IMPROVEMENT OF BAND-WIDTH PERFORMANCE OF HAIPRPIN BAND-PASS FILTER USING DEFECTED GROUND STRUCTURES

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Abstract

In this paper, a novel technique for improving the return loss of three poles hairpin band-pass filter incorporating defected ground structure is presented. As a result, the structure is simple, wideband with compact size. The expected result of a BPF with DGS is to have a compact band-pass filter with significantly improvement in return loss. The filter performances are exhibits |S21| more than -0.5 dB, |S11| less than -30dB, and center frequency of proposed filter is around 4.2GHz with operating bandwidth of 35%.

Keywords: Band-pass Filter, Defected Ground Structure, Band-Width

Introduction

Nowadays, band-pass filters with high selectiveness and low internal losses in band-pass width are required in most of the communication applications, especially mobile systems. In order to fulfill these criteria and to reduce size and cost, there has been a growing interest in designing with planar structure (Pozar, 1998). To obtain higher selectiveness, poles degree of the filter, the quantity of resonators must be increased.

Recently, defected ground structure (DGS) for planar transmission lines has drawn a wide interest because of their extensive applicability in antenna and microwave circuits (Kim, et al., 2000, Ahn, et al., 2001, Liu, et al. 2004). DGS etched in the metallic ground plane of microstrip lines, are attractive to obtain unwanted frequency rejection and circuit size reduction. Since DGS have an inherent resonance property, many of them have been applied for improvement of filter circuits.

In this paper, we designed a three-pole hairpin lines band-pass filter with 4.2GHz center frequency and 1.4GHz band-with. In order to enhance the performance of the filter, the DGS structures are used under input and output lines of the proposed filter. Defected ground structures disturbs the shielded current distribution in the ground plane and thus changes characteristics of microstrip line such as its inductance and capacitance, so they have rejection band in some frequency ranges. Also these structures have slow-wave proprieties. By proper used of the ground plane these structures reduce the size of microstrip component significantly. Both the electrical length and coupling effect of the resonators are modulated by the slow wave characteristics of DGS, which have been used to tune the band-pass of the filter. The coupling between the coupled lines of the BPF gets enhanced for a given spacing of the resonators and thus improves the band-pass performance by providing almost zero insertion loss. By varying only the dimensions of DGS, we can improve the adaptation of Band-pass filter.

Design of Microstrip Band-pass Filter

The layout of a three-pole hairpin lines band-pass filter (BPF) is shown in figure 1. The width of feed line is 1.85mm for proper matching of impedance. The hairpin lines have width of 0.5 mm and they are separated by a gap of 0.3 mm. The length of the parallel coupled hairpin lines is around 10 mm, taking center frequency at 4.2 GHz and for substrate having dielectric constant 6.15 and thickness 1.27 mm.

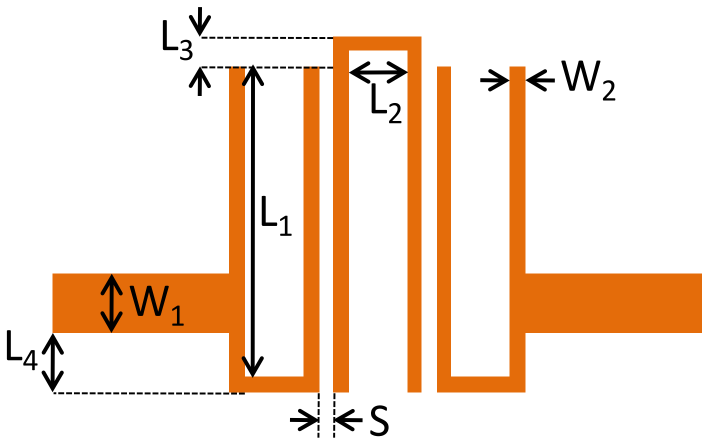

Figure 1: Layout of three poles hairpin line BPF on a 1.27mm thickness substrate with a relative dielectric constant of 6.15 (W_1=1.85mm, W_2=0.5mm, S=0.3mm, L_1=10mm, L_2=1mm, L_3=1mm and L_4=2.2mm)

The BPF is simulated by using CST software. The S-parameters of the filter are shown in figure 2. We observe that the 3dB filter bandwidth is approximately 35% and the center frequency is around 4.2GHz. The insertion loss less than 0.5 dB has been obtained, but the return loss is around 10dB.

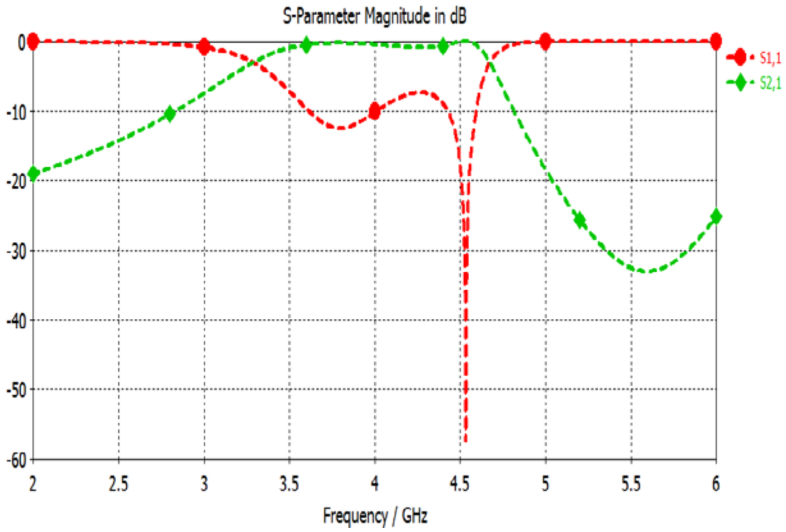

Figure 2: Simulation response of three poles hairpin line BPF

In order to improve the adaptation of the band-pass filter, we proposed to incorporate the DGS structures under input and output microstrip lines.

Filter Incorporating Defected Ground Structure

One method to improve the filter performance is to use microstrip structures with defected ground plane. DGS cells are used as complementary of the main filter and also independently in executing the filter, due to having natural resonant characteristic (Abdel-Rharman, et al. 2004). DGS structures generally affect the filter rejection band but, regarding band-pass filters, the effects of these structures on improving the filter performances in band-pass are also discussed (Ahn, et al., 2001, Yang, et al., 1999, Wang, et al., 2011, Karthikeyan, et al., 2011). Easily fabrication, low insertion loss, and size reduction of the filters are some advantages of using DGS structure in design of filters (Ahn, et al., 2001).

DGS cells etched in the metallic ground plane of microstrip under feed lines. The slow-wave factor of a DGS increases towards the edge of stop-band. So if we design the band-pass of a BPF near the edge of the stop-band of DGS, we can avail the maximum effect of slow wave characteristics. Due to slow wave, the effective electrical length of the resonator increases. Therefore, the cutoff frequency decreases and thus provides compactness in design.

In figure 3, we showed the hairpin filter incorporating tow DGS cells. A DGS etched in the metallic ground plane under the feed lines of hairpin filter enhances the coupling between the lines due to its slow-wave effect and therefore, yields higher adaptation of the band-pass filter. In order to enhance the band-with adaptation of the proposed filter, we choose to study the effect of DGS dimensions.

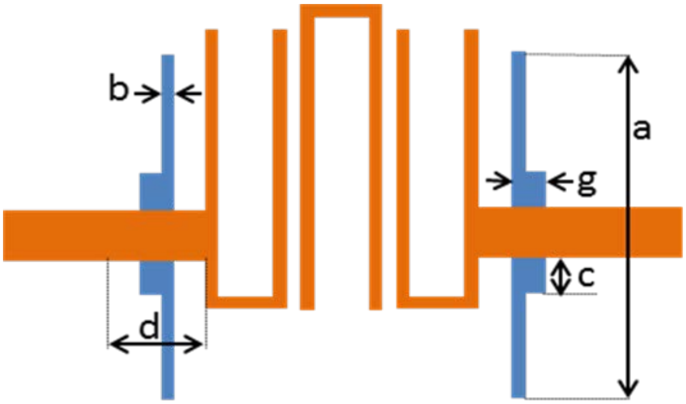

Figure 3: Layout of three poles hairpin line BPF with defected ground structure

When we vary the slot dimensions of DGS, the band-pass of the filter improves. Here, we vary one dimension of the rectangular DGS cell and keeping other dimensions fixed.

Plots of the return loss coefficient with different slot length dimension are shown in figure 4; the slot length is indicated by a parameter. So we can see that the return loss improve with the increment of slot-length dimension, but for slot-length higher than 5mm, the adaptation decreases.

The filter shows clearly three transmission poles for slot-length higher than 4mm. This indicates that the proposed filter is a three-pole filtering structure.

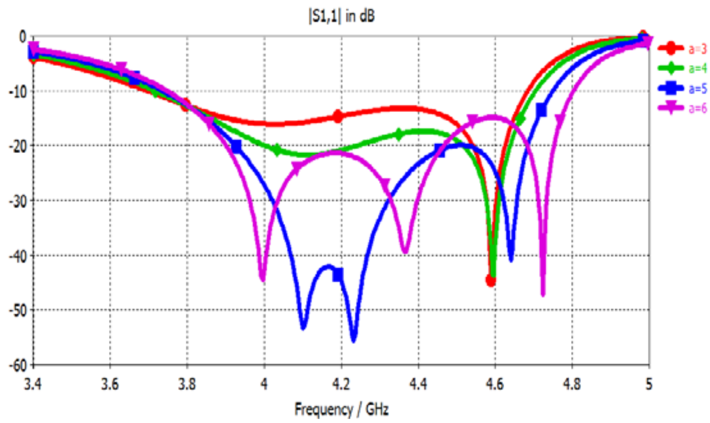

Figure 4: Investigate parameter a (varies a, b = 0.2 mm, c = 1 mm, d=3mm and g = 1 mm)

Plots of the return loss coefficient with different slot width are shown in figure 5; the slot width is indicated by b parameter. We can see that the return loss improves with decrement of slot-width of DGS cell.

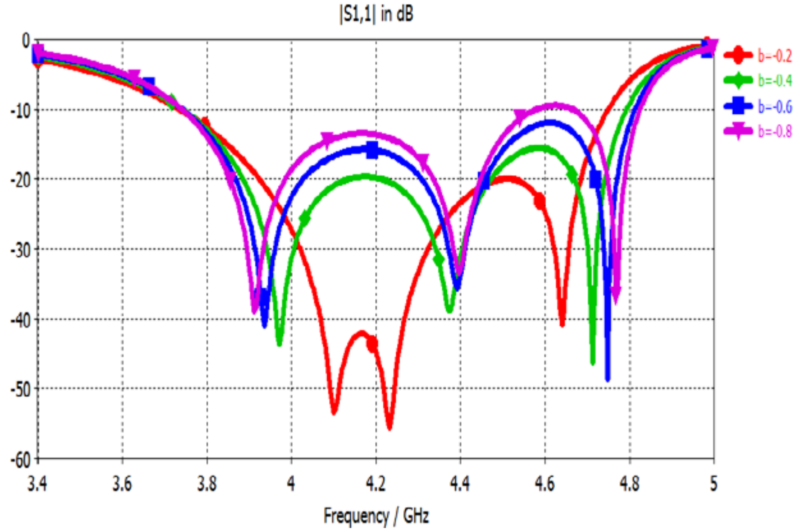

Figure 5: Investigate parameter b (a =2mm, varies b, c = 1 mm, d=3mm and g = 1 mm)

Plots of the return loss coefficient with different c parameter of DGS cell are shown in figure 6. We can see that the best result is obtained for c parameter equal to 1mm.

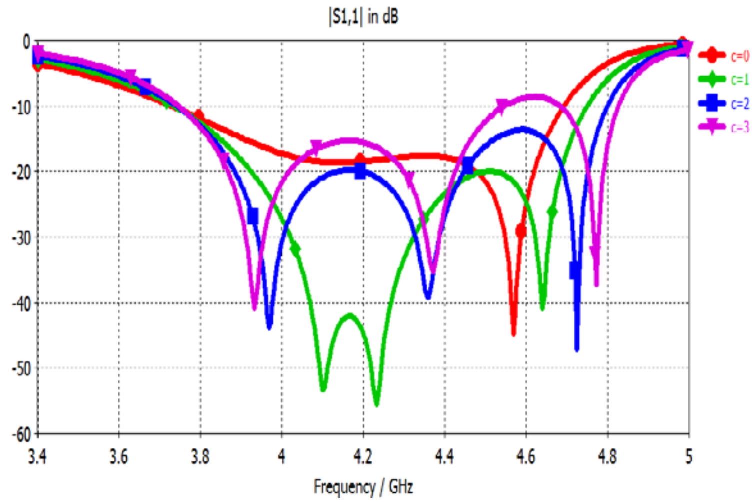

Figure 6: Investigate parameter c (a =2mm, b = 0.2 mm, varies c, d=3mm and g = 1 mm)

Plots of the return loss coefficient with different g parameter of DGS cell are shown in figure 7. We can see also that the best result is obtained for g parameter equal to 1mm.

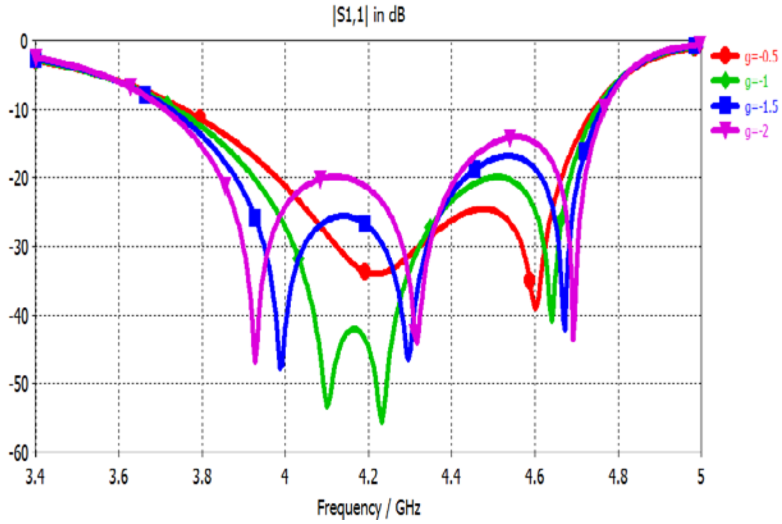

Figure 7: Investigate parameter g (a =2mm, b = 0.2 mm, c=1mm, varies g and d=3mm)

Plots of the return loss coefficient with different d parameter of DGS cell are shown in figure 8. Also in this case, we can see clearly that the best result is obtained for d parameter equal to 3mm.

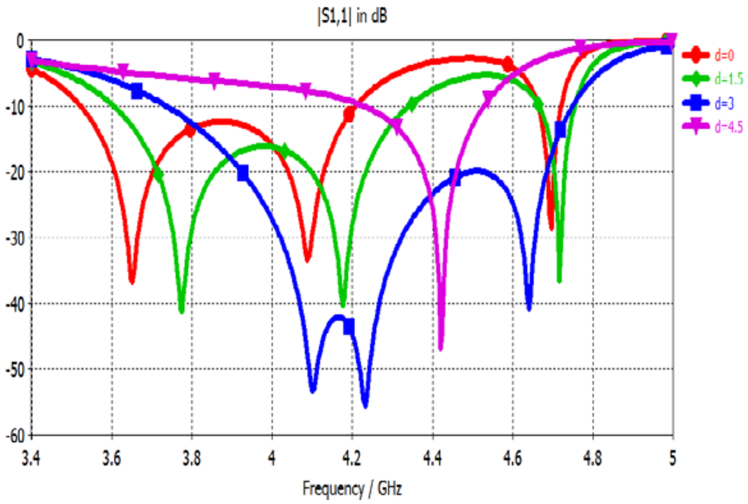

Figure 8: Investigate parameter d (a =2mm, b = 0.2 mm, c=1mm, g=1mm and varies d)

Consequently, the greatest response used for improve the adaptation band-width occurs for the following DGS parameters: a=2 mm, b=0.2 mm, c=1 mm, d=3 mm, g=1 mm.

Finally, we present the S parameters of hairpin filter incorporating DGS structures with optimal dimensions. We observe that the return loss of the filter improves significantly with DGS cells.

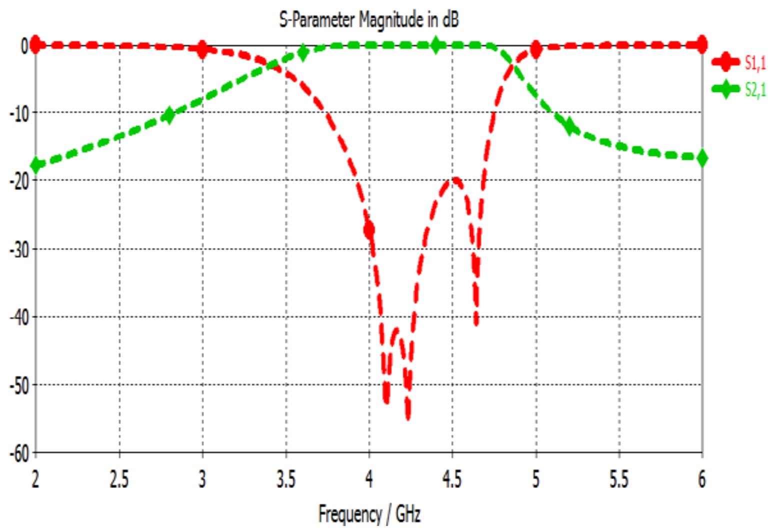

Figure 9: Simulation response of three poles hairpin line BPF with optimal dimensions of the DGS cell.

Conclusion

Band-pass filter is firstly designed and its response proposed return loss around 10dB. The cascading DGS with that hairpin line BPF improved the return loss of the filter and showed clearly three transmission poles. This indicates that the proposed filter is a three-pole filtering structure.

The filter performances are exhibits |S21| less than 0.5dB, |S11| more than 30 dB, and center frequency of proposed filter is around 4.2GHz with operating bandwidth of 35%.

References:

Abdel-Rahman, A., Verma, A. K., Boutejdar, A., and Omar, A. S. (2004), “Compact stub type microstrip band pass filter using defected ground plane," IEEE Microwave and Wireless Components Letters, Vol. 14, No. 4.

Ahn, D., Park, J.S., Kim, C.S., Kim, J., Qian, Y. and Itoh, T. (2001), ”A design of the lowpass filter using the novel microstrip defected ground structure”, IEEE Trans. Microwave Theory and Techniques, 49(1): 86-93.

Karthikeyan, S. S. and Kshetrimayum, R. S. (2011), “Compact, Deep, and Wide Rejection Bandwidth Low Pass Filter Using Open Complementary split Ring Resonator”, Microwave and optical Technology Letters, Vol. 53, No. 4.

Kim, C.S., Park, J.S., Ahn, D. and Lim, J.B. (2000), “A novel one dimensional periodic defected ground structure for planar circuits”, IEEE Microwave and Guided wave Letters, 1(4): 131-133.

Liu, H.W., Li, Z.F., Sun, X.W., and Mao, J.F. (2004), “An improved 1-D periodic defected ground structure for microstrip line”, IEEE Microwave and Wireless Comp. Letter, 14,(4):180- 182.

Pozar, D. M. (1998), Microwave Engineering, 2nd ed. New York: Wiley.

Wang, L. and Guan, B. R. (2011), “Compact Dual-mode DGS Resonators and Filters”, Progress In Electromagnetics Research Letters, Vol. 25, 47-55.

Yang, F.R., Qian, Y. and Itoh, T. (1999), “ A novel uniplanar compact PBG structures for filter and mixer applications”, IEEE Microwave Theory Tech. Symposium, MTT (S).