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Compact Wide Stopband Half-Mode Substrate Integrated Waveguide Bandpass Filter with Co-planar Waveguide

Sambaiah pelluri(1) and MV Kartikeyan(1)
(1) Indian Institute of technology Roorkee, Roorkee-247667, India, spelluri@ec.iitr.ac.in

Abstract

In this paper a quarter-wavelength co-planar (CPW) resonator based bandpass filter is proposed. The main advantage of the proposed half-mode substrate integrated waveguide (HMSIW) bandpass filter structure is its compactness and two transmission zeros for wide stopband. The design and optimization of the proposed filter is carried out using the EM simulator HFSS at the designed frequency of 3.65 GHz. In order to achieve the compactness of the proposed filter, the quasi-TEM mode of HMSIW resonator and quarter-wavelength CPW resonator both are designed on the thin substrate (0.254 mm) with $\varepsilon_r = 2.2$. Further a wide stopband characteristic is studied using higher order mode of the HMSIW to suppress its first spurious passband. Finally, the S-parameter response of the simulated and fabricated prototype is studied where the simulated and measured S-parameters are in close agreement with the corresponding simulated data.

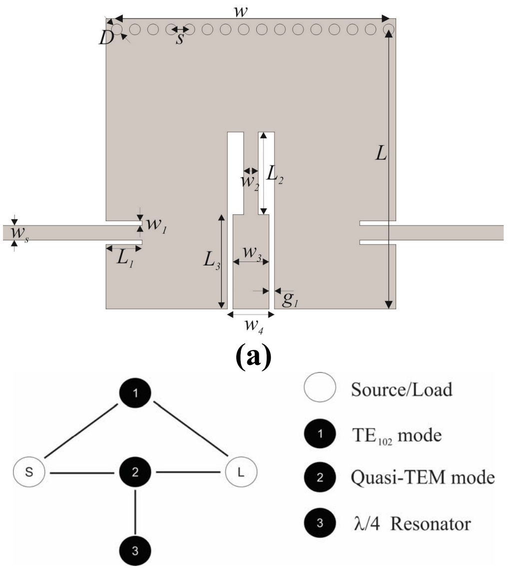
1. Introduction

Modern communication systems demand a new class of bandpass filters which are compact, sharp roll of rate, high performance and wide stopband. Substrate integrated waveguide (SIW) can be synthesized by printed circuit board (PCB) with an array of metallic vias to form side walls of the waveguide. It is more preferable to design systems and circuits at microwave wave frequency due to its low profile, less losses and easily integrated with other planar circuits [1]. However, SIW is too large at lower frequency band when compared with its counterparts of microstrip line. In order to reduce the footprint size by half, half-mode SIW (HMSIW) structure is discussed in [2]. And then, Different approaches for bandpass filter were subsequently presented in [2-6]. An SIW transversal filter is proposed using dual-mode co-planar waveguide (CPW) resonator [4]. It has given better spurious response and high selectivity simultaneously.

In this paper, a compact bandpass filter with HMSIW is proposed. The quasi-TEM mode of HMSIW resonator and quarter-wavelength CPW resonator both are fabricated on the metalized part of the substrate (RT/Duroid 5880) to achieve the compact size. In addition, a wide stopband characteristic is studied using the higher order mode of the HMSIW to suppress its first spurious passband. Finally, the S-parameter response of the simulated and fabricated structure is studied where it is in good agreement to each other.

2. Filter Design

The proposed structure of the HMSIW bandpass filter and the corresponding coupling scheme are shown in Figure 1(a) and Figure 1(b), respectively.



(a)

(b)

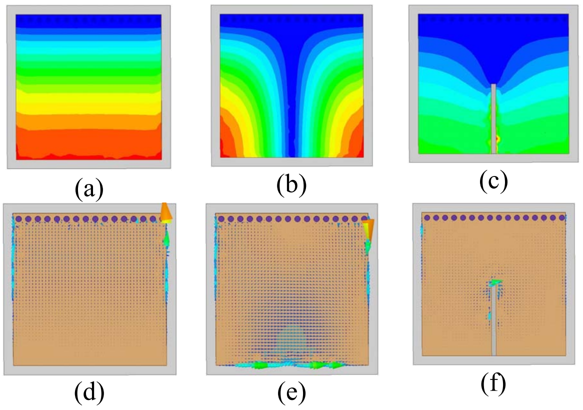
Figure 1. (a) Configuration of the proposed filter (b) Coupling scheme

The proposed HMSIW bandpass filter is obtained by using the quasi-TEM mode which is the lower mode of HMSIW, and is likely as a short circuited quarter wavelength resonator, and the second resonant mode of HMSIW cavity-TE$_{102}$ mode. The quasi-TEM mode resonance frequency is given by [7]:

$$f_{TEM} = \frac{c}{4 * L\sqrt{\varepsilon_r}} \tag{1}$$

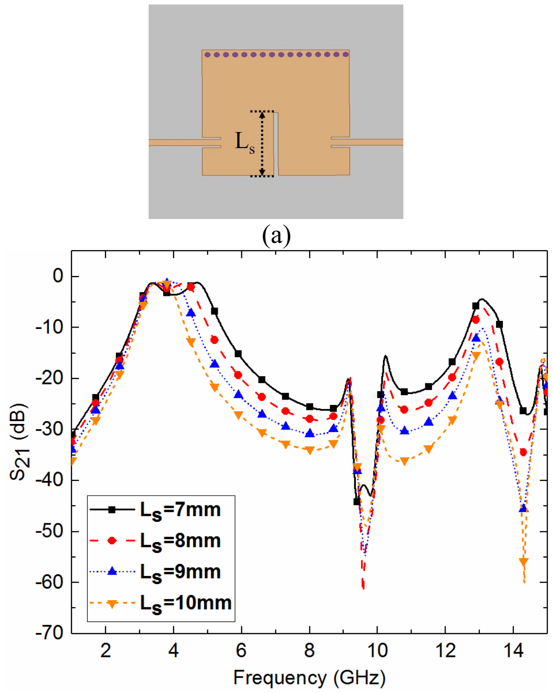
while the resonance frequency of TE$_{102}$ mode of HMSIW is calculated by[7]

$$f_{TE_{102}} = \frac{c}{2\pi\sqrt{\mu_r\varepsilon_r}}\sqrt{\left(\frac{\pi}{2L}\right)^2+\left(\frac{\pi}{w}\right)^2}$$


(a) (b) (c)

(d) (e) (f)

Figure 2. Electric fields of (a) first (quasi-TEM) mode, (b) Second (TE_{102}) mode, (c) slot perturbed second (TE_{102}) mode; and surface currents of (d) first (quasi-TEM) mode, (e) Second (TE_{102}) mode, (f) slot perturbed second (TE_{102}) mode

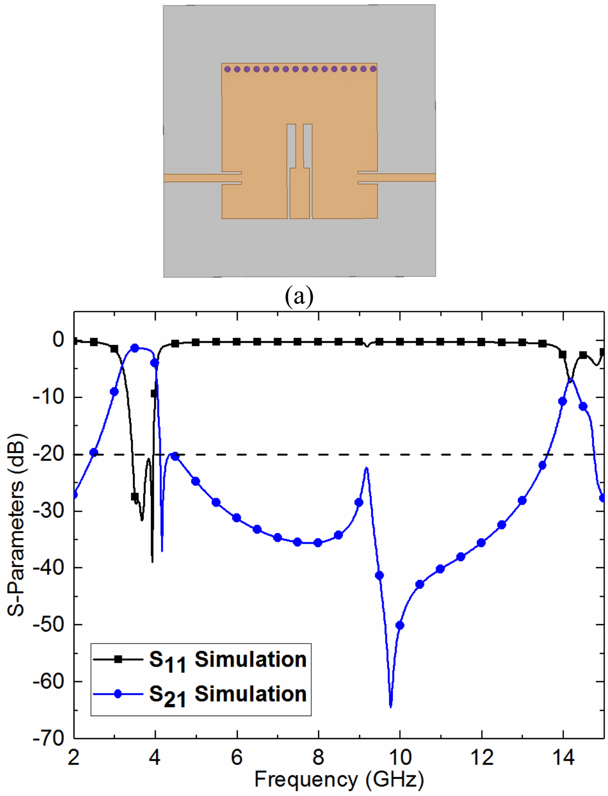


(a)

(b)

Figure 3. (a) Configuration of the HMSIW filter with slotline perturbation, (b) frequency response of the filter with varied L_s.

The electric field within HMSIW and surface current of different modes are shown in Figure 2. The currents of the first (quasi-TEM) mode are transversely distributed, and the currents of the second (TE_{102}) mode are concentrated at the middle of the bottom edge. By inserting perturbation at correct location, the resonant frequency of the second mode can be shifted to the desired frequency point without disturbing the first mode. Figure 3. Shows the structure as well as the frequency response of the structure with different slotline lengths. It can be seen that a transmission zero is appearing which is used to suppress its first spurious passband.



(a)

(b)

Figure 4. (a) Configuration of the HMSIW filter with quarter-wavelength CPW resonator, (b) frequency response of the filter

To get sharp skirt in the proposed HMSIW filter, the quarter-wavelength CPW resonator is introduced in place of slotline. Figure 4. Shows the structure as well as the frequency response of the structure. It can be seen that a transmission zero is obtained at the higher stopband which enhances frequency selectivity.

3. Results and Discussion

The proposed filter is fabricated on a thin substrate (Roger) to minimize undesired coupling and radiation where the thickness of the substrate is 0.254 mm and the relative permittivity of $\varepsilon_r = 2.2$ in order to validate the simulated and measured S-parameters response. The fabricated structure is shown in Figure 5(a). In Figure 1. The geometrical parameters have been shown where the actual value of different parameters are summarized in TABLE I. To measure the area of the filter the length of the feed line is neglected where $\times L = 15 \times 15.4\, mm^2$ $(0.27 \times 0.28\lambda_g^2)$. In the fabricated HMSIW cavity structure the diameter of via holes is 0.6 mm with the pitches of S=1 mm.

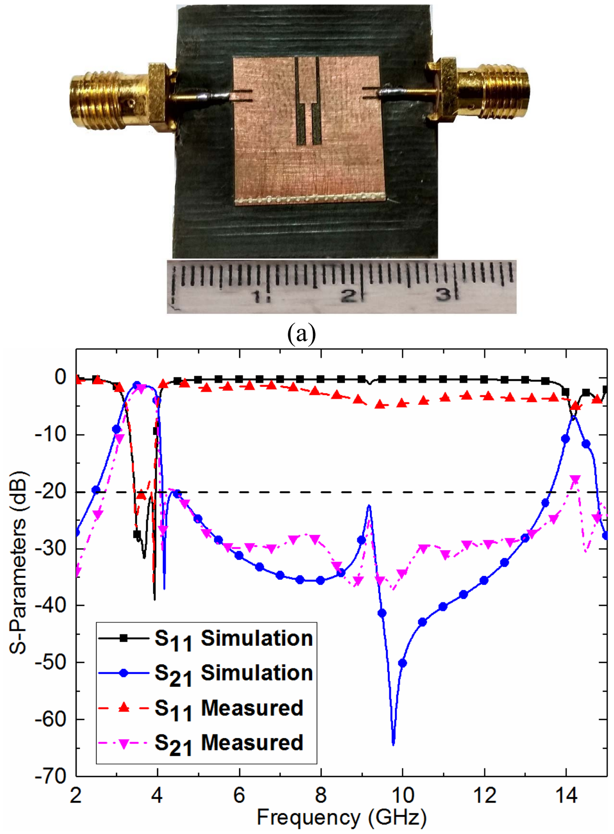
The simulated S-parameter response of the filter is shown in Figure 4 & the simulated vs measured S-parameters responses are plotted in Figure 5. From the measured S-parameter plot in Figure 5 it is observed that the centre frequency and 1-dB bandwidth is 3.67 GHz and 560 MHz

TABLE I. Geometrical sizes of the filter (unit: mm)

Variable	Value	Variable	Value
w_s	0.8	L_3	5.2
w_1	0.25	L_2	4.55
L_1	2	w_2	0.8
D	0.6	w_3	2
S	1	g_1	0.3
w	15	w_4	2.6
L	15.4		

TABLE 2. Comparison with other designs

Ref	Order	f_o / FBW	IL (dB)	Rejection Level	Size (λ_g^2)
[3]	4	5.57/7.44	2	20/2f_o	0.25
[4]	3	3.6/9.7	1.35	20/1.99f_o	0.625
[5]	4	20/2.75	2.78	50/1.9f_o	2.53
[6]	3	3.7/6.7	1.49	20/2.65f_o	0.32
This work	3	3.67/15.34	1.45	20/3.8f_o	0.076



(a)

(b)

Figure 5. (a) The fabricated structure of the proposed filter and (b) Simulated and measured S-parameters of proposed filter.

respectively. Two transmission zeros are located at 4.1 GHz and 9.56 GHz. In the measured s-parameter plot the return and insertion losses are greater than 19.5 dB and 1.45 dB. A wide stopband, contributed by the suppression of the first spurious passband at 9.2 GHz, is extended to 14 GHz with a rejection level of -20 dB.

In TABLE 2, a comparison study has been carried out in order to compare the proposed HMSIW filter with the state-of the art designs where the proposed structure is compact in size and two transmission zeros are present for wide stopband.

5. Conclusion

A compact HMSIW bandpass filter using quarter-wavelength CPW resonator is proposed to quantify the compactness of the structure to achieve the transmission zero at first spurious band. The simulation and optimization of the proposed filter has been carried out using the HFSS in order to obtain the better selectivity. In the fabricated structure both the resonator i.e. the quasi-TEM mode of HMSIW resonator and quarter-wavelength CPW resonator are etched on the metallic part of the substrate to obtained wide stopband characteristics. The proposed filter can find its potential application due to having two transmission zeros which is desirable for wide stopband application.

7. References

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