Research Journal of Applied Sciences, Engineering and Technology 11(5): 532-536, 2015
DOI: 10.19026/rjaset.11.1858
ISSN: 2040-7459; e-ISSN: 2040-7467
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Submitted: May 16, 2015 Accepted: July 14, 2015 Published: October 15, 2015

Research Article

Cascaded Microstrip Trisection Stub Loaded Resonator Bandpass Filter

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Abstract: A microstrip filter with cascaded Electric coupling trisection and magnetic coupling trisection is proposed. This study aims to create transmission zeros at both the side of the passband. Optimal performance is achieved by creating variable gaps in the resonators and providing open ended tuning stubs at appropriate locations. To demonstrate the concept a filter is realized and fabricated operating at 905 MHz with a pass band of 877 to 917 MHz (5%). The inherent disadvantage of wider roll off from the conventional filter is overcome by the introduction of stubs. Measured results are compared and found to be in good agreement with simulated results.

Keywords: Bandpass filter, cascaded trisection, transmission zero

INTRODUCTION

Filters are essential circuits to pass the wanted signal and to eliminate the unwanted signal in the frequency domain. High performance filters are very important in microwave application such as Satellite communication, Radar, Navigation. Requirements of high performance filters are: high selectivity, low insertion loss, small size and low cost (Pozar, 2004; Liu *et al*., 2009; Maryam and Majid, 2011). High filter selectivity requires high order filter and more resonators (Saghlatoon and Neshati, 2012). High selectivity filters can minimize the guard band between adjacent channels which uses the spectrum more efficiently. In Hong and Lancaster (1999, 2001) and Hanna *et al*. (2005) filters with asymmetric response are characterized. However, these filters suffer from poor attenuation at any one side of the passband.

In this study, a bandpass filter is proposed to create the high selectivity on both the sides of the pass band. A microstrip filter with symmetric frequency response is realized by cascading electric coupling trisection filter and magnetic coupling trisection filter (Chu-Chen and Chi-Yang, 1999; Castillo-Aranibar *et al*., 2013; Ching-Luh, 2012). By cascading the trisection filter, it is observed that the selectivity on both the sides of the pass band is achieved.

Proposed filter configuration operating at 905 MHz exhibits a pass band of 877 to 917 MHz (5%). The inherent disadvantage of wider roll off from the conventional filter is overcome by the introduction of stubs in the filter configuration. To suppress the harmonics in the stop band, a stub is introduced in the main transmission line of the filter. In order to reduce the insertion loss, stubs are introduced between the gaps in the magnetic coupling trisection filter. The filter provides very sharp roll of on both the sides and a pass band insertion loss of -1.9 dB at midband frequency. The filter performance is simulated using Ansoft HFSS before fabrication. Measured results are compared with a three dimensional electromagnetic solver and found to be in good agreement with each other.

MATERIALS AND METHODS

Electromagnetic tool Ansoft HFSS is used to design the proposed filter model. Simulation results are collected from this. RT-duroid substrate with dielectric constant 0.635 mm is used as substrate material in this filter design.

Cascaded electric and magnetic trisection and bandpass filter: Three pole trisection filter is the simplest filter and its equivalent circuit is shown in Fig. 1. This is the basic unit for construction of higher order filter.

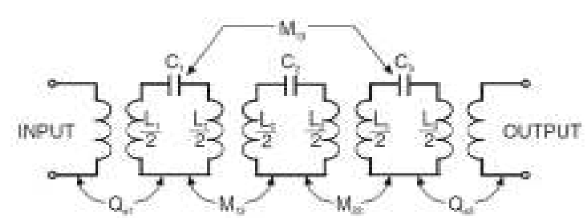

Fig. 1: Equivalent circuit of trisection band pass type

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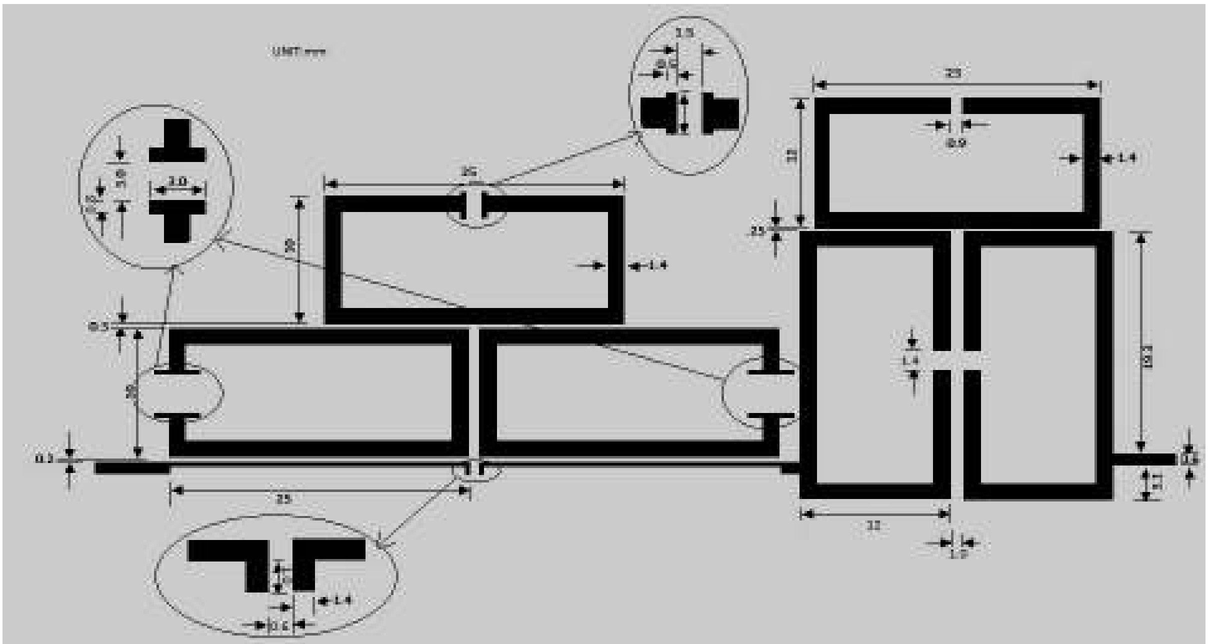

Fig. 2: Layout of the cascaded microstrip trisection filter

The coupling between the adjacent resonators is denoted by the coupling coefficients. M_{12} and M_{23} and the cross coupling is denoted by M_{13}. Q_{e1} and Q_{e3} are external quality factors denoting input and output couplings. Due to the symmetry $M12 = M_{23}$, $Q_{e1} = Q_{e3}$ and $\omega_{01} = \omega_{03}$. The proposed cascaded electric and magnetic trisection band pass filter is realized in microstrip configuration and is shown in Fig. 2.

To reduce the insertion loss, microstrip open ended stubs were introduced in magnetic trisection resonators. Gaps in the resonators were also adjusted and optimized to improve the performance of the filter. To suppress the harmonics in the higher side of the stop band, stubs were included in the transmission line. Better performance was obtained by optimizing the stub length.

Initially, magnetic coupling trisection filter and electrical coupling trisection filters were designed as two different circuits on RT Duroid with 0.635 mm thickness substrate and a relative dielectric constant of 10.2. The results show that these circuits exhibit an asymmetric response with minimum insertion loss. In this approach higher selectivity is obtained only on one side of the pass band, either at the higher side or at the lower side of the passband. The design goal was to create a sharp roll off on both the sides of the pass band such that the selectivity can be improved. When the selectivity is improved, this can reduce the guard band between adjacent channels by which spectrum can be used more efficiently (Saghlatoon and Neshati, 2012). Selectivity at both sides of the passband was achieved by cascading magnetic and electric coupling mechanism. But when the number of resonators increases, the insertion loss will also increase.

Fig. 3: Photograph of fabricated cascaded magnetic trisection and electrical trisection bandpass filter

To improve the performance stubs were introduced in the resonators in the magnetic coupling trisection filter. In order to eliminate the harmonic in the stop band on the higher side of the passband, which was observed when cascading, can be eliminated by introducing the stubs between the feed lines. The photograph of the proposed fabricated filter is shown in Fig. 3.

RESULTS AND DISCUSSION

When the electrical trisection filter and magnetic trisection filter were simulated as two different circuits, it was observed that the insertion loss was below -1 dB each but they provide asymmetric response. In order to get the symmetric response, both trisection filters (magnetic and electric) were cascaded. After cascading, the insertion loss was increased to -3 dB. Since number of resonators increase, the insertion loss also be increased. A full wave 3D simulator working on Finite Element Method is employed to simulate the S parameters of the designed bandpass filter.

Figure 4 shows the simulated result after cascading the electrical trisection and magnetic trisection filter. It is observed that, the insertion loss is nearly -3 dB.

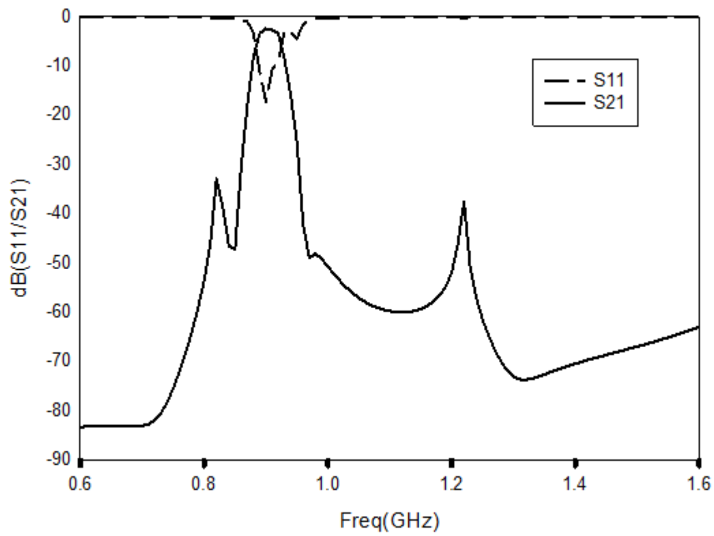

Fig. 4: Result after cascading magnetic coupling and electric coupling trisection filter

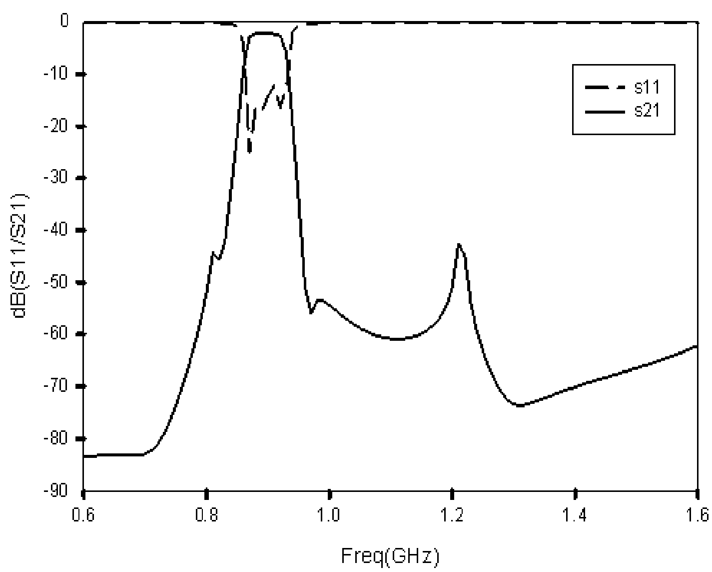

Fig. 5: Result after including the stubs in the magnetic coupling trisection filter

It is also noted that the harmonics also appeared on the right side of the stop band. To address this issue, micro strip open ended stubs were introduced in proposed filter configuration. Figure 5 shows the simulation results after including the stubs in the magnetic trisection filter.

This gives a better performance of the filter when compared to the previous case by reducing the insertion loss to -2 dB and return loss is improved to -15 dB. However the harmonic produced outside the stop band is still persist.

In order to eliminate the harmonic at the right side of the stopband, microstrip open ended stubs were added in the transmission line in between the feed lines and the resonators. Optimum values of the stubs were obtained by parametric study of the stub length. The simulation results of various stub length is shown in the Fig. 6.

Better performance was achieved for stub length of 1mm. For the stub length of 1mm, the higher selectivity was achieved at both the ends of the passband. The return loss in the passband is -15 dB of the bandpass filter and insertion loss is -1.9 dB. The simulation results were shown in Fig. 7.

This filter is fabricated on RT/duroid substrate with relative dielectric constant 10.2 and a thickness of 0.635 mm. Figure 8 shows the measured results of the fabricated filter. The return loss in the pass band is below -15 dB and insertion loss is relatively high and is round -3.8 dB. The roll off obtained is 40 dB on both

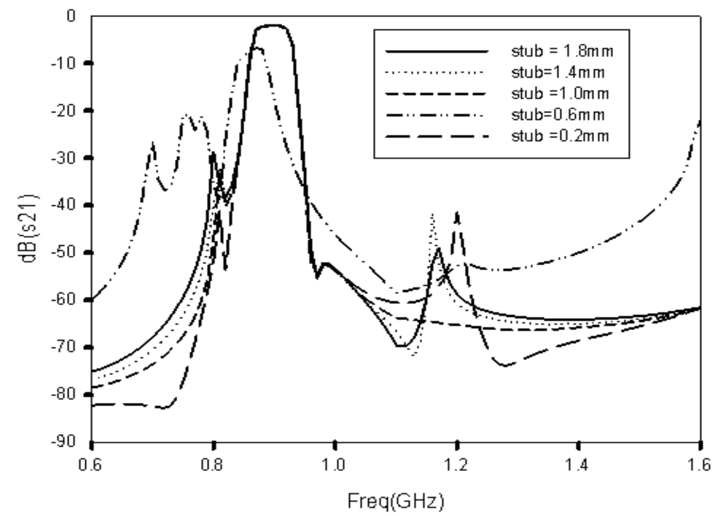

Fig. 6: Optimization results by varying stub length value in the transmission line

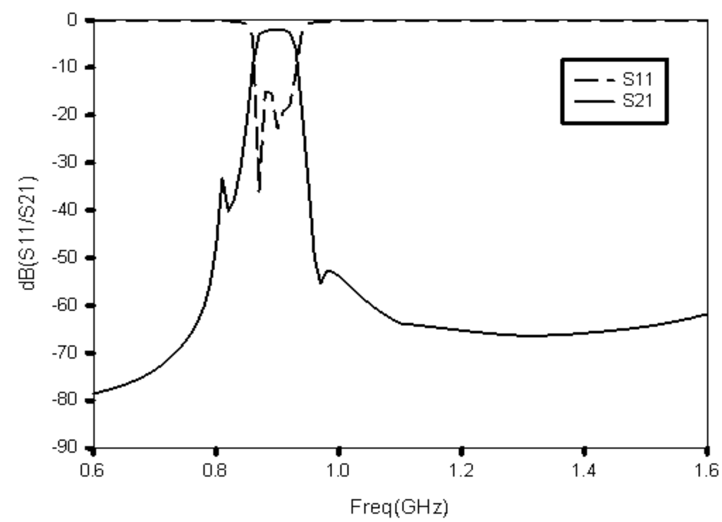

Fig. 7: Simulated result of stub loaded cascaded magnetic trisection and magnetic trisection band pass filter

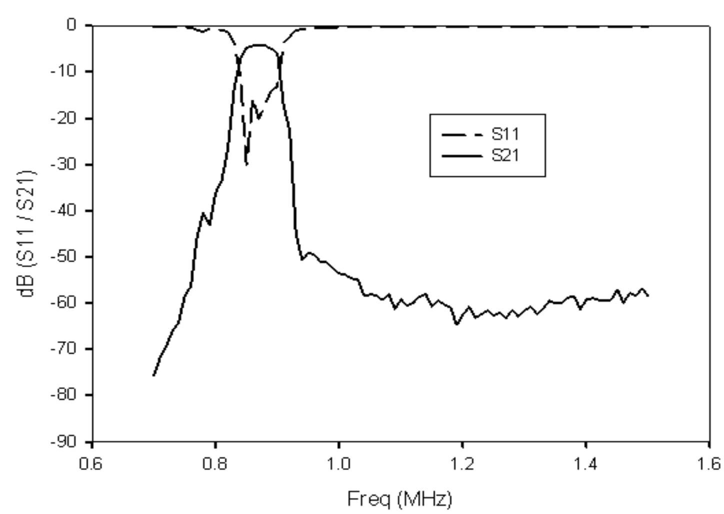

Fig. 8: Measured results of stub loaded cascaded electrical trisection and magnetic trisection band pass filter

the sides of the pass band. The measured result has good agreement with the simulated result. The degradation in the insertion loss is mainly attributed to fabrication error tolerances.

CONCLUSION

A microstrip filter with cascaded Electric coupling trisection and magnetic coupling trisection is realized in microstrip configuration. Transmission zeros at both the side of the pass band are created in novel ways by creating variable gaps in the resonators and open ended tuning stubs at appropriate locations. The inherent disadvantage of wider roll off from the conventional filter is overcome by the introduction of stubs in the filter configuration. The filter provides very sharp roll of on both the sides and a pass band.

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