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NOVEL DESIGN OF DUAL-MODE DUAL-BAND BANDPASS FILTER WITH TRIANGULAR RESONATORS

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Abstract—A novel dual-mode dual-band bandpass filter based on conventional triangular dual-mode filter is designed in this paper. The filter has the characteristics of compact structure, low insertion loss and so on. Based on the current design schemes, the design of dual-mode and dual-band filter can be integrated in a novel filter structure. Several attenuation poles in the stopband are realized to improve the selectivity of the proposed bandpass filter. The experimented results were in good agreement with simulated results.

1. INTRODUCTION

With recent development in wireless communication systems, dual-band filters have been needed for many dual band operation systems. Therefore, as a key component filtering unwanted frequencies in RF systems, the bandpass filter is necessary to generate two or more transmission frequency bands. Recently, the synthesis theory of microwave filters presenting two passbands mostly use frequency-variable transformations [1]. However, the strong attenuation is required for practical applications. Many new structures, such as stepped impedance resonators (SIRs) or parallel coupling [2, 3] or equal-length coupled-serial-shunted lines [4], have been proposed for a dual-band bandpass filter. In [5], a dual-mode dual-band bandpass filter was initially reported. Unfortunately, this solution suffers from high insertion loss and none transmission zeros in the stopband. And an extra matching network is needed to combine them. Recently, the dual-mode resonator using patch [6] or triangular structure has attracted many attentions for its low insertion loss and compact structure in design of single band filter [11–15]. A dual-mode dual-band filter with stacked loop structure is proposed in [7]. However, the stacked loop structure may introduce higher cost and difficulties in fabrication.

In this paper, a dual-mode dual-band bandpass filter using coupled microstrip triangular open-loop resonator based on conventional triangular structure is presented. The filter, with low insertion loss, provides two transmission bands. At the same time, there is good isolation between the two passbands.

2. TRIANGULAR DUAL-MODE RESONATOR

As a kind of special filters based on a variety of symmetric dual-mode resonating structures, dual-mode filter can be equivalent to dual tunable resonator circuit in practical application [8, 9]. Therefore, the number of the patch can be decreased 50 percent and the size of circuit can also be reduced in the current application. Based on the characteristics above, the dual-mode filter can be used sharply in miniaturized communication system.

Some people such as Wolf have advanced many designs of microstrip dual-mode bandpass filters, owning the same characteristics, which introduce asymmetry feed-lines, slots or pins and so on for a perturbation in the resonator in order to couple its two degenerate modes, with tuning the correlative parameters of circuit so as to obtain the work condition of dual-mode resonator. In the conventional design of filters, circular and square patches have used widely. However, triangular microstrip loop was used in the design of filter in this paper for its smaller size.

Fig. 1 shows the conventional design of dual-mode bandpass filter, different filter responses can be obtained with different positions and sizes of the perturbation, which is analyzed in detail in [6]. According to the analysis of resonant mode theory and slow-wave effect, the function of triangular patch is equal to cut a part of the structure [6].

Cutting a part of the structure can change the field distribution and inspire the degenerate modes, meanwhile, the cross couplings between the degenerate modes can not only generate attenuation poles but also cause the resonant frequency of higher harmonic wave to shift. In this case, it can be used for the miniaturization of the filter design.

The fundamental resonance occurs when λ_g is the perimeter of the outer isosceles triangle, where λ_g is the guided wavelength.

$$\lambda_g = \frac{c}{f\sqrt{\varepsilon_{eff}}} \tag{1}$$

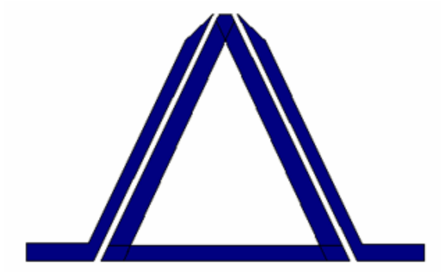

Figure 1. Configuration of the conventional triangular dual-mode filter.

where c is the velocity of light in free space, and ε_{eff} is the effective dielectric constant of the substrate. According to (1), while a resonant frequency is fixed, λ_g is decreased to realize size reduction as ε_{eff} increased. Similarly, for a fixed ε_{eff}, the resonant frequency f is decreased as the perimeter increased.

3. TRIANGULAR OPEN-LOOP RESONATOR

Compared with the conventional dual-mode filters, the microstrip triangular open-loop resonator filters can have a smaller size [11]. In this paper, as an open-loop resonator, the inner loop plays an important role in couplings between the outer and inner loop. The nature and the extent of the fringe fields determine the characteristics and the strength of the couplings. It is obviously that any coupling in those coupling structures is the proximity coupling, which is, basically, through fringe fields. The open-loop resonator has the maximum electric field density at one side where the electric fringe field is stronger and the maximum magnetic field density at the other side where the magnetic fringe field is stronger. The fringe field exhibits an exponentially decaying character outside the region. In order to obtain a better coupling and lower insertion loss, it is necessary that both electric coupling and magnetic coupling occur. The physical configuration underlying the resonant mode splitting is that the coupling effect can both enhance and reduce the stored energy of the filter. The coupling coefficients can be easily obtained if the resonant mode splitting is given, meanwhile, the coupling is dependent not only on the size of the hatch of the inner loop but also other parameters. In the process of simulation, the electric coupling has a great effect while the dielectric constant changes. The lower the dielectric constant is, the stronger the electric coupling is. However, the magnetic coupling obviously exhibits an independence of the dielectric constant. In the proposed structures, mixing coupling also has a great effect while the dielectric constant changes, because the electric coupling is involved. The width and length of side of the triangular open-loop resonator are other parameters on which the couplings depend. For a given substrate with a relative dielectric constant ε_r and a thickness h, the coupling coefficients can be characterized by the dimensions of the open-loop resonator.

4. TRIANGULAR DUAL-MODE DUAL-BAND BANDPASS FILTER

Fig. 2 shows the proposed triangular open-loop structure, where the outer and inner structures have different lengths of side. So far, the study of microstrip triangular resonator filters has received little attention. Based on the former concerns on filtering characteristics, a novel dual-mode dual-band bandpass filter is presented. There are two different passbands for the proposed structure. Two connecting patches at the corners, applying for feeding the inner loop, can implement the control of the second passband, and the size of the patches plays a key role in the quality of the filter. Given the lengths of side of the outer loop, the waveguide wavelength corresponding to

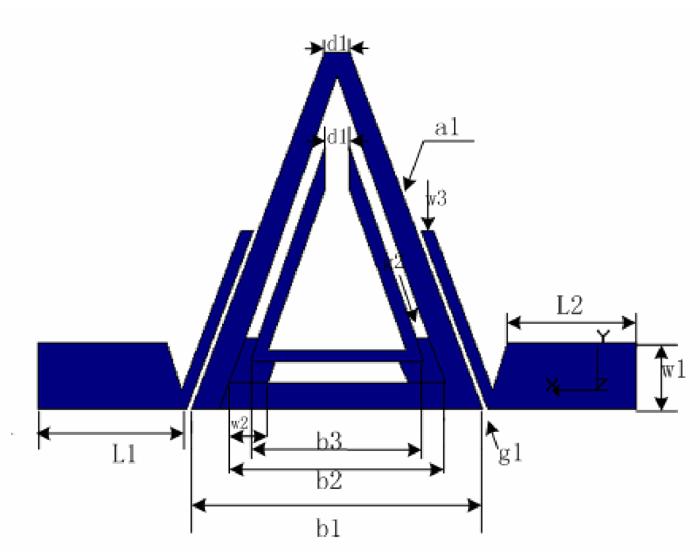

Figure 2. Configuration of the dual-mode dual-band bandpass filter.

the lower passband is

$$\lambda_{g1} = 2a_1 + b_1 \tag{2}$$

where a_1, b_1 are the lengths of side and base of isosceles triangle.

According to (1), it should be noticed that the center frequency will have a shift to lower frequency when the dimension of the outer isosceles triangle increased. Despite of a similarity of the resonator structure, the input and output coupling structures and locations in the filter are different for they operate at different modes. Owing to the different sizes and feed-line modes, outer structure and inner loop have different self-coupling and mutual-coupling. The filtering characteristics are dependent on the relation of the self- and mutual-couplings. Comparing with the square or circular dual-mode filter, the field distribution varies obviously in triangular resonator filter for its asymmetric structure.

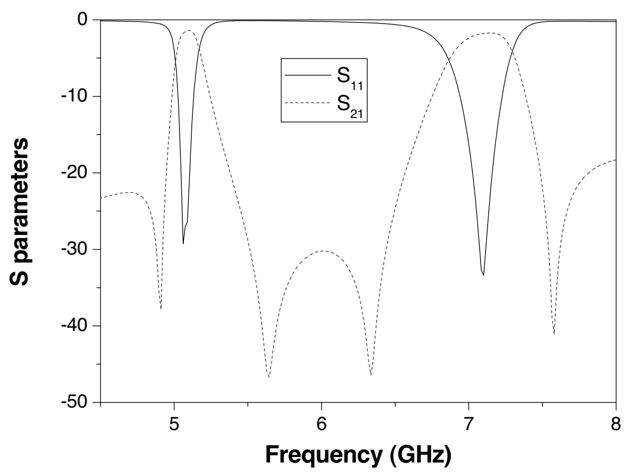

Figure 3. Simulation results of proposed dual-band filter.

As shown in Fig. 3, the simulated result of the proposed dual-band filter is obtained using simulator IE3D V10 based on MOM. From which, dual-band, low insertion loss, high selectivity, and good isolation characteristics can be observed clearly.

5. FABRICATE FILTER AND MEASURED RESULT

The proposed dual-mode dual-band bandpass filter is fabricated with design parameters as follows: $d_1 = 1$ mm, $a_1 = 15.9$ mm, $b_1 = 11.8$ mm, $b_2 = 8.8$ mm, $b_3 = 5.6$ mm, $L_1 = 6$ mm, $L_2 = 5.2$ mm, $w_2 = 1.5$ mm,

$w_3 = 0.5\,\mathrm{mm}$, $g_1 = 0.2\,\mathrm{mm}$, $g_2 = 0.5\,\mathrm{mm}$, and $w_1 = 2.8\,\mathrm{mm}$ is the width of 50 microstrip feed-line. The outer loop and inner loop provide two transmission paths for RF signal. Based on the discussions above, the proposed filter generates two separated passbands by using two triangular resonating structures in different frequencies, the outer triangular structure for the first passband, and the inner triangular loop for the second passband. The photograph of the fabricated filter is shown in Fig. 4.

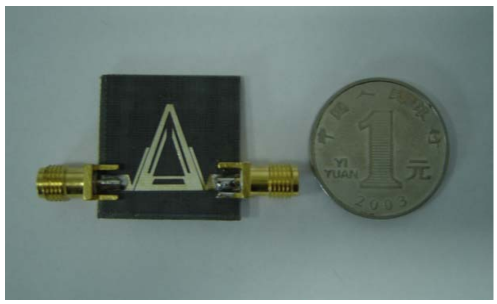

Figure 4. Photograph of the fabricated filter.

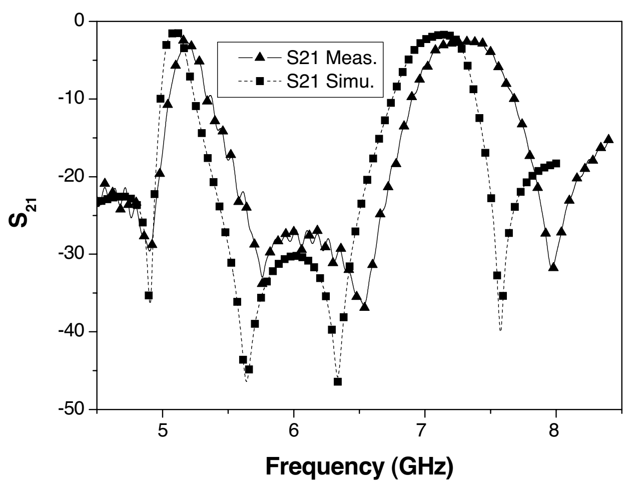

Figure 5. Comparison of the simulation and measurement results.

The filter is measured with Agilent 8719ES network analyzer. The results are shown in Fig. 5. Four attenuation poles in the stopband as follows: 4.9 GHz, 5.76 GHz, 6.54 GHz, 7.98 GHz. The center frequencies of the first and second passbands are at 5.15 GHz and 7.28 GHz, respectively. Return loss larger than 20 dB is achieved in the passband.

Compared with the simulation results, slightly shift to the higher frequency occurred between the simulation result and the measurement result for the machining tolerance. The insertion loss in passband is mainly due to the conductor loss of the triangular resonators. Good agreement between the simulation and measurement is achieved.

6. CONCLUSION

In this paper, a dual-mode dual-band bandpass filter using triangular structure is presented. The outer and inner structures generate respective passbands, and several attenuation poles in the stopband are realized. Numerical simulations using IE3D show the feasibility of the dual-mode dual-band bandpass filter. It has been shown that the proposed microstrip filter can provide good selection and better insertion loss. Simulated results are in good agreement with the synthesized responses.

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