Implementation and Performance Analysis of N-Way Wilkinson Power Divider

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***Abstract*- In this paper, a N-way multi-frequency equal Wilkinson power divider (WPD) is proposed, implemented and analyzed. The proposed N-way power divider is based on microstrip line with 50 ohm characteristic impedance. The dividers are composed of multi-section transmission line and isolation resistors. They provide high isolation and very good input/output ports matching simultaneously at arbitrary design frequencies. The power divider geometry is analyzed using ADS simulator and the performance metrics such as insertion loss, return loss and isolation loss is computed. This study reports the successful implementation of microstrip line based 16-way Wilkinson power divider with low losses for a frequency range of 0 to 3 GHz with 1.5GHz centre frequency.**

Keywords- Advanced Design System (ADS); Wilkinson Power Divider (WPD); Printed Circuit Board (PCB); Microstrip Line (MLIN); Transmission Line (TLIN)

I. INRODUCTION

Power dividers called as power splitters and when used in reverse it acts as the power combiner a vital role in various RF and communication application [1, 2]. It is a passive device which is used in the field of radio technology which requires power to be distributed among different paths. The easiest way to approach this method can be done by using a power splitter/divider. Basically power dividers are reciprocal devices (i.e.) they can also be used to combine power from output ports into the input port. The two main categories of power dividers are reactive and resistive and each can be suited for its own specific applications. Wilkinson Power Divider (WPD) belongs to reactive power divider in which it has some special properties such as lossless network, high isolation between output ports and low insertion and isolation loss [1, 2].

It has a single input port and more than one output port. But the main advantage of divider is that all ports are theoretically matched and output ports are isolated from one another [4]. It is usual, but not mandatory, for the transmission from the input port to be identical to all output ports. It can be designed with different transmission line sections such as s stripline, coaxial, microstrip, airstrip and lumped element circuit topographies to realize its designs. But historically, power divider is a 1:a 2N device; that is to say that a single input was divided into 2, 4, 8, 16, etc. outputs [10]. Such a device was structurally the interconnection of 0/180° hybrids whose difference ports were terminated, often internally. Three hybrids were required for a 1:4 device, seven for a 1:8 device and in general, 2*N* outputs required (2*N*-1) individual two-way divisions. In earlier for larger values of 2*N*, one or more outputs could be terminated without a large loss. For example, an 8-way power divider could be made to serve as a 7-way with something less than a 1 dB loss penalty over the theoretical 7-way splitting loss. Section I deals with determination of parameters where as Section II and III deals about WPD and Model of WPD using ADS respectively. Section IV, V and VI tells about Results and Discussions, Conclusion and Reference respectively.

II. DETERMINATION OF PARAMETERS

Isolation, VSWR, Input power, Amplitude balance, return loss, and insertion losses [1, 3] are the common measurable parameters for the WPD. Isolation is measured the difference in dB of the signal level between output ports with the input port properly terminated [4] and Voltage Standing Wave Ratio is a measure of the deviation of impedance from the characteristic impedance of the power divider and it is determined from [4]

$$SWR = \frac{V_{max}}{V_{min}} \quad (1)$$

Amplitude Balance is determined by the maximum peak-to-peak difference in amplitude (dB) between the output ports of the power divider over the specified frequency range [18] and also phase Balance is determined by the maximum peak-to-peak difference in phase (in degrees) between the output ports of the power divider over the specified frequency range [18]. Input Power is the maximum power that may be supplied to the input port with all output ports are properly terminated [18].

The insertion Loss produced due to insertion of new devices in a system and it is given by [18]

$$IL = -20logT\ dB \quad (2)$$

Where T is the transmission coefficient and is given by

$$T = 2Z1(Z1 - Z0) \quad (3)$$

III. WILKINSON POWER DIVIDER:

WPD is especially suitable for the field of microwave engineering and circuit design that can achieve high isolation between the output ports while maintaining matched conditions on all ports [11]. WPD design can also be used as a power combiner because it is made up of passive_components and hence reciprocal. It was first published by Ernest J. Wilkinson in 1960. In that they determine that it can be used widely in radio_frequency communication systems utilizing multiple channels [6]. A crosstalk between the individual channels can be prevented by this since it has isolation between the ports [14, 15].

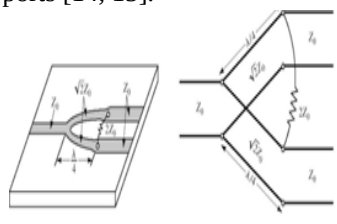

Fig. 1(a) General design of WPD[1,10]
Fig. 1(b) Equivalent circuit of fig1(a)[1,10]

The scattering parameters for the common case of a 2-way equal-split Wilkinson at the design frequency is given below by [2]

$$[s] = \frac{-j}{\sqrt{2}}\begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} \quad (4)$$

Inspection of the S matrix reveals that the network is reciprocal ($S_{ij}=S_{ji}$), that the terminals are matched (S_{11}, S_{22}, $S_{33}=0$), that the output terminals are isolated (S_{23}, $S_{32}=0$) and that equal power division is achieved ($S_{21}=S_{31}$).

The non-unitary matrix results from the fact that the network is lossy. An ideal WPD would yield [11, 12].

$$S21 = S31 = -3dB = 10log_{10}\ (1/2) \quad (5)$$

It is particularly simple and it is easily realized using printed components on a PCB. It can also possible to use lumped elements, but this complicates the overall design of the circuit. When WPD is realized using PCB elements, the cost is very low. However to reduce losses, a low loss PCB substrate may need to be used. The losses of WPD are less when compared to resistive power dividers. It provides a high degree of isolation between the "output" ports [14, 2].It is mainly applicable in base stations to divide the power equally, antenna arrays to provide more control over the amplitude and phase of each element, in building wireless communication systems, transmission line fault testing ratio measurements (to measure the transmitted and received power) and also in signal processing applications. For a wide bandwidth application, a multi-section Wilkinson unit will be suitable [5, 12, 17].

IV. MODEL OF WILKINSON POWER DIVIDER

The designs of 2-way, 4-way, 8-way, 16-way WPD using MLIN with the operating frequency 0-3GHz are shown in below figures which are done by ADS.

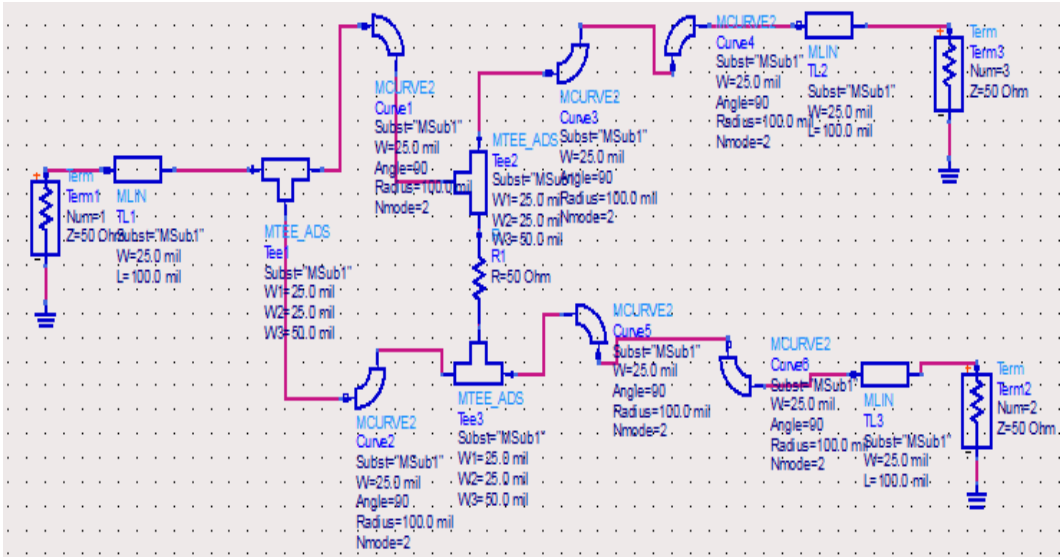

Fig. 2 2-way WPD in ADS

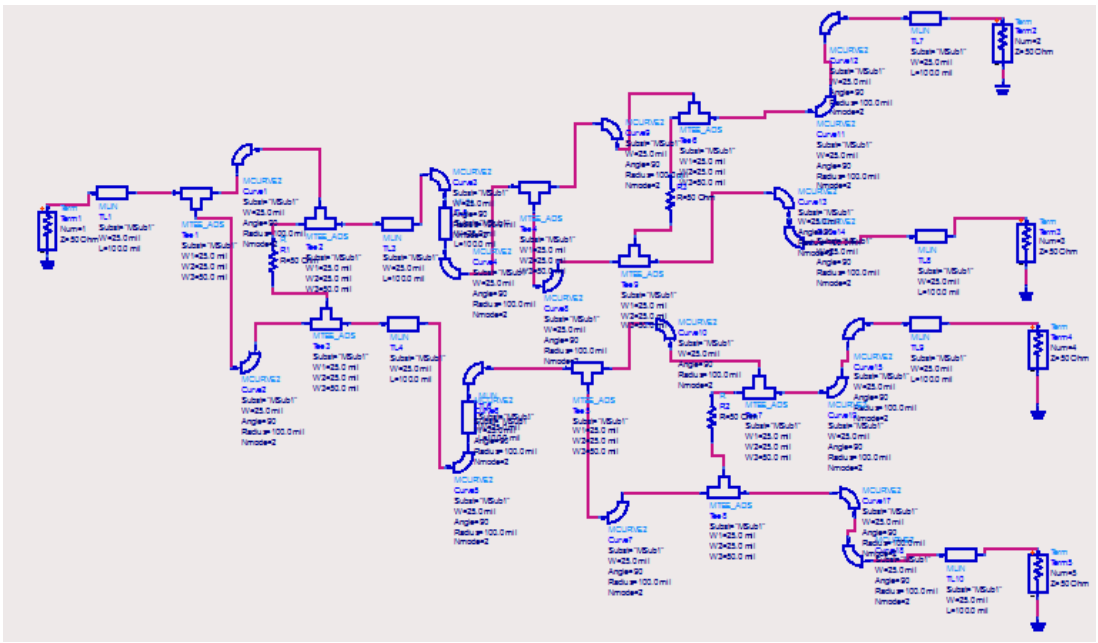

Fig. 3 4-way WPD in ADS

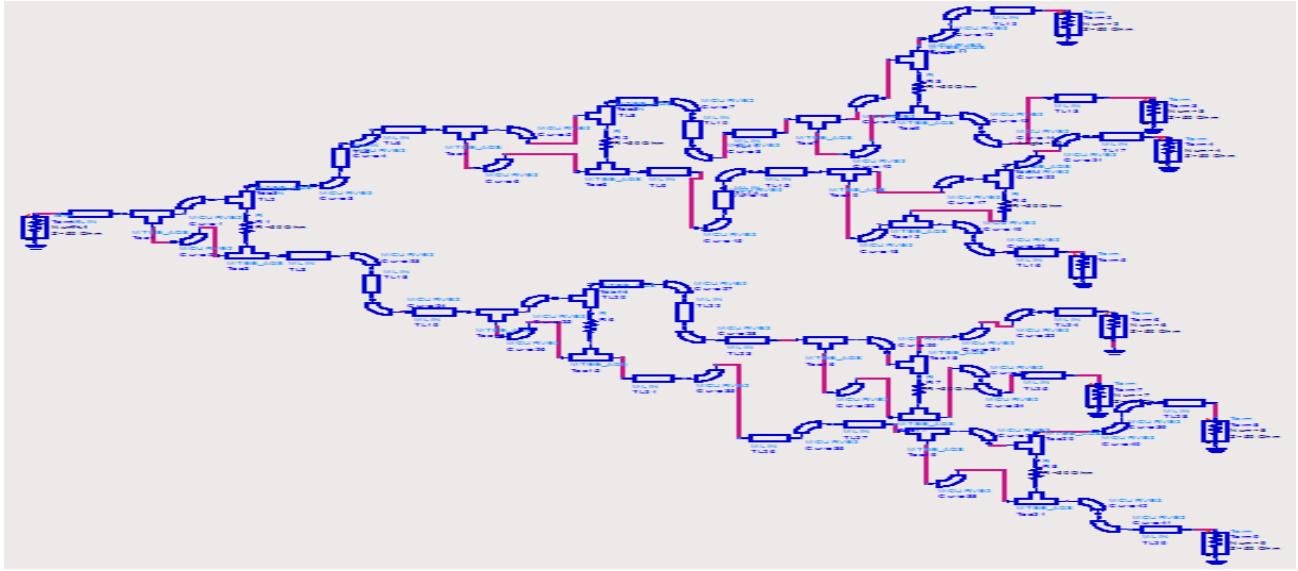

Fig. 4 8-way WPD in ADS

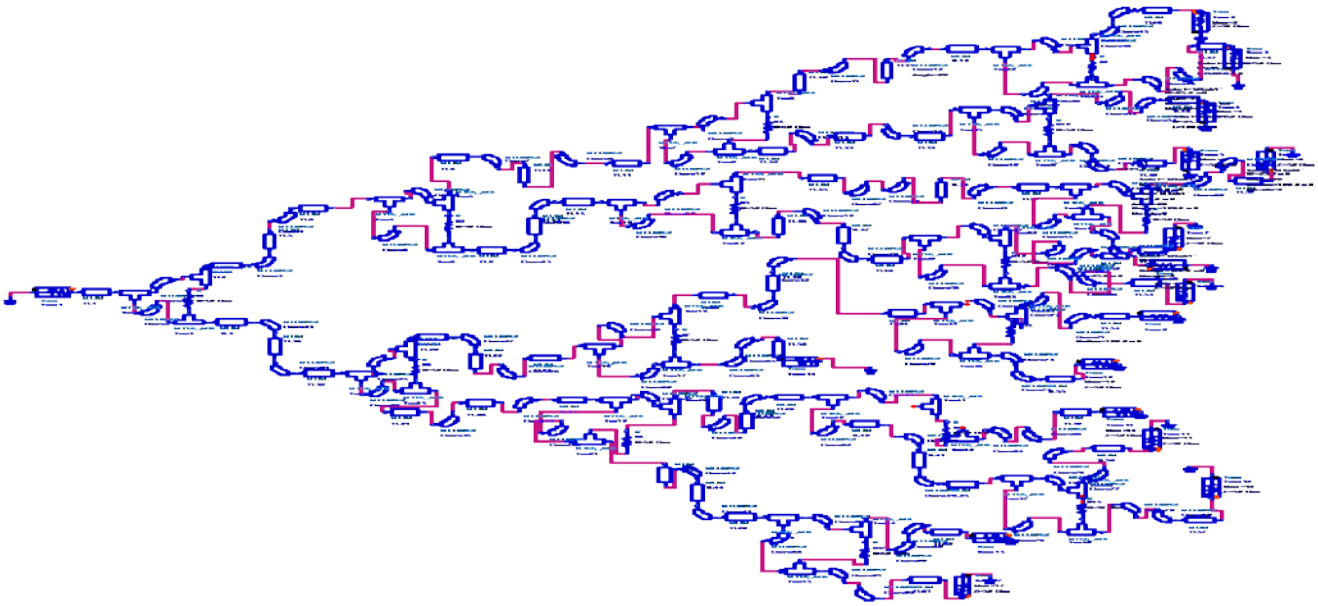

Fig. 5 16-way WPD in ADS

V. RESULTS AND DISCUSSIONS

The following figures show the simulation result of insertion loss, return loss and isolation loss of 4-way and 8-way WPD with MLIN using ADS. From the figures, the return loss is highly desirable and the insertion loss is low when compared with 4-way WPD. Fig. 6 and Fig. 9 shows the return loss of 4-way WPD and 8-way WPD of about -9.767dB and -2.846dB respectively. Comparing these two figures return loss is highly desirable of about -6.921dB.

And also Fig. 7 and Fig. 10 shows the insertion loss of about -6.393dB and -12.045dB respectively. Comparing these two figures the insertion loss gets minimized of about -6.652dB. From Fig. 8 and Fig. 11 the isolation loss is of about -5.412dB and -5.579dB respectively. By comparing these two figures the isolation loss gets minimized of about -0.167dB. Which concludes that 8-way WPD performance is better when compared with 4-way WPD. Like the same way, it can be determined for 16-bit, 32-bit and so on. For 16-way the insertion loss gets minimized of about -13.643dB where as for 32-bit it gets minimized of about -13.256dB.

A. Results for 4-way WPD

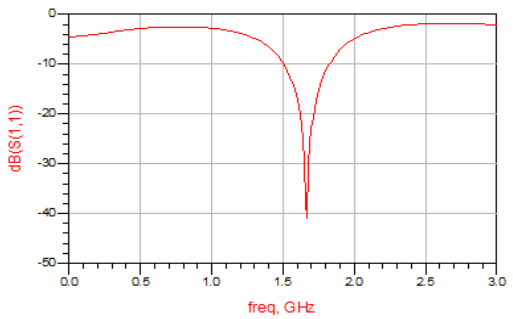

Fig. 6 Return loss of 4-way WPD

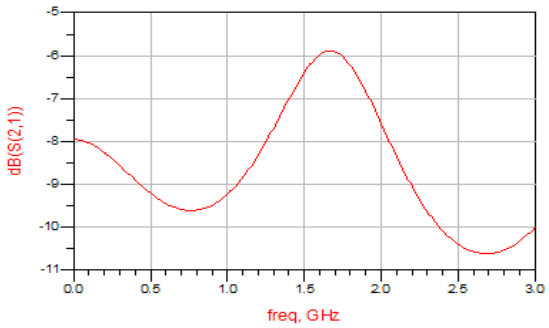

Fig. 7 Insertion loss of 4-way WPD

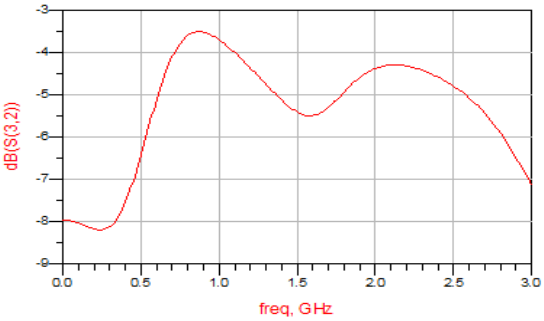

Fig. 8 Isolation loss of 4-way WPD

B. Results for 8-way WPD

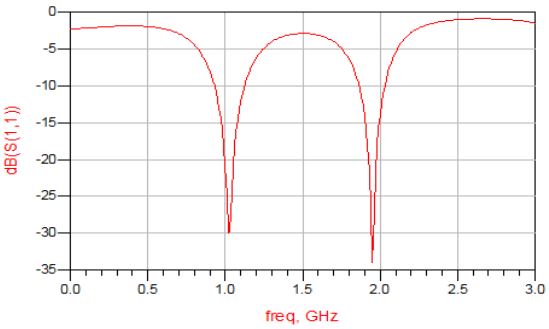

Fig. 9 Return loss of 8-way WPD

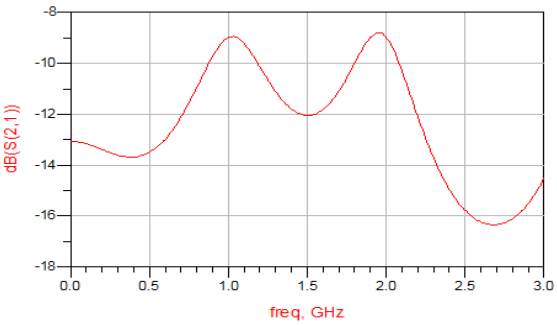

Fig. 10 Insertion loss of 8-way WPD

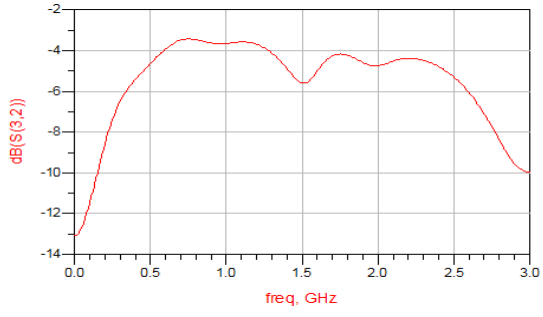

Fig. 11 Isolation loss of 8-way WPD

IV. CONCLUSION

This paper has presented a detailed analysis of a Wilkinson Power Divider using ADS software. The analyses have taken important parameters like isolation loss, insertion loss and return loss are determined for 4-way, 8-way, 16-way etc. High return loss is desirable where as the insertion loss and isolation loss should be a minimum value for power dividers. The analyses have shown that WPD satisfies the above constraints.

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