Wideband Power Divider Using Novel Split-Ring Resonator

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Abstract **—** A set of novel split-ring resonator basic block Hybrid-Microwave Integrated-Circuit (HMIC) components (transmission line, open and short stubs) is presented with applications to the RF/Microwave power divider. This new open and short LH HMIC resonators have compact sizes of 0.81 and 1.44 mm^2, respectively. The prototypes of an LH power divider constructed from these basic components have been designed, fabricated, and characterized. The LH power divider including two LH branches shows equal power split from 1 to 7 GHz. The proposed power divider benefit from the miniaturized LH HMIC components and have compact sizes of 2.205 mm^2, respectively. There is a good agreement between the full-wave simulations and measurement results with 0.254-mm thick RT5880 substrate. While maintaining similar performance, a 50% reduction in impedance transformer is achieved in comparison to a conventional design.

Index Terms **—** Compact, power divider, Split Ring Resonators (SRRs).

I. INTRODUCTION

There is an increasing demand to design compact broad-band components for modern wireless communication systems. A key aspect in such components is to achieve their functionality at the required system frequencies. In this regard, due to the possibility of engineering their dispersion diagram, metamaterial-based artificial lines provide a good solution [1]. Such artificial lines have been applied to the design of broad-band power dividers, among other microwave components [2]. Recently, several works have demonstrated the possibility of implementing broad-band and even multiband components by means of metamaterial-based artificial lines, including the experimental validation of a broad-band microwave passive circuit. One of these approaches consists on the implementation of microwave components by means of metamaterial transmission lines. Such lines are artificial lines consisting on a host line loaded with reactive elements, and they can be implemented by means of two main approaches: (i) the CL-loaded approach, where conventional transmission lines are loaded with series capacitances and shunt inductances, and (ii) the resonant-type approach, where the lines are loaded with sub-wavelength resonators, such as Split-Ring Resonators (SRRs) or Complementary Split-Ring Resonators (CSRRs) combined with shunt inductances and series capacitances, respectively [3]. These lines exhibit controllable electrical characteristics, beyond what can be achieved in conventional lines, because of the fact that there are more degrees of freedom. In addition, metamaterial transmission lines can be designed to be electrically small, which makes them suitable for the synthesis of compact microwave circuits. In the case of the resonant-type approach, the size of the line is determined by the size of the resonators; for this reason, it is possible to obtain an important level of miniaturization (the use of electrically

Submitted On: May 17, 2013
Accepted On: October 6, 2014

small resonators and the possibility to implement artificial lines with the required phase and impedance with a single unit cell is relevant for size reduction).

The power divider and combiner are very important components for microwave power amplifiers [4-6]. Recent years have seen a worldwide effort to develop wide-band power dividers due to the trend of broad band mobile systems. A conventional power divider operates only at one design frequency. Therefore, it is not suitable for some broad-band operations. In some applications, a broad-band operation is needed. In the literature, most of the papers are based on the power divider and their multi-band operation is achieved by using open and short-ended stubs, by multiple transmission line transformers or by coupled lines. All these devices use the classical microstrip transmission line and therefore show low performances regarding miniaturization or operating bandwidth. The Split Ring Resonators (SRRs) is a practical implementation of a left-handed metamaterial which is generally defined as an artificial, effectively homogeneous electromagnetic structure with unusual properties, not readily available in nature [7]. Several power dividers based on the Split Ring Resonators (SRRs) have been proposed. However, they are single band and have either high insertion loss or narrow band between output ports. This paper presents a novel broad-band power divider also based on the SRRs, but with improved performances as compared to the previous mentioned work.

II. POWER DIVIDER DESIGN

The geometry of the proposed novel broadband power divider is shown in Fig. 1. This power divider printed on a 0.254-mm thick RT5880 (substrate with dielectric constant ε_r =2.2 and loss tangent tan=0.0009) with dimension of 15×14.97 mm^2. The size of inner-square (R_1, R_2) should be adjusted to determine the central frequency of power divider as simulated in Fig. 2. If other parameters are fixed, the central frequency will increase with the decrease of R_1 and R_2. If R_1 and R_2 are fixed, the central frequency could be also enhanced by increasing slit width of squares (g) as simulated in Fig. 3. For the convenience of optimization, the width of squares (d_1, d_2) and distance between squares are set to be the same as (g). After that, the height (h) and length(s) should be also optimized. These optimization works were managed by using commercial 3-D electromagnetic software HFSS [8].

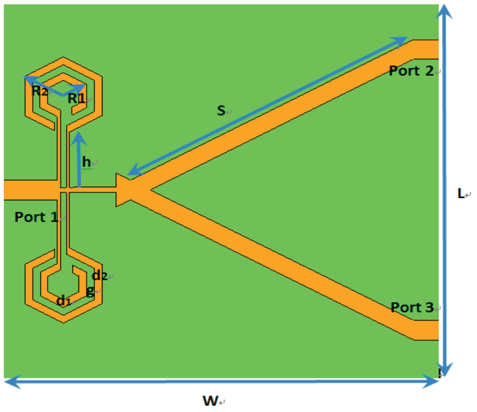

Fig. 1. Geometry of power divider, the dimensions are: R_1=0.9 mm, R_2=1.29 mm, d_1=0.2 mm, d_2=0.2 mm, g=0.19 mm, S=10.9 mm, h=1.02 mm, W=15 mm, and L=14.97 mm.

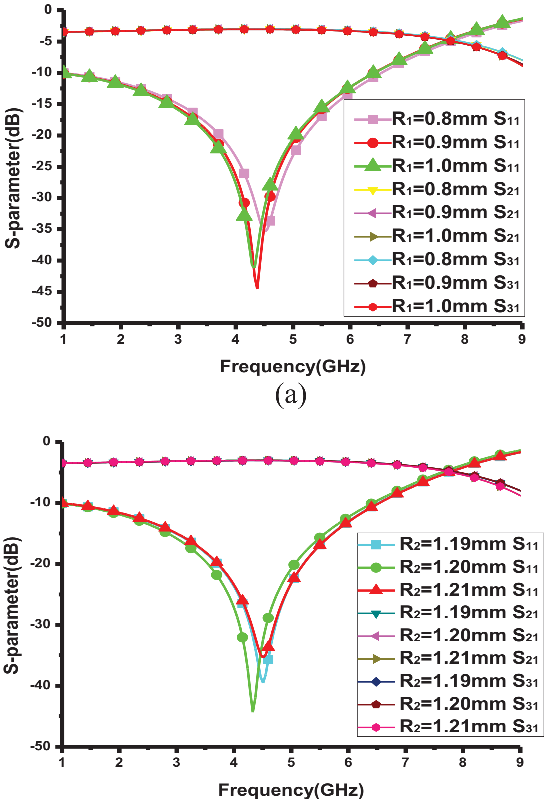

Fig. 2. (a) Simulated S-parameters of different radius of R_1, and (b) simulated S-parameters of different radius of R_2.

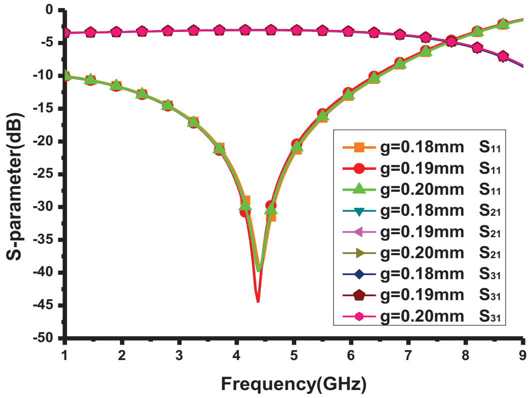

Fig. 3. Simulated S-parameters of different slit width of squares (g).

III. RESULTS AND DISCUSSION

To validate the proposed design, the novel split-ring resonator unit cell based power divider was fabricated [9]. The photograph of the fabricated device is shown in Fig. 4, and we can see its compact size from Table 1. The prototype has been characterized and its relevant measured scattering parameters (return losses and transmission coefficient) are shown in Fig. 5. By comparing Fig. 5 and Fig. 6, it can be seen that there is good agreement between simulated and measured results for the novel broadband microstrip power divider. However, the measured central frequency (4.45 GHz) is higher by approximately 2.2% than the simulated frequency (4.35 GHz). This shift can be attributed to fabrication tolerances, connectors, and the substrate properties [15-17]. The measured return loss is below -45 dB, and the measured insertion loss at each branch, is approximately -3.5 dB. The slightly higher loss value approximately 0.5 dB is attributed to inaccuracies in fabrication of the structure. The measured results show that this new unit cell can be used in the design and fabrication of miniaturized RF and microwave circuits.

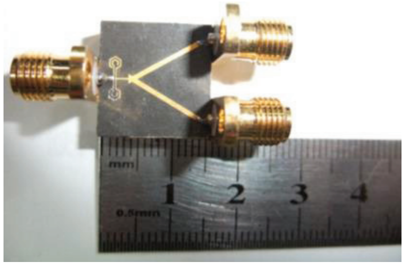

Fig. 4. Photograph of the proposed novel power divider.

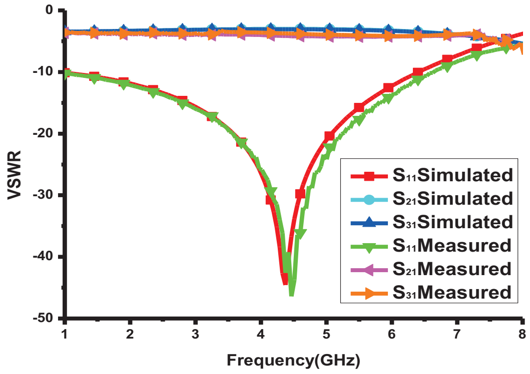

Fig. 5. Measured and simulated frequency responses for the thrus (S_{21} and S_{31}), and the return loss (S_{11}) of the broadband power divider.

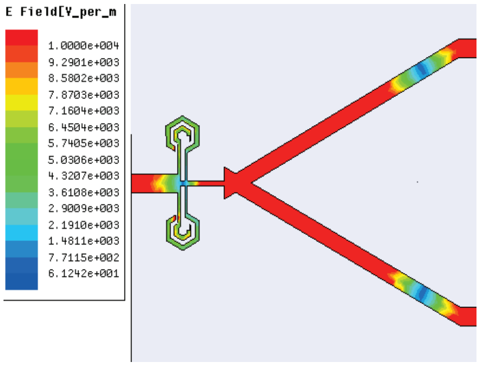

Fig. 6. Simulated electric field (4.35 GHz) on the proposed broadband power divider.

Table 1: Comparison of sizes with reported power dividers

	[10]	[11]	[12]	[13]	[14]	This work
Frequency Range (GHz)	3.1~10.6	3~4.7	1.15~2.21	4.25~4.75	2.7~4.7	1~7
Power-Dividing Radio	1:1	1:1	1:1	2:1	1:1	1:1
Size ($\lambda_g \times \lambda_g$)	0.75x1.12	1.04x0.28	0.69x0.59	0.98x0.98	0.81x0.40	0.33x0.33

IV. CONCLUSION

In this paper, a novel broadband microstrip power divider utilizing Split Ring Resonators (SRRs) has been proposed. Based on the unique properties of the split ring resonators, the designed wideband power divider that can operate multi-frequency bands, covering the requirements of the most common telecommunication systems. The power divider shows good performances, low insertion loss and compact size. In contrast to the conventional power divider, its size does not depend on the operating frequency. The proposed broadband microstrip power divider is a promising device for microwave and millimeter wave communication systems.

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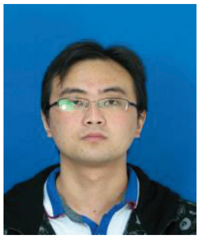

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