Miniaturized Microstrip Dual-Band Bandpass Filter

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Abstract

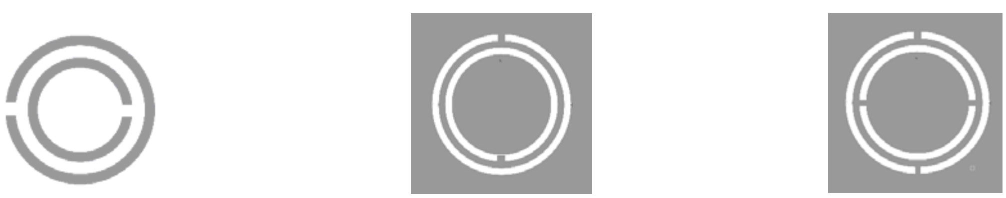
This paper presents a miniaturized dual-band bandpass filter design for a potential application in multi-channel communication. The design is based on planner split ring resonator (SRR) and its image. The size of the filter is reduced by a scaling factor of 5 comparing to filters designed from conventional resonators. A prototype dual-band filter is fabricated and the measurements agree well with the results predicted by the design simulated with Agilent's Momentum.

1. Introduction

The need for multiband RF front-end in modern communication system is clear. For example, satellite system always uses a complex arrangement of frequency plans and consequently needs filters for each communication channel [1] and it will be ideal to have a single filter module that does jobs of all those channel filters to reduce the size and pay load of the system. Also, multiband satellite terminals are calling for small and mobile sets as opposite to traditional large ground station [2], and therefore demanding not only multiband filters, but also miniaturized ones that can be easily integrated with antennas.

Although there are many reports on multiband filters from waveguide type [3] to microstrip type [4], the size of those filters needs to be and can be further reduced. It is the purpose of this paper to present our progress on miniaturized dual passband filters that can be easily modified to satellite communication applications. Two bands of the proposed filter can be tuned independently and can easily be designed to operate with any two frequencies within the entire Ka band.

The design philosophy is to make use of microstrip split ring resonators (SSR) [5], which has the built-in advantage of being small. A microstrip SSR is illustrated in Figure 1 (a). The resonator shown in Figure 1 (b) is a complementary split ring resonator (CSRR), which is a negative image of a SRR [6]. One can easily fabricate a CSRR by etching the metal on a microstrip substrate. Figure 1 (c) shows the topology of a double split CSRR [7] and the meaning of "double" is obvious from the illustration. Given the resonant nature of SRR and CSRR/ DS-CSRR, and the fact that they can be fabricated on opposite sides of a circuit board, it is intuitive to design a compact dual-band filter based on SRR and CSRR/ DS-CSRR, where SRR and CSRR/ DS-CSRR represents two passbands respectively.



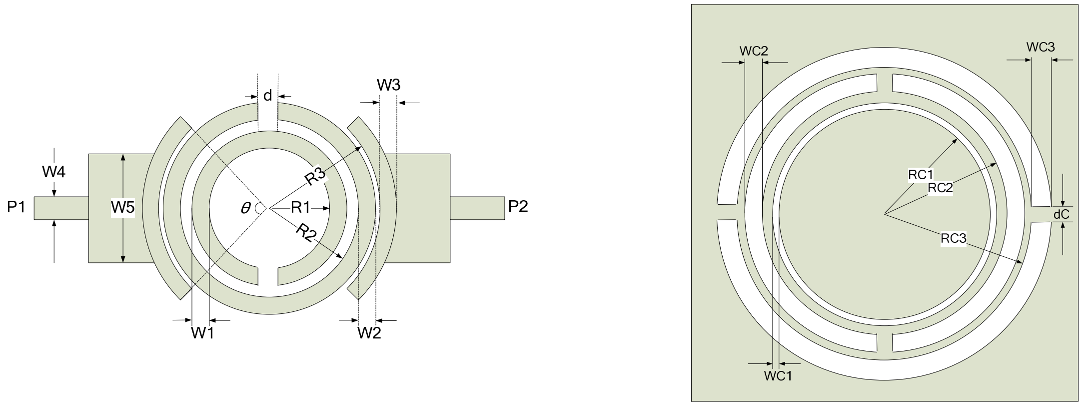
(a) (b) (c)

Figure 1. Topology of SRR, CSRR, DS-CSRR (Metal regions are marked in dark gray).

2. Design Method

The circuit layouts of two bands are as shown in Figure 2 (a) and (b). Note that any two rings (ones on the same plane or opposite planes), circles or arches are concentric. A complementary ring (CR) with radius RC1 and the width WC1 (Figure 2 (b)) is introduced to ground the SRR without disturbing the resonance of the DS-CRSS.

We designed the filter such that the SRR provides the resonance for the upper passband and DS-CSRR for the lower band. Both resonators share the same feedlines for excitation and it is straightforward to see that the SRR is excited by magnetic coupling where as the DS-CSRR is by electric coupling. Although we have designed the lower band with DS-CSRR, it is possible to choose CSRR for the lower band and the design process is similar to the one presented here. The choice of DS-CSRR or CSRR depends on the center frequencies of each band and the effectiveness in exciting the lower band resonator with the feedlines on the top plane.



(a) Top plane: SRR and feedlines (b) Bottom plane: DS-CSRR

Figure 2. Circuit layout of two passbands.

We found that the coupling between the SRR and DS-CSRR is weak, and accordingly the filter model can be simplified as shown in Figure 3 (block diagram) and Figure 4 (lumped element model). The filter prototype is derived from low-pass prototype [8]. The resonators are coupled by admittance inverters, which are implemented by the arch with an inner radius of R3 as shown in Figure 2. *Lr* and *Cr* in Figure 4 are equivalent lumped inductance and capacitance for the DS-CSRR. *Ls* and *Cs* are equivalent inductance and capacitance for the SRR. *L* is the inductance between the feed port and the arch. *Cg* is the gap capacitance between the arch and the SRR, and *Cc* is the capacitance between the arch and the DS-CSRR. Finally *Cri* is the capacitance introduced by the CR inside the DS-CSRR.

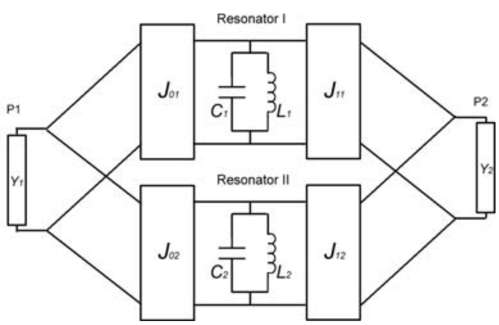


Figure 3. Generalized circuit model for the dual-band filter using shunt LC resonator tanks and admittance inverters.

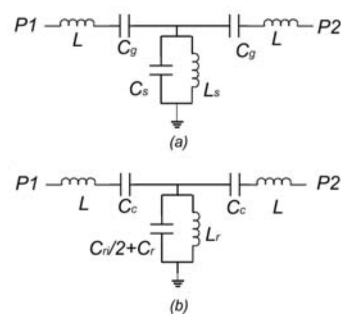


Figure 4. Lumped element model for upper passband (a) and lower passband (b).

3. Dual Passband Filter Example

As an example, we designed a dual-band filter with liquid crystal polymer (LCP) as the substrate. The material parameters of the LCP are concluded in Table 1. The center frequencies of two bands are designed to be 11.5 GHz and 18.5 GHz, and Agilent's Momentum is used for the design. The computed radius and line width of two resonators and feedlines are concluded in Table 2 and Table 3. The magnitude of S11 and S12 is plotted in Figure 5, and Figure 6 shows the phase response of S21. We can see a good linearity of filter in both passbands. The insertion loss (from Figure 6) is found to be slightly low, and a discussion on that is presented in session 5. The attenuation in the first stop band is not as strong as a preferred value (such as -20 dB), and a proposed fixture is presented in session 5.

TABLE 1: Summary of LCP Parameters

Substrate Thickness	Relative Permittivity	Metal Thickness
203.2 μm	2.9	35 μm

TABLE 2: Circuit layout parameters for the upper band and feedlines

R1	R2	R3	W1	W2	W3	W4	W5	d	θ
550 μm	830 μm	950 μm	100 μm	100 μm	100 μm	180 μm	700 μm	150 μm	75°

TABLE 3: Circuit layout parameters for the lower band

RC1	RC2	RC3	WC1	WC2	WC3	dC
1100 μm	1250 μm	1450 μm	50 μm	100 μm	100 μm	100 μm

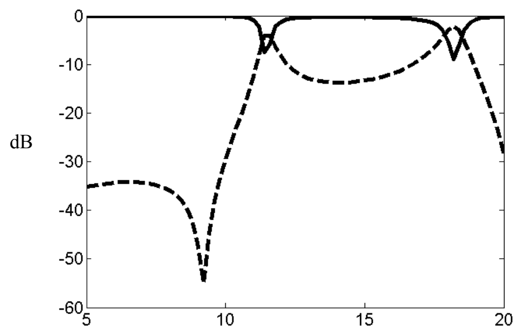


Figure 5. Magnitude of S11 and S12 of the dual-band filter.

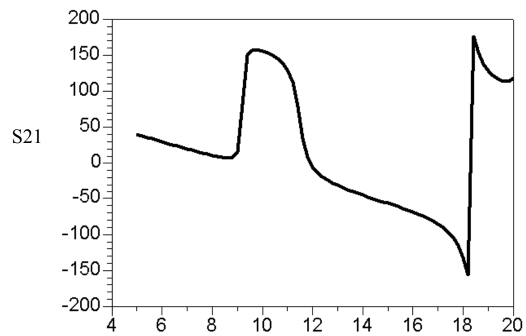
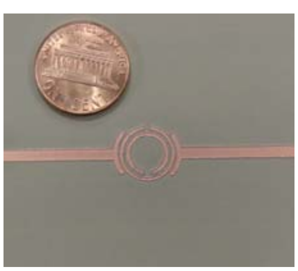


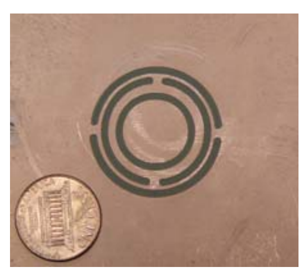
Figure 6. Phase of S21 of the dual-band filter.

4. Experimental Validation

Since the current fabrication facility at USU is not sufficient for K band and above, in order to verify our design, we scaled the filter to 1 GHz range in design and built a filter prototype for validation purpose. The fabricated filter is shown in Figure 7 and the Momentum simulation plus the measurements are presented in Figure 8. Please note that we did not show the grounding of the inner most metal disk inside the DS-CSRR in Figure 7. In order to have the correct filter response, the disk has to be grounded, and we have experimented with several grounding methods. The measured results in Figure 8 are taken when using 4 patches of copper tapes to ground the disk. As seen in Figure 8, the experimental results agree very well with the simulation and validate our design.



(a) SRR (upper band)



(b) DS-CSRR (lower band)

Figure 7. A dual-band (880 MHz and 1.64 GHz) filter fabricated with Rodgers RO 3010 substrate.

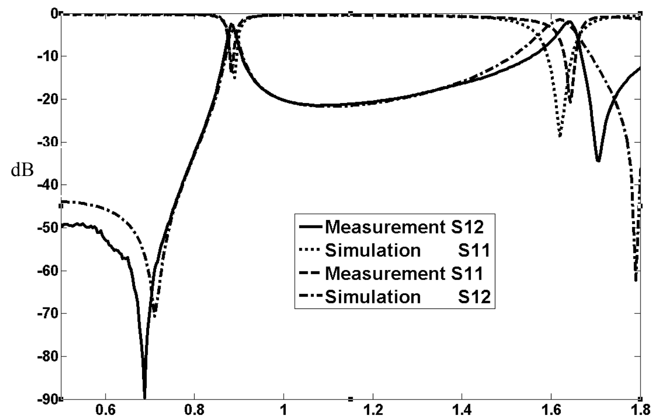


Figure 8. Comparison of measured response and simulations.

5. Conclusion

The proposed filter can be used to implement periodic structures such as Chebyshev filters. Two resonators of the filter operate at their fundamental modes to offer a stable response. Two passbands can be tuned separately and can be easily designed to operate at any two frequencies in the entire Ka band. The size of one resonator is about 3 times smaller than a conventional half wavelength resonator, and we gain an additional scaling factor of 2 by integration two resonators. So the overall miniaturization factor is larger than 5.

As shown in section 3, the insertion loss is slightly low. This is due to the metal loss at the high frequency since this low insertion loss is not seen in the design at 1 GHz range. We expect to improve the design choosing a proper metal coating. Another observation of the filter designed with LCP is the relatively low attenuation in the first stop band. This can be improved by adjusting the feedlines and the coupling, i.e. by adjusting the spacing between the arch (Figure 2 a) and the SRR.

6. References

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