LETTER

A Power Divider with Adjustable Dividing Ratio

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SUMMARY An unequal Wilkinson power divider with adjustable power dividing ratio is proposed. The proposed power divider consists of rectangular defected ground structure (DGS), isolated island in DGS, and varactor diodes. The impedance of the microstrip line greatly increases due to the DGS, and varies because of the varying capacitance of diodes. The measured unequal dividing ratios vary from 1.97–13.4 and 2.25–10.6 when 2- and 4-diodes are adopted.
key words: defected ground structure, DGS, power dividers

1. Introduction

The Wilkinson divider is one of the most popular high frequency circuits since it has been proposed [1]. If the input power is divided unequally, the characteristic impedance of transmission line to Port 3, Z_3 in Fig. 1 should be much larger than the standard value as listed in Table 1 [2]. However, the reliably realizable impedance limit of microstrip line falls on 100–120 Ω, even though it depends on the thickness and dielectric constant of substrate [3].

One of methods to design the highly asymmetrical divider is to increase the realizable line impedance by combining defected ground structure (DGS). In practice, the 1:4 divider with 158 Ω microstrip line, 1:6 divider with 207 Ω line, and 10 dB branch line coupler (1:9 divider) having 150 Ω line have been designed and measured successfully using DGS [4]–[6].

However, previous unequal dividers using DGS are not adjustable. Therefore, once they have been fabricated, their dividing ratio, N, never change. In this paper, a new unequal divider with variable unequal dividing ratio is proposed. In order to get the adjustable N, a rectangular-shaped DGS, island in DGS, and varactor diodes are adopted.

2. Unequal Divider Having DGS with Fixed Ratio

Figure 1 shows the topology of 1:N Wilkinson power dividers, and Table 1 summarizes the required transmission line impedances, isolation resistor and termination
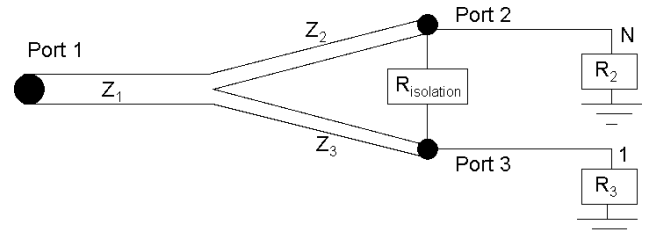
Fig. 1   Topology of 1:N unequal Wilkinson power dividers.

Table 1   Impedance and resistor values of 1:N unequal dividers for various N.

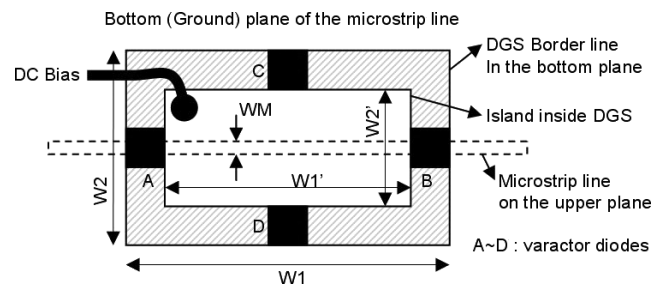| N	$Z_2[\Omega]$	$Z_3[\Omega]$	$R_{isolation}[\Omega]$	$R_2[\Omega]$	$R_3[\Omega]$
1	70.7	70.7	100.0	50.0	50.0
2	51.5	103.0	106.1	35.4	70.7
3	43.9	131.6	115.5	28.9	86.6
4	39.5	158.1	125.0	25.0	100.0
5	36.6	183.1	134.2	22.4	111.8
6	34.5	207.0	142.9	20.4	122.5

Fig. 2   207 Ω Microstrip line having DGS, island, and varactor diodes (substrate thickness=31 mils, dielectric constant=2.2, W1=22, W2=12, W1′=18, W2′=8, WM=0.4, Unit=mm).

impedances for $N = 1$–6. In order to realize the highly increased Z_3, DGS is placed on the ground plane under the microstrip line.

Figure 2 shows the bottom view of the proposed microstrip line with DGS, island and varactor diodes. WM, W1, W2, W1′ and W2′ represent dimensions of the microstrip line and DGS. It should be noted that 0.4 mm of WM is the width for 123 Ω in the standard microstrip line, however in this work, 0.4 mm of WM is used in realizing a 207 Ω DGS microstrip line. A to D represent the posi-

tion of varactor diodes. Since the method which calculates the highly increased characteristic impedance by DGS has been already presented several times in [4]–[6], it is not discussed here. DGS line in Fig. 2 has 207 Ω of line impedance for 1:6 dividers. In previous studies, it has been shown that the equivalent inductance and capacitance of DGS are added to the microstrip line, and the line impedance increases as a result.

Figure 3 is the layout of a 1:6 Wilkinson divider including DGS and island. The impedance values in Table 1 are realized in this layout. A 150 Ω chip resistor has been adopted for the isolation resistor in fabrication because the theoretical resistor value, 143 Ω, was not available.

Figure 4 illustrates the measured S-parameters of the fabricated 1:6 unequal power divider itself without diodes attached. S_{21} and S_{31} are −0.72 dB and −8.18 dB, respectively, which are very similar to the ideal performances of a 1:6 divider, i.e., −0.67 dB and −8.45 dB.
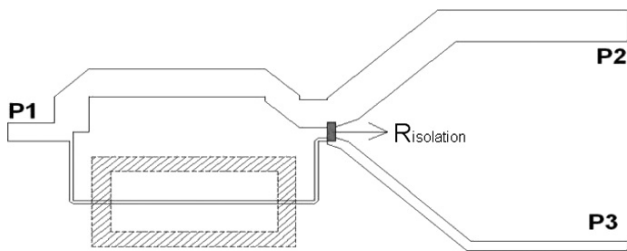

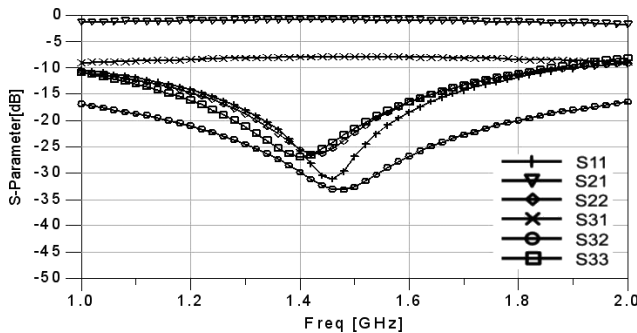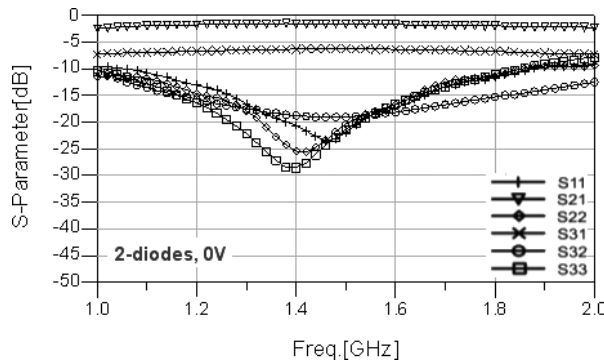**Fig. 3** Layout of the Wilkinson divider with the fixed 1:6 dividing ratio.

Fig. 4 Measured data of the 1:6 unequal divider itself shown in Fig. 3.

3. Adjustable Unequal Dividing Ratio

The key idea in this paper is that the attached adjustable capacitor of diodes causes the line impedance to change, and this gives rise to the adjustable dividing ratio of Wilkinson divider. In order to get variable dividing ratios, two diodes have been attached at the position A and D for the first test, and four diodes at A to D for the next measurement.

Figure 5 shows the bottom views of fabricated divider with 2- and 4-varactor diodes attached. DC bias voltage is applied to the island inside of DGS. The bottom area outside of DGS is the ground plane. The varactor diode is SMV1233 from Skyworks.

Figure 6 illustrates the measured S-parameters when 2-diodes are attached and the applied bias voltages are 0 V and 6 V. The matching (S_{11}, S_{22}, S_{33}) and isolation (S_{32}) are still good even after diodes have been attached and DC bias has been applied. The same conditions apply when there are 4-diodes. It is noted that the performance of Wilkinson dividers is not radically sensitive to the slight variation of line impedance values, electrical length of transmission lines, and even isolation resistor value. So the overall matching performances are still excellent even after diodes have been attached and bias applied.

In Fig. 6, the measured S_{21} and S_{31} are −1.55 dB and −6.22 dB, respectively, even DC bias voltage has not applied yet. Therefore, it is easily understood that N has moved from 6 to 2.93 ($\approx$3). It is assumed that the attached capacitors due to diodes played a role in changing the Z_3 to about 131 Ω which is required for 1:3 dividers in Table 1. If the bias voltage is 6 V, S_{21} and S_{31} are −0.98 dB and −8.1 dB,
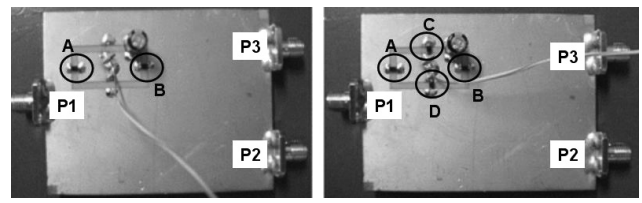

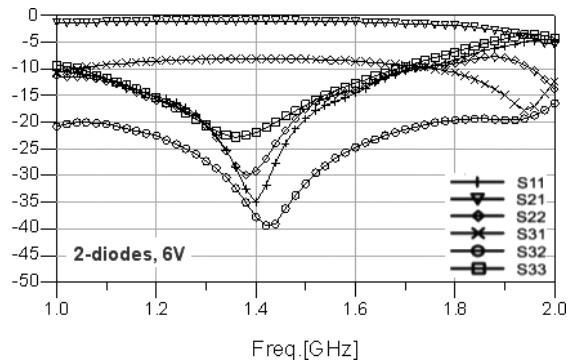**Fig. 5** Bottom views of divider with varactor diodes attached (a) 2 diodes (b) 4 diodes.

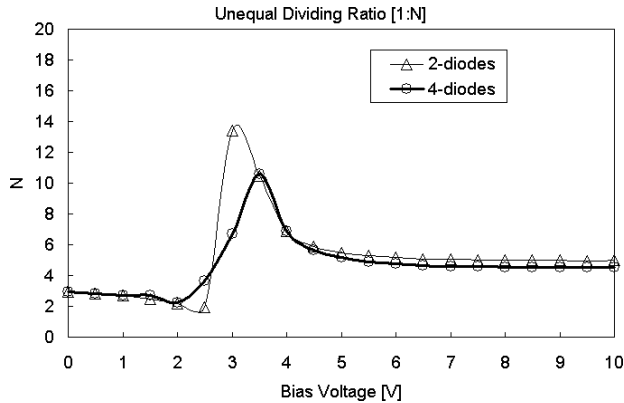**Fig. 6** Measured S-parameters of dividers when 2-diodes are attached.

Fig. 7 Measured dividing ratios according to the bias voltage.

respectively, and the resulting *N* is 5.15.

Figure 7 shows the measured dividing ratios according to the bias voltage and number of diodes. The measured range of *N* are 1.97–13.4 and 2.25–10.6 for dividers with 2- and 4-diodes, respectively. It is noted that the dividing ratios converge to a finite value, near 6, as the bias voltage increases because the equivalent capacitance of diodes decrease according to the increase of bias voltage.

4. Conclusion

A Wilkinson power divider with adjustable power dividing ratio has been designed and measured. The fixed 1:6 divider having the rectangular DGS and island were fabricated first, and combined with varactor diodes. The unequal dividing ratio of the proposed divider has been adjusted due to the varying equivalent capacitance of varactor diodes. The measured unequal ratio was 1.97–13.4 and 2.25–10.6 according to the DC bias voltage when 2- and 4-diodes have been attached, respectively.

References

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