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Design and EM Analysis of 1:4 Wilkinson Power Divider

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Abstract: ***In this paper, two configurations (T and Y-Serpentine type) of the 4-way equal Wilkinson Power Divider are designed and analyzed. The proposed configurations are designed using microstrip technology on a high resistive silicon substrate for a frequency range of 1 to 3 GHz with 1.575 GHz as the center frequency. Both the configurations have return loss better than 30 dB and an insertion loss of around 6 dB. Also isolation better than 30 dB is achieved in both the models of 1:4 WPD.***

Keywords: Wilkinson Power Divider, Serpentine, microstrip, Hi-resistive silicon, microwave

1. Introduction

Power dividers are the vital components of various microwave and millimeter wave circuits and also form an integral part of the feeding network of antenna array [1]. They are basically power splitters as they split power, from input to the output ports, into required ratio and the same circuits can also be used as power combiners when used in reverse direction [2]. They play a crucial role in various RF and communication applications such as in building wireless communication systems, transmission line fault testing ratio measurements, power amplifiers, linearizers, test equipment's and also in signal processing applications [3-4]. Resistive Type, T-Junctions and Wilkinson Power Dividers are traditional three types of available power dividers [5]. Resistive type and T-junction type are the least preferred power dividers owing to the reason that a poor isolation is observed between the output ports in comparison with Wilkinson power divider.WPD, if matched at all ports, is almost lossless and provides high isolation between output ports, however, if any mismatch occurs, the reflected power is dissipated through the isolation resistor [6]. This makes WPD an ideal choice for power division.

In this work, two configurations of WPD have been demonstrated namely Y-Serpentine model and T-Serpentine model. Structures are implemented on high resistive silicon substrate (ρ>8kΩ, h=675μm, tanδ=0.001and ε_r= 11.8) for the 1-3 GHz band taking center frequency as 1.575 GHz (L1 frequency). RF performance has been analyzed in MOM based electromagnetic solvers for entire frequency band of 1-3 GHz.

Detailed design description of both the models has been discussed in section II of this paper with results comparing both configurations has been elaborated in section III.

2. Design Methodology

2.1 T-Serpentine Model

The proposed structure consists of three 2-way Wilkinson Power Divider sections connected in a T- type configuration. Both the output sections are at right angle with respect to the input section. Cross-sectional view of 4-way WPD is shown in figure 1. Input and output impedance has been chosen as standard 50Ω. Each section consists of two quarter-wavelength transmission lines of impedance √2Z0, where Z0 is the characteristic impedance (50Ω) of the circuit, and an isolation resistor of value 2Z0 between each output port [7-8]. In order to miniaturize the circuit, the signal lines are meandered into serpentine structure. Overall structure looks like a 'T' resulting into cross-sectional area of '25.4×12.9' mm. The minimum distance in the entire structure is 0.8mm. The output ports of each section are 4.9mm apart; therefore, an isolation resistor can be placed easily between these ports. The distance between two output sections is 8mm. Another important aspect of the design is to keep the two signal lines apart in a manner that no mutual coupling occurs.

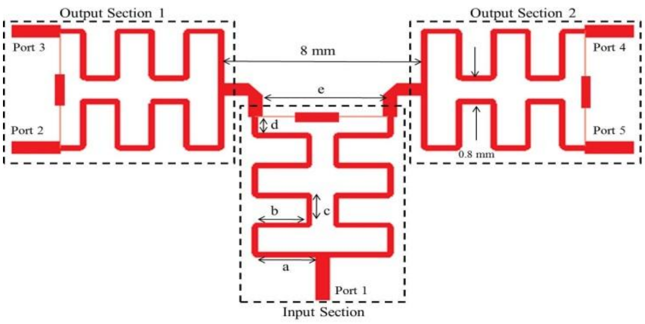

Figure 1: Layout of T-Serpentine Model of 4-way WPD

2.2 Y-Serpentine Model

In this section, a Y-Serpentine model of 4-way power divider is presented. In applications where the output ports are along same axis, Y-Serpentine model will be a potential choice. The complete structure with detailed dimensioning of each section is shown in figure 2. Three sections of 2-way WPD are connected in a manner that overall structure looks like a 'Y' shape. The distance between two output ports is 4.7mm, thereby, eliminating the spurious resonance created by signal line. In addition to this a remarkable amount of space is freed between two output sections using this topology. Numerous circuit elements can easily fit into the space freed when this type of WPD is chosen as a part of system design. The resultant cross-sectional area of Y-Model is around '17×18.4' mm.

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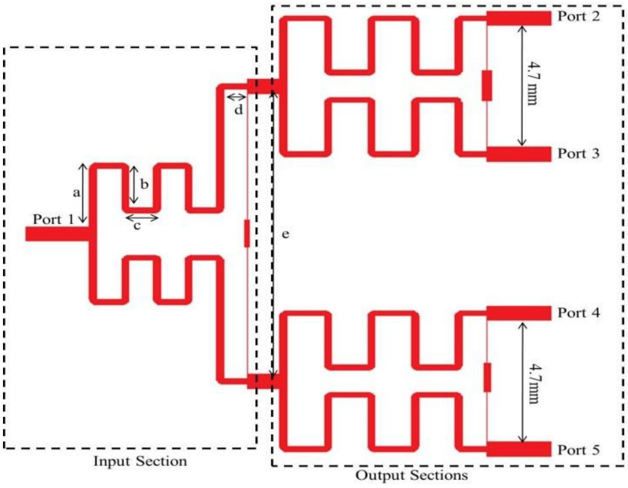

Figure 2: Layout of Y-Serpentine Model of 4-way WPD

Both the T and Y-Serpentine Models are designed using 1:2 Wilkinson Power Divider. The detailed dimensioning of 2-way WPD section is presented in table 1.

Table 1: Physical Parameters of t and y-serpentine models

Parameters (mm)	*T-Model*	*Y-Model*
a	2.37	2.37
b	1.97	1.97
c	1.18	1.18
d	0.79	0.79
e	4.9	10.98

3. Results and Discussion

Both the configurations are analyzed in MOM based electromagnetic solvers [9]. Structures are simulated on a high resistive silicon substrate (ρ>8kΩ, h=675µm, tan$_\delta$=0.001and ε_r= 11.8) for the frequency range of 1-3 GHz. RF performance of T-topology and Y-topology are shown in figure 3, 4 and 5 respectively. Table-2 summarizes the comparative performance study of both the configuration.

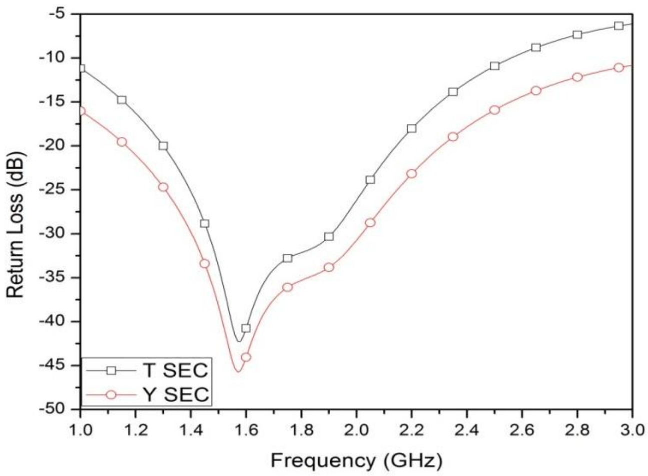

Figure 3: Return Loss characteristics

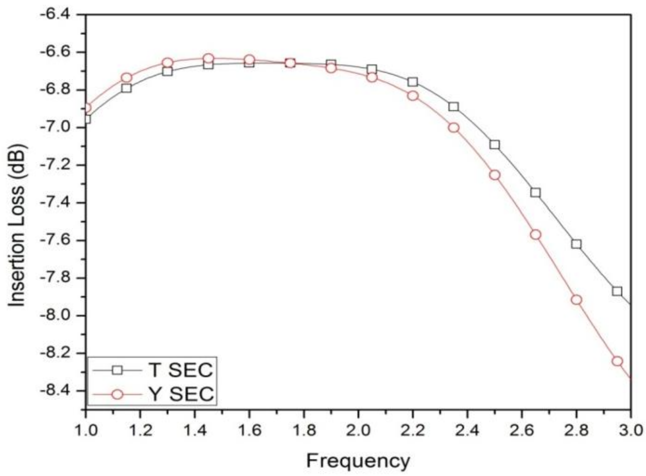

Figure 4: Insertion Loss Characteristics

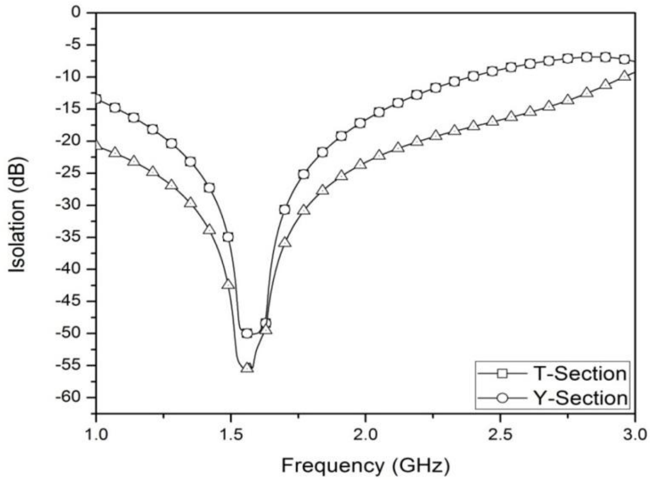

Figure 5: Isolation

Table 2: Comparison of Different 1:4 WPD Models

Parameters	*T-Model*	*Y-Model*
Operating frequency (GHz)	1.575	1.575
Return loss (dB)	-42.25	-45.75
Insertion loss (dB)	-6.66	-6.63
Isolation (dB)	-50.02	-56.28
Size (mm)	25.4×12.9	17×18.4

4. Conclusion

The two models of 1:4 Wilkinson Power Dividers have been analyzed and simulated. Y-Serpentine Model has high return loss as well as isolation in comparison to T-Serpentine Model. Also, the cover area of Y-Model is smaller than T-Model by 14.8 mm^2. So, in applications where high return loss, high isolation and smaller size is required, Y-Serpentine Model will be preferred. However, where output sections are required to be at right angles to the input section with moderate return loss and isolation values, T-Serpentine Model can be preferred. Overall, high return loss is desirable whereas the insertion loss and isolation loss should be a minimum value for power dividers. The analyses have shown that both the configurations satisfy the above constraints.

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