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Complete List of Authors:	Yang, Cheng; National University of Kaohsiung, Chemical and Materials Engineering Yang, Hung-Chi; Southern Taiwan University, Department of Electrical Engineering Cheng, Chien-Min; Southern Taiwan University, Department of Electronic Engineering Chen, Kai-Huang; Tung Fung Institute of Technology, Department of Electronics Engineering and Computer Science Chen, Ying-Chung; National Sun Yat-Sen University, Department of Electrical Engineering
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Design a New Structure 2.4GHz/5.2GHz Dual-Band Bandpass Filters on the $MgTa_{1.5}Nb_{0.5}O_6$ Ceramic

Cheng-Fu Yang[1], Hung-Chi Yang[2], Chien-Min Cheng[3*], Kai-Huang Chen[4] and Ying-Chung Chen[5]
[1]Department of Chemical and Materials Engineering, National University of Kaohsiung, Kaohsiung, Taiwan, R.O.C.
[2]Department of Electrical Engineering, Southern Taiwan University, Taiwan, R.O.C.
[3]Department of Electronic Engineering, Southern Taiwan University, Taiwan, R.O.C.
[4]Department of Electronics Engineering and Computer Science, Tung Fung Institute of Technology, Taiwan, R.O.C.
[5]Department of Electrical Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan, R.O.C.
[*]Corresponding author, E-mail address: ccmin@mail.stut.edu.tw

In this paper, a λ/2 u-shaped hairpin resonator was contained in a modified end-coupled microstrip line. The increase of the sizes of u-shaped hairpin resonator and modified end-coupled microstrip line had no influence on the lower operating frequency and would shift the upper operating frequency to lower values. After finding the best designed parameters, a miniature dual-band microstrip bandpass filter with three transmission zeros generated in the stop-bands was developed on the $MgTa_{1.5}Nb_{0.5}O_6$ microwave dielectric ceramic substrates. The dual-band filter had the central frequencies of 2.45 and 5.2 GHz and was suitable for the applications in the modern WLAN communication.

KEYWORDS: Cross coupling, ceramic substrate, dual-band, end-coupled, transmission zero

1. Introduction

Microstrip line filters have found wide applications in RF and microwave circuits. In order to improve filter performance, one of the most effective methods is to insert transmission zeros into the stop-bands. In [1], the SIR resonators were cascaded to generate fifth-order Chebyshev stacked-line dual-band bandpass filters. In [2], the λ/2 SIR resonators were used to accomplish dual-band (2.45/5.2 GHz) filters by the parallel-coupled microstrip line, and the bandwidth was controllable by the variation of coupling. And in [3], the authors modified the parallel-coupled bandpass filters, and the transmission zeros besides the operating frequency could be controlled independently. Most of the microwave filters were fabricated on FR4 or RO substrates; hence, the reduction of the size of the filters was difficult because the dielectric constants of the substrates are still too high. Besides, in the design of higher frequency microwave devices, the lower quality factors of the FR4 and RO substrates would cause the dielectric loss increased. Hence, the high dielectric constant and high quality microwave dielectric ceramics substrates would be the best choices in the future.

For the purpose of miniaturization and response improvement, the most effective method is the use of high quality and high dielectric constant ceramic substrates. However, there were few reports of the microwave devices which used microwave dielectric ceramics as its substrates. Microwave dielectric ceramic exhibits high quality value ($Q \times f$ value) and high dielectric constant (ε_r), which is suitable for the use of high frequency devices (high Q×*f* value) and for the miniaturization of the devices (high ε_r). In this paper, the end-coupled microstrip line structure was combined with a high impedance $\lambda/2$ cross coupling resonator [4, 5], the new type of miniature microstrip dual-band filters were developed on the $MgTa_{1.5}Nb_{0.5}O_6$ microwave dielectric ceramic substrates [6]. By varying the size of the $\lambda/2$ cross coupling resonators (2.45 GHz), two transmission zeros would generate beside the pass band, furthermore, the adding of a smaller $\lambda/2$ hairpin resonator (5.2 GHz) would generate another transmission zero at the upper skirt of 5.2 GHz, which would improve the upper skirt of 5.2 GHz up to −56 dB.

2. The Design Procedures

According to the coupling technique of resonators and the combination method, the main motivation of this paper is to develop a dual-band filter on the $MgTa_{1.5}Nb_{0.5}O_6$ microwave dielectric ceramic substrates with three transmission zeros generated in the stop-bands to modify the response of the filter. The design procedures would be divided into three steps, and detailed discussion would be following:

Step 1. Using a Modified End-Coupled Structure to Generate a Dual-Band (2.45 / 5.2 GHz) BandPass Filter

Fig. 1(a) shows the pattern and the simulated result of the modified end-coupled microstrip line structure with an upper $\lambda/2$ resonator (operating at 2.45 GHz). For the purpose of the insertion of transmission zeros between the pass bands, the upper $\lambda/2$ resonator was modified to a $\lambda/2$ cross coupling resonator as shown in Fig. 1(b), and the total length of the upper $\lambda/2$ resonator was unchanged. Two transmission zeros were generated between the pass bands, the stop-band rejection between two pass bands was −46 dB, and the depth of transmission zeros were −75 dB and −60 dB, respectively. However, the major drawback for this structure was that the upper skirt of 5.2 GHz was still not good enough. Therefore, the next step would generate a transmission zero at this band to improve it.

Step 2. Using a $\lambda/2$ Hairpin Resonator to Generate a Zero at the Upper Skirt of 5.2 GHz

Fig. 2 shows the same end-coupled microstrip line structure as in Fig. 1 but with a $\lambda/2$ U-shaped hairpin resonator, which had the operating frequency around 5.2 GHz. As the size of the resonator (X and Y length) increased, a transmission zero was generated at the upper skirt of 5.2 GHz. This zero could be used to low down the upper skirt of 5.2 GHz in Fig. 1(b). In Fig. 2(a), as Y was fixed at 1.8 mm and X increased (total length>$\lambda/2$), the operating frequency and zero would shift toward lower frequency. Furthermore, the depth of zero increased as X increased, due to the length of the $\lambda/2$ U-shaped hairpin resonator increased and the variation of coupling. And as X was fixed at 2.6 mm and Y was increased, the operating frequency and zero moved toward lower frequency too, as

Fig. 2(b) shows. Generally speaking, increasing the size of this hairpin resonator would shift the operating frequency and transmission zero to lower values.

Step 3. Combining above two Structures

For the purpose of modify the upper skirt in Fig. 1(b), one combination method would be used. The 5.2 GHz λ/2 hairpin resonator was added into the original 2.45 GHz λ/2 resonator, as Fig.3 shows. As the length of Y1 increased (the size of the inner U-shaped resonator increased), as shown in Fig.4, a transmission zero was generated at the right-side of 5.2 GHz, and this phenomenon is as same as Fig. 2(b). The depth of the zero was increased to −68 dB, and that would improve the upper skirt of 5.2 GHz strongly. Furthermore, the characteristics of the designed filters had well zero effects due to the mutual coupling of the two resonators.

3. The Fabrication Processes

The $MgTa_{1.5}Nb_{0.5}O_6$ ceramic substrates [6] were fabricated by the conventional solid-state reaction (thickness was 1 mm), the dielectric constant was 27.9 and the quality factor (Q value) was 33,100 at 1 GHz. The width and length of the microstrip line were according to the matching of 50 Ω. The mask was done according to the simulated patterns, and using this mask and Ag/Pd paste to print the filter patterns on the $MgTa_{1.5}Nb_{0.5}O_6$ ceramic substrates by a screen printer. Then the printed pattern was fired at 800^oC for 30 min. Finally, two SMA connectors were soldered to each filter, and the characteristics were measured by an impedance analyzer (HP-8720). The detailed parameters of the designed filter are shown in Fig.3.

3. Results and Discussion

The photograph of the fabricated filter is showed in Fig. 5, owing to the use of high dielectric constant substrate, the size of this filter is only 26.3 mm×3.7 mm, which is smaller than other dual-band filters fabricated by FR4 or RO substrates. The simulated and measured results of the filters are compared in Fig. 6. For simulation, the maximum S_{21} of stop-band rejection between two pass bands is −30.5 dB, the bandwidths for two resonate frequencies (2.45 GHz and 5.2 GHz) are 12.6 % (310 MHz) and 23.0 % (1200 MHz), and the insertion losses are 0.16 dB and 0.38 dB, respectively; For measurement, the maximum S_{21} of stop-band rejection between two pass bands was −29.9 dB, the bandwidths for two resonate frequencies (2.45 GHz and 5.2 GHz) were 13.8 % (340 MHz) and 23.2 % (1210 MHz), and the insertion loss was 0.18 dB and 0.64 dB, respectively. As above characteristics shows, the fabricated filters are suitable for the application of WLAN (2.45/5.2 GHz).

4. Conclusions

In this letter, the basic end-coupled microstrip line structure is combined with a 2.45 GHz λ/2 cross coupling resonator and a 5.2 GHz λ/2 U-shaped hairpin resonator to develop a miniature dual-band filter on the $MgTa_{1.5}Nb_{0.5}O_6$ microwave ceramic substrate. In this simple structure, three transmission zeros are inserted into the stop-band, while two zeros are located between the pass bands, and the third is located at the upper skirt of 5.2 GHz, all of these zeros improve the characteristics of stop-band obviously, and all the insertion losses of the fabricated filter at the two resonate frequencies are smaller than 0.65 dB due to the use of high quality factor and dielectric constant ceramic substrates. The proposed filters are small and simple, and all the characteristics of the filters are good enough for the applications of WLAN communication systems.

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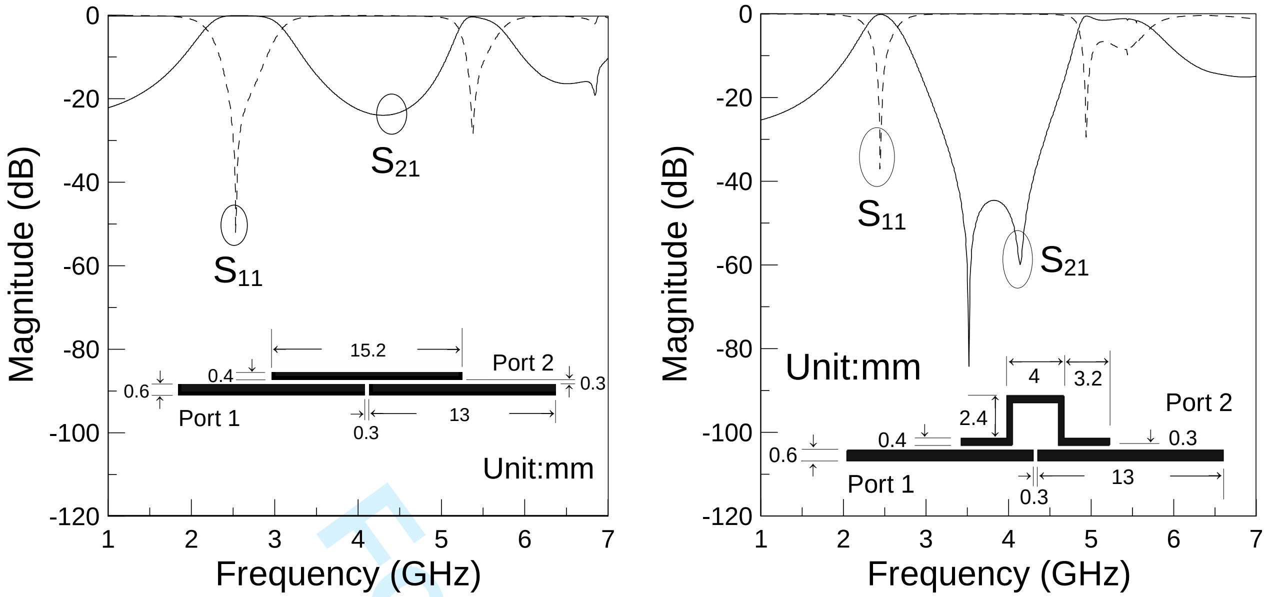
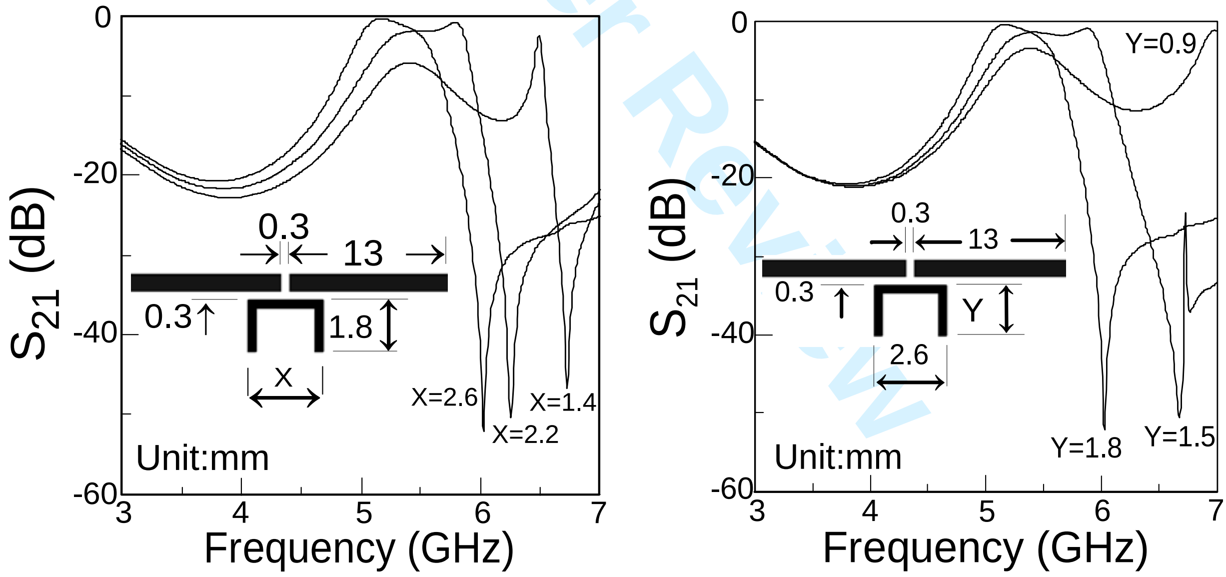


(a) (b)

Fig. 1. Structure and simulated results of (a) end-coupled microstrip line structure with a λ/2 resonator (central frequency 2.45 GHz) (b) end-coupled microstrip line structure with a λ/2 cross coupling resonator



(a) (b)

Fig. 2. Structure and simulated S_{21} results of the end-coupled microstrip line with a λ/2 U-shaped hairpin resonator. (a) Y= 1.8 mm, and X=1.4, 2.2, 2.6 mm and (b) X= 2.6 mm, and Y=0.9, 1.5, 1.8 mm, respectively

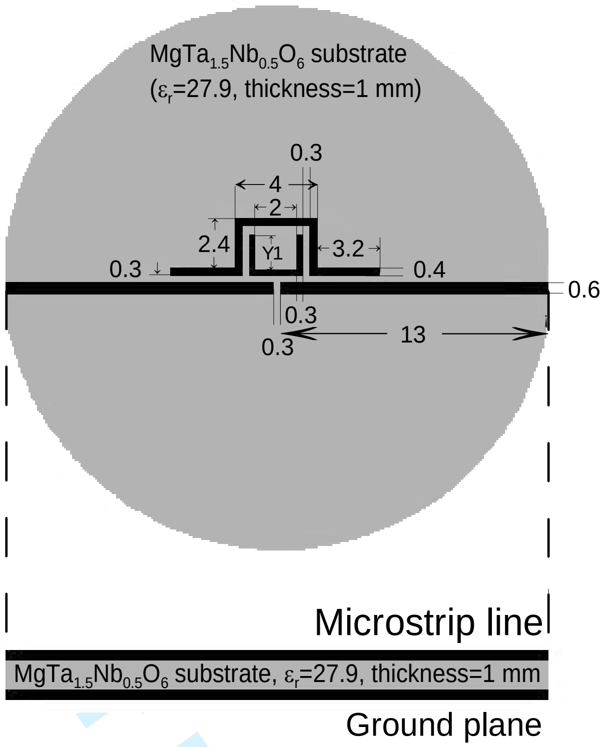


Fig. 3 The parameters to get the optimal characteristics of the designed filter.

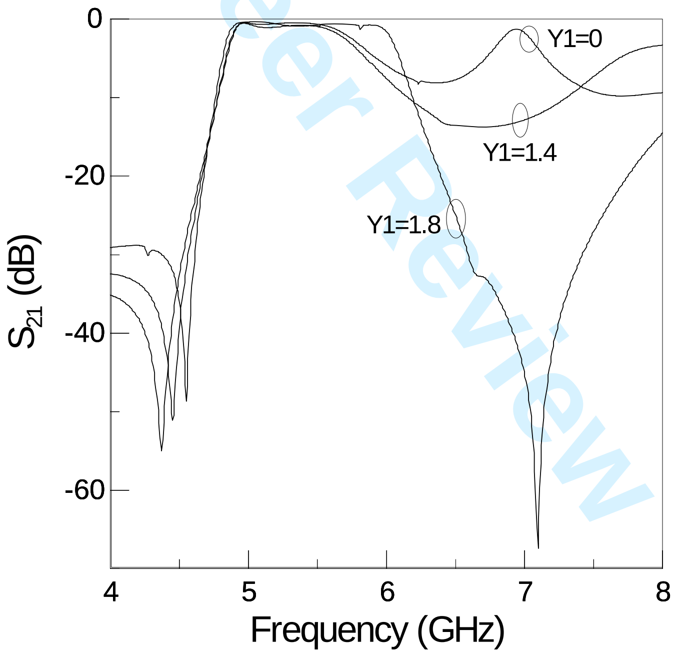


Fig. 4. Simulated S_{21} results of the combined structure.

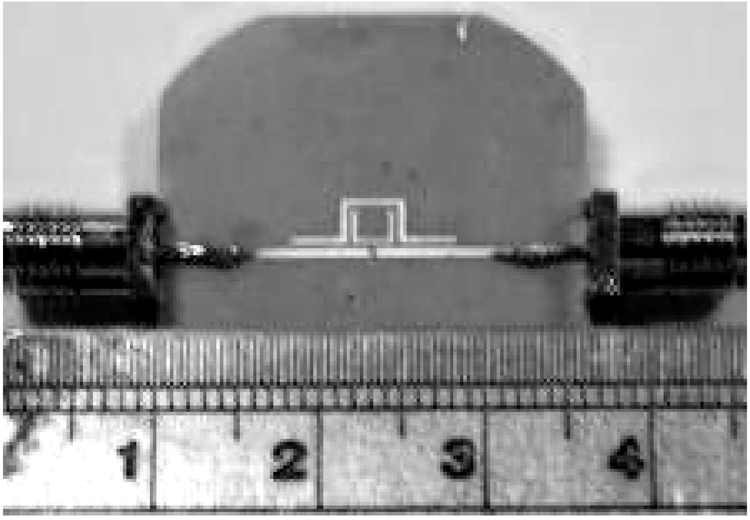


Fig. 5. Photograph of the proposed filter.

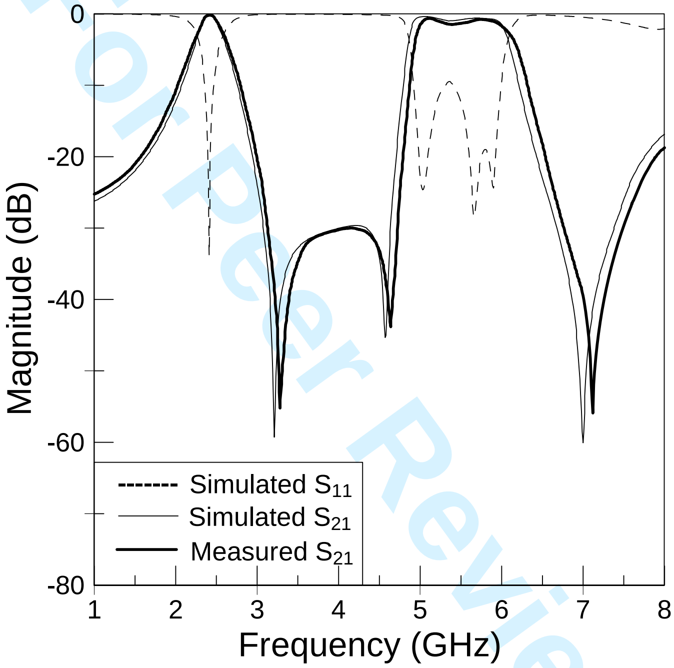


Fig. 6. Simulated and measured results of the designed filter.