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ANALYSIS OF N-WAY POWER DIVIDER USING CHEBYSHEV TRANSFORMATION

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Abstract - The power dividers are one of the most ubiquitous passive circuit elements in RF/Microwave applications. They are widely used in antenna arrays, balanced amplifiers, mixers, frequency multipliers etc. as power combiners or splitters. The Wilkinson power divider (WPD) and the Gysel power divider (GPD) are the two most useful of all the power dividers because of it low insertion loss, matched ports and isolated outputs ports. The conventional WPD has a simple structure and good performance except that its bandwidth, especially the bandwidth, is limited. Therefore, this thesis aimed at exploring the ways to enhance this Figure of Merit (FOM). To that end, a Chebyshev multi-section impedance transitions with a isolation resistors is proposed as one of the methods to achieve higher bandwidth with better isolation among lines . Simulation results indicate that for 15dB reference, a return loss bandwidth of 150% is possible as compared to 45% for the conventional methods. Furthermore, a WPD utilizing the concept of port extension is also proposed that provides complete DC isolation along with a higher bandwidth. This technique is fully planar and easy to fabricate and easy for integration as well with other subsystems.

***Key Words*:** Gysel power divider(GPD), Figure of Merit(FOM), WPD.

1. INTRODUCTION *(Size 11, Times New roman)*

power dividers are important components in microwave technology. A multi way power divider is a key component in phase-array antennas, power amplifiers, and six-port circuits. Wilkinson-type power dividers are generally adopted, but it is planar only for two-way power division. Therefore, for an N-way power divider, where N is equal or larger than 3, it is generally realized by interconnecting two-way power dividers. In some cases, a multi way power divider is composed of interconnection of three-way or more-way power dividers to reduce the design complexity and difficulty. Although power dividers have been studied by many authors the interconnection of power dividers with fewer ways of division into a multi way power divider has not been investigated in detail until recently. many calculations were made for the interconnection of two-way power dividers to achieve multi way power divider.

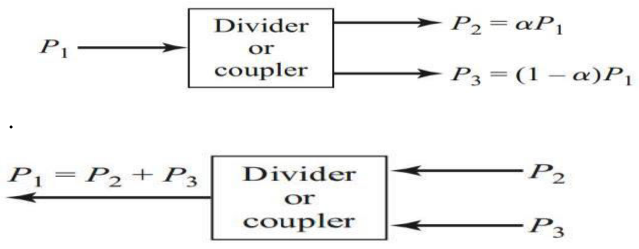


Fig: power splitting and combining

1.1 The Wilkinson Power Divider

A Wilkinson power divider (WPD) is a lossy three-port network having all ports matched, with good isolation between output ports.It comprises of two quarter wavelength transmission lines each having a characteristic impedance of $\sqrt{2}Z_0$ and an isolation resistor $R = 2Z_0$. When a signal enters into port 1, it splits into equal-amplitude, equal-phase output signals at ports 2 and 3. Because of symmetry, each end of the isolation resistor is at the same potential, no current flows through it and therefore the resistor is decoupled from the input. Thus, the operation boils down to matching $2Z_0$ to Z_0, as the two branches are in effect, in parallel. The quarter wavelength transmission lines are to facilitate this impedance transformation and the characteristic impedance of the quarter wavelength lines must be equal to $1.414Z_0$. When a signal enters into port 2, a part of it goes clockwise through the resistor and part goes counterclockwise through the upper arm, then splits at the input port, then continues counterclockwise through the lower arm toward port 3.

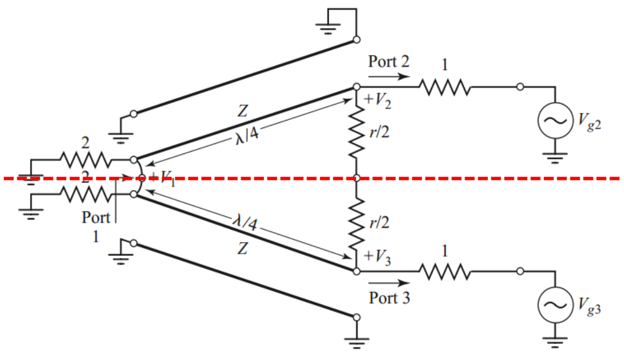


Fig1.1(a): The symmetric and normalized form of WPD

The WPD can be readily analyzed using even-odd mode procedure [1]. To that end, the WPD shown earlier in in Fig. 1.1(a) in symmetric and normalized form. In the normalized form each impedance is divided by the port impedance, Z_0. Now in the even-mode, $V_{g2}=V_{g3}=2V_0$ and therefore, each point along the middle horizontal symmetric line is open-circuited. On the other hand, in the odd-mode, $V_{g2}=-V_{g3}=2V_0$ and therefore, each point along the axis of symmetry is short-circuited.

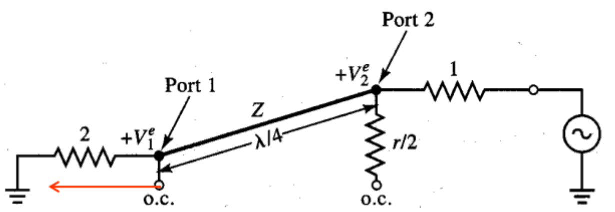


Fig 1.1(b): The even-mode equivalent network of the WPD

The even-mode half circuit is shown in Fig. 1.1(b). It is apparent that the isolation resistor has no role in this mode as the one of its end is open-circuited.

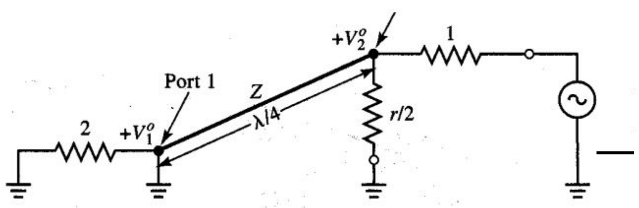


Fig1.1(c): The odd-mode equivalent network of the WPD

For odd-mode excitation, the half circuit is depicted in Fig. 1.1(c). Since, port 1 is short-circuited and the line is λ/4 long, the input impedance looking into the line at port 2 is infinite. And therefore, for matching at port 2; r = 2. Then, $V_1^o = 0$ and $V_2^o = V_0$.

Finally, as pointed out earlier, the equivalent circuit looking from the port 1 consists of two quarter wavelength lines in parallel loaded with a unity resistor (since the isolation resistor has no impact due to zero voltage across its ends), the normalized input impedance is just unity. It can be concluded from the above analysis that $S_{11} = S_{22} = S_{33} = S_{23} = S_{32} = 0$, $S_{12} = S_{21} = S_{13} = S_{31} = j/\sqrt{2}$. The ideal line performance of the WPD is shown in Fig. 1.1(d) Due to the use of quarter wavelength lines, the response is narrow-band.

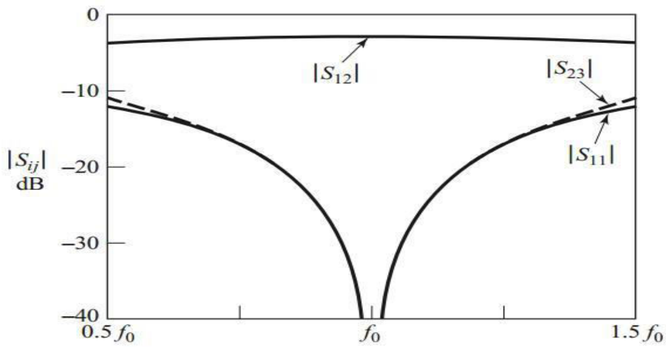


Fig1.1(d): Simulated frequency response of 3dB WPD

2. PROPOSED DIVIDER

The proposed divider is apparent that it has only one grounded resistor. The two 90º TL sections with characteristic impedance Z_C in the conventional divider is now replaced with two TL sections of different characteristic impedance, namely, Z_{C1} and Z_{C2}. Since, the only difference between the conventional and the proposed divider is in the structures within the dashed boxes, derivation of the design equations of the proposed divider can be easily done by equating the ABCD parameters of Box1 (p-q) and Box2 (u-v).

The ABCD parameter of Box1 is as follows:

$$[ABCD]_{p-q} = [ABCD]_{R_2} \times [ABCD]_{Z_C} \times [ABCD]_{R_2}$$

$$= \begin{bmatrix} 1 & 0 \\ G_2 & 1 \end{bmatrix} \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ G_2 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} -1 & 0 \\ -2G_2 & -1 \end{bmatrix} \quad (2.3)$$

Where, $G_2 = 1/R_2$.

3. Simulation And Discussion

The general design equations have been developed in the previous section; here they are used to assess the capabilities of the proposed UWB 3 way Wilkinson power divider . To that end, we begin with the special case mentioned If Z_s =50Ω, the difference between the even-odd-mode impedances are required to be 150Ω. The simulated S-parameters and phase difference of a design at f_0=3.5GHz for different value of Z_{ol} =Z_{or} =Z_o. It is apparent from these simulation results that as the value of Z_o is increased, the corresponding bandwidth of return loss (S_{11}) and that of the transmissions (S_{21}, S_{31}) shrinks. Specifically, the bandwidth for 10dB return loss is 200% for Z_o=50Ω.Enhancement on return loss is done by tuning and optimization on calculated values for chebyshev Multisection transformations . For isolation (S_{23}) bandwidth, if 15dB isolation criteria is adopted then the bandwidth is higher than the entire simulated frequency range, that is, more than 200%. However, if 14dB isolation criteria is adopted, then a higher value of Z_o (1:3 Ultra Wideband Equal Power dividers from 1GHz to 6 GHz.

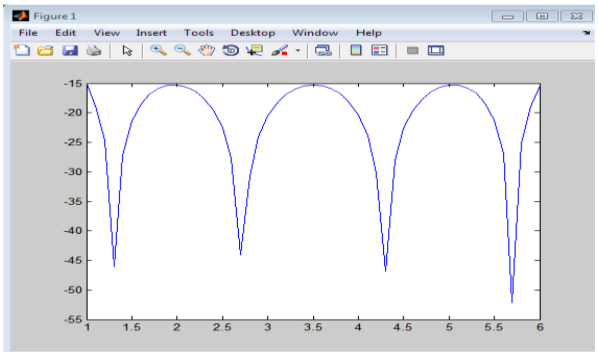
N= number of quarter wave sections

f0= Centre frequency (in GHz)

f1= lowest cut=off frequency (in GHz)

f2=highest cut=off frequency (in GHz)

fa=frequency array with steps



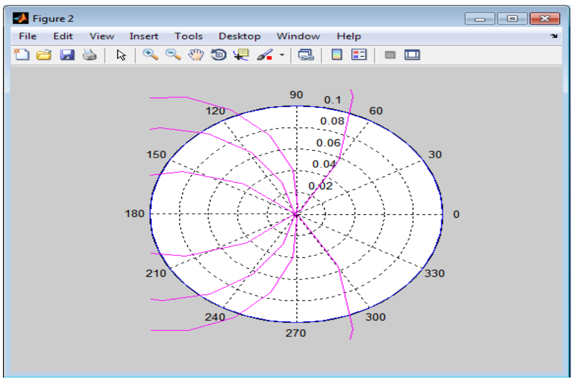


Fig3: Return loss and smith chart

4. CONCLUSION

The objective of this thesis was to pursue wideband techniques to tackle this problem. To that end, a scheme to get best out of the advantages that WPD offer was discussed . Specifically, a clear design methodology to for Power divider as a combination of multi section transformer and WPD employing some isolation resistor was discussed. It is found that considering 15dB return-loss reference, the bandwidth is 200% for the proposed design.

By employing matching network at each port of conventional Wilkinson divider core structure, a 3 way UWB Power Divider with fairly good performance was described . Specifically, parallel coupled lines were used at each port to facilitate a wideband matching. Due to the use of these coupled line structure, a DC isolated WPD is obtained which can be potentially be used in balanced amplifiers with having requirement of coupling capacitors. A prototype was fabricated to validate the proposed theory. The EM simulated results matches quite well with the measured results and the measured isolation bandwidth is 200% considering 15dB reference.

5. REFERENCES

1. S. P. Benz and C. A. Hamilton, “Application of the Josephson effect to voltage metrology,” *Proc. IEEE*, vol. 92, no. 10, pp. 1617–1629, Oct. 2004

2. Microwave power dividers and couplers tutorial: overview and definition of terms (online), Accessed: July 04, 2016, URL:https://www.markimicrowave.com/Assets/appnotes/microwave_power_dividers _and_couplers_primer.pdf

3. R. Gómez-García, R. Loeches-Sanchez, D. Psychogiou, and D. Peroulis, “Single/multi-band Wilkinson-type power dividers with embedded transversal filtering sections and application to channelized filters,” *IEEE Trans. Circuits Syst. I, Reg. Papers*, vol. 62, no. 6, pp. 1518–1527, Jun. 2015.

4. X. Wang, I. Sakagami, K. Takahashi, and S. Okamura, “A generalized dual-band Wilkinson power divider with parallel L, C, and R components,” *IEEE Trans. Microw. Theory Techn.*, vol. 60, no. 4, pp. 952–964, Apr. 2012.

5. N. Gao, G. Wu, and Q. Tang, “Design of a novel compact dual-band Wilkinson power divider with wide frequency ratio,” *IEEE Microw. Wireless Compon. Lett.*, vol. 24, no. 2, pp. 81–83, Feb. 2014.

6. A. Genc and R. Baktur, “Dual- and triple-band Wilkinson power dividers based on composite right- and left-handed transmission lines,” *IEEE Trans. Compon., Packag., Manuf. Technol.*, vol. 1, no. 3, pp. 327–334, Mar. 2011.

7. K.-K. M. Cheng and F.-L. Wong, “A new Wilkinson power divider design for dual band application,” *IEEE Microw. Wireless Compon. Lett.*, vol. 17, no. 9, pp. 664–666, Sep. 2007.

8. Y. Shin, B. Lee, and M. -J. Park, “Dual-band Wilkinson power divider with shifted output ports,” *IEEE Microw. Wireless Compon. Lett.*, vol. 18, no. 7, pp. 443–445, Jul. 2008.