Sonnet Modelling and Simulation of Broadband Branchline Coupler

Abdulkadir Yilmaz [1], Emine Rumeysa Cetiner [1], and Moamer Hasanovic [1]

[1] Faculty of Engineering and Natural Sciences (FENS)
International University of Sarajevo, Hrasnicka Cesta 15, 71210 Ilidza Sarajevo, Bosnia-Herzegovina
abdlkdrylmz@gmail.com, era.ylmaz@gmail.com, mhasanovic@ius.edu.ba

Abstract: Modern communication systems need various hybrids to enable digital data transmit via microwave bands. Thus, several types of microwave quadrature hybrids have been reported for the realization of balanced circuits, matched attenuators, and phase shifters. The branch-line coupler is one of the most popular hybrids for the convenience of design and implementation. But, it offers limited bandwidth and requires a large circuit area [1]. Thus, in this paper, a study and investigation of the simulation performance of subdivision of the multisectional broadband branchline coupler is to be carried out using SONNET®. The purpose is to overcome problems with regard to high memory space usage and time consumption due to large circuitry of broadband branchline coupler with the goal of increasing the bandwidth at the same time. The simulation results of the full model is to be compared to that of sub-models to evaluate potential differences in the performance and further examination would be conducted in terms of having more sections added to the broadband branchline coupler to study the multisectional branchline hybrid from performance and size point of view. The results of this study are to be reported and presented in this work.

Keywords: Broadband Branchline Hybrid, 90° Hybrid, Multisection Branchline Coupler, SONNET®

1. Introduction

A branchline hybrid is a special case of directional coupler with a coupling factor of 3 dB and a 90° phase difference in the outputs of the through and coupled arms. It has a high degree of symmetry since any port can be used as the input port, with output ports always being on the opposite side of the junction from the input port, and the isolated port remaining on the same side as the input port [2]. The 90° phase difference alters over ±5° for a 10% change in frequency around the center frequency [3].

Branchline hybrids are widely used in the actualization of microwave circuits such as data modulators, phase shifters, discriminators, attenuators, balanced mixers, and power combined amplifier circuits [3,4]. In practice, the bandwidth of a single section branchline hybrid is limited to 10-20% due to the quarter wavelength requirement. Therefore, branchline hybrids are modeled in cascades as multisection broadband hybrids to increase the bandwidth significantly to higher rates [2].

A coupled line configuration can be used instead to achieve a higher bandwidth over a multi section branchline hybrid, but these are difficult to be actualized if microwave monolithic integrated circuit (MMIC) implementation is used since branchline couplers offer the advantage of being realized using slot lines in the ground plane of a microstrip circuit. This may be an important factor if hybrid is to be a part of a larger MMIC circuit [4].

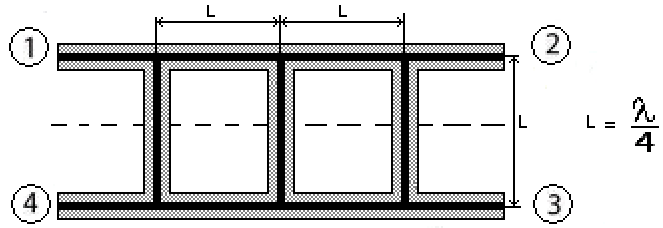


Fig. 1. Two-section broadband branchline hybrid with line lengths L.

2. Design and Simulation of the Broadband Branchline Coupler

The broadband branchline coupler is designed in stripline technology which has two conductors and a homogeneous dielectric and supports TEM wave as its usual mode of operation [2]. The dielectric layers are selected to be ROGERS RO3003 with a dielectric constant of 3 and a thickness of 60 mils. As a choice of metal, copper is used and the frequency band of the broadband branchline coupler is centered to operate at 10 GHz.

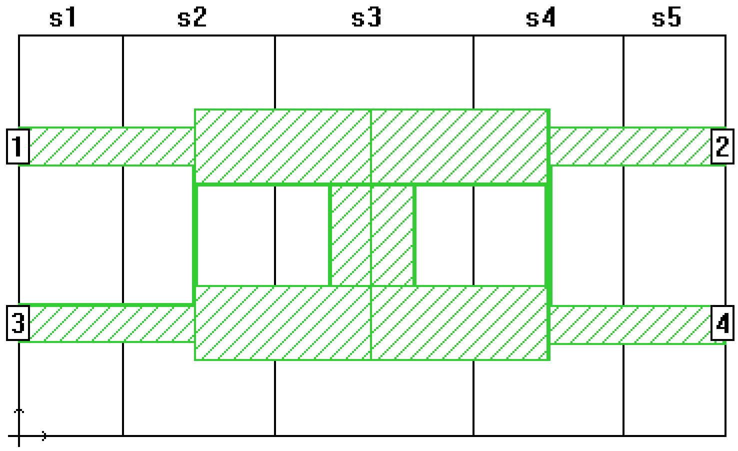
All these specifications are integrated into the geometrical design of the two-section branchline coupler and simulated in SONNET® [5].

SONNET® provides the capability to take a large circuit and split it into any number of smaller projects, then connect the results in a netlist project to produce a response for the whole circuit. This method can significantly reduce the required processing time and memory necessary to analyze the circuit while still obtaining an accurate answer [5]. Therefore, the multisection broadband branchline coupler can be split into sub-models in such a way that no coupling across the subdivision line should take place and all the significant coupling in the model is accounted for the accuracy of results to be high.

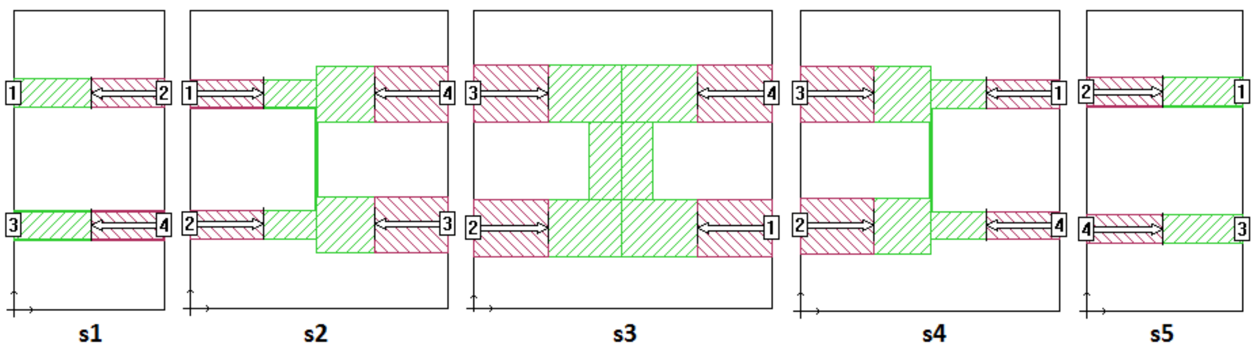
In order to accomplish subdivision of broadband multisection branchline hybrid, the properties of the circuit must be fully fed with appropriate data such as metal types, grid sizes, dielectric layers, etc. because the created sub-models inherit these attributes. The location of the subdivision must be decided carefully which may require special expertise as splitting the model at a junction with a coupling across subdivision line has to be avoided. After determining the place of subdivision, the lines are to be created which are used to form the subprojects. These smaller projects are composed of smaller geometries and hence they require less memory and time to be run during the simulation phase. The netlist project is to be analyzed and the data response will provide the results for the whole circuit [5].

Another approach that can be undertaken is that the division can take place using SONNET®'s co-calibrated ports. Co-calibrated ports are internal ports that are de-embedded as a group with a common ground. When em performs the electromagnetic analysis, the co-calibrated ports within a group are simultaneously de-embedded using a high accuracy de-embedding technique; thus, coupling between all the ports within a calibration group is removed during de-embedding. Apart from this, it, also, gives the ability to take S-parameter data from SONNET® and connect devices or models to the accurately de-embedded ports. The method for using the co-calibrated ports would be to remove sections of metal for ease of tuning. EM simulation could be run once with high accuracy and then with less accuracy or even circuit theory could be used to tune the lengths. In order to verify the results, another EM analysis can be run with high accuracy. With co-calibrated ports, the circuit can be broken down into one or more projects with different meshing even if the geometry rests inside the internal ports [5].

Fig. 2. (a) shows the subdivision lines drawn for the two-section branchline coupler using the guidelines mentioned above and the latter Fig. 2. (b) is the generated subprojects with smaller geometry. These are analyzed and simulated individually as s1, s2, s3, s4, and s5, separately, and then combined together and re-simulated and the results are obtained to achieve higher accuracy and less processing time.



(a)



(b)

Fig. 2. (a) Two section broadband branchline coupler with subdivision lines added.
(b) Generated subprojects.

3. Simulation Results

The broadband branchline hybrid with optimized impedances of quarter wave branches is illustrated in the Fig. 3. which is used as a base to model the corresponding geometry in SONNET® shown in Fig. 4. The choice of the level of meshes to be used had a great effect on the time and results of the simulation as the number of cells created would be higher taking more memory space and, hence, reducing the pace of the simulation. More accurate results would be obtained with a finer mesh. Thus, for better results, the finest mesh is used as a choice in setting up the simulation.

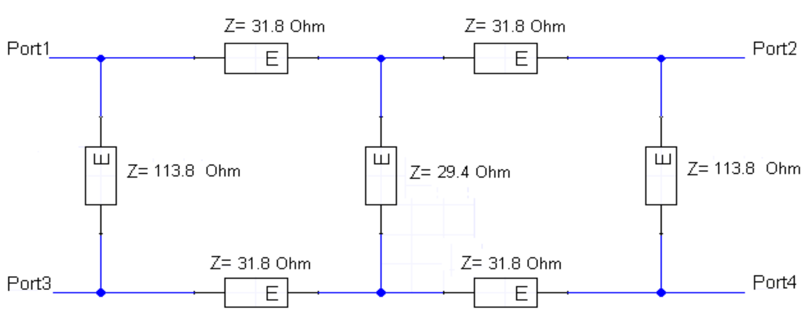


Fig. 3. Two-section branchline hybrid with optimized impedances of quarter wave branches.

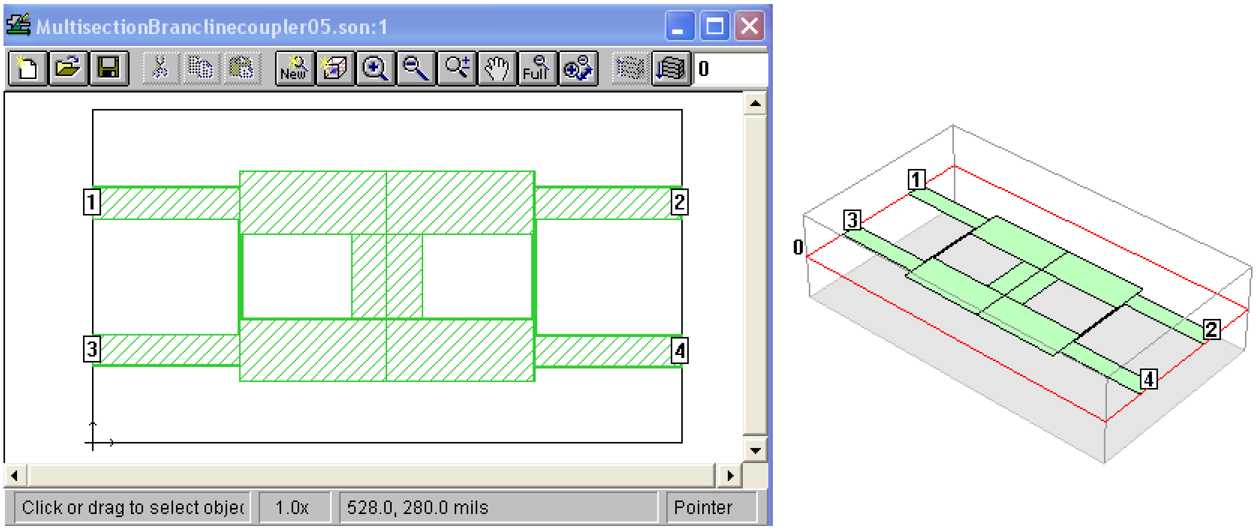


Fig. 4. SONNET Model and its respective 3D view in right side.

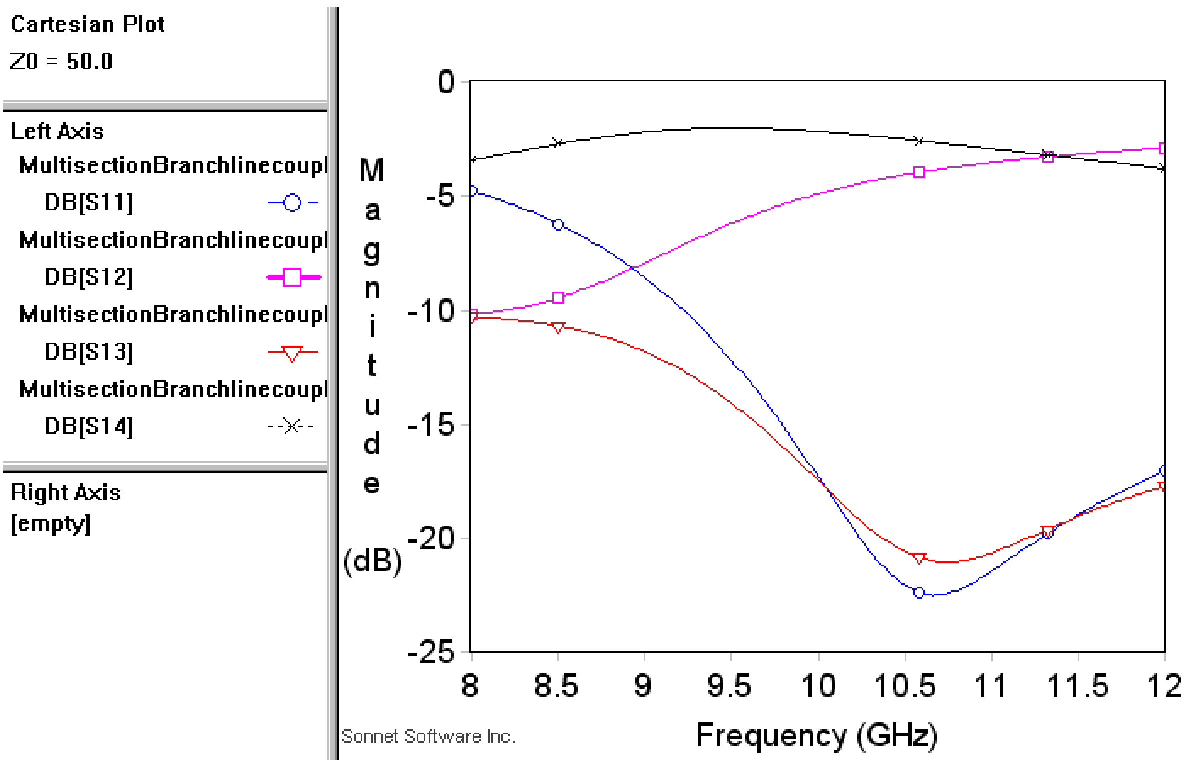


Fig. 5. S-parameters of the broadband branchline coupler.

From Fig. 5, it can be clearly observed that the input coefficient reflection is at -5 dB in the beginning where the frequency is 8 Ghz and it decreases to -20 dB at approximately 10.5 Ghz and again becomes better by rising to -17 dB at frequency of 12 Ghz. At 10.5 Ghz, -4 dB of coupling is achieved and the through port is almost -2.6 dB at this frequency. The isolation port follows the pattern of input port with some significant changes near 10.5 GHz.

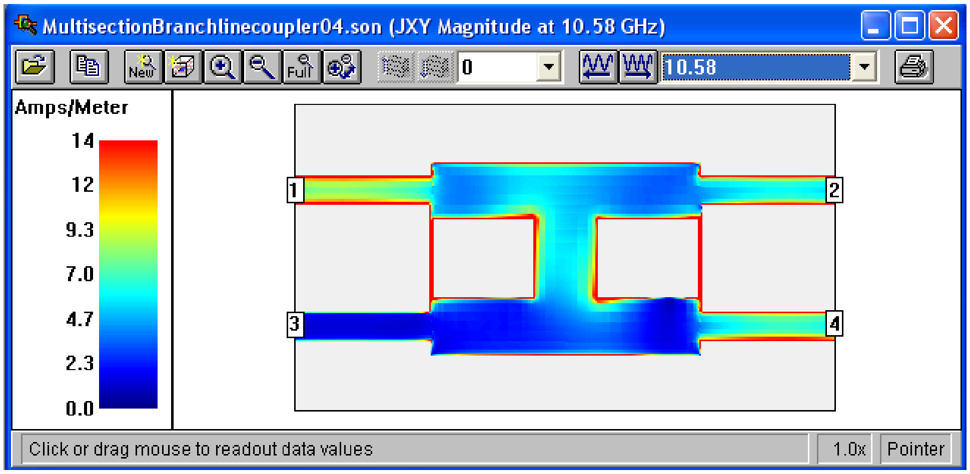


Fig. 6. Current distribution of broadband branchline coupler.

Fig. 6. indicates the distribution of the current through the arms of the multisectional branchline coupler at 10.58 GHz where current is crowded in the mid branches and finds a path to the coupled and through port from the input port. The isolated port is observed to have almost no current but there is also less power travelling to the coupled arm.

4. Conclusions

In this paper, a cascaded two-section broadband branchline coupler has been designed and simulated using SONNET® to have low input VSWR and high isolation over a wider bandwidth. The results of the simulation provide satisfactory results with a deviation of 5% in the frequency band. The increase achieved in the bandwidth however causes a higher amount of loss in the second section of the branchline coupler. Apart from this work, in this paper, broadband branchline couplers with two, three, and four sections are to be studied and simulated using the subdivision concept described earlier. All the data related to the simulation time and memory usage would be generated to draw conclusions on whether the subdivision of geometry brings advantages in terms of better processing time and memory usage while achieving a better bandwidth. Also, the concept of co-calibrated ports would be applied as another approach which offers highly accurate de-embedding. The accuracy of the simulation by refining the cells and applying the outlined approaches would be examined for the broadband branchline coupler and the results would be compared against each other. For further future studies, optimization techniques can be applied to the design of a broadband branchline hybrid using SONNET® to enhance the desirable coupler characteristics of constant coupling. In addition to this, the analyzed and simulated two-section hybrid coupler can be fabricated to measure and compare its practical performance against the simulation results found.

References

[1] Y. H. Chun, and J. S. Hong, “Compact Wide-Band Branch-Line Hybrids,” IEEE Trans. Microwave Theory and Techniques, vol. 0018-9480, 2006.
[2] D. M. Pozar, *Microwave Engineering*, John Wiley & Sons, Inc., USA, 2005.
[3] I. Bahl, and P. Bhartia, *Microwave Solid State Circuit Design*, John Wiley & Sons, Inc., New Jersey, 2003.
[4] S. Kumar, C. Tannous, and T. Danshin “A Multisection Broadband Impedance Transforming Branch-line Hybrid,” *IEEE Trans. Microwave Theory and Techniques*, Vol. 43, No 11, 1995.
[5] Sonnet User Guide, Release 12. Sonnet Software, Inc.. North Syracuse, NY 13212, USA, April 2009.