ISBN-978-989-9121-13-3
ISTANBUL 22nd International Conference on "Innovations in Science, Engineering & Technology" (ICISET-22)
Nov. 23-25, 2022 Istanbul (Turkey)

C Band Diplexer in New Emerging Technology SIW (Substrate Integrated Waveguide)

Rahali Bouchra

STIC Laboratory, Department of Electrical Engineering, Faculty of Technology,
University of Tlemcen, Post Box 230, Pole of Chetouane, 13000 Tlemcen, Algeria;

***Abstract*:** A C band planar microwave diplexer in the new emerging technology substrate integrated waveguide (SIW) is based on two channel filters, a power divider and three SIW microstrip transitions for input or output purpose. It is conceived under two designs, the first is such that the two channels filters are perpendicular the second they are linear. Using 3D simulator HFSS a C band SIW diplexer is investigated in this paper. The channel 1 has a centre frequency of 5.27 GHz, with bandwidth from 5.20GHz to 5.33GHz, and the channel filter 2 has a centre frequency of 5.80GHz, with bandwidth from 5.76GHz to 5.84GHz. The maximal insertion loss of channel 2 is -6.42 dB, while it is -4.62 dB for channel 1. The return loss is less than -10.5dB for channel 2, and is less than -11.8 dB for channel 1.

Keywords: *Substrate integrated waveguide, C band, Filter, Diplexer, HFSS.*

1. Introduction

Great interest and special effort have been directed to the development of different types of Waveguide diplexer for different applications. However, the manufacturing of the rectangular waveguide structure [1][2][3] is rather expensive because of the bulky size and in a form of non-planar. This contributes to the difficulty to integrate with other planar circuits. In order to overcome this problem, new technique of designing millimeter-wave circuit has been introduced which is called SIW (Susbtrate Integrated Waveguide (SIW). This waveguide is composed of two parallel rows of metallic posts inserted in a plated substrate in order to realize bilateral edge walls. The distance between the posts and their diameter are chosen as demonstrated in [4][5]. Integrated transitions can be designed on the same substrate compatible with planar structures such as microstrip [6][7][8][9]. SIW structure can be fabricated by using any standard process including low-cost PCB techniques and have small and compact size circuit. SIW components are covered by metal surfaces on both sides of substrate which contribute to have low insertion loss, low radiation loss and insensitive to outside interference. Numerous microwave and millimeter-wave components such as filters [3], six ports [4] and diplexers [5] have been converted from metallic waveguide to SIW circuits. Waveguide diplexers [6] are widely applied to all kinds of electronic and communication systems such as base stations of mobile communications. Their applications are used in these systems in order to discriminate between wanted and unwanted signal frequencies. Diplexers are essential structures in front-end systems in order to separate transmit and receive bands. In this work we analyzed the square diplexer [5] in C band , we conceived another longitudinal diplexer in same band and compared frequency responses.

2. Development of Planar SIW Diplexer

The goal of the paper is to demonstrate the design and optimization of a diplexer operating within the frequency range of [4.5-6.5] GHz. The channel filters [1][2][3] of the diplexer can thus be realized by a series of connected waveguide cavities (resonators), coupled to one another by small apertures (irises). The diplexer is then constructed by connecting each channel filter to a waveguide T-junction. In this paper, based on the studies in [4][5], a planar microwave band pass filter [3] is designed on the substrate integrated waveguide (SIW) technique. The substrate-integrated waveguide (SIW) is an interesting low-cost, low-loss planar technology [4]. The different components designed in SIW can be integrated in the same substrate using conical micro-strip transitions [5][6][7]. In this application [5] a chebyshev filter Figure 1 is presented and designed for millimeter wave applications. Initially, it was designated from the equivalent rectangular waveguide based on the same substrate then the transformations using equations [8] make it possible to design the filter in SIW technology, such that the lateral walls are based on metal cylinders [9]. Iris waveguide band pass filters are realized using SIW technology in [8][9] . The initial steps of the design of these chebyshev filters are performed in a similar method to that of conventional rectangular waveguide iris filters [7]. Iris walls Figure 1 with finite thickness t, in this topology have two parameters di and li (i=1,2,… n) respectively window width and distance between two irises , to be determined and optimized. The circuit is designated on a height substrate H = 0.5mm, its dielectric constant εr = 3, its loss tangent tanδ = 0.001, the dimensions of the metal cylinders constituting the walls of the SIW in the plane E, are the diameter d = 0.5mm, and the space between two cylinders adjacent p = 1mm. Figure 2 shows the electromagnetic field distribution of the TE10 mode guided in the SIW band pass filter with taper adaptation [9][10][11] using 3D FEM simulator HFSS[12] while an optimization procedure was followed in order to meet the desired specifications .

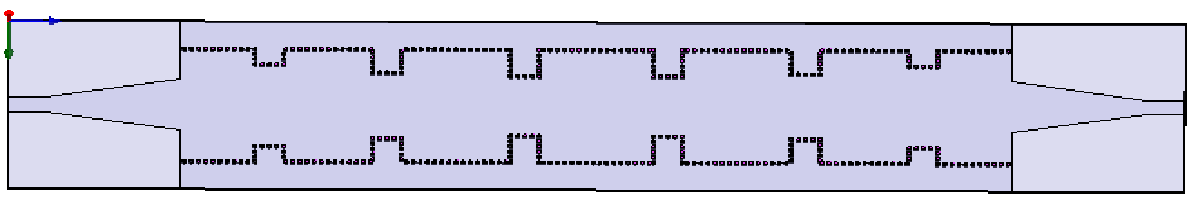


Fig.1: SIW Filter [5]

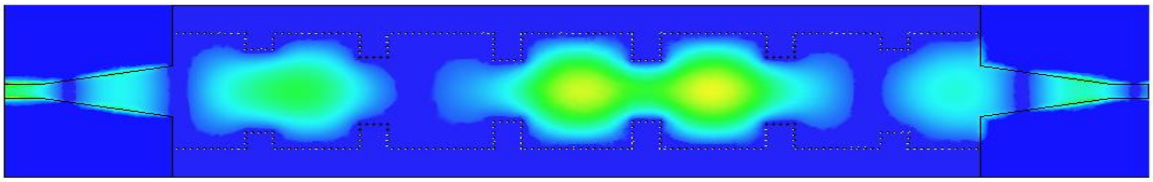
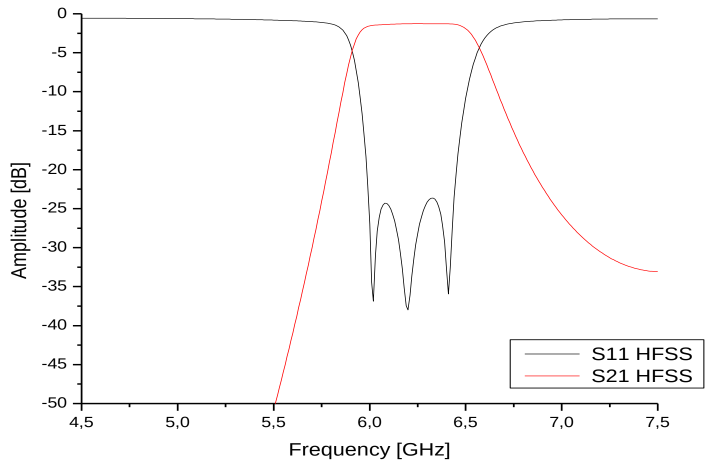
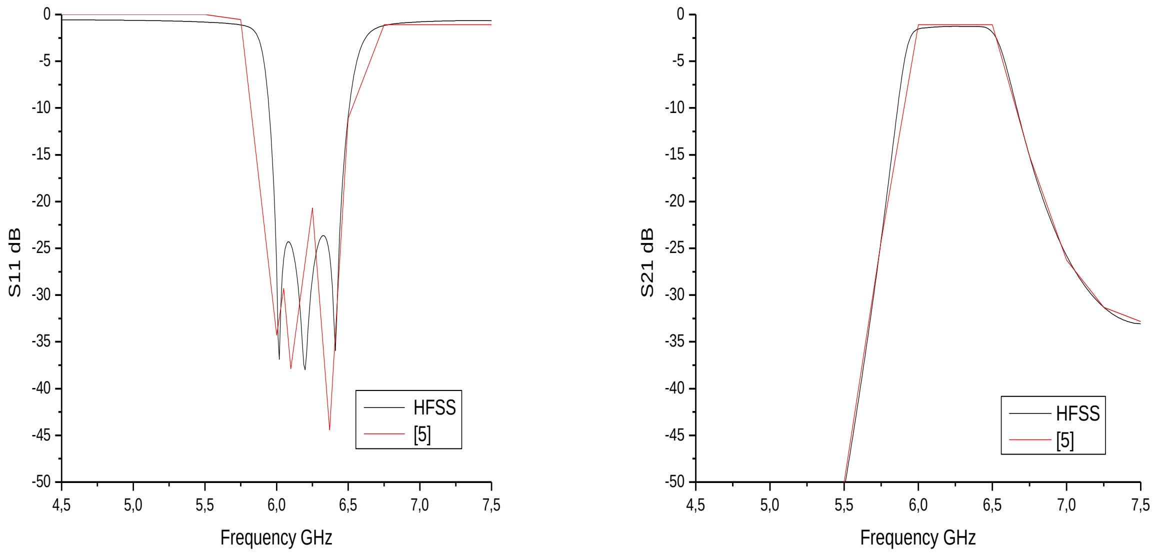


Fig. 2: TE_{10} Electric field magnitude in SIW Filter

The frequency responses of the scattering parameters of S11 and S21 are shown in Figure 3a.Figure 3b shown the comparison of the frequency response obtained by [5] and by electromagnetic simulation with the HFSS simulator Figure 3a. It can be seen that a return loss of less than -24.69 dB and an insertion loss of about 1.25 dB are achieved in the pass-band from 5.97GHz to 6.50GHz.



(a)



(b)

Fig. 3: a Simulated parameters Sij of SIW filter b Comparison of HFSS Simulated parameters Sij and [5]

Diplexers are devices used in RF and microwave systems to combine two disjoint-band signals from separate channels into a single signal, and project it onto a common port. They are generally synthesized by combining a set of channel filters with a power-distribution network Figure 4 [10]. Signals of frequencies F1 and F2 enter the system and with power divider each channel filter selects its corresponding signal to pass through to the output.

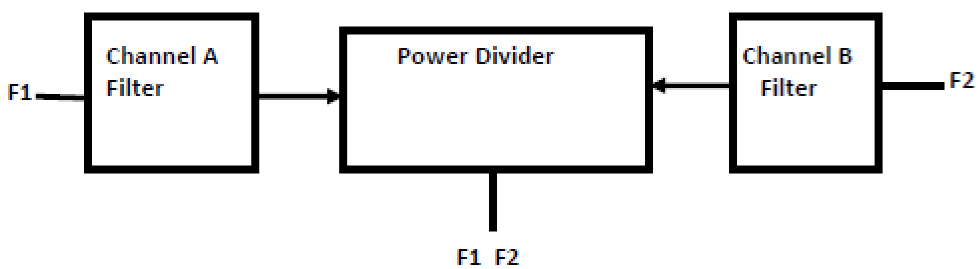


Fig. 4 : Schematic of diplexer configuration

The aim of this study is to compare the frequency responses of two duplexers designed in the same frequency band, the first one being such that the two channels are perpendicular in the second they are aligned. As shown in Figure 5, the SIW diplexer is equivalent to a conventional rectangular waveguide filled with dielectric and therefore the diplexer topology [11] illustrated, is conceived and optimized just by using the width of the equivalent waveguide. The input ports of both channel filters are simply connected to a waveguide T-junction, which then serves as a power divider.

3. Simulation Results

Geometrical parameters filter have been adjusted using [5], then the diplexer has been configured after some optimizations Figure 5, it consists of two channels of SIW filters and three planar transitions [5][6][9].

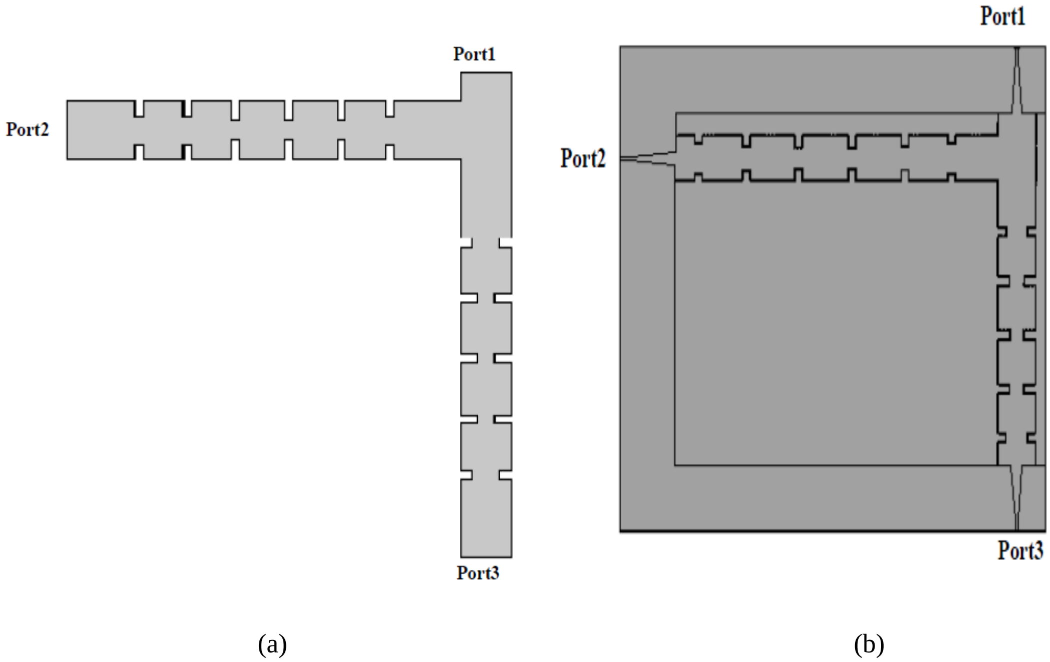


Fig. 5: a waveguide diplexer b SIW diplexer

We have analyzed this structure using 3D simulator HFSS [12] taking frequency responses Figure 6. The Figure 7 represents the comparison between the transmission and reflection coefficients S21, S31, S11 obtained in [5] and following the simulation.

Figures 8a and 8b, respectively, show magnitude surface plots of the electromagnetic field propagating in the complete structure as microwave signals of (a) 5.42GHz and (b) 5.84 GHz are excited into the common port. As can be seen in the Figure 8, the 5.42 GHz signal is only permitted to propagate through channel A, and the 5.84 GHz signal can only propagate through channel B.

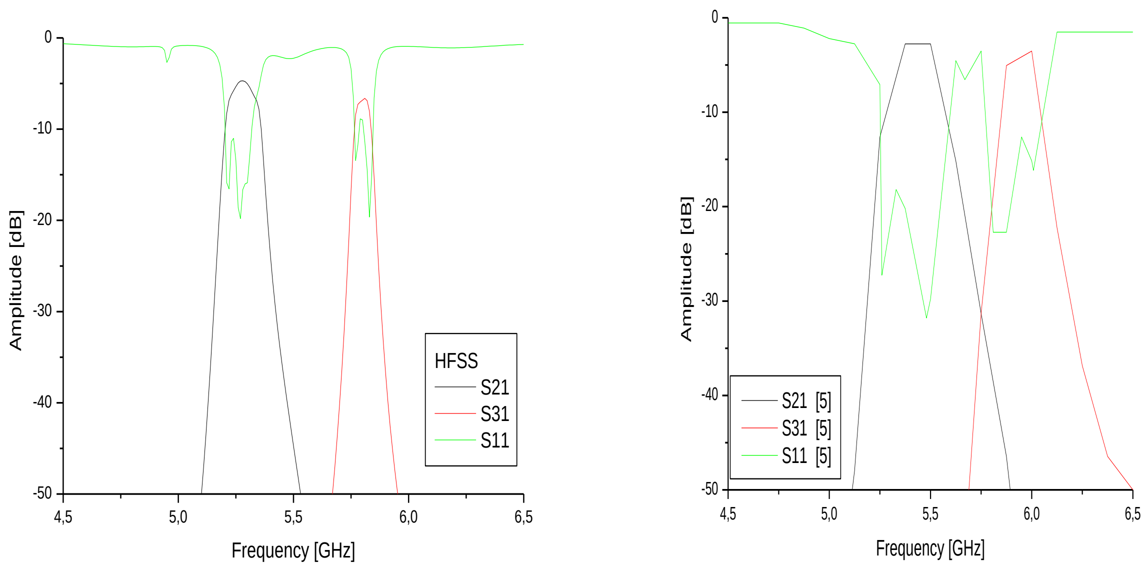


Fig. 6: Sij Coefficients of square SIW diplexer [HFSS] and [5]

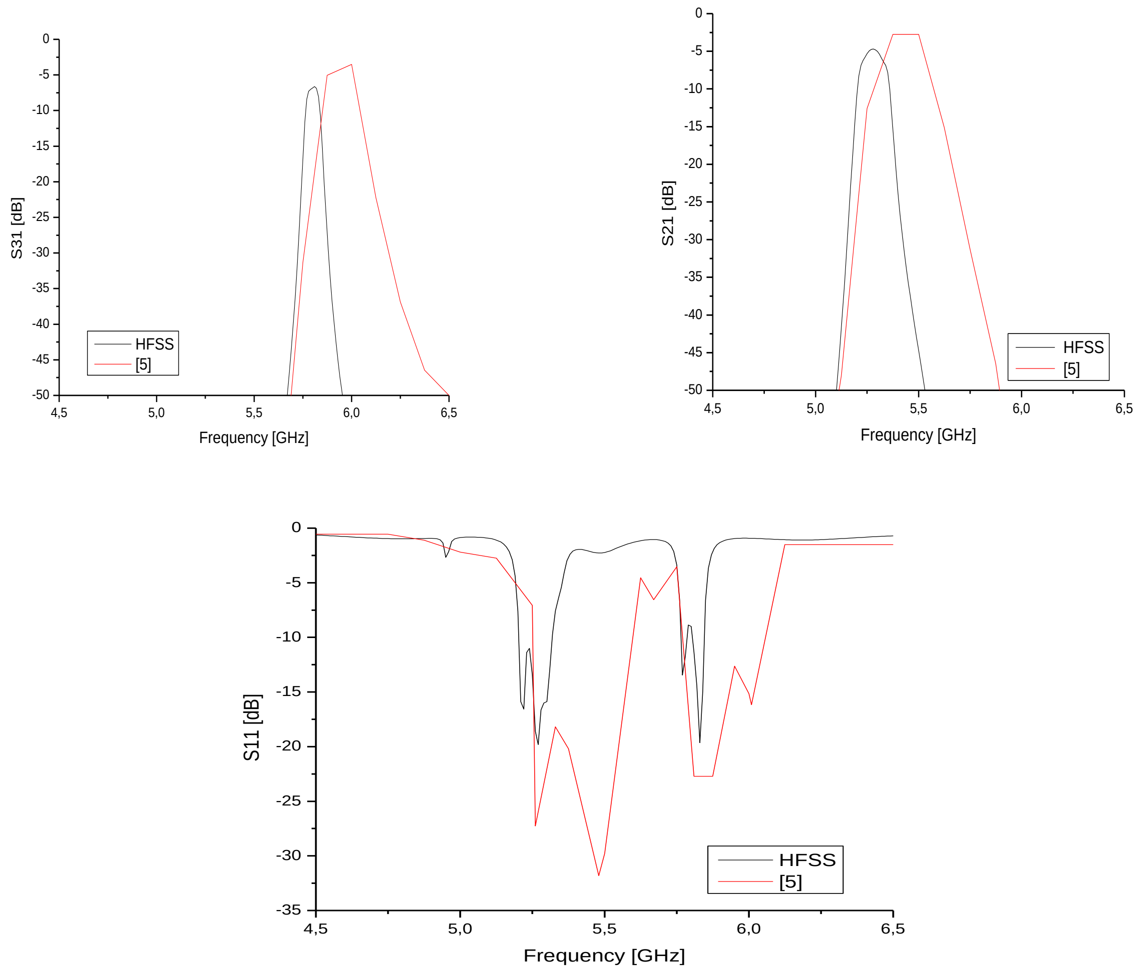
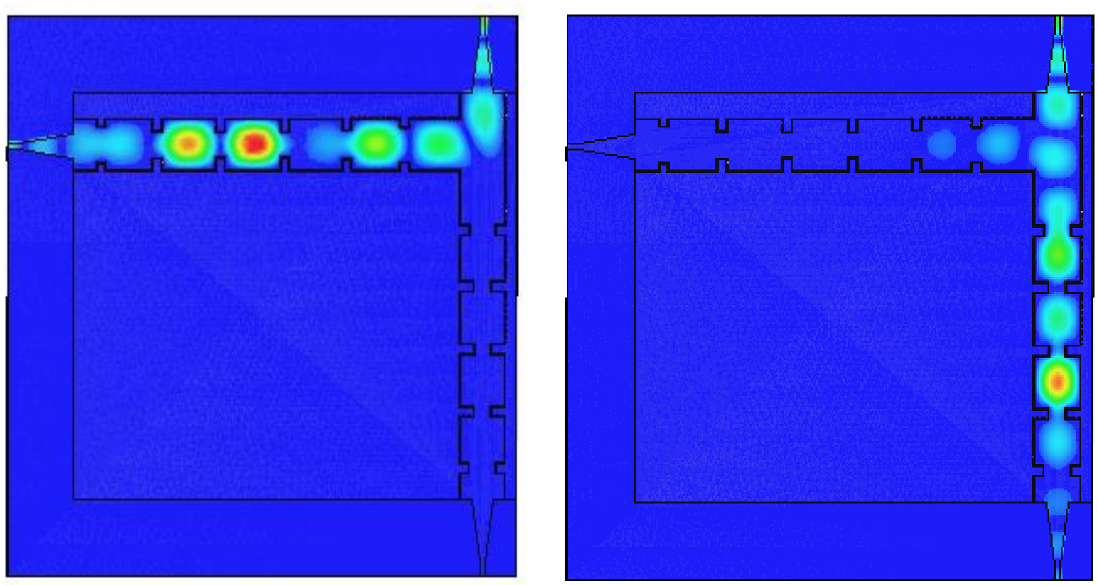


Fig. 7: Comparison of simulated coefficients Sij of SIW diplexer and [5]

Channel A



(a) F=5.42 GHz

(b) F=5.84 GHz

Channel B

Fig. 8: a TE10 electric field magnitude of S21 b TE10 electric field magnitude of S31 in square SIW Diplexer

As mentioned before, a second diplexer Figure 9 is conceived in the same frequency band based on the same channels A and B being aligned. As expected, the HFSS simulations of this design required optimization of the entire diplexer to achieve frequency responses Figure 6. The optimization was done in HFSS, in the same way as for each individual filter, combining the optimization tools integrated in the software and the manual adjustment.

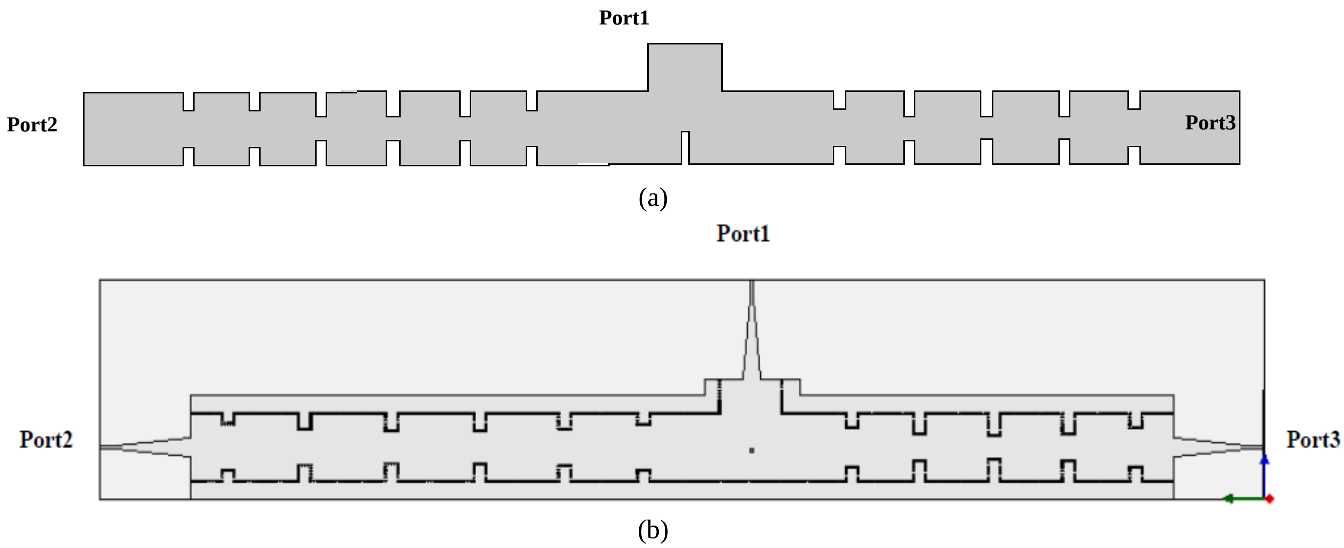


Fig. 9 : a waveguide Diplexer   b Longitudinal SIW diplexer

The HFSS model of this design is presented in Figure 10, the Figure 11 represents the comparison between the transmission and reflection coefficients S21, S31, S11 obtained for the longitudinal SIW diplexer Figure 10 and the square SIW diplexer Figure 6.

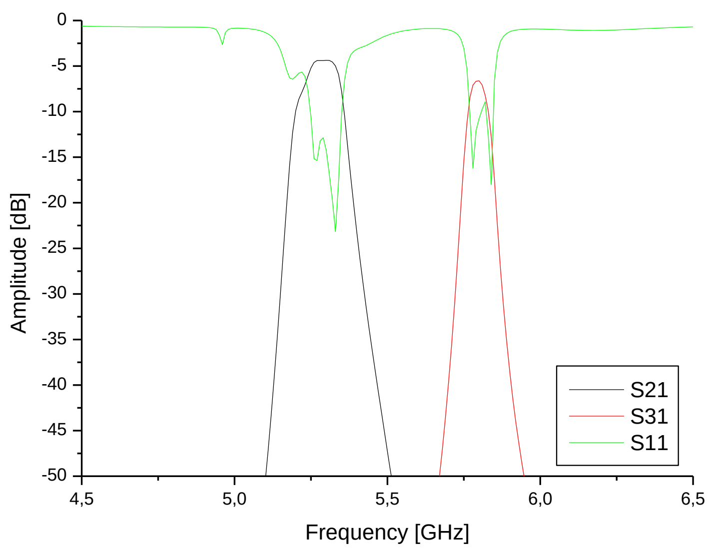


Fig. 10: Simulated coefficients Sij [HFSS] of SIW longitudinal diplexer

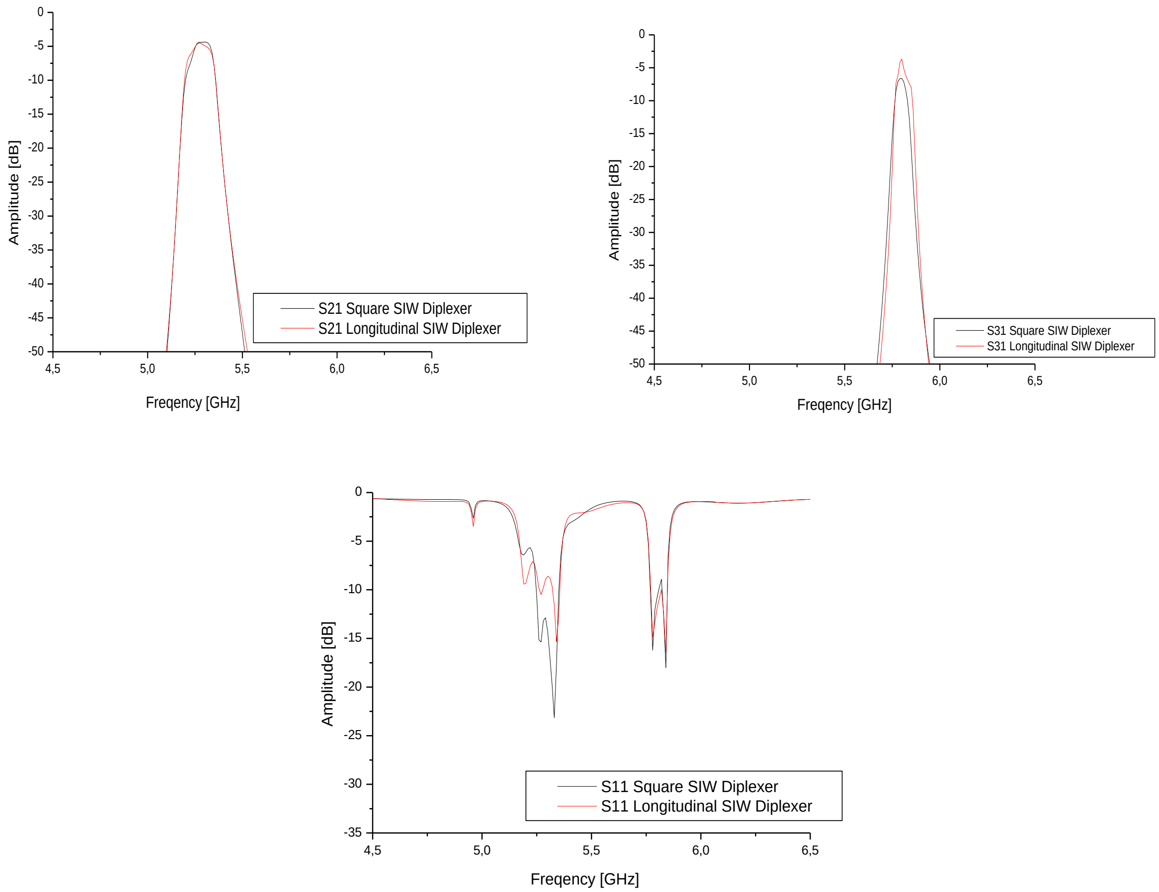
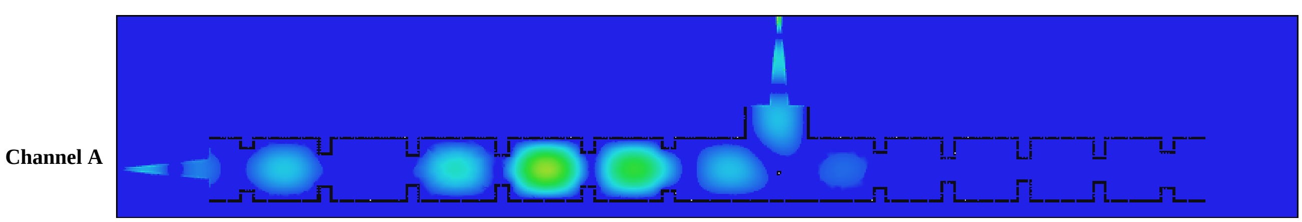
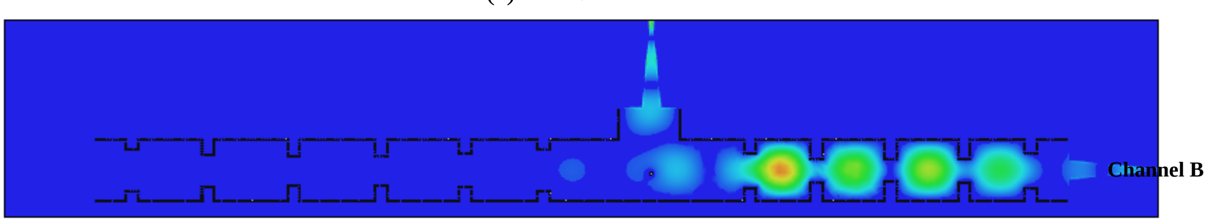


Fig. 11: Comparison of simulated coefficients Sij of square and longitudinal SIW diplexers

For longitudinal SIW diplexer, Figures 12a and 12b, respectively, illustrates magnitude surface plots of the electromagnetic field propagating in the complete structure as microwave signals of (a) 5.36GHz and (b) 5.79 GHz are excited into the common port. Like before, as can be seen in the Figure 13, the 5.36 GHz signal is only permitted to propagate through channel A, and the 5.79 GHz signal can only propagate through channel B.



(a) F=5.36 GHz



(b) F=5.79 GHz

Fig. 12: a TE10 electric field magnitude of S21 b TE10 electric field magnitude of S31 in longitudinal SIW Diplexer

4. Conclusion

In this paper a planar microwave C band diplexer based on the substrate integrated waveguide (SIW) technique is presented using two geometries such that the two channels are perpendicular or linear. The channel 1 has a centre frequency of 5.27 GHz, with bandwidth from 5.20GHz to 5.33GHz, and the channel filter 2 has a centre frequency of 5.80GHz, with bandwidth from 5.76GHz to 5.84GHz. The maximal insertion loss of channel 2 is -6.42 dB, while it is -4.62 dB for channel 1. The return loss is less than -10.5dB for channel 2, and is less than -11.8 dB for channel 1. The simulated results show good channel isolation, moderate insert losses and small return losses in pass-bands for two designs. The diplexer takes a planar form and can be easily integrated in microwave integrated circuits.

5. References

[1] Shen, M., et al., "Ka-band multilayered substrate integrated waveguide narrowband filter for system-in-package applications,"Microwave & Optical Technology Letters, Vol. 58, No. 6, 1395-1398, 2016.doi:10.1002/mop.29833

https://doi.org/10.1002/mop.29833

[2] Jia, D., et al., "Multilayer Substrate Integrated Waveguide (SIW) filters with higher-order mode suppression," IEEE Microwave & Wireless Components Letters, Vol. 26, No. 9, 678-680, 2016.doi:10.1109/LMWC.2016.2597222

https://doi.org/10.1109/LMWC.2016.2597222

[3] M. Guglielmi, P. Jarry, E. Kerherve, 0. Roquebrun and D. Schmitt, "A New Family cd All-Inductive Dual-Mode Filters," ," IEEE Trans. on Microwave Theroy and Tech., vol. 49, no. 10, pp. 1764-1769,Oct. 2001.

https://doi.org/10.1109/22.954782

[4] Xinyu Xu, Renato G. Bosisioand and Ke Wu, (2005) "A New Six-Port Junction Based on Substrate Integrated Waveguide Technology", IEEE Transactions on Microwave Theory and Techniques, Vol. 53, No. 7.

https://doi.org/10.1109/TMTT.2005.850455

[5] Z.C. Hao, W. Hong, J.X. Chen, X.P. Chen and K. Wu, "Planar diplexer for microwave integrated circuits ",IEE Proc.-Microw. Antennas Propag., Vol. 152, No. 6, December 2005

https://doi.org/10.1049/ip-map:20050014

[6] D. Deslandes and K. Wu, "Design Consideration and Performance Analysis of Substrate Integrated Waveguide Components," Europ. Microw. Conf., pp.1-4, Oct. 2002.

https://doi.org/10.1109/EUMA.2002.339426

[7] Dominic Deslandes and Ke Wu "MILLIMETER-WAVES SUBSTRATE INTEGRATED WAVEGUIDE FI LTERS" CCECE 2003 - CCGEI 2003, MontrBal, May/mai 2003 0-7803-7781-8/03/$17.00 0 2003 EEE

[8] Review of Substrate Integrated Waveguide Circuits for Beam-Forming Networks Working in X-Band by Giuseppe Venanzoni , Davide Mencarelli , Antonio Morini , Marco Farina and Francesco Prudenzano Appl. Sci. 2019, 9(5), 1003; https://doi.org/10.3390/app9051003 - 11 Mar 2019

https://doi.org/10.3390/app9051003

[9] Dominic Deslandes "Design Equations for Tapered Microstrip-to-Substrate Integrated Waveguide Transitions", Microwave Symposium Digest, IEEE MTT-S International, pp. 704-707, 2010.

https://doi.org/10.1109/MWSYM.2010.5517884

[10] Amir Moallemizadeh , Motjaba Khiani Kharadji and Sajad Mohammad Ali Nezhad "A simple design substrate-integrated waveguide horn antenna with reduced back lobe" International Journal of Electronics Volume 107, 2020 - Issue 3

https://doi.org/10.1080/00207217.2019.1661025

[11] Parment, F., et al., "Ka-band compact and high-performance bandpass filter based on multilayer air-filled SIW," Electronics Letters, Vol. 53, No.486-488,2017.
https://doi.org/10.1049/el.2016.4399

[12] User's guide – High Frequency Structure Simulator (HFSS), v11.0 Ansoft Corporation.