A REVIEW ON MODIFICATIONS OF WILKINSON POWER DIVIDER FOR DIFFERENT APPLICATIONS

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Abstract : Power dividers have been widely used in microwave circuits like power amplifiers, phase shifters, mixers and antenna arrays. They perform the function of splitting the input power into two or more output powers of lesser amplitude with same or different phase. Among different types of power dividers, Wilkinson power divider (WPD) is widely using because of its characteristics like simple geometrical shape, compact size, low insertion loss and good isolation characteristics. But different applications require different power divider characteristic. This can be achieved by applying some modifications on the conventional WPD. Modification of WPD for the applications like harmonic suppression, tunable characteristics, high power division ratio and ultra wide band (UWB) characteristics etc. are discussed in this paper.

***IndexTerms* – Wilkinson Power Divider (WPD), Ultra Wide Band (UWB).**

I. INTRODUCTION

Power dividers are very important component in microwave circuits. They are indispensable component in power amplifiers, phase shifters and mixers. The purpose of the power divider is to split the input signal into two or more output signals with same phase or 180^0 phase difference. In the reverse direction, power dividers act as power combiners. T junction and Wilkinson are the common types of power dividers. T junction divider can be lossless or resistive. Lossless T junction divider suffers from the problem of not being matched at all ports and isolation is not achieved between output ports. And the resistive T junction divider can be matched at all ports, but isolation is not achieved [1]. Wilkinson power divider (WPD) has been widely used because of its simple geometrical shape, compact size, and low insertion loss and isolation characteristics [2].

Ernest J. Wilkinson introduced The Wilkinson Power Divider in 1960. The conventional Wilkinson power divider is made by two parallel uncoupled quarter wavelength transmission lines. It has the useful property of being lossless when the output ports are matched. And hence only reflected power is dissipated. Wilkinson divider can be made to give arbitrary power division ratios. The configuration of the conventional Wilkinson power divider and its equivalent circuits are shown in Figure.1 and Figure.2.

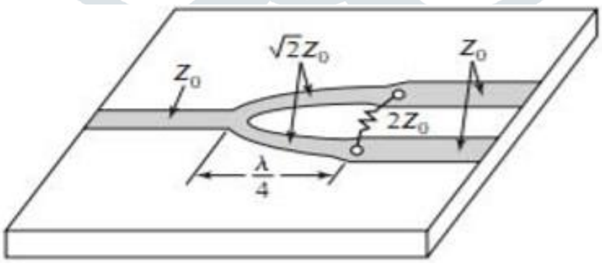

Fig.1 Conventional Wilkinson Power Divider (WPD) [1]

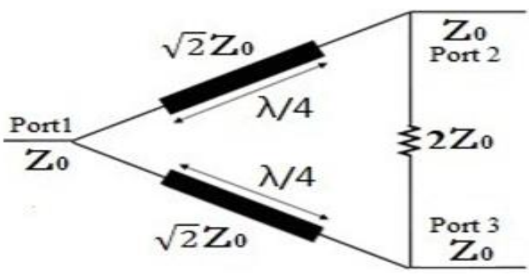

Fig.2 Equivalent circuit of conventional WPD [1]

Based on the requirements of applications, modifications can be applied on the conventional Wilkinson divider. Some applications may require dual band performance, high power division ratio, broad band harmonic suppression, different frequency ratio ranges etc. Some of the modifications of the conventional Wilkinson power divider for different applications are discussed in this paper.

II. MODIFICATION FOR SUPPRESSING HARMONICS

Harmonic suppression in the conventional Wilkinson PD can be achieved by introducing a harmonic suppression unit [3]. It consists of a Frequency Selecting Coupling Structure (FSCS) unit and two transmission lines. The FSCS unit can provide wide stop band [4]. Equivalent circuit of WPD with harmonic suppression capability is shown in the Figure.3.

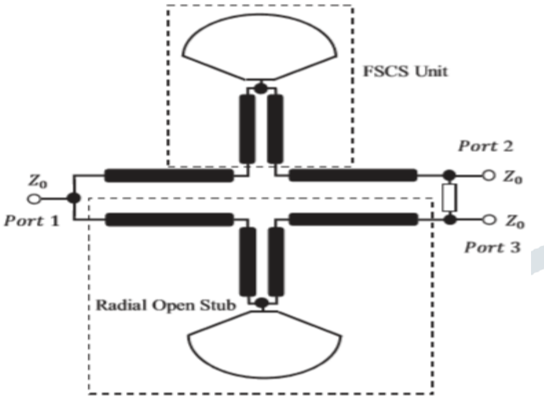

Fig.3 Modified WPD for Harmonic suppression [3]

Due to the symmetric nature of the circuit, odd and even mode analysis can be applied. Even and odd mode input impedances are given below.

$$Z_{ine} = Z_{1e} \frac{Z_{Le} + jZ_{1e} \tan\theta}{Z_{1e} + jZ_{Le} \tan\theta} \quad \text{..........................(1)}$$

$$Z_{ino} = jZ_{1o} \tan\theta \quad \text{..(2)}$$

$$Z_{Le} = 2Z_L = -j \frac{120\pi h}{r_i \frac{\alpha}{2} \sqrt{\varepsilon_r}} \cot(kr_i, kr_o) \quad \text{........(3)}$$

Where Z_L is the characteristic impedance of the radial open stub, Z_{1e} and Z_{1o} are the even- and odd-mode characteristic impedances of the coupled line parts. θ is the electrical length. r_i is the inner radius and r_o is the outer radius. α is the angle subtended by the radial open stub. h is the thickness of the microstrip substrate, ϵ_r is the substrate relative permittivity.

Using straight open stub WPD operates up to 4.6GHz with insertion loss of less than 4dB. Stop band is generated from 7 to 17 GHz with insertion loss of more than 15dB. But WPD with radial stub operates up to 2.6GHz with insertion loss less than 4dB and stop band is generated from 4.6GHz to 16GHz with insertion loss of more than 15dB.

III. COMPACT TUNABLE WILKINSON POWER DIVIDER

Reconfigurable system requirements demands WPD that can alter the operating frequency and maintain port matching and output port isolation in the entire tuning frequency range [5]. A compact WPD with tuning function can be achieved by replacing quarter wave transmission line by T type structure containing six varactors and one stub [6]. The configuration of the tunable Wilkinson power divider with compact simple structure is shown in the Figure.4

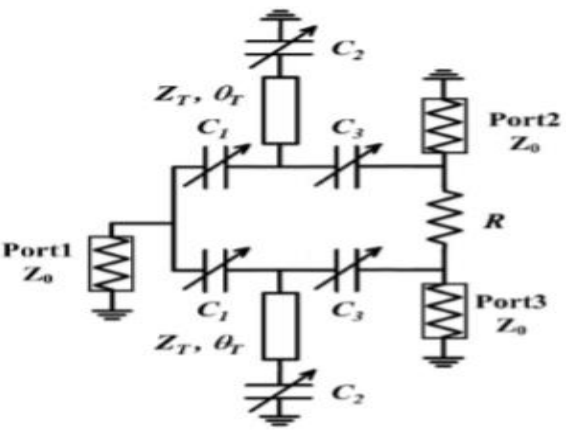

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Fig.4 Compact tunable WPD [6]

ABCD matrix of the T structure is given by

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & \dfrac{1}{j\omega C_1} \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ Y_{in} & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & \dfrac{1}{j\omega C_3} \\ 0 & 1 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where $Y_{in} = \dfrac{j}{Z_T} \cdot \dfrac{\omega C_2 Z_T + \tan\theta_T}{1 - \omega C_2 Z_T \tan\theta_T}$

Both characteristic impedance and electrical length of the stub determine tuning frequency range. Hence by selecting these two parameters we can realize different tuning frequency ranges.

IV. MODIFICATION FOR HIGH POWER RATIO

Conventional unequal WPD with high power ratio requires high and low characteristic impedance quarter wavelength transformers between isolation resistor and input port. Since narrow line width is difficult to realize in microstrip line process, it is not easy to implement high impedance microstrip quarter wavelength transformer. To overcome this problem, it is possible to make use of transmission line transformers in the conventional WPD [7]. The modified WPD consists of one π shaped impedance transformer, one 3λ/4 impedance transformer, two λ/4 impedance transformer and an isolation resistor. Two shunt shorted stubs and one capacitor of capacitance C makes π shaped transformer equivalent to 3λ/4 impedance transformer. Phase delay of 3λ/4 impedance transformer and π shaped impedance transformer satisfies the condition $\theta = 90^0 + n180^0$. Hence the response of this PD is similar to that of conventional WPD around the operating frequencies. The configuration of modified Wilkinson power divider for high power ratio is shown in the Figure.5.

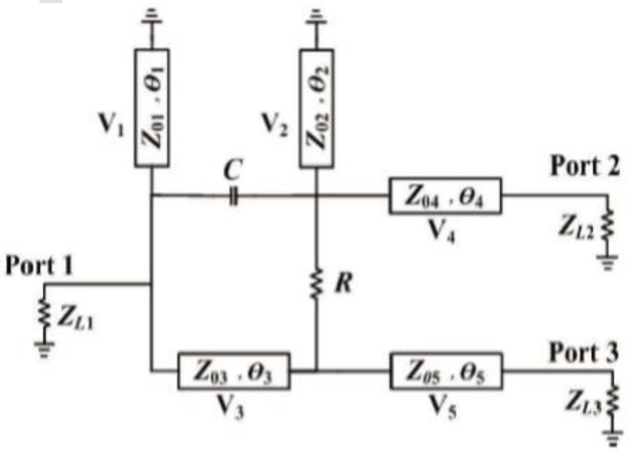

Fig.5 Modified WPD for high power ratio [7]

By keeping this PD as high power ratio divider, a modification can be applied by replacing 3λ/4 impedance transformer by three section T shaped transmission lines. Electrical length of each T shaped transmission lines are equivalent to 90^0 impedance transformer. That is the three sections T shaped transmission lines are equivalent to 270^0 impedance transformer.

V. MODIFICATION FOR DIFFERENT FREQUENCY RATIO RANGES

The modified WPD with different frequency ratio ranges is possible by selecting different physical lengths ratio of two transmission lines [8]. l_1/l_2 is the physical length ratio. Configuration of the dual band Wilkinson power divider with different frequency ratio ranges is shown in the Figure.6.

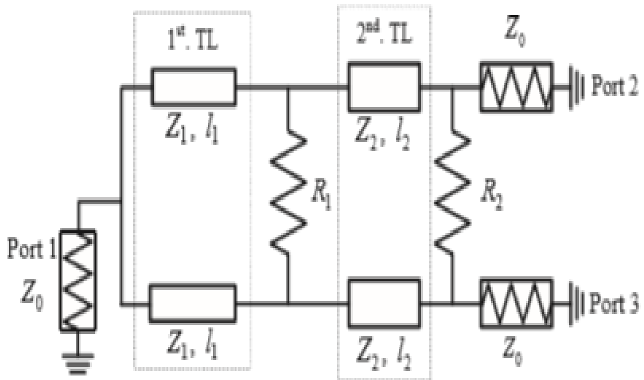

Fig.6 Modified WPD for different frequency ratio ranges [8]

VI. MODIFICATION FOR ULTRA WIDE BAND APPLICATIONS

Conventional Wilkinson power divider has the drawback of narrow bandwidth. Ultra wide band WPD can be implemented using binomial multi section matching transformer [9]. The bandwidth of input and output responses of the power divider increases with the number of binomial multi section matching transformers. Characteristic impedance of multi sections can be calculated by the following formula:

$$\ln \frac{Z_{n+1}}{Z_n} = 2^{-N} C_n^N \ln \frac{Z_L}{Z_0} \text{..................}(5)$$

Where $C_n^N = \dfrac{N!}{(N-n)!n!}$

Where N is the number of multi sections and n varies from 0 to N-1.

For Wilkinson power divider Z_L=50Ω and Z_0=100Ω.

The impedance discontinuity between the input line and two λ/4 lines decreases when the number of sections increases. As a result the input reflection coefficient improves. The transmission coefficient (S21) yields better characteristics for more number of sections.

VII. DISCUSSION

Power dividers are indispensable component in microwave circuits. Wilkinson power divider (WPD) has been widely used because of its simple geometrical shape, compact size, low insertion loss and good isolation characteristics [2]. Based on the requirement of applications several modifications can be applied on the conventional Wilkinson power divider. Harmonic suppression in the conventional Wilkinson PD can be achieved by introducing a harmonic suppression unit consisting of a Frequency Selecting Coupling Structure (FSCS) unit and two transmission lines [3]. A compact WPD with tuning function can be achieved by replacing quarter wave transmission line by T type structure containing six varactors and one stub [6]. A modified WPD consisting of one π shaped impedance transformer, one 3λ/4 impedance transformer, two λ/4 impedance transformers and an isolation resistor can provide high power ratio [7]. The modified WPD with different frequency ratio ranges is possible by selecting different physical lengths ratio of two transmission lines [8]. Conventional Wilkinson power divider has the drawback of narrow bandwidth. Ultra wide band WPD can be implemented using binomial multi section matching transformer [9].

VIII. CONCLUSIONS

Power dividers are very important component in power amplifiers, phase shifters, mixers and antenna array. Due to the features like simple geometrical shape, compact size and low insertion loss Wilkinson power dividers are widely used. Depending on the requirements of a particular application, several modifications can be applied on the conventional Wilkinson power divider. Harmonic suppression, tunable characteristics, high power division ratio and ultra wide band characteristics etc. can be achieved by modifying the conventional WPD.

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