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REALIZATION OF DUAL-BAND FILTER CHARACTERISTICS BY BOX CONFIGURATIONS

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Abstract—This work demonstrates that the well-known box configuration comprising four inverter-coupled resonators is capable of realizing a dual-band filter characteristic. A dual-band filter is designed at 1 GHz and subsequently implemented as a Combline microstrip filter exhibiting measured frequency characteristics which closely matched the simulations.

1. INTRODUCTION

Dual-band filters find a wide range of applications in modern Radio Frequency (RF) frontends. The design of such filters is generally requires the realization of advanced filtering transfer functions; a topic that has resulted in many interesting contributions such as [1–6], just to name a few. Cameron et al. [7] first introduced the box configuration which basically comprises four inverter-coupled resonators with only a single negative coupling branch. As already demonstrated in [7] the box configuration is capable of realizing a finite-frequency transmission zero located either in the lower or upper stopband of a single-band filter.

The objective of this communication is to demonstrate for the first time, that the box configuration is also capable of realizing a dual-band filter response.

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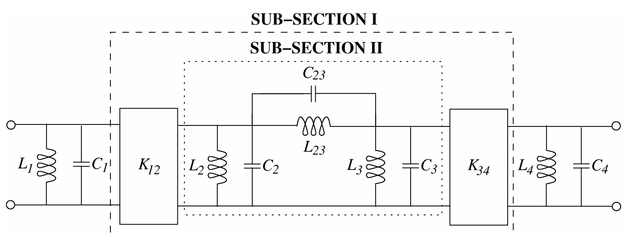
2. DESIGN OF BOX CONFIGURATION DUAL-BAND FILTER

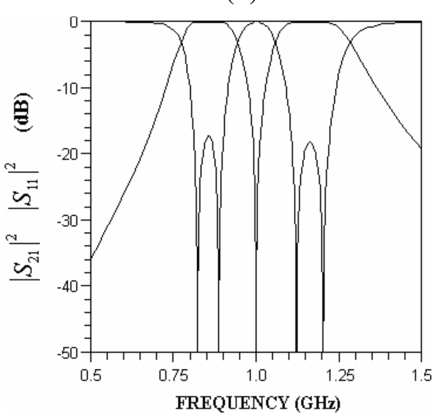
The design concept is easily understood upon examining the block diagram shown in Figure 1(a) that comprises a pair of bandpass filters separated by a bandstop filter. The two bandpass filters are assumed identical, i.e., both have the same fractional bandwidth and center frequency, f_o. On the other hand the bandstop filter is centered at f_o with passband edge frequencies located within the fractional bandwidth of either of the bandpass filters. Therefore it is straightforward to appreciate that the block diagram of Figure 1(a) will produce a dual-band filter response. Of course the mismatches at the interfaces between the different sub-blocks must be accounted for

(a)

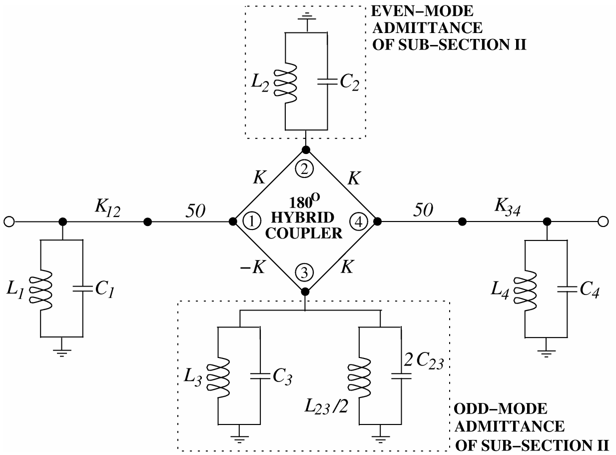


$L_1 = 2.016 = L_4$; $L_2 = 7.276 = L_3$; $L_{23} = 2.624$;
$C_1 = 12.689 = C_4$; $C_2 = 3.515 = C_3$; $C_{23} = 9.561$; $K_{12} = 50 = K_{34}$.

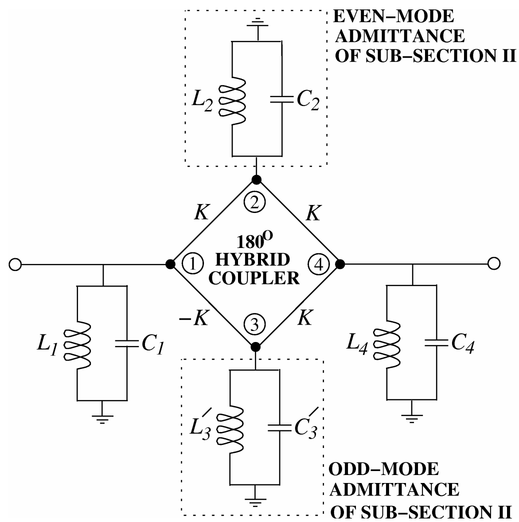
(b)



(c)



(d)

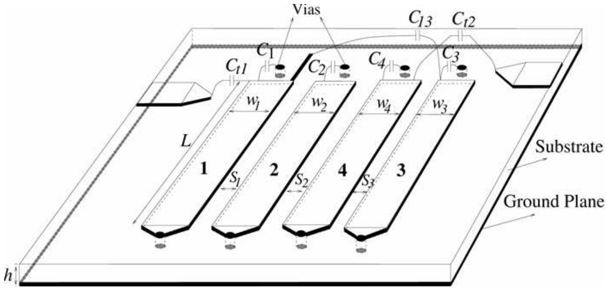


$L_1 = 2.016 = L_4$; $L_2 = 7.276$; $L_3 = 1.111$;
$C_1 = 12.689 = C_4$; $C_2 = 3.515$; $C_3 = 22.818$; $K = 70.7106$.

(e)

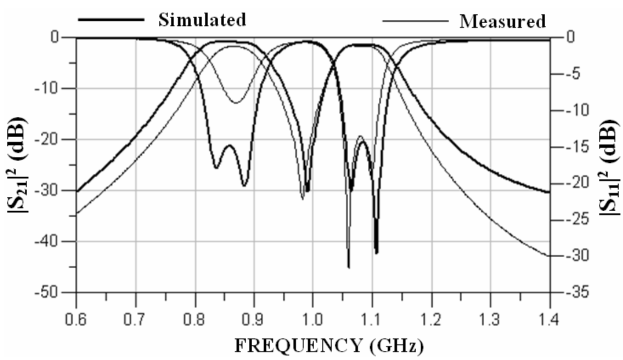
Figure 1. A 2nd-order dual-band filter: (a) Its sub-blocks; (b) its optimized circuit prototype; (c) the simulated electrical characteristics of the filter; (d) and (e) transformation to the box configuration. (The system impedance is $50\,\Omega$. All inductors, capacitors, and inverters are in nH, pF, and Ω respectively).

through some circuit optimization. The following is an example of a 2nd-order dual-band filter comprising a single box configuration.

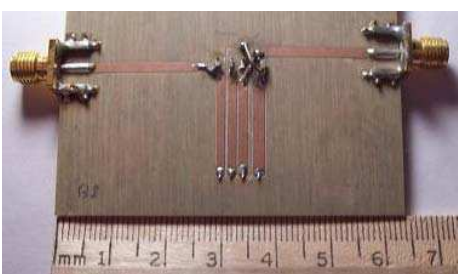


$C_1 = 1.5$ pF; $C_2 = 3.2$ pF; $C_3 = 2.8$ pF; $C_4 = 2.6$ pF; $C_{13} = 0.63$ pF;
$C_{t1} = 1.6$ pF; $C_{t2} = 1.4$ pF;
$\omega_1 = 1.57$ mm; $\omega_2 = 1.82$ mm; $\omega_3 = 1.7$ mm; $\omega_4 = 2.11$ mm;
$S_1 = 0.53$ mm; $S_2 = 0.41$ mm; $S_3 = 0.88$ mm; $L = 20.32$ mm;
$h = 0.81$ mm.

(a)



(b)



(c)

Figure 2. The microstrip dual-band Combline filter: (a) Electrical layout; (b) simulated and measured performances; and (c) photograph of the implemented filter.

Here a pair of *2nd*-order Chebyshev bandpass filters was synthesized each centered at 1 GHz and with a 40% fractional bandwidth. A *1st*-order bandstop filter was also synthesized that is centered at 1 GHz but with a 20% fractional bandwidth. The configuration was then cascaded and optimized leading to the physically symmetrical circuit illustrated in Figure 1(b) whose electrical performance is shown in Figure 1(c). Clearly a dual-band filter characteristic has been realized. At this point the physically symmetrical Sub-Section I (within the dashed box) in Figure 1(b) was exactly transformed into a *2nd*-order Cul-De-Sac network utilizing a 180° hybrid coupler following the methodology presented by Fathelbab [8]. This leads to the prototype of Figure 1(d) which is easily simplified to that of Figure 1(e). It is clear at this point that the circuit of Figure 1(e) is the well-known box configuration presented by Cameron et al. [7] with a single negative inverter.

3. A COMBLINE FILTER IMPLEMENTATION

The inter-resonator couplings of the box configuration of Figure 1(e) were evaluated and the physical layout of a microstrip Combline filter was generated. Full EM optimization was performed with the aid of CST Microwave Studio† for the implementation on a Rogers RO4003C‡ substrate with a dielectric constant of 3.38, a loss tangent of 0.0027, and a thickness of 0.8128 mm (32 mil). The resonators of the filter were loaded by high Q lumped capacitors while the single negative cross-coupling inverter was implemented as a lumped capacitor. The electrical layout of the filter is illustrated in Figure 2(a) which was subsequently fabricated leading to the measured frequency performance shown in Figure 2(b). Close agreement with the simulations is evident. Finally a photograph of the fabricated filter is also depicted in Figure 2(c).

4. CONCLUSION

This study concludes that the well-known box configuration comprising four inverter-coupled resonators with a single negative inverter can realize a dual-band filter response. This enhances our understanding of the properties of this coupled-resonator section and extends its usage to dual-band filtering applications.

† CST Studio Suite, CST computer simulation technology, Version 2009.

‡ http://www.rogerscorporation.com.

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