A 1:6 Unequal Wilkinson Power Divider

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Abstract

A 1:6 Unequal Wilkinson power divider is proposed. The proposed 1:6 divider has the microstrip line with 207Ω characteristic impedance by adopting a simple rectangular-shaped defected ground structure (DGS). Instead of the previous meander-shaped DGS, the proposed rectangular-shaped DGS produces the transmission line having much higher characteristic impedance because of the decreased equivalent capacitance as well as the increased inductance. The analytic verification procedure for 207Ω is also illustrated. The measured performances show that the proposed 1:6 Wilkinson divider has excellent performances with a good agreement with the predicted ones.

I. INTRODUCTION

Wilkinson power divider is one of the most widely used high frequency components. The standard 2-way Wilkinson divider has the equal power dividing ratio [1]. However, if N≥2 in 1:N unequal dividing ratio, a transmission line having very high characteristic impedance is required [2]. For instances, 103Ω and 132 Ω transmission lines are required for N=2 and N=3, respectively. It is a serious problem that, for standard microstrip line case, the generally accepted impedance limitation to realize is around 100 Ω ~130 Ω. In order to solve this problem previously, a meander-shaped DGS was designed to increase the characteristic impedance and realize the 1:4 unequal divider [3].

The meander-shaped DGS pattern in [3] gives an increased equivalent inductance (L), so the realizable characteristic impedance ($Z_o = \sqrt{L/C}$) of the microstrip was able to reach 158Ω. However, the previous DGS structure has also an equivalent capacitance which should not be ignored, so another limitation of high impedance occurred again at around 150 Ω ~160 Ω.

In this work, a rectangular-shaped DGS pattern is adopted to reduce the equivalent capacitance and increase highly the limitation of realization up to 207Ω. Finally, a 1:6 Wilkinson divider having the 207Ω microstrip line is fabricated and measured.

II. HIGH IMPEDANCE DGS MICROSTRIP LINE HIGHER THAN 200Ω

Fig. 1 shows the schematic of 2-way Wilkinson power dividers. If the dividing ratio is 1:N and N≥2, Z_3 should be a very high impedance. Sometimes, for microstrip line case, it is too high to realize practically. Table 1 shows the required Z_3 for N=1 to N=6. When N is equal to 6, a 207Ω microstrip line should be provided.

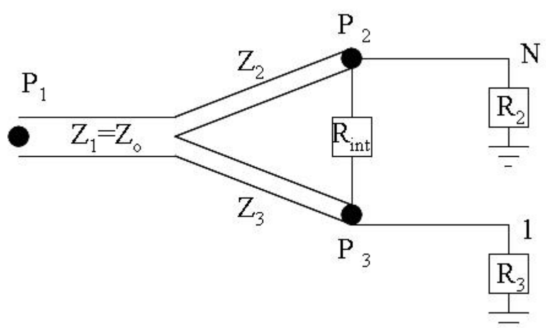


Fig. 1 Topology of 1:N unequal Wilkinson power divider

In a previous work, a 1:4 unequal Wilkinson divider has been designed using a 158Ω microstrip line having meander-shaped DGS [3]. However, although the effective inductance has highly increased due to the meander-shape, the effectively added capacitive component by DGS was not ignorable. This created another bound of realizable high impedance of microstrip line having DGS at around 150Ω~ 160Ω.

Table 1 Characteristic impedance and resistor values of 1:N power divider

N	Z_o [Ω]	Z2 [Ω]	Z3 [Ω]	R_{int} [Ω]	R2 [Ω]	R3 [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

In order to increase the realizable characteristic impedance up to 200Ω and more, it is necessary to increase the equivalent inductive component (L) much highly or decrease the equivalent capacitive component (C) radically. But the former to increase the inductive component by adopting meander- or other complex-shaped DGS will meet a saturation of inductance and lead to co-increased capacitance, in practice. In this work, a simple rectangular-shaped DGS is used to reduce radically the capacitive components and realize a high impedance microstrip line higher than 200Ω.

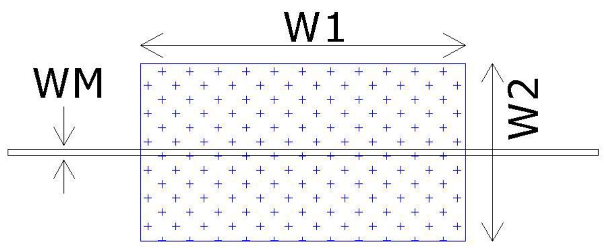


Fig. 2 Rectangular-shaped DGS for 207Ω microstrip line.

Fig. 2 shows the microstrip line having simple rectangular-shaped DGS ("DGS line") which will be adopted for the proposed 1:6 divider. The substrate for microstrip line has the thickness of 31mils and dielectric constant of 2.2. W1, and WM are dimensions of DGS on the ground plane, and WM is the width of microstrip line on the top plane. Here W1, W2, and WM are 22mm, 12mm, and 0.4mm, respectively.

When the rectangular-shaped DGS is inserted on the ground plane, the effectively added inductance increases as has been discussed already in [3], [4], and many other works, while the effective capacitance is extremely small. The reason is that there are no close node points, which are the cause of the added capacitance, just around the microstrip line on the along-side of DGS. As a result, very high impedance values are obtained. According to LINECALC from Agilent Technologies, the corresponding characteristic impedance is 124Ω only when the width of microstrip line is 0.4mm. Also, it should be noted that the width of 207 Ω standard microstrip line is 0.06mm.

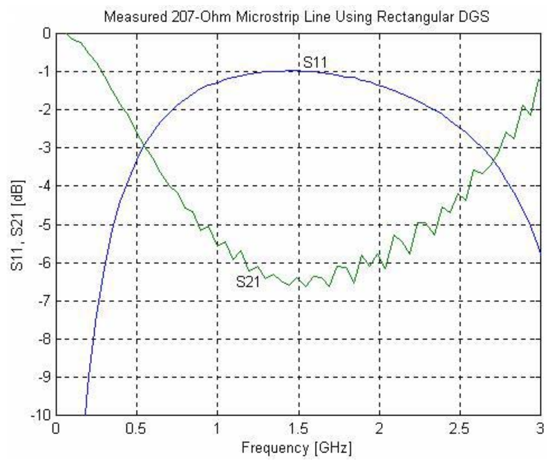


Fig. 3 Measured S-parameters of the 207 Ω DGS line

Fig. 3 shows the measured S-parameter of the "DGS line" shown in Fig. 2. The effective length of the DGS line was chosen for a quarter-wavelength at center frequency 1.5GHz (Fo). In order to be 207Ω, the S11 must be -1.01dB at Fo.

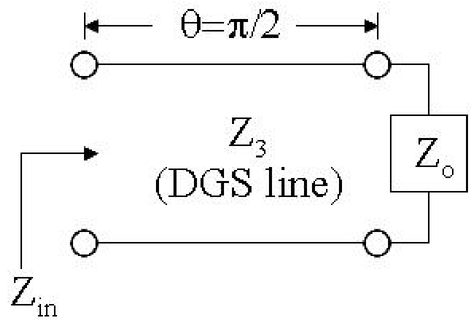


Fig. 4 Simplified model to determine the characteristic impedance (Z_3) of DGS line

The verification procedure for the exact 207Ω microstrip line is proven by Fig. 4 and eqs. (1)~(3). Fig. 4 shows the simplified model to determine the characteristic impedance (Z_3) of the DGS line. When θ=π/2 at Fo, the magnitude of the reflection coefficient (Γ) is maximum and can be calculated from S_{11} using (1). Once |Γ| is known, Z_{in} is calculated by (2). Finally, Z_3, the characteristic impedance of the DGS line is calculated to be 207Ω.

$$S_{11}[dB] = 20\log|\Gamma| \tag{1}$$

$$Z_{in} = Z_o \frac{1+|\Gamma|}{1-|\Gamma|} \tag{2}$$

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

III. Layout and Fabricated of the 1:6 Unequal Divider

Fig. 5 shows layout of the proposed 1:6 Wilkinson divider, whose R2 and R3 have been transformed to 50Ω for convenient measurement. The simple DGS shown in Fig. 2 is inserted here.

Fig. 6 shows the top and bottom planes of the fabricated 1:6 divider using the microwave substrate mentioned above. Even though the exact R_{int} is 143Ω for 1:6 Wilkinson divider, a 150Ω chip resistor was attached because it is not always possible to supply all kind of arbitrary resistance value. However the minor deviation of R_{int} does not lead in any critical effect on the final performances.

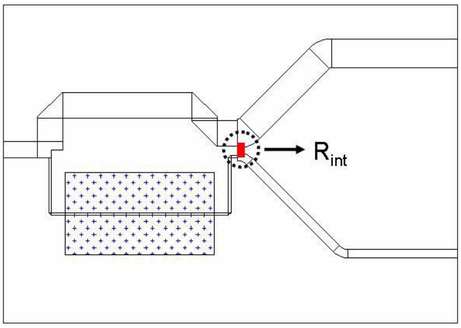


Fig. 5 Layout of the proposed 1:6 Wilkinson divider

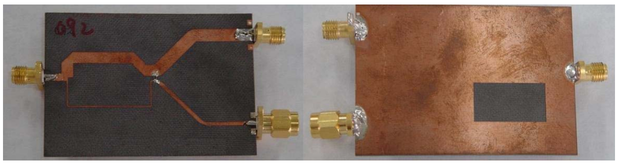
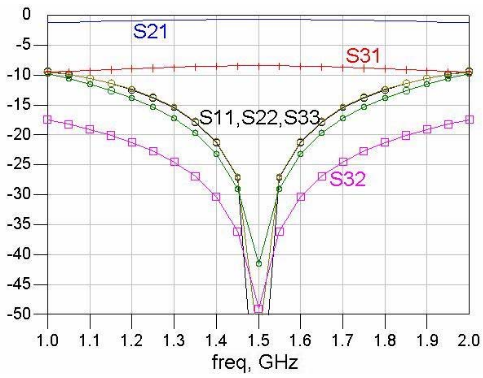


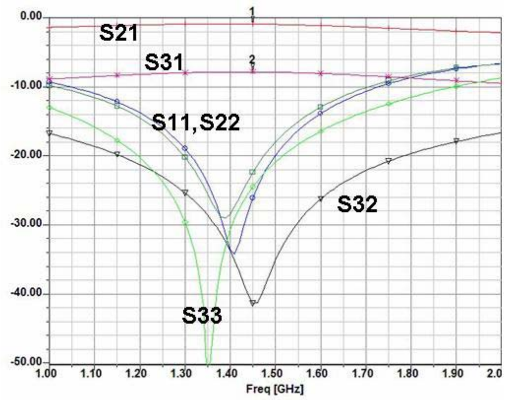
Fig. 6 Photo of the fabricated 1:6 Wilkinson divider

IV. Measurement

Fig. 7(a) and (b) show the calculated and measured S-parameters of the proposed 1:6 Wilkinson divider. It should be noted that Fig. 7(a) is an ideal performance because it has been predicted using ideal transmission line elements provided by Agilent Advanced Design System. Even though some minor discrepancies are observed, the measured S-parameters show an excellent performance as a 1:6 power divider in the matching, power dividing, and isolation. In our knowledge, this is the first implementation of 1:N unequal Wilkinson power divider having such a highly unequal dividing ratio more than N ≥ 5.



(a)



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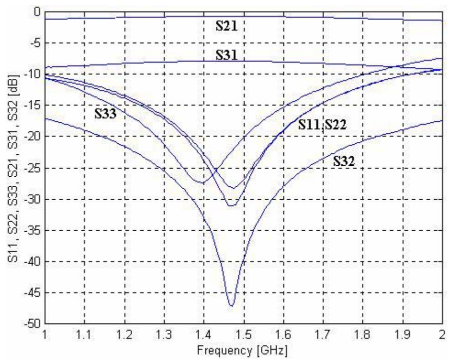
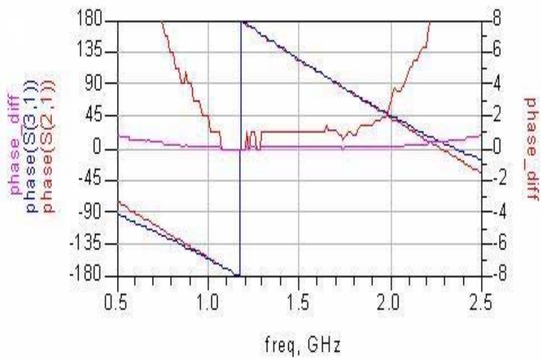


(c)



(d)

Fig. 7 Predicted and measured performances of the proposed 1:6 Wilkinson divider (a) Ideal S-parameters (ADS) (b) EM simulation (HFSS) (c) measured S-parameters (d) measured phase difference

V. CONCLUSION

A microstrip line with 208Ω of characteristic impedance has been realized using a simple rectangular-shaped DGS, and a 1:6 unequal Wilkinson power divider has been designed adopting the DGS line and measured. The verification procedure for 207 Ω characteristic impedance has also been described. The measured performance of the 1:6 divider was excellent as had been expected, and an excellent agreement between the prediction and measurement was obtained.

References

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