Miniaturized Defected Ground High Isolation Crossovers

D. Packiaraj, K. J. Vinoy, P. Nagarajarao, M. Ramesh, and A. T. Kalghatgi

***Abstract*—This letter relates to the design of crossovers for carrying criss crossing signals. Two types of crossovers are proposed in this letter. Both the crossovers are designed using a two layer printed circuit board. An unbroken continuous transmission line is routed in the top layer for carrying signal 1 from one node to another node. Transmission line used for carrying a signal 2 consists of three physically discontinuous, but electrically connected segments. Two end segments of these are located in the top layer while the middle segment is placed in the bottom layer. While Type I crossover offers an isolation of 25 dB, Type II crossover offers isolation better than 35 dB from dc to 10 GHz. These crossovers are compact and measure an actual size of $10 \times 10 \times 0.78\ \mathrm{mm}^3$.**

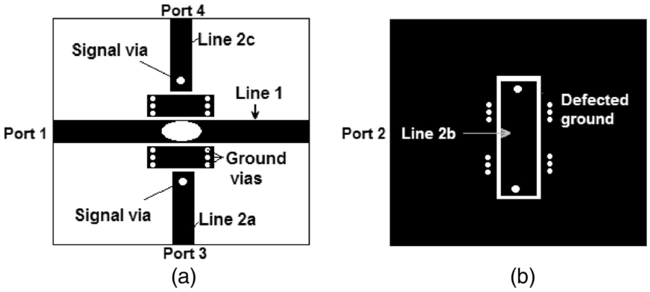
***Index Terms*—Crossover, defected ground, isolation, top layer, via.**

I. INTRODUCTION

CROSSOVERS are the devices used for carrying signals over the traces which cross each other physically. Crossovers while carrying the signals need to provide high amount of isolation between the signals. Crossovers find numerous applications in filters, mixers and antenna array beam forming matrices. Crossovers can be constructed either with vias or without vias. Conventional crossovers are formed using wire bonds [1]–[4]. These will limit the frequency of operation and pose stringent fabricational constraints. Via less crossovers reported in literature use cascaded branch line hybrids or broadside coupled lines [5], [6]. Though these crossovers offer wide band of operation, they occupy lot of printed circuit board real estate. On the other hand crossovers [7] used vias with plated through hole (PTH) in multi-layer PCB technology.

This letter presents two other types of wideband high isolation crossovers using vias and slots. The proposed method can be treated as modification that reported in [7]. The letter is organized as follows. Section II demonstrates the design of Type I crossover using elliptic slot over one of the lines. Type II crossover using an embedded ground strip inside the rectangular slot over one of the lines is explained in Section III. Section IV concludes the present letter.

II. DESIGN OF TYPE I CROSSOVER



(a) (b)

Fig. 1. Type I crossover.

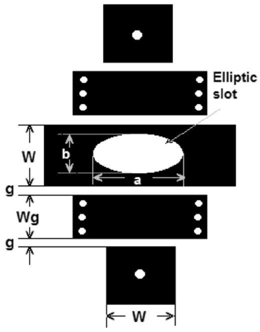


Fig. 2. Crossing portion of Type I crossover.

Crossovers discussed in this letter are designed in a two layer microstrip medium having a substrate thickness of 0.78 mm and permittivity of 2.17. The proposed Type I crossover is shown in Fig. 1. This crossover effectively utilizes the top and bottom layers of the microstrip medium. Line 1 is a continuous transmission line and has an elliptic shaped slot over the region where the middle segment of Line 2 crosses Line 1. Line 2 consists of three transmission line segments namely Line 2a, Line 2b and Line 2c. As shown in Fig. 1(b), while the transmission line "Line 2b" is placed in bottom layer (in the defected portion of the ground), transmission lines "Line 2a" and "Line 2c" are placed in the top layer. Segment Line 2b is connected to segments Line 2a and Line 2c through PTH vias at both ends. Diameter of the PTH is optimized through simulations to achieve better matching and is found to be 0.2 mm. Fig. 2 shows the signal crossing region of the crossover. The crossing area between the lines is minimized by removing the metal in the central portion of the Line 1 to improve the isolation. An elliptic shaped slot is created in Line 1 to avoid the coupling between Line 1 and Line 2. Centrally located slot in Line 1 will not disturb the impedance characteristics since slot is located in the middle of the line where the current distribution is negligible. Additional grounding pads are placed on the top layer on either side of Line 1 and are connected to bottom layer through ground vias. This preserves the impedance characteristics of the transmission line Line 2b.

Equivalent circuit of the cross over is shown in Fig. 3. Series inductances "L" account for the signal vias. The capacitance "C" between the lines accounts for the undesired cou-

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Color versions of one or more of the figures in this letter are available online at http://ieeexplore.ieee.org.

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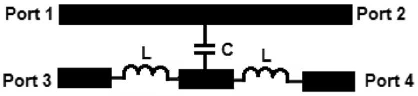

Fig. 3. Equivalent circuit of Type I crossover.

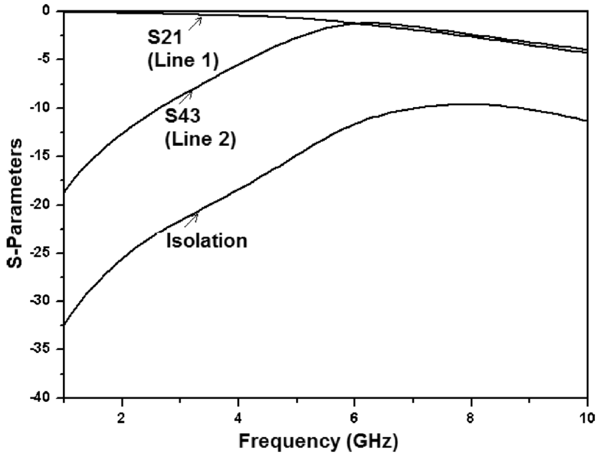

Fig. 4. Simulation results of crossover without slot in Line 1.

TABLE I
TYPE I CROSSOVER DIMENSIONS

Via diameter	0.2*mm*
Line width ‘W’ and Gap ‘g’	2.4*mm and 0,.2mm*
Ground pad width ‘Wg’	2*mm*
Elliptic slot dimensions	a=3*mm*, b=2*mm*

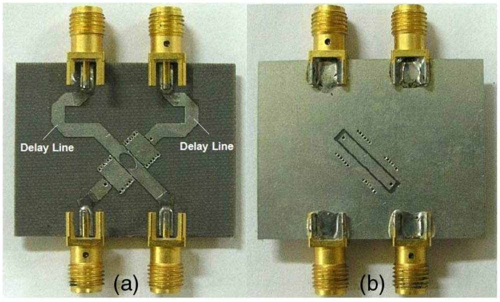

Fig. 5. Photograph of realized Type I crossover.

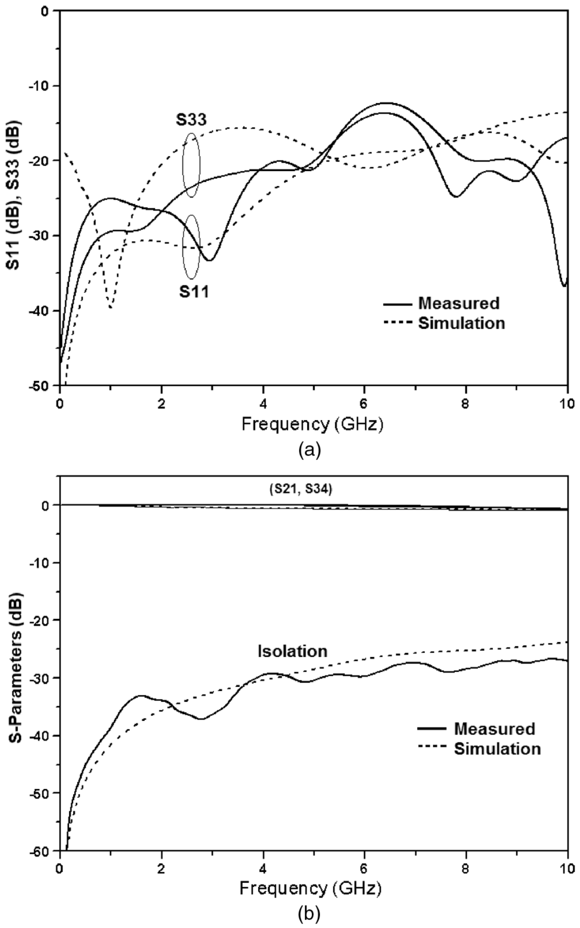

Fig. 6. Measured results of Type I crossover.

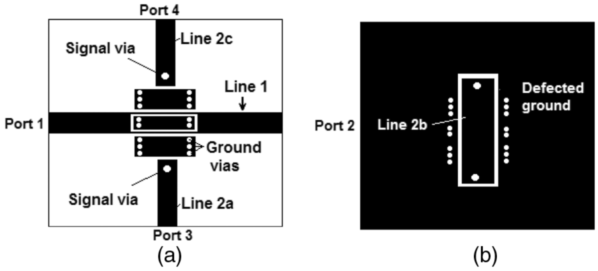

Fig. 7. High isolation Type II crossover.

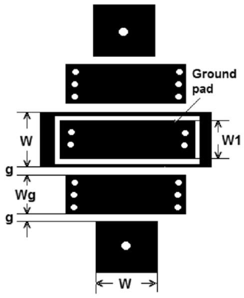

Fig. 8. Crossing portion of Type II crossover.

pling. All the transmission lines between ports are designed to be 50 Ω and the corresponding line widths are calculated using the standard synthesis formulas available in open literature [1]. Designed crossovers are optimized using full wave simulations using IE3D from mentor graphics [8]. Fig. 4 shows the simulation results of crossover without slot in Line 1. It shows that the transmission loss, isolation and matching are very poor due to cross coupling effect between Lines. It can be observed that though Line 1 still exhibits conventional transmission line characteristics, transmission characteristics of Line 2 are degraded. The above observation confirms the necessity of slot in Line 1. Table I lists the physical dimensions of optimized crossover.

The above crossover with physical dimensions given in Table I was fabricated using standard printed circuit board fabrication techniques. Photograph in Fig. 5 shows the top and bottom layers of the crossover. Measured return loss, insertion loss and isolation are shown in Fig. 6 along with the simulation results. Measured insertion loss in both lines is less than 0.75 dB and return loss is better than 13.5 dB over dc to 10 GHz. Measured isolation (S_{41}, S_{31}, S_{32} or S_{42}) is more than 25 dB.

III. DESIGN OF TYPE II CROSSOVER

Type II crossover shown in Figs. 7 and 8 is designed by modifying the Type I crossover. A ground strip is embedded inside

TABLE II
TYPE II CROSSOVER DIMENSIONS

Via diameter	0.2mm
Line width ‘W’ and Gap ‘g’	2.4mm and 0.2mm
Ground pad width ‘W_1’ and Wg	2.2mm and 2 mm

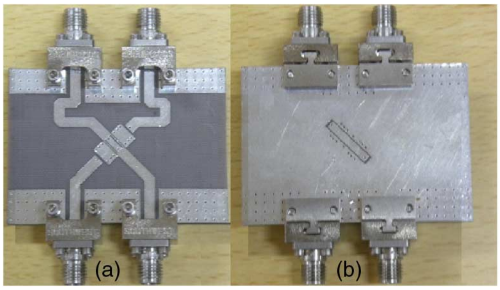

Fig. 9. Photograph of realized high isolation Type II crossover.

TABLE III
COMPARISON OF CROSSOVERS

Crossover Type	Frequency	Minimum Isolation
Proposed Type I crossover	0-10GHz	25dB
Proposed Type II crossover	0-10GHz	35dB
Crossover reported in [6]	3.1-10.6GHz	15dB
Crossover reported in [7]	0-6GHz	20dB

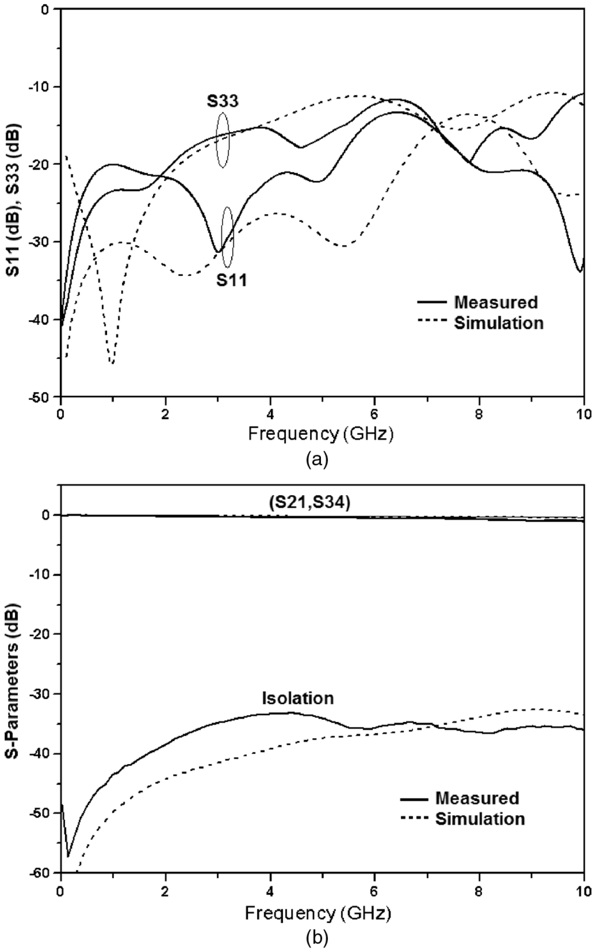

Fig. 10. Measured results Type II crossover.

the slotted portion of Line 1. This strip which acts as a ground for the Line 2b is connected to the bottom layer through vias as shown in Fig. 7. The region where signal crosses each other is shown in Fig. 8. This crossover offers higher isolation compared to Type I crossover. Physical dimensions of type II crossover are listed in Table II. Through simulations the slot dimensions in Line 1 connecting port 1 and port 2 are optimized to achieve minimum cross coupling (low value of ‘C’) that is high isolation between lines. Photograph in Fig. 9 shows the top and bottom layers of the Type II crossover. Measured return loss, insertion loss and isolation are shown in Fig. 10. Measured insertion loss in both the lines is less than 0.65 dB and minimum return loss is 14 dB over dc -10 GHz. Experimental results show a better isolation (more than 35 dB) for Type II crossover compared to Type I crossover. In both type I and Type II crossovers, due to the presence of DGS and vias, there is a difference of 1.5 mm in lengths between the lines from port 1 to port 2 and port 3 to port 4 to obtain equal phase response. As discussed in [9], this difference is due to slow wave effect.

Table III compares the performances of the proposed crossovers against other crossovers reported in literature [6], [7]. This comparison clearly shows that the proposed crossovers offer wide bandwidth and high isolation.

IV. CONCLUSION

This letter presented the design of two types of broadband miniaturized high isolation crossovers. These crossovers are compact as they take advantage of the top and bottom layers of microstrip medium effectively. Crossover junctions were designed by embedding a slot and a ground strip inside the line. The proposed crossovers offer 25–35 dB of isolation from dc to 10 GHz with minimum return loss of 14 dB.

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