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Research Article

IMPROVING DISTRIBUTED BRANCH LINE COUPLER PERFORMANCE BY ADDING LUMPED COMPONENTS

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ABSTRACT

A four port branch line coupler is designed and introduced in three versions. The first version is the distributed branch line coupler which is only made of microstrip lines. The second and the third versions are lumped-distributed branch line couplers which are made of microstrip lines and lumped resistors. Both schematic diagram and layout diagram are designed and presented for each version of the proposed couplers. Moreover, a comparison of the performances of the distributed coupler and the lumped-distributed coupler is conducted, and also a comparison between the two lumped-distributed versions is conducted. Each version of these couplers is analyzed and simulated. In addition, the theoretical analyses are almost matching with the simulation results. All proposed designs and their simulations are implemented and produced using the Advance Design System (ADS) software.

Keywords: Branch line, Coupler, Distributed, Lumped-distributed, Microstrip line.

INTRODUCTION

Nowadays, after the technology revolution, improving the wireless communication network is demanded to meet users' needs in the present and the future. This network is an integrated system that forms of lots of units and parts. One of these parts is called the coupler used to split an incoming signal to two or more signals. Improving a coupler performance can be done by more than one way. For example, reducing the size of the coupler is one way to enhance that coupler. Furthermore, extending the bandwidth range and changing the coupling level of that coupler. Reducing the size of the coupler can be achieved by using lumped components, and extending the range of the bandwidth can be accomplished by using distributed elements. Therefore, the new technique here is mixing these two types of elements the lumped and the distributed elements in one design in order to take advantage of them both. As a result, building a coupler using lumped-distributed technique is able to create a small size coupler with wide range of bandwidth. In addition to that, this new technique can be also useful with fabricated couplers. Adding lumped components such as resistors, capacitors, and inductors to distributed couplers may improve their performances as it will be proved in this paper.

Proposed Designs:

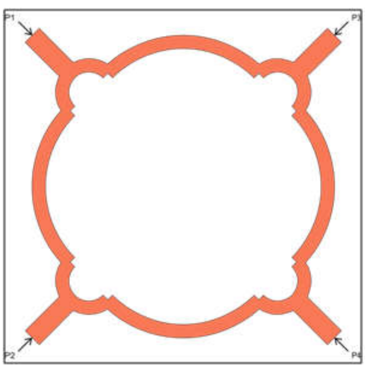

Fig (1) : Distributed branch line coupler

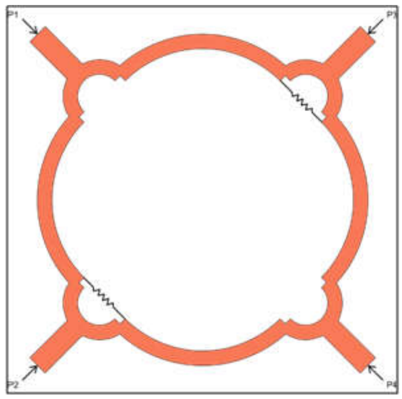

Fig (2) : Lumped-distributed branch line coupler v1

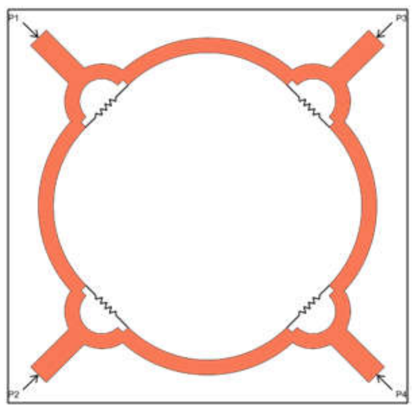

Fig (3) : Lumped-distributed branch line coupler v2

As it is shown in these three figures, the first branch line coupler is formed only of distributed elements. However, the other two couplers are lumped-distributed which are built of lumped and distributed elements. One of these two lumped-distributed couplers is constructed with two lumped resistors, and the other one is constructed with four lumped resistors.

DESIGN & IMPLEMENTATION

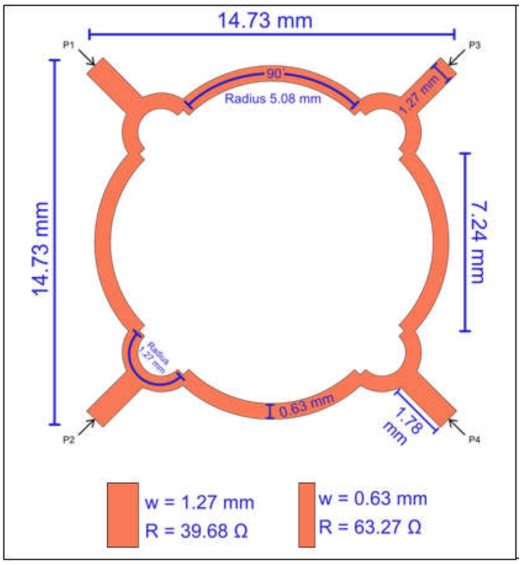

Fig (4) : Dimensions & impedances of the distributed branch line coupler

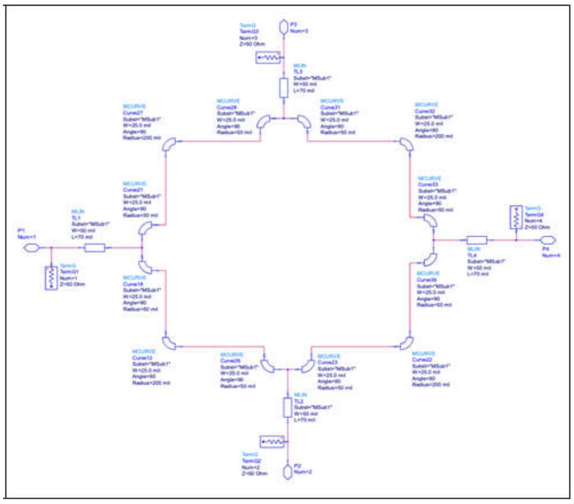

Fig (5) : Schematic diagram of the distributed branch line coupler

It can be noticed that the shape of this branch line coupler looks like the quatrefoil shape, and its total length and width are equal to 14.73 mm. The width of the main microstrip lines is 0.63 mm, and the width of ports branches are 1.27 while their lengths equal 1.78 mm. Additionally, the thickness of the design is H = 0.280 mm, and the dielectric constant is Er = 2.5. Moreover, in terms of impedance, this coupler is made of two variant widths. The first one has a width that equals 1.27 mm, so its impedance is 39.68 Ω. The second width is equal to 0.63 mm, so its impedance is 63.27 Ω.

After running the simulation, the following results are presented:

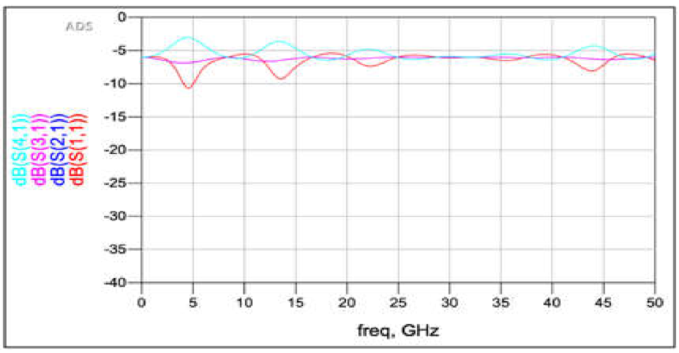

Fig (6) : Reflection coefficients of the distributed branch line coupler

According to the graph shown in the figure (6), the S(1,1) refers to that there is no any good bandwidth for the entire period from 0 GHz to 50 GHz because the reflection on the input port is too high. Furthermore, Looking at the S(4,1), the isolation level is very bad, and this means that a huge amount of the input signal is detected on port 4 as losses. Even though the coupling level represented by the S(2,1), the transition level represented by the S(3,1) are showing very good results, this distributed coupler is not practical and has to be fixed. The theoretical analysis of this distributed coupler is presented in the following:

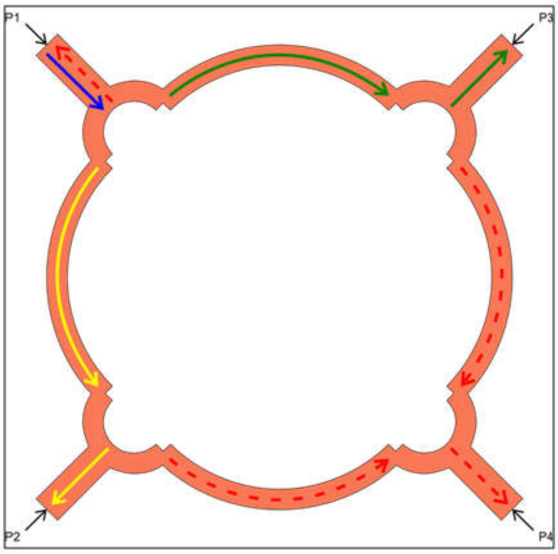

Fig (7) : Theoretical analysis of the distributed branch line coupler

It is obvious that this coupler is symmetrical, so using any port as an input port gives same results. According to the figure 6, the input port is the port 1 (P1). The input signal is represented by the blue arrow, and then it divides to two signals. One is going toward the port 2 called the coupled signal, and the other is going to the port 3 called the transmitted signal. However, due to impedance mismatch a reflection of the input signal is detected as loss getting back to the same input port. Similarly, not the complete signal can reach the port 2 and 3. Some parts of the coupled and transmitted signals can escape toward port 4 as losses. Fixing this coupler can be done as following:

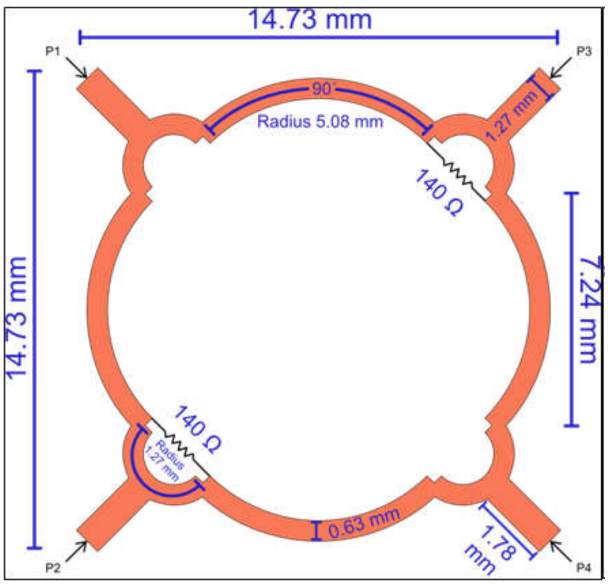

Fig (8) : Dimensions of the lumped-distributed branch line coupler v1

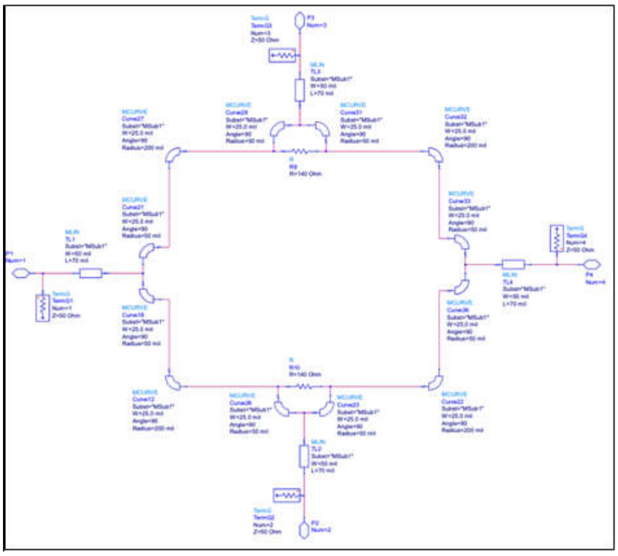

Fig (9) : Schematic diagram of the lumped-distributed branch line coupler v1

In this version there is no any change from the main distributed design except adding two lumped resistors with the value 140 Ω. One resistor is parallel with the port 3, and the other is parallel with the port 2. After running the simulation, the effect of lumped resistors appears in the following graph:

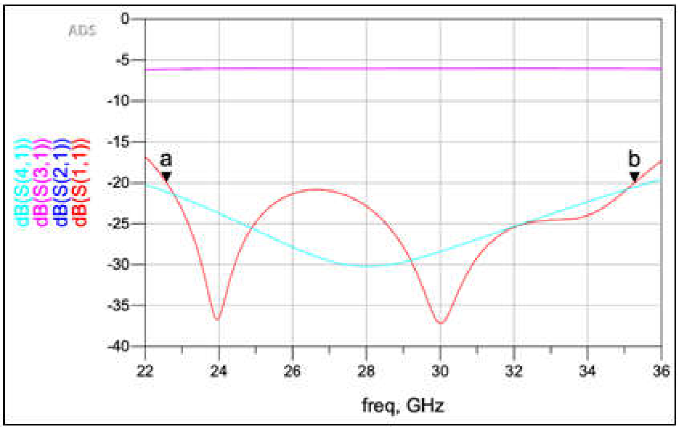

Fig (10) : Reflection coefficients of the lumped-distributed branch line coupler v1

According to the S(1,1), the bandwidth becomes ultra-broadband that ranges from 22.58 GHz till 35.27 GHz. This means that the bandwidth range is equal to 12.69 GHz, and for this range, the level of the S(1,1) is under -20 dB which means that there is no any return loss on the input port. Similarly, for the whole bandwidth, the isolation level represented by the S(4,1) is under -20 dB as well, and this means that there is no power leaking as loss on the port 4. Regarding the transmitted and coupled powers, both levels are at -6 dB which is a very good level for real life applications. The theoretical analysis of this version is shown in the following:

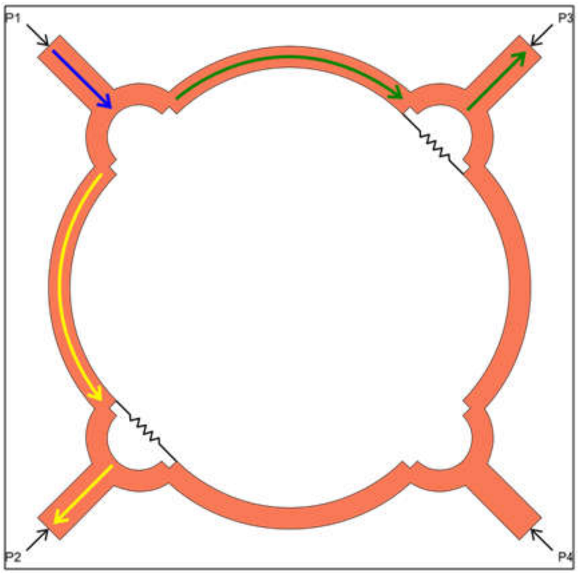

Fig (11) : Theoretical analysis of the lumped-distributed branch line coupler v1

As it is shown in the previous graph in the figure (10), the input signal gets into the coupler from port 1. It can be noticed that there is no any reflected that reflects back to the port 1 as loss, and this is attributed to the fact that these two lumped resistor makes the coupler impedances are matched. After that, the input signal divides to two signals. The transmitted signal goes directly to the port 3, and the coupled signal goes directly to the port 2. Additionally, unlike the distributed branch line coupler shown in the figure (4), this coupler has almost zero power leaking come out from the port 4. This is because the two lumped resistors block the way in front of the signals, so the only ways for signals are the port 3 and port 2.

Overall, this lumped-distributed version is perfect, but it has only one issue. The issue is that this coupler is not symmetrical. This means that not all ports can be used as an input port, but only the port 1 and the port 4 can be used as an input port. If the port 2 or port 3 is used as an input port, the two resistors become useless, and the results become so bad as it is shown in the following:

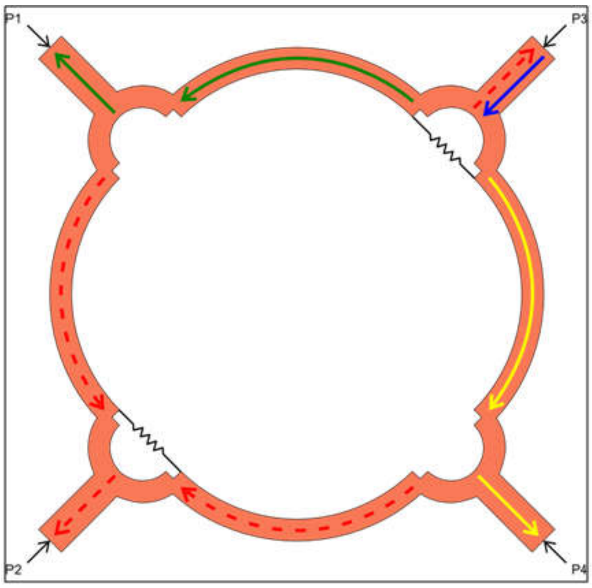

Fig (12) : Theoretical analysis of the second case of the lumped-distributed branch line coupler v1

In this case, the input signal gets inside the coupler from the port 3, and then it divides to two signals. One signal goes toward port 1,

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and the other goes toward port 4. Because there is no resistor on the port 1 and port 4, parts of both signals can leak and go toward port 2 as losses. As a results, impedance matching is not achieved, and the reflected power on the input port can be detected. The simulation graph of this case can be found in the following:

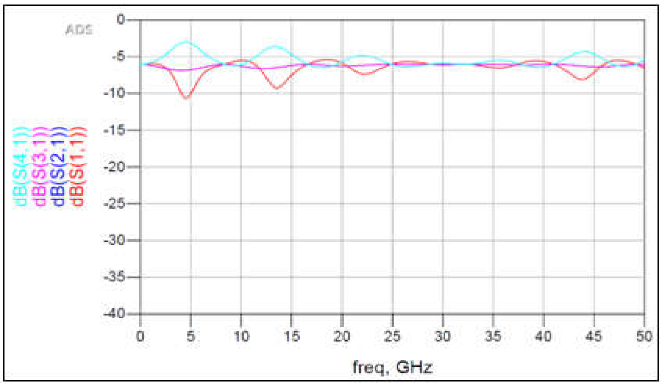

Fig (13) : Reflection coefficients of the second case of the lumped-distributed branch line coupler v1

This problem can be solved by adding two more lumped resistors as following:

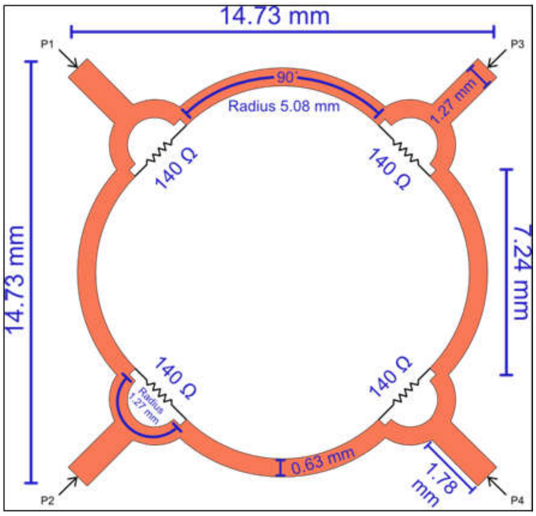

Fig (14) : Dimensions of the lumped-distributed branch line coupler v2

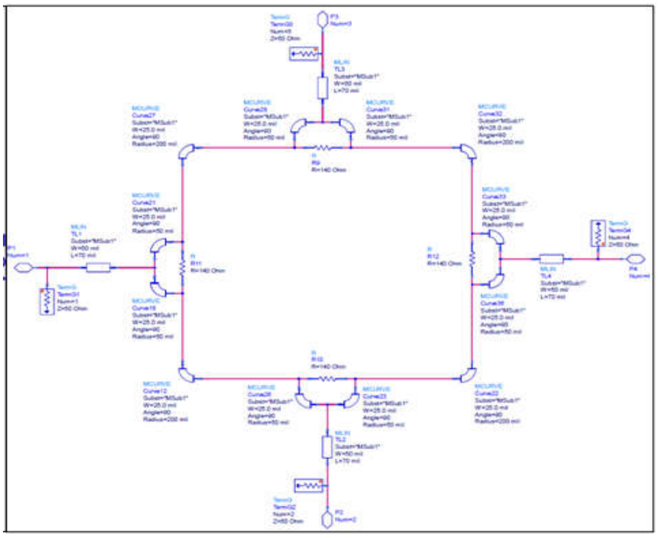

Fig (15) : Schematic diagram of the lumped-distributed branch line coupler v2

In this lumped-distributed coupler, there are four lumped resistors connected in parallel with each port. Now, this coupler is symmetrical, and any port can be used as an input port. After running the simulation, the next graph is presented:

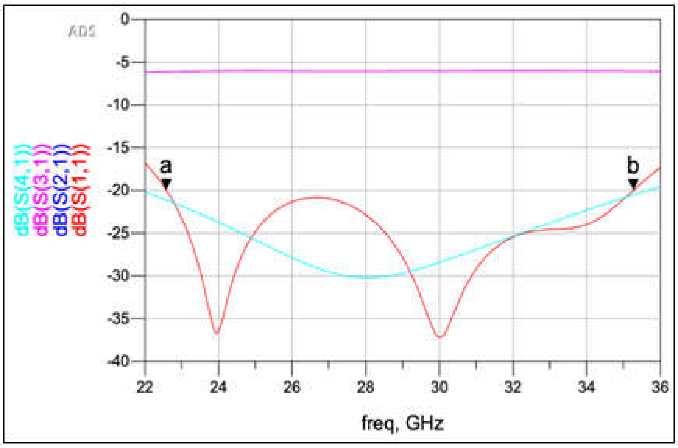

Fig (16) : Reflection coefficients of the lumped-distributed branch line coupler v2

It can be noticed that there is no any change in the performance after adding two more resistors. The same performance is achieved by having only two resistors in the previous version. However, the advantage of having four resistors is making the system symmetrical. The theoretical analysis of this lumped-distributed version is shown in the following:

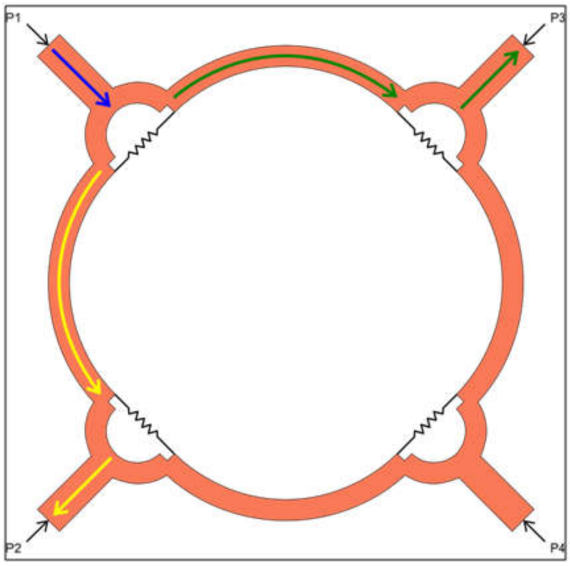

Fig (17) : Theoretical analysis of the lumped-distributed branch line coupler v2

Using any port as an input port leads to the same results which is already explained and discussed earlier in the second version in the figure (11).

CONCLUSION

In conclusion, the main function of the coupler is dividing the incoming signal. While the majority of couplers are distributed, this paper proves that injecting lumped components into distributed couplers can improve that couplers performances. Moreover, adding lumped components can help in impedance matching, and also block any power leak.

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