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Design of Microstrip line & Coupled line based equal & unequal Wilkinson Power Divider

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Abstract— **The passive devices are most commonly used in radio technology and power dividers are one among them. These power dividers are used to split the power and combine the power. It is a passive device used to couple a defined amount of power in a transmission line from one port to another port. Wilkinson power divider is implemented using various technologies like micro stripline technology, Coupled Line technology and strip line technology.**

In this paper, the design of 3dB Wilkinson Power Divider(WPD) to split the power equally & unequally at the output ports by using microstrip line technique and Coupled Line technique is proposed. This is useful mainly for mobile applications which has the operating frequency of 915MHz. The simulation is done using Advanced Design System (ADS) tool. Some of the performance parameters like return loss, isolation loss & insertion loss are measured in terms of scattering parameters.

Index Terms:— Wilkinson Power Divider(WPD), microstrip line, coupled line, return loss, isolation loss, scattering parameters, Advanced design system(ADS).

INTRODUCTION

The Power divider/combiner is a passive device that divides/combines RF input power among several output ports. The power divider and power combiner are very popular components for a microwave power combining system.

High power solid state RF power divider/combiner are essential due to modest power of solid state devices. As such, most of the popular power combining schemes have emerged from communication system requirement; generally, a passive power divider can work as a power combiner without any modification due to the reciprocity. Hence the concepts developed for the power divider equally applies to a combiner. Power dividers are usually designed to provide equal and unequal power division ratio.

The Wilkinson Power Dividers(WPD) are essential components of microwave electronics that have been employed for decades for signal power splitting or combining in power amplifiers, transceivers, antenna feed networks etc. It is a three port network that is lossless when the output ports are matched, only reflected power is dissipated. Input power can be split into two or more in phase signals with the same amplitude. Fig.1a shows the power divider in microstrip line form. The equivalent circuit using transmission lines is shown in Fig.1b.

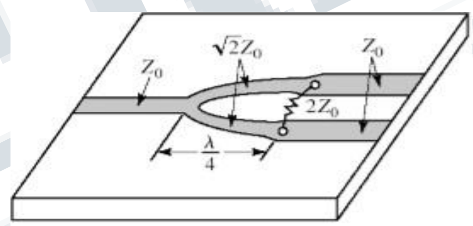

Fig.1a: WPD in microstrip form with equal power split.

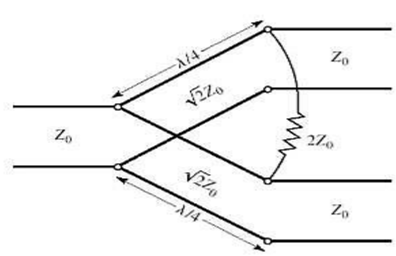

Fig.1b: WPD in terms of transmission lines

The simplest two-way Wilkinson power divider consists of two quarter-wavelength transmission line(TL) sections (θ = 90°) and an isolation resistor connected between the output ports. In case of equal power division, the normalized TL characteristic impedance and isolation resistor values are Zo = 50Ω & R = 2Zo.The design of the Wilkinson divider is composed of a transmission line (typically micro strip line) that has been split into a specific number of transmission lines, each one quarter-wavelength long.

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III. DESIGN METHODOLOGY & SPECIFICATIONS

In this paper, WPD is designed using microstrip line & coupled line technique using ADS tool.

1. Microstrip line technique

Microstrip planar transmission lines are most commonly used to build power dividers because it is easy to manufacture, cost effective & circuit size reduction. The microstrip layout shown in Fig.2 is composed of a dielectric substrate between a ground plane and thin conductor of width(W), D is the thickness of the dielectric substrate, and is the relative permittivity of the substrate.

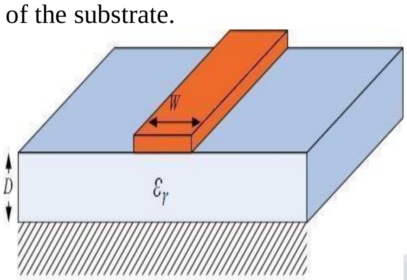

Fig.2: Microstrip Line

2. Coupled Line technique

Coupled Line is a planar transmission line .It is widely used for microwave integrated circuit design. The coupled Line consists of a conductor strip at the middle and ground planes are located on either side of the center conductor. All these lie in the same plane. In Coupled Line, EM energy is concentrated within the dielectric. The leakage of the electromagnetic energy in the air can be controlled by having substrate height (h) twice that of the width (s).Fig.3 shows the coupled line structure.

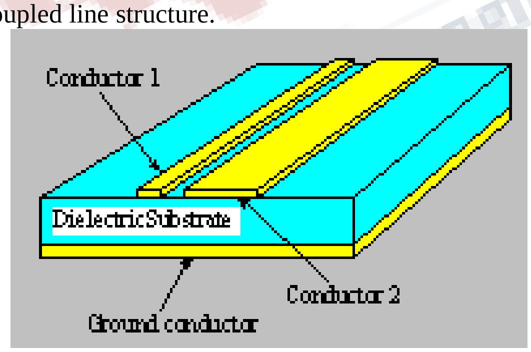

Fig.3:Coupled line structure

The odd & even mode characteristic impedances are computed using the following design equations for the given value of coupling coefficient Co.

$$Zo_e = Zo\sqrt{\frac{1+Co}{1-Co}} \qquad (1)$$

$$Zo_o = Zo\sqrt{\frac{1-Co}{1+Co}} \qquad (2)$$

The power divider is constructed using one input and two output ports which are terminated by characteristic impedance of Zo=50Ω. Table.1 gives the design specifications of WPD using both the techniques.

Table.1: Design specifications of WPD

Parameters	Values
FR4 Substrate dielectric constant	4.4
Substrate thickness	1.6mm
Centre frequency	915MHz
Planar Technology	Microstrip line & coupled line
Coupling factor	30dB

III. DESIGN

The WPD is shown in Fig.4. It consists of input & output quarter wave transformers, isolation resister (R) & input & output ports terminated with characteristic impedance Z0=50Ω. The impedances Zo2 & Zo3 form the input transformer & Zo4 & Zo5 form the output transformer. These impedance values & resistance R are determined based on the power division ratio K2 .The electrical length of the transformers is θ=900.

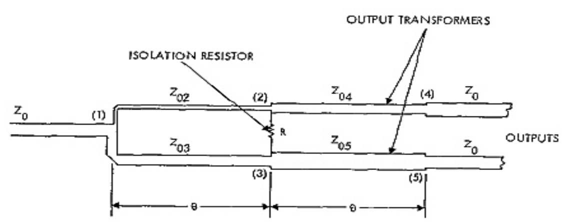

Fig.4:Wilkinson Power Divider(WPD)

The following design equations are used to determine the impedance values of WPD.

$$\frac{P_4}{P_5} = \frac{1}{K^2} \qquad (3)$$

$$Zo_2 = Zo\sqrt{K(1+K^2)} \qquad (4)$$

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$$Zo_3 = Zo\sqrt{\frac{1+K^2}{K^3}} \quad (5)$$

$$Zo_4 = Zo\sqrt{K} \quad (6)$$

$$Zo_5 = \frac{Zo}{\sqrt{K}} \quad (7)$$

$$R = Zo\left(\frac{1+K^2}{K}\right) \quad (8)$$

IV. IMPLEMENTATION

The WPD is constructed based on the design equations. Using LineCalc in ADS tool, the physical dimensions width(W), length(L) & spacing(S) are found.

1. WPD with equal power division

The WPD is designed with equal power division ratio K2=1. The power at the output ports 2 & 3 is -3dB. Table.2 shows the dimensions of WPD with equal power division.

Table.2: Dimensions of WPD with equal power division.

Component	Electrical Parameters	Physical Parameters
Input Transformer of WPD	$Zo=Zo_4=Zo_5=50\Omega$ $\Theta=90^0$	W=3.053460mm L=44.817700mm
Output Transformer of WPD	$Zo=Zo_2=Zo_3=70.71\Omega$ $\Theta=90^0$	W=1.607660mm L=45.986100mm Rad=29.2756mm
Isolation resistor of WPD	$R=100\Omega$	
Coupled line	$Zo_e=51.60\Omega$ $Zo_o=48.44\Omega$ $Zo=50\Omega$ $\Theta=90^0$	W=3.048660mm L=44.976600mm S=5.3241200mm

Fig.5a & b shows the schematic diagram and layout of WPD with equal power division using microstrip line technique respectively.

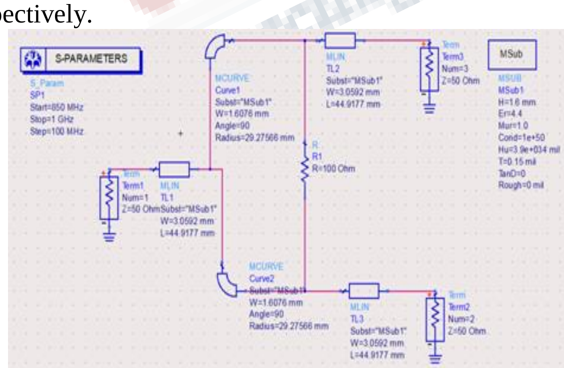

Fig.5a: Schematic diagram of WPD with equal power division.

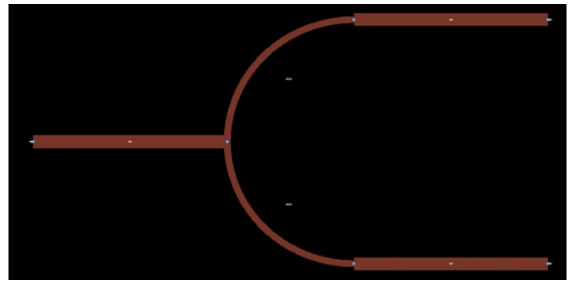

Fig.5b:Layout of WPD with equal power division.

Fig.6 shows the schematic diagram of WPD with equal power division implemented using coupled line technique.

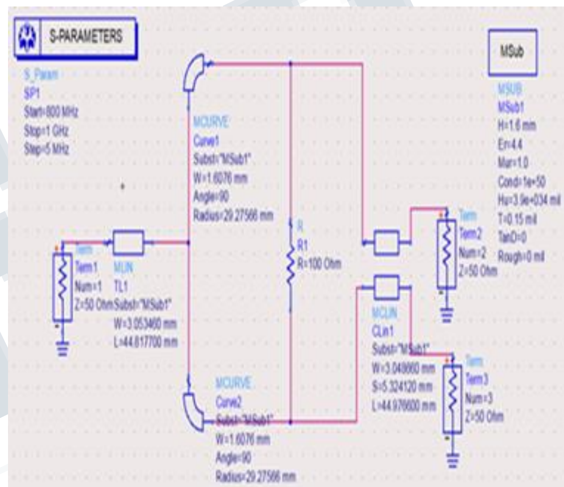

Fig.6: Schematic diagram of WPD with equal power division using coupled line.

WPD with unequal power division

The WPD is designed with unequal power division ratio K2=0.5. The power difference at the output ports 2 & 3 is -3dB. Table.3 shows the dimensions of WPD with unequal power division.

Table.3: Dimensions of WPD with unequal power division.

Component	Electrical Parameters	Physical Parameters
Input Transformer of WPD	$Zo_2=51.48\Omega$ $\Theta=90^0$	W=2.907320mm L=44.914300mm Rad=28.63mm
	$Zo_3=103\Omega$ $\Theta=90^0$	W=0.641655mm L=47.143800mm Rad=30mm
Output Transformer of WPD	$Zo_4=42.04\Omega$ $\Theta=90^0$	W=4.030180mm L=44.256100mm

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	Zo_5=59.46Ω Θ=90^0	W=2.254390mm L=45.399000mm
Isolation resistor of WPD	R=106.07Ω	
Coupled line	Zo_e=51.60Ω Zo_o=48.44Ω Zo=50Ω Θ=90^0	W=3.048660mm L=44.976600mm S=5.3241200mm

Fig.7a & b shows the schematic diagram and layout of WPD with unequal power division using microstrip line technique respectively.

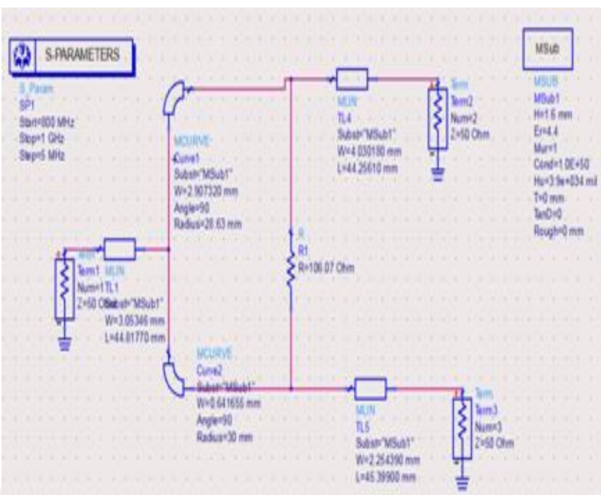

Fig7a: Schematic diagram of WPD with unequal power division.

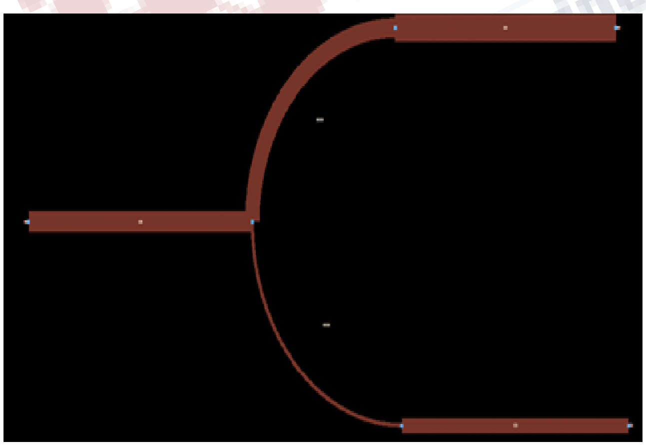

Fig.7b:Layout of WPD with unequal power division.

Fig.8 shows the schematic diagram of WPD with unequal power division implemented using coupled line technique.

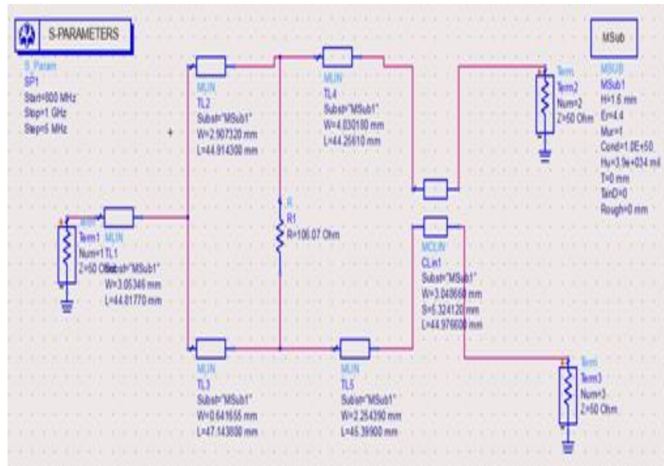

Fig.8: Schematic diagram of WPD with unequal power division using coupled line.

RESULTS

There are different types of losses that occur in power divider which are defined in terms of scattering parameters namely

1.Return loss(dB) = $-20log|S_{11}|$

2.Insertion loss(dB) = $-20log|S_{21}|$ and $-20log|S_{31}|$

3.Isolation loss(dB) = $-20log|S_{23}|$

The variation of scattering parameters as a function of frequency is shown in plots.Fig.9a & b indicates the plot of S-parameters as a function of frequency for equal power power division WPD using microstrip line & coupled line techniques respectively.

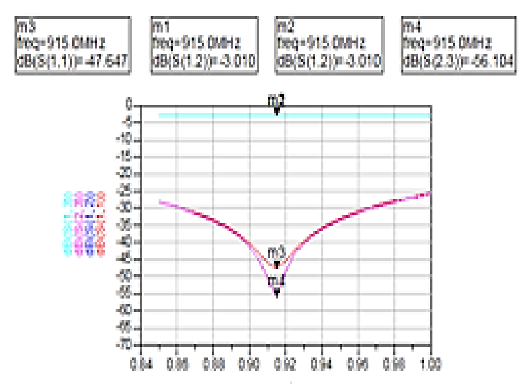

Fig.9a:Plot of S-parameters for equal power division WPD using microstrip line.

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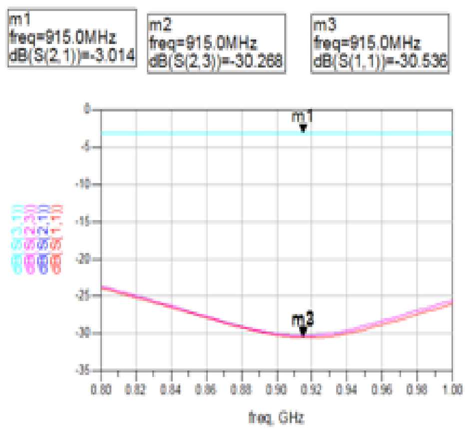

Fig.9b:Plot of S-parameters for equal power division WPD using coupled line.

Fig.10a & b indicates the plot of S-parameters as a function of frequency for unequal power power division WPD using microstrip line & coupled line techniques respectively.

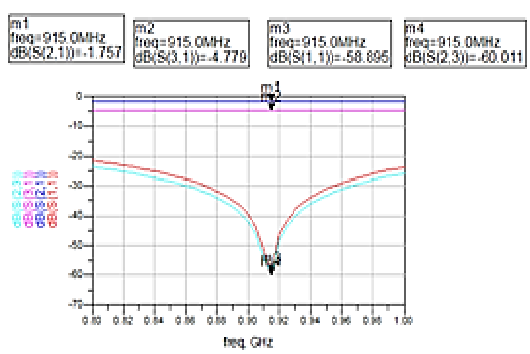

Fig.10a:Plot of S-parameters for unequal power division WPD using microstrip line.

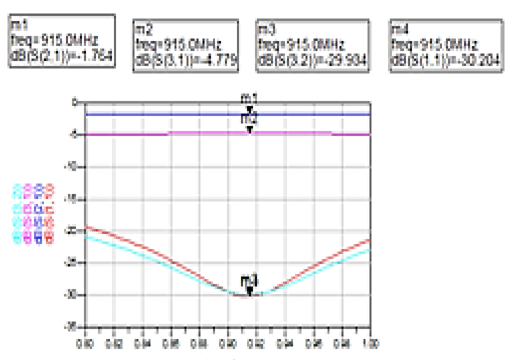

Fig.10b:Plot of S-parameters for unequal power division WPD using coupled line.

CONCLUSION

In this paper, WPD is designed with equal & unequal power division using microstrip line technique & coupled line technique at centre frequency of 915MHz.

From the Table.4, it is observed that equal power division at output ports 2 & 3 obtained for power division ratio of 1 & -3dB less power at port 3 than port 2 for power division ratio of 0.5. Better input return loss & isolation loss between ports 2 & 3 are obtained for the design using microstrip line technique.

Table.4:S-parameter values for the design of WPD using microstrip line.

S-Parameters in dB	Equal power division	Unequal power division
S11	-47.647	-58.895
S21	-3.010	-1.757
S31	-3.010	-4.779
S23	-56.104	-60.011

From the Table.5, it is observed that equal power division at output ports 2 & 3 obtained for power division ratio of 1 & -3dB less power at port 3 than port 2 for power division ratio of 0.5. Better input return loss & isolation loss between ports 2 & 3 are obtained for the design using coupled line technique.

Table.5: S-parameter values for the design of WPD using coupled line.

S-Parameters in dB	Equal power division	Unequal power division
S11	-30.536	-30.204
S21	-3.014	-1.764
S31	-3.014	-4.779
S23	-30.268	-29.934

However, much better return loss & isolation loss characteristics are obtained for the design of WPD using microstrip line technique.

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