ISSN: 2449 - 0539

BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY (BJET) VOL.14 NO.1, FEBRUARY, 2019

DESIGN AND SIMULATION OF 2-SECTION MICROSTRIP WILKINSON POWER DIVIDER

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ABSTRACT

Power division is always required in most wireless/wire line communications such as industrial systems and consumer electronics. However, the design of an unequal Wilkinson power divider, particularly with a large division ratio, becomes a challenge in engineering because of the impractical realization of the high- or low-impedance transmission lines on a dielectric substrate. ***.*** *In this paper a 2-Section microstrip Wilkinson Power divider is designed, the circuit was designed and simulated using advanced design system (ADS) Simulator.*
with equal output power division of -3dB matched to 50 Ω transmission line, and frequency centered at 3.5GHz with Chebyshev multisection quarter wave transformer and maximum reflection coefficient in the passband=0.05. The proposed power divider has a typical Wilkinson power divider performance of 0.2 dB insertion loss within 85% fractional bandwidth (17 dB return loss) and -25 dB isolation at the operating frequency

Keywords: Wilkinson power divider, ADS, Microstrip, S-Parameters, Transmission line, isolation, return loss.

1. INTRODUCTION

The performance of lots of microwave subsystems, such as Power amplifiers, mixers, linearizers, and frequency multipliers, depend on the proper functionality of power combiners or splitters (David Pozer, 2005).

Wilkinson power divider is a 3-port network that can achieve all port matched with isolation between the output ports. The conventional equal and unequal Wilkinson power dividers consist of two quarter-wavelength lines with the same and different characteristic impedances, respectively, at the designed frequency. The Wilkinson power is a solution of the lossless T-junction and resistive divider problems. It is not matched at all ports and non-isolated between output ports for T-junction divider, and non-isolated output ports for the resistive divider. (Woo, & Lee, 2005). Therefore, a lot of methods were proposed to adjust the size of power divider as reported in (J.kao, 2012). Especially, a compact microstrip Wilkinson power divider by using capacitive loading of the quarter-wave transmission lines was suggested, but the alternative transmission lines impedance is correspondingly increased. Reduction of the transmission line through capacitive loading is still limited, because the very high impedance transmission lines cannot be implemented in practice. (M.A Maktoomi, 2016), proposed a matching network in which the length was reduced by incorporating RLC isolation impedance instead of the resistor. The resultant divider had 50% size reduction.(W.choe, 2014). A wider isolation bandwidth was achieved by employing parallel coupled lines at the ports. Those coupled lines provided matching and complete DC isolation as well. (Wonbin Hong, & Kwang-Hyun, 2012) the isolation bandwidth was extended by an additional isolation network. In This paper a 2-secton

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microstrip Wilkinson power divider only with the equally division of power is designed with a center frequency of 3.5 GHz matched to 50 Ω transmission line was implemented. The circuit was designed and simulated on ADS using microstrip Line technology. The designed power divider has to have equal power division output (-3dB) and at least 10 dB return loss and isolation between port 2 and port 3.

2. MATERIAL AND METHODS

The schematic of the proposed power divider is demonstrated in fig 3.the design specification consist of substrate with Dielectric constant Ɛr=4.50, the substrate has a thickness h=0.508 mm, Loss tangent tan δ =0.0020, the Metallization (the thickness of the conductor is 35µm). The copper has an electrical conductivity $\sigma = 5.96\times10^{7}$ S/m. The design will be implemented using chebyshev with (maximum reflection coefficient in the passband=0.05) tables for multisection quarter wave transformer.

The proposed equal Wilkinson power divider is depicted in Fig.1. The idea behind equally division is to split the incident power at port 1 into two halves (-3dB) between ports 2 and 3 the circuit is shown in fig 1. (David Pozer, 2005).The Scattering-matrix for the ideal Wilkinson power divider with matched load is shown in equation (1) and (2).

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix} \tag{1}$$

$$[S] = \frac{-j}{\sqrt{2}} \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} \tag{2}$$

The ideal Wilkinson power divider would have perfect matching at all the ports which indicated in the matrix as $S_{11}=S_{22}=S_{33}=0$. Moreover, there would be perfect isolation between ports 2 and port 3 as written $S_{23}=0$, and $S_{32}=0$, $S_{23}=S_{32}$ because the Wilkinson power divider is symmetric. Although, an ideal (matched, reciprocal, and lossless) power divider is not physically realizable, there are power dividers that demonstrate two of the three properties. T-junction dividers, resistive dividers, and the Wilkinson power divider are three common power dividers featuring unique characteristics. These power dividers can be constructed using various types of transmission lines (i.e. waveguides, microstrip, or stripline) or using resistive networks (David Pozer, 2005).

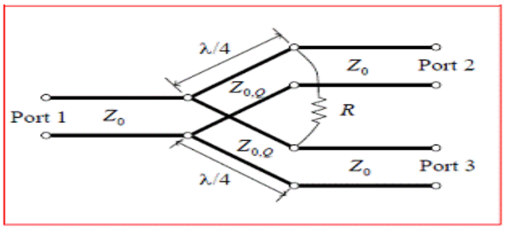

Fig 1: The equivalent transmission line circuit of an equal-split Wilkinson power divider.

The insertion loss between ports 1 and port 2 should be $\frac{1}{\sqrt{2}}$, and the insertion loss between ports 1 and port 3 should be $\frac{1}{\sqrt{2}}$, means ($|S_{12}| = |S_{13}| = \frac{1}{\sqrt{2}}$). Since the Wilkinson power divider is symmetric, then $S_{13}=S_{31}$, and $S_{12}=S_{21}$ as shown in the S matrix. The implementation of the divider uses quarter wavelength lines which cause the phase shift of 90°. Since the device is passive. The S-matrix is reciprocal (David Pozer, 2005).

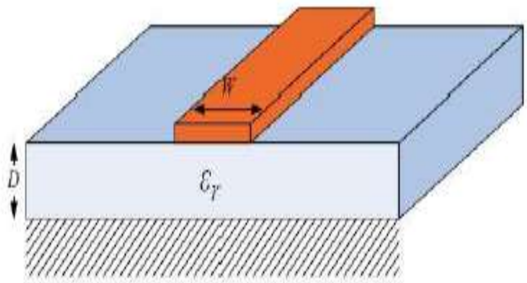

Fig 2: Microstrip line

Microstrip transmission lines are commonly used to build power dividers among other devices, because it can be easily fabricated through various techniques such as photolithography or milling. Additionally, it can be used for a wide frequency range, spanning from below 1 GHz up to tens of GHz.(Grebennikov,2011).

3. RESULTS AND DISCUSSION

ADS were used to design the proposed Wilkinson power divider, however for the theoretically ideal case. An ideal half-split power divider would divide incident power at port 1 equally between ports 2 and 3. The S-matrix for the ideal Wilkinson divider is shown in equation (1) & (2). Even-odd mode analysis can be used to derive the proper three-port circuit to be used to create the ideal Wilkinson power divider.

The center frequency f_0=3.5GHz. Therefore, to find the bandwidth we do the following:

$$\frac{f_1 + f_2}{2} = 3.5\ GHz \tag{3}$$

Since for 2-sections Wilkinson power divider the bandwidth has to be $f_2 : f_1$ = 2:1. Then,

$$\frac{f_2}{f_1} = 2 \tag{4}$$

From (3) and (4) we found that:

$$f_1 = \frac{7}{3} = 2.33\ GHz \quad and\ f_2 = \frac{14}{3} = 4.66\ GHz$$

From the Even-odd mode analysis we found that:

$$\frac{Z_L}{Z_0} = \frac{2.Z_0}{Z_0} = N = 2 \tag{5}$$

Using result in (5) and since N=2 for 2-section power divider, from Chebyshev Tables at 0.05 we found that:

$$\frac{Z_1}{Z_0} = 1.2193 \quad and \quad \frac{Z_2}{Z_0} = 1.6402$$

For $Z_0 = 50\Omega$, then

$Z_1 = 60.97\ \Omega$ and $Z_2 = 82.01\ \Omega$

The circuit was designed as shown in fig 3.

So by calculating the parameters, we find that:

$$\varphi = 90° \left[1 - \frac{1}{\sqrt{2}} \left(\frac{f_2 - f_1}{f_2 + f_1}\right)\right] = 68.7868° \tag{6}$$

$$R_2 = \frac{2.Z_1.Z_2}{\sqrt{[(Z_1+Z_2).(Z_2 - Z_1 \cot^2 \varphi)]}} = 98.0022\Omega \tag{7}$$

$$R_1 = \frac{2.R_2.(Z_1 + Z_2)}{R_2.(Z_1 + Z_2) - 2Z_2} \times 2.Z_0 = 202.3688\Omega \tag{8}$$

So, after we implement the parameters provided using LINECALC (Line Calculator)in ADS and then convert them to Mictostrip Line Values. The resulted Microstrip Widths (W) and lengths (L) were used in the schimatic as shown in fig 3.

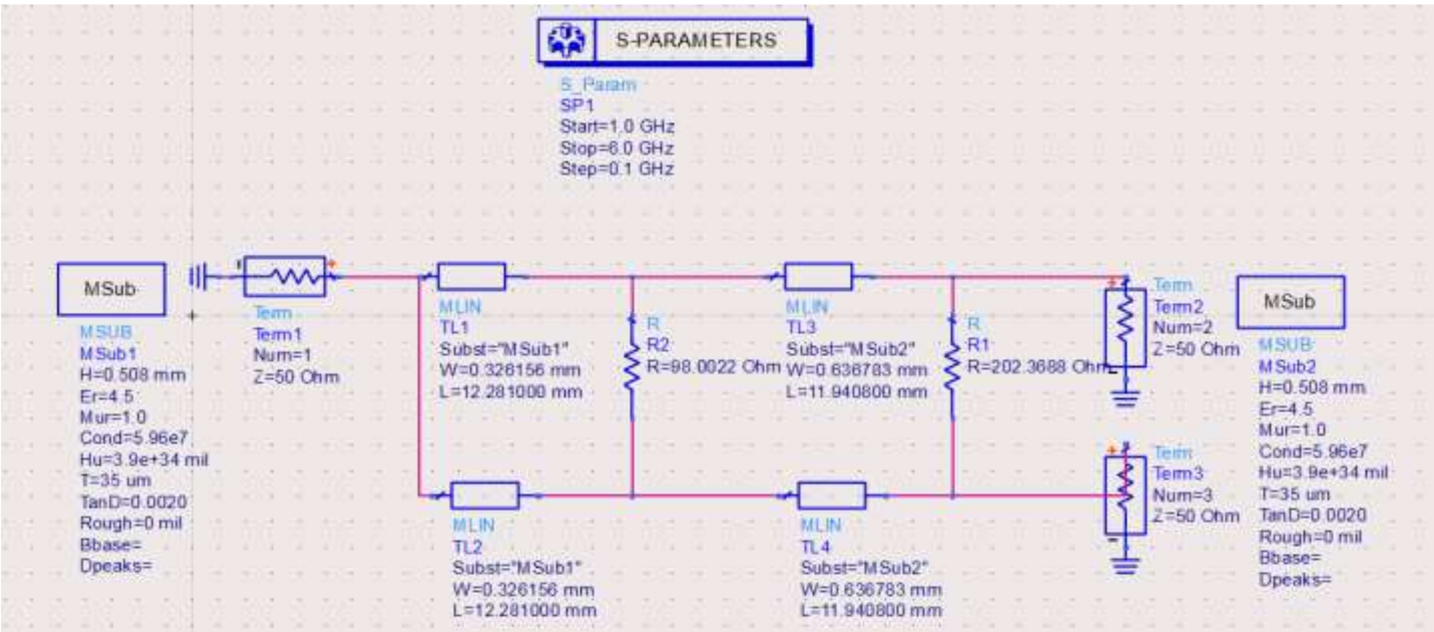

Fig 3: Circuit design as implemented in ADS.

Despite having isolated output ports and functioning as a lossless divider when the ports are matched, the quarter-wave sections of the Wilkinson make it a narrowband, or frequency dependent device. The circuit's three main S-parameters were plotted on the ADS simulation. The plots of S-parameters indicate matching parameters at port 1 (S_{11}), at port 2 (S_{22}), and at port 3 (S_{33}), power division parameters ($S_{21}=S_{12}=S_{13}=S_{31}=-3dB$), and output port isolation parameters ($S_{23}=S_{32}$). After simulation the circuit as shown in fig 3, we got the following result:

3.1 Matching Parameters S_{11}, S_{22} and S_{33}:

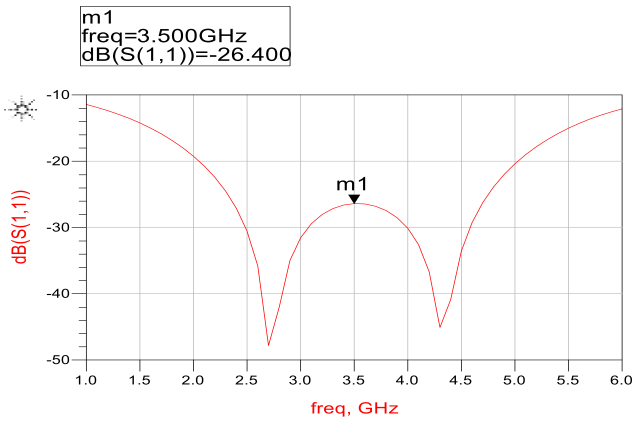

Fig 4: S_{11} Matching parameter for the power divider.

Fig 4 indicates that the reflection coefficient performed as expected, which has very small value close to zero that is (-26dB) at the centered frequency 3.5GHz. Hence port 1 is matched to the transmission line.

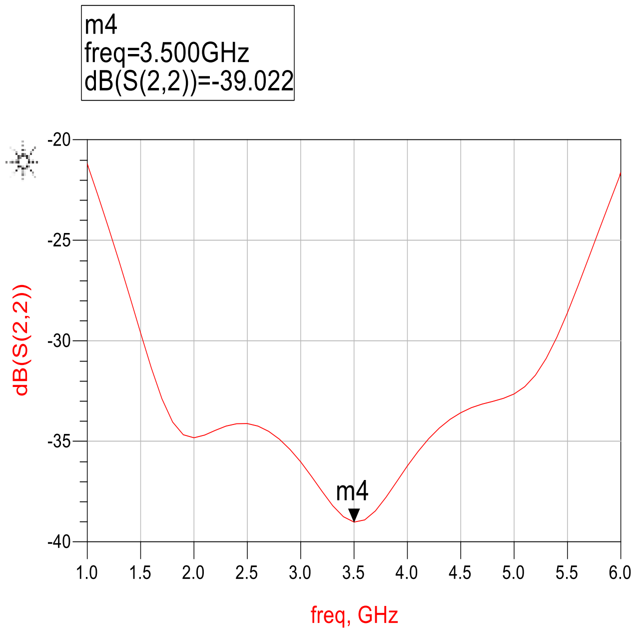

Fig 5: S_{22} Matching parameter for the power divider.

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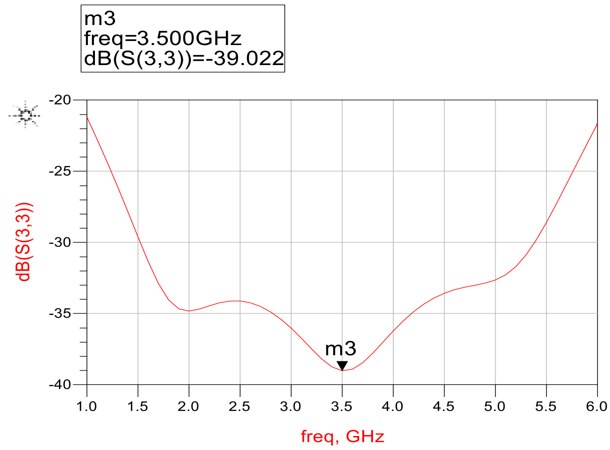

Fig 6: S_{33} Matching parameter for the power divider.

Fig 5 and 6 show that the reflection coefficient at port 2 (S_{22}) and at port 3 (S_{33}) is very low (-39dB) each, which is better than the design target (-10dB). Thus port 2 and 3 are matched to the transmission line.

3.2 Output Isolation Parameters S_{23} and S_{32}:

From fig 7 and 8, it can be clearly seen that the isolation parameters S_{23} and S_{32} between the output ports is about (-25dB) each at the centered frequency, which is better than the design requirement. Hence, that indicates that the output ports are isolated on each other. Notes that S_{23}=S_{32} because the power divider is symmetric.

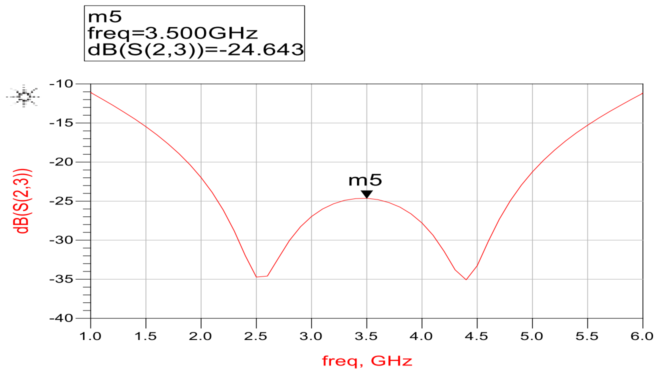

Fig7: S23 Isolation parameter for the power divider.

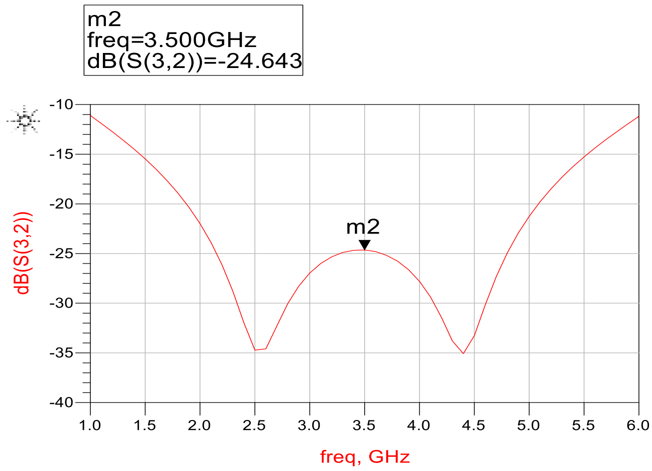

Fig 8: S_{32} Isolation parameter for the power divider

3.3 Power Division Parameters S_{31}, S_{13}, S_{12} and S_{21}:

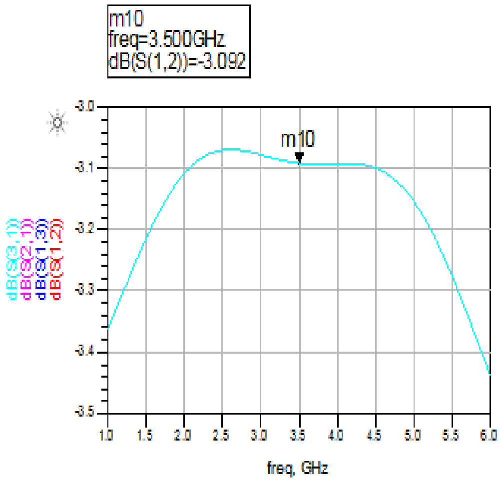

Fig 9: S_{12}Power Division Parameter for power divider

From Fig 9, it can be seen that the power division was fairly good. As shown in the simulation plot the division is -3.092 dB at the center frequency (3.5GHz), which is very close to the desired ideal (-3dB). The rest of the power division parameters are the same as S_{12}, which indicates and proves that the designed Wilkinson power divider is equally split power divider.

Fig 10. Shows the main S-Parameters together.

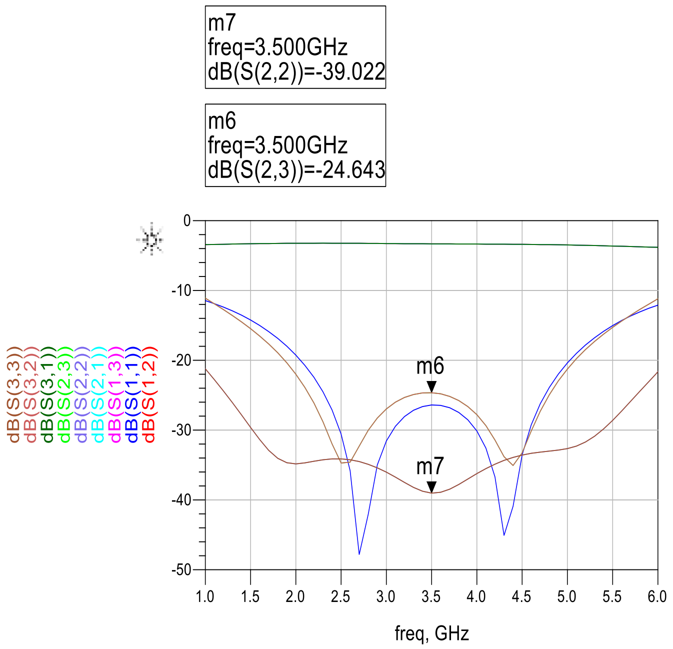

Fig 10: The main S-Parameter for the designed Wilkinson power divider.

4. CONCLUSIONS

In this paper a 2-Section microstrip Wilkinson Power divider is designed, the circuit was designed and simulated using advanced design system (ADS) Simulator. with equal output power division of -3dB matched to 50 Ω transmission line, and frequency centered at 3.5GHz with Chebyshev multisection quarter wave transformer and maximum reflection coefficient in the passband=0.05. The proposed power divider has a typical Wilkinson power divider performance of 0.2 dB insertion loss within 85% fractional bandwidth (17 dB return loss) and -25 dB isolation at the operating frequency. The simulation studies are conducted to evaluate the performance of the divider for different applications. The design theoretically has achieved the design requirement for 2-section microstrip Wilkinson power divider.

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