Short Paper

A Triangular Wilkinson Power Divider with Spaced Output Ports

M. Khalaj-Amirhosseini*, M. Moghavvemi** and A. Attaran**

Abstract: This paper proposes an idea to modify the conventional Wilkinson power dividers to have physically spaced output ports. The well-known internal resistor of Wilkinson power divider is now connected to output ports by two additional transmission lines to create a triangular shape power divider. Several modified power dividers are designed at frequency of 1.0 GHz and one of them is fabricated and measured. The measured results of the fabricated diplexer have very good agreement with the theoretical results.

Keywords: Wilkinson Power Divider; Triangular power divider; Spaced Output Ports.

1 Introduction

Microstrip power dividers are commonly used in microwave circuits to divide a power to at least two channels, or combine the powers in a channel. A commonly used microstrip power divider is Wilkinson [1, 2] type. There are two practical drawbacks for Wilkinson power divider in its original shape or all other shapes proposed to miniaturize [3-5], operate as multi-frequency [6-9] or broaden the bandwidth [10-12]; the output ports must be very near to each other and straight transmission lines can't be used. This caused by the well-known internal resistor connected between two output ports where its physical size is very small. In this article, the conventional Wilkinson power divider is modified by adding two transmission lines to the internal resistor at the output ports. In the proposed power divider which has a triangular shape, the output ports are essentially spaced out. In fact, the internal resistor is connected to output ports by two transmission lines and not directly alone. The performance of the proposed power divider is evaluated using few examples including one fabricated and operating at frequency 1.0 GHz.

2 Triangular Power Divider

Fig. 1 depicts an actual conventional Wilkinson power divider composed of two quarter wavelength

transmission lines connected to a very short length resistor, i.e. the well-known internal resistor at its two output ports. As it is observed, two transmission lines cannot be straight because the output ports must be physically near to each other. Fig. 2 depicts the proposed power divider (Triangular Power Divider) which has not the aforementioned practical drawbacks of the conventional Wilkinson power divider. Two vertical lines of arbitrary length θ_0 have been added to the resistor at the output ports as well as one horizontal line of the same length θ_0 at the input port. Two transmission lines connecting the input to outputs are quarter wavelength with characteristic impedance giving by

$$Z_1 = \sqrt{2}Z_0 \cos\theta_0 \tag{1}$$

Having found the input and output impedances of the proposed power divider in two cases of even and odd modes, the S parameters of the whole structure can be determined as follows

$$S_{11} = \frac{Z_{in}/2 - Z_0}{Z_{in}/2 + Z_0} \tag{2}$$

$$S_{22} = S_{33} = \frac{1}{2}\frac{Z_{out}^e - Z_0}{Z_{out}^e + Z_0} + \frac{1}{2}\frac{Z_{out}^o - Z_0}{Z_{out}^o + Z_0} \tag{3}$$

$$S_{23} = S_{32} = \frac{1}{2}\frac{Z_{out}^e - Z_0}{Z_{out}^e + Z_0} - \frac{1}{2}\frac{Z_{out}^o - Z_0}{Z_{out}^o + Z_0} \tag{4}$$

$$|S_{21}| = |S_{31}| = \sqrt{(1 - |S_{11}|^2)/2} \tag{5}$$

where Z_{in} is the input impedance of one of two branches in the even mode and also Z_{out}^e and Z_{out}^o are the output impedances of that branch in the even and odd modes, respectively.
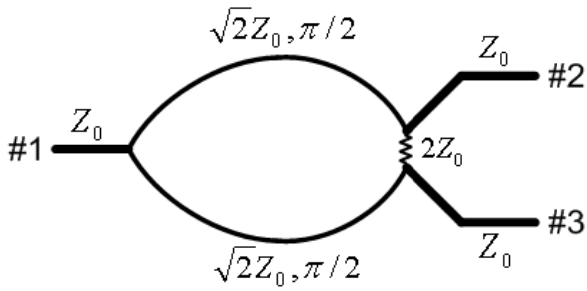
Fig. 1 An actual conventional Wilkinson power divider

3 Examples and Results

In this section the proposed power divider is designed, fabricated and measured at frequency $f_0 = 1.0$ GHz considering $Z_0 = 50$ Ω. Figs. 3-6 illustrate the amplitude of the scattering parameters of four power dividers for $\theta_0 = 45^o$, 30°, 10° and 0° (conventional). The deep nulls at desired frequency are observable for the input and output return losses as well as the output isolation. It is seen that as θ_0 is increased, the bandwidth of power divider is decreased although it is negligible for θ_0 less than about 10°. It is worthy to note that in the case of $\theta_0 = 45^o$, all the transmission lines will have the same characteristic impedance Z_0. The designed power divider with $\theta_0 = 30^o$ is fabricated on a substrate with $\varepsilon_r = 2.2$ and $h = 20$ mil $= 508$ μm (RT/Duroid 5880 from Rogers) as shown in Fig. 7. Fig. 8 shows the measured amplitude of the scattering parameters of the fabricated power divider. It is seen from Figs. 4 and 8 that the agreement between theoretical and measurement results is good except a minus shift frequency around 50 MHz which may be related to the effect of microstrip discontinuities at the connection points. The insertion loss of the fabricated diplexer is 0.3 dB which is due to the losses of substrate, conducting strips and connectors. Also, the input and output return losses and also the output isolation are 26 dB at the optimum frequency.
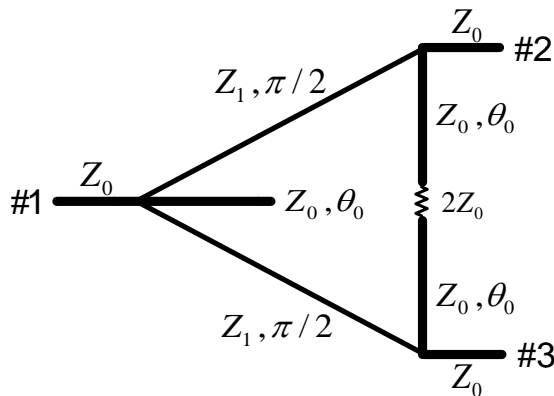

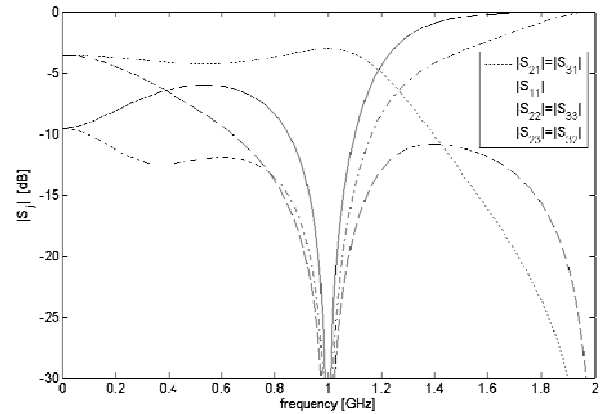**Fig. 2** The modified Wilkinson power divider with spaced output ports

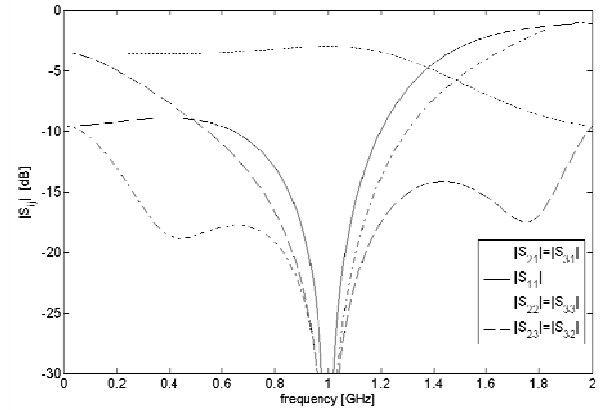**Fig. 3** The amplitude of the scattering parameters of power divider with $\theta_0 = 45^o$ and $Z_1 = 50.0$ Ω

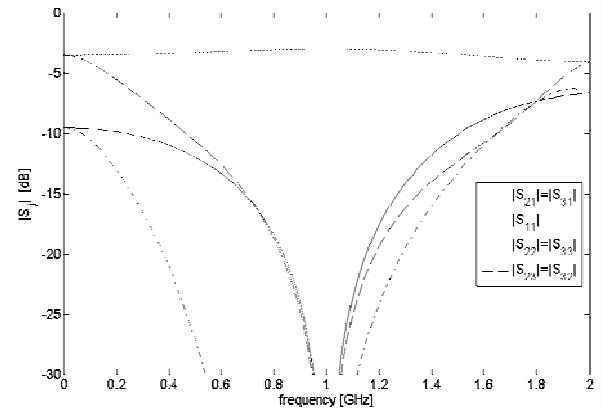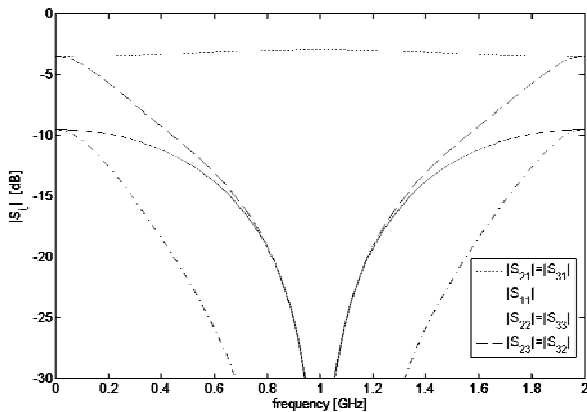**Fig. 4** The amplitude of the scattering parameters of power divider with $\theta_0 = 30^o$ and $Z_1 = 61.24$ Ω

**Fig. 5** The amplitude of the scattering parameters of power divider with $\theta_0 = 10^o$ and $Z_1 = 69.63$ Ω

4 Conclusion

An idea is proposed to modify the conventional Wilkinson power dividers to have physically spaced output ports. The well-known internal resistor of Wilkinson power divider is connected to output ports by two additional transmission lines. Several modified

power dividers are designed at frequency of 1.0 GHz and one of them is fabricated and measured. The measured results of the fabricated diplexer have a good agreement with the theoretical results. It is seen that as the length of connected lines to the internal resistor is increased, the bandwidth of power divider is decreased. Also, when the electrical length of the connected lines is 45°, all the transmission lines in the power divider will have the same characteristic impedance.

Fig. 6 The amplitude of the scattering parameters of power divider with $\theta_0 = 0^o$ and $Z_1 = 70.71\ \Omega$ (conventional)
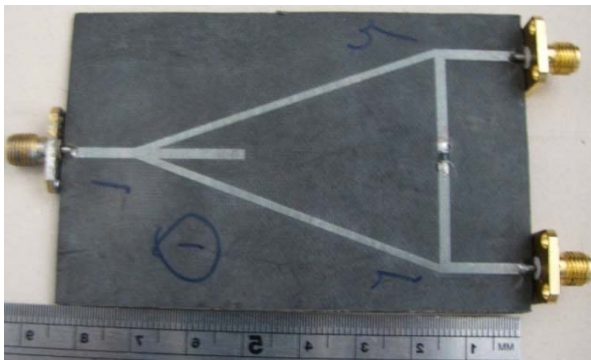
Fig. 7 The photo of the fabricated power divider
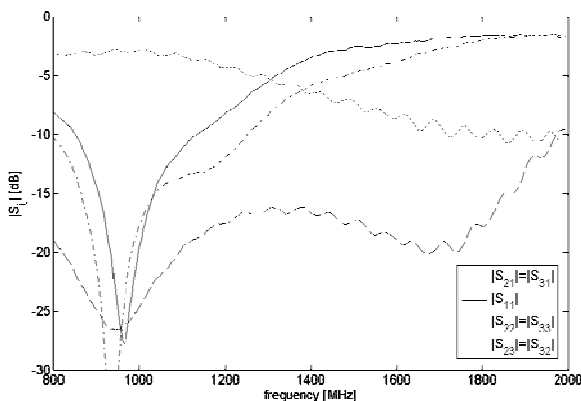
Fig. 8 The measured scattering parameters of the fabricated power divider

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Mohammad Khalaj Amirhosseini was born in Tehran, Iran in 1969. He received his B.Sc, M.Sc and Ph.D. degrees from Iran University of Science and Technology (IUST) in 1992, 1994 and 1998 respectively, all in Electrical Engineering. He is currently an Associate Professor at College of Electrical Engineering of IUST. His scientific fields of interest are electromagnetic direct and inverse problems including microwaves, antennas and electromagnetic compatibility.

Mahmoud Moghavvemi was born in Tehran, Islamic republic of Iran in 1969. He obtained his BSc in Electrical Engineering from the State University of New York, MSc from University of Bridgeport and PhD from the University of Malaya. Prof. Moghavvemi is the Director of Centre for Research in Applied Electronics (CRAE). He is an invited member of New York Academy of sciences and member of who is who in the world since 2007. His current research interests are; Electronic circuit design; application toward sensory interface electronics in industrial, commercial, scientific, transportation, and biomedical systems.
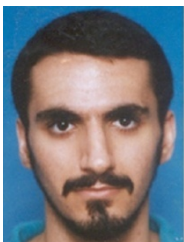
Aliyar Attaran was obtained his BSc in Electrical Engineering from the Multimedia University in Malaysia in 2009, and currently pursuing MSc degree under center of research and applied electronics (CARE) center in University of Malaya.