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A Size-Reduced Wilkinson Power Dividers Using Defected Microstrip Structure

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Abstract. A size-reduced Wilkinson power divider is designed using defected mcirostrip structure (DMS). DMS patterns are inserted for the desirable effects of periodic structure such as size-reduction and increased line width for high characteristic impedance. As an example of circuit application, a DMS is adopted in a microwave Wilkinson power divider. The microstrip line with DMS is designed first for the 70.7Ω line impedance. The line width of 70.7Ω with DMS is wider than that of normal microstrip line. The size of designed power divider with DMS patterns is only 82% of normal power divider composed of standard microstrip lines, while the circuit performances are well preserved even after the size-reduction.

Keywords: defected microstrip structure, DMS, power dividers.

1 Introduction

Recently, perturbation structures such as photonic bandgap (PBG) and defected ground structure (DGS) for microstrip lines have been widely studied as planar periodic structures which modify the characteristic impedance of microstrip lines. Additional inductance and capacitance are added to those of normal microstrip line, and related physical phenomenon occurs because of those perturbation patterns. So the characteristic impedance of microstrip line increases and slow-wave effect is observed. Those properties are applied to high frequency circuits for size-reduction or performances improvement [1-2].

However it is not easy to define a unit section and to extract the equivalent circuit elements of PBG patterns because an enormous number of periodic pattern is required on the ground plane. This drawback has prevented ones from applying PBG patterns to microwave circuits. To the contrary, there are some advantages in DGS compared to PBG such as; 1) less DGS elements are required for the similar effects, 2) it is easy to define a unit element and to model the equivalent circuit, and 3) DGS patterns have a great potential of applicability. But, DGS patterns should be etched off from the ground plane of microstrip lines, and this has been known as a disadvantage of DGS so far [3-6].

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Defected microstrip structure (DMS) has been proposed recently in order to solve the drawback of DGS [7,8]. The microstrip lines with DMS patterns have the same pros of previous PBG and DGS, and do not have the cons mentioned above because the perturbation pattern are realized on the upper side signal pattern of microstrip line instead of bottom side ground plane.

So it is necessary to study the applications of DMS to microwave circuits because of the drawback of DGS can be eliminated by replacing DGS. In this study, a high frequency Wilkinson power divider is designed and measured in order to present an example of DMS application. The designed power divider has a smaller size compared to the normal one due to the equivalent additional inductance and capacitance of the inserted DMS pattern, although the performances of the size-reduced power divider are quite comparable to the original ones.

2 Microstrip Line with Defected Microstrip Structure Pattern

Fig.1 shows the pattern of recently studied defected microstrip structure (DMS) pattern [7,8]. In DMS pattern, the ground plane is not modified as has been in PBG and DGS, but slot-like patterns are inserted on the signal plane of mcirostrip line. Therefore the critical drawbacks of PBG and DGS do not occur such as leakage of signal through the etched ground plane and ground contact problem in metal housing.

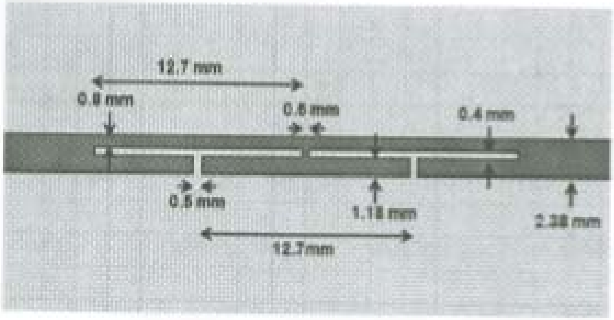


Fig. 1. Microstrip line with defected microstrip structure (unit: mm)

The electrical length of microstrip line is prolonged for the same physical length due to the inserted DMS patterns because the slots present the additional equivalent inductance to the original line. Additionally, coupling exists in the slots patterns and leads the equivalent capacitance to increase. It is noted that the increase of the equivalent inductance is dominant over the capacitance. Hence the characteristic impedance (Z_c) of the DMS microstrip line is larger than that of normal microstrip line because the line impedance of transmission lines is determined by (1).

$$Z_c = \sqrt{L/C} \tag{1}$$

where L and C are the equivalent inductance and capacitance of transmission lines of unit length [9-11]. Furthermore it is noted that the width of DMS microstrip line is wider than that of normal microstrip line for the same Z_c value because one should increase the width for higher C in order to keep the same Z_c.

One simple example may be presented here with the microstrip substrate of which dielectric constant (ε_r) and thickness (H) are 2.2 and 31mils, respectively. This substrate has been selected to design the DMS line shown in Fig.1. Fig. 2 represents the predicted S-parameters which have been simulated on Ansys HFSS (high frequency structure simulator). The line width 2.38mm corresponds to the width of 50Ω normal microstrip line. However the characteristic impedance of the DMS microstrip line in Fig. 1 is no more 50Ω because the S11 in Fig. 2 is not perfect within the passband. Fig. 2 shows S11 is -9.5dB, and this means the characteristic impedance of DMS line in Fig. 1 is around 70.7Ω, which is desired impedance for the design of Wilkinson power divider [11]. It is noted that the width of 70.7Ω normal microstrip line is only 1.37mm, while that is 2.38mm in DMS line as shown in Fig. 1.

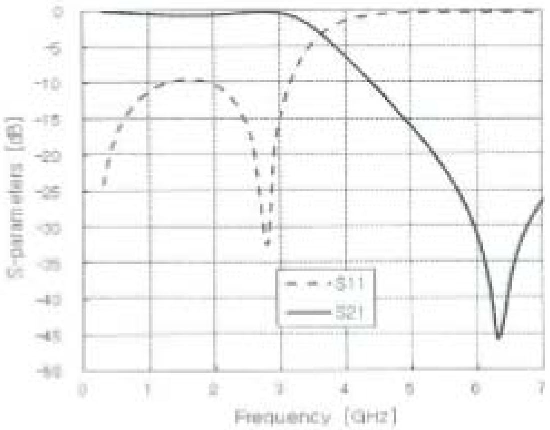
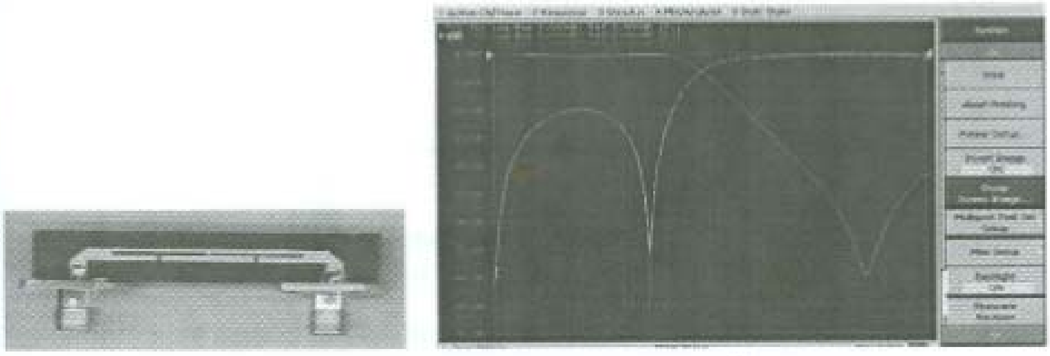


Fig. 2. Simulated S-parameters of the DMS microstrip line



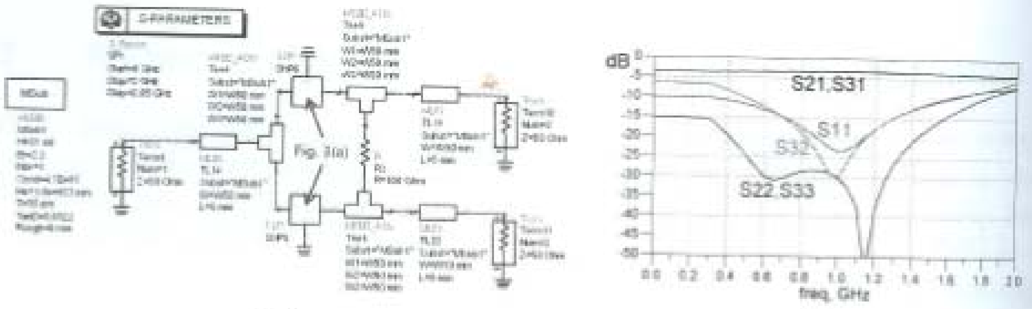
(a) (b)

Fig. 3. (a)Fabricated 70.7Ω DMS line and (b)measured S-parameters

The 70.7Ω DMS line has been fabricated and its characteristic impedance was verified through the S-parameter test. Fig. 3(a) and (b) show the photograph of the fabricated DMS microstrip line and its measured S-parameters. The measurement has been performed using Agilent E5071B vector network analyzer. The measured S11 is exactly the same as the predicted one. The change of characteristic impedance from 50Ω to 70.7Ω has been caused by the inserted DMS patterns.

3 Size-Reduced Wilkinson Power Divider Using DMS

A Size-reduced Wilkinson power divider has been designed using the DMS line presented in Fig. 3(a). Agilent Advanced Design System (ADS) has been adopted as the simulator in order to design the divider. Fig. 4 shows the schematic design of divider in which the HFSS simulation results of the DMS line is included, and the simulated S-parameters.



(a) (b)

Fig. 4. (a) Schematic design of DMS power divider and (b)Simulated S-parameters of the power divider using ADS

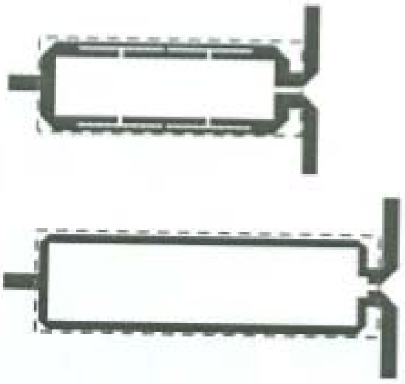


Fig. 5. Layout of power dividers using DMS microstrip line (upper) and normal microstrip line (lower)

Fig. 5 shows the layout of size-reduced Wilkinson power divider using DMS micorstrip line and normal divider. In order to present the effect of DMS in size-reduction, 1GHz has been selected as the center frequency. As has been described already, the width of DMS line is fixed to 2.38mm whether it is 50Ω or 70.7Ω line. The dimensions of DMS in the size-reduced divider are the same as those in Fig. 1.

It is definite to show the effect of DMS patterns comparing two dividers in Fig. 5. Eliminating the port feeding lines with 50Ω, one can compare the pure divider areas designated by dotted boxes. Those are 534mm^2 and 654.7 mm^2 for the size-reduced divider and normal one. The size of DMS divider is only 82% of normal one. The size-reduction is caused by the slow-wave effect due to the added equivalent circuit element of the DMS patterns.

Fig. 6 shows the simulated S-parameters of the DMS power divider using HFSS. All required performances are desirable and excellent such as divided power at output ports (S21, S31), matching performances at all ports (S11, S22, S33), and the isolation between output ports (S32).

The designed DMS power divider has been fabricated practically as shown in Fig. 7. The 70.7Ω DMS line in Fig. 3(a) has been adopted in the final layout. The substrate with the dielectric constant of 2.2 and thickness of 31mils has been selected for the design.

Fig. 8 illustrates the measured S-parameters of the fabricated DMS divider. The input power has been equally and exactly divided at the center frequency. The measured S21 and S31 are -3.1dB and -3.14dB, respectively, with less than -20dB of matching and isolation performances. It is observed that the measured S-parameters are in excellent agreement with the predicted ones. Therefore it can be said that the design of size-reduced Wilkinson power divider using DMS has been completed successfully.

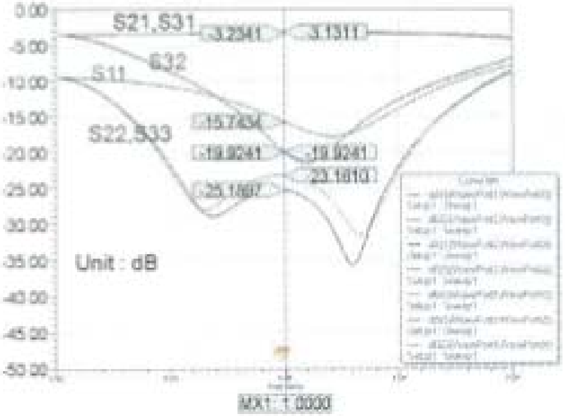


Fig. 6. Simulated S-parameters of the power divider using HFSS

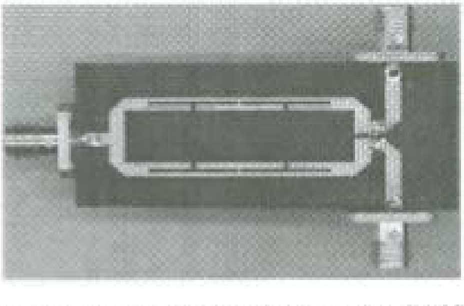


Fig. 7. Fabricated power divider using DMS

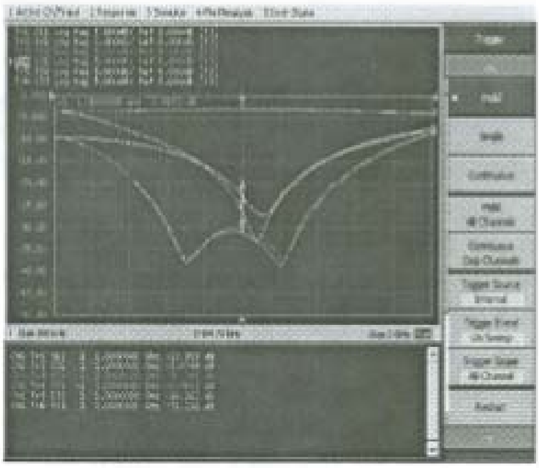


Fig. 8. Measured performances of the fabricated power divider

4 Conclusion

A size-reduced Wilkinson power divider has been designed and fabricated successfully using the microstrip line with DMS patterns. The measured performances of the divider are exactly the same as the simulated S-parameters. The size of the fabricated DMS divider is only 82% of the normal one while the performances have been well preserved. There was no leakage or ground contact problem in the designed DMS divider, and also no performances degradation, either. The insertion loss at two output ports was order of 0.1dB, which is so small value, and all matching and isolation performances were excellent. It is expected that DMS pattern has a great potential for further application to microwave circuits without the well-known drawbacks of PBG and DGS.

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