



Dual-band substrate integrated waveguide (SIW) band pass filter for scientific radar applications

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Abstract In this paper, a dual-band substrate integrated waveguide filter is proposed for 45.5–52.5 GHz and 60–62.5 GHz band. Dual-band substrate integrated waveguide filter is a three pole filter and with multiple transmission zeros. The substrate integrated waveguide (SIW) is designed by inserting metallic vias along the side walls of the substrate with specific spacing and varying diameter. A parametric study by varying the vias geometry is presented with vias diameter as 0.10, 0.12 and 0.18 mm. The return loss and insertion loss of the proposed filter are better than 15 and 1.18 dB, respectively at 0.12 mm which is the improved result as compared when the vias diameter is 0.10 mm and 0.18 mm. The fractional bandwidth is 8.9 and 4.09% from 45.5 to 52.5 GHz and 60 to 62.5 GHz, respectively.

Keywords Substrate integrated waveguide · Dual-band · Band pass filter · Transmission zeros

1 Introduction

The investigation in the field of wireless communications has led to a vast development in the design of RF circuits and has been more inclined on the miniaturization of these circuits. Earlier for transmission of signals in circuits the traditional transmission lines metallic waveguides were used for guiding the electromagnetic energy. Rectangular waveguides being non-planar and bulkier are expensive and voluminous [1]. The more viable option developed in 1998 is substrate integrated waveguide (SIW). Substrate integrated waveguide are designed with cylindrical vias embedded in the substrate. SIW technology is used vastly in design of active and passive devices such as antennas, filters [2] etc. SIW technology can be fabricated on a printed circuit board (PCB) offering wide commercial applications in radar imaging and biomedical devices [3]. This SIW technology is also used in circuits and components such as filters, oscillators, power dividers [4–6] etc. Substrate integrated waveguide (SIW) filters are one of the advanced filters that offer high performance as compared to conventional waveguide filters. SIW filters have a high quality factor, compact size that is conformable with planar circuits and it requires low cost for fabrication. SIW technology uses standard PCB or Low temperature co-fired ceramic (LTCC) process for designing and offers an attractive solution for minimized volume of circuits that can be integrated with planar circuits on the same substrate [7–9]. SIW technology uses metallic vias to limit the propagating region. These vias are embedded in the substrate with spacing such that losses are minimized. Microstrip lines are used to realize SIW structures with planar circuits. Dual band filters have two pass bands with two different centre frequencies [10]. Cascading a broadband filter and a band stop filter is constructed in [11, 12].

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But these designs have high insertion loss and large size. In [13, 14] dual-band filter is realized by introducing transmission zeros among a passband filter. It uses dual-resonance structures or step impedance resonators [15, 16]. By using SIW valuable research has been done in the field of dual-mode filters [17, 18], half mode filter [19] or dual-band filter [20]. Dual-band filters are mostly used in wireless communications. In this paper, a dual-band three pole filter in 45.5–52.5 GHz and from 60 to 62.5 GHz band is designed. This dual-band SIW filter can be deployed for millimeter-wave radar in scientific research.

2 Design of SIW filter

SIW structure is a progression between microstrip and dielectric filled waveguide (DFW). SIW is a linear periodic arrangement of metallic vias or holes which are embedded along the side walls of waveguide. SIW structure supports the propagation of quasi transverse electric (TE) modes. The cut off frequency of the rectangular waveguide is [20]:

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

where f_c is the cut off frequency, m and n are the mode numbers, c is the speed of light, a and b are the broader and narrower dimensions, respectively. For TE_{10} mode which is considered to be the dominant mode, the cut off frequency is given as [22]:

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

The effective length of the dielectric filled waveguide is

$$a_d = \frac{a}{\sqrt{\epsilon_{eff}}}. \quad (3)$$

Once dimension “ a_d ” of dielectric filled waveguide is determined, design equation for the SIW correlating width a_s is given by

$$a_s = a_d + \frac{d^2}{0.95P}. \quad (4)$$

Proposed filter is designed using Computer Simulation Technology Microwave Studio which uses finite element method (FEM) techniques. The designed filter is a dual band pass filter with frequency 45.5–52.5 GHz and in 60–62.5 GHz. The designed filter has best response when the diameter of the vias of the substrate integrated waveguide filter is 0.12 mm. The Fig. 1 shows the design of the filter. ROGERS RT5880 has been used as the

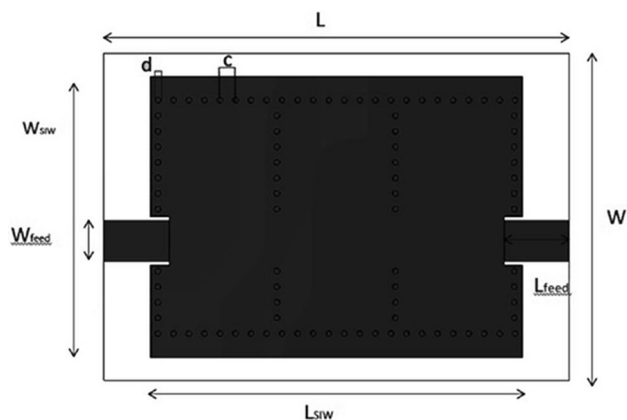


Fig. 1 Structure of the designed SIW dual band filter

substrate with height of 0.762 mm and relative permittivity ϵ_r of 2.2. Table 1 shows the tabular dimensions of the geometry of the filter. By increasing the diameter of vias the poles shift towards right with better return loss when the d is 0.12 mm, where L is the length of filter, L_{SIW} is the length of SIW, W is the width of filter, W_{feed} is the width of feed lines, L_{feed} is the length of feed lines, d is the diameter of vias and c is the center to center separation between vias. The width of SIW is considered to be 16 mm.

3 Simulation of filters

Figure 2 shows S_{11} (Return loss) of the designed dual band filter by varying the changing the diameter of the vias. It has been observed that the dimensions of the vias critically affect the return loss. The return loss when the diameter of the vias is 0.10 mm in 45.5–52.5 GHz band is 32 dB and in 60–62.5 GHz band it is 35 dB. Then diameter of the vias when increased to 0.12 mm the return loss is improved 53 dB in 45.5–52.5 GHz band and 30 dB in 60–62.5 GHz band. The return loss is increased when the diameter of the vias is further increased to 0.18 mm. The return loss in 60–62.5 GHz band is 39 and 36 dB. Insertion losses for the three different vias dimensions is shown in Fig. 3. The insertion loss when p is 0.10, 0.12 and 1.28 are 1.23, 1.18 and 1.34 dB in 45.5–52.5 GHz band whereas it is 1.7 dB, 1.4 dB, 0.8 dB respectively in 60–62.5 GHz band. The 3 dB bandwidth of the dual band filter is 4.5 and 2.5 GHz in the two bands. The fractional bandwidth is 8.9 and 4.09% in 45.5–52.5 GHz and 60–62.5 GHz respectively. The return and insertion loss are better when vias diameter (p) is 0.12 mm. Figure 4 shows the return and insertion loss of the best response by considering with

Table 1 Parameters of the designed dual band SIW filter

Case	L (mm)	L _{SIW} (mm)	W (mm)	W _{feed} (mm)	L _{feed} (mm)	d (mm)	C (mm)
I	30	24	21	2.55	4.22	0.10	1
II	30	24	21	2.55	4.22	0.12	1
III	30	24	21	2.55	4.22	0.18	1

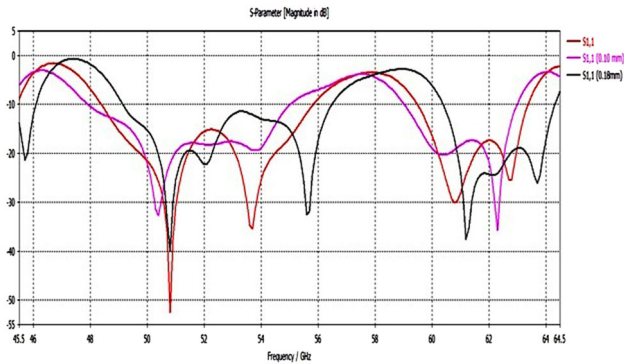


Fig. 2 Return loss of the designed SIW dual band filter for different vias dimensions

$p = 0.12$ mm. The return loss is better than 15 dB in 45.5–52.5 GHz and 18 dB in 60–62.5 GHz.

The proposed filter response is better than as obtained by Guo-Hui et al. [10].

The power flow is shown in Fig. 5 across the dual band pass filter. Most of the power is transmitted from port 1 to the other port.

Fig. 3 Insertion loss of the designed SIW dual band filter for different vias dimensions

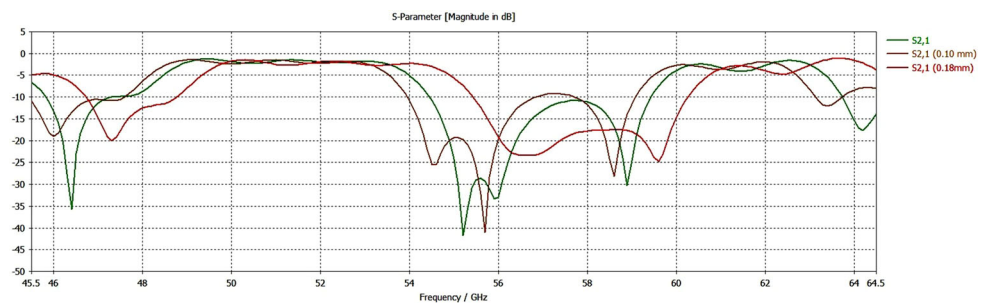


Fig. 4 Insertion loss and return loss of the SIW dual band pass filter for vias diameter 0.12 mm

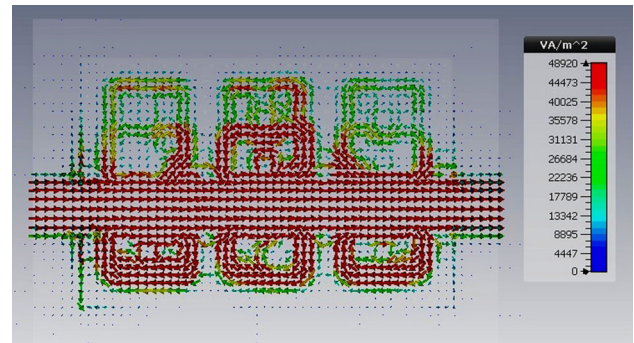
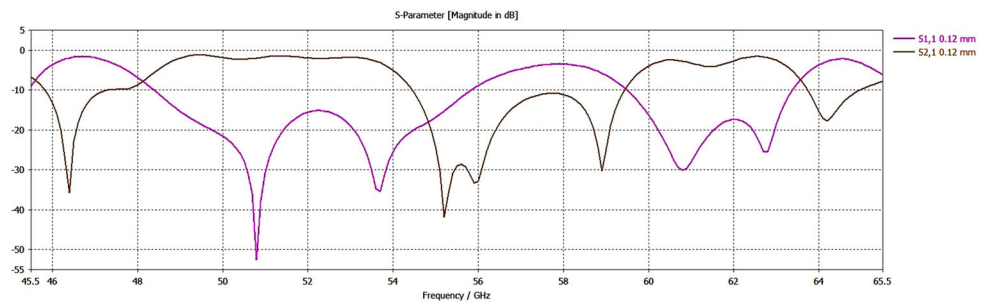


Fig. 5 Power flow across the SIW dual band pass filter with vias diameter 0.12 mm

4 Conclusion

In this paper, a dual-band substrate integrated waveguide filter is proposed and based on parametric study, it has been investigated that the return and insertion loss of the SIW filter are critically affected when the diameter of the vias is varied. The dual-band filter is designed in frequency range

from 45.5–52.5 GHz and 60–62.5 GHz. It has 3 poles in each band and multiple transmission zeros. The proposed filter has better response when the vias diameter is 0.12 mm with insertion loss of 0.18 dB and return loss of 53 dB. The dual-band filter can be used for millimeter wave radar application in scientific research.

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