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BUILDING LOW COST COUPLER: MADE EASY

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Abstract *- Power dividers (also power splitters and, when used in reverse, power combiners) are passive devices used in the field of radio technology. They couple a defined amount of the electromagnetic power in a transmission line to another port where it can be used in another circuit. The Wilkinson divider splitter / Wilkinson combiner is a form of power splitter / power combiner that is often used in microwave applications. It uses quarter wave transformers, which are easily fabricated as quarter wave lines on printed circuit boards and as a result it offers the possibility of proving a very cheap and simple splitter / divider / combiner while still providing high levels of performance. In principle, low loss specialized microwave substrates are used for best results. However, since substrate cost is the dominant factor for microstrip passive circuits there is a need to use cheaper materials such as FR4 without compromising the performance.*

Keywords *– Power combiner, power splitter, FR-4, Wilkinson combiner, power dividers.*

I. INTRODUCTION

The Wilkinson Power Divider/Coupler is a specific class of power divider circuit that can achieve isolation between the output ports while maintaining a matched condition on all ports. The Wilkinson design can also be used as a power combiner because it is made up of passive components and hence reciprocal. First published by Ernest J. Wilkinson in 1960, this circuit finds wide use in radio frequency communication systems utilizing multiple channels since the high degree of isolation between the output ports prevents crosstalk between the individual channels. It is also possible to use other forms of transmission line (e.g. coaxial cable) or lumped circuit elements (inductors and capacitors) to implement the design.

TYPES OF COMBINERS/DIVIDER

- The **lossless T-junction divider** suffers from the disadvantage of not being matched at all ports, and it does not have isolation between output ports.
- The **resistive divider** can be matched at all ports, but even though it is not lossless, isolation is still not achieved.
- A lossy three-port network can be made having all ports matched, with isolation between output ports. The ***Wilkinson power divider*** [1] is such a network, with the useful property of appearing lossless when the output ports are matched; that is, only reflected power from the output ports is dissipated.

Table 1: Comparison of Passive Power Divider

Passive power divider	Advantage	Disadvantage
T-junction	Lossless	Not matched at all ports No isolation between output ports
Resistive	Can be matched at all ports	No isolation between output ports Poor power handling, limited by resistor tolerances Lossy
Wilkinson	Lossless (if matched at all ports) High isolation	Reflected power is dissipated through isolation resistor if mismatched

The purpose of the Wilkinson Power Divider is to split the power of the input equally between two output ports, ideally without loss. It can also be used in the reverse direction – as a power combiner. Other properties of the Wilkinson power

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divider is that all ports are matched, the two output terminals are isolated from one another, and that it is reciprocal. Reciprocity means that you get the same result if you send the signal from one port to another in either direction. Three-port networks cannot be reciprocal and matched without being lossy [2]. The solution to this, in the Wilkinson Power Divider, is to add a resistor between the two outputs. This resistor absorbs energy if there is a mismatch between the outputs. It also helps isolating the two outputs when the circuit functions as a power combiner.
If TEM mode is injected at port 1, equal in phase signals reach point a and b in figure 1.1b. Thus, no current flows through the resistor, and equal signals emerge from port 2 and port 3.the device is thus 3dB divider. If TEM mode is injected at port 2, with matched loads placed on port 1 and port 3, the resistor is effectively grounded at point b. equal signals flow towards port 1 and down the resistor, with port 2 seeing a match. Half the incident power emerges from port 1 and half is dissipated I the resistor film. Similar performance occurs when port 1 and port 2 are terminated in matched loads, and TEM mode is injected at port 3.

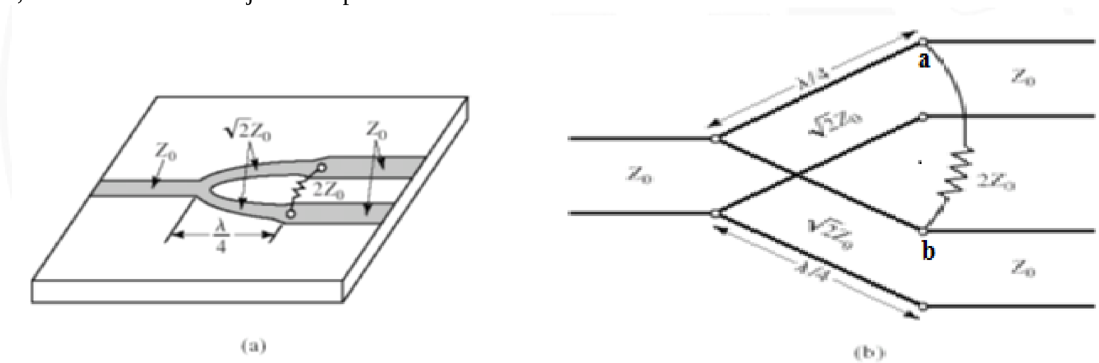


Fig. 1.1: The Wilkinson power divider. (a) An equal-split Wilkinson power divider in microstrip form. (b) Equivalent transmission line circuit

II. DESIGN APPROACH

Assuming a system impedance of 50 Ω, 50 Ω would have to appear at the input for this to be matched. With the two loads being 50 Ω each in parallel, we would achieve match if they both were transformed to 100 Ω (two 100 Ω loads in parallel equals 50 Ω). The way that this is achieved in the original Wilkinson Power Divider is by the use of quarter-wave transformers as shown in figure 1.1a and 1.1b [3 4 5]. We can see that this if possible by looking at the formula for a quarter wavelength transmission line:
$Z_{in} = Z^2{}_0 / Z_{load}$
By using lines with the appropriate characteristic impedance, we can theoretically transform the 50 Ω loads to any real impedance. To transform the 50 Ω loads to 100 Ω, we would need lines with characteristic impedance of 70.7 Ω.
One of the biggest drawbacks of the Wilkinson Power Divider is that it has a quite narrow bandwidth. This can be improved by adding a quarter-wavelength section in front of the power combiner. In this way the impedance transformation is done in two steps, thereby improving the bandwidth. The bandwidth of the power divider can also be increased by splitting the two quarter wavelength sections into multiple sections with a resistor between each section [6]. A common realisation is to use three sections instead of one. More than this can also be used to further increase the bandwidth. This obviously makes the circuit more complex, with added loss and increased area consumption on the chip.

2.1 Design Specification

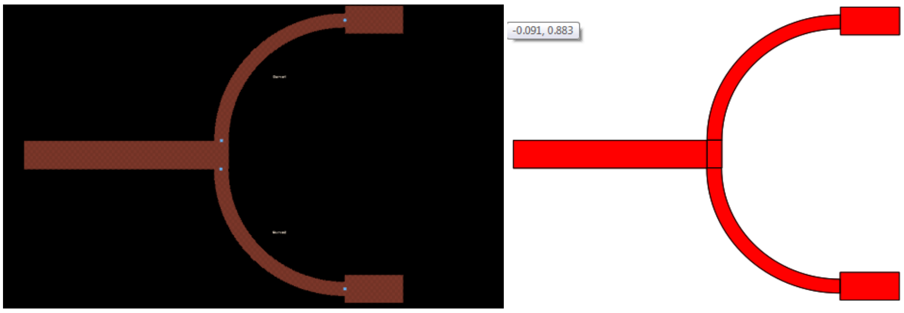
Specifications are

- Frequency = 1.98 GHz
- Source Impedance = 50 ohms.
- Load Impedance = 50 ohms
- Substrate permittivity = 4.8 (FR 4)
- Thickness of substrate = 1.6 mm
- Thickness of conductor = 0.15 mm

III. STEPS INVOLVED

The final layout is reached in three steps from the regular lumped Wilkinson Power Divider.
Steps involved – Lumped ideal, Lumped Real, Distributed and Final Layout.

The goal is to try to make the s-parameters at each step as close as possible to the previous step. This should, ideally, make the s-parameters of the final layout close to that of the ideal circuit. Because of the parasitic resistance, inductance and capacitance of the components as well as the effects of the transmission lines and cross-talk this is, as we will see, not possible to achieve. The layout is done in ADS based on the distributed circuit and the gerber file generated is as shown in below in figure 3.1(a) and 3.1(b) respectively.



(a) (b)

Fig: 3.1(a) Layout of the Wilkinson Power Divider, (b) Gerber file

IV. FABRICATION

In the Wilkinson divider design, the most significant loss will be the dielectric-induced loss of FR-4, which is inversely proportional to the loss tangent. The loss tangent of FR-4 is approximately 0.02 much higher than low loss substrates such as Teflon which has a loss tangent of 0.001. in addition FR4 is easily available at competitive price. Hence FR-4 is used is as a substrate which is of low cost.

The 2:1 power divider is fabricated using 1.6 mm thick, FR-4 substrate and 35 µm of layer of copper depositions. The connectors used for each port are N-type female UHF SMA Connector to suit 2.78GHz.

The PCB is housed in 5mm thick aluminium enclosure with CCC (Chromium Conductive Coating) finish for better electrical conductivity, to suppress parasitic effects and to confirm to EMI and EMC.

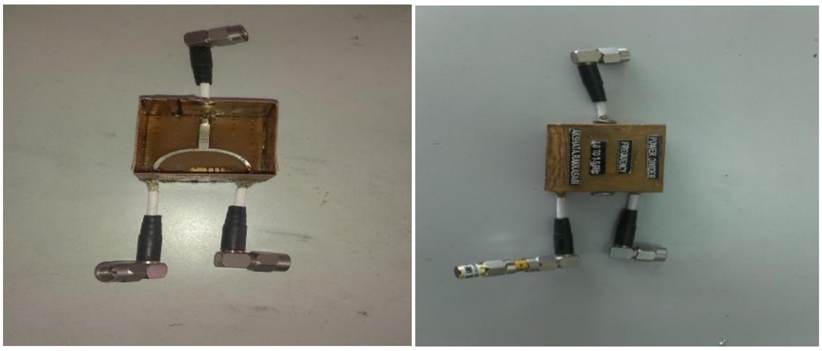


Fig: 4.1 Fabricated Wilkinson Power Divider with Housing.

V. RESULT AND ANALYSIS

Wilkinson coupler module is tested using Network Analyzer and the following results were obtained at resonating frequency 2.78 GHz which is designed for wireless applications as mentioned earlier.

5.1 Frequency v/s Return Loss:

The figure 5.1 shows the simulation result of frequency v/s Return Loss of a Wilkinson Power Coupler.

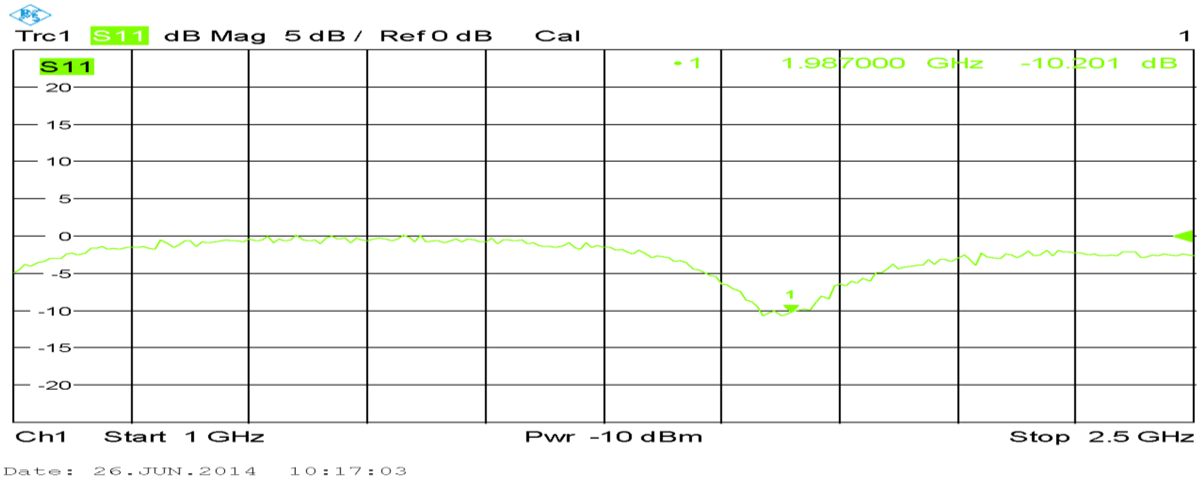


Fig 5.1: Frequency v/s Return loss

By observing Fig. 5.1, the Return Loss at 1.98 GHz is approximately equal to -10.201 dB

5.2 Frequency v/s Insertion Loss:

The figure 5.2 shows the simulation result of frequency v/s Return Loss of a Wilkinson Power Coupler.

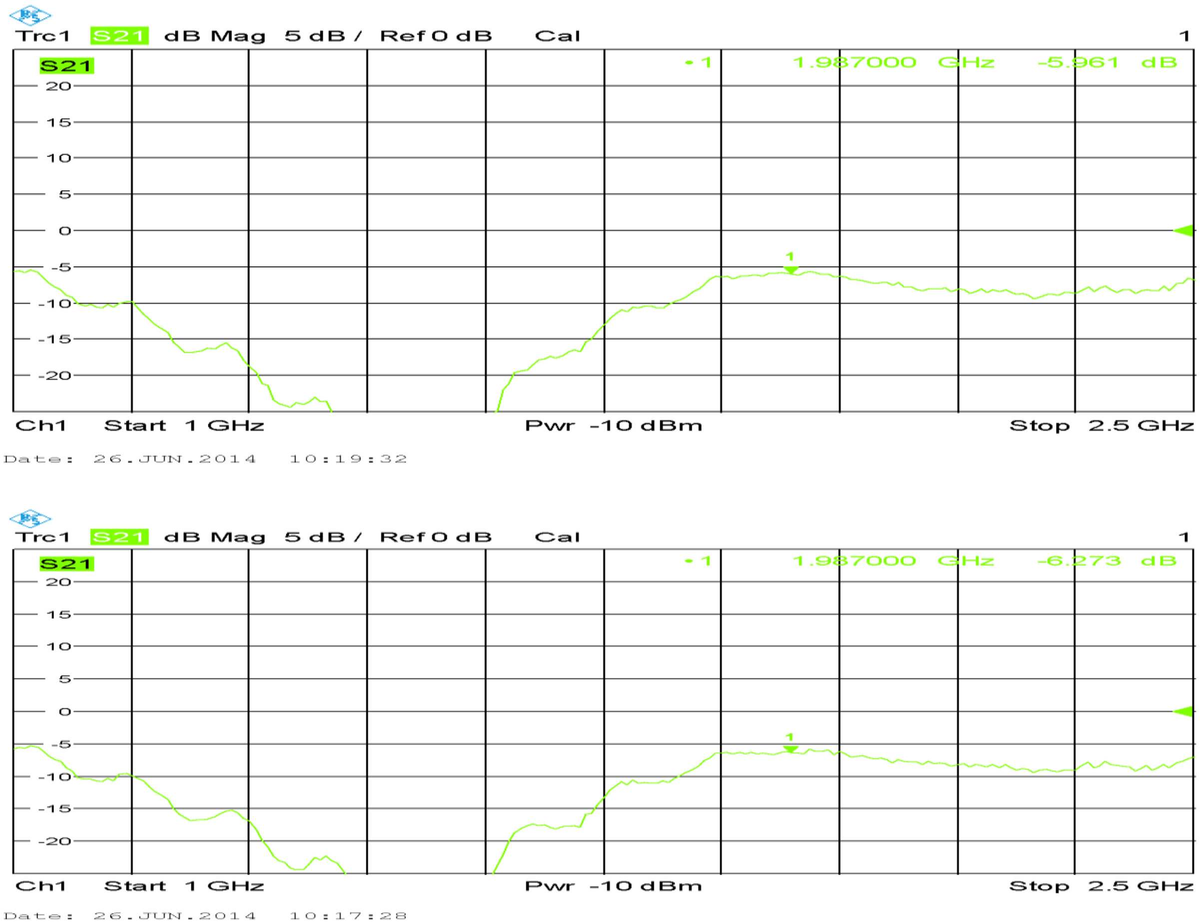


Fig. 5.2: Frequency v/s Insertion Loss

By observing Fig. 5.2, the Coupling Loss at port 2 and port 3 at 1.98 GHz is approximately equal to -5.961 dB.

Minor deviations in test results are noticed while testing the coupler with and without housing. Hence it is mandatory for RF circuits above 2 GHz to be enclosed in a proper shielded housing with relevant coatings to minimize these deviations.

VI. CONCLUSION

Wilkinson coupler module which is designed fabricated was tested using R&S Network analyzer ZVL132 and the results obtained are indicated in fig 4.1 and 4.2 which confirm to theoretical design figures. All parameters like frequency response, insertion loss return loss/VSWR are measured. Most of the measured results confirm to theoretical values. The fabricated module gives insertion loss of about -5.961 dB and return loss of about -10.201 dB. Hence we can say that the Wilkinson power divider is, in its most basic form, a relatively simple yet incredibly effective RF device.

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