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Compact Narrow Band Non-Degenerate Dual-Mode Microstrip Filter with Etched Square Lattices

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ABSTRACT

A compact narrowband non-degenerate dual-mode microstrip filter with square shape cuts is presented. The structure is developed by loading the conventional non-degenerate dual-mode resonator by open circuit stubs at two opposite corners. The filter bandwidth is controlled by only decreasing the higher cutoff frequency of the conventional type. With Square shape cuts, return loss is improved. A 20% fractional bandwidth filter is designed and implemented on FR4 material with 4.4 dielectric constant and 1.6 mm thickness at center frequency of 1.5 GHz with passband of 1.3 GHz to 1.6 GHz. Analysis has been achieved using the IE3D simulator. Experimental results do agree with simulations.

Keywords: *Microstrip, Dual Mode, Narrowband Filter, Square Patch Resonator*

1. Introduction

Now-a-days compact microwave filters are widely used in various wireless communication applications. Dual-mode resonators have been used for such purposes. Each of dual-mode resonators act as a doubly tuned resonant circuit and therefore the number of resonators required for a given filter is reduced by half, resulting in a compact configuration. Dual-mode microstrip resonators have the advantages of low profile, simple fabrication, ease of integration in addition to low cost. The first microstrip dual-mode filter was presented by Wolff [1] in 1972. Degenerate modes based filters have been investigated in various topologies such as square patch [2], circular patch, triangular patch, square loop [3], circular ring [4] and meander shape [5]. Square and circular patches structures have negligible conductor loss but suffer from higher radiation loss. However, square loop and circular ring structures have less radiation loss but suffer from higher conductor loss, especially for thin strip conductors [2]. Degenerate dual mode filters have usually narrow bandwidth of (< %5). Filters with higher bandwidth up to 25% have been investigated using non-degenerate dual-mode structure [6–7].

2. Proposed Structure and Modes of Operation

The fields within a square patch resonator can be expanded by the TM^z_{mn0} modes [2], where 'z' is perpendicular to the ground plane. The two fundamental degenerate modes correspond to TM^z_{100} and TM^z_{010} and the first higher order mode correspond to TM^z_{110} [6]. These three modes can be excited simultaneously by a square shape resonator with feed lines, as shown in Figure 1. The simulated response is shown in Figure 2.

The etching of slots in square patch resonator as shown in Figure 3 decreases the resonance frequencies of the

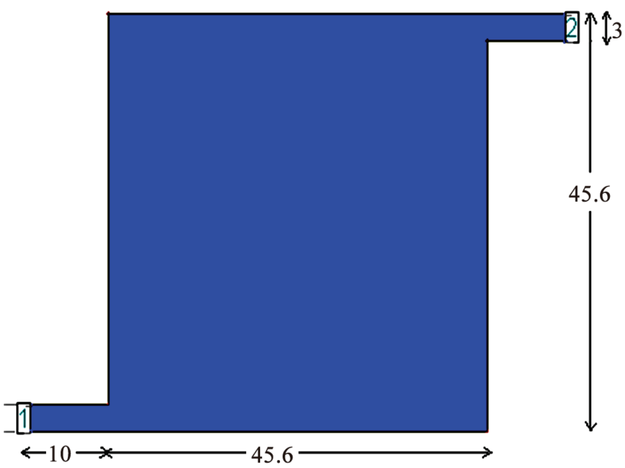

Figure 1. Layout of square patch resonator with feed lines (All dimensions are in mm)

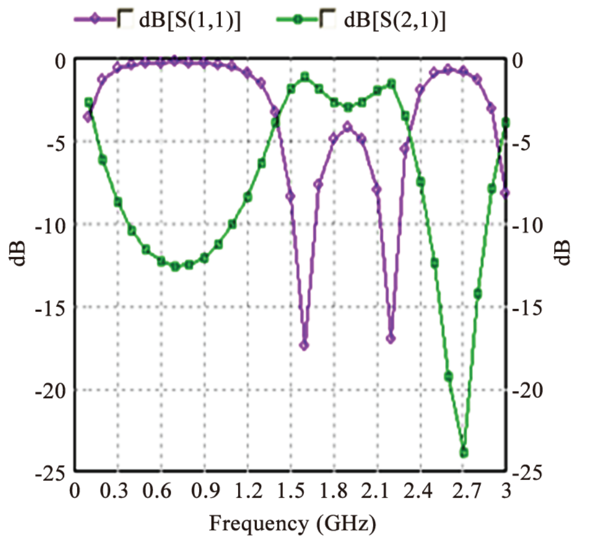

Figure 2. Simulated response of square patch resonator with feed lines

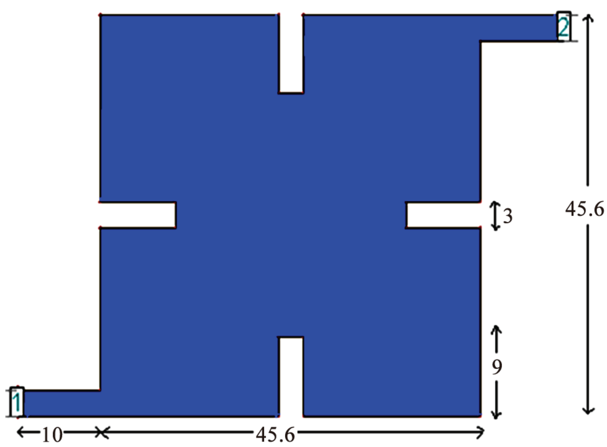

Figure 3. Layout of square patch resonator after etching slots (All dimensions are in mm)

three modes but the resonance frequency of the mode TM^z_{110} decreases faster. Therefore, band pass filter behavior can be obtained [7]. This is shown in Figure 4. The resultant size and bandwidth decreases as the slot length increases. The square patch has a length W, while the slots have equal lengths L and width S. The physical dimensions of the simulated patch are W = 45.6 mm, L = 9 mm and S = 3 mm. Denoting f_1 as the resonance frequency of the degenerate modes TM^z_{100} and TM^z_{010} and f_2 as the resonance frequency of the mode TM^z_{110}. The effect of the slots length L on the resonance frequencies f_1 and f_2 for the patch is that the two resonance frequencies, f_1 and f_2, decrease as L increases [7]. The difference f_2 - f_1 can be used as first approximation of the possible bandwidth of the filter. For L = 9 mm, a fractional bandwidth of about 33% can be obtained using the given parameters.

Based on this design configuration, it is difficult to achieve bandwidth less than this value. However, loading the patch by open circuit stubs as shown in Figure 5 will decrease the resonance frequency f_2 of the mode TM^z_{110} and approximately maintains the resonance frequency of the degenerate modes constant. Therefore, band pass filters with fractional bandwidth less than 25% can be achieved.

The layout of the filter with the stubs of width 1 mm and length 12 mm can be seen in Figure 5. The subsequent effect on the resonance frequencies f_1 and f_2 is

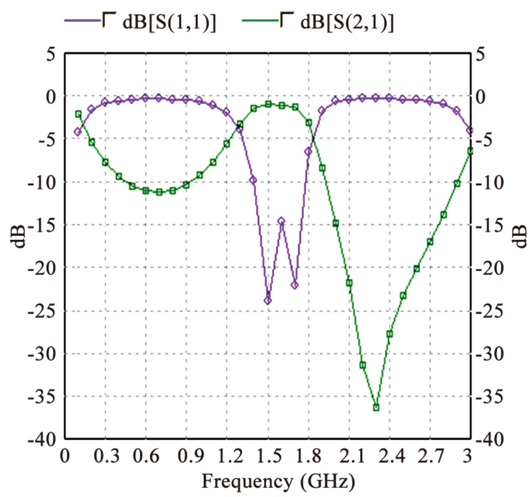

Figure 4. Simulated response of square patch resonator after etching slots

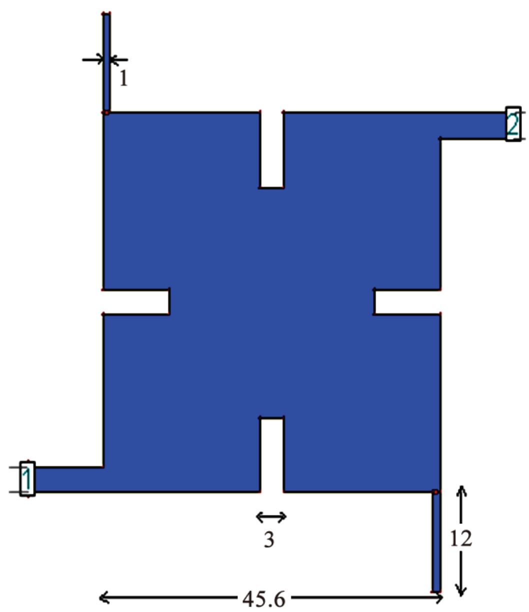

Figure 5. Layout of non-degenerate dual-mode filter with stubs of length 12 mm

shown in Figure 6. This analysis is carried out using the moments method IE3D simulator, on a conducting patch of W = 45.6 mm on a substrate of dielectric constant 4.4, with height 1.6 mm. The slot length and width used are 9 mm and 3 mm, respectively. These parameters have been chosen to fix f_1 at 1.3 GHz.

As described in the previous section, almost no effect is observed on the resonance frequency of the first two degenerate modes TM^z_{100} and TM^z_{010}. The resonance frequency of these modes f_1 is almost constant and equal to 1.3 GHz for stubs length of 0 to 18 mm. However, the first higher order mode TM^z_{110} is highly affected and its resonance frequency f_2 decreases. This variation allows the design of narrow band filter, with careful control of its bandwidth. Bandwidth selection can be obtained by first choosing f_1 and then finding the appropriate stub lengths for a specific value of f_2.

3. Filter Design Parameters

For the proposed narrowband band pass filter the design parameters are:

Dielectric Constant = 4.4,

Height of Substrate = 1.6 mm,

Corresponding length of the Square patch, W = 45.6 mm,

Corresponding width of the slots, S = 3mm,

Corresponding length of the slots, L = 9mm,

Corresponding width of the stubs, W_s = 1mm,

Corresponding length of the stubs, L_s = 16mm,

The layout of the non-degenerate dual-mode filter with stubs of length 16 mm is shown in Figure 7 and Figure 8 shows the fractional bandwidth obtained is about 20% in

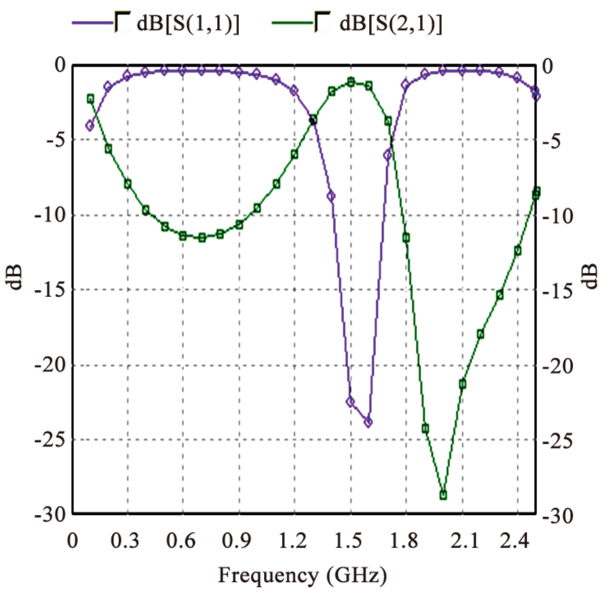

Figure 6. Simulated response of non-degenerate dual-mode filter with stubs of length 12 mm

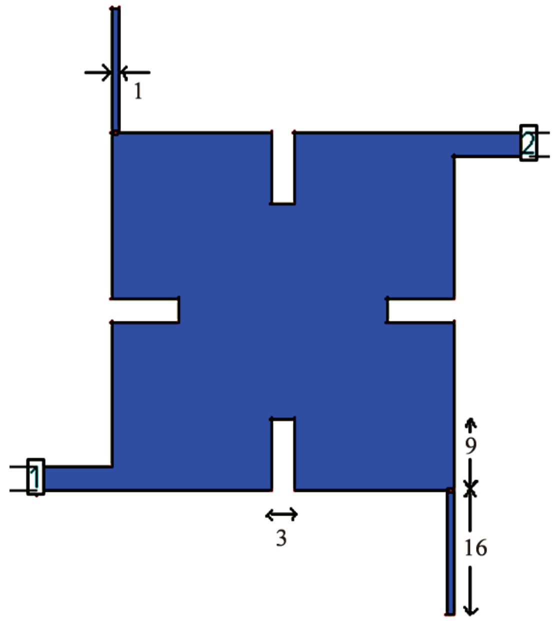

Figure 7. Layout of the dual-mode filter with stubs of length 16 mm

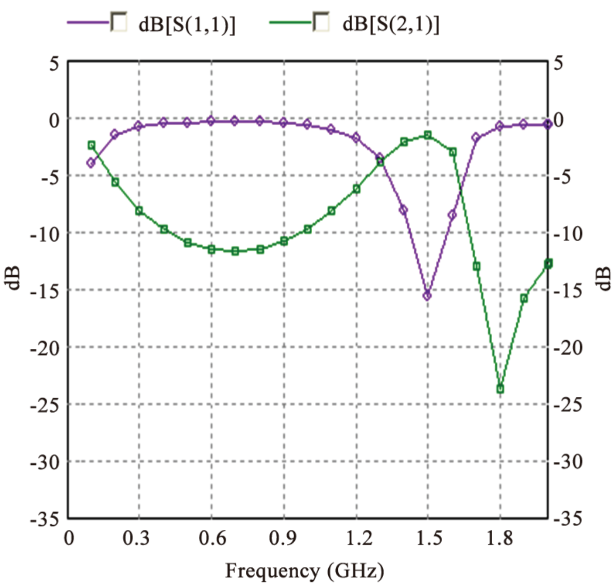

Figure 8. Simulated response of dual-mode filter with stubs of length 16mm

the passband 1.3 GHz -1.6 GHz and the return loss is found to be 15.11dB. The layout as shown in Figure 9, is obtained after etching one square lattice of dimension of 6 mm × 6 mm, on the center of the conventional non-degenerate dual mode filter. The corresponding return loss of the bandpass filter at the center frequency is found to be improved and becomes 22.56 dB. The fabricated layout is shown in Figure 10. The simulated and measured results are shown in Figures 11, 12.

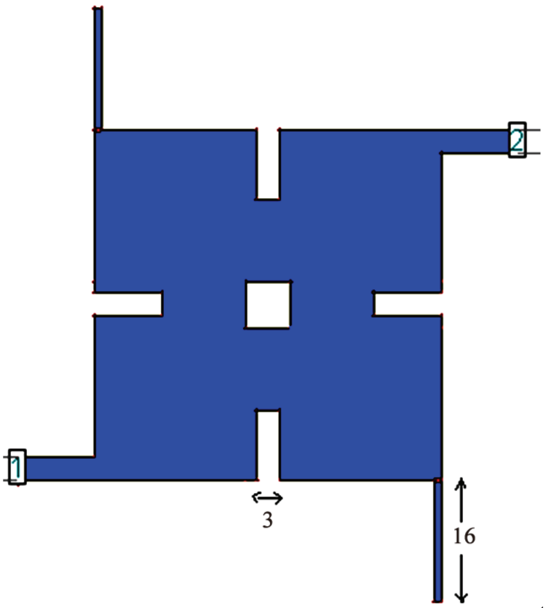

Figure 9. Layout of the non-degenerate dual mode filter with etching of one square lattice

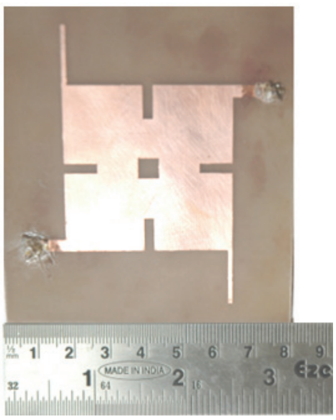

Figure 10. Photographed layout of non-degenerate dual mode filter with etching of one square lattice

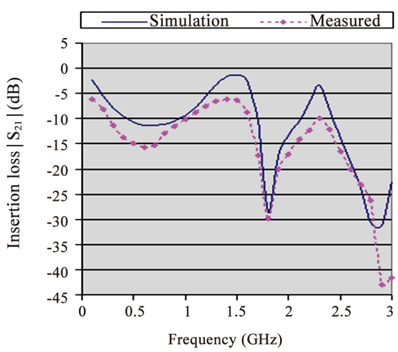

Figure 11. Simulated and measured results of insertion loss of non-degenerate dual mode filter with etching of one square lattice

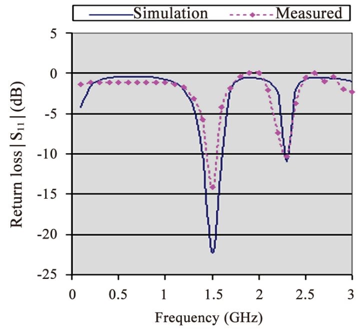

Figure 12. Simulated and measured results of return loss of non-degenerate dual mode filter with etching of one square lattice

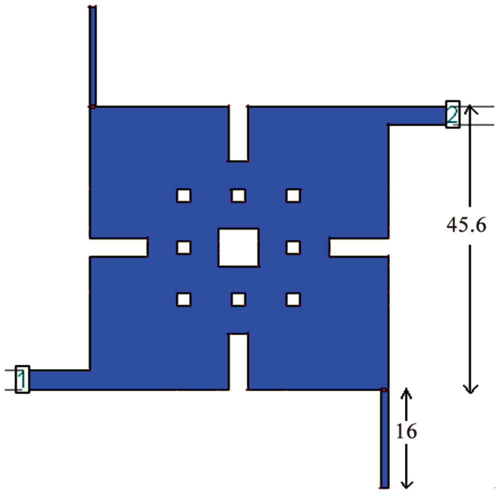

Figure 13. Layout of the non-degenerate dual mode filter with eight square lattices

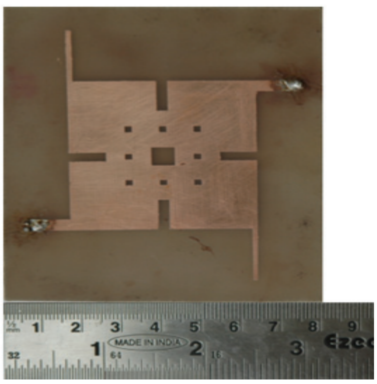

Figure 14. Photographed layout of the non-degenerate dual mode filter with eight square lattices

Now, with additional eight small square lattices of dimension 2mm × 2mm etched as shown in Figure 13, the frequency response can further be improved as shown in Figures 14, 15. The return loss now is 26.12 dB. Figure

16 shows the fabricated layout of the non-degenerate dual mode filter with eight square lattices.

Figure 17 shows the layout of non-degenerate dual mode filter with a carpet of square lattices of very small dimension 1mm × 1mm. It further improves the return loss to 30.06 dB which is shown in Figure 18.

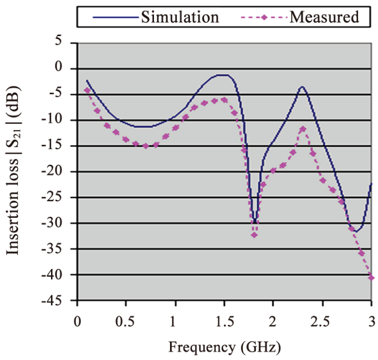

Figure 15. Simulated and measured insertion loss plots for non-degenerate dual mode filter with eight small square lattices

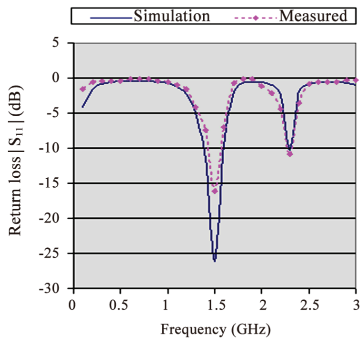

Figure 16. Simulated and measured return loss plots for non-degenerate dual mode filter with eight small square lattices

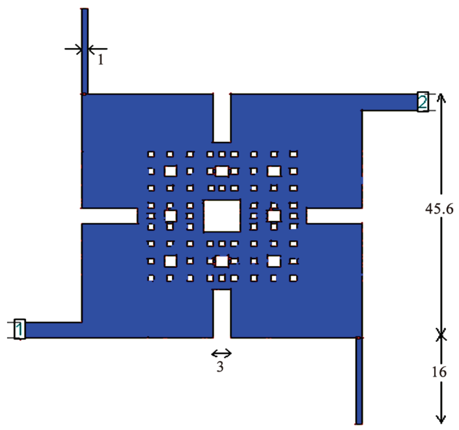

Figure 17. Layout of non-degenerate dual mode filter with carpet square lattices

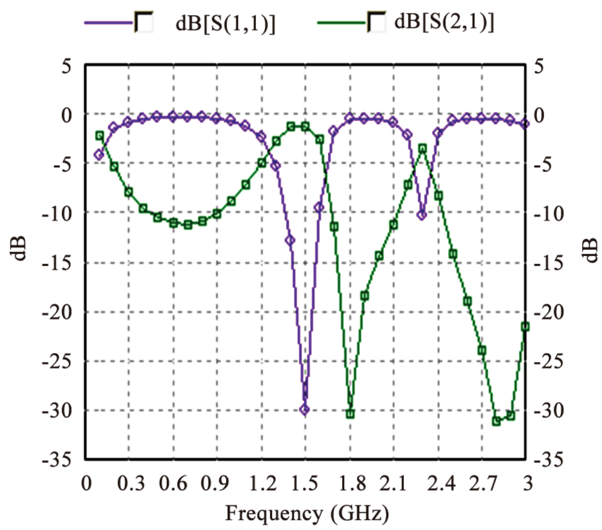

Figure 18. Simulated response of non-degenerate dual mode filter with carpet square lattice

4. Conclusions

A compact narrow band filter based on non-degenerate dual-mode resonator is proposed. The narrow bandwidth characteristic is achieved by loading the slotted square patch at opposite corners. Such loading affect only the higher cutoff frequency of the filter. The effect of this loading has been discussed.

For improved performance in terms of return loss for the narrowband band pass filter, square shape lattices of different dimensions etched on the conventional design. It significantly improves the return loss with 30.06 dB at the center frequency. Hence, a narrowband filter of fractional bandwidth 20% is designed and implemented with better performance on transmission and reception. Good agreement between simulated and measured responses is observed.

5. Acknowledgment

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