Microstrip Wilkinson power divider with Enhanced isolation and Miniaturisation for Defence applications

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Abstract

The design of modified Wilkinson power divider is done by dividing Quarter wavelength transmission line into two, in-between that complex isolation component and compensation capacitor is added. Complex isolation component provides physical separation and electrical isolation between two output ports. It consist of parallel or series RLC circuit is chosen to realize. To get the widest bandwidth, inductors in both components are omitted. In the proposed method, Parallel RLC circuit is chosen because of easy design and soldering. A coupled line section with a compensation capacitor is introduced to reduce the circuit size and also compensates the coupling effect produced by the coupled line section. The circuit is designed with the operating frequency 1GHz on CGK-500 substrate with thickness 1.965 and simulated using ADS software.

Index Terms—*Wilkinson power divider (WPD), Complex isolation component, Compensating capacitor, Coupled line section.*

I. INTRODUCTION

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 divider is that all ports are matched, the two output terminals are isolated from one another, and that it is reciprocal. Reciprocality means get the same result if send the signal from one port to another in either direction.

Three-port networks cannot be reciprocal and matched without being lossy. 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.

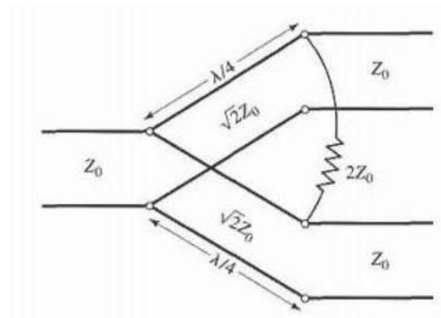

Fig 1. Traditional Wilkinson power divider

The problem in traditional Wilkinson power divider is that the two output ports are physically close to each other in order to accommodate the isolation element (the resistor), since this resistor must be small in terms of the operating wavelength or else the electrical port isolation could suffer. As a result, the two outputs of the Wilkinson divider are electrically isolated but not physically isolated. The close proximity of the two output ports needs an additional transmission lines to physically isolate the ports before they can be connected to other circuitry.

To overcome this, a complex isolation component is placed between two 90 transmission lines, a small electrical size WPD has been produced in [3]. It provides physical and electrical port isolation between the output ports, and it is easy to connect to other circuitry without extra transmission lines at output ports. However, only a series *RC* circuit was discussed to realize complex isolation component. But, the series RC circuit is difficult to design and soldering in the coupled line section.

In [7], Capacitive loading is used to reduce the circuit size. Length of the transmission line reduced from λ/4 to λ/8. Input and output ports are made of Coplanar waveguide, divider itself is made of Asymmetric coplanar stripline. But, Isolation is very low due to the use of waveguides. In [6], Additional transmission line is added between resistor and Quarterwave transformer. Integrated resistor is used-have fewer parasitic effect. It eases planar implementation and useful at millimeter-wave frequency. But, the additional transmission line reduces necessary characteristic impedance, length increases and bandwidth decreases.

II. PROPOSED WORK

Based on the above problems, the proposed Wilkinson power divider is designed with complex isolation component using parallel RLC circuit. To achieve wide bandwidth, L is omitted. The parallel RLC circuit is easy to design and soldering in the coupled line section compared to the series RLC. First, the λ/4 transmission line is split into two, in-between that the complex isolation component and compensation capacitor are connected at an angle θ=45.

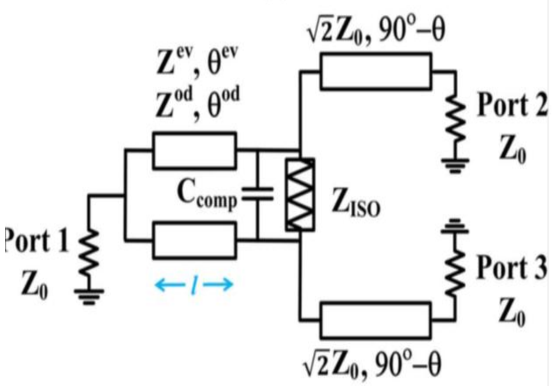

Fig 2. Proposed design

The first part of the λ/4 transmission line is coupled together to reduce the circuit size. The compensation capacitor is connected to the coupled line section compensates the coupling effect and also compensates the characteristic impedance difference and electrical length difference.

III. DESIGN EQUATION

Complex Isolation Component Z_{ISO}

For Parallel RLC Component:

$$R_p = Z_0(3 + cos2\theta)$$

$$C_p = \frac{1}{\omega_0}\left(\frac{\sqrt{2}cot\theta}{Z_0(3 + cos2\theta)} + \frac{1}{\omega_0 L_p}\right)$$

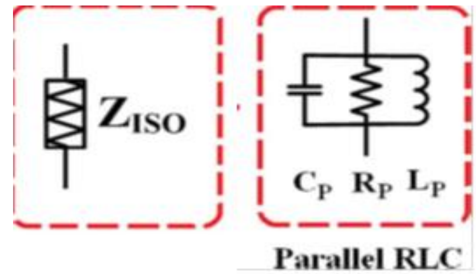

Fig 3. Equivalent circuit

The coupling strength in decibels is defined by K

$$K = 20log_{10}\frac{Z^{ev} - Z^{od}}{Z^{ev} + Z^{od}}$$

Where $Z^{ev} = \sqrt{2}Z_0 \ and \ \theta^{ev} = \theta$

The compensation capacitor value can be calculated by using

$$C_{comp} = \frac{1}{2\omega_0}\left(\frac{1}{Z^{od}tan\theta^{od}} - \frac{1}{\sqrt{2}Z_0 tan\theta}\right)$$

TABLE I

Design parameters for parallel RLC component

Θ (°)	L_p	C_p (pF)	R_p (Ω)	C_{comp} (pF)
45	∞	1.50	150	2.25

$Z_0 = 50\Omega, K = -7.5 \ dB \ and \ f_0 = 1GHz$

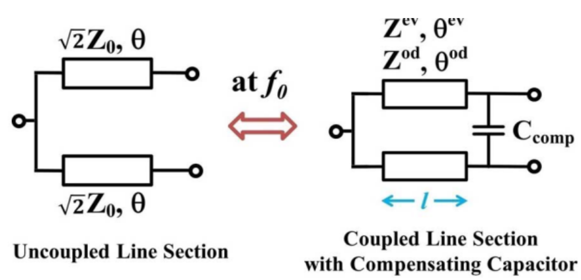

Fig 4. Coupled Line Section

IV. DESIGN OF TRADITIONAL WPD

The general Wilkinson power divider is designed by using $Z_0 = 50\Omega$ in the operating frequency 1GHz. The substrate used is CGK-500 with thickness H=1.965mm and effective dielectric constant $\varepsilon_r = 5$ with θ=90°. Using linecalc in ADS software, length L=38.8169mm, width W= 3.40235mm for input and output ports and for λ/4 transmission line Z=70.71, length L=39.8846mm, width W=1.75247mm and radius r=25.404mm are calculated.

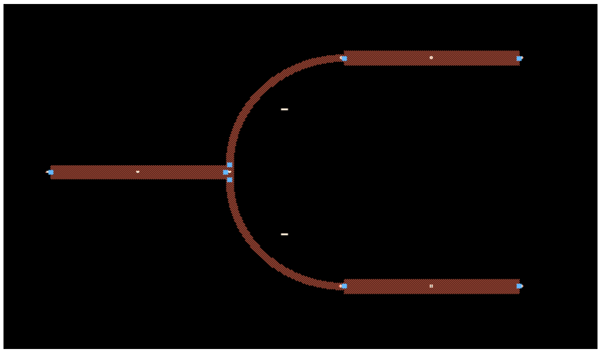

Fig 5. Layout Diagram

Since R=2Z_0,

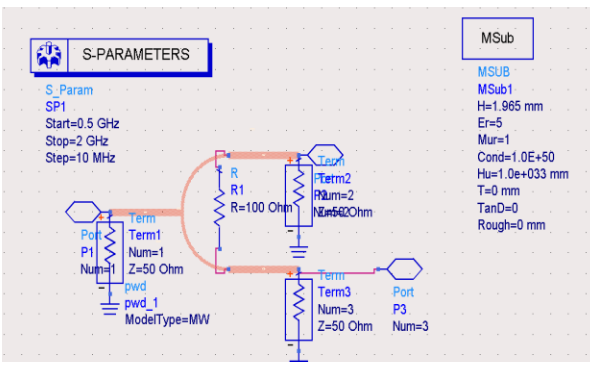

Fig 6. Schematic Diagram

The simulated results obtained are

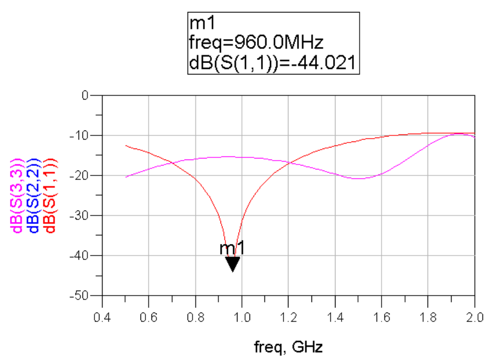

Fig 7. Return Loss

The return loss and insertion loss obtained are better but the isolation loss is very poor. The isolation loss should be ideally -30dB but it is only -15.716dB.

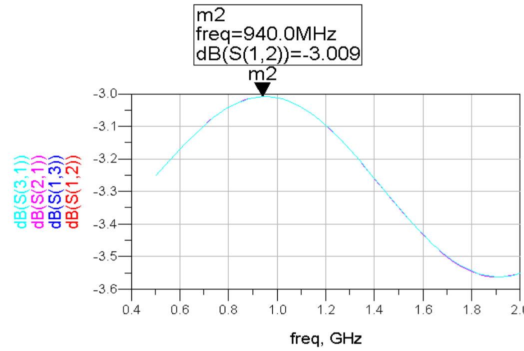

Fig 8. Insertion Loss

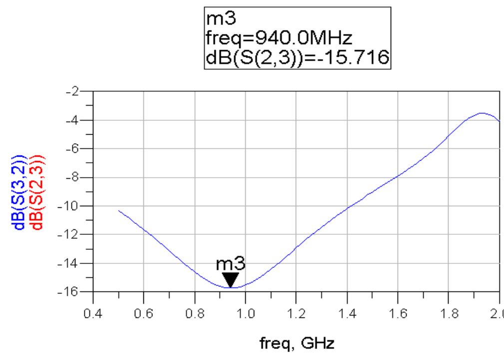

Fig 9. Isolation Loss

V. DESIGN OF PROPOSED WPD

The modified Wilkinson power divider is designed by using $Z_0 = 50\Omega$ in the operating frequency 1GHz. The substrate used is CGK-500 with thickness H=1.965mm and effective dielectric constant $\varepsilon_r = 5$. For θ=45°, Ze – 70.71Ω, Zo- 28.76Ω , λ/4 transmission line is coupled together with length L=20.0146mm, width W=2.909mm and space S=0.113799mm are calculated by using linecalc. The another part θ=45°, Z=70.71Ω, the length L= 19.9423mm, width W= 1.75247mm are calculated.

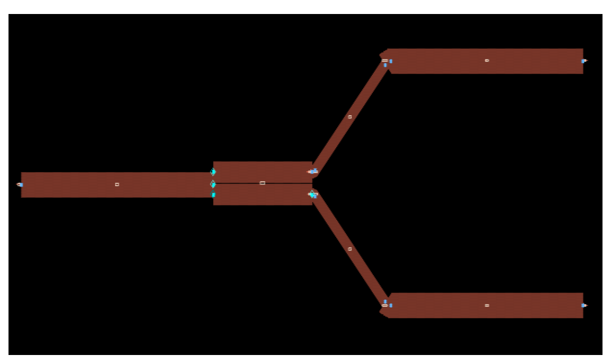

Fig 10. Layout Diagram

In the layout diagram, the lumped elements cannot be placed. Therefore, the diagram is transferred to the schematic and the resistor R=150Ω and C=

2.25+1.5= 3.75pF are connected. The resistor placed between the output ports provides better isolation, so that the power in 1 transmission line cannot leak to another transmission line. Capacitor compensates the coupling effect due to the coupled line section. Hence, it provides both physical separation and electrical isolation. And also, it doesn't need any extra transmission line to connect to other circuitry and connectors at the output ports can be connected without any disturbance.

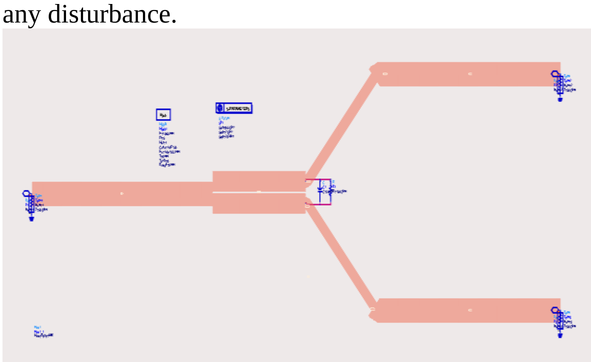

Fig 11. Schematic Diagram

The simulated results obtained are

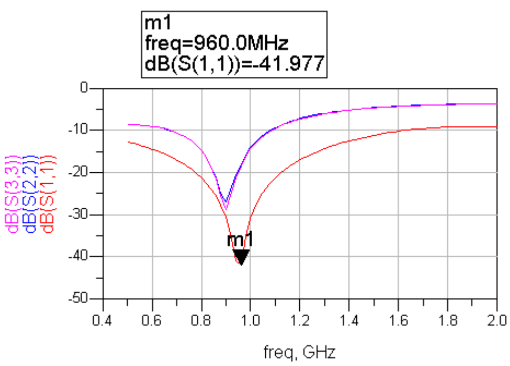

Fig 12. Return Loss

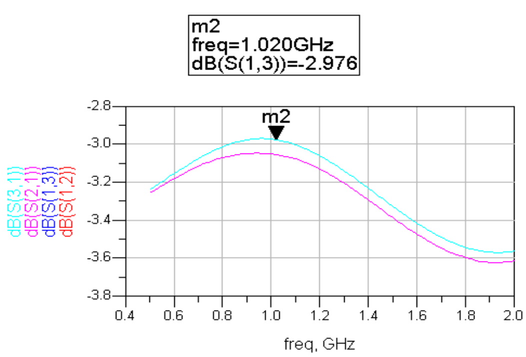

Fig 13. Insertion Loss

The return loss and insertion loss are better similar to the traditional WPD. The improved isolation is achieved in the proposed method of -35.646dB. This is due to the use of complex isolation component with parallel RLC circuit. Return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually expressed as a ratio in decibels (dB). Insertion loss is the loss of signal power resulting from the insertion of a device in a transmission line and is usually expressed in decibels (dB).

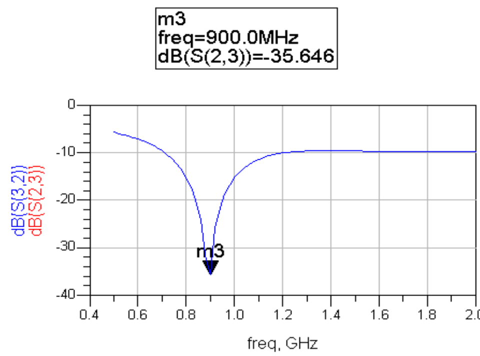

Fig 14. Isolation loss

VI. COMPARISON OF OUTPUTS

Table II

PARAMETERS	GENERAL MICROSTRIP POWER DIVIDER	PROPOSED MICROSTRIP POWER DIVIDER
Return loss(dB)	-44.021	-41.977
Insertion loss(dB)	-3.009	-2.976
Isolation loss(db)	-15.716	-35.646
Size(cm)	60	41.9

VII. CONCLUSION

The modified Wilkinson power divider with improved isolation and size reduction is designed by placing complex isolation component and compensation capacitor at an angle θ=45° in the λ/4 transmission line. The complex isolation component consists of parallel RLC circuit which is easy to design and soldering in the coupled line section. Capacitor in the complex isolation component and compensating capacitor can be combined to one capacitor $C_{tot} = C_p + C_{comp}$. A coupled line section with a compensating capacitor is introduced to reduce the circuit area.

The traditional WPD and modified WPD are designed and simulated using ADS software. The results are compared and tabulated in which the modified WPD provides improved isolation and reduced in size than the traditional WPD.

REFERENCE

[1] E. J. Wilkinson, "An -way hybrid power divider," IRE Trans. Microw. Theory Techn., vol. MTT-8, no. 1, pp. 116–118, Jan. 1960.

[2] D. Pozar, Microwave Engineering, 3rd ed. New York, NY, USA: Wiley, 2005, ch. 7.

[3] C. J. Trantanella, "A novel power divider with enhanced physical and electrical port isolation," in IEEEMTT-S Int. Microw. Symp. Dig., May 2010, pp. 129–132.

[4] X. Tang and K. Mouthaan, "Analysis and design of compact two-way Wilkinson power dividers using coupled lines," in Proc. Asia–Pacific Microw. Conf., Dec. 2009, pp. 1319–1322.

[5] J. Wang, J. Ni, Y. X. Guo, and D. Fang, "Miniaturized microstrip Wilkinson power divider with harmonic suppression," IEEE Microw. Wireless Compon. Lett., vol. 19, no. 7, pp. 440–442, Jul. 2009.

[6] S. Horst, R. Bairavasubramanian, M. M. Tentzeris, and J. Papapolymerou, "Modified Wilkinson power dividers for millimeter-wave integrated circuits," IEEE Trans. Microw. Theory Techn., vol. 55, no. 11, pp. 2439–2446, Nov. 2007.

[7] M. C. Scardelletti, G. E. Ponchak, and T. M. Weller, "Miniaturized Wilkinson power dividers utilizing capacitive loading," IEEE Microw. Wireless Compon. Lett., vol. 12, no. 1, pp. 6–8, Jan. 2002.