Substrate Integrated Waveguide hybrid coupler with integrated filter for radar applications

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***Abstract*—This paper proposes a substrate integrated waveguide (SIW) 180 degrees hybrid coupler with an integrated filter. This device operates at 24.1 GHz for radar applications and the filter removes the frequency of 22.1 GHz coming from de local oscillator. This device is the RF passive part of a single balanced diode mixer. The passive part has been designed, fabricated and measured.**

Keywords— Substrate integrated waveguide, hybrid couplers, filters.

I. Introduction

Radar safety systems are crucial for reducing road accidents. In particular 24 GHz automotive short-range radar finds application in parking aid, blind spot detection and pre-crash detection [1][2].

The 180-degree hybrid couplers are necessary components when signals are separated equally between the output ports, with different phases for both ports. Conventional rectangular waveguides have been employed in this kind of devices, however are highly costly and difficult for integration with planar technology. The substrate integrated waveguide technology has opened new perspectives for circuits and systems in the microwave and millimeter-wave frequencies. A rectangular guide is created within a substrate by adding a top metal over the ground plane and caging the structure with rows of plated vias on either side. SIW exhibit many advantages such as compact size, low loss, complete shielding, easy fabrication and easy integration with active devices [3][4]. This technology has been employed in the design of different kinds of microwave circuits, such as filters, antennas and power dividers. In particular, several 180-degree coupler dividers have been implemented in SIW technology, where the phase difference has been obtained by changing the width of the output SIW sections [5]-[7] or the length [8].

In this work we propose a 180-degree hybrid coupler where a high-pass filter has been integrated in order to remove the signal coming from the local oscillator. The device has been designed with the aim of a compact overall structure and low losses coming from the filter.

II. Design and Fabrication

A. Design of the high-pass filter

First of all, a filtering structure has been designed in order to reject the frequency coming from the local oscillator. This filter is composed of a SIW section acting as a high-pass filter with two attached TE_{102} mode cavities that introduces a transmission zero. The objective of this filter is to introduce a transmission zero around de local oscillator frequency of 22.1 GHz, while preserving a flat response with low insertion and return losses for the RF frequency of 24.1 GHz. The width w of the SIW section controls the level of attenuation in the lower band.

Fig. 2 shows the simulated scattering parameters of the structure of Fig. 1, where the substrate is Arlon 25N with height 0.508 mm, dielectric constant 3.38 and tangent losses 0.0021. The assumed conductivity was 1x10e7. The attenuation for the OL frequency is higher than 30 dB, with 20 dB of return losses and 1.2 dB of insertion losses in the RF frequency. Fig. 3 shows the electromagnetic field for the two frequencies of interest, where the resonant cavities introduce the transmission zero at 22.1 GHz.

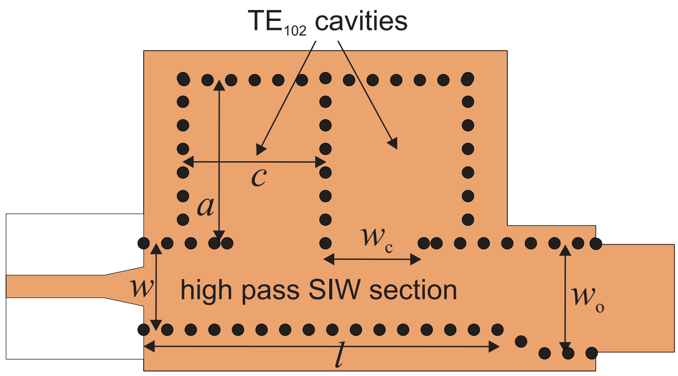

Fig.1. Layout of the proposed filter, where w=4.4 mm, w_c=5 mm, w_o=5.6 mm, l=18.3 mm, a=8.3 mm, and c=7.25 mm.

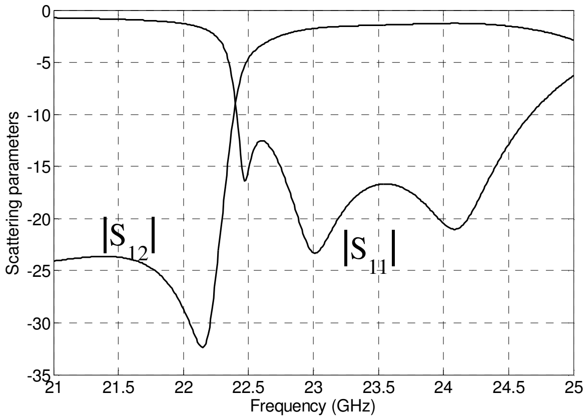

Fig. 2. Scattering parameters of the filter of Fig. 1.

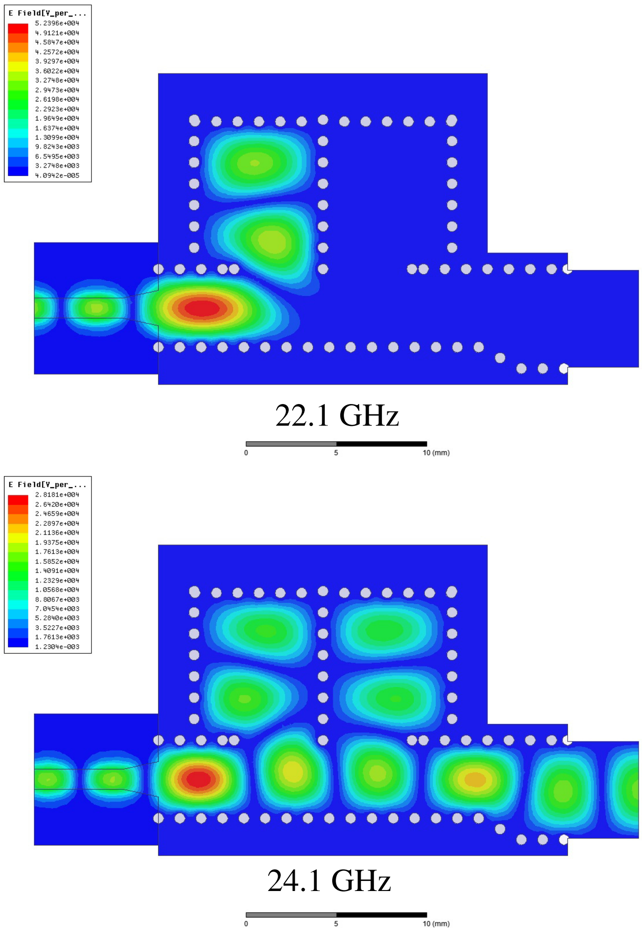

Fig. 3. Electromagnetic filed for the proposed filter.

B. Hybrid coupler with filter

Once the filter has been designed we proceed with the design of the whole structure of the hybrid coupler with the integrated filer. The Fig. 4 shows the layout of the whole device. The SIW input section of RF port has been reduced in order to make more compact the device. Once the filter has been integrated with the hybrid coupler the dimensions of the filter have been optimized, resulting in slightly different values from those obtaining for the design of Fig. 1. In this case the new dimensions for the filter are w=4.6 mm, w_c=5 mm, l=15.7 mm, a=8.25 mm, and c=7.2 mm. The length l_{23} and widths w_2 and w_3 have been optimized for the 180 degrees phase difference between ports 2 and 3 when signal is introduced by the RF port at 24.1 GHz, and 0 degrees when signal is introduced by the LO port at 22.1 GHz. The dimensions w_4, l_c and w_c have been chosen to optimize the return losses and similarity between the amplitudes at the output of ports 2 and 3 at 24.1 GHz when signal is introduced by RF port, and 22.1 GHz when signal is introduced by OL port. The RF and OL ports are implemented with 50 ohm microstrip lines, whereas the ports 2 and 3 are implemented in 30 ohm coplanar lines to be connected to pin diodes with this input impedance. The diameter of the via holes is 0.6 mm. The transitions from microstrip and coplanar to SIW have been optimized to reduce return losses. For port 1 the transition has width 2 mm and length 1.8 mm, and width 1.34 mm and length 1.1 mm for port 4. The transitions from coplanar to SIW are implemented with slots of width 0.4 mm, with length 2.05 mm for port 2, and 1.85 mm for port 3, and inclination angle of 30º.

Fig. 5 shows the fabricated circuit with the same substrate employed for the filter of section II. A. In order to facilitate the measurements, the coplanar lines have been converted to 50 ohm microstrip lines. The next figures show the simulated and measured results for the different parameters of interest.

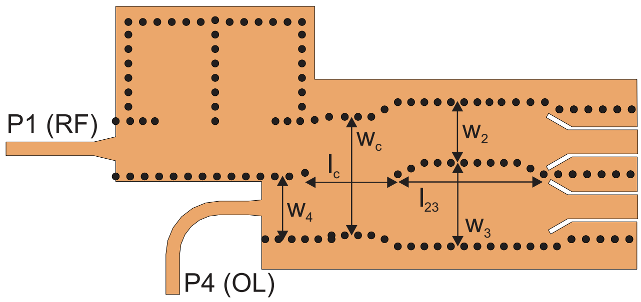

Fig. 4. Layout of the proposed hybrid coupler with integrated filter, where w_4=5.22 mm, l_c=7.7 mm, w_c=9.86 mm, l_{23}=12.1 mm, w_2=5.05 mm and w_3=6.95 mm.

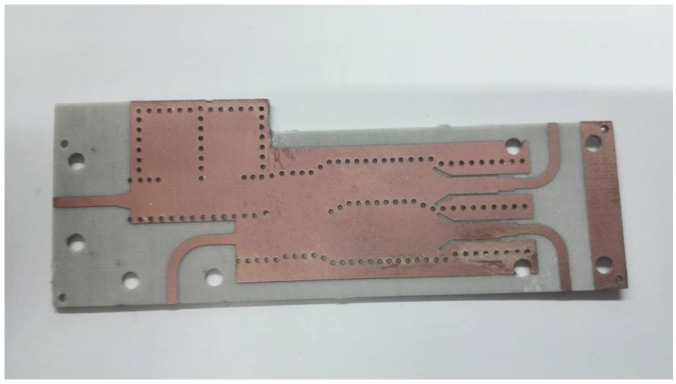

Fig. 5. Fabricated hybrid coupler with integrated filter.

Fig. 6 shows the transmission from RF port to ports 2 and 3. In this case the insertion losses at 24.1 GHz have to be similar for S_{21} and S_{31}. The simulated results give 5.3 dB and 5.6 dB respectively, whereas the measured results are 6.5 dB and 7 dB. In this case the effect of the filter can be appreciated, where the signal at 22.1 GHz is strongly attenuated. Fig. 7 shows the phase difference for the same parameters S_{21} and S_{31}, where the objective is to obtain 180º. The simulated phase difference was 183º and the measured 180º.

Fig. 8 shows the transmission from OL port to ports 2 and 3. The insertion losses at 22.1 GHz have to be similar for S_{42} and S_{43}. The simulated results give 4.9 dB and 5.1 dB respectively, whereas the measured results are 5.6 dB and 6.1 dB. Fig. 9 shows the phase difference for the same parameters S_{42} and S_{43}, and in this case the objective is to obtain 0º. The simulated phase difference was lower than 2º and the measured 10º.

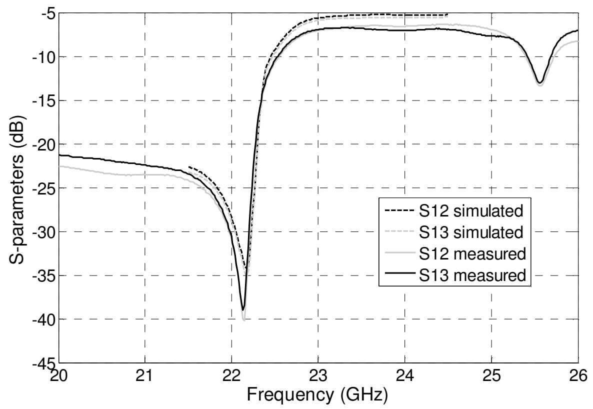

Fig. 6. Transmission from the RF port to the ports 2 and 3.

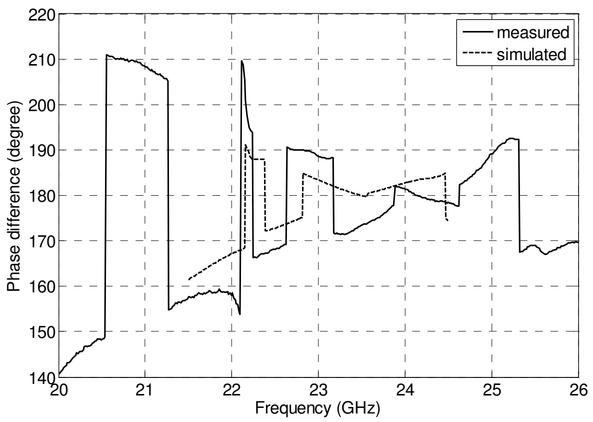

Fig. 7. Phase difference between for parameters S_{12} and S_{13}.

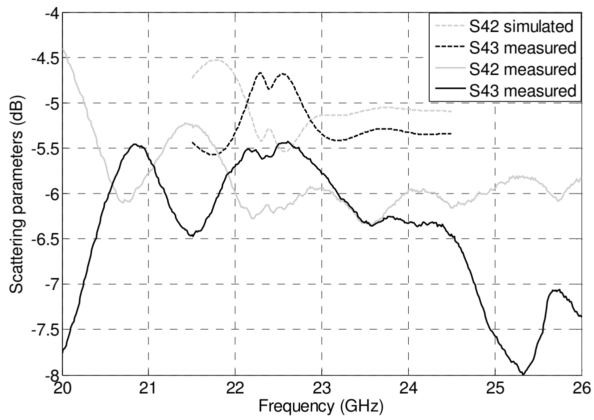

Fig. 8. Transmission from the OL port to the ports 2 and 3.

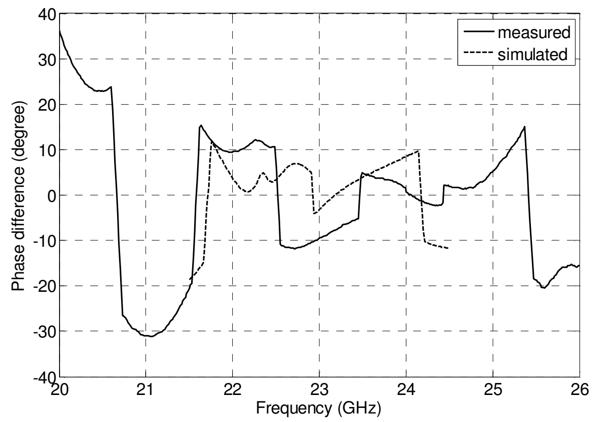

Fig. 9. Phase difference between for parameters S_{42} and S_{43}.

The reflected power for all the ports is shown in Fig. 10. Only the measured results are presented in this case. For RF port 15 dB are measured for return losses at the frequency of interest, and 18 dB for the OL port at 22.1 GHz. The ports 2 and 3 show better results for the RF frequency where the filter allows for the pass of the signal.

Finally, Fig. 11 shows the measured isolation between the RF and OL ports, with 23 dB for the RF frequency, and around 50 DB for the OL frequency due to the attenuation introduced by the filter.

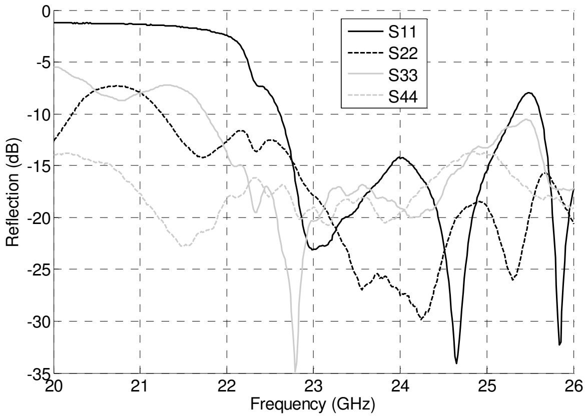

Fig. 10. Reflection for the four ports of the hybrid coupler.

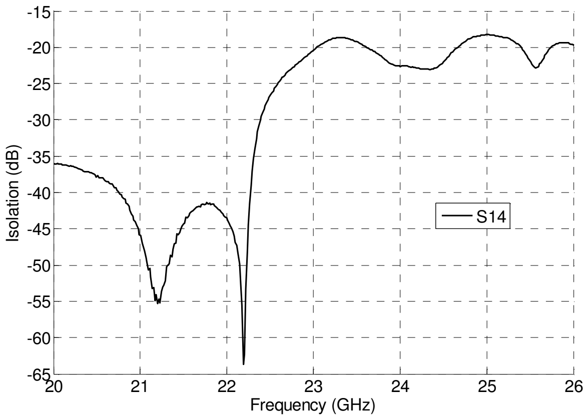

Fig. 11. Isolation between RF and OL ports.

III. CONCLUSION

A 180-degree hybrid coupler with an integrated filter in SIW technology has been designed, fabricated and measured. The proposed design has compact size and shows a good performance for 24 GHz applications.

ACKNOWLEDGMENT

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