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Research Article

BROADBAND DUAL BRANCH LINE COUPLER

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ABSTRACT

A broadband dual branch line coupler with four ports is designed and proposed in this paper. The dual coupler term means that two different couplers are combined in one coupler. The first branch line coupler is built with only distributed elements such as transmission lines and microstrip lines. The second branch line coupler is distributed, but it is injected with lumped components such as inductors. Switching between these two couplers can be done manually by a mechanical switch used to connect or disconnect the lumped components from the coupler. Both couplers are broadband, but the first couple has only one bandwidth while the lumped-distributed coupler has dual bandwidth. 3D designing, fabrication, simulation, practical measurements are implemented. Moreover, comparison between practical and theoretical results are covered in this study as well. The practical results of both couplers are perfectly agreed with the simulated results. All coupler designs, circuits and simulations are implemented using the Advance Design System (ADS) software.

Keywords: Branch line coupler, Distributed, Dual coupler, Lumped-distributed, Microstrip line, Variable coupler.

INTRODUCTION

Any technology once it comes out, it comes in its first and standard edition. After that, it will be improved and enhanced in the new editions. For example, passive components such as resistors, capacitors, and inductors came out at first in fixed values. Then, they got improved and became available in variable versions like variable resistors, capacitors, and inductors. However, since the invention of couplers till now, couplers have fixed bandwidth ranges, and fixed coupling levels. Converting this classical coupler to a variable coupler or a dual coupler can be done using lumped-distributed technique. By adding lumped components to a distributed coupler, this coupler becomes another new coupler with a different bandwidth, coupling level, or both. Combining these two couplers in one coupler can be achieved by adding a switch. This switch is responsible for connecting and disconnecting the lumped components from the coupler. Therefore, this dual coupler can be set at a required bandwidth range and coupling level. In this case, the proposed switch has only two positions, and that is way this coupler is called the dual coupler. During this study the ability of lumped-distributed technique in improving couplers performances and converting regular couplers to variable couplers will be proved.

Proposed Designs:

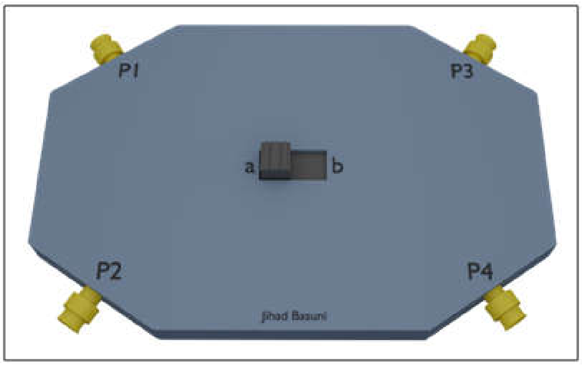

Fig (1): Front side of the dual branch line coupler module

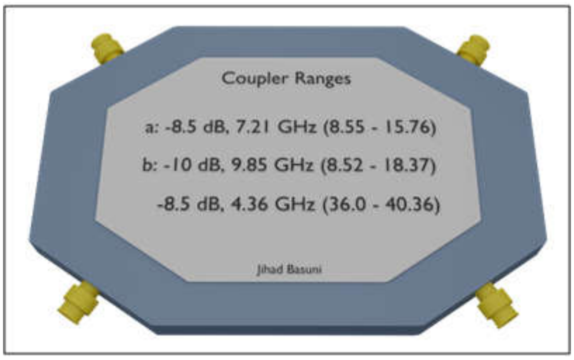

Fig (2): Back side of the dual branch line coupler module

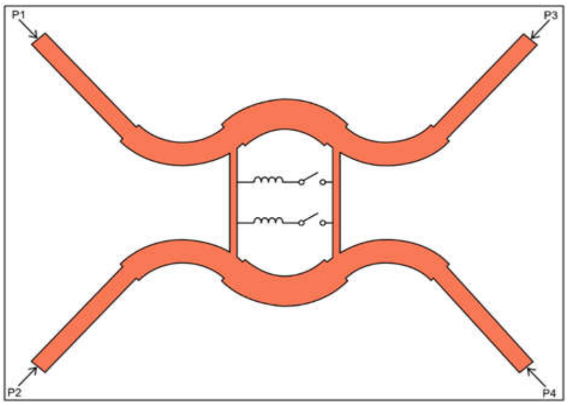

Fig (3): Internal circuit of the dual branch line coupler

The first picture in figure (1) presents the front side of the external case of the dual branch line coupler. It has one mechanical switch that has two positions. Every position is linked specific bandwidth and coupling level as it is shown in the back side of the module in figure (2). At position a, the bandwidth of the coupler is 7.21 GHz from 8.55 GHz to 15.76 GHz, and the coupling level is -8.5 dB. At position b, the couple has dual bandwidths. The first bandwidth ranges 9.85 GHz from 8.52 GHZ to 18,37 GHz, and its coupling level is -10 dB. The second bandwidth ranges 4.36 GHz from 36 GHz to 40,36 GHz, and its coupling level is -8.5 dB. The mechanical switch shown in figure (1) is connected to the internal circuit shown in figure (3). Therefore, this switch can control the two internal switches which are connected to two lumped inductors.

DESIGN & IMPLEMENTATION

This proposed dual variable coupler has two scenarios. Both of them will be presented, studied, and analyzed individually in the following:

A. First scenario, the mechanical switch at position a

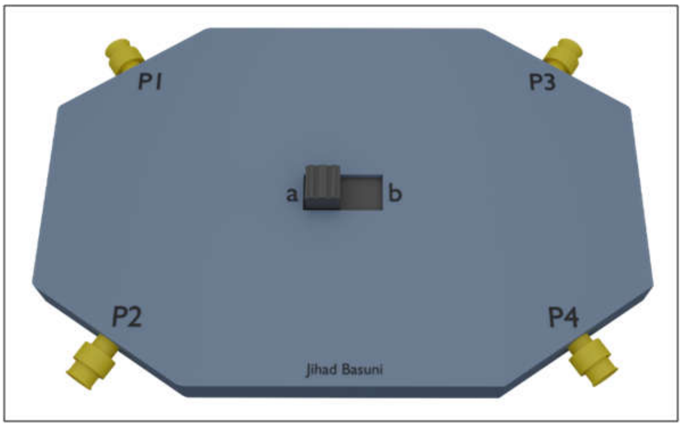

Fig (4): First scenario of the mechanical switch

Having the mechanical switch at the position a makes the two internal switches open as it is illustrated in the following figure (5). This means that the two inductors are not connected to the coupler. Therefore, this coupler is considered as a distributed coupler.

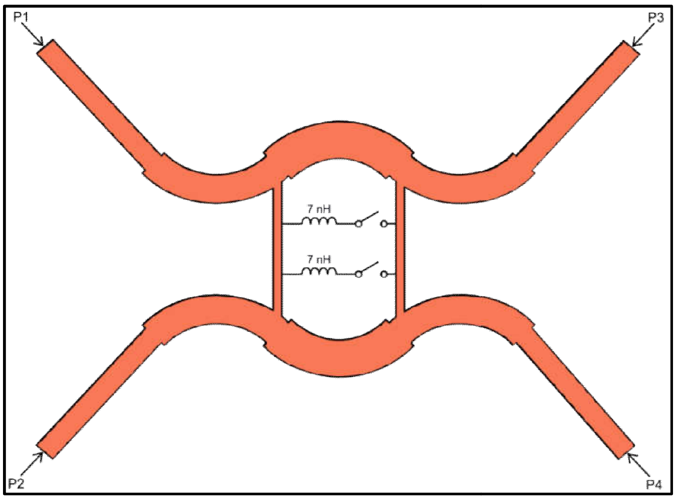

Fig (5): Internal circuit of the dual branch line coupler at position a

The equivalent coupler for the case a is presented in the following as a distributed coupler:

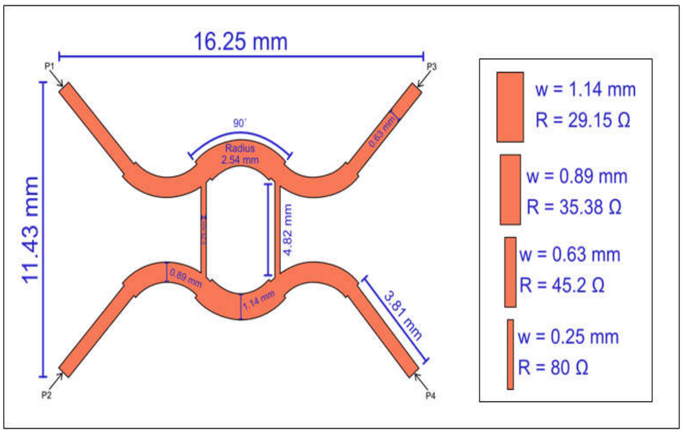

Fig (6): Dimensions & impedances of the dual branch line at position a

From figure (6), all dimensions and impedances are mentioned. The total length of this coupler is 16.25 mm, and its total width is equal to 11.43mm. Regarding the impedances, the transmission line impedance gets effected by two factors: the width of the transmission line and the dielectric constant. This coupler has four different widths of its transmission lines as they are appeared on figure (6). The wider the width is, the lower impedance the transmission line has and vice versa. The dielectric constant (Er) is equal to 2, and the thickness (H) equals 0.168 mm. After running the simulation, the following graph got produced:

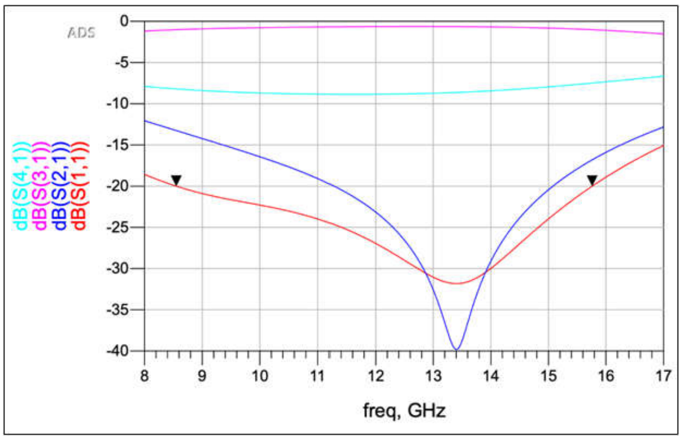

Fig (7): Reflection coefficients of the first scenario

The figure(6) shows that this distributed version has a very wide bandwidth. By looking at S(1,1), the bandwidth is equal to 7.21 GHz from 8.55 GHz to 15.76 GHz, and the entire range is under -20 dB. Therefore, there is no any power can reflect back to the input port as loss. The coupling level represented by the S(4,1) is almost at -8.5 dB for the whole bandwidth range. In terms of the isolation level represented by the S(2,1), the best result can be achieved is under -20 dB, and here in the figure (6),the period from 11.2 GHz to 15 GHz is the only period under -20 dB. The remaining of the isolation range is below -15 dB which is considered acceptable. Moreover, the central frequency is the lowest point of the bandwidth range, so it is almost equal to 13.4 GHz at -32 dB.

These results are simulated. To present the practical results, the fabrication of this coupler has been implemented as following:

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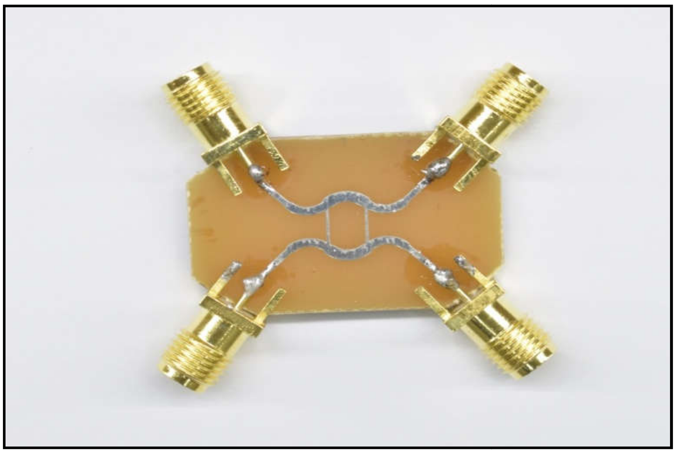

Fig (8): Fabricated coupler of the first scenario

To present the practical measurements, this fabricated coupler has to be connected to an analyzer. The solid line represents the simulated results, and the dashed line represents the practical results as it is shown in the following:

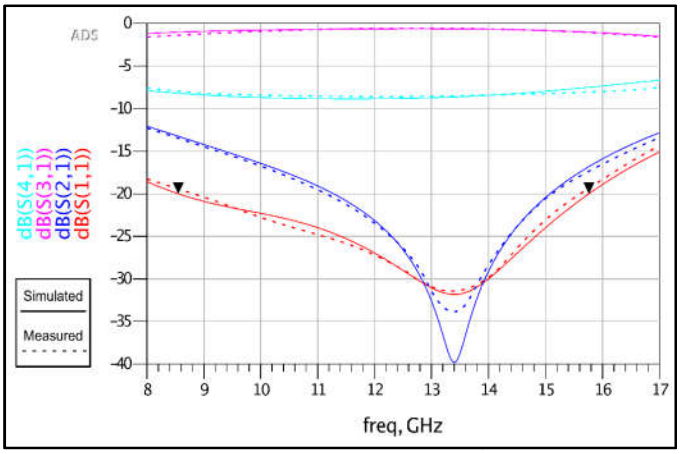

Fig (9): Reflection coefficients of the simulated and practical distributed branch line coupler

It can be seen that for all parameters S(1,1), S(2,1), S(3,1), and S(4,1), the practical measurements almost match with simulated measurements. Therefore, all these tiny differences can be neglected because they have no effect on the coupler performance.

However, to improve the coupler performance, change its coupling level, or move to another bandwidth, there is no need to have another coupler. Instead, the switch has to be moved to the position b as it is shown in the following:

B. Second scenario, the mechanical switch at position b

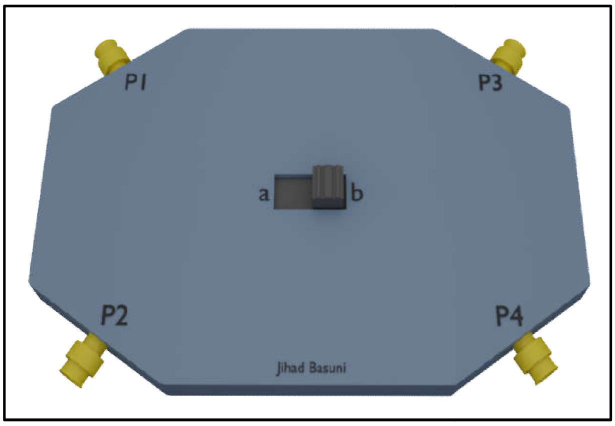

Fig (10): Second scenario of the mechanical switch

Having the mechanical switch at the position b makes the two internal switches closed as it is illustrated in the following figure (11). This means that the two inductors are connected to the coupler. Therefore, this coupler is considered as a lumped-distributed coupler.

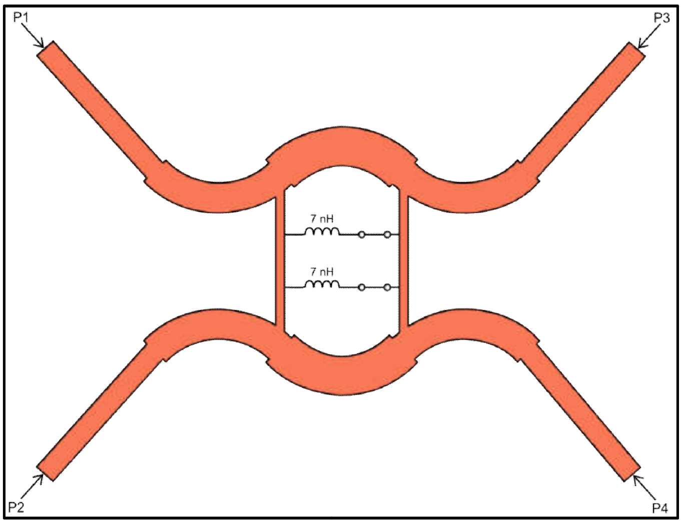

Fig (11): Internal circuit of the dual branch line coupler at position b

The equivalent coupler for the case b is presented in the following as a lumped-distributed coupler:

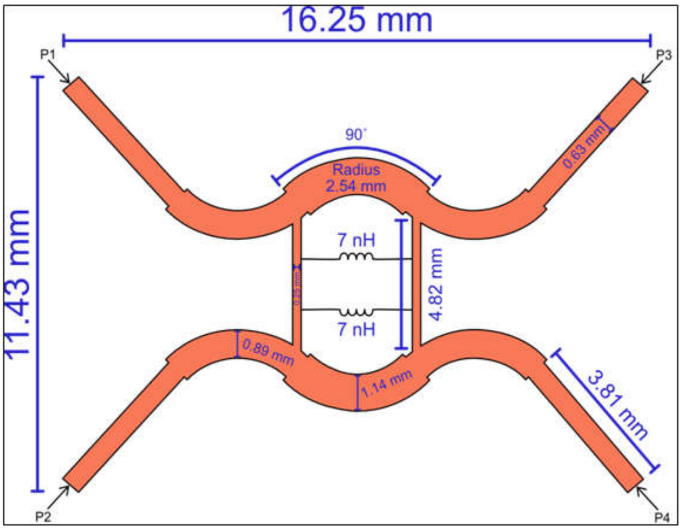

Fig (12): Dimensions of the dual branch line at position b

Apart from having two lumped inductors, the coupler in the case b is exactly the same as the coupler in the case a. Both have same dimensions, impedances, thickness, and dielectric constant. However, even though adding two lumped inductors is a minor change, there is a big and noticeable improvement in the coupler performance. Unlike the case a, the coupler in the case b has dual bandwidths. The first bandwidth is an improved version of the bandwidth of the case a, and the second bandwidth is a new range that does not exist in the case a. These two ranges can be seen in the following:

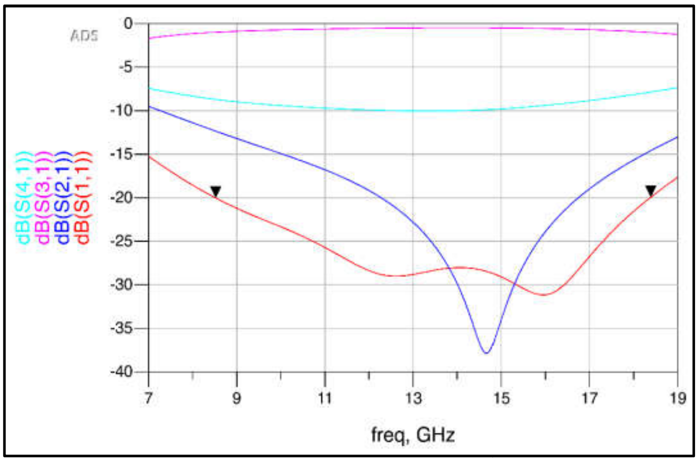

Fig (13): Reflection coefficients of the first bandwidth of the second scenario

The first bandwidth range is presented in figure(13). This range is wider than the case a range by around 2.5 GHz. According to the S(1,1), this bandwidth ranges 9.85 GHz from 8.52 GHz to 18.37 GHz while the bandwidth of the case a ranges 7.21 GHz. It is clear that the entire bandwidth range is under -20 dB, so the reflection is almost zero. The coupling level represented by the S(4,1) is around -10 dB for the whole bandwidth range. In terms of the S(2,1) which refers to the isolation level, the period from 12.3 GHz to 16.8 GHz is the only period under -20 dB. However, the period from 10 GHz to 12.3 GHz and the period from 16.8 GHz to 18.37 have an acceptable of the isolation levels because they are under -15 dB. The last parameter is the S(3,1) which refers to the transmission. This parameter has a very good value that has no comments Moreover, the central frequency is around 16 GHz.

Now, it has been obvious that adding lumped components to a distributed coupler can improve its performance dramatically. The other bandwidth range is showing in the following:

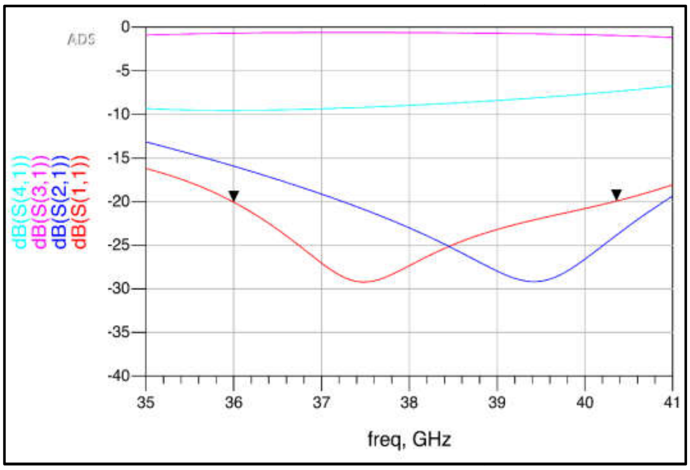

Fig (14): Reflection coefficients of the second bandwidth of the second scenario

According to the S(1,1), this second bandwidth is not that wide but is considered very good. It ranges from 36 GHz to 40.36 GHz. This means that the whole bandwidth range is 4.36 GHz under -20 dB. The isolation level is very good. It is acceptable from 36 GHz to 37.2 GHz because it is under -15 dB, and it is perfect from 37.2 GHz to 40.36 GHz because it is under -20 dB. The average of the coupling level is -8.5 dB according to the S(4,1). Moreover, the central frequency is around 37.4 GHz.

These results are simulated. To present the practical results, the fabrication of this coupler has been implemented as following in figure (15):

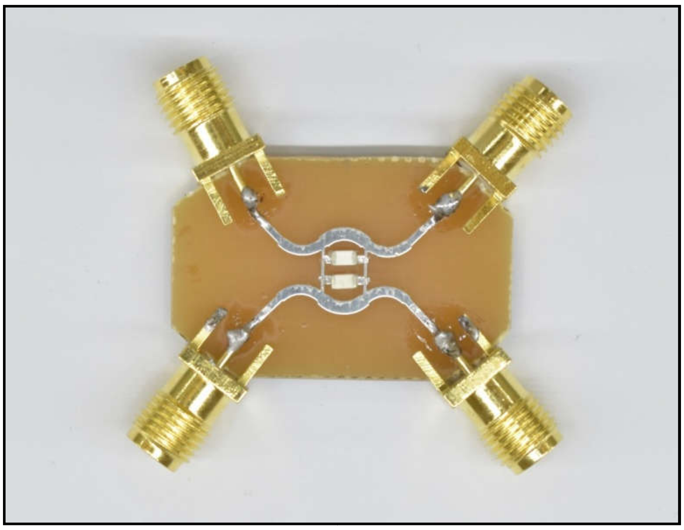

Fig (15): Fabricated coupler of the second scenario

To present the practical measurements, this fabricated coupler must be connected to the analyzer. The solid line represents the simulated results, and the dashed line represents the practical results as it is shown in the following:

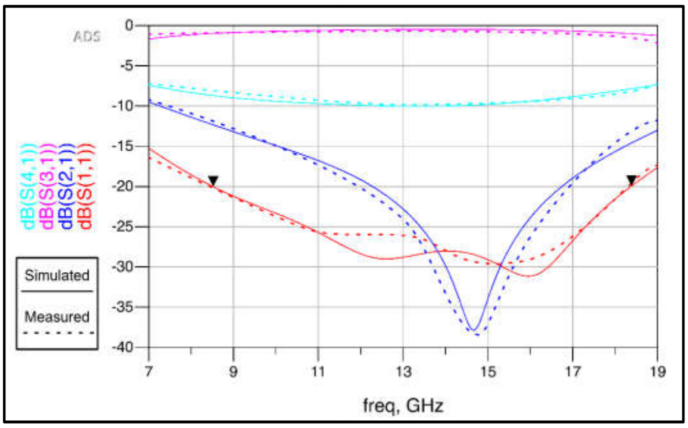

Fig (16): Reflection coefficients of the simulated and practical first bandwidth of the lumped-distributed branch line coupler

The second bandwidth of the case b:

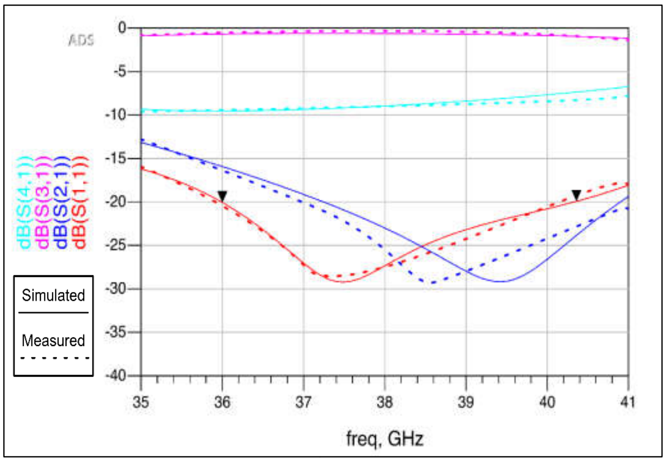

Fig (17): Reflection coefficients of the simulated and practical second bandwidth of the lumped-distributed branch line coupler

From these two graphs in figure (16) and figure (17), it is easy to notice that there are no to much differences between simulated and practical results, and all these differences can be ignored because they do not have serious impacts on the coupler performance.

CONCLUSION

To sum up, building branch line couplers is normal, but combining two branch line couplers in one variable coupler is novel. Furthermore, it is obvious that adding lumped components to a branch line coupler is not only can improve the coupler performance, but it is able to convert that coupler to a new coupler with a different bandwidth and different coupling level.

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