New Compact Dual Bandpass Filter Using Coupled Double-Ring Resonators and DGS-Technique

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Abstract **─** This paper presents a design of dual-band bandpass filter using novel ring resonator and H-defected ground. The bandpass filter is designed optimized and realized using mixed coupled microstrip double ring resonators and two electrically coupled H-cells DGS resonators, which are etched in background of the structure. Using this new ring structure leads to generate a selective bandpass filter with two isolated passbands. The measurement results show that the optimized filter has two passbands, the first band from 1.6 GHz to 2 GHz and the other from 3.6 GHz to 5.5 GHz. The proposed structure occupies an area of ($0.45\lambda g \times 0.35\lambda g$) with $\lambda g = 0.044$ m. The simulated and experimented results show good agreement and validate the proposed approach.

Index Terms **─** Coupled resonators, defected ground structure (DGS), double-ring resonators, dual-band bandpass filter.

I. INTRODUCTION

Recently, defected ground structures (DGS) and electromagnetic band gap (EBG) structures have drawn a great interest in microwave and millimeter wave applications because of their numerous advantages like significant size compactness and undesired harmonic suppression and their using in mobile communication systems and in various applications of microwave technology. DGS can be etched periodically or non-periodically cascaded shapes in ground of a planar transmission line. DGS caused disturbance in a shield current distribution in the metallic ground plane. This disturbance leads change of characteristics of a transmission line such as line capacitance and inductance. Thus, DGS elements are equivalent to the LC circuit [1]. Compact filters which use DGS structures as main block of resonators are investigated [2], [3] and antennas [4], [5]. To meet the requirements in modern microwave engineering and mobile communication systems, much effort has been made in the past years to develop a variety of the compact bandpass filter with sharp and deep rejection outside the passband by generating transmission zeros or attenuation poles [6-8]. The DGS-technique presents one of the very successful solutions to achieve significant size compactness and to suppress the undesired periodicity effect [9], [10].

With recent development in wireless communication systems, dual-band filters have been needed for many dual-band operation systems. A dual-band bandpass filter was implemented by a cascade connection of two single-band filters [11]. However, this approach not only increases the overall size of the filter, but also requires extra impedance matching networks. Defected ground structure is also used to achieve dual-band filter [12], [13].

In this paper, a new type of dual bandpass filter using microstrip coupled double-ring resonators and

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defected ground structure technique is designed, fabricated, and measured. In order to tune the desired transmission zeros which determine the sharpness of the transitions of the stop domain, the slot between the internal-arms of the ring resonator and the position of the 50 Ω microstrip feeds are optimized.

The proposed filter shows two passbands from 1.6 GHz to 2.0 GHz and from 3.6 GHz to 5.5 GHz. The out-band rejection between both passbands is better than 20 dB from 2.2 GHz to 3.3 GHz. The two passbands of the filter at 1.8 GHz center frequency with 22.2% fractional bandwidth (FBW) and at 4.5 GHz center frequency with 42.2 % fractional bandwidth at -3 dB have been implemented for the applications of L- and C-band communication systems respectively. The proposed filter is fabricated and measured. The CST software was employed in the full wave simulations. Finally, the measured results exhibit good agreement with the simulations. The out-band rejection is better than 20 dB up to 10 GHz.

II. CHARACTERISTICS OF THE NEW DOUPLE RING RESONATOR

The configuration of the double-ring resonator is shown in Fig. 1. It consists of a small interior ring, which is connected to a wide exterior ring. The new double-ring resonator can be presented as LC resonator, in which the arms present the inductance and the slot the capacitor. The proposed resonator acts as a dual resonator of different circumstances. Hence, the proposed resonator can behave as a dual bandstop filter. By loading this resonator with the microstrip line, the whole structure acts as a dual bandstop filter. The frequency response of the filter can be adjusted. The lower frequency stopband is mainly controlled by the larger loop dimensions, whereas the higher frequency is controlled by the smaller loop. To examine the proposed dual-band resonator response, it has been examined for different small loop gap (s) so that the return loss and the insertion are demonstrated in Fig. 2.

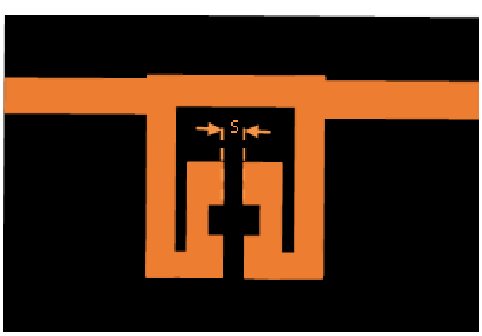

Fig. 1. The 2-D layout of the double microstrip ring resnator.

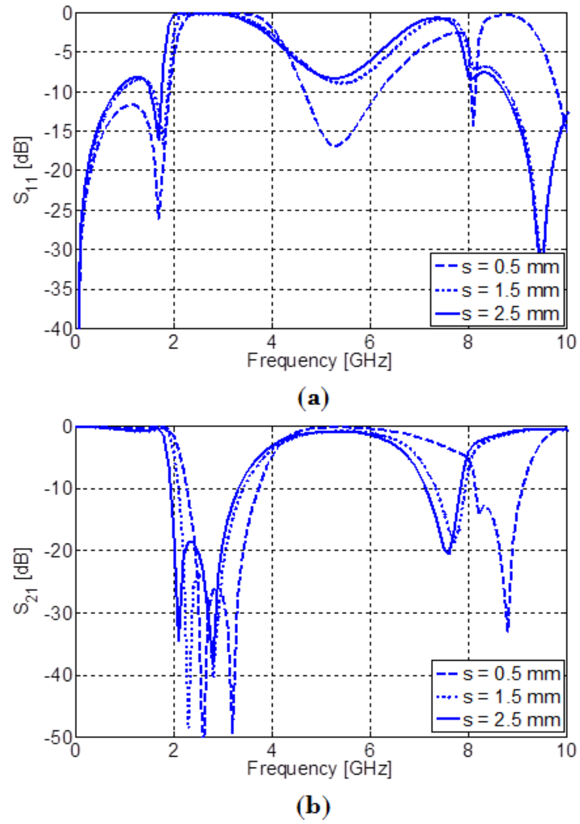

Fig. 2. Parametric study of the double microstrip ring resonator at different value of (s): (a) return loss, and (b) insertion loss.

Based on the several proposed resonator structures and their analysis in our published papers [1], [9], [10], the equivalent circuit of the investigated microstrip resonator, corresponds to a parallel LC circuit. The values of the L and C can be calculated as following:

$$C = \frac{5 f_c}{\pi Z_0 \left(f_0^2 - f_c^2 \right)}, \tag{1}$$

$$L = \frac{250}{C_p (\pi f_0)^2}. \tag{2}$$

By increasing S from 0.5 mm to 2.5 mm, it is clear that the structure has dual-bands. The first stopband is from 2 GHz to 4 GHz and is not affected by changing (s). On the other hand, a second stopband which is approximately from 6 GHz to 8 GHz for S = 1.5 mm and 2.5 mm. However, by decreasing the distance (s) to 0.5 mm, this stopband can be shifted up to be from 8 GHz to 9 GHz. In effect, we can say the propose resonator introduces a LPF from 0 to 2 GHz along with bandpass filter. These results confirm that by controlling each loop individually, a dual bandstop filter can be obtained. The filter performance can be further investigated by plotting the electric field at different frequencies as shown in Fig. 3.

As shown in the figure, two passband filed profile (from port 1 to port 2) is clear at 1.8 GHz and 5 GHz in Fig. 3 (a) and Fig. 3 (b), respectively. At 2.3 GHz, a total reflection (stopband) field concentration at the input as illustrated in Fig. 3(c).

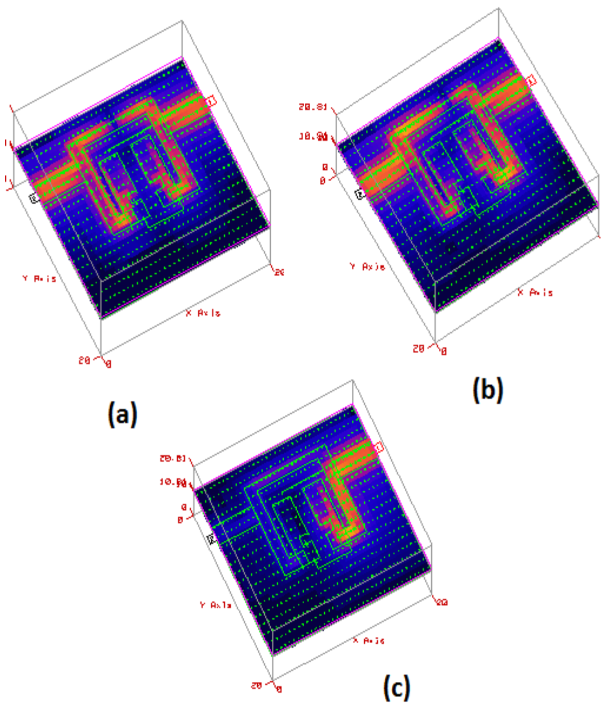

Fig. 3. Elcetric field distribution results in the double microstrip ring resnator: (a) passband at 1.8 GHz, (b) passband at 5 GHz, and (c) reject band at 2.3 GHz.

III. SIMULATETED RESULTS AND DISCUSSIONS

The dual-band performance in our reported filter can be introduced by coupling the before designed dual-band resonator to be as shown in Fig. 4. This structure acts as a coupled line bandpass filter with two possible bandpass. The first band is around 2 GHz due to the first resonator loop, whereas the second one is around 6 GHz as a result of the second resonator loop.

To enhance the attenuation between the two passbands, a two pairs of H-DGS cells are etched under feed lines. The H-DGS is functioned as a notch stopband pass filter. By adjusting its center frequency to be around 2.5 GHz, this can improve stopband rejection after the first passband without affecting the center frequency and insertion loss of basic filter passbands. To confirm our design methodology, the proposed filter as in Fig. 4, is simulated and its scattering parameters are shown in Fig. 5 which confirms the dual passband filter performance at 2 GHz and 6 GHz with 2.5 GHz attenuation up to 50 dB.

Fig. 4. 3-D model of the proposed dual-band bandpass filter.

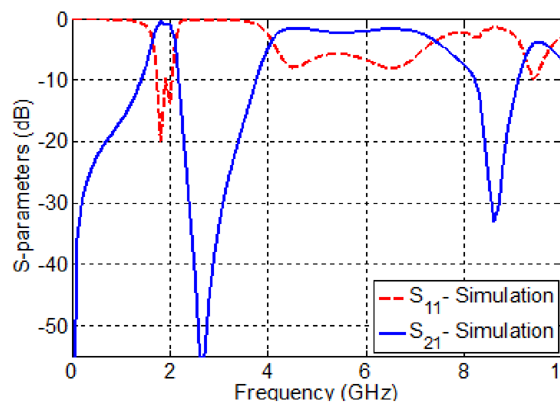

Fig. 5. The simulated S-parameters results of the proposed dual-band bandpass filter.

The function of the introduced H-DGS is examined by comparing the field profile at 1.8 GHz and 2.5 GHz as shown in Fig. 6. It is quite clear that at 1.8 GHz, the passband field is from port 1 to port 2. On the other hand, at 2.5 GHz, the field can reach the middle of the filter and dies there where the H-DGS is inserted. From the results shown in Fig. 5, we can claim that the second passband has a poor passband compared to the first one. This can be as a result of the position of the feeding transmission line as shown in Fig. 7. The filter scattering parameters magnitudes are examined for different (t) values and its insertion loss and return loss are depicted in Fig. 8. As shown in the figure, the first passband is not affected by changing the value of (t). On the other hand, the second passband insertion loss level can be enhanced by changing the value of (t). For t = 0, the first passband has almost 0 dB insertion loss and the second passband demonstrates almost flat insertion loss with a 1 dB average value.

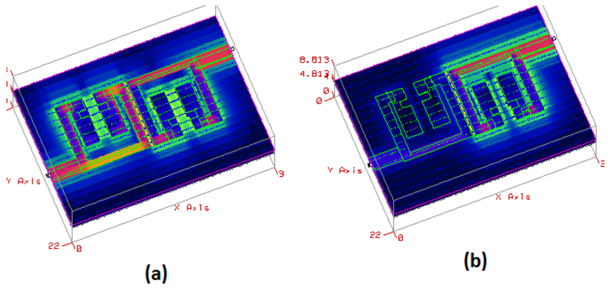

Fig. 6. Elcetric field distribution results in the proposed dual-band bandpass filter: (a) passband at 1.8 GHz, and (b) reject band at 2.5 GHz.

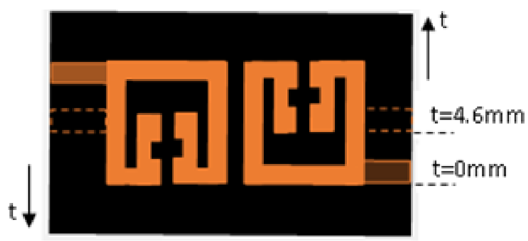

Fig. 7. 2-D layout of the proposed dual-band bandpass filter at different value of (t).

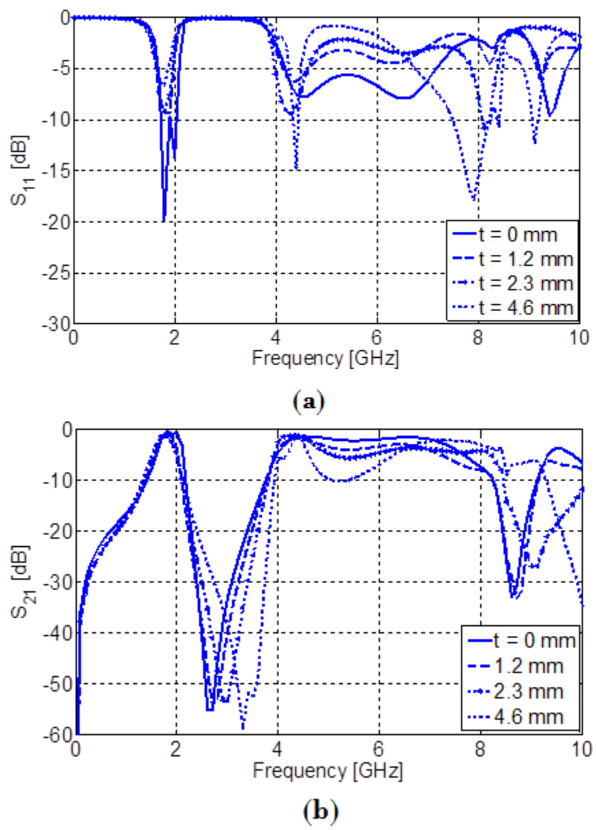

Fig. 8. Parametric study of the proposed dual-band bandpass filter at different value of (t): (a) return loss, and (b) insertion loss.

IV. EXPEREMENTAL RESULTS

The proposed dual-band bandpass filter has been fabricated using substrate Rogers RO4003 with dielectric constant of 3.38, a thickness of 0.813 mm and a dielectric loss tangent (δ) = 0.0027. The feeding microstrip line width is equal to 2 mm to have a characteristic impedance of 50 Ω.

The photograph of the fabricated dual-band filter is illustrated in Fig. 9. From Fig. 9 (a) is the top view of the proposed filter, it is clear that the filter consists of two mixed coupled microstrip double-ring resonators. On the other hand, from Fig. 9 (b), it is obvious that there are two electrically coupled H-cells DGS resonators, which is used to enhance the stopband rejection of the filter.

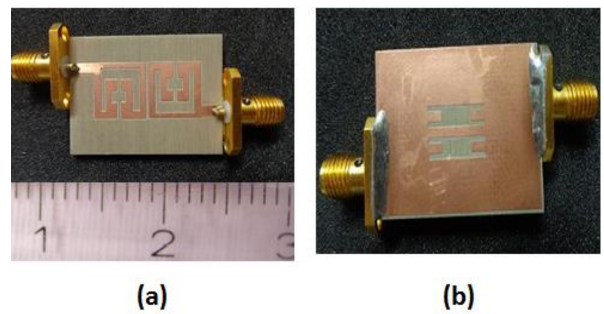

Fig. 9. Photograph of the fabricated dual-band bandpass filter: (a) top view, and (b) bottom view.

The fabricated filter is tested and measured using HP8722D network analyzer and the results are demonstrated in Fig. 10. From Fig. 10, it is seen that from the insertion loss result the proposed filter has dual frequency band from 1.6 GHz to 2 GHz and the other from 3.6 GHz to 5.5 GHz. The filter has high stopband rejection from 2.3 GHz to 3.5 GHz, this stopband is achieved using the H-Shaped DGS resonators.

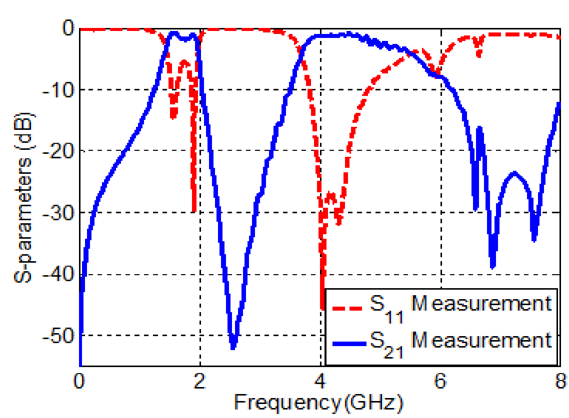

Fig. 10. Measured S-parameters of the proposed dual-band bandpass filter.

Finally it is claimed that there is good agreement achieved between the simulated and measured results. However, there is slightly deviation between the simulated and experimental results which can be observed. This can be caused by the usual connectors and manufacturing errors or by the undesired DGS radiations.

V. CONCLUSION

A design of dual-band bandpass filter using ring resonator and H-defected ground has been introduced. The optimized bandpass filter is designed and realized using mixed coupled microstrip double-ring resonators and two electrically coupled H-cells DGS resonators. The final two pole Chebyshev DGS microstrip filter obtained has been simulated and fabricated. Two passbands from 1.6 GHz to 2.0 GHz L-band applications and from 3.6 GHz to 5.5 GHz C-band applications have been achieved. The out-band rejection between both passbands is better than 20 dB from 2.2 GHz to 3.3 GHz. The proposed structure occupies an area of ($0.45\lambda g \times 0.35\lambda g$) with $\lambda g = 0.044$ m. Good agreement between the simulated and measured results has been achieved.

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