Progress In Electromagnetics Research, PIER 78, 17–24, 2008

DESIGN OF NOVEL DUAL-BAND BANDPASS FILTER WITH MICROSTRIP MEANDER-LOOP RESONATOR AND CSRR DGS

G.-L. Wu, W. Mu, X.-W. Dai, and Y.-C. Jiao

National Key Laboratory of Antennas and Microwave Technology
Xidian University
Xi'an 710071, China

Abstract—A novel dual-band bandpass filter with meander-loop resonator and complement split-ring resonator (CSRR) defected ground structure (DGS) is proposed in this letter. Microstrip meander-loop resonator and CSRR DGS are operated for respective passbands. Several finite attenuation poles in stopbands are realized to improve the selectivity of the proposed bandpass filter and isolation between the two passbands. Compact size, dual band and high selectivity characteristics are realized by this type of filter structure. The filter is evaluated by experiment and simulation with very good agreement.

1. INTRODUCTION

Recent development in wireless communication systems has presented new challenges to design and produce high-quality miniature components with a dual-band operation. For example, global systems for GSM operate at both 900 and 1800 MHz. IEEE 802.11b and IEEE 802.11a wireless local area network (LAN) products operate in the unlicensed industrial-scientific-medical (ISM) 2.4 and 5 GHz bands, respectively. Therefore, to reduce the volume and weight of communication circuits and equipments, many dual-band components, including antennas [1], couplers and filters [18, 19], have recently received much attention and been developed. A number of publications have provided a variety of solutions to the realization of dual-band bandpass filter [2–6], which is a key component filtering unwanted frequency in RF systems [14].

The synthesis theory of microwave filters presenting two passbands mostly use frequency-variable transformations [2]. However, strong attenuation between the two passbands is required for practical applications. Stepped impedance resonators (SIRs) structure of the dual-band bandpass filter, has been proposed, which is mainly utilizing the dual-band characteristic of SIR [3, 16]. In [4], a dual-band bandpass filter, composed of two single-band bandpass filter using LTCC techniques is proposed. However, an additional circuit network is needed to combine these two filters. Recently, the dual-mode resonator using patch [7] or loop [8] has attracted much attention in design of single band filter, which meets the demands for compact size and high-performance filters.

In this paper, a highly selective dual-band bandpass filter with meander-loop resonators and SRR DGS is presented. The two passbands are generated through respective resonators. High selectivity is obtained by the introduction of several finite attenuation poles in stopbands. Compared with the conventional dual band filter, the filter is smaller in size and better in performance.

2. MICROSTRIP MEANDER-LOOP RESONATOR

Based on a variety of symmetric dual-mode resonating structures, dual-mode microstrip bandpass filters have been investigated by many researchers for applications in both wired and wireless communication. The typical schematic layouts of the dual-mode resonators are shown in Figure 1, which shows that the mender-loop resonator has advantage of compact size.

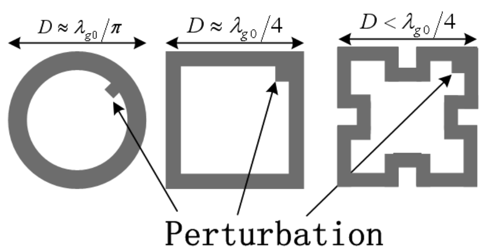


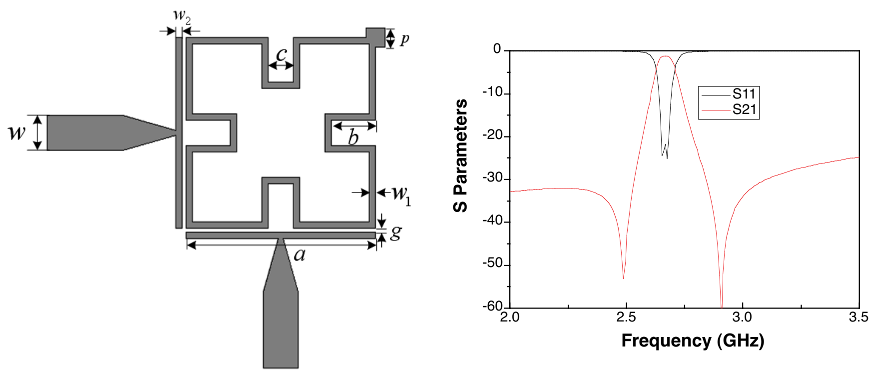
Figure 1. Typical dual-mode microstrip loop resonators.

Due to the high desirability for compact high-performance in wireless communication systems, dual-mode microstrip filters have been widely studied by numerous researchers for its advantages in applications requiring filter with features such as small size, low mass, and low loss. For dual-mode operation, a perturbation is introduced in the resonator in order to couple its two degenerate modes. The response of the dual-mode filter can be changed from elliptic to Chebyshev by simply adjusting the size of the perturbation. The appearance of the two transmission zeros in the response, is due to the presence of a parasitic coupling between the input and output. In addition to the two degenerate modes in the loop, there are higher modes (and possibly surface waves), which provide additional paths between the input and output. This situation can also be seen from the coupling coefficient computed using the relationship between the split in the resonance frequency of the two modes and the coupling, as described by

$$k = \frac{f_1 - f_2}{f_1 + f_2} \qquad (1)$$

The total length of the dual-mode resonator is λ_g, which is the guided wavelength at the fundamental resonance frequency.

The typical dual-mode filter with meander-loop resonator is shown in Figure 2(a), while its response is shown in Figure 2(b) [9]. It is clearly observed that two poles in stopband are realized, which can improve the selectivity of the filter.



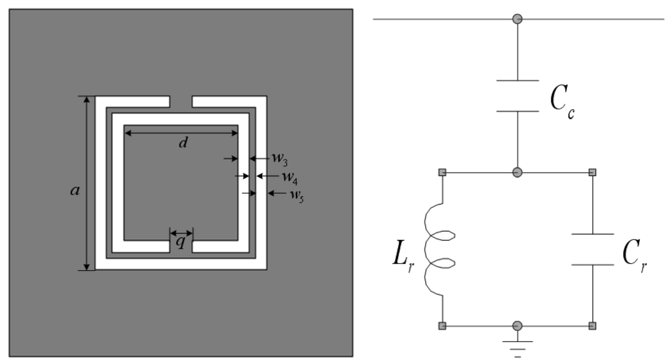
(a) Typical Structure (b) Response

Figure 2. Typical dual-mode bandpass filter with meander loop resonator and its elliptic response.

3. SRR DGS

Based on the idea of photonic band-gap (PBG) structure, defected ground structure (DGS) was firstly proposed by Park et al. in 1999, and has found its application in the design of planar circuits and low-pass filters [10]. DGS is realized by etching a defective pattern in the ground plane [17], which disturbs the shield current distribution in the ground plane. This disturbance can change the characteristics of a transmission line such as equivalent capacitance and inductance to obtain the slow-wave effect and band-stop property.

Split-ring resonators (SRRs) have been successfully applied to the fabrication of left-handed metamaterial (LHM) and the design of planar circuits. Pendry et al. have demonstrated that an array of SRRs exhibits negative permeability near its resonant frequency. Very recently, complementary split-ring resonator (CSRR) [15], which is the negative image of split-ring resonators (SRR) [11], has been reported by some authors. It has been demonstrated that CSRR etched in the ground plane or in the conductor strip of planar transmission media provides a negative effective permittivity to the structure. CSRR has been successfully applied to the narrow band filters and diplexers with compact dimensions [12, 13].



(a) CSRR DGS (b) Equivalent circuit

Figure 3. CSRR DGS and its equivalent circuit.

The topology of CSRR DGS is shown in Figure 3(a). From the equivalent circuit of CSRR DGS, shown in Figure 3(b), we can get the position of the transmission zero. This is given by the frequency that nulls the shunt impedance as follows:

$$f_Z = \frac{1}{2\pi\sqrt{L_r(C_r + C_c)}} \tag{2}$$

4. PROPOSED FILTER

The structure of proposed dual-band bandpass filter is shown in Figure 4, whose dimensions are as follows: $a = 15\,\text{mm}$, $g = 0.3\,\text{mm}$, $b = 3.5\,\text{mm}$, $c = 2.0\,\text{mm}$, $d = 10\,\text{mm}$, $p = 1.5\,\text{mm}$, $q = 2.0\,\text{mm}$, $w_1 = w_2 = w_4 = 0.5\,\text{mm}$, $w_3 = w_5 = 1.0\,\text{mm}$ and $w = 2.8\,\text{mm}$, which is the width of $50\,\Omega$ microstrip line. The tapered feed-line is used

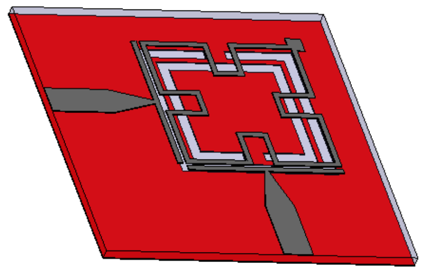


Figure 4. Proposed dual-band bandpass filter.

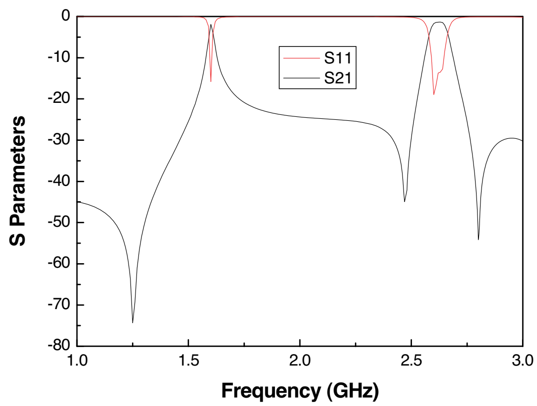


Figure 5. Response of the proposed dual-band bandpass filter.

in the proposed filter. Based on the discussion mentioned above, two transmission paths for RF signal can be generated by the meander loop and CSRR DGS. The response of the proposed filter is illustrated in Figure 5, where the dual-band characteristic and several transmission zeros can be observed clearly.

5. FABRICATED FILTER AND MEASURED RESULTS

To confirm and demonstrate the dual-band function response of the proposed filter, a structure shown in Figure 4 is designed, whose dimensions are given in Section 4. The filter is designed and fabricated on the substrate with a thickness $h = 1$ mm and a relative dielectric constant $\varepsilon_r = 2.65$. The photograph of fabricated filter is shown in Figure 6. The simulated performance was obtained using simulator IE3D V10 based on MOM, and measurement is accomplished with Agilent 8719ES network analyzer. The simulated and measured

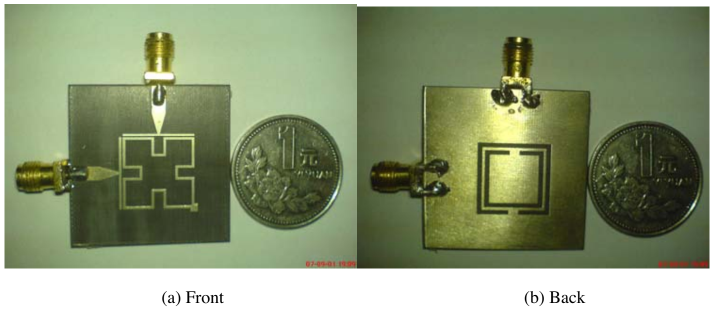


Figure 6. Photograph of the fabricated filter.

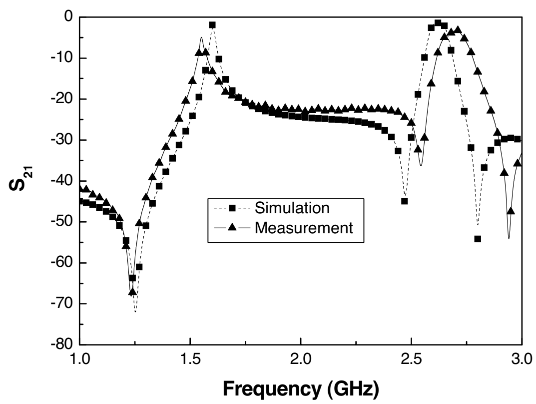


Figure 7. Comparison of the simulated and measured results.

results are shown in Figure 7. Referring to the measured results, the two passbands centered at 1.55 and 2.68 GHz, respectively. Three attenuation poles at 1.24, 2.54 and 2.94 GHz are realized, which can greatly improve the selectivity and stopband suppression of the proposed dual-band bandpass filter. The insertion loss in passband is mainly due to the conductor loss of the meander-loop resonators. Compared with the simulated results, the passbands and several attenuation poles have slightly shifts. This is due to the inaccuracy in fabrication and implementation. Good agreement between the simulation and measurement is achieved.

6. CONCLUSION

In this paper, a novel dual-band bandpass filter with microstrip meander-loop resonator and CSRR DGS is presented. The meander-loop resonators and CSRR DGS generate respective passbands. Several transmission zeros in stopbands are realized to improve the selectivity of the filter and isolation between the two passbands. Compared with the conventional dual-band filter, the proposed filter is smaller in size. Good agreement between the simulated and measured results demonstrates our proposed structure.

ACKNOWLEDGMENT

This work is supported by the National Natural Science Foundation of China (NNSFC) under Contract No. 60501023.

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