# Dual Band Substrate Integrated Waveguide (SIW) Filter with Curved Comb Shape Slots on Top for High Selectivity

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**Abstract** This article presents a dual-band Substrate Integrated Waveguide (SIW) filter using a variable comb shape slot on the top metal surface of the SIW cavity. These comb shape slots create a slow wave effect and the dual cavity produces a dual-band with high selectivity. The proposed filter used Rogers 5880 as a dielectric material with a permittivity($\varepsilon_r$) of 2.2 and thickness of 0.508 mm. The simulated results obtained by HFSS 19.1 has two narrow bands at 3.6 and 7.8 GHz with the fractional bandwidth of 10.8% and 8.8% for satellite communication. The insertion loss is less than 0.6 dB and the return loss is better than 15 dB. The size of the filter is $0.88 \times 0.44\ \lambda_g^2\ mm^2$.

**Keywords** Substrate Integrated Waveguide (SIW) filter · Curved comb shape · Dual-band

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## 1 Introduction

The growing interest in the wireless technology domain from researchers and industry calls for demand in the study and research into precision miniature devices which give us accuracy in practical operation at optimum bandwidth and ease of manufacturing. A bandpass filter is an integral component of any wireless device operating in the megahertz to gigahertz range, especially in this day and age there is observable crowding of devices on the wireless spectrum, filter design requires faster and better upgradations even in minuscule ranges at the fastest pace. As such great care has been taken in proposing a novel dual-band filter design in this paper that offers high selectivity to optimise the signal to noise ratio and low insertion and return loss in the order of 0.5 to 12 dB respectively. Even though Substrate Integrated Waveguides were introduced in 2003, to integrate the benefit of the good quality factor of non-planar technologies and compact size and economic feasibility of planar circuits [1], they still remain relevant today mainly for high-frequency millimeter and submillimeter applications, especially as filters because these metallic vias have been optimised in size and spacing to ensure certain modes of operation do not resonate. Existing dual-band filters based on SIW cavity resonators have been investigated. In [2] very compact size is achieved, but insertion loss is high and Q factor is decreased and in [3] capacitively-loaded SIW vias is proposed for miniaturized circuits, however excited higher-order modes are located too close to passband for accuracy in practical applications. Slots in folded SIW was a bandwidth enhancement technique introduced in [4], however, selectivity was unsatisfactory just as in the case of [5] wide bandpass filter realised using U-shaped slots on the upper plane of the substrate and H-shaped fractal defect on the ground plane of SIW cavities. Even amongst miniature bandpass filters of comparable size such as [6] and [7] which use E-shaped slots and resonators, bandwidth achieved poses room for improvement to meet present demand. In SIW with electromagnetic bandgap (EBG) structure etched with S-shaped slots [8], heavy insertion losses are observable. A substrate that creates a multi-mode resonator [9] and accomplishes narrow passband of operation with the added functionality of high selectivity and compact size is ideal for miniaturized integrated and nano-circuits.

Keeping these lofty design challenges in mind and intricately balancing the inverse relationship between bandwidth and quality factor, our paper has proposed the novel design of a filter with dual-band mode at 3.6 GHz and 7.8 GHz which has a radially cut curved comb shape slot on the top of Rogers RT Duroid 5880.

## 2 Dual-Band Filter Design

A new method is devised for the miniature filter design which is proposed in this paper. It is composed of a rectangular SIW cavity. It is a three-layer structure where the top and bottom are metal and between the metal layers, there is a substrate layer.

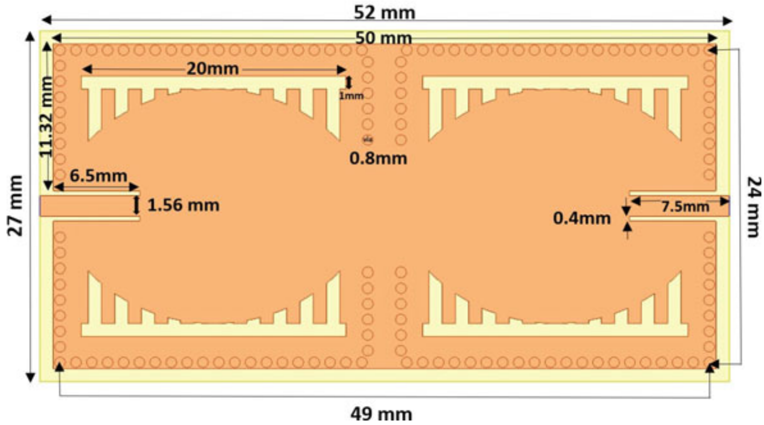


**Fig. 1** Top View of proposed Dual-Band SIW BPF with its Dimensions

The proposed structure has two cavities as the design is for dual-mode. A curved comb shape structure is etched on the top metallic layer of substrate in two parts. It is composed of two rectangular SIW cavities with two feeding lines that use coplanar waveguides (CPW), and two curved comb shape slots are positioned facing each other on the edges of the cavity.

By optimizing all the dimensions, we get the proposed dual-band filter. The top view is represented in Fig. 1 with the filter's optimized dimensions.

## 3 Simulation Results and Discussion

The dual-band SIW bandpass filter has been realized on a 0.508-mm-thick RT/Duroid 5880 substrate with a dielectric constant of 2.2. The dimensions of the design have been mentioned in Fig. 1. The via's diameter is 0.8 mm and the pitch (spacing between the two via-centers) is 1.2 mm.

The simulation results of the designed dual-band SIW BPF are done using HFSS 19.1 software. The proposed filter has two narrow passbands at 3.6 GHz and 7.8 GHz with high selectivity. The bandwidth of the two passbands is 390 MHz and 690 MHz simultaneously. The fractional bandwidth is 10.8% for the first band and 8.8% for the second band. Within the two passbands, the return losses are both greater than 12 dB. This result is achieved through making inward curved comb shape slots utilizing different lengths of each slot which leads to the respective operation frequencies. The insertion loss is less than 0.5 dB in both bands. Also, the designed BPF exhibits exceptional selectivity when compared to its previous predecessors. Figure 2 represents the simulated S-parameter of the proposed design.

The surface current density of the proposed dual-band SIW filter is shown in Fig. 3. From the current density response, it is observed at the center frequency

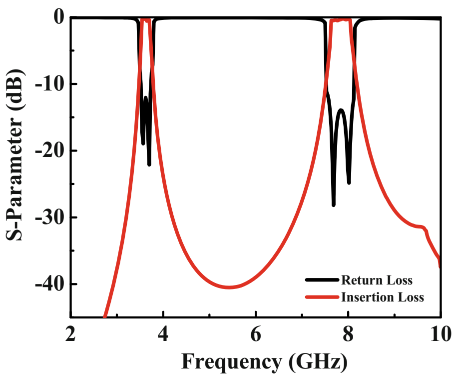


**Fig. 2** S-Parameter of proposed Dual Band SIW BPF Design

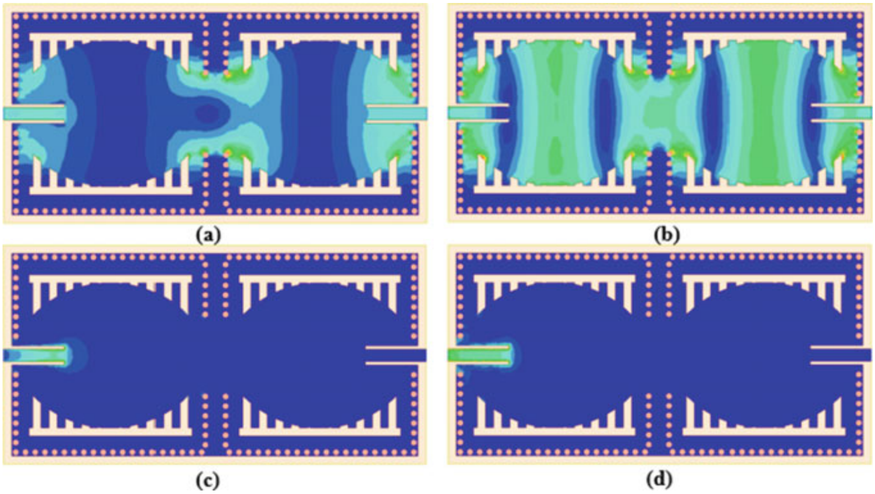


**Fig. 3** Surface Current Density of proposed Dual Band SIW BPF filter at different frequencies (**a**) 3.6 GHz (**b**) 7.8 GHz (**c**) 2 GHz and (**d**) 6 GHz

of both dual bands highest current density distribution is shown at (a) and (b). By observing the (c) and (d) current distribution it concludes that after the passband no frequency is transmitted from port 1 to port 2 which means the selectivity of the proposed dual-band SIW filter is very good.

For the validation of our proposed design, these results are compared with the previously published papers. Table 1 represents the result validation. It is observed that the proposed design has less insertion loss and high selectivity.

**Table 1** Comparison of proposed Dual-Band SIW BPF with other reported works

| Ref | Topology | $f_O$ (GHz) | FBW (%) | IL (dB) | Size (λg × λg) |
|---|---|---|---|---|---|
| [7] | SIW CSRR | 4.05/5.8 | 4.6/3.6 | 2/1.9 | 0.199 × 0.187 |
| [9] | SIW | 6.9/7.95 | 2.6/2.3 | 1.47/1.65 | 2.2 × 0.61 |
| [6] | SIW E-Shape Slot | 3.6/6.4 | 3.3/2.4 | 1.3/1.8 | 0.29 × 0.58 |
| [8] | SIW E-Shape Slot | 2.4/5.2 | 5.8/6.5 | 3/3.1 | 0.152 × 0.156 |
| **This Work** | **SIW Curved Comb Shape Slot** | **3.6/7.8** | **10.8/8.8** | **0.5/0.6** | **0.88 × 0.44** |

* $f_O$: Center Frequency, FBW: Fractional Bandwidth, IL: Insertion Loss, λg: Guided Wavelength

## 4 Conclusion

A dual narrow band substrate integrated waveguide (SIW) filter using a curved comb shape structure has been designed and simulated in this paper. The proposed design has two narrow bands at 3.6 and 7.8 GHz with the fractional bandwidth of 10.8% and 8.8%. The selectivity of the filter is very good.

## References

1. Deslandes D, Wu K (2003) Single-substrate integration technique of planar circuits and waveguide filters. IEEE Trans Microw Theory Tech 51(2):593–596
2. Szydlowski L, Leszczynska N, Lamecki A, Mrozowski M (2012) A substrate integrated waveguide (SIW) bandpass filter in a box configuration with frequency-dependent coupling. IEEE Microw Wirel Compon Lett 22(11):556–558
3. Li M, Chen C, Chen W (2017) Miniaturized dual-band filter using dual-capacitively loaded SIW cavities. IEEE Microw Wirel Compon Lett 27(4):344–346
4. Muchhal N, Chakraborty A, Vishwakarma M, Srivastava S (2018) Slotted folded substrate integrated waveguide band pass filter with enhanced bandwidth for Ku/K band applications. Progr Electromagn Res 70:51–60
5. Liu J-P, Lv Z-Q, An X (2016) Compact substrate integrated waveguide filter using dual-plane resonant cells. Microw Opt Technol Lett 58(1):111–114
6. Zhang H, Kang W, Wu W (2018) Miniaturized dual-band SIW filters using E-shaped slotlines with controllable center frequencies. IEEE Microw Wirel Compon Lett 28(4):311–313
7. Dong Y, Itoh T (2011) Miniaturized dual-band substrate integrated waveguide filters using complementary split-ring resonators. In: IEEE MTT-s international microwave symposium, pp 1–4
8. Xu S, Ma K, Meng F, Yeo KS (2015) Novel defected ground structure and two-side loading scheme for miniaturized dual-band SIW bandpass filter designs. IEEE Microw Wirel Compon Lett 25(4):217–219
9. Muchhal N, Srivastava S (2019) Design of wideband comb shape substrate integrated waveguide multimode resonator bandpass filter with high selectivity and improved upper stopband performance. Int J RF Microw Comput-Aided Eng 29(9):2180