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Design and Implementation of a Power Divider 1 to 16 Ports for 1 to 12 GHz Frequency Range

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Abstract: *This article presents the design and implementation of a power divider with a power division ratio of 1 to 16. This power divider is designed for the ultra-wide frequency bandwidth of 1 to 12 GHz. For this purpose, we used four sections of 1:2 power division. In each section, stepwise tapering for impedance matching and multiple 0402 package RF resistors are used for isolation implementation. Furthermore, many stubs are used to enhance the operating bandwidth. Then, the 1:16 power divider is implemented by cascading these sections. The design divider has been fabricated on the Ro4003C substrate and verified. The measurement results show less than 0.5dB and 5 degrees dividing unbalancing in amplitude and phase, respectively. Further more, the dividing excess loss is about 1dB in the bandwidth. The minimum isolation of 12dB is another property of the structure. The overall compactness of 235×198×0.5 mm3, ease of fabrication, and promising performance make the proposed design a good candidate in ultra-wideband applications.*

Keywords: *Powerdivider-Wilkinson-UltraWideBand-1to16 power division-multi section.*

1. Introduction

Power dividers are important tools in RF and microwave systems that are used to divide the power of input signals into multiple outputs. They are key tools in microwave and RF systems, widely used in applications such as antennas, filters, and amplifiers, and help split an input signal into multiple output signals with low power loss. One of the most popular types of power dividers is Wilkinson, which is used in complex and high-power systems due to its special features, such as impedance balance and maintaining the power ratio. These systems can distribute the power without the possibility of excessive reflections or splitting the efficiency loss into several different lines. In modern communication systems that need to separate and distribute signals with different frequencies, these dividers are widely used. Different types of power divider designs in the number of power divisions in different bandwidths can be seen in the literature. An axially symmetric radial waveguide power divider, which utilizes a specific Cycloidal-Like tapered transition between a central coaxial launcher and a radial waveguide, is presented in this paper [1]. In this paper, an approach to 1 to 2n ($n = 2.3.4.\cdots$) way microstrip balanced power divider is proposed. This approach is realized by one B. balanced to-single-ended power divider, $2n-1$ single-ended-to-balanced power dividers, and $2n-1-2$ single-ended power dividers [2]. In the design of a microstrip power divider, there are some important factors, including harmonic suppression, insertion loss, and size reduction, which affect the quality of the final product. Thus improving each of these factors contributes to a more efficient design. In this respect, a hybrid technique to reduce the size and improve the performance of a Wilkinson power divider (WPD) is introduced in this paper [3]. This paper an ultra-wideband Wilkinson power divider (WPD) using a binomial multi-section matching transformer proposed [4]. This study shows the improvement of output responses due to the introduction of $\lambda/4$ multi-sections and isolation resistors[5]. In this paper, a wideband filtering power divider (PD) with ultra-wideband harmonic suppression and isolation is proposed. The dual coupled-line sections are embedded in the conventional quarter-wavelength transmission lines, which helps to extend the passband of the PD [6]. This work presents a 1×4 fully reconfigurable power divider with a wide range of power divisions and reduced size, designed for adaptive null forming and beam steering networks in RF front ends. The design is based on the impedance transformation of series-coupled cascaded transmission lines and a reconfigurable isolation network [7]. A Compact Ultra-Wideband (UWB) single-layer power divider with an out-of-phase feature is proposed in this work [8].

In this research to design the 1:16 power divider, we have focused on enhancing the bandwidth to cover the frequency range of 1 to 12 GHz. This system consists of four levels of dividers, to achieve 1:16 dividing ports. Next, in the system design section, the method of enhancing the bandwidth of the system is explained. The results of the system were tested after the implementation. It is shown that the simulation and measurement results are in good agreement.

2. System Design and Simulation

The design of this system consists of four separate power divider floors. These four floors are finally cascaded to implement a 1:16 power divider.

2.1. First Floor Design Method

In the design of this floor with the theory of matching the 50 Ohms impedance of port one (input) with two 50 ohm impedances in ports 2 and 3 (outputs) which are placed in parallel and the final impedance of the two from the point of view of port 1, is 25 Ohms, the tapering method is used. In order to cover this bandwidth, the number of tapering sections of the structure has been increased. The dimensions and length of each tapering section and its impedance characteristics are shown in Table I and Fig 1. In Wilkinson's method, the location of lumped elements is clear to create optimal isolation. In this design, there was an optimization need to decide on the location and number of elements used. This optimization was done using CST software and finally, $N = 5$ was selected as the number of elements to achieve the best S_{11} and isolation between the two output ports. The comparison diagram of the effect of the number of elements on the value of the structure parameters in Fig 2. is clear.

2.2. Introducing the Method

As we see in all Wilkinson power divider designs, the following relationships are utilized in the designs. In the design of this type of power divider, the quarter-wavelength ($\lambda/4$) microstrip lines are significant. However, this becomes challenging in wideband designs due to the absence of a single selected frequency. Therefore, after discussing tapering and multi-section binomial methods, we will cover the topic of quarter-wavelength in this study.

To enhance the impedance bandwidth of input and output return loss of the power divider, our study employs a binomial multi-section matching transformer rather than a Chebyshev multi-section matching transformer. This choice is made to reduce ripple levels. The binomial design provides a flatter response, which is advantageous for applications requiring minimal signal variation across the operating bandwidth. In contrast, while Chebyshev transformers can achieve wider bandwidths, they often introduce passband ripple, making them less suitable for our objectives of maintaining signal integrity. So, to find the characteristic impedance of the lines, inspired by this method, equation (1) along with the optimization of the software, we proceed [5] and [9].

$$ln\frac{Z_{n+1}}{Z_n} = 2^{-N} C_n^N ln\frac{Z_l}{Z_0} \quad where; C_n^N = \frac{N}{(N-n)n} \tag{1}$$

Where ; $N =$ number of multisections , $n = 0$ to $N - 1$.

According to the obtained results, it is necessary to use at least five lumped elements to achieve isolation better than $-20\ dB$.

Further along the path, with a 1:2 divider system, Fig 1. and the results: $S_{11} < -20\ dB, S_{ii} < -20\ dB, S_{i1} = -3.5\ dB$ and $S_{23} < -20\ dB$. In the next step, we will cascade three dividers to implement a 1:4 one. In the next step, another divider is placed in each of the 4 ports and a power divider of 1:8 is made. The tapering information of each section all follows from Table 1. The results of the 1:4 and 1:8 divider are shown in Fig 3. In the last step, we cascade the power divider at the output of all 8 ports and implement 1:16 divider. The simulation results of this divider are shown in Fig. 4.

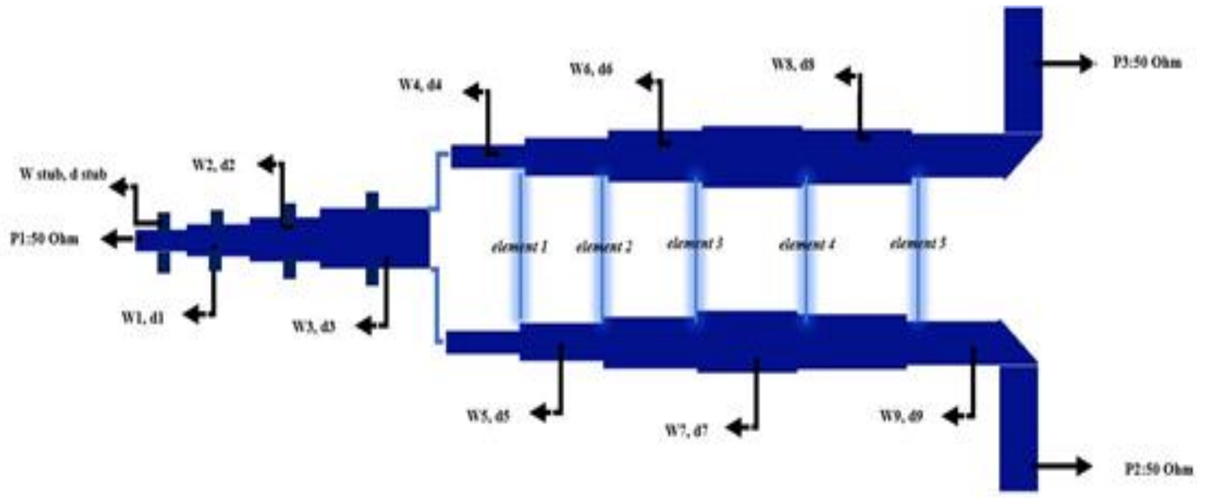

Fig1. *Schematic design of the construction classes of the power divider*.

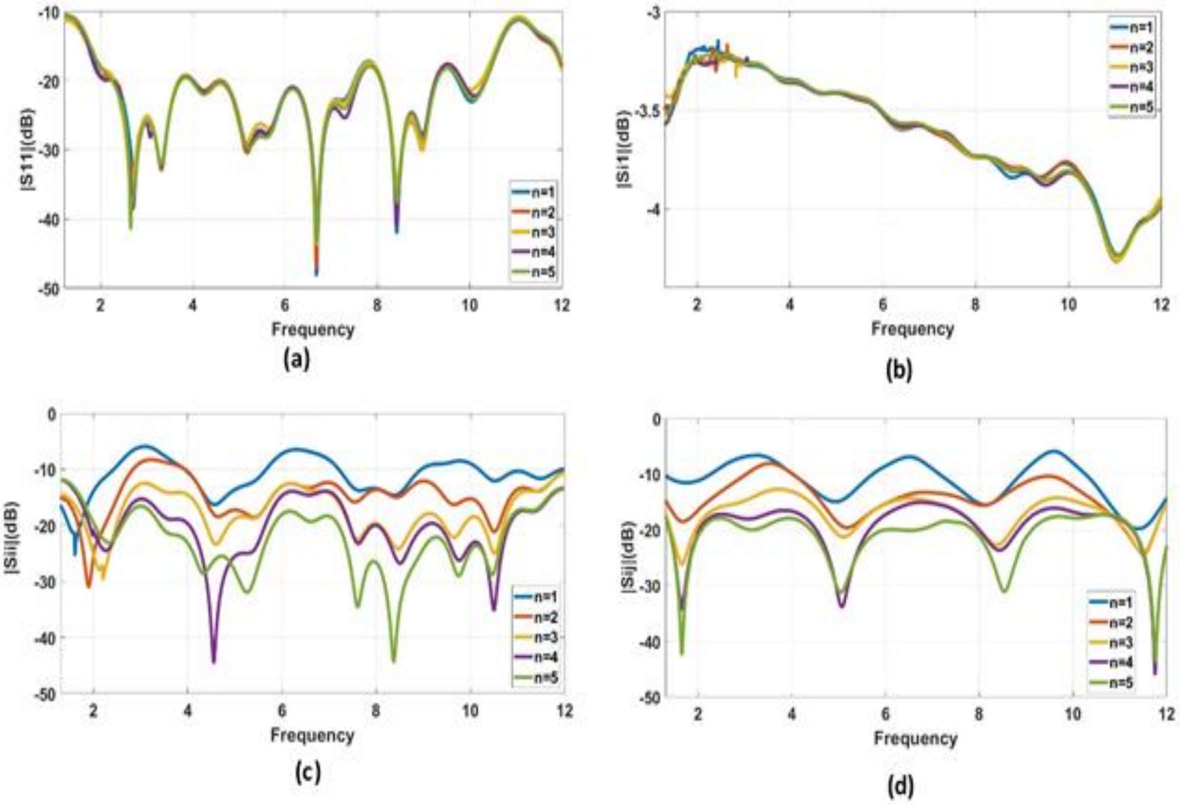

Fig2. *Comparison of the number of lumped elements (a) S_{11} , (b) S_{i1} , (C) S_{ii} , and (d) S_{ij} isolation.*

Table1. *Guide to simulation dimensions*

Line No.	**Dimensions of the structure**		
	Parameter	**Value (mm)**	$Z_n(\Omega)$
1	W_1& d_1	**1.34 & 6**	**43.7**
2	W_2& d_2	**1.7 & 6**	**37.3**
3	W_3 & d_3	**2.18 & 6**	**31.2**
4	W_4 & d_4	**0.94 & 6**	**54**
5	W_5 & d_5	**1.074 & 4.58**	**50.1**
6	W_6 & d_6	**1.144 & 3.23**	**48.2**
7	W_7 & d_7	**1.48 & 6**	**48.1**
8	W_8 & d_8	**1.11 & 6**	**49.1**
9	W_9 & d_9	**1.077 & 2**	**50**
10	W_{Stub}& d_{Stub}	**0.1 & 0.1**	**124.91**

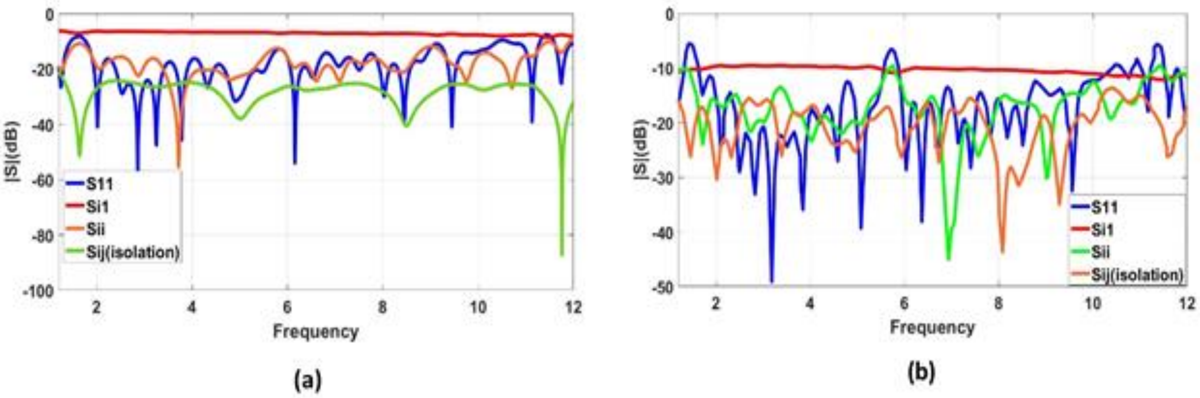

Fig1. *The results of 4 and 8 port divider (a) 1 to 4 and (b) 1 to 8.*

3. System Implementation and Testing

In this section, the test results and implementation of the structure have been presented. The structure is made on a Ro4003C substrate with a dielectric coefficient of 3.55 and a thickness of 0.5 mm. The structure is shown in Fig. 5. We used a VNA device to test this structure. The port of one device was connected to the input port and the second port of the device was connected to one of the output ports. Other outputs are matched by 50 ohm matching load. This test was repeated for all outputs.

In the next test stage, both network ports were connected to the outputs of the power divider to check the isolation between the ports. The results obtained from the test are shown in Fig. 6. The test results were in good agreement with the simulation results. Considering the achieved results in comparison to those reported in the literature reveals an enhancement in the performance, as shown in Table 2.

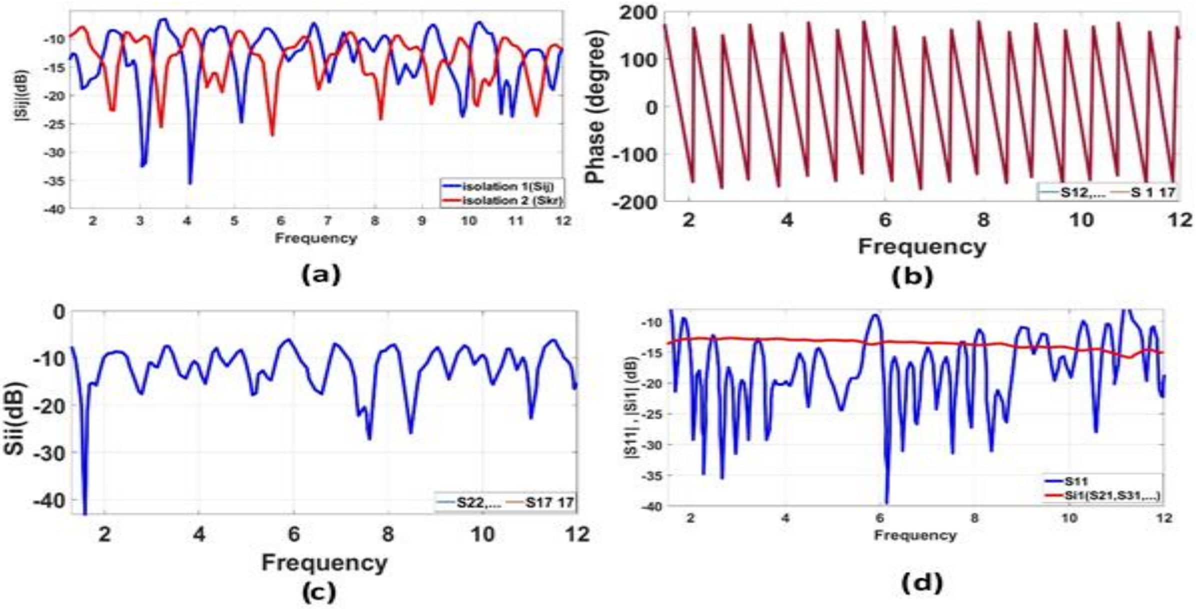

Fig2. *Simulation and results of 16-port power divider (a) S isolation, (b) Phase, (c) S_{ii} , and (d) $S_{11}$and S_{i1}.*

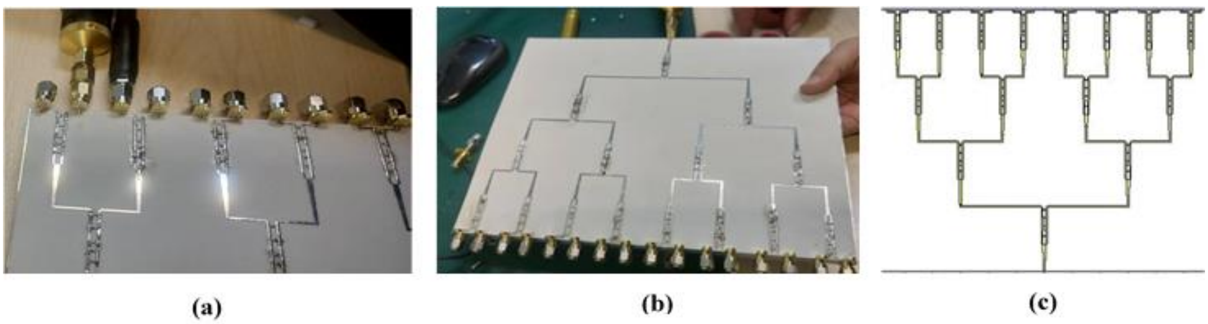

Fig3. *Power divider Structure (a) Zoom in structure, (b) Connected to the network, and (c) Simulation in CST.*

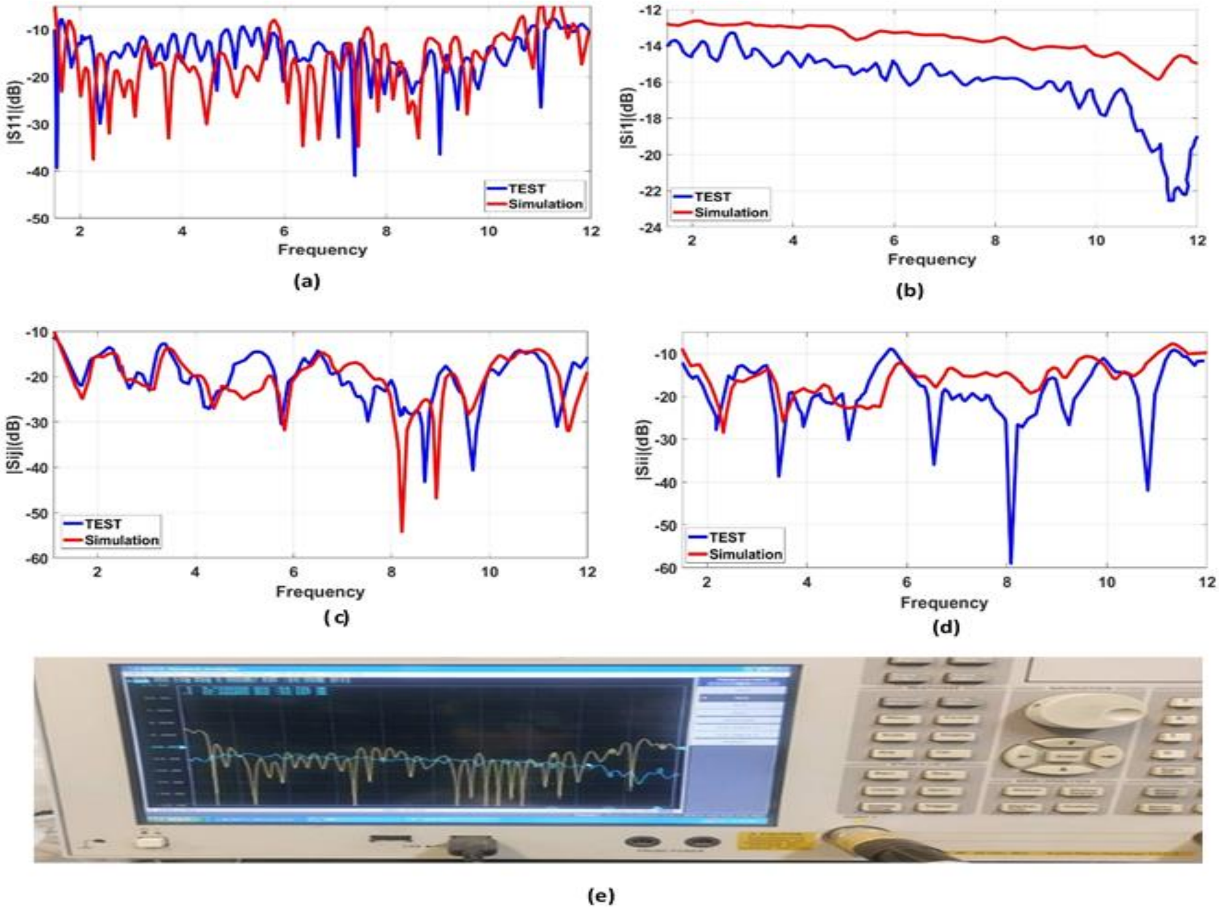

Fig4. *Comparison of test and simulation results (a) S_{11}, (b) S_{i1} , (c) isolation, (d) S_{ii} , and (e) Network test.*

Table2. *Comparison with other works*

Reference	Number of out port	Lumped element	Isolation	Frequency Bandwith (GHz)
[10]	3	R,C	$15dB >$	2.5-18
[12]	2	R,L,C	$13dB >$	1-9
[13]	4	R,L,C	$15dB >$	7-11.8
[14]	2	R	$10dB >$	3.1-10.6
[15]	2	R	$11dB >$	3-27
This Work	16	R	15dB>	1-12

4. Conclusion

Proposed power divider, capable of efficiently distributing power across 16 ports over a wide frequency range of 1 to 12 GHz, shows considerable promise for advanced RF and microwave applications. This system shows how the design is realized with this 12 GHz bandwidth and is a solution for widebanding the future works in these fields. The achieved results show less than 0.5dB and 5 degrees dividing unbalancing in amplitude and phase, respectively. furthermore, the dividing excess loss is about 1dB in the bandwidth. The minimum isolation of 12dB is another property of the structure. The overall compactness of 235×198×0.5 mm^3 show a success in reducing dimensions. This means reducing construction costs. In view of the ultra-wide band operation, this structure is a serious competitor to the radial or coaxial TEM structures. The ultra-wideband power divider presented in this study, with its smaller dimensions compared to existing designs, is an ideal choice for biomedical engineering applications. Its high efficiency, low power loss, and compact design make it suitable for medical imaging systems, patient monitoring devices, and wireless power transfer for implants, significantly enhancing the performance and accuracy of medical equipment. While the simplicity and ease of fabrication is undeniable advantage of the proposed structure.

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