Progress In Electromagnetics Research Letters, Vol. 71, 103–108, 2017

A Novel and Compact UWB Bandpass Filter-Crossover Using Microstrip to CPS Transitions

Mohamed L. Seddiki[1, 2, *], **Mourad Nedil**[1], **and Farid Ghanem**[3]

Abstract—In this letter, a new compact UWB uniplanar crossover with bandpass filter characteristics is proposed and implemented. The UWB Filter-Crossover is composed of two novel UWB filters placed on the top and bottom of the substrate to obtain the crossover features. These proposed filters are based on microstrip to coplanar stripline (CPS) transitions and sections of CPS section line used as a multiple mode resonator (MMR). The simulated and measured results show a good result in terms of isolation, return loss and insertion loss in the entire UWB band.

1. INTRODUCTION

Since the Ultra-Wideband (UWB) (3.1–10.6 GHz) spectrum was regulated for unlicensed use in 2002, several UWB devices and circuits have been developed [1]. In this area, various studies are under progress, especially UWB crossovers which are one of the important components in microwave integrated circuits to isolate the signal with two paths without disturbing the performance of the RF systems [2]. Furthermore, the crossovers are fundamental for great density microwave monolithic circuits, microwave multichip modules, MIMO antennas, and many other microwave planar systems [3]. Air-bridge bond structures and wired vias are the first developed crossovers [3, 4]. However, those circuits lead to non-planar circuits which reduce performances and increase the fabrication cost and complexity [2].

Hence, planar crossovers can be constructed using microstrip patch or cascading two hybrid directional couplers [2, 5]. The crossover structure presented in [5] includes cascading two quarter-wavelength branch line couplers and offers good performances in terms of isolation and simplicity. However, the drawbacks of using this technique are its very large size and narrow bandwidth. In [6], two- and four-port microstrips to slotline transitions were proposed to develop planar crossover with 40% of bandwidth. Also, a microstrip to coplanar waveguide transitions was introduced with 44% of bandwidth [7]. Lately, integrated circuits with combining functions in one device, such as filtering power divider [9], filtering crossovers [10, 11] and filtering butler matrix [12], were introduced. These functions when combined become very important for size reduction and low-cost RF integrated circuits. However, most of the proposed Filter-Crossovers in the literature have narrow band [2, 8, 10, 11].

In this paper, a new compact UWB Bandpass Filter-Crossover is proposed and implemented. The structure of the uniplanar device is composed of four UWB microstrip-to-CPS transitions and two section lines to create two different UWB filters mounted on different layers of the same substrate. To the best of our knowledge, no research works have been reported on designing of UWB filter based on both microstrip and CPS-MMR technologies. The proposed bandpass Filter-Crossover offers a good performance in terms of compactness, bandwidth, isolation, insertion loss and wide out-of-band rejection.

Received 27 August 2017, Accepted 9 October 2017, Scheduled 10 November 2017

[*] Corresponding author: Mohamed Lamine Seddiki (sadikilamine@ymail.com).

[1] Université du Québec en Abitibi Témiscamingue Val-d'Or, Québec J9P 1Y3, Canada. [2] Réseaux de Communication, Architectures et Multimédia (RCAM), University of Sidi Bel Abbes, Algiers. [3] Telecom Product Direction R&D&I, Brandt Group, Cevital Industry Pole, Garidi II, Algiers, Algeria.

2. MICROSTRIP TO CPS UWB FILTER

The layout of the proposed UWB filter is shown in Fig. 1. It is composed of two microstrip-to-CPS transitions and a section of CPS transmission line used as a multiple mode resonator (MMR) between the two transitions. At the center frequency of the concerned UWB bandpass, the side sections of this MMR (microstrip-to-CPS transition) are simply chosen as one quarter-wavelength ($\lambda_g/4$) while the middle section (CPS section line) is set as one half-wavelength ($\lambda_g/2$) [13].

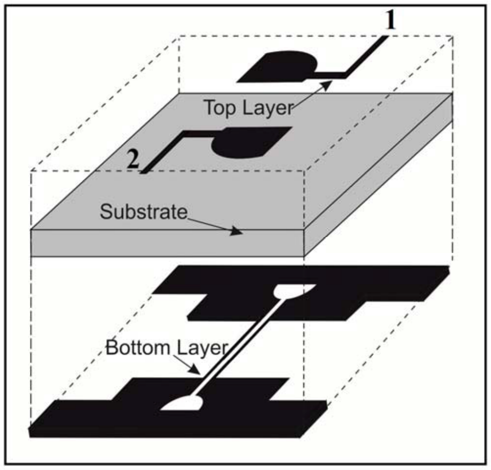


Figure 1. Layout of the proposed UWB filter.

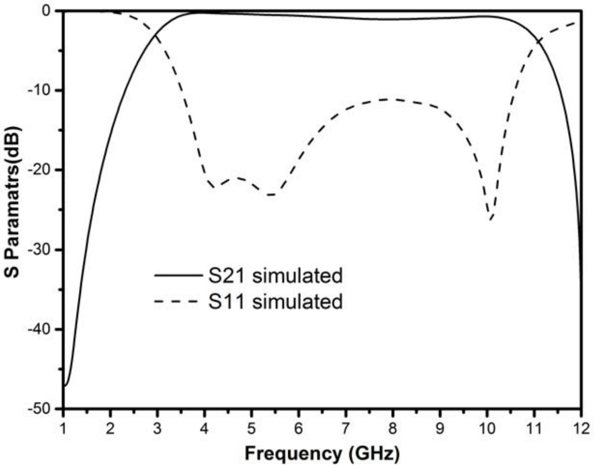
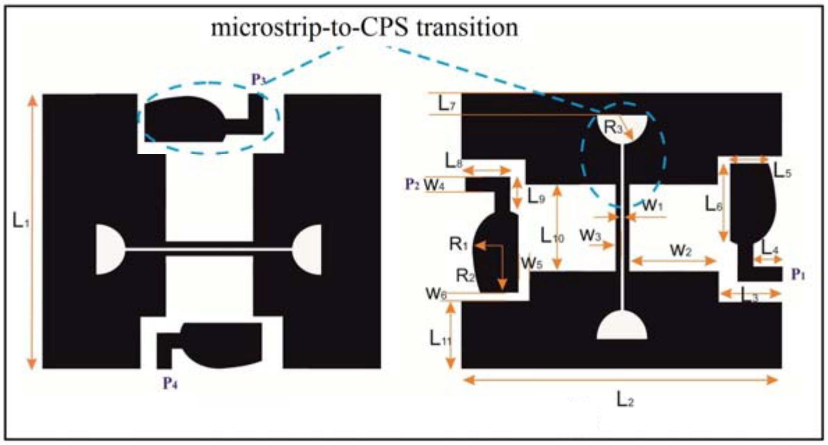


Figure 2. Simulated results of the proposed filter.

Table 1. The detailed dimensional parameters (mm).

$L1$	$L2$	$L3$	$L4$	$L5$	$L6$	$L7$	$L8$	$L9$	$L10$
26	28	7.4	4.35	4.45	4.6	2.3	5.8	5.55	11.48
$L11$	$W1$	$W2$	$W3$	$W4$	$W5$	$W6$	$R1$	$R2$	$R3$
4	0.1	6.1	0.45	1.17	0.3	2.3	3.5	5	1.8



(a) (b)

Figure 3. Layout of the proposed uniplanar Filter-Crossover, (a) top layer, (b) bottom layer.

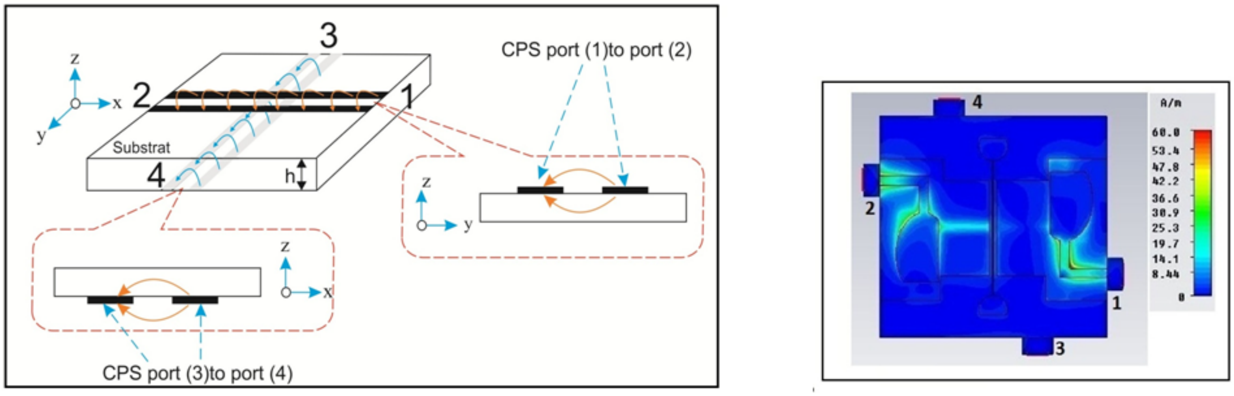
To examine the performance of this filter, numerical simulations were carried out using the full-wave CST Microwave Studio. The circuit is designed on a low cost RT 4003 with a dielectric constant of 3.38. To optimize the performance of the filter, a parametric study was also performed, and the optimal dimensions, as sketched in Fig. 3, are given in Table 1.

Simulated results are shown in Fig. 2. From these results, it can be seen that this filter has several promising UWB bandpass behaviors with a low insertion loss and high return loss within the UWB frequency range. As an application of this new filter, a UWB Filter-Crossover is introduced in the next section.

3. BANDPASS FILTER-CROSSOVER DESIGN

The layout of the proposed uniplanar bandpass Filter-Crossover is shown in Fig. 3. The structure is based on two filters (Section 2) placed on different layers of the same substrate to create UWB crossover. The Filter-Crossover is composed of four-port microstrip to CPS transitions, where two ports are located on the top, and the others on the bottom. The first path connects Port 1 to Port 2, whereas the second one connects Port 3 to Port 4. Connections between port1-to-port2 and port3-to-port4 are placed symmetrically on the top and bottom of the substrate.

The electric field distribution at the crossing region between the orthogonal CPS transmission lines from the top (port 1 to 2) and bottom (port 3 to 4) is shown in Fig. 4(a) and Fig. 4(b). It can be seen that almost all power is transmitted from Port 1 to Port 2 with a neglected part coupled to the CPS line of Ports 3 and 4. This is because the electric field lines are concentrated across the strip conductors and oriented through the gap between the strips and roughly parallel to the face of the dielectric substrate. As a result, a poor coupling between the two orthogonal CPS cross lines is achieved. This feature makes the CPS technology more suitable in terms of isolation between crossing lines than the conventional microstrip and CPW transmission lines.



(a) (b)

Figure 4. (a) Distribution of the electric field between CPS cross lines, (b) surface current density distribution.

4. RESULTS AND DISCUSSIONS

Photographs of the prototype of the bandpass Filter-Crossover are shown in Fig. 5. The overall dimensions of the fabricated crossover without the feeding SMA ports used for the testing are $28 \times 28\,\mathrm{mm}^2$. The simulations were carried out using CST Microwave studio software and validated with measurements (network analyzer of Agilent E5071C). Good agreement between the simulated and measured results is obtained.

The simulated and measured performances of the designed Filter-Crossover are illustrated in Fig. 6. It can be seen that the insertion losse results of S_{21} and S_{34} are better than 1 dB through the UWB

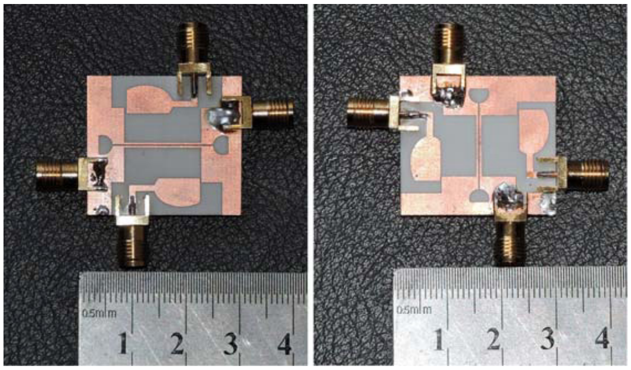
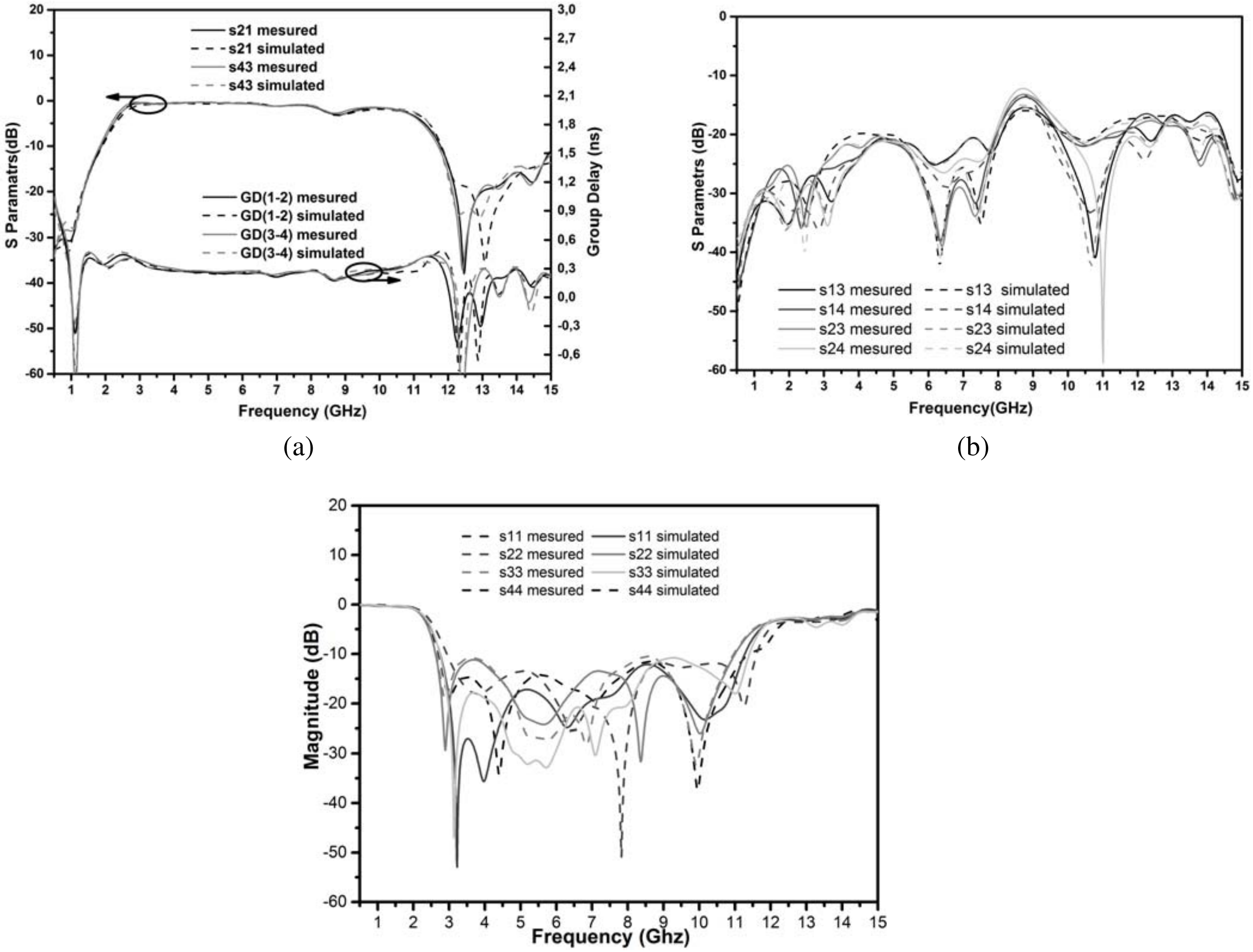


Figure 5. Photographs of the fabricated Filter-Crossover.



(a)

(b)

(c)

Figure 6. Measured and simulated results of the proposed Filter-Crossover: (a) insertion loss and group delay, (b) isolation and (c) return loss.

frequency range except at around 9 GHz where the loss is around 1.8 dB. Furthermore, a good out-of-band rejection and an excellent isolation of more than 18 dB are achieved between Ports 1 to 3 and 2 to 4, at the whole frequency range. The simulated and experimental results of the return loss for all ports

(S_{11}, S_{22}, S_{33}, S_{44}) are better than 15 dB.

Figure 6(a) Shows the measured and simulated group delay responses of the Filter-Crossover. The results show that the group delays vary between 0.25 and 0.3 ns with a maximum variation of 0.05 ns, which leads to a good linear phase response. It can be noted that this Filter-Crossover satisfies the requirement of small and flat group delay over the operating band, which is desired for impulse radio systems to minimize the distortion of the short pulse transmission.

Table 2 summarizes the performance comparison between the proposed Filter-Crossover and several reported works in terms of filtering responses, isolation, bandwidth and size. The proposed Filter-Crossover has an excellent performance in reference to compactness, isolation and UWB filtering response compared to the works cited in Table 2.

Table 2. Performance comparison with recent works.

crossover	BW	Isolation (dB)	Filtering response	Size (mm)
[2]	59%	17	yes	42 × 42
[11]	26%	25	yes	51 × 51
[7]	110%	15	no	8 × 15
[8]	—	20.4	yes	13 × 13
[10]	9.5%	20	yes	29 × 29
This work	110%	18	yes	28 × 28

5. CONCLUSION

A new UWB Filter-Crossover using microstrip to CPS transitions has been proposed, designed and implemented. It has advantages of UWB isolation performance, dual functions (crossover and UWB bandpass filtering) and compactness. The results show that this Filter-Crossover has several promising UWB bandpass features with a low insertion loss and high isolation between cross lines. This circuit is useful for UWB wireless communication system applications and could be used in antenna arrays.

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