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Analysis and Design of Substrate Integrated Waveguide Bandpass Filter with DGS for Ku-Band Applications

Banu Priya A[1], Umma Habiba H[2]
[1]Ph.D scholar, [2]Professor
Department of Electronics and Communication Engineering, Sri Venkateswara College of Engineering, Anna University, Sriperumbudur, Tamil Nadu, India
Email: *[1] banuannadurai@gmail.com, [2]ummahabiba@svce.ac.in*
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Abstract

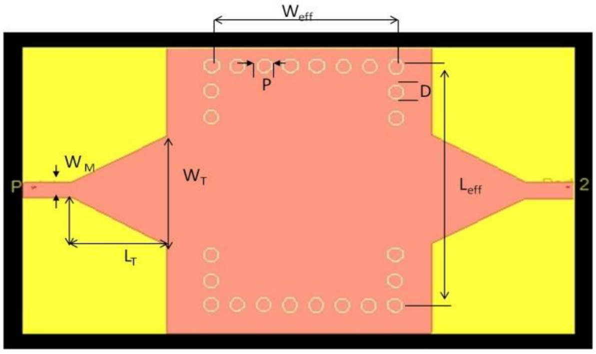
The technology of Substrate Integrated Waveguide (SIW) and Defected Ground Structure (DGS) are combined and a novel compact bandpass filter is proposed in this paper. The SIW cavity connected in between two tapered microstrip lines used to provide passband characteristic and it has the advantage of high quality factor, low insertion loss. The proposed filter is designed by square slots connected with narrow slot at the edge is etched on the bottom ground plane in order to provide stopband performance of the filter. Moreover a flexible bandwidth and center frequency can be achieved by proper adjusting the dimensions of the SIW and DGS of the filter. The simulated results used to verify the defected characteristic of the filter. The simulated insertion loss and return loss of the filter operated at center frequency of 13.85GHz are 0.002dB and better than 26dB respectively, which makes it suitable for Ku-band applications. The proposed filter structure has been simulated using Advanced Design Software (ADS).

Keywords: *Bandpass filter, Substrate Integrated Waveguide (SIW), Defected Ground Structure (DGS), Ku-band application, Advanced Design Software (ADS).*

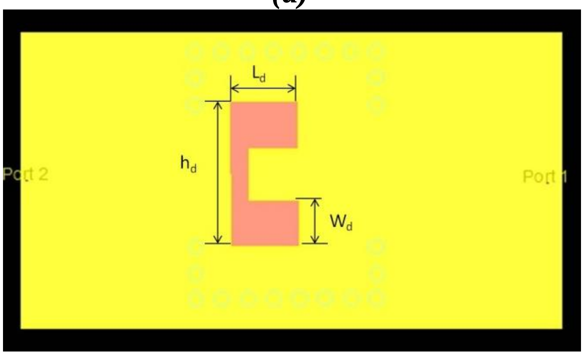
INTRODUCTION

Bandpass filters are widely used in RF and Microwave subsystems due to its compact size, low cost and reliability. In order to overcome the microstrip line filters with high insertion loss, large parasitic radiation loss and low selectivity, metal rectangular waveguides are used. However it offers large size, low integration with planar circuits, a novel planar circuit called Substrate integrated waveguide (SIW) is proposed and developed [1]. The substrate integrated waveguide (SIW) has been widely used in wireless communication systems of its high performance, low fabrication cost, size and its power handling capability. Hybrid cavity substrate integrated waveguide filter which is the combination of both circular and rectangular cavity, shows better frequency selectivity and quality factor in comparison with other substrate integrated waveguide filters [2]. In [3], sharp rejection and upper stopband can be improved by Quarter mode substrate integrated waveguide (QMSIW) with source load coupling structure. A microstrip narrow bandpass filter with good selectivity and wide stop band rejection can be provided by using triple mode stub resonators as the resonant frequency of the degenerate mode can be adjusted to satisfy the bandwidth of the narrow bandpass filter [4]. Further to improve the stop band performance and to provide high selectivity by slots or defects etched on the bottom ground plane of the microwave planar circuits called Defected Ground Structure(DGS) is introduced [5-6]. The dual mode SIW bandpass filter is composed of two orthogonal modes and a low pass cleanup filter generated by using DGS pattern is used to provide upper stopband performance [7]. A simple systematic approach for the design of elliptic low pass filter using rectangular slot DGS is designed for critical filter specifications and DGS can be optimized for reducing the parasitic effects of the filter[8]. The dual band BPF offers fixed passband and controllable second passband. The tuning of second passband can be done by characteristic impedance of theshunt open stub load resonator with the help of DGS transmission lines and varactor diodes [9]. Based on the different structures of DGS, this paper presents the design of substrate integrated waveguide bandpass filter with much compact size and narrow passband can be obtained. The filter consisted of input and output microstrip line with tapered transition with DGS loaded on the ground plane of the SIW cavity. Using the high pass characteristic of SIW cavity and stopband characteristic of DGS, a SIW bandpass filter is designed and simulated. The proposed filter is designed at the center frequency of 13.85GHz, which is usable for Ku-band applications.

FILTER DESIGN AND ANALYSIS



(a)



(b)

Figure 1: *Structure of the proposed SIW BPF* ***(a)*** *Top view* ***(b)*** *Bottom view*

Figure.1 shows the layout of the proposed SIW bandpass filter, which contains SIW cavity, two 50Ω microstrip feeding lines and DGS on the bottom part of the SIW cavity. The microstrip energy can be easily transformed to the SIW cavity by the tapered transition. The SIW cavity is constructed by series of metallic vias on the two rows of the side walls of the SIW cavity sandwiched between two copper layers. The equivalent width is the effective width of the SIW cavity and it can be calculated as follows,

$$a_{equi} = a - \frac{d^2}{0.95.p} \quad (1)$$

Where d is the diameter of the via hole, p is the post spacing. The gap between the metallic vis holes are arranged by the following conditions in order to avoid the dispersion losses in the SIW structure.

$d < 0.2\lambda_g$
$d/W < 0.2$
$d/p \geq 0.5$

where λ_g, is the guided wavelength of the SIW.

The DGS has recently been presented; basically it consists of slots or defects made on the ground plane of the SIW structure. Figure 1(b) shows the layout of the SIW with DGS etched on the bottom substrate. Let us now analyze the DGS loaded SIW. The DGS consists of square slots connected with narrow slot at the edge is etched on the center of the bottom layer of the substrate in order to improve the out of band rejection. The dimensions of the DGS slots are optimized to get the passbands within the stopband of the filter. The scattering parameters of the proposed filter is obtained by using EM simulations.

Table 1: *Parameters of the filter*

Parameter	Value(mm)	Parameter	Value(mm)
L_{eff}	15.9	L_d	3.6
W_{eff}	14.1	W_d	2.5
W_m	0.8	h_d	8
W_T	6.1	d	0.8
L_T	5	p	1.5

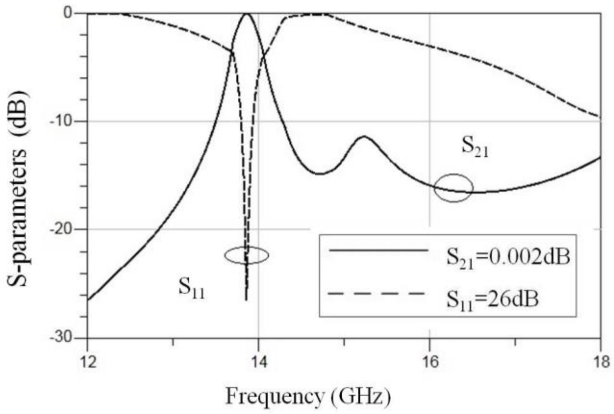


Figure 2: *Frequency response of the proposed filter*

The parameters of the filters are adjusted with the help of EM simulation called ADS, which have the center frequency of 13.85GHz and their dimensions are shown in table.1.

SIMULATED RESULTS AND DISCUSSION

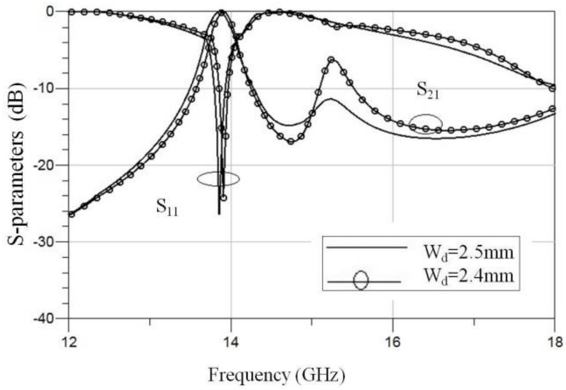


Figure 3: *Simulated results of SIW BPF for various DGS widths*

The filter structure is developed on the Rogers substrate with dielectric constant of 3.5 and thickness of 0.5mm. The transmission response of the proposed filter is shown in figure.2, has the insertion loss of 0.002dB and return loss >26dB at the center frequency of 13.85GHz. In the simulation process the bandwidth and center frequency of the SIW BPF are sensitive to the DGS dimensions. Figure.3 shows the simulated results of the filter for different DGS widths. It can be seen that, by tuning the DGS width, the resonant frequency and the lower attenuation shifts towards its higher frequency side without any changes in upper stopband attenuation.

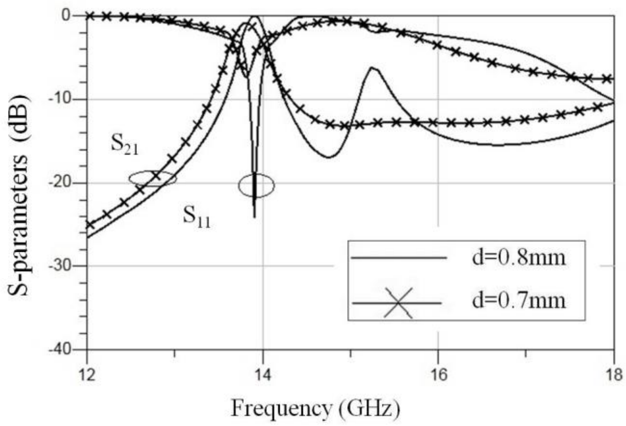


Figure 4: *Simulated results of the proposed SIW BPF for different via diameter*

Figure 4 shows the simulated results of the proposed filter for various via diameters. It depicts that by decreasing via diameter the lower stopband attenuation moves towards its lower frequency side and the center frequency moves upwards with insertion loss gets lower.

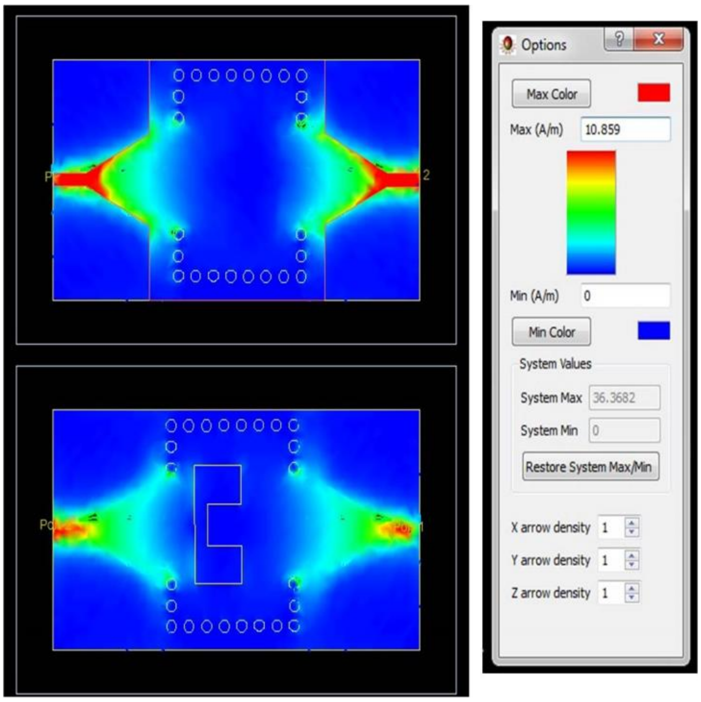


Figure 5: *Current distribution of the filter*

CONCLUSION

In this paper, SIW bandpass filter with DGS made of square slots connected with narrow slot at the edge is designed and analyzed. The filter structure provides narrow passband within stopband. The proposed filter has the advantage of compact size, return loss better than 26dB, low insertion loss and center frequency of 13.85GHz which is usable for Ku-band applications.

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