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Control of Insertion Loss in Substrate-Integrated Waveguide Band-Pass Filter Using New Tapered Waveguide Iris Technique

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ABSTRACT

An approach to obtain effective control of insertion loss (IL) in wideband substrateintegrated waveguide (SIW) band-pass filter with several tapered Iris configurations is presented in this paper. Several iris configurations and iris parameters have been minutely studied and effective postulates have been provided for accurate design of filters with low IL throughout the transmission bandwidth. Basic structure is designed over a substrate with dielectric constant 3.2 and material thickness of 30 mils. The structures are then successfully modified into a band-pass filter with its pass band in Ku bands with minimal IL using waveguide iris method. The technique effectively serves the purpose to achieve greater control over the IL and isolation. Maximum IL of 2 dB is reduced by 1.5 dB and close to 0.5 dB IL is obtained in the final configuration using the tapering technique. Proposed techniques are supported with theoretical explanations. All designs are fabricated, and measured results are found to validate the concept produced in this paper. The study provides a direct solution to the SIW Iris filter design engineers considering all major parameters necessary forilndustrial/scientific productions.

Index Terms— Substrate integrated waveguide (SIW), waveguide iris, insertion loss (IL), band pass filter (BPF), Ku-band

I. INTRODUCTION

Recent developments in the field of wireless components for designing compact circuits created a vast scope for microwave and millimeter wave design engineers. Development of band-pass filters is an important section in this domain where high end circuits with minimal loss characteristics can be designed. Substrate-integrated waveguide (SIW), because of their manifold advantages like low loss, high power handling capability, and high quality factor, happens to be a bankable technology in this aspect [1-3]. Basic properties of SIW structures are studied to establish comparable field patterns and dispersion characteristics [4]. Moreover, SIW structures are compact in size similar to microstrip line circuits while displaying all major advantages of classical rectangular waveguides [5]. Due to these eminent advantages several components are designed and presented in recent times for wide range of applications.

In comparison to rectangular waveguides, SIW elemental structures are designed with perfect electrical conductor (PEC) layers at top and bottom. The side surfaces are integrated with metallic vias which act as an electrical wall. Thus, it is well suited to act as a planar waveguide structure. The basic layout of elemental SIW transmission line section is shown in Fig. 1.

The planar structure facilitates SIW to incorporate all the planar feeding techniques like microstrip feed, inset feed, coupled line feed, and coaxial feed. Thus, all the planar circuits including antennas, filters, couplers, and power dividers can be designed easily using this technique. Further, the bulkiness of rectangular waveguides, which limits their usage in compact circuits, can be avoided. High density integrated circuit design and low cost are some of the other major advantages of the SIW technology. In this paper, a new technique of using gradually tapered iris structure is used to obtain band-pass characteristics in SIW elemental structures. Novelty of this work stands on the concept of gradual iris tapering structure. Using this methodology the insertion loss (IL) is reduced to a large extent (close to 0.5dB) without using any other band gap structure. This enhances the simplicity in the geometry of the structures which in terms eases fabrication

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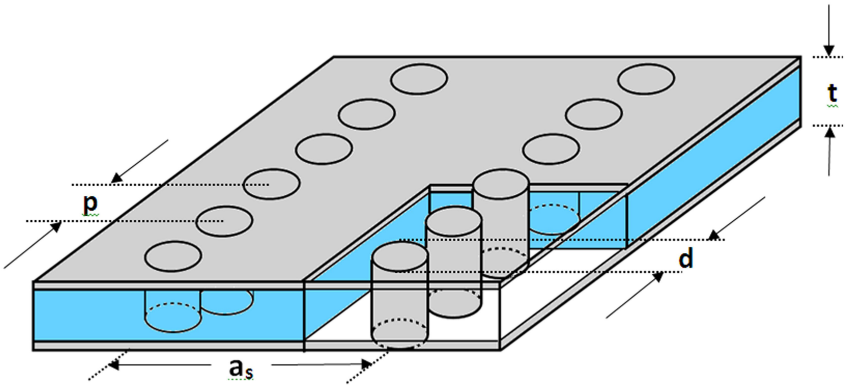

Fig. 1. Basic SIW structure realized on a dielectric substrate. a_s, effective width of SIW element; d,diameter of each vias; p, pitch or center to center gap between successive vias; t, thickness of dielectric substrate.

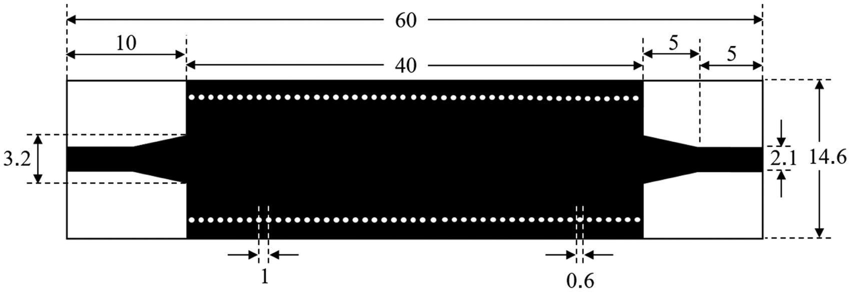

Fig. 2. Basic SIW transmission line section with dimensions

complexity. The IL and return loss (RL) of the filter are improved significantly with modification in the iris structures and are presented in serial order. However, with IL reduced to 0.5 dB, the overall RL within the entire passband shall be improved further using the tapered iris configurations and serve as encouraging scope of future research.

II. SIW BPF DESIGN AND ANALYSIS

The design of basic SIW structure is the first step toward the efficient design of a complete SIW component. Problems like accurate operation bandwidth, radiation leakage, and dielectric and conductor losses have to be considered while designing an SIW Filter. Several SIW filters using various techniques have been presented in recent times in [6-11], which are widely used in microwave and millimeter-wave systems due to their merits of low IL and high power handling capacity. However, accurate control over the passband with reduced IL for designing broadband of band-pass filters (BPFs) is still an open area for improvements. In [6], design of SIW inductive post and dual mode filters has been discussed. The designs are found to work as BPF in K-band but passband obtained is small compared to BPFs with higher operational bandwidths. Improvement in IL over the entire passband looks like another issue of concern. The SIW filter with defected ground structure (DGS) has been reported in [7]. Here the passband is in microwave C-band but again the bandwidth obtained is smaller with satisfactory IL over the passband. Introduction of complementary split ring resonator (CSRR) happens to be a good solution in this regard, which has been reported in [8]. However, the bandwidth here is still smaller, which reflects a scope to increase it as suited for broadband applications. In [9], an evanescent mode SIW filter with CSRRs have been reported. Several CSRR structures have been used with good effect for applications in particular frequencies. Substrate-integrated waveguide filter based on S-shaped electromagnetic

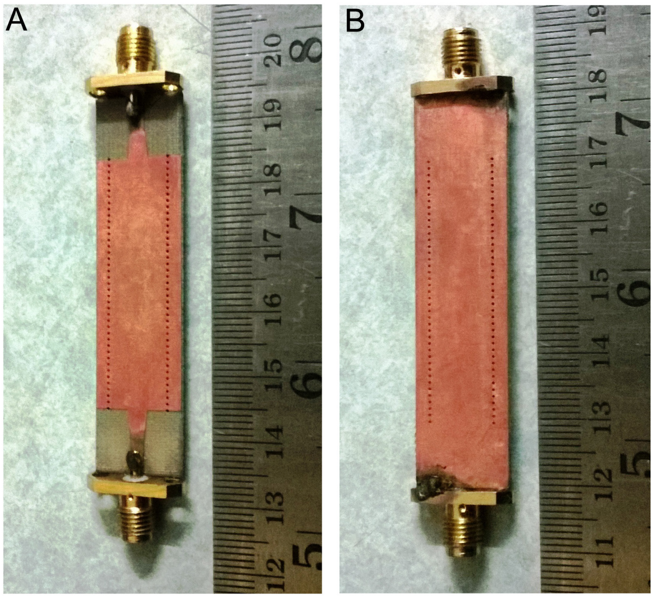

Fig. 3. Fabricated prototypes of SIW transmission line section using microstrip to SIW transition feeding technique. (a) Top view. (b) Bottom view.

bandgap (EBG) structure has been reported in [10], where array of S-shaped structures are used for BPF operation of the SIW filter. The filter provides good power transmission over the later part of microwave C-band and towards the start of X-band frequencies. However, although IL is quite good, wideband SIW BPFs still remains an area to be inculcated. Mushroom-shaped resonators are also used [11] effectively to obtain band-pass response. However, larger bandwidth to cover the entire Ku-band with minimal IL is one desired objective in this study.

Basic design started with a section of SIW transmission line with high-pass characteristics. The basic SIW transmission line section with its dimensions, the fabricated prototype, and the s-parameter characteristics are given in Fig. 2, Fig. 3, and Fig. 4, respectively

The high-pass characteristics have been obtained with a lower cutoff around 9 GHz with IL of around 0.7 dB from 11 GHz. The cutoff is surely a function of separation between the rows a_s of vias at alternate sides of the structure. For smaller values of separation, the cutoff may be obtained at desired higher frequencies. The cutoff frequency for SIW under the condition ($a >> b = h$), where a and b are the horizontal and vertical length of rectangular waveguide, may be obtained by the following relation [12].

$$f_{c_{mn}} = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \rightarrow f_{c_{10}} = \frac{1}{2a\sqrt{\mu\varepsilon}} \tag{1}$$

Designed rectangular SIW structure can support $TE_{(1,0)}$ mode similar to rectangular waveguides. The structure can be considered equivalent to a high-pass filter due to its inherent sharp cutoff in lower frequency. The important parameters need to be considered of the design of SIW structure are diameter of the holes d, the spacing between the holes p (pitch), and the spacing between the centers of two rows a_s. a is the spacing between end points of the rows of two metallic vias. The pitch p must be kept small to reduce the leakage loss between adjacent vias. It has been observed that the post diameter d is also subject to the loss problem. As a result, the ratio d/p is considered to be more critical than the pitch length because the post diameter and the pitch length are interrelated. Dispersion characteristics of TE_{10} like mode in the SIW are almost identical with the mode of a dielectric filled rectangular waveguide with an equivalent width. This equivalent width is the effective width of the SIW, and can be obtained by the following relation.

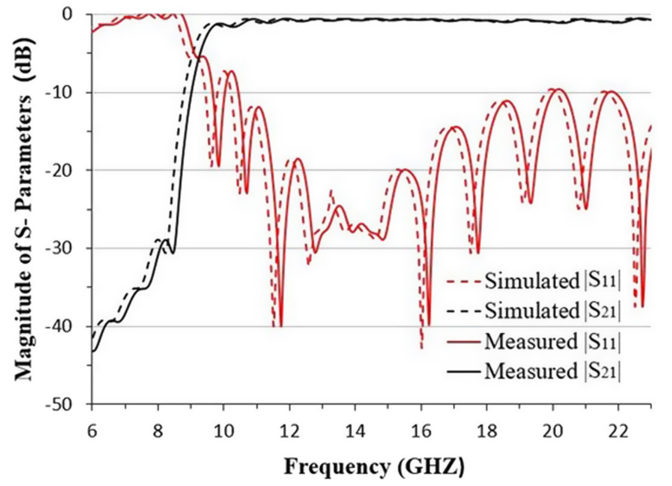

Fig. 4. Scattering parameter of basic SIW transmission line section.

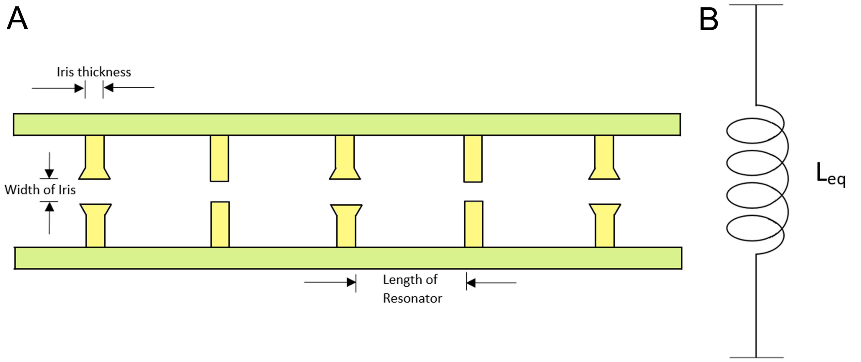

Fig. 5. Tapered Iris model as implemented over SIW Iris waveguide BPF and its equivalent circuit.

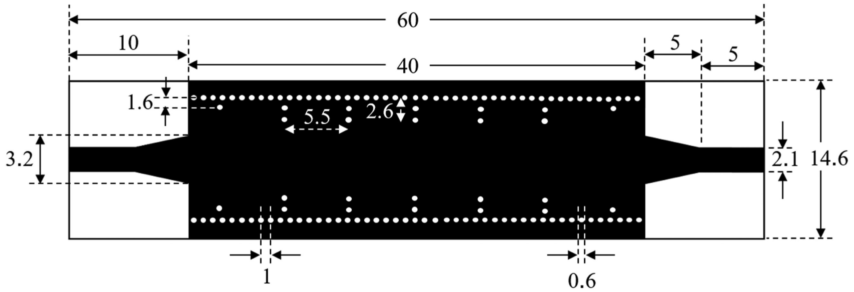

Fig. 6. SIW Iris fFilter with five iris columns (four cascaded cavities) with all iris diameter of 0.6 mm.

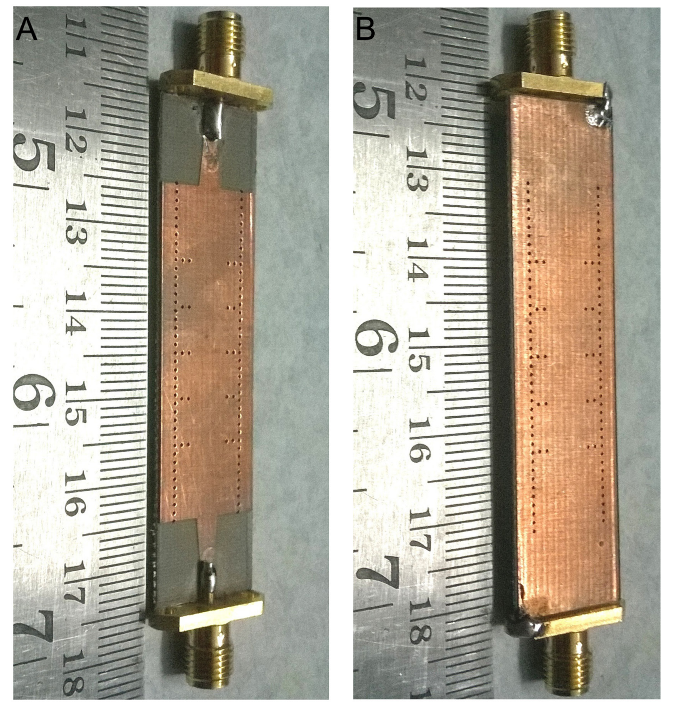

Fig. 7. Fabricated prototypes of SIW Iris filter with five iris columns (four cascaded cavities) with all iris diameter of 0.6. (a) Top view. (b) Bottom view.

$$a_s = a_d - \frac{d^2}{0.95p} \tag{2}$$

To prevent radiation loss between successive vias, following condition must sustain [12].

$$p \le 2d \tag{3}$$

$$\text{And } d < 0.2\lambda_{gsiw} \tag{4}$$

where λ_{gsiw} is the guided wavelength of SIW. The guided wavelength in case of SIW may be obtained by using the following relation.

$$\lambda_{gsiw} = \frac{\lambda_{diel}}{\sqrt{1-\left(\frac{\lambda_{diel}}{2a_{eff}}\right)^2}} \tag{5}$$

where λ_{diel} is the free space wavelength and a_{eff} is the rectangular width.

Using these empirical relations, the basic structure has now been modified to allow transmission of power for a particular frequency bands (in this case it is in Ku-band), and it prevents the transmission of higher frequencies which will enable the filter to work effectively from 12–18 GHz with minimal IL. Introduction of waveguide iris structures have been found to provide this effect on compact SIW structures [12-14]. Substrate-integrated waveguide based on waveguide iris filter in [12], which was reported in 2005, provides the band-pass characteristics but still with small bandwidth. Substrate-integrated waveguide iris BPF at K-band may be referred from [13], which again operate in smaller bandwidth. Wideband SIW iris filter operable in Ka-band has been presented in [14], which provides good idea to obtain band-pass characteristics. However, methods to reduce IL over the entire passband and also the effect of several iris configurations over the transmission bandwidth remain an area to investigate.

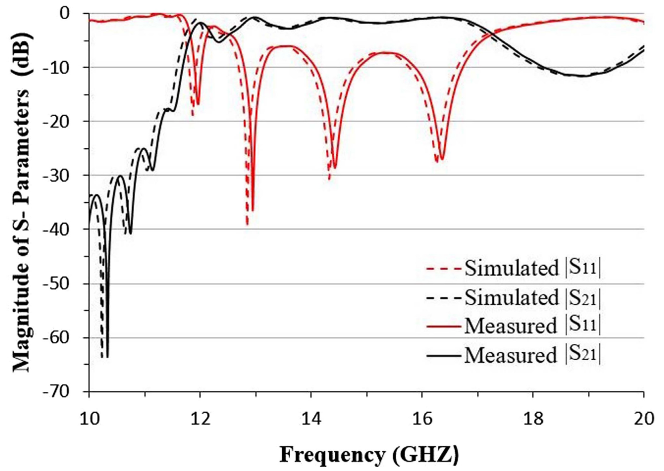

Fig. 8. Scattering parameter of SIW Iris filter with five iris columns (four cascaded cavities) with all iris diameter of 0.6.

TABLE I. DIMENSIONS OF DIFFERENT SIW IRIS BPF CONFIGURATIONS*

Variables	Configuration 1 (Fig. 6)	Configuration 2 (Fig. 9)	Configuration 3 (Fig.14)
W	14.6	14.6	14.6
L	60	60	60
W_{FSIW}	10	10	10
F_1	5	5	5
F_2	5	5	5
W_{IRIS1}	NA	1.6	1.6
W_{IRIS2}	2.6	2.6	2.6
W_{TAP}	3.2	3.2	3.2
G_1	5.5	5.5	5.5
D_1	0.6	0.6	0.8
D_2	0.6	0.6	0.6
D_3	1	1	1
D_4	0.6	0.6	0.6
W_F	2.1	2.1	2.1

*All dimensions are in millimeters.
W, width of SIW element; L, length of SIW element; W_{FSIW}, is the equivalent width of SIW element (as) ; F_1, feeding section (not tapered); F_2, feeding section (tapered and microstrip to SIW transition section); W_{IRIS1}, length of end wall iris section; W_{IRIS2}, length of successive iris section; W_{TAP}, width of tapered section; D_1 , D_3 diameter of last iris via; D_2, diameter of other iris vias; G_1, is the gap between successive vias (p); D_4, diameter of vias of SIW sections.

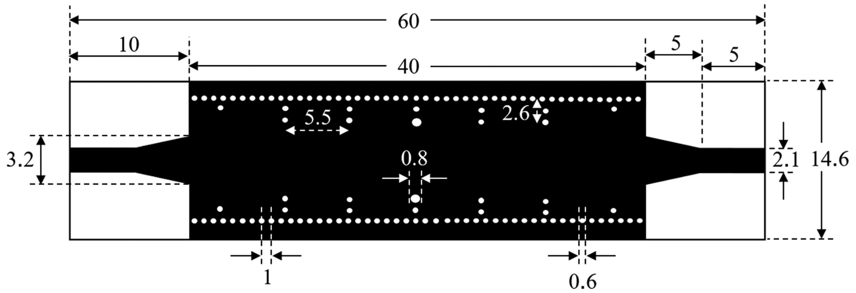

Fig. 9. SIW Iris filter with seven iris columns (six cascaded cavities) with all iris diameter of 0.6 mm.

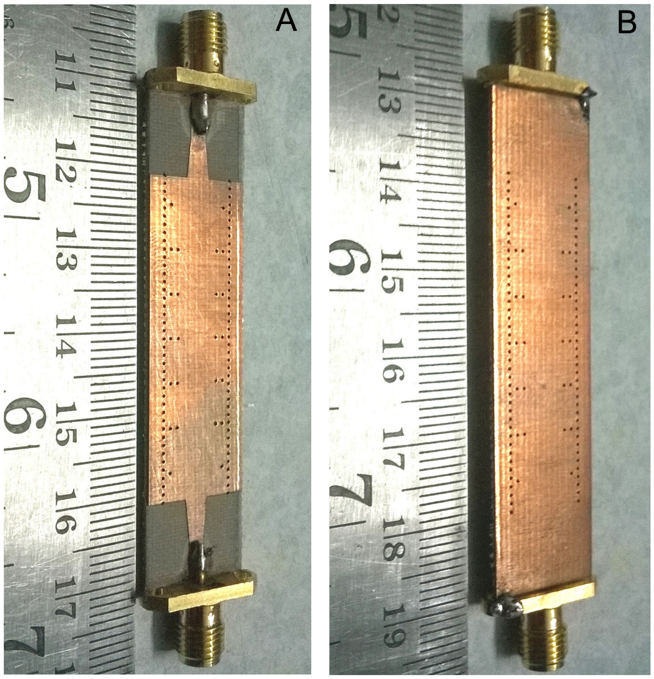

Fig. 10. Fabricated prototypes of SIW iris filter with seven iris columns (six cascaded cavities) with an iris diameter of 0.6. (a) Top view. (b) Bottom view.

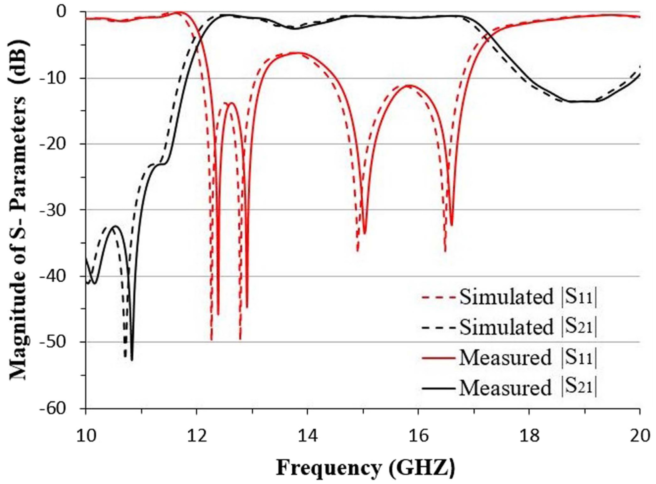

Fig. 11. Scattering Parameter of SIW Iris filter with seven iris columns (six cascaded cavities) with all iris diameter of 0.6.

For a symmetrical iris pair, which behaves as an inductive circuit, the waveguide length between adjacent iris structures may be obtained by the following relation [13].

$$l_i = \frac{\lambda_{g0}}{2\pi}\$_i \tag{6}$$

where λ_{g0} is the wavelength in the SIW and Φ_i is the electrical length of the SIW section. Fig. 5 shows the alternate tapered iris model which has been implemented over SIW elemental structures.

Detailed analysis of the effects of various iris configurations over the passband (Ku-band) is produced in the present study. The

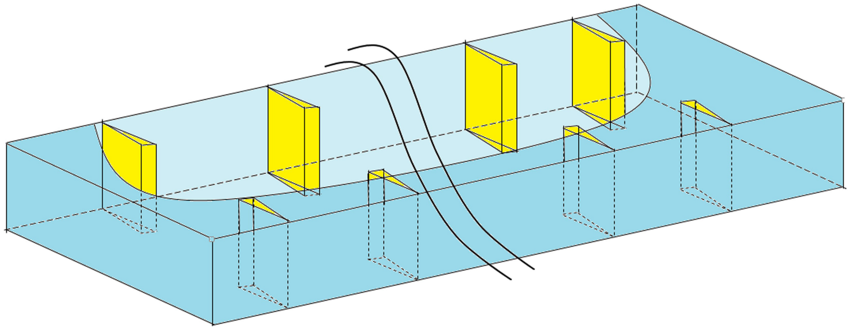

Fig. 12. Equivalent waveguide model of the tapered iris section used for the proposed method (gradual tapering of iris elements).

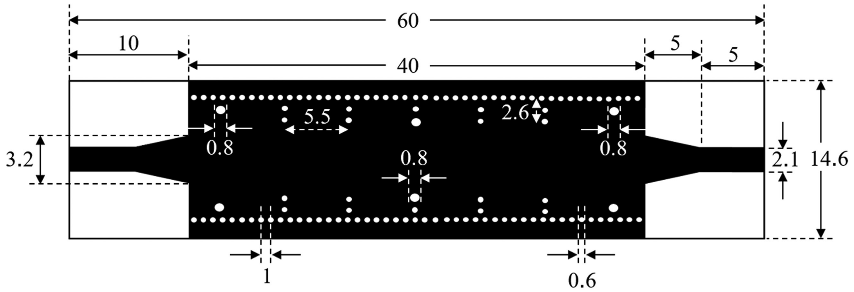

Fig. 13. SIW Iris filter with seven Iris columns (six cascaded cavities), central column last iris diameter 0.8 mm, and last via diameter of end iris columns as 0.8 mm.

electrical coupling among co-channel resonators is dependent on the two end points of iris structures. In order to obtain alteration within the co-channel coupling, the magnetic coupling has to be minimized. Since the locus of the iris end points are fixed and without any additional via wall, it is being noted that there is negligible effect over the coupling coefficient of the configurations. In addition to this, the electrical via walls surrounding the resonant cavities are mostly fixed with only alteration in the last via diameter. This results in minor enhancement in the efficiency of the filter configurations. However, with cavity-backed structure the efficiency of the filter can be enhanced further. The techniques implemented also reduce IL over the entire passband. The SIW iris filter layout, the fabricated prototypes, and its transmission characteristics are shown in Fig. 6, Fig. 7, and Fig. 8, respectively. The geometrical variables of all filter configurations are given in Table I. Fabrication is carried out using normal printed circuit board design technique over Neltec NH9320 double-side copper-coated substrate, whereas laser drilling is used to design via holes. These via holes are electroplated from inside to connect between top and bottom conducting surfaces. Measurement is carried out using ZNB20 vector network analyzer with continuous wave source.

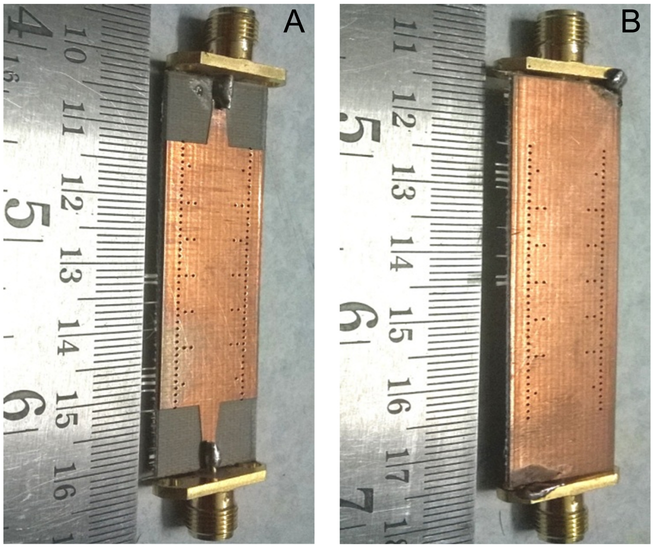

Fig. 14. Fabricated prototypes of SIW Iris filter with seven iris columns (six cascaded cavities), central column last iris diameter 0.8 mm, and last via diameter of end iris columns as 0.8 mm.

The effect of introduction of simple iris structures found to create a stopband nearly at 17 GHz. The gap between successive iris columns can be varied for proper selection of stopband by the design engineers. However, the result shows distributed IL characteristics over the passband with maximum loss of 5.3 dB at 12.32 GHz and minimum loss of 0.61 dB at 16.3 GHz. This variation of loss must be minimized for which additional columns of waveguide iris structures

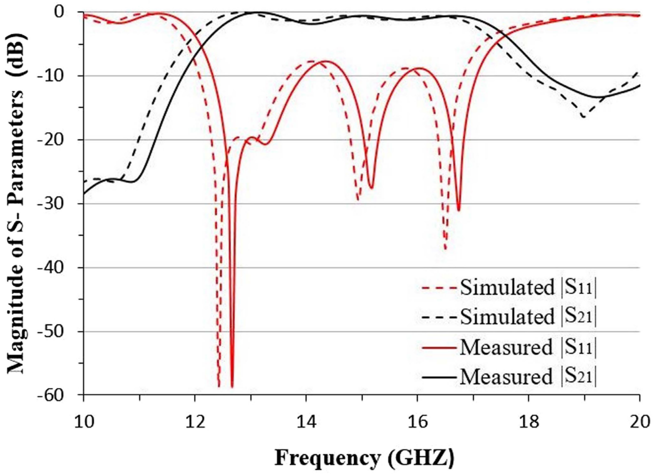

Fig. 15. Scattering parameter of Substrate integrated Waveguide (SIW) iris filter with extra iris columns, central column last iris diameter 0.8 mm and last via diameter of end iris columns 0.8 mm.

TABLE II. PERFORMANCE COMPARISON TABLE OF THREE SIW IRIS BPF CONFIGURATIONS

Parameter	**Configuration 1**	**Configuration 2**	**Configuration 3**
Minimum insertion loss (dB)	0.61	0.3	0.2
Maximum insertion loss (dB)	5.3	2	1.8
Min return loss (dB)	6	6	8
Max return loss (dB)	40	50	58
Stopband attenuation (dB)	12	15	17
Stopband attenuation range (GHz)	>3	>3	>3

TABLE III. COMPARISON TABLE WITH SOME RECENT REPORTED ARTICLES

Filter Structures	Fractional Bandwidth(FBW)	Insertion Loss (dB)	Max Return Loss (dB)	Stopband isolation range (GHz)	Size (L × W) mm²	Substrate ε_r h (mm)
References [12]	≈5%	3.6	>−50 dB	≈0.8 GHz	(29.68 × 6.2)	10.2, 0.635
References [13]	≈3%	0.8	>−50 dB	≈0.8 GHz	(40 × 12)	–
References [14]	≈25.35%	0.74	>−50 dB	≈1 GHz	(50 × 15)	2.2, 0.254
References [15]	≈6.7%	0.5	>−48 dB	≈2 GHz	–	4.4, 0.9
Our proposed design	≈42.46%	0.2	>−55 dB	≈2 GHz	(60 × 14.6)	3.2, 0.8

are used to solve this problem. The lengths of these additional columns are properly adjusted so as to obtain closest possible results. The modified design with extra iris columns, the fabricated prototype, and its transmission properties are displayed in Fig. 9, Fig. 10, and Fig. 11, respectively.

The introduction of additional iris columns have been found with significant effect over the passband. Insertion Loss at 12.3 GHz has got minimized upto −2dB. Although maximum IL of −1.9 dB has been obtained at 13.7 GHz. Clearly the transmission characteristics have been significantly improved than the previous case (without extra iris columns). However, more improved performance may be desired throughout the entire passband for its practical applications. To obtain this the diameter of the iris structures have been studied and a novel method of using gradual tapered iris structure rather than a straight iris section is proposed. The equivalent waveguide iris structure related to this idea is presented in Fig. 12.

This modification proved to be extremely helpful as alterations in the last iris of the central column and the last iris of the last column significantly reduces the uneven ripples in the passband property. In Fig. 13 the last iris diameter has been increased from 0.6 mm to 0.8 mm. Adjustments in the diameters of these iris diameters results in much more control in IL over the entire passband. This minimizes the loss at 13.8 GHz without hampering transmission at other frequencies. Good isolation at the stopband is also achieved. The fabricated prototype and the comparison between simulated and measured results are shown in Fig. 14 and Fig. 15, respectively. Critical dimensions of all design configurations are given in Table I.

The result shows improved transmission over the passband (12.3–17.1 GHz) covering the major part of microwave Ku-band with minimum IL of 0.5 dB at 12.8 GHz and maximum of 1.85 dB at 13.8 GHz. The modified iris technique provides a stopband from 17.2 GHz to 20.8 GHz with greater isolation at the stopband attenuation, which can be varied by simple variation of iris dimensions. Comparison between the SIW filter configurations are given in Table II, while comparison with some recently reported articles are presented in Table III. All filter configurations are designed targeting microwave ku band applications. The frequency selectivity is dependent on the iris cavity resonator geometry. It is to be noted that using modified iris technique the selectivity remains largely intact. However, the out of band rejection happens to a function of the vertical length of the iris wall cavity. This length is optimized to obtain reasonable stopband attenuation. Greater attenuation is generally obtained by varying the via pitch *p* and via diameter *d* following the empirical relation (3). It is worthy to note that the length of the SIW transmission line is kept little larger (by 10 mm) to accommodate the series cavity resonators as required for designing iris configuration. This is important as further reduction of geometrical length might reduce the electrical coupling between adjacent cavity resonators. However, this length can be reduced in such cases, where tapered technique is not used as reported in the referred articles.

III. CONCLUSION

The concept of using various tapered waveguide iris configurations over SIW transmission line section to attain the band-pass characteristics is furnished for the first time in this paper. Reduction of IL over the entire bandwidth is achieved after minute study on various iris parameters. Improved transmission property is obtained by replacing iris structures with vias of larger cross-sectional area. The measured results of the fabricated prototypes are found to match with attributes of simulated designs. Small discrepancies, which are seen mostly, are due to some parasitic elements and human measurement errors. The design are relatively compact in size, lightweighted which provides the luxury of integrating ability with other microwave and millimeter wave components within the same printed circuit board. Not only the designs are worthy for wideband applications but also the methods presented in this paper will provide a direct solution to obtain reduced IL over transmission bandwidth of SIW iris filters.

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REFERENCES

1. K. Wu, D. Deslandes, and Y. Cassivi, “The substrate integrated circuits- A new concept for high-frequency electronics and optoelectronics,” Proc. of 6th Int. Conf. on Telecomm. in Modern Sat, Cable, Broadc. Service (TELSIKS), Vol. 1, 2003, III–X. [CrossRef]
2. M. Bozzi, F. Xu, D. Deslandes, and K. Wu, “Modeling and design considerations for substrate integrated waveguide circuits and components,” Proc. of 8th Int. Conf. on Telecomm in Modern Sat, Cable, Broadc. Service (TELSIKS), Serbia, Nis, Sept. 26–28, 2007, P–VII. [CrossRef]
3. M. Bozzi, A. Georgiadis, and K. Wu, “Review of substrate-integrated waveguide circuits and antennas,” *IET Microw. Antennas Propag.*, vol. 5, no. 8, pp. 909–920, 2011. [CrossRef]

4. F. Xu, and K. Wu, “Guided-wave and leakage characteristics of substrate integrated waveguide,” *IEEE Trans. Microw. Theor. Tech.*, vol. 53, no. 1, pp. 66–73, 2005.
5. F. Shigeki, “Waveguide line”, (in Japanese) Japan Patent 06-053 711, 1994.
6. D. Deslandes, and K. Wu, “Millimeter-wave substrate integrated waveguide filters,” *Proc. of IEEE CCECE, Canada*, 2003, pp. 1917–1920. [CrossRef]
7. W. Shen, W. Y. Yin, and X. W. Sun, “Compact substrate integrated waveguide (SIW) filter with defected ground structure”, *IEEE Microw. Wireless Comp. Lett*, Vol. 21, no. 2, 2011.
8. X. C. Zhang, Z. Yu, and J. Xu, “Novel band-pass substrate integrated waveguide (SIW) filter based on complementary split ring resonators (CSRR),” *Prog. Electromagn. Res. PIER*, vol. 72, pp. 39–46, 2007. [CrossRef]
9. Q. L. Zhang, W. Y. Yin, S. He, and L. Wu, “Evanescent-mode substrate integrated waveguide (SIW) filters implemented with complementary split ring resonators,” *Prog. Electromagn. Res.*, vol. 111, pp. 419–432, 2011. [CrossRef]
10. D. Li, C. Tong, J. Bao, P. Peng, and D. Yu, “A novel bandpass filter of substrate integrated waveguide (SIW) based on S-shaped EBG,” *Prog. Electromagn. Res. Lett.*, vol. 36, pp. 191–200, 2013. [CrossRef]
11. C. Tomassoni, L. Silvestri, M. Bozzi, and L. Perregrini, “Substrate integrated waveguide filters based on mushroom shaped resonators,” *Int. J. Microw. Wireless Technol.*, vol. 8, no. 4–5, pp. 741–749, 2016. [CrossRef]
12. M. Nosrati, and M. Daneshmand, “Substrate integrated waveguide L-shaped iris for realization of transmission zero and evanescent-mode pole,” *IEEE Trans. Microw. Theor. Tech.*, vol. 65, no. 7, pp. 2310–2320, 2017. [CrossRef]
13. S. Srivastava *et al.*, “Bandpass filter (BPF) design using waveguide iris conformation over substrate integrated waveguide (SIW) Bend,” 2017 1st International Conference on Electronics, Materials Engineering and Nano-Technology (IEMENTech). Kolkata, India, pp. 1–3, 2017. [CrossRef]
14. Y. Zhai, Q. Wang, Z. Wang, and X. X. Gao,” The Design of an Iris Waveguide Filter at 35.75 GHz, Proc. of IEEE Global Symposium on Millimeter Waves, 2008, pp. 348–350.
15. B. J. Zhong, and S. M. Wu, “Design SIW iris bandpass filter at 18GHz,” 2020 International Workshop on Electromagnetics: Applications and Student Innovation Competition (iWEM), Makung, Taiwan, pp. 1–2, 2020. [CrossRef]

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