Comparative Analysis and Design of SHF H-K (H Shaped-K Ports) Power Divider and Wilkinson's Power Dividers

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***Abstract*—A novel H-K (H shaped-K ports) power divider with manual control was proposed earlier to provide appropriate power division to different parts / segments of networks for their smooth operation. Wilkinson's power dividers are widely used in telecommunication industry; these are simulated and compared with the novel H-K structure. Both designs of Wilkinson's power divider using single section and double section are simulated. A four port 2in × 0.9in H-K structure is modeled and analyzed using Ansoft HFSS 11, while Wilkinson's power dividers are simulated using CST Microwave Studio. Comparison in terms of S- parameters for above mentioned structures is also presented in this paper.**

***Index Points*—*H-K* power divider, Wilkinson's power divider, Ansoft HFSS, 2D S-parametric plots**

I Introduction

Power dividers are the widely used microwave components in communication systems mostly used in antennas and transceivers [1]. Power coupling or dividing at higher frequencies is a problem that has been solved with the help of matching networks [2], [3] and adaptive multistage networks [4]. A new structure H-K (H shaped-K ports) power divider has been proposed for high frequencies in [5]. For the illustration purpose a four port 2in × 0.9in structure was presented in [5] which has moveable septums at different stages. It had been driven by a signal of 10GHz. Input loss for the structure was about -18 dB at lower frequencies and at certain higher frequencies it had been observed as -50 dB less. This four port structure can be thought of as a building block that can be extended to any number of ports by replicating it in any desired direction to perform any application. Septum positions have been selected for this divider to operate as 3 dB divider.

Similarly, the Wilkinson's power dividers are considered. They are widely used dividers due to higher return losses in its all three ports while a high isolation between its output ports [6]. Both single and double stage varieties are investigated for designing wideband Wilkinson power dividers [7]. These designs aim at very wide operational bandwidth within frequency band of 1 GHz to 13 GHz as H-K divider is also operated at almost same frequency range. Rogers 4003C substrate with a dielectric constant of 3.4 and thickness of 0.510 mm is used. This design is aided with the full wave EM analysis and he CST Microwave Studio.

First we will present models of H-K power divider, Wilkinson's single stage divider and double stage divider; then we simulate it through Ansoft HFSS 11 and CST Studio respectively, where 2-D S parametric graphs are obtained and compared.

II Model of H-K Controller

Model of H-K (H shaped-K ports) controller is depicted in Fig. 1 with K=4 [5].

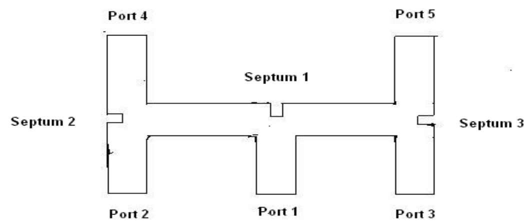

Figure 1. Model of H-K controller for power division

Here 10 GHz signal is entered through port 1, which through septum 1 is halved into two portions having equal power levels and similarly signals will be halved in two portions through septums 2 and 3. We have now obtained a fall of 6 dB from input port to all four output ports. Scattering parameters for this structure is as follows [5].

$$S_{21} = \frac{V_2^-}{V_1^+} = \frac{1}{4} = 10\mathrm{Log}\frac{1}{4}\,\mathrm{dB} = -6\ \mathrm{dB} \quad (1)$$

$$S_{31} = \frac{V_3^-}{V_1^+} = \frac{1}{4} = 10\mathrm{Log}\frac{1}{4}\,\mathrm{dB} = -6\ \mathrm{dB} \quad (2)$$

$$S_{41} = \frac{V_4^-}{V_1^+} = \frac{1}{4} = 10\mathrm{Log}\frac{1}{4}\,\mathrm{dB} = -6\ \mathrm{dB} \quad (3)$$

$$S_{51} = \frac{V_5^-}{V_1^+} = \frac{1}{4} = 10\mathrm{Log}\frac{1}{4}\,\mathrm{dB} = -6\ \mathrm{dB} \quad (4)$$

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Simulation of model is presented in Fig. 2 in Ansoft HFSS using duplication techniques. Septum is incorporated in design using a variable named offset which is introduced in the Y coordinate of the septum. By changing the value of offset, septum's Position is also moved.

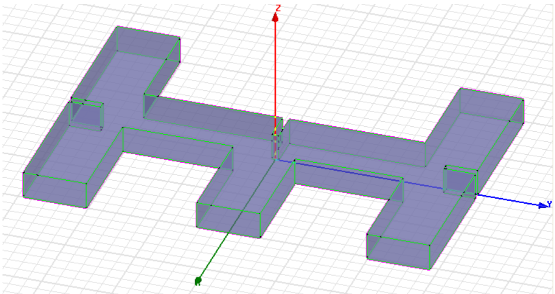

Figure 2. Simulation of H-K controller for power division

III THE ORATICAL AND SIMULATED MODELS OF WILKINSON'S POWER DIVIDERS

A. *Single Section Wilkinson Power Divider*

The basic configuration for Wilkinson power divider is shown in Fig. 3 as below.

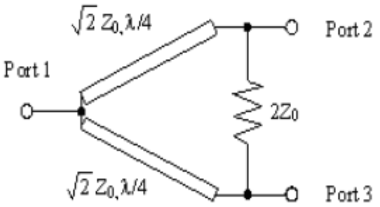

Figure 3. A 2-way equal split Wilkinson power divider equivalent circuit

The single stage Wilkinson power divider comprises of two parallel uncoupled quadrature transmission lines with characteristic impedance, √2Z0. A 2Z0 of shunt resistor is connected between the two output ports to provide the isolation between the output ports. Fig. 4 shows the simulated model of single stage power divider with optimized dimensions.

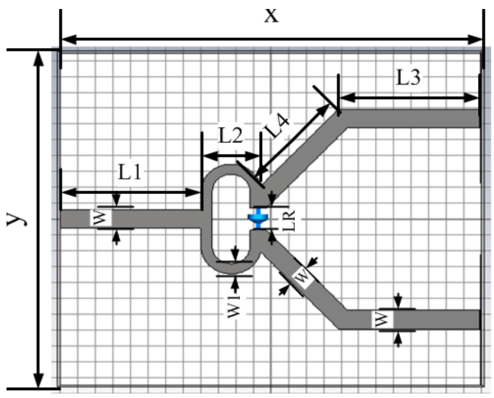

Figure 4. CST layout of Single Stage Wilkinson's Power divider

B. *Double Section Wilkinson Power Divider*

Fig. 5 shows the basic layout of the double-stage Wilkinson power divider.

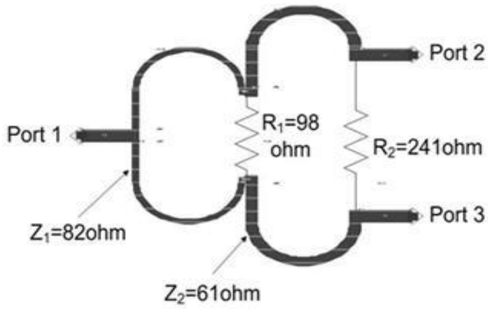

Figure 5. Basic layout of Wilkinson's double Stage power divider

Fig. 6 shows the CST layout of the double stage power divider with optimized dimensions. Two stages of quarter wave transformers are present I this structure. Widths of the two quarter wave transformers should be obtained by using separate values as shown in the Fig. 5 where Z_1 = 82 ohm and Z_2 = 61 ohm. Width W_1 would usually be smaller than the width W_2 as depicted in Figure 6 as the Z_1 is usually greater than Z_2.

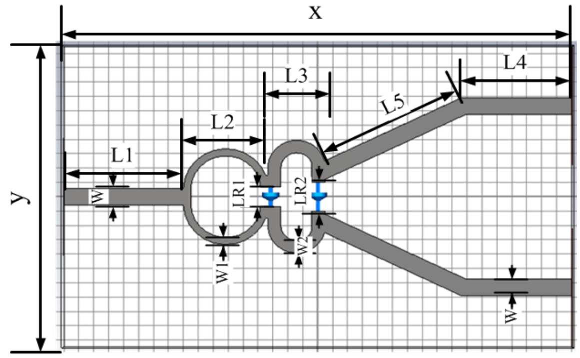

Figure 6. CST Layout of double stage Wilkinson's power divider

IV RESULTS AND COMPARISON

Structure as in Fig. 2 is analyzed and run in frequency sweep from 8 GHz to 10 GHz for better understanding . Its 2-D S parametric plot is then obtained, where x-axis is showing frequency.

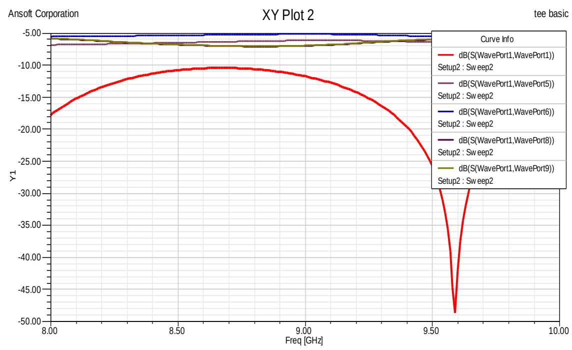

Figure 7. 2-D S parametric plot for H-K Power Divider

This plot depicts in form of red line that input or return loss (shown as red line) has the minimum value of -18 dB throughout the range except at 9.60 GHz where it falls to -49 dB, which is the best matched frequency for this model. S parameters (as shown in different colors for all output ports) have the values round about -6 dB, which is in accordance with what we have expected.

Here the maximum electric field strength is of value $3.696 \times 10^{3} \frac{Volts}{m}$. This structure can also be upgraded to larger structures with ease.

2D S-Parametric plot of Single Stage Wilkinson's Power Divider is shown in the figure.

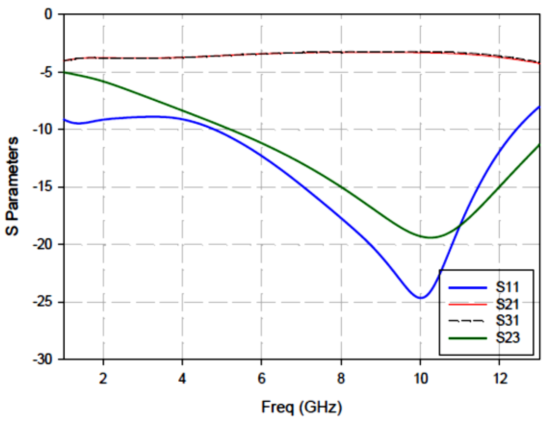

Figure 8. 2-D S parametric plot of single stage Wilkinson's power divider

The simulated power division of 3±0.5 dB can be noticed across the whole band. The reflection coefficient, S11 and the simulated isolation, S23 is greater than 10 dB. By considering all s-parameters, the bandwidth of the simulated single stage power divider is from 4.8 GHz to 12.3 GHz. In terms of percentage, the simulated bandwidth of the single stage power divider is 87.7%.

2D S-Parametric plot of the double stage Wilkinson's power divider is shown below in Fig. 9.

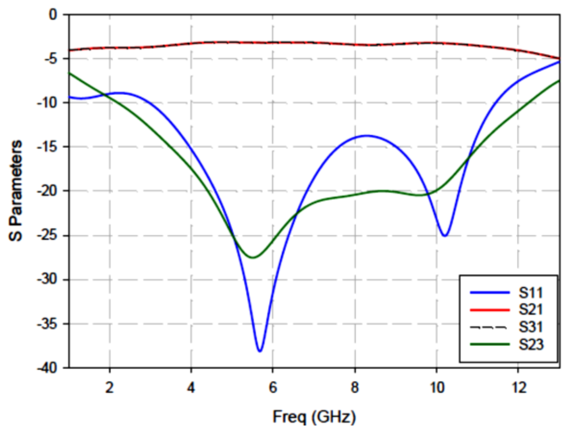

Figure 9. 2-D S parametric plot of Double Stage Wilkinson's Power Divider

The simulated power division of 3±0.5 dB can be noticed from 1 GHz to 12 GHz. The simulated reflection coefficient, S11 is better than 10 dB across the band of 3 – 11.2 GHz. The simulated isolation, S23 is greater than 10 dB across 2.1 GHz to 12.1 GHz. By considering all s-parameters, the bandwidth of the simulated double stage power divider is from 3 GHz to 11.2 GHz. In terms of percentage, the simulated bandwidth of the double stage power divider is 115.5%. The bandwidth is increased from 87.7% to 115.5% when double stage approach is used in the Wilkinson Power Divider.

Now consider another aspect of H-K controller that lacks in Wilkinson's power dividers and that is its flexibility in power division. Only septum has to be moved to change the amount of power coupling in any of the output ports. Now consider the Fig. 10 in which the septum is moved by 0.2 towards the port 3.

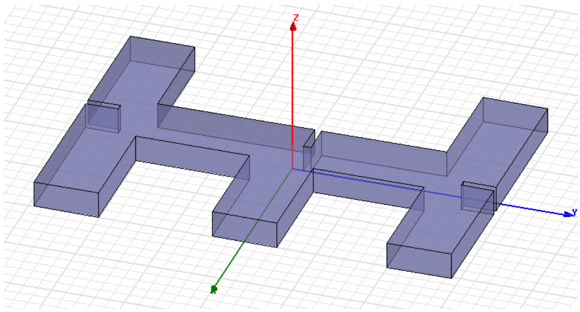

Figure 10. Simulation of model with septum moved

Its 2D S-parametric plot is as shown below.

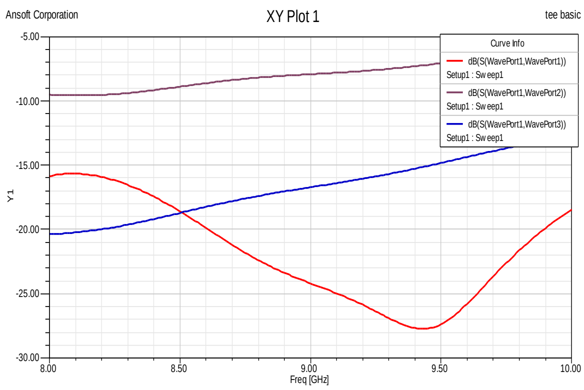

Figure 11. 2-D S parametric plot for model with septum moved

Here the brown line shows that port 2 at left side has much higher value for S parameter than the port 3 on the right side of model, so the power coupled to ports on right side is much lower than that to the left side. Similarly different positions of septums will result in different power divisions. The illustrated example shows another advantage of H-K power divider over Wilkinson's power dividers as for change of power division within output ports, all dimensions of the Wilkinson's power divider have to be changed.

V Conclusion

H-K controller for power division presented here is very efficient as its return loss lies between -18 dB to -49 dB throughout the frequency sweep and also flexible as its septum can be controlled to deliver power at different levels in any direction through any port, while Wilkinson's single stage power divider not only has high return loss (-10 dB to -25 dB) but also comprised of three ports which are not entirely isolated. Wilkinson's double stage power divider although more efficient than single stage Wilkinson's power divider in terms of return loss (-10 dB to -38 dB) and increased bandwidth from 87.7% to 115.5%, but its return loss is not better than H-K power divider. Due to its flexibility, isolation between output ports and better return loss, H-K power divider stands as the best structure among three for various applications.

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