TE_{20} Mode Air Filled SIW based Balun Bandpass Filter

Moitreya Adhikary, Anirban Sarkar, Abhishek Sharma, Animesh Biswas and M. J. Akhtar
Department of Electrical Engineering, Indian Institute of Technology Kanpur, Kanpur, UP-208016, India

***Abstract* – In this paper, a TE_{20} mode air filled substrate integrated waveguide (AFSIW) based balun bandpass filter design has been proposed by using coupled resonator cavities for X band applications. The proposed design utilizes a novel microstrip to TE_{20} mode AFSIW transition. The use of air filled SIW significantly reduces the insertion loss of the filter. The filter is designed at 11 GHz center frequency with 8.6% fractional bandwidth (FBW). The insertion loss for both the output ports is 3.9 dB. All the fullwave simulations are carried out in Ansoft HFSS.**

***Index Terms* — Air filled SIW, Balun filter, Bandpass, Coupled resonator, TE_{20} mode.**

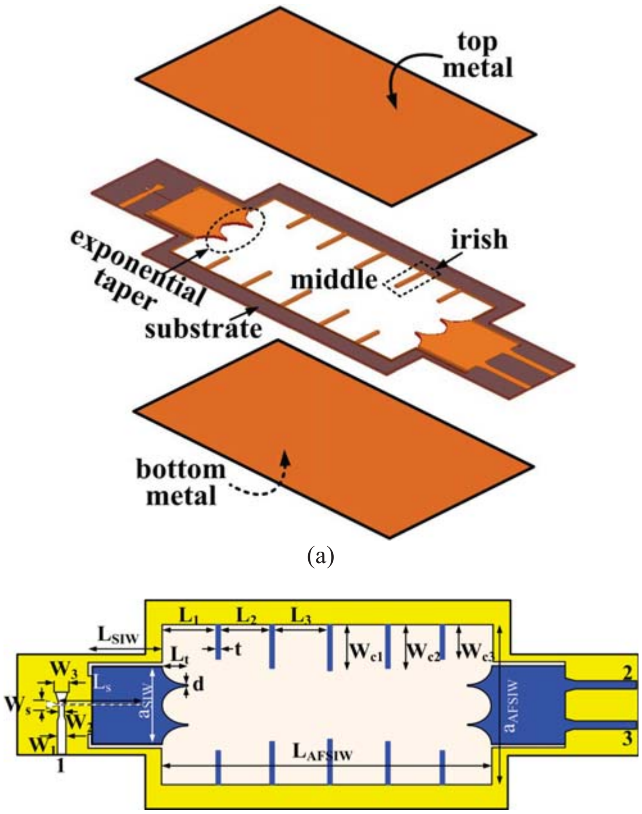
1. Introduction

Microwave balun filters have found wide applications in modern communication systems owing to their compactness achieved by the combination of balun and filtering performance in a single circuit module. Several balun bandpass filters on microstrip based environment [1,2] or using SIW technology [3,4] have been reported in literatures. However, one problem with most of the reported designs is that they have significant insertion loss. The SIW technology is more preferable for high frequency designs because of their lower loss than microstrip structures. A newly reported technique, air filled SIW [5], can reduce the insertion loss even further by reducing the inherent dielectric loss component of ordinary SIW structures.

In this paper, an air filled SIW based compact balun bandpass filter has been designed to minimize the insertion loss. The use of TE_{20} mode AFSIW makes the design compact as it provides inherent balance between the ports because of the out of phase nature of the two half wave variations. The main challenge in this design is to implement a suitable transition from microstrip to AFSIW. A novel microstrip to AFSIW transition to excite TE_{20} mode has also been discussed in this paper.

2. Design of Balun Filter

The proposed balun filter as shown in Fig. 1, consists of three layers. Fig. 1(a) shows the top, middle and bottom layers of the structure and Fig. 1(b) shows the top view of the middle layer with detailed dimensions. The TE_{20} mode is excited in SIW section by using a microstrip to slotline and a slotline to SIW transition [6]. The SIW to AFSIW transition is done by exponentially tapering the SIW to match the characteristic impedance of the AFSIW. The tapered



(a)

(b)

Fig. 1. (a) 3D exploded view of multiple layers of the proposed balun filter, (b) top view of the balun filter (all dimensions in mm): W_1=2.4; W_2=1.6; W_3=3.5; W_s=2; W_{c1}=13.17; W_{c2}=12.45; W_{c3}=9.84; L_1=14.5; L_2=14.3; L_3=15.45; t=0.5; L_t=7.25; L_s=24.445; d=0.4; L_{SIW}=20; L_{AFSIW}=93.5; a_{SIW}=31.12; a_{AFSIW}=45.72.

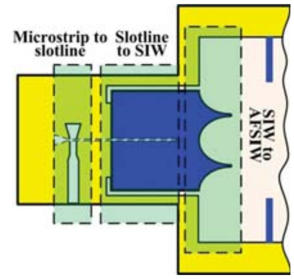


Fig. 2. Microstrip to TE_{20} mode AFSIW transition steps.

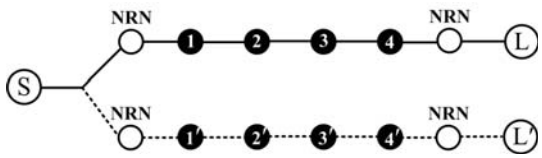


Fig. 3. Coupling topology of the balun filter.

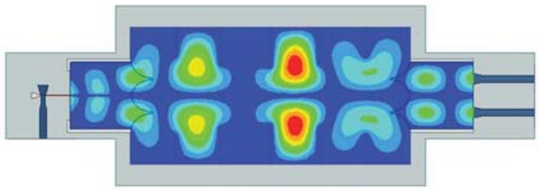


Fig. 4. Magnitude plot of surface current distribution showing TE_{20} mode propagation.

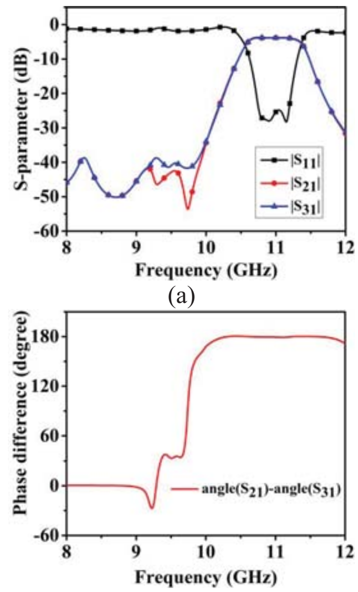
transition is designed using the design equations given in [5]. Two tapered transitions are required for guiding each half-wave variation of the TE_{20} mode. The different parts of the transition are shown in Fig. 2.

The proposed balun filter is composed of 4th order Chebyshev coupled cavity resonator bandpass filtering section. Along the each half-wave section of the TE_{20} mode AFSIW, each half-wave variation propagates along the AFSIW with 180º phase difference which enables the realization of balanced filter. The coupling topology for the generalized Chebyshev bandpass filtering section is shown in Fig. 3. The optimized coupling coefficient values for the specifications (center frequency=11 GHz, FBW=8.6%, maximum passband return loss=24 dB) are given by: $K_{S1}=K_{L4}=0.0883$, $K_{12}=0.0792$, $K_{23}=K_{34}=0.0591$. The loaded Q factors (source and load) are 10.0374 and the cavities are synchronously tuned at 11 GHz. However, the length of the irishes and cavity dimensions are further optimized for suitable performance.

Owing to the absence of dielectric, the filtering section achieves low insertion loss compared to the ordinary SIW counterparts. The first and last cavities are non-resonating nodes (NRN) and instead provide the required loaded quality factor to implement the filtering characteristics, since direct connection of the tapered transition does not provide the matching and the required quality factor simultaneously. Hence only four cavities take part in filtering and implement a 4th order bandpass filter. The surface current magnitude plot, shown in Fig. 4, depicts the TE_{20} mode propagation and coupling between the resonant cavities. The outputs are taken at port 2 and port 3 by using an AFSIW to SIW followed by an SIW to microstrip transition.

3. Results and discussions

The proposed balun filter is designed and simulated in Ansoft HFSS using Rogers RT/duroid 5880 substrate (ε_r=2.2; tanδ=0.0009, height=0.787 mm). The S-parameter magnitude and phase responses are shown in Fig. 5. The proposed filter provides a bandpass response around 11 GHz



(a)

(b)

Fig. 5. (a) S-parameter plot versus frequency, (b) phase difference between two output ports.

center frequency, having 8.6% FBW and 24 dB passband return loss. The insertion loss is 3.9 dB throughout the band (3 dB for ideal lossless balun filter). There is slight mismatch in the magnitude of transmission parameters and the phase difference between the two ports is 180º throughout the band of interest.

4. Conclusion

A novel balun bandpass filter design using AFSIW has been proposed in this paper. Also a novel transition from microstrip to AFSIW has been demonstrated to excite TE_{20} mode in the guide. A significant reduction in insertion loss has been achieved by the technique. The proposed design can be used for X-band RADAR and communication systems.

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