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Research paper

A Compact Wideband SIW Bandpass Filter For UWB Applications

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Abstract

In this paper wideband Band Pass Filter is proposed using vertical array of vias in split ring resonator for UWB applications. As frequency of operation increases microstrip devices are not efficient because of its small wavelength and it requires very tight tolerances for manufacturing. Waveguide devices are preferred at high frequency, however their manufacturing process is difficult. Therefore a new design guiding architecture called Substrate Integrated Waveguide(SIW) is proposed. A typical SIW is designed by using geometrical parameters. The performance of SIW-BPF has been analysed for different via diameters by maintaining the pitch ratio between 0.4 and 0.8. Proposed filter provides return loss of greater than 10 dB and insertion loss of 0 dB. Designed filter is simulated using ADS software.

Keywords: *bandpass filter, UWB, pass band.*

1. Introduction

The Federal Communications Commission (FCC) release the frequency band 3.1 - 10.6 GHz in early 2002. Ultra Wideband (UWB) technology offers high data rates, low-power transmissions, low cost, excellent range resolution (geolocation) capabilities in the research community and in industry. UWB filters have lower insertion loss, good return loss performance, good selectivity and better rejection performance. A new design of wideband microwave bandpass filter based on intercoupled split-ring resonator is designed for frequency range from 10-17GHz[6]. A compact planar bandpass filter using two stubs is proposed for UWB applications shows good return loss performance and sharp selectivity. Microstrip stopband bandpass filters are proposed using two shapes of split ring resonator(SRR) [12].In ref [1], splitting resonator is used as multimode resonator through interdigital coupled lines is designed for UWB applications.In this paper, novel UWB bandpass filter is realized using split ring resonator. A microstrip transmission line is attached with the split ring resonator. Here, vertical array of vias are placed in the stubs of the split ring.

2. Modeling of Substrate Integrated Waveguide

Substrate integrated waveguides (SIWs) are integrated waveguide like structures fabricated byusing two rows of metal vias embedded in a dielectric that connect two parallel metal plates. The rows of metal vias form the side walls. This relatively new architecture has the properties of both microstrip line and waveguide. Its manufacturing process is also similar to other printed planar architectures. A typical SIW geometry is illustrated in Fig.1, where its width (i.e., the separation between the vias in the transverse direction (as)), the diameter of the vias (d) and the pitch length (p) are the most important geometrical parameters (as shown in Fig.1) that are used for designing SIW structures as will be explained in the next section.
For a rectangular waveguide, cut off frequency of arbitrary mode is found by the following formula:

$$f_c = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2} \qquad (1)$$

where:
c : speed of light
m, n : mode numbers
a, b : dimensions of the waveguide

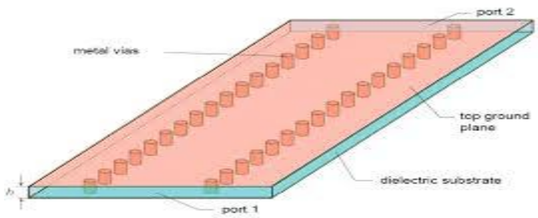

Fig.1: Substrate integrated waveguide(SIW)

For TE_{10} mode, the much-simplified version of this formula is:

$$f_c=\frac{c}{2a} \quad (2)$$

For DFW with same cut off frequency, dimension "ad" is found by:

$$a_d=a/\sqrt{\varepsilon_R} \quad (3)$$

Having determined the dimension "a" for the DFW, we can now pass to the design equations for SIW.

$$a_s=a_d+d^2/0.95p \quad (4)$$

Where :
d:diameterofthevia
p: pitch (distance between the vias)

Note that the thickness of the substrate does not affect these design equations, but it affects the loss of the structure in such a way that the low loss advantage of a high thickness substrate should be considered. One way to interpret above two equations is that for a fixed via diameter, d, the pitch length, p, affects the performance of a SIW. Therefore, to investigate the reception and transmission properties of a SIW structure for varying p values, it is clear that the design equations work well. However, a better strategy to design a SIW is to use them as initial design equations and after the initial design; they can be optimized. Flexibility of determining the cut-off frequency is an advantage of SIW compared to STD WAVEGUIDE.

3. Design of SIW-BPF Operating in UWB (3.1-10.6 GHz)

Substrate integrated waveguide (SIW) bandpass filter (BPF) is designed to operate in UWB frequency range of (3.1-10.6) GHz. Various input/output port topologies of the filter are discussed. Design considerations including the design approach and filter configuration are addressed. A typical SIW is designed by using its geometrical parameters like width between the vias in the transverse direction (a),diameter of the vias (d) and the pitch length (p). This SIW BPF is designed for the pitch ratio (d/p) of 0.714mm and simulated using FR4 substrate with dielectric constant of 4.4 and thickness of 1.6 mm with via diameter of 0.4mm. The designed filter is simulated and the result shows the passband between (3-9) GHz with insertion loss equal to 0dB and return loss of greater than 10dB . The dimensions for the proposed SIW are chosen in such a way that it is used for high frequency applications.

3.1 Analysis And Performance Of Siw-Bpf For Different Via Diamaters

A SIW-BPF is analyzed for different via diameters, by varying the via diameter(d) the pitch ratio of the filter is altered (d/p), variation in the pitch ratio affects the filter performance , so analysis based on the performance of the filter for different pitch ratio is performed and results corresponding to it are compared , it is seen that when the pitch ratio is slightly increased the performance is improved , but the range for pitch ratio is kept fixed for every cut-off wavelength and frequency of operation. For operation of the filter in higher frequency the range lies between 0.4mm and 0.8mm.

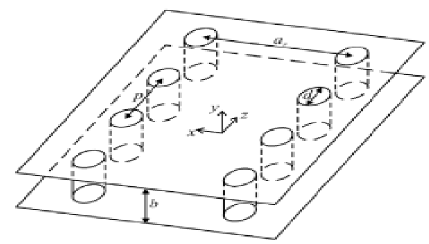

Fig3.1: Via Diameter And Via Separation

- p-period between vias
- d-diameter of vias
- b-height of substrate
- d/p=0.4-0.8

3.2 Proposed Layout of Bandpass Filter Split Ring Resonator- Without Vias

A single Split ring resonator has a pair of loops and strong couplings are desirable. The small gap between the stubs produces large capacitance values. Strong coupling determines every half-wavelength resonators are intercoupled with adjacent resonators to form split-ring structures along half of their length. Therefore, the quarter-wavelength coupling length (a) that consisted of split-ring resonator determines the center frequency (f) of the passband region.

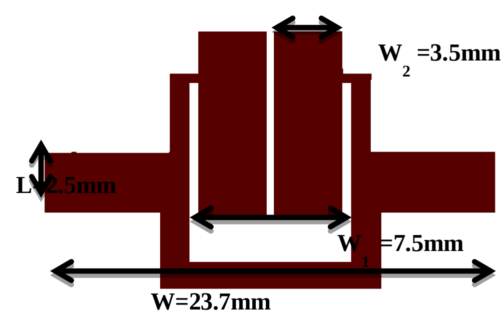

Fig 3.2: proposed layout of bandpass filter split ring resonator- without vias

3.3 Proposed Layout of Bandpass Filter Split Ring Resonator- With Vias

The split ring resonator bandpass filter has low radiation losses and high quality factor. The Surface current distribution of bandpass filter is shown in Fig 3.3. This wide band bandpass filter are proposed and analyzed on FR4 substrate with thickness 1.6mm and dielectric constant of 4.4.

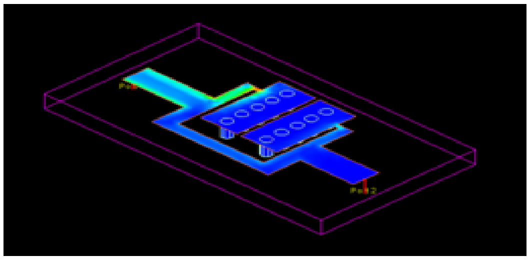

Fig 3.3: Surface current distributions of bandpass filter using vertical array of vias.

The layout of novel compact bandpass filter using split ring resonator produces a notch band and act as a band stop filter as shown in Fig 3.6 . By adding vertical array of vias in the split ring resonator produces wide band frequency ranges from (3.1-10.6). The BPF is designed using split ring resonator to provide more transmission zeros in the pass band and lower insertion loss. Figure 3.4 shows the configuration of the novel compact BPF using vertical vias.

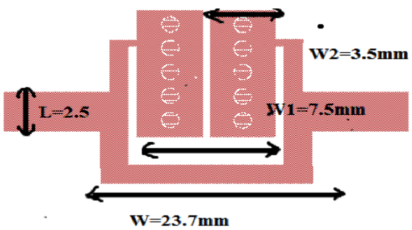

Fig 3.4: Proposed Layout Of Bandpass Filter Split Ring Resonator- With Vias

4. Simulation Results

The simulation result in passband without vertical array of vias is shown in fig 3.5

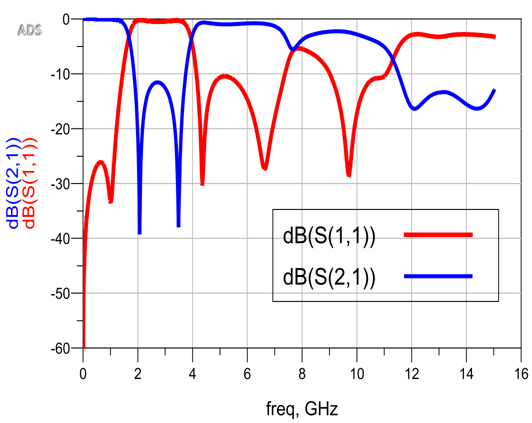

Fig 3.5: Simulated Result of proposed layout without vias

The simulation result of the pass band is mainly determined by the vertical array of vias in the resonator and the frequency of the pass band . Here via diameter is D=1mm and the gap between vias is G_1= 0.5mm.The proposed filter structure is operated at UWB range (3.1-10.6GHz).

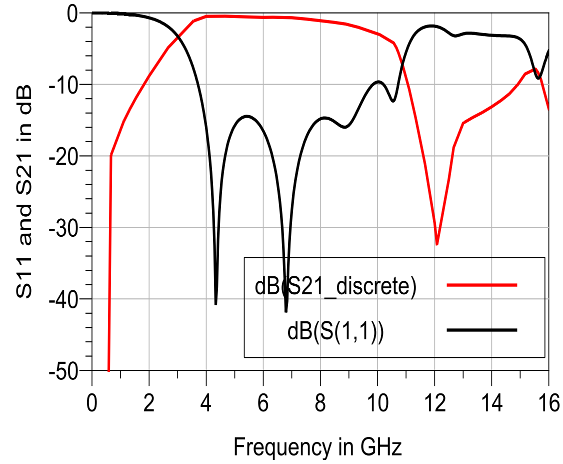

Fig.3.6: Simulated Result of SIW Bandpass filter using vertical array of vias.

Using vertical vias in split ring resonator produces attenuation about -42dB and obtain wide band characteristics. This produces a complete ultra wide band range of 3.1-10.6 GHz frequency range, return loss achieved about 10dB, as shown in Fig.3.6.

5. Conclusion

Substrate integrated waveguide band pass filter is proposed and designed for high frequency applications like in satellite receiver systems and also in ultra-wide band applications. Two designs of SIW-BPF is proposed to operate in UWB frequency range of 3.1-10.6 GHz. The performance of the filter is improved by varying the via diameter of the SIW-BPF and a analysis is made for different (d/p)pitch ratios and the results are compared. For the pitch ratio of 0.714mm , a good return loss of 10dB and insertion loss of nearly 0dB is obtained. The proposed layouts are fabricated and its simulated and measured results are compared and analysed. This work can be further enhanced by providing proper matching at the output side and improvement in the return loss at the higher frequency range.

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