printed microstrip filter is one of most important components in the RF front-end. It has very small size and high performances. However, planar microstrip filters are mostly implemented on a single microstrip substrate layer which takes often a large size. Another technique based on using high dielectric constant material to reduce the size of microwave has been proposed but it is very expensive[2][5]. To overcome the size problem, there have been increasingly interests in two-layers structure[1][7]. In this paper a compact two-layers microstrip bandpass filter using improved interdigital-loop resonator is proposed.

In this research, we proposed a new technique to reduce microstrip bandpass filter using a two-layers structure with interdigital-loop resonator is based on a parallel coupled line step impedance resonator (SIR) combined with loaded capacitive gap at the ends[2][3][4]. The interdigital-loop resonator has been improved by increasing the gap length, resulting in further size reduction due to the effect of loading capacitance shifting down the center frequency. Fig 1(a) shows the conventional single-layer four-pole open-loop cross-coupled resonators. Fig. 1 (b) shows a new cross-coupled microstrip bandpass filter with improved interdigital-loop resonators . A new filter consists of four-resonators configulation placed on two microstrip stacked layer substrates. The coupling between the upper layer and lower layer is obtained by using three coupling apertures on common ground plane.

This technique can be reduce size about 50% reduction compared with conventional single-layer microstrip bandpass filters. The simulation software using IE3D to designed filter at the center frequency of 1.95GHz and fabrication on two identical substrate layer of 0.762mm thickness have been performed.

II. A multilayer filter structure

Fig. 2 illustrates the exploded view of a stack of four resonators (four poles) of the proposed bandpass filter. These resonators are located on the external side of two dielectric substrates that are separated by a common ground plane. The upper and lower layer produces the necessary mixed coupling between the resonators. The electric coupling and magnetic coupling between the upper and lower resonators are then ensured by inserting three identical apertures on the common ground plane. However, the electric coupling and magnetic coupling coefficient is depended on the dimension of aperture.



(a) (b)

Fig. 1 (a) A conventional single-layer four-pole open-loop cross coupled resonators, (b) a new cross-coupled microstrip bandpass filter with improved interdigital-loop resonators .

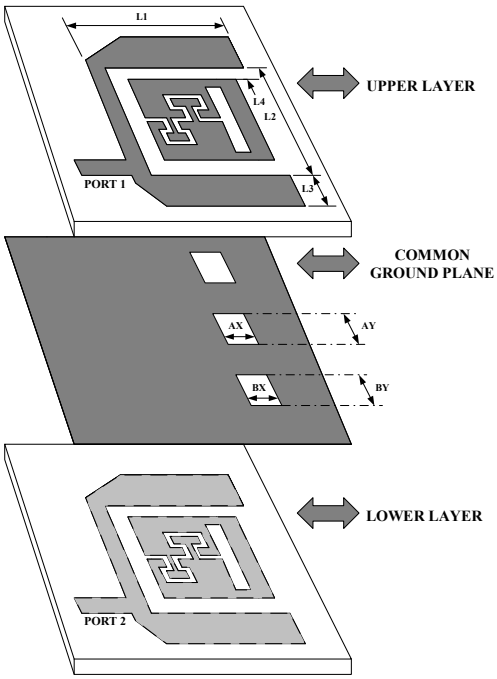


Fig. 2 A view of the proposed multilayer bandpass filter.

III. Interdigital-loop resonator

Fig. 3 shows the details of the proposed interdigital resonator structure. This structure based on basic stepped impedance resonator structure and interdigital capacitively loaded at the coupled-ends. The open-loop resonator in Fig. 4(a) which folded arm of resonator has a capacitively loaded line resonator. Fig. 4(b)shows its quasi equivalent circuit when C_L is the loaded capacitance and C_S is the series capacitive gap component. Fig. 5(a) shows the improved resonator when folded arm of resonator has an interdigital finger. This will enhance the value of series capacitance gap component[6]. Fig. 5(b) is a quasi equivalent circuit of the proposed resonator, when C_S and R_S are the series loaded capacitance and resistance. However, the value of the series capacitance will be higher compared with the conventional resonator. This will cause for shifting down of the fundamental resonant frequency. As we can see when designing the conventional step impedance resonator and the improved interdigital resonator with the same dimensions, resulting in the difference resonant frequencies as shown in Fig. 6 . We also found that at the same resonant frequency, the structure size of the proposed resonator will be smaller than the conventional structure about 40%. Nevertheless, the proposed interdigital resonator will have a key disadvantage of incremental loss due to the series resistance. Therefore, we have to careful for trading off the resonator size and the loss. Fig. 7 shows the simulated resonance frequency responses of coupling from these, which we can see two split resonance peaks. The coupling coefficients can be graphically estimated from these two resonance frequencies. The full wave EM simulator IE3D has been used to determine the resonance responses and then the coupling coefficients can then be extracted by

$$K_{ij} = \pm \frac{f_{p2}^2 - f_{p1}^2}{f_{p2}^2 + f_{p1}^2} \qquad (1)$$

Where f_1 and f_2 are the split resonance frequencies.

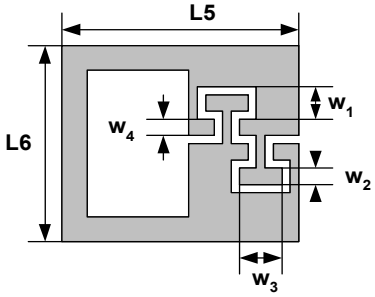
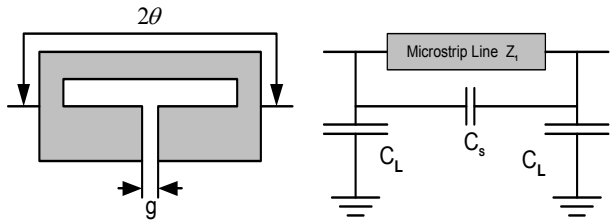
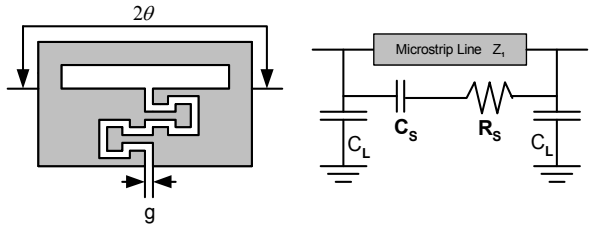


Fig .3 Microstrip improved interdigital resonator.



(a) (b)

Fig. 4(a) Slow-wave open-loop resonator with series capacitive gap. (b) Quasi-equivalent circuit.



(a) (b)

Fig. 5(a) Microstrip interdigital resonator and (b) its quasi equivalent circuit.

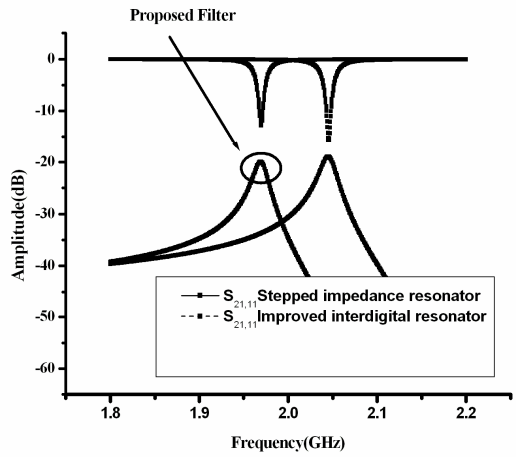


Fig. 6 A frequency response of each resonator structure.

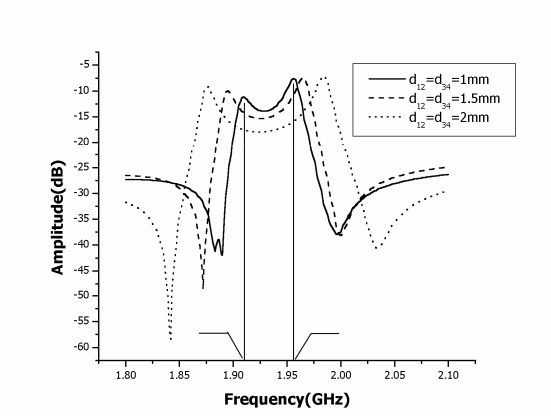


Fig. 7 A typical frequency response of a resonator pair for extracting coupling coefficient.

IV. Design and results

To demonstrate our approach, the proposed microstrip two-layers bandpass filter using improved interdigital-loop resonators is completely designed for IMT-2000 band with the center frequency f_0 at 1.95GHz and the band width of 60MHz (FBW=3.076%). The filter circuit has been designed on the GIL Technology GML 1000 substrate with relative dielectric of 3.2, loss tangent of 0.004, and thickness of 0.762 mm. The corresponding low-pass prototype element values are given as: be g_0=1, g_1=0.7422, g_2=1.2133, J_1= -0.1601 and J_2=0.9762 . The coupling between a resonator and its microstrip feed line characterized by the external quality factor of resonator, Q_{ext} this parameter can be calculated as follow:

$$K_{12} = K_{34} = \frac{FBW}{\sqrt{g_1 g_2}} = 0.0324$$

$$K_{23} = \frac{FBW.J_2}{g_2} = 0.0247$$

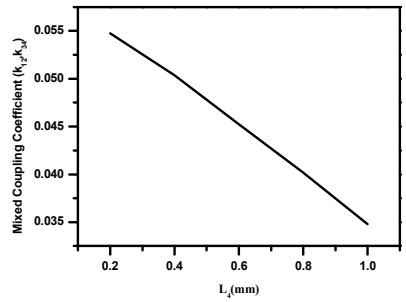
$$K_{14} = \frac{FBW.J_1}{g_1} = -0.00663$$

$$Q_{ext} = \frac{g_0 g_1}{FBW} = 24.128$$

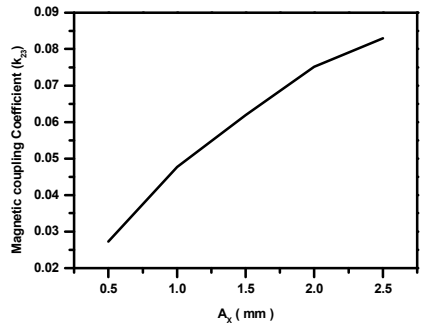
Fig. 8 shows three possible coupling coefficient curves as a function of distance L_4, A_X, B_X for the mixed coupling , magnetic coupling and electric coupling can be varied by increasing and decreasing the size of aperture in order to fine the suitable coupling coefficient.

The filter has been then optimized using IE3D software , resulting to the final circuit as shown in Fig. 9. The frequency responses from simulation and measurement are shown in Fig. 10 and 11, respectively.

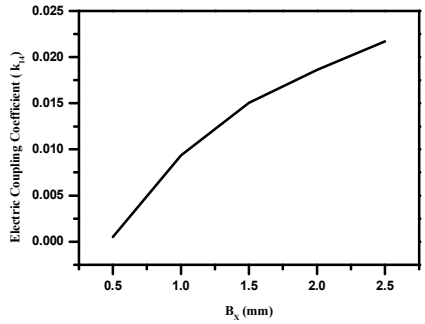
The optimal size of the proposed filter include L_1 =13.75 mm, L_2 = 14 mm, L_3= 3 mm, L_4= 0.2 mm, L_5= 10.97 mm, L_6=10.3 mm, W_1=1.9 mm, w_2=1 mm, w_3 = 3 mm, w_4 =1 mm, A_x= 0.75mm, A_y=3mm, B_x=0.8mm, B_y=6.3mm. The value of insertion loss (S_{21}) is lower than 3 dB and the value of return loss(S11) is better than 15dB on the passband.The constructed circuit is shown in Fig. 9.



(a)



(b)



(c)

Fig. 8 Coupling coefficient of coupled microstrip resonators (a) mixed coupling (b) magnetic coupling (c) electric couling.

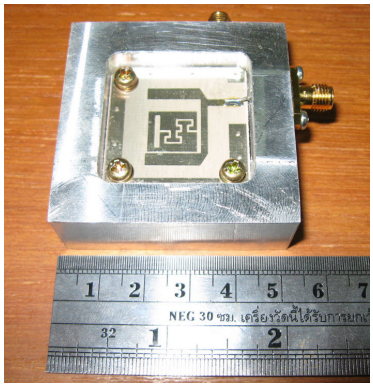
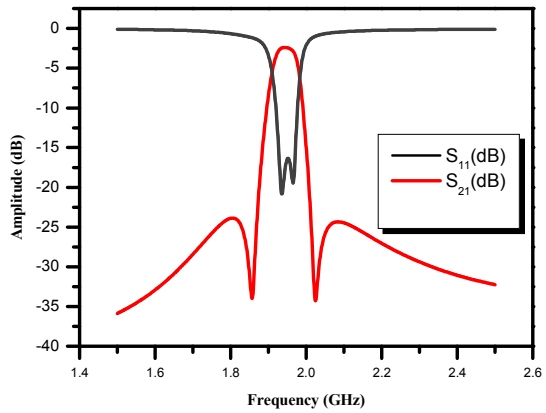
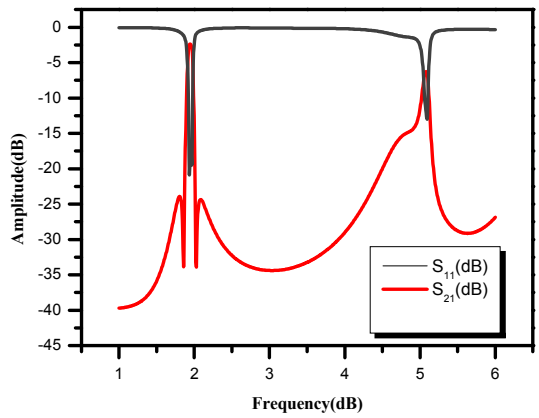


Fig. 9 Photograph of the proposed filter.

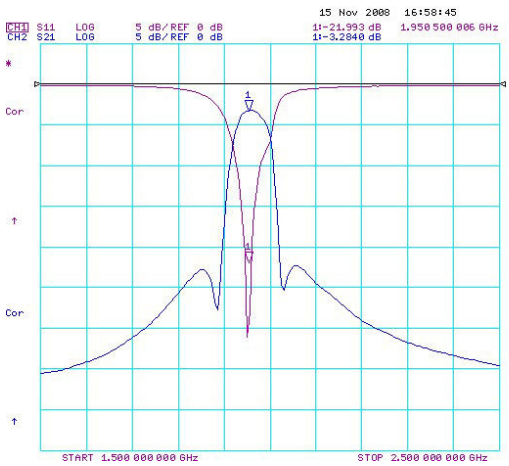


(a)

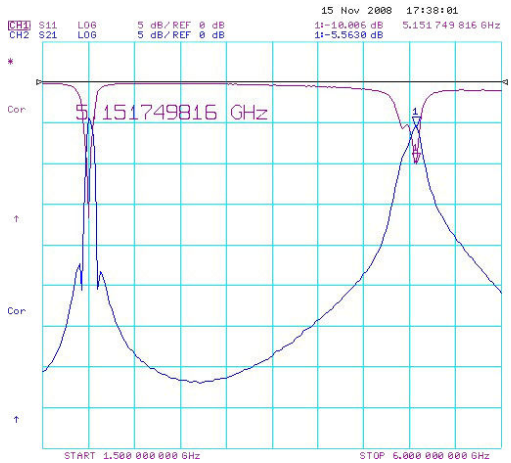


(b)

Fig. 10 Simulation Results S_{11} and S_{21} of microstrip two-layer bandpass filter using improved interdigital-loop resonator structure.



(a)



(b)

Fig. 11 Measurement results of S_{11} and S_{21}

V. Conclusions

We have presented a technique to miniaturize the bandpass filter using a multilayer structure with interdigital-loop resonators. The calculation of coupling parameters using IE3D has been also demonstrated. The results show that the proposed filter has excellent performances of low insertion loss (≈ 3dB) in the passband and return loss (≈ 20 dB) at the band center with a very compact size about 50% reduction compare with conventional structures. A good agreement between measurement and simulation results has been obtained. This technique should be attractive and suitable for microwave integrate circuits application.

Acknowledgement

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