Compact Branch Line Coupler with Rectangular Defected Ground Structure (DGS) for 6G

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Abstract - This Article presents a Compact Branch Line Coupler operating at 95 GHz using FR4 substrate εr = 3.4 for Radar Applications with Rectangular Defected ground structure at the Ground Layer using ADS tool .The Designed Coupler exhibits , The Return Loss (S11), Insertion Loss (S21), Coupling Factor (S31), Isolation Value (S14) . The proposed DGS design confers size reduction because of the shift of the operating frequency to higher values.

Key Words: Defected Ground Structure, Compact Branch Line Coupler

1.INTRODUCTION

Couplers are widely used in microwave circuit design. A very commonly used basic element in microwave system is the directional coupler[14]. Directional couplers are the key passive microwave components used for distributing or tapping signals in various microwave subsystems such as power amplifiers, detectors, modulators, mixers, phase shifters, and antenna arrays for the use in communication systems[9]. Printed edge-coupled line directional couplers are well known and require a close spacing (less than 100 μ) to achieve the tight coupling [6]. This poses a constraint in the fabrication using the printed circuit board (PCB) technologies, and hence, limits the applications of these couplers. Its basic function is to sample the forward and reverse travelling waves through a transmission line or a waveguide. The common use of this element is to measure the power level of a transmitted or received signal. The model of a directional coupler is shown in Figure 1. [4]

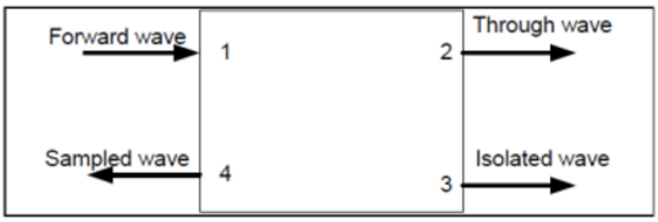

Fig 1. Physical Model of Directional Coupler

Directional coupler model As seen in the figure is a four-ports device. The forward travelling wave goes into port 1 and exit from port 2. A small fraction of it goes out through port 4. In a perfect coupler, no signal appears in port 4. Since the coupler is a lossless passive element, the sum of the signals power at ports 3 and 2 equals to the input signal power. The reverse travelling wave goes into port 2 and out of port 1. A small fraction of it goes out through port 3. In a perfect coupler, no signal appears in port 4.

. There are few simple parameters to describe the functionality of a coupler

- Insertion Loss: 20 log(S21)
- Return Loss: 20 log(S11)
- Coupling: 20 log(S31)
- Directivity: 20 log(S31) − 20 log(S41).

Recently, there has been an increasing interest in studying the microstrip line with various periodic structures including photonic bandgap (PBG) and defected ground structure (DGS) [1]-[8]. Each .periodic structure has its own properties and advantages. DGS, which is realized by etching only a few defects on the ground plane under the microstrip line, is also a kind of periodic structures [4]. Most of PBG applications are limited to providing deep and wide stopband performance for circuits. [1]-[2] Meanwhile, DGS has prominent advantage in extension its applicability to other microwave circuits such as filters, dividers, couplers, amplifiers, and so on. [3]-[8] PBG has been also used in filter designs to improve stopband performance by rejecting the higher order passbands, due to its inherent stopband behavior. Specially, both PBGs and DGS have been very effectively used to terminate the harmonics for power amplifiers. However, it is very difficult for implementing the PBGs or DGS circuits for the purposed of the harmonic termination to satisfy simultaneously the excellent passband and stopband characteristics [3]. In this paper a microstrip directional coupler is designed first and then a Rectangular shaped ground plane is used underneath the coupler To extract design parameters such as characteristic impedance and electrical length, S-parameters for an DGS section microstrip line are calculated using the finite element method (FEM)[7].

2. Proposed Design

The configuration of the proposed directional coupler is shown in Figure 1. The top layer contains the Branch Line Coupler, while the ground plane is in the bottom layer. There is a Defected ground structure on the ground plane below the coupled lines. The 3 dB coupled branch coupler requires quarter-wave transmission lines with 50 ohms and 35.6 ohms,

For both ideal - forward and backward - couplers the ref lection coefficients are zero. Port 1 is called the insertion port. Port 2 is the transmission port. In a forward coupler port 3 is the coupled port and port 4 is called the isolated port. In a backward coupler it's the other way around. The reduction in size and the Frequency Shift in the proposed DGS coupled line coupler structure are described.[14]

With reference to Figure 1, the basic operation of the branch-line coupler is as follows. With all ports matched, power entering port 1 is evenly divided between ports 2 and 3, with a 90◦ phase shift between these outputs [11] .No power is coupled to port 4 (the isolated port). The scattering matrix has the following form:

$$[S] = \frac{-1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}.$$

Fig 2. S-Parameters of Ideal Directional Coupler

Observe that the branch-line hybrid has a high degree of symmetry, as any port can be used as the input port. The output ports will always be on the opposite side of the junction from the input port, and the isolated port will be the remaining port on the same side as the input port. This symmetry is reflected in the scattering matrix, as each row can be obtained as a transposition of the first row.[9]

The Branch line coupler is designed for 95 GHz , with the addition of Rectangular Defected Ground Structure at the Ground Layer using FR-4 Substrate

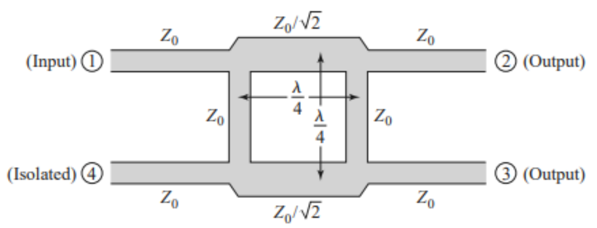

Fig 3. Branch Line Coupler Equivalent Model

Zo= 50 ohms

Zo/1.414 = 35.36

For 50 ohm Microstrip Line , Physical Parameters of Microstrip Line is

Length of Microstrip line = 54.7 mil

Width of Microstrip Line = 25.7 mil

For 35.36 ohm Microstrip Line , Physical Parameters of Microstrip line is

Length of Microstrip Line = 53.5 mil

Width of Microstrip Line = 42.6 mil

Physical Dimensions of Rectangular Defected Ground Structure

Length of Rectangle = 43.3 mil

Width of Rectangle = 185.03 mil

3. Simulation and Measurements

The Schematic Model , Layout and S-Parameters are obtained on Simulating the Circuit with ADS Tool ,

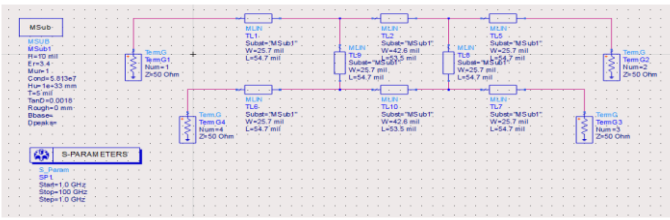

Fig 4. Schematic of Designed Branch line Coupler

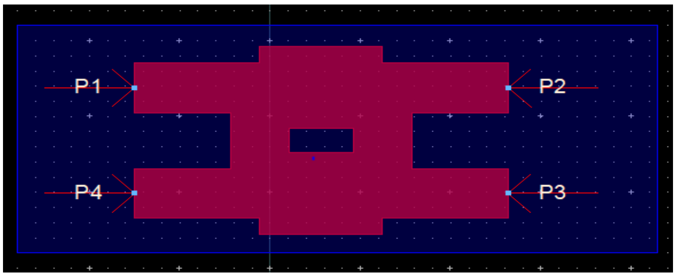

Fig 5. Layout of Designed Branch Line Coupler

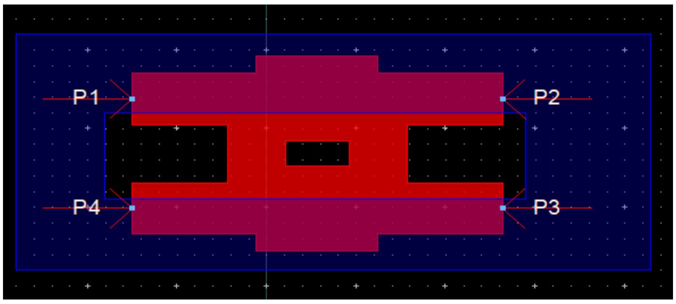

Fig 6. Layout of Designed Branch Line Coupler along with DGS

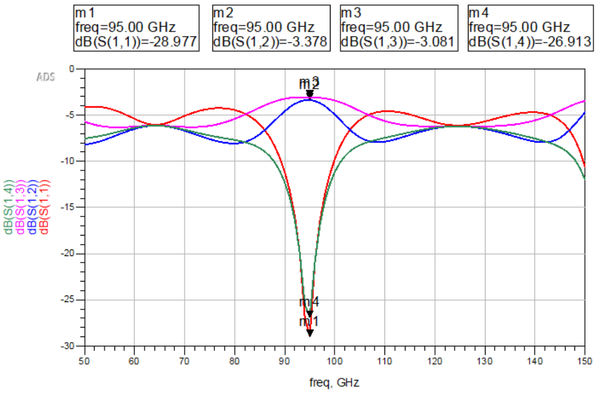

Fig 7. S-Parameters of the Designed Branch Line Coupler

S-Parameters of the given Coupler

$$\begin{bmatrix} -28.977 & -3.378 & -3.081 & -26.913 \\ -3.378 & -28.977 & -26.913 & -3.081 \\ -3.081 & -26.913 & -28.977 & -3.378 \\ -26.913 & -3.081 & -3.378 & -28.977 \end{bmatrix}$$

1. Return Loss of Coupler = -28.9 dB
2. Coupling of Coupler = -3.081 dB
3. Insertion Loss of Coupler = -3.378 dB
4. Directivity of Coupler = -23.832 dB
5. Isolation of coupler = -26.913 dB

Conclusion

In this article, We implement a new branch Line coupler with the proposed Rectangular DGS (Defective Ground Structure) to implement the high-impedance line sections. In addition, we observe the performance through electromagnetic simulations. The widening of the conductor width was achieved with the proposed DGS profile to conventional microstrip. Simulation performances for the proposed trace coupler showed good directivity, return and insertion loss The miniaturization microwave circuit has been the main target of many researchers to reduce the cost of microwave systems. The corresponding design equations equivalent branch-line coupler structures that employs Rectangular DGS is demonstrated. The proposed new branch-line hybrid coupler was designed, simulated at the frequency of 95 GHz, simulation results have a good agreement by using ADS Keysight Technologies Software. So this new design should have many applications of microwave integrated circuits where conventional branch-line hybrid coupler is used.

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The heading should be treated as a 3rd level heading and should not be assigned a number.

5. References

1. Y. Haoka, T. Kawai and A. Enokihara, "X-Band Broadband Branch-Line Coupler with Loose Coupling Utilizing Short-/OpenCircuited Coupled-Transmission Lines," 2018 Asia-Pacific Microwave Conference (APMC), 2018, pp. 1498-1500, doi: 10.23919/APMC.2018.8617195.

2. D. Ahn, J.-S. Park, C.-S. Kim, J. Kim, Y. Qian, and T. Itoh, "A design of the low-pass filter using the novel microstrip defected ground structure," IEEE Transactions on Microwave Theory and Techniques, vol. 49, no. 1, pp. 86–93, 2001.

3. K. C. Gupta, Microstrip Lines and Slotlines, Artech House, Norwood, Mass, USA, 1996

4. C. S. Kim, J-S. Lim, J. S. Park, D. Ahn, and S. Nam, "A l0 dB branch line coupler using defected ground structure," 'in Proc. EUMC2000, vo1.3, pp.68-71, Oct. 2000.

5. S.B. Cohn and R. Levy, History of microwave passive components with particular attention to directional couplers, IEEE Trans Microwave Theory Tech 32 (1984), 1046–1054.

6. Ji G, Chong JW. A new directional coupler design with high directivity for PCS and IMT2000. ETRI J. 2005;27:697–707

7. Feng, W., Zhao, Y., Che, W., Chen, H., & Yang, W. (2018). Dual-/triband branch line couplers with high power division isolation using coupled lines. IEEE Transactions on Circuits and Systems II: Express Briefs, 65(4), 461-465.

8. Pozar, D. M. (2009). Microwave engineering. John Wiley & Sons

9. Arriola, W. A., Lee, J. Y., & Kim, I. S. (2011). Wideband 3 dB Branch Line Coupler Based on λ/4 Open Circuited Coupled Lines. IEEE microwave and wireless components letters, 21(9), 486- 488.

10 . He J., Wang B.-Z.: 'Compact rat-race ring coupler with meander high impedance transmission line and port impedance matching', IET J. Eng., 2015, pp. 1–3, doi:10.1049/joe.2015.0102

11. Lee, S., & Lee, Y. (2012). Wideband branch-line couplers with singlesection quarter-wave transformers for arbitrary coupling

levels. IEEE Microwave and Wireless Components Letters, 22(1), 19-21.

12. Park, M. J. (2009). Dual-band, unequal length branch-line coupler with center-tapped stubs. IEEE Microwave and Wireless Components Letters, 19(10), 617-619

13 . Levy, R., & Lind, L. F. (1968). Synthesis of symmetrical branch-guide directional couplers. IEEE Transactions on Microwave Theory and Techniques, 16(2), 80-89

14 . Park, M. J. (2009). Dual-band, unequal length branch-line coupler with center-tapped stubs. IEEE Microwave and Wireless Components Letters, 19(10), 617-619

15. Shibata K, Yangisawa H. Method for improving microstrip coupler directivity. Electron. Lett. 1981;17:732–733.

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