

An Unequal Wilkinson Power Divider with Variable Dividing Ratio

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Abstract — In this paper, an unequal 1:N Wilkinson power divider with variable power dividing ratio is proposed. The proposed unequal power divider is composed of the conventional Wilkinson divider structure, rectangular-shaped defected ground structure (DGS), island in DGS, and varactor diodes of which capacitance is adjustable according to bias voltage. The high impedance value of microstrip line having DGS is going up and down by adjusting the bias voltage for varactor diodes. Output power dividing ratio (N) is adjusted from 2.59 to 10.4 for the unequal power divider with 2 diodes.

Index Terms — Unequal wilkinson power divider, defected ground structure, DGS, variable power divider

I. INTRODUCTION

Wilkinson power divider is one of extensively used high frequency devices. The input power is equally divided into two output ports in the basic Wilkinson divider [1]. If N is greater than 1 in 1:N two-way Wilkinson dividers, the required transmission line impedance for one path is larger than 70.7Ω [2]. For example, if N is 2 or 3, 103Ω or 132Ω transmission line should be realized instead of 70.7Ω which is the standard value for 1:1 divider.

However, the generally realizable impedance limit is $100\Omega\sim 120\Omega$ in microstrip line, as has been known widely, even though it depends on the thickness and dielectric constant of the substrate [3].

Recently, a 1:4 unequal Wilkinson divider designed by adopting DGS (defected ground structure) on the ground plane and increasing the impedance of DGS microstrip line up to 158Ω has been presented [4]. In addition more recently, a 1:6 unequal power divider has been proposed by Lim et al [5]. In [5] a 207Ω DGS microstrip has been realized by inserting a lone rectangular-shaped DGS on the ground plane. Because of the rectangular-shaped DGS, it is possible to increase the equivalent inductance L highly, and to decrease the equivalent C at the same time, and finally to raise the impedance of the microstrip line more than 200Ω .

However, the previous unequal Wilkinson dividers having DGS are not adjustable. In other words, the unequal dividing

ratio, N, is fixed once it is designed and fabricated. In this paper, an unequal Wilkinson power divider having variable dividing ratio is designed and discussed. In order to get the adjustable dividing ratio, a large rectangular-shaped DGS, island in the defected area in DGS, and varactor diodes for variable capacitors are adopted.

II. MICROSTRIP LINE HAVING VARIABLE CHARACTERISTIC IMPEDANCE

Fig. 1 shows the topology of the basic Wilkinson divider. If the power dividing ratio is unequal, i.e. N is greater than 1, a high impedance transmission line should be adopted, so Z3 must be higher than 70.7Ω . Table 1 shows the required transmission line impedances, isolation resistor value, and termination impedance for N=1~6.

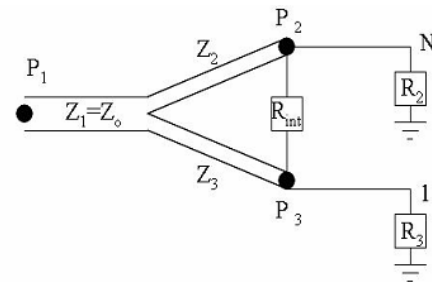


Fig. 1 Topology of 1:N unequal Wilkinson power dividers

According to the previous studies, it is possible to realize a very high impedance microstrip line over 150Ω by adopting DGS, because the equivalent elements of DGS consist of additional inductance and capacitance and the added equivalent inductance is dominant over the capacitance [5]. The characteristic impedance of a DGS microstrip line is calculated using Fig. 2 and eqs. (1) ~ (3).

Table 1 Required impedance and resistor values of 1 : N unequal Wilkinson power dividers

N	Z_o [Ω]	Z_2 [Ω]	Z_3 [Ω]	R_{int} [Ω]	R_2 [Ω]	R_3 [Ω]
1	50	70.7	70.7	100.0	50.0	50.0
2	50	51.5	103.0	106.1	35.4	70.7
3	50	43.9	131.6	115.5	28.9	86.6
4	50	39.5	158.1	125.0	25.0	100.0
5	50	36.6	183.1	134.2	22.4	111.8
6	50	34.5	207.0	142.9	20.4	122.5

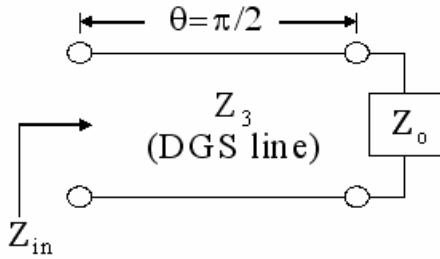


Fig. 2 Equivalent model of a DGS line to calculate the characteristic impedance

$$S_{11}[dB] = 20 \log|\Gamma| \quad (1)$$

$$Z_{in} = Z_o \frac{1+|\Gamma|}{1-|\Gamma|} \quad (2)$$

$$Z_3 = \sqrt{Z_{in}Z_o} = Z_o \sqrt{\frac{1+|\Gamma|}{1-|\Gamma|}} \quad (3)$$

In the previous studies, the high impedance value of DGS line, and resultantly the unequal dividing ratio (N) was fixed once the DGS had been realized in the divider. If it is desirable to modify the dividing ratio, N, there is no way to adjust N in the previous design.

However, it is the target of this paper to present the design technique for variable unequal Wilkinson power divider. The main idea is that if the equivalent inductance and capacitance of DGS section are able to be modified, then the characteristic impedance changes, and finally the dividing ratio is adjustable even though some other minor negative effects may occur. In order to change the impedance of DGS line, an island is

inserted in the mid of DGS area and varactor diodes are adopted as shown in Fig. 3.

Fig. 3 shows the bottom side of microstrip line having DGS on the ground plane. A rectangular island is inserted in the mid of rectangular DGS. The microstrip line on the upper plane is illustrated for the purpose of graphical understanding for the proposed structure. W1 and W2 are dimensions of DGS and W1' and W2' island, respectively, and WM is the width of microstrip line on the upper plane. It should be noted that the high impedance of DGS line is preserved even after the island has been inserted.

There are two diodes inserted between the island and surrounding ground plane in Fig. 4. It is important that the capacitance of diodes varies depends on the applied bias voltage and effective range of diode capacitance. By applying the bias voltage and adjusting it, it is possible for the total equivalent inductance and capacitance, and resultantly the impedance value of the DGS line to be controlled effectively.

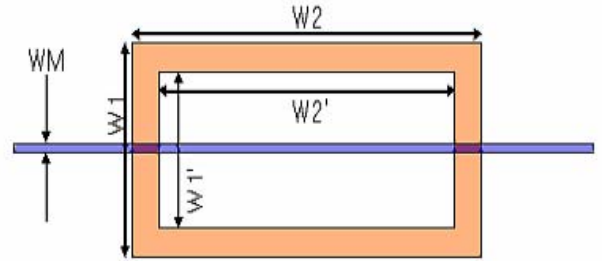


Fig. 3 DGS with island for high impedance microstrip line

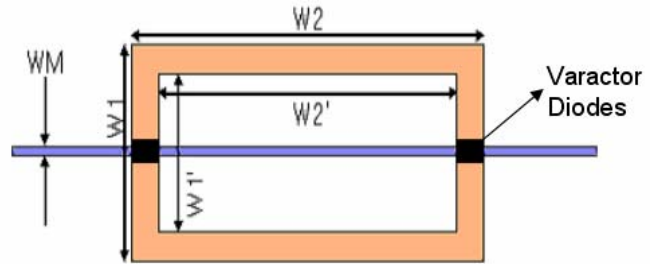


Fig. 4 DGS line with island and diodes

III. DESIGN OF UNEQUAL WILKINSON DIVIDER

Now it is possible to design the proposed variable unequal Wilkinson power divider by adopting the DGS line section shown in Fig. 4. To begin with, it is noted that the basic unequal power divider which has DGS and island pattern, and of which unequal dividing ratio is fixed should be designed

first. In this paper, as an example, a 1:6 unequal power divider has been designed first as the basic unequal divider.

Fig. 5 shows the layout of the basic 1:6 unequal divider which has DGS and island on the ground plane [6]. The microstrip substrate for the unequal divider is duroid 5880 of which dielectric constant and thickness are 2.2 and 31mils, respectively. W_1 , W_2 , W_1' , W_2' , and W_M are 12mm, 22mm, 8mm, 18mm, and 0.4mm, respectively. It should be noted that 0.4mm is the width for 123Ω standard microstrip line, while the resulting impedance is 207Ω due to DGS in Fig. 4.

Fig. 6 shows the measured S-parameters of the fabricated basic 1:6 unequal power divider. The measured S_{21} and S_{31} are -0.72dB and -8.18dB , respectively, which are so similar to the ideal performances of 1:6 dividers, i.e. -0.67dB and -8.45dB , respectively. In addition, all ports matching and isolation between output ports are excellent. Even though the predicted results are not shown in this abstract, a very good agreement has been obtained.

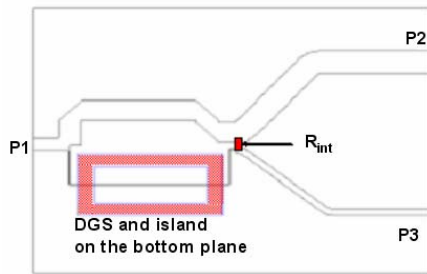


Fig. 5 Layout of the basic 1:6 unequal power divider

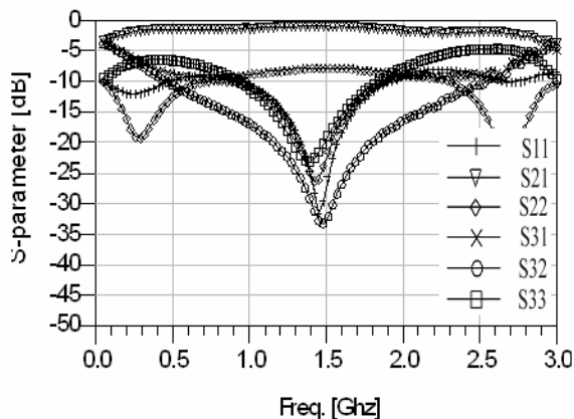


Fig. 6 Measured performances of the basic 1:6 unequal divider

IV. MEASUREMENT FOR THE VARIABLE UNEQUAL POWER DIVIDING RATIO

The proposed variable unequal power divider has been build by attaching two varactor diodes to the basic 1:6 power

divider as shown in Fig. 7. Fig. 8 shows the measured S-parameters of the variable unequal power divider when the bias voltage is 0V. The applied bias voltage triggers varactor diodes to change the added capacitances and eventually the characteristic impedance impedance of DGS line. Lots of unequal dividing ratio have been measured and shown in Fig. 9. It is seen that the measured dividing ratio at output ports are not fixed but adjustable according to the bias applied voltage. The unequal dividing ratio varied from 2.95 to 10.4 when the bias voltage was adjusted 0V ~ 10V.

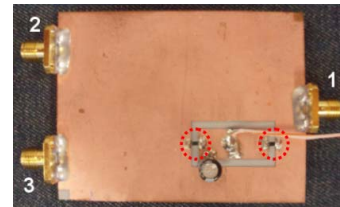


Fig. 7 Fabricated variable unequal power divider having DGS, island, and 2 varactor diodes.

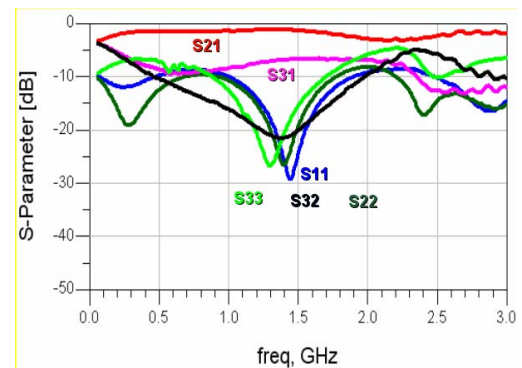


Fig. 8 Measured S-parameters of the proposed variable unequal divider. (Bias voltage = 0V)

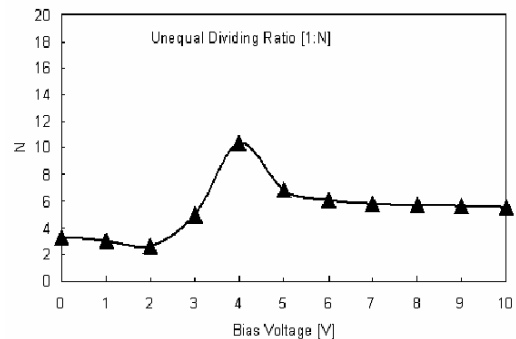


Fig. 9 Measured unequal power dividing ratio(N) with various bias voltage

V. CONCLUSION

An unequal Wilkinson power divider with variable dividing ratio has been proposed and discussed. In order to design the proposed divider, the previous 1:6 unequal divider, a rectangular DGS, island in the defected area, and varactor diodes have been adopted. Due to the applied bias voltage, the resulting equivalent capacitance of DGS and varactors was adjusted, and finally the unequal ratio was controlled.

It is believed that the technical contents in this paper will be extensively applied for further applications and other microwave circuits and system to provide the more desirable flexibility.

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