Novel Model Design of Compact Dual Notch-Bands of Attenuation for Bandpass Filters

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Abstract

In this paper, a new microstrip model design of bandpass filter is proposed. Open stubs are applied to the band pass filter to refine the skirt selectivity on both sides of the upper and lower frequency band. Two attenuation poles are produced by this new structure. The upper band pole is introduced by the hairpin-comb structure. The lower band pole is introduced by the tapped open stubs. We fabricated a new structure using milling machine at the Lab in University of North Texas (UNT). Two attenuation poles are realized at the upper band and the lower band respectively, one at 1.71GHz and one at 1.93GHz. Sharp roll-off on both sides of the pass band is obtained. Measured results show good selectivity at both upper and lower bands

Keywords: bandpass filter, dual notch-band, resonator.

التصميم الجديد لمرشح الإمرار المدمج ذو مجالي التوهين المتشعب

الخلاصة

في هذا البحث جرى عرض التصميم الجديد لمرشح الإمرار. تمت اضافة الصفائح ذات الحدود المفتوحه الى مرشح الامرار وذلك لتحسين الانتقائية في المجالات الترددية الأعلى والاوطأ . ان إضافة الصفيحتين إلى الشكل يؤدي إلى ظهور قطبين للتوهين . في النطاق العالي امكن الحصول على قطب التوهين بواسطة التركيب هايبرن- كومب اما في النطاق الاسفل فتم الحصول عليه بواسطة الصفائح ذات الحدود المفتوحه . تمت صناعة النموذج في مختبرات جامعة شمال تكساس وامكن الحصول على قطبي توهين في المجال الترددي الاعلى والاوطأ على التوالي , احدهم عند التردد 1.71 كيكاهيرتز والاخر عند التردد 1.93 كيكاهيرتز , وتم الحصول على قطع حاد على جانبي نطاق الامرار . نتائج القياسات اظهرت انتقائية جيدة عند الحزم الترددية الاعلى و الاوطأ.

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1. Introduction

Recently,as a result of rapid progress in wireless communication systems, dual band bandpass filters (BPF) have become more and more attractive as one of the most important circuit blocks in exploring advanced dual band wireless systems[1]. The hairpin-line resonator has been widely used in the narrowband bandpass filters due to its easy implementation in high-order filter design[2]. However, it suffers from poor skirt selectivity near the passband, which is undesirable in modern communication systems. To overcome this disadvantage, a hairpin-comb structure was proposed to provide additional attenuation poles by simply re-arranging the orientations of the hairpin resonators[3]. Tapped open stubs are also used as an alternative way to introducing attenuation poles near passband to improve the skirt selectivity in hairpin resonators[4]. The tapped open stub structure, however, is asymmetric and not suitable for conventional filter design. In this paper, we propose to combine the hairpin-comb structure and tapped open stub structure to realize a symmetric bandpass filter with two attenuation poles for improved skirt selectivity. The lower and upper attenuation poles are produced by the open slot between the hairpins and the open stubs tapped at the center of the hairpin resonator, respectively. An experimental prototype of proposed bandpass filter was designed at the center frequency of 1.8 GHz and fabricated using milling machine at the Lab in the University of North Texas (UNT) on low-cost FR4 print circuit boards (PCB). Measured results show good selectivity at both upper and lower bands as predicted.

2. Structure And Characteristic Of Proposed Bandpass Filter

As has been mentioned, the hairpin-comb structure can be used to introduce one attenuation pole at upper band. The structure of a typical hairpin-comb filter is shown in Fig. 1(a). The slot mode propagating between the two coupled lines (with length L_1 and gap S_2) performs like a series stub. This series stub acts as a bandstop filter and produces the attenuation pole. Thus, the position of this pole depends on the length of the slot. Since the coupling length (L_1) is always less than $\lambda/4$, the attenuation pole introduced by the coupling slot is always located at the upper stop band. For the lower band pole, tapped open stub can be used because of its flexible length. The additional stub is tapped at the center of the hairpin resonator and produces a notch frequency to the filter. Besides, it performs as a K-inverter and transforms the $\lambda/2$ resonator into two $\lambda/4$ resonators as shown in Fig. 1(b). Combining the hairpin-comb and tapped open stub, the topology of the proposed filter is given in Fig. 2. Two tapped open stubs with the same length and a coupled slot are used to introduce the desired attenuation poles at the upper and the lower bands of a bandpass filter [5]. Compared with the filter using hairpin-comb lines shown in Fig. 1(a), one additional attenuation pole is realized in the new design, which improves the band selectivity [6-8]. As for the filter only using tapped stubs, two separate attenuation poles can also be introduced by using different lengths for the two stubs [9]. We fabricated a new structure using milling machine at the Lab in the University of North Texas (UNT). However, the difference in stub lengths makes the topology asymmetric. Asymmetric structures are not accommodated in conventional filter designs where symmetrical coupling coefficients are used . Our proposed structure maintains the structure symmetry, while delivering two attenuation poles.

3. Results

In our proposed filter structure, the coupling slot should produce an attenuation pole at the upper band. However, a discrepancy has been observed in [2], where the pole always appears at the lower band even though the length of the slot is shorter than λ/4 [7]. To confirm the effects of the coupled slot, a hairpin-comb type filter is designed . This filter is designed at center frequency1.8GHz and fabricated on low-cost FR4 PCB board (dielectric constant=4.5,substrate hickness=1.6mm, loss tangent = 0.02). As shown in Fig. 1(a), the dimensions of the filter are: L_1 = 20mm, L_2 = 3mm, S_1 = 0.4mm, S_2=0.2mm,W_1=3mm. Measured results are plotted in Fig. 3. An upper band attenuation pole at 1.93GHz is observed. As shown in Fig. 2, two additional tapped open stubs are added to the hairpin-comb filter and fabricated on the same FR4 board. The final dimensions of the new filter are: L_3=20mm, L_4=3mm, L_5=27mm, S_3=0.4mm, S_4=0.2mm, W_2=3mm, W_3=0.4mm. The length of the stubs is larger than that of the basic resonator to implement the lower band pole . Measured results are given in Fig. 4. The center frequency is 1.8 GHz and the insertion loss in the passband is about 5.2dB. As expected, two attenuation poles are realized at the upper band and the lower band respectively, one at 1.71GHz and one at 1.93GHz. Sharp roll-off on both sides of the passband is obtained. The measured insertion loss is high because of two reasons - 1) the low-cost FR4 board is used in the tested filters, which degrades the insertion loss due to its high loss tangent; 2) additional loss can be introduced by the fabrication error and the SMA connectors used in our measurement. Therefore, if the insertion loss is a design concern, we can apply a low-loss printed circuit board such as RT / duroid 6010 from Rogers Corporation, and high performance SMA connectors in the proposed filter. In this way, the insertion loss can be reduced greatly.

4. Conclusions

A symmetric bandpass filter combining tapped open stubs and hairpin-comb structure is proposed to improve the selectivity of the conventional hairpin bandpass filter. An experimental prototype of proposed bandpass filter was designed at the center frequency 1.8 GHz and fabricated on low-cost FR4 print circuit boards (PCB).Sharp skirt selectivity around the passband has been obtained in the new filter. Two attenuation poles are realized at the upper band and the lower band respectively, one at 1.71GHz and another one at 1.93GHz. Our proposed structure maintains the structure symmetry, while delivering two attenuation poles. Owing to its symmetric structure, the proposed filter can be easily implemented to the conventional high-order filter designs. Measured results show good selectivity at both upperand lower bands

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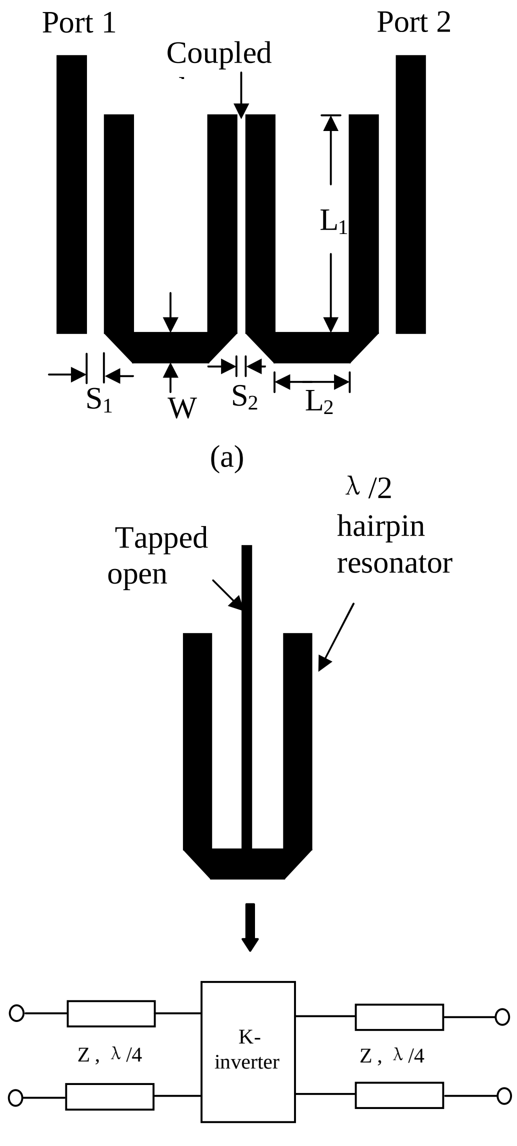

(b)

Figure (1) Structures that can be used to improve the skirt selectivity in hairpin bandpass filters(a) the hairpin-comb bandpass filter (b) the tapped open stub

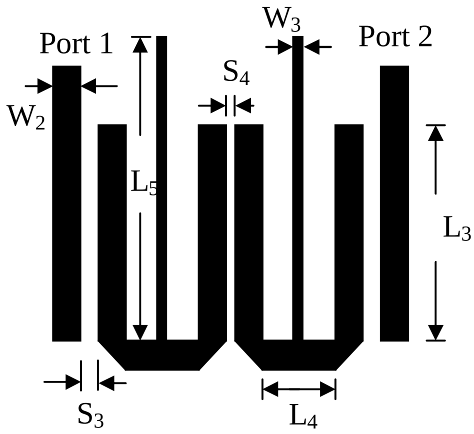

Figure (2)Topology of the proposed bandpass filter

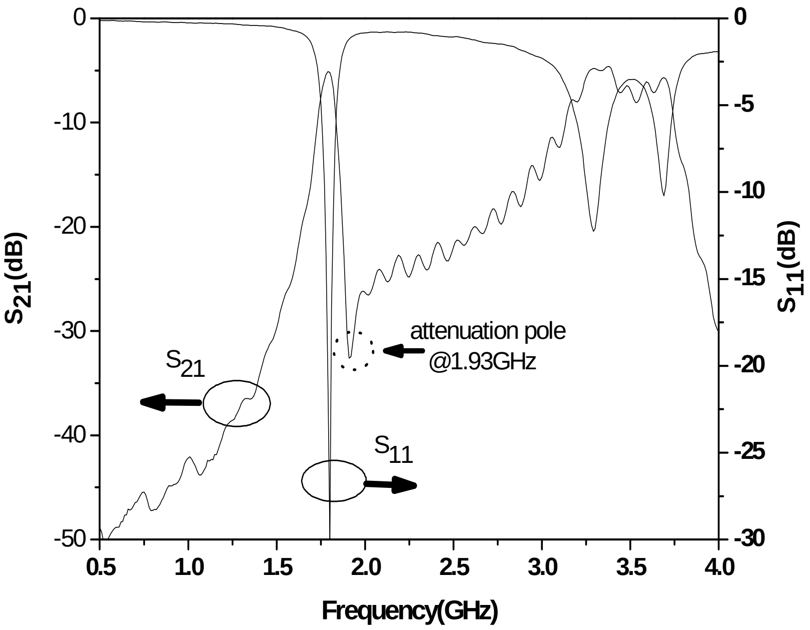

Figure (3) Measured S-parameters(frequency response) of a hairpin-comb bandpass filter

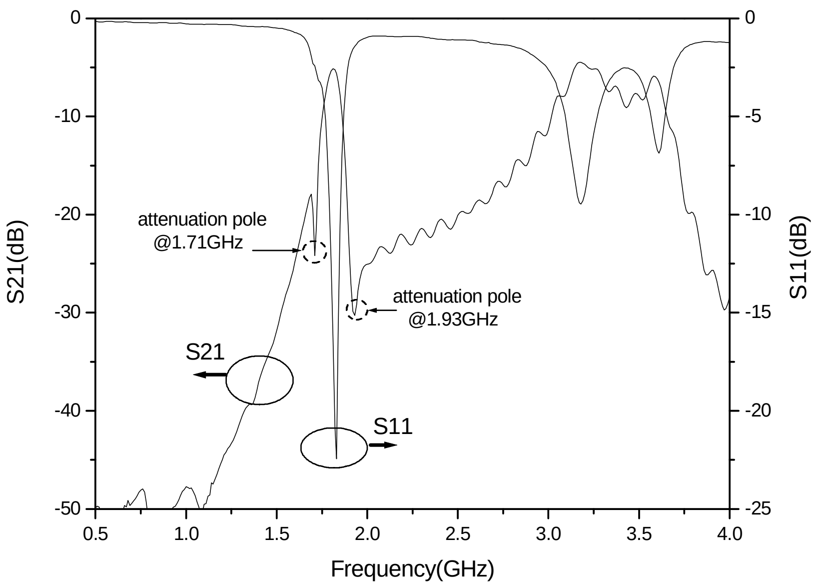

Figure (4) frequency response of the proposed bandpass filter