COMPACT, HARMONIC SUPPRESSED POWER DIVIDER USING OPEN COMPLEMENTARY SPLIT-RING RESONATOR

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ABSTRACT: *An open complementary split-ring resonator (OCSRR) based T-junction power divider working at 900 MHz frequency is proposed in this paper. By embedding the OCSRR in the microstrip transmission line, slow wave effect is introduced to achieve size reduction. The proposed power divider size is 47% smaller than the conventional power divider. Besides, the proposed power divider provides better third harmonic suppression. The simulated results are verified with the experimental results.* Microwave Opt Technol Lett 53:2897–2899, 2011; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.26393

Key words: *power divider; open complementary split-ring resonator; slow wave effect*

1. INTRODUCTION

Microstrip power dividers are widely used in RF/microwave front-end systems such as power amplifiers, mixers, feed network of an antenna array system for distribution of low-power signals and laboratory equipments. In order to meet the growing demands of size miniaturization and cost reduction of various communication systems, many attempts have been made to reduce the size of the microwave circuits. Defected ground structures (DGSs) and photonic bandgap structures (PBGs) have been used to reduce the size of the power dividers and couplers [1–7]. In Ref. [1], a new type of compact microstrip ring hybrid incorporating PBG cells embedded in the ring is presented and 23% size reduction is achieved. A 4:1 Wilkinson power divider with DGS is proposed in Ref. [2]. An EBG embedded in-phase hybrid ring equal power divider, providing a much broader bandwidth and occupying a smaller area with harmonic suppression characteristic is presented in Ref. [3]. Wilkinson power divider using microstrip EBG cells for the suppression of harmonics and size reduction is presented in Ref. [4]. Using I-shaped DGS and complementary split-ring resonator (CSRR) DGS, compact power divider and branchline coupler for wireless application are presented in Refs. [5] and [6]. Recently, a metamaterial based T-junction power divider with considerable size reduction is discussed in Ref. [8].

In our work, we propose a new compact T-junction power divider using an open complementary split-ring resonator (OCSRR) for 900 MHz GSM operation with considerable size reduction. The proposed power divider occupies lesser area than the conventional power divider and provides better third harmonic suppression.

2. OPEN COMPLEMENTARY SPLIT-RING RESONATOR

OCSRR is a negative image of the open split-ring resonator (OSRR). It was first proposed by some of the authors in CPW technology [9] and mostly used for the design of size miniaturized filters [9–12]. In our work, OCSRR is first time used for the size miniaturization of power divider using microstrip technology. The schematic of the OCSRR is shown in Figure 1(a).

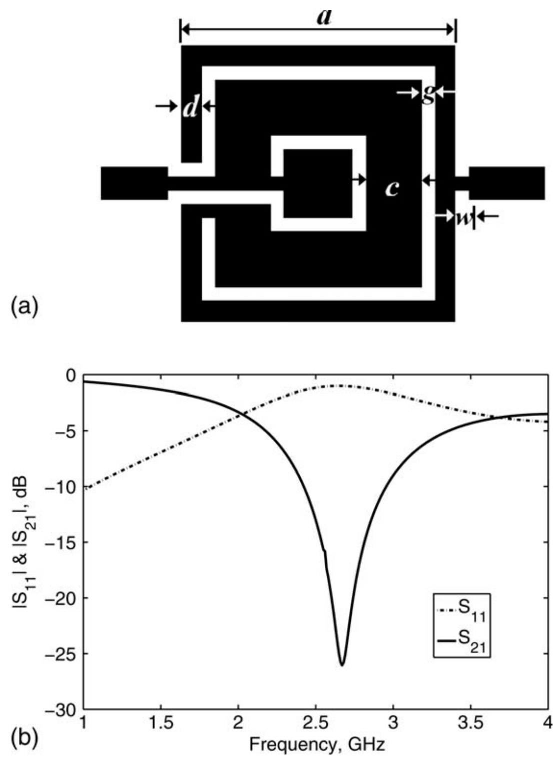

Figure 1 Open complementary split-ring resonator (a) geometry (b) simulated scattering parameters

When compared with the CSRR, the electrical size of the OCSRR is roughly half for the same resonant frequency [9] and hence, size miniaturization is possible. To study the frequency response of the OCSRR, this structure is designed on a FR4 substrate having a dielectric constant of $\varepsilon_r = 4.4$ and a thickness of 1.6 mm. The dimensions of OCSRR are as follows: $a = 6$ mm, $c = 1.45$ mm, $d = 0.3$ mm, $g = 0.4$ mm, and $w = 0.4$ mm. Commercial full-wave simulator CST Microwave Studio is used for simulation purpose. The simulated results are shown in Figure 1(b). During resonance, the OCSRR acts as an open resonator and the total transmitted energy is reflected back to the source, thereby causing an attenuation pole at $f_r = 2.67$ GHz. As the OCSRR is embedded in a microstrip line, it increases the inductance and capacitance of the microstrip line resulting in a slow-wave effect.

3. POWER DIVIDER USING OCSRR

To validate the size reduction capability of OCSRR, a compact T-junction power divider using an OCSRR is presented here. First, the conventional power divider is designed using two quarter wavelength transmission line with characteristics impedance of 70.7 Ω. The center frequency of the power divider is chosen as 900 MHz. Figure 2 shows the simulated results of the conventional equal split power divider. To design an OCSRR-based power divider, the OCSRR is embedded in a 50-Ω microstrip line. The length of the microstrip line is 30 mm, which is approximately equal to the $\lambda_g/4$ at 1.3 GHz. The dimensions of the OCSRR are adjusted to obtain 70.7 Ω line impedance and 90° phase shift at the center frequency. The characteristics impedance of the OCSRR embedded microstrip line is calculated using the method described in [2] as follows. Figure 3 shows the simplified transmission line model to determine the characteristic impedance of the OCSRR-embedded microstrip line, where Z_0 is the port impedance. When $\theta = \Pi/2$ (at the

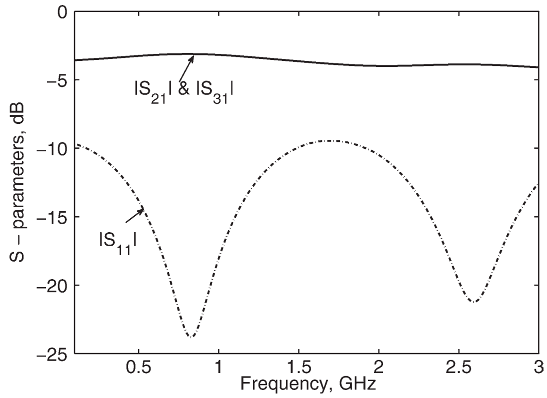

Figure 2 Scattering parameters of conventional power divider

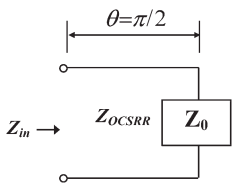

Figure 3 Simplified transmission line model to determine the characteristic impedance of OCSRR-embedded line

center frequency), the magnitude of the reflection coefficient (Γ) is maximum and it can be calculated from S_{11} by Eq. (1). Once $|\Gamma|$ is known, Z_{in} is calculated by Eq. (2). Finally, the impedance of OCSRR embedded line is calculated from Eq. (3).

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

$$Z_{\text{in}} = Z_0 \frac{1 + |\Gamma|}{1 - |\Gamma|} \quad (2)$$

$$Z_{\text{OCSRR}} = \sqrt{Z_{\text{in}} Z_0} = \sqrt{\frac{1 + |\Gamma|}{1 - |\Gamma|}} \quad (3)$$

Figure 4 shows the simulated phase response of the OCSRR-embedded microstrip line and the conventional microstrip line. From the figure, it is observed that the phase of the OCSRR embedded line is -90° at 0.9 GHz and the phase of the conventional microstrip line is -90° at 1.3 GHz. The low-resonant frequency shows that the OCSRR-embedded microstrip line generates the slow-wave effect. To validate the proposed method, a T-junction power divider operating at 900 MHz GSM frequency is designed and fabricated. The layout and fabricated prototype of the proposed power divider are shown in Figure 5. The dimensions of the OCSRR are adjusted to obtain the required line impedance. The optimized dimensions of OCSRR used in the proposed power divider are a = 7 mm, c = 0.9 mm, d = 0.4 mm, g = 0.4 mm, and w = 0.4 mm. The simulated and

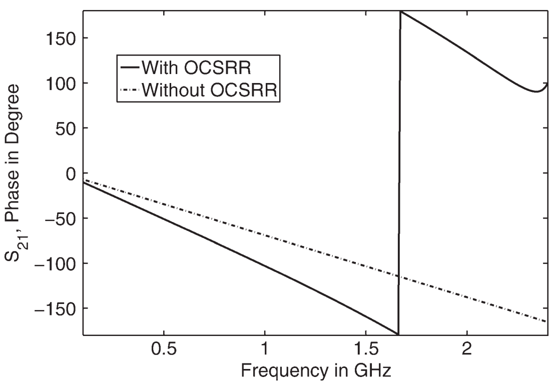

Figure 4 Simulated phase response of microstrip line with and without OCSRR

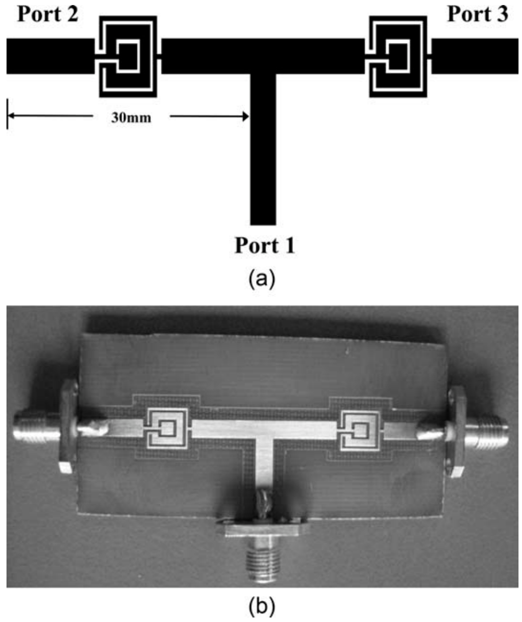

Figure 5 Proposed power divider (a) layout and (b) fabricated prototype

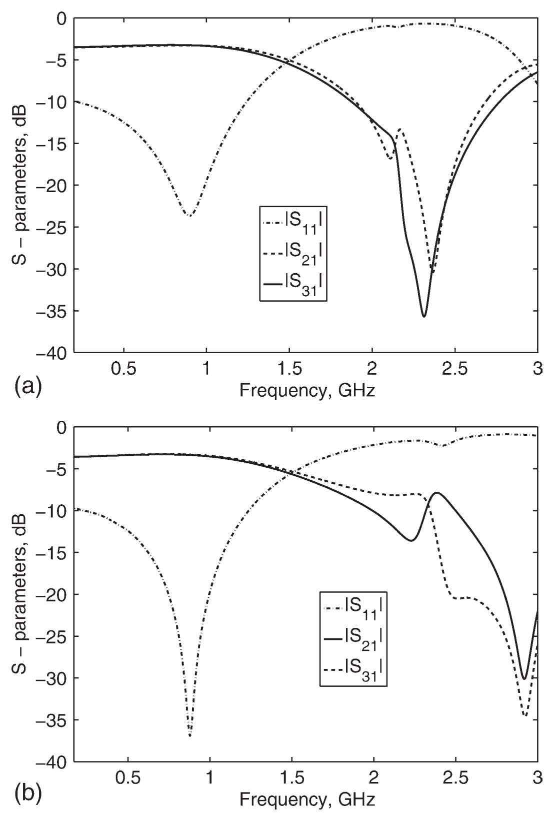

Figure 6 Proposed power divider (a) simulated scattering parameters and (b) measured scattering parameters

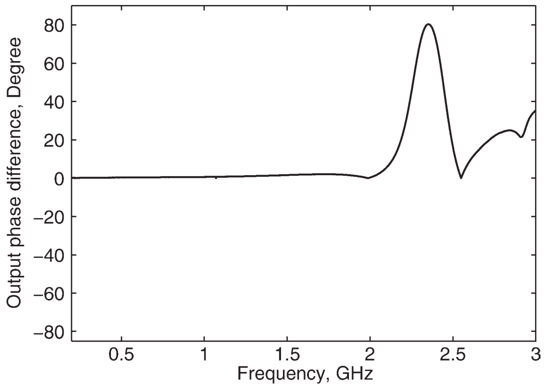

Figure 7 Measured phase difference between the output ports of the proposed power divider

TABLE 1 Comparison of Various Power Dividers

Power Divider	Circuit Area (mm^2)	Relative Area (%)	Size Reduction (%)	Third Harmonic Suppression (dB)
Conventional	3520	100	No	No
Reference [6]	Not shown	68	32	Not shown
Proposed	1890	53	47	22

measured frequency responses of the proposed power divider are shown in Figure 6. As seen from the figures, the power is equally divided between the two output ports with measured insertion loss of −3.325 dB which is very close to the ideal −3 dB. The measured reflection coefficient is more than −36 dB in the center frequency of the band and the third harmonic suppression is more than 22 dB. The shift in measurement and the simulation frequency is mainly due to the reflections from the connectors and tolerances in fabrication process. Figure 7 shows the measured phase difference between the output ports of the proposed power divider. It was observed that the two output port signals are in phase with each other around the center frequency with the maximum phase imbalance of 0.5°. Table 1 gives a comparison between the power dividers.

4. CONCLUSIONS

Size reduction is the major concern for the design of microwave devices operating in the low-frequency range. Hence, in this letter, mainly the size reduction capability of the OCSRR is presented with the help of T-junction power divider. However, the same technique can be used for other power dividers such as Wilkinson power divider, branchline coupler, and so on. The proposed power divider size is 47% smaller than the conventional power divider and the third harmonic suppression is achieved without adding any additional structure. This power divider is simple from fabrication point of view as well, because it does not involve any via holes.

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ALL-ELECTRONIC TERAHERTZ SPECTROMETER FOR BIOSENSING

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ABSTRACT: *A compact and cost-efficient all-electronic terahertz (THz) system is presented for the spectroscopic read-out of marker-free THz biosensor chips. The table-top system is based on only one oscillator for emitter and quasi-heterodyne detector operation. Frequency mixing is applied to perform THz signal frequency sweeps from 220 to 320 GHz in less than 250 μs. The concept is explained and demonstrated at exemplary biochip measurements. Results and performance of the electronic system are compared with the laser-based THz-time-domain spectroscopy.* © 2011 Wiley Periodicals, Inc. Microwave Opt Technol Lett 53:2899–2902, 2011; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.26392

Key words: *terahertz; biosensing; heterodyne; spectroscopy; split-ring resonator*

1. INTRODUCTION

Research in the field of terahertz (THz) biosensing created new analysis methods for biological or medical examination [1], such as the spectroscopic read-out of application specific