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Research paper

Wide band multi stage eight way Wilkinson power divider for defense applications

M. Siva Charan [1] *, A. Rajasekhar [1] *, K. V. Venkateswara Rao [1], Ch. Lakshmi Prasanna [1], Praveen Vummadisetty. Naidu [1], Gaurav Bansod [3], Arvind Kumar [2]

[1] Velagapudi Ramakrishna Siddhartha Engineering College, Vijayawada, India-520007
[2] K.I.T.E, Jaipur, India-302022
[3] PICT, Pune, India-411043
**Corresponding author E-mail: rajaalladi.com@gmail.com*

Abstract

In this paper, a compact 8 way microstrip line Wilkinson Power Divider (WPD) is designed and proposed. The equal power divider consists of multiple multi-section WPD's with isolation resistors. By utilizing the multi-sections concept, a remarkably increase in the bandwidth is observed. In the design process, RT 5880 substrate is used with the thickness of 0.8 mm and dielectric constant of 2.2 and loss tangent of 0.0004. The simulated results such as return loss, insertion loss and isolation are plotted by using ADS simulation software and obtained results show good agreement.

Keywords: *ADS; Microstrip Line; Multi-Section Wilkinson; N-Way; Wilkinson Power Divider (WPD).*

1. Introduction

The modern communication system widely uses multi-band/wideband antennas [7-21], [26-45], the phased array antennas [22-25] for various commercial and defense applications. Wilkinson power divider plays a vital role in phased array antennas such as power splitting among the antenna array elements with equal amplitude and phase [1]. When the system impedance is matched with ports then reelection co-efficient is zero and maximum power can be delivered. Therefore, the Wilkinson divider is the best choice when compare to T- junction in antenna array [1]. The Wilkinson power divider provides the larger isolation between the output ports so the mutual coupling between the antenna arrays can be reduced.

In 1960, Wilkinson [1] proposed an N-way power divider which split the input signal into 'N' number of equal phase and amplitude. The standard Wilkinson power divider design has problem at beyond X-band [2]. When the operating frequency increases, the size of the power divider decreases due to the mutual coupling between the output ports [3]. The coupling between the ports causes the power-split ratio and often it is difficult to design the power divider bend semi-circle at higher frequencies [2]. To overcome this problem, in this paper a 3λ/4 length of branch line is used in design process instead of λ/4. In [4] multiple sections are used to increase the bandwidth. In [5] multiple frequencies are obtained by replacing the quarter wave branches with multiple sections.

In this paper, Multi-sections of two way port cascaded Wilkinson power divider with equal power splitting is designed on the RT 5880 substrate. The simulated return loss and isolation are obtained from 6 GHz to 18 GHz with -10 dB and -15 dB values respectively.

2. Power divider design and analysis

The conventional Wilkinson power divider is shown in Fig.1 consists of a two quarter-wave (λ/4) transformer with terminating impedance Z_0. The conventional Wilkinson power divider is symmetrical along the mid-line. The basic equal-split Wilkinson power divider has two number of √2 Z_0 transform impedance ($Z_0$is total system impedance). Impedance calculations and isolation resistor values for equal split WPD is shown in below equations (1)-(6).

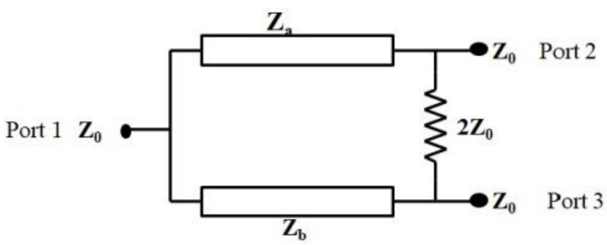

Fig. 1: Conventional WPD [1-5].

$$K^2=\frac{P_3}{P_4} \tag{1}$$

K^2= 1 (For equal power split P_2=P_3=1)

$$Z_a= Z_0\sqrt{K(1+K^2)} \tag{2}$$

$$Z_a=\sqrt{2}Z_0 \tag{3}$$

$$Z_b = Z_0\sqrt{\left(\frac{1+K^2}{K^2}\right)} \tag{4}$$

$$Z_b = \sqrt{2}\, Z_0 \tag{5}$$

$$R = 2\, Z_0 \tag{6}$$

The general circuit of N-section is shown in Fig.2 which consists of a pair of equal length transmission line with isolation resistors from port 1 to 2 and 3. The impedance bandwidth can be improved with increasing the sections. The impedance and isolation resistors values are considered to operate in the frequency range of 6-18 GHz [4].

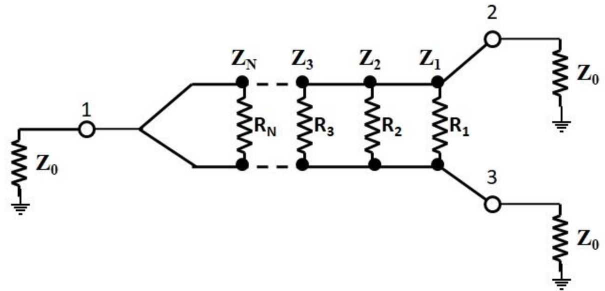

Fig. 2: General Circuit for Multiple-Section Three Ports WPD [4].

Table 1: Impedance and Isolation Resistor Values [4]

Quarter wave section impedance (values in ohm)	Isolation resistance (values in ohm)
$Z_1 = 57.485$	$R_1 = 400$
$Z_2 = 70.7$	$R_2 = 107.8 \approx 100$
$Z_3 = 86.98 \approx 87$	$R_3 = 107.8 \approx 100$

3. Proposed design with simulated results and discussion

The proposed WPD printed on a Rogers RT 5880 substrate with dielectric 2.2 and tangent loss 0.004. The proposed design consists of 3-stages to increase the bandwidth. Each stage is designed with multi section 2- way WPD shown in Fig 3. Block diagram.

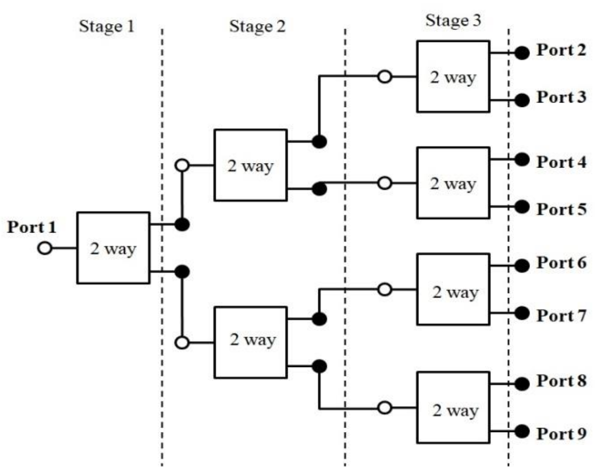

Fig. 3: Multi-Stage WPD Block Diagram.

The 2-Way WPD has designed with pair of equal length impedance values of Z1, Z2 and Z3 and isolation resistors (R1, R2 and R3) as shown in Table 1. By using ADS MLIN calculator we find the width and length of the microstrip lines with related impedance values shown in Table 1.The designed schematic diagram and layout diagram of two ways WPD in ADS software are shown in fig 4 and 5 respectively.

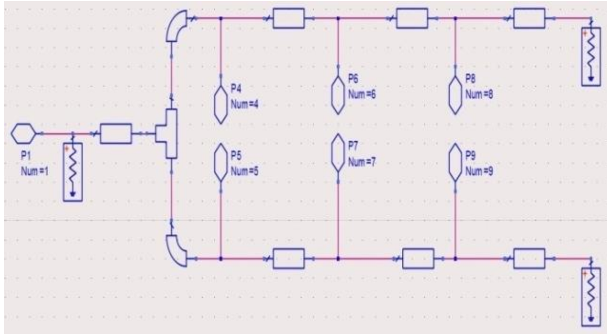

Fig. 4: Schematic Diagram of Single Multi-Section 2-Way WPD.

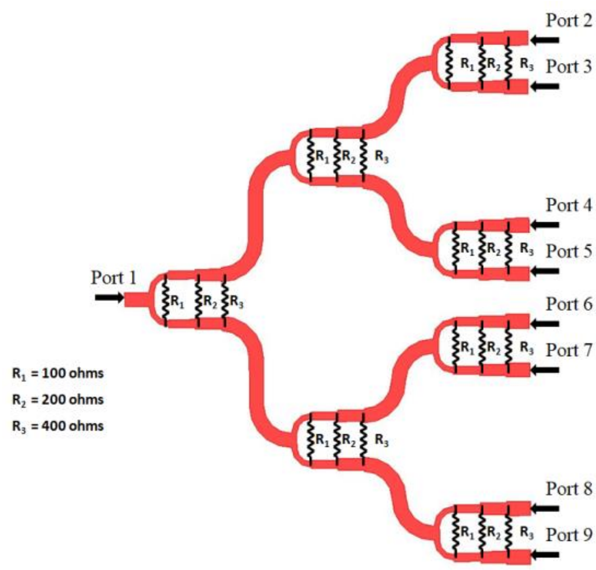

Fig. 5: Layout Diagram of Multi-Section 8-Way WPD.

The simulated results such as return loss, isolation and insertion loss are discussed in this section. The return loss S11 is below -10dB from 6-18 GHz. The return loss of 8-way is given in Figure 6 while the isolation is presented in Figure 7. The insertion loss and phase are given in Figure 8 and 9 respectively. From the figures, it is observed that the impedance is matched at all ports so the network is lossless.

An isolation about -15dB is obtained throughout the frequency range of 6 GHz to 18GHz and insertion loss about -10.5 dB is observed at operating frequency and phase of all the ports is within ± 3 degrees and an equal phase and equal amplitude is observed across all the output ports.

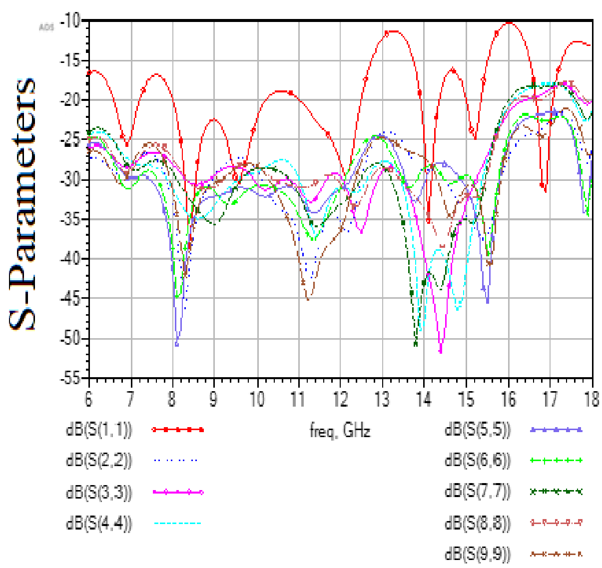

Fig. 6: Return Loss of Multi-Section 8-Way WPD.

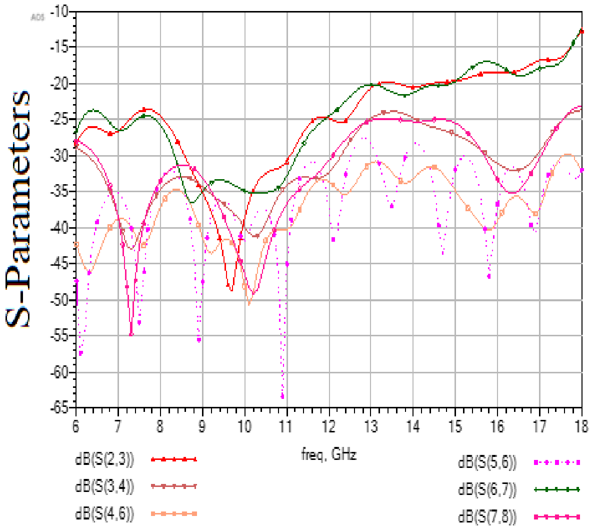

Fig. 7: Isolation of Multi-Section 8-Way WPD.

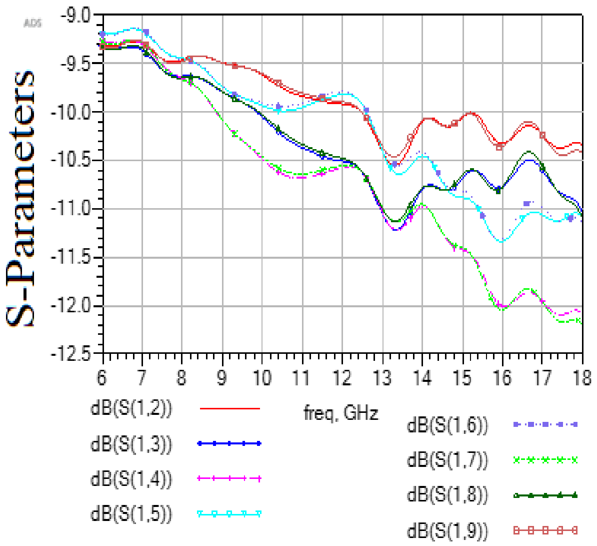

Fig. 8: Insertion Loss of Multi-Section 8-Way WPD.

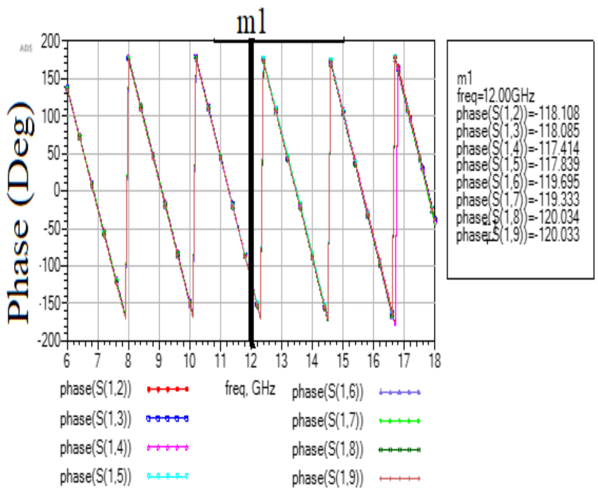

Fig. 9: Phase of Multi-Section 8-Way WPD.

4. Conclusion

The wideband multistage eight way WPD is designed and its results are discussed. By utilizing the multi-sections concept, a remarkably increase in the bandwidth is observed. It shows that proposed design is operating from 6-18 GHz band with good isolation and insertion loss. Hence, the proposed power divider can be used for communication systems and defence applications.

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