A Novel Miniaturization Wilkinson Power Divider using Complementary Spiral Resonators (CSRs)

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***Abstract*-In this article, a novel miniaturized power divider operating at 0.9GHz is presented. By replacing the 90° branch line of conventional Wilkinson power divider with the novel 90° composite right/left handed (CRLH) lines realized by complementary spiral resonators (CSRs), the occupied effective area of our proposed power divider can be reduced by about 70% from that of the conventional one. The performances are demonstrated by simulated and measured results, which are in good agreement.**

I. INTRODUCTION

Artificial transmission lines exhibiting left and right-handed wave propagation are useful for the implementation of microwave components with superior characteristic. Such composite right/left handed (CRLH) lines are implemented by loading a host line either with series capacitances and shunt inductances [1]–[3], or with sub wavelength resonators, such as split ring resonators (SRRs) [4-5] or complementary split ring resonators (CSRRs). Compared to conventional lines, these lines have more degrees of freedom to exhibit controllable electrical characteristics (frequency and phase) [6]. In particular, CSRRs have attracted many attentions in recent years, which have been applied to the design of different microwave components, such as filters [7–11], hybrid couplers [12, 13] and antennas [14], among others.

Power dividers are very important structures in microwave engineering. However, a shortcoming of conventional power divider is large because of the 90° branch line in the very low frequency. To overcome this shortcoming, several methods are proposed to reduce the occupied area. The representative is Marta Gil, Jordi Bonache and coworkers who proposed a CRLH line with CSRR to reduced size of power dividers [15].

In this article, a smaller resonant particle, the complementary spiral resonators (CSRs) is studied and used for the design of Wilkinson power dividers. The results show, the occupied area of the Wilkinson power divider with CSRs can be reduced by about 70% from that of the conventional one.

II. THE COMPLEMENTARY SPIRAL RESONATOR

The complementary spiral resonator (CSR) is a slot resonator etched in a metallic layer which is depicted in

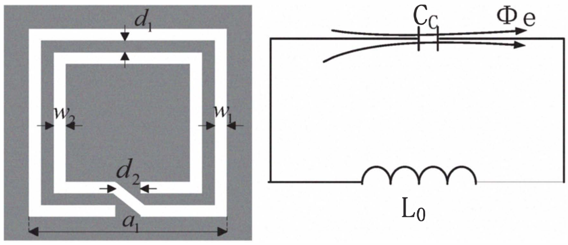

Fig. 1. The complementary spiral resonator (CSRS)

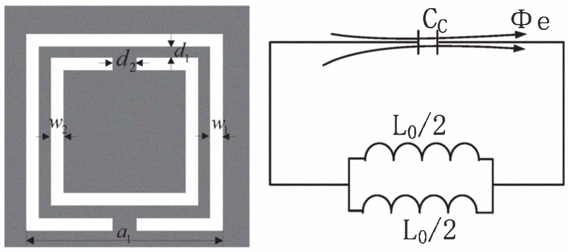

Fig. 2.The complementary split ring resonator (CSRR)

Figure 1. Comparing with the complementary split ring resonator (CSRR), the resonance frequency of the CSR is just half of the CSRR. In both particles, the capacitance C_c is the capacitance between square ring with side length of (a_1 – $2*w_1$) (where a_1 is the side length of the square and w_1 is the slot width) and two slots surrounding it. In the CSR, the inductance L is the inductance of the square ring with side length of ($a_1 - 2*w_1$), however, in the CSRR the inductance L is parallel combination of the two half square ring inductances. Hence, the inductance of the CSR is larger than the inductance of the CSRR by a factor of 4 (the circuit models of both particles are also depicted in Fig. 1 and Fig. 2). The formula (1) and (2) shows the frequency of CSR and CSRR.

$$f_{CSR} = 1/2\pi\sqrt{L_0 C_c} \quad (1)$$

$$f_{CSRR} = 1/\pi\sqrt{L_0 C_c} \quad (2)$$

This explains that the electrical length of the CSR is half of the CSRR for the same resonance frequency. In another word, the occupied area of our proposed components can be reduced by about 50% with CSR compared to that with CSRR.

As shown in Figure 3, the conventional Wilkinson power divider is composed of two 90° branch lines and one $2z_0$

The work is supported by National Natural Science foundation of China Grant NO 60971122 and the Aeronautical Science Foundation Grant No.2009ZA52008 and Open Topics Foundation of the State Key Laboratory of Millimeter Waves NO K200802

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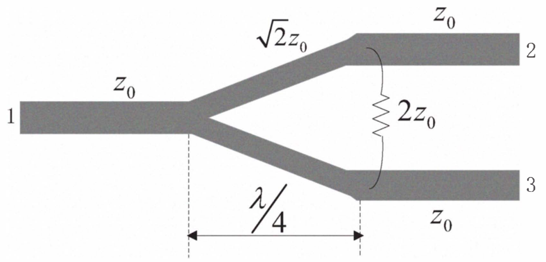


Fig. 3. Conventional Wilkinson power divider

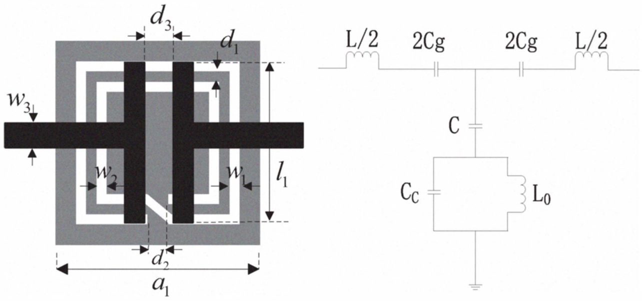


Fig. 4. The layout of 90° CRLH branch line and equivalent circuit

isolation resistance. In our design, the permittivity of substrate F4B2 is 2.65 and thickness is 1 mm. At the frequency of 0.9 GHz, the length of 90° branch is $\lambda/4 = 57\text{mm}$, and λ is the wavelength. In the proposed one, 90° branch line is realized by utilizing the structure composed of complementary spiral

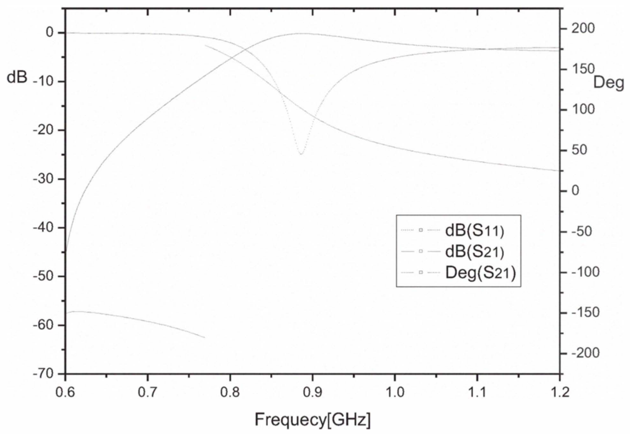
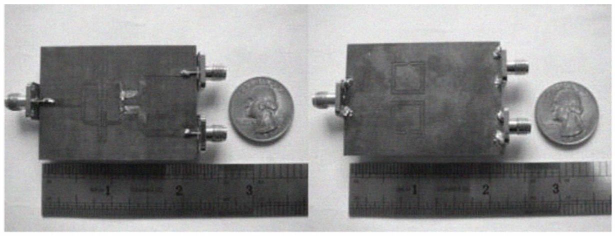


Fig. 5. The simulated S-parameters of CRLH with CSRs

resonators and microstrip series gap which can produce composite CRLH transmission band characteristic impedance. This component can be used to produce 90° phase operation, as shown in Fig. 4. The parameters of 90° CRLH branch line are designed as follows: $w_1 = 0.5mm$ $w_2 = 0.5mm$ $d_1 = 0.6mm$ $d_2 = 0.8mm$, $d_3 = 0.6mm$ $a_1 = 11.2mm$ $l_1 = 13mm$ $w_3 = 1.43mm$ designed for 70.7 ohm characteristic impedance. The simulated results obtained from HFSS are shown in Figure 5 and 90° phase delay can be found at 0.9 GHz.



(a) top face (b) bottom face

Fig. 6. Photographs of the proposed power divider with CSRRs

A miniaturized Wilkinson power divider with CSRs operating at 0.9 GHz is fabricated, whose photographs are shown in Fig. 6. The occupied effective area of the proposed hybrid ring can be reduced by about 70% from that of conventional one.

III. Result

The simulation of proposed miniaturized Wilkinson power divider is carried out using HFSS and measurement is carried out using an Agilent vector network analyzer N5230A. The

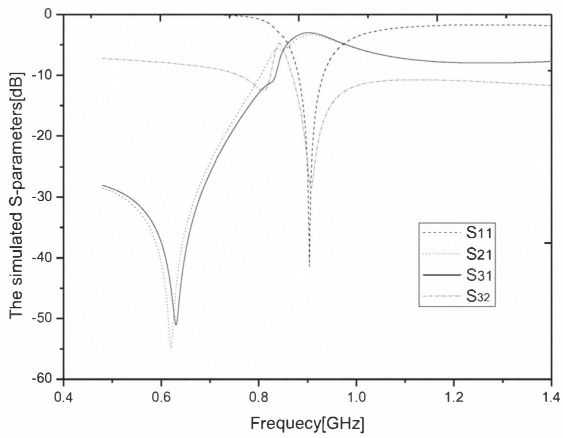


Fig. 7. The simulated S-parameters of power divider with CSRs

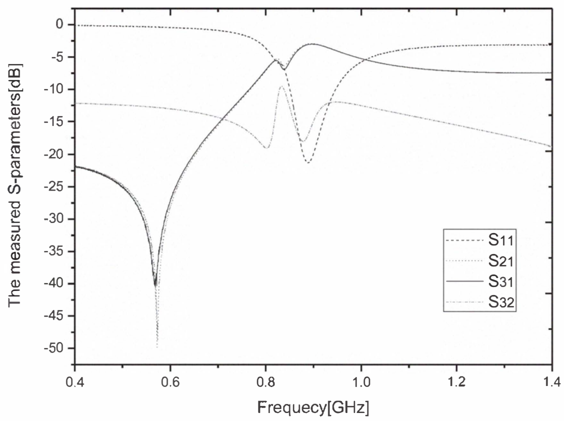


Fig. 8. The measured S-parameters of power divider with CSRs

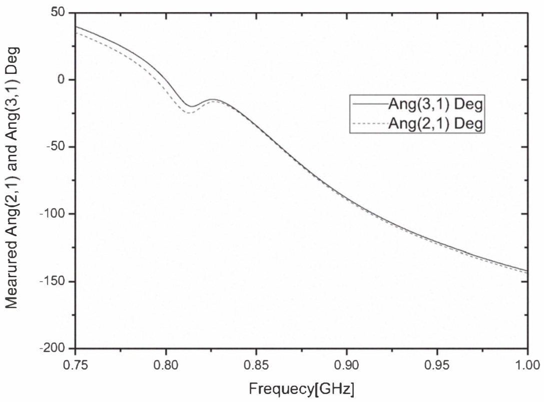


Fig. 9. Measured Phase of S_{21} and S_{31}

simulated S-parameters of power divider with CSRs are shown in Figure 7. The measured S-parameters are shown in Figure 8. The Simulation and measurement are in very good agreement. The measured results of phase difference are presented in Figure 9. From these figures, we can find that the measured central frequency is 0.89 GHz. The measured output S_{21} is -3.15dB and S_{31} is -3.17 dB at 0.89 GHz. The measured return loss S_{11} is -21.11 dB at 0.89 GHz. The measured isolation S_{41} is -18.05 dB at 0.89 GHz. The measured phase difference between S_{21} and S_{31} is 0.5°at 0.89 GHz. -20dB bandwidth is about 15%.

Comparing the fabricated device with other fully planar power dividers, our device exhibits comparable insertion loss and isolation, but slightly higher returns loss and the bandwidth is comparable in the band. However, the designed Wilkinson power divider with CSRs is very compact (the size of the square is $0.12\lambda \times 0.06\lambda$, where λ is the guided wavelength at 0.9GMHz).

IV. CONCLUSION

It has been demonstrated that CRLH transmission line based on CSRs is useful for the design of miniaturized microwave components. We have designed a Wilkinson power divider which is small, exhibits reasonable performance, and is fully planar. The CRLH line loaded by CSRs can be used in other microwave components. Work is in progress in this direction.

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