Wideband Gysel Power Divider Based on Parallel-Coupled Microstrip Line with Bandstop Filter for the 2nd Harmonic Suppression

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ABSTRACT

This paper presents a new design of wideband in-phase power divider/combiner with parallel-coupled microstrip line. The proposed design applies a modified Gysel structure for an increased passband bandwidth and spurious response suppression (at the 2nd harmonic frequency) with Bandstop filter (BSF). Simulated and measured results at the 900 MHz operating frequency of the conventional and the proposed Gysel power dividers with BSF are compared. The measured results exhibit the insertion loss of less than 3.0 dB (S_{21}, S_{31}) and the return loss of more than 20 dB (S_{11}, S_{22}, S_{33}) with wideband at the 900 MHz. Moreover, the proposed Gysel power divider provides the 2nd harmonic frequency suppression of more than 10 dB.

Keyword: *Microstrip, Gyseal power divider, Parallel-coupled microstrip line, and Bandstop filter*

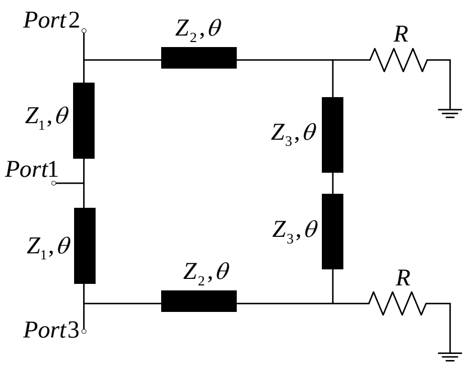
1. INTRODUCTION

The power divider is one of the most widely used passive elements in modern RF and microwave systems for power division and/or combination, microwave amplifier modules and feeding networks for the antenna arrays. The Wilkinson and Gysel power divider (PD) are the most common structure [1] – [3]. The Wilkison PD has low insertion loss and high isolation. However, its power handling capability is low [1]. The main advantages of the Gysel PD over the Wilkinson power divider are first, its capability of heat transfer to the ground plane because of external isolation load resistors, and second, monitoring capability for imbalances at the output ports [2]. Fig. 1 (a) shows the conventional Gysel PD. The Gysel PD has the main advantage of heat-sinking capacity with the connection of isolation resistors (R) to the ground plane, the possibility of even connecting them outside the circuit using a suitable transmission lines and it has many high-power combination applications [4] – [6]. There is no research involving the 2nd harmonic suppression with the Gysel PD with BSF. In this paper, we present a simple technique with effective harmonic suppression at the $2f_O$ to improve the BSF of the parallel-coupled microstrip lines. The technique can achieve high isolation and hence wideband the Gysel PD with BSF depend on coupled microstrip lines instead of the ordinary $\lambda/4$ transmission lines (Z_3) depicted in Fig 1. (b). The paper is organized as follows: Section II presents proposed the Gysel PD based on parallel-coupled microstrip BSF technique as well as the electromagnetic (EM) simulated and measured results will be presented in Section III. The paper is finally concluded in Section IV.

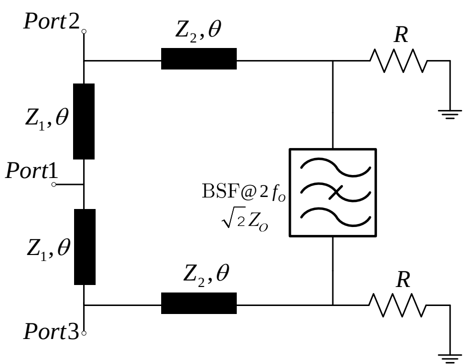
2. THEORY

2.1 The Gysel PD

The Gysel PD is one of the most widely employed passive elements in modern RF and microwave systems for power division and/or combination. Present, a instantly development of microwave and millimeter wave communication systems mainly stimulates the demand on high performance PD with compact size, low insertion loss, wide bandwidth input/output ports return loss, isolation and low cost. The conventional Gysel PD consists of two quarter-wavelength branch transmission lines with characteristic impedance of $\sqrt{2}Z_0$ and a isolation resistor (R) of $2Z_0$, as shown in Fig. 1(a), the element values for the PD consist of: $Z_1 = \sqrt{2}Z_O$, $Z_2 = R$, $Z_3 = \sqrt{2}R$, isolation resistance *(R)* and $\theta = 90^\circ$ where $Z_O = 50\Omega$ is the impedance of the input/output ports. The power divider is designed based on the electrical length of a desired fundamental frequency; however high-order harmonic signals usually appear at the output ports due to the periodic characteristics of the transmission lines. This will be each additional harmonic tuning circuit parts or external lowpass filters to be inserted to suppress the unwanted harmonics. The present a simple technique in accordance with harmonic suppression at $2f_O$, its technique can achieve high isolation and hence wideband the Gysel PD with BSF depend on coupled microstrip lines show in Fig 1 (b).



(a)

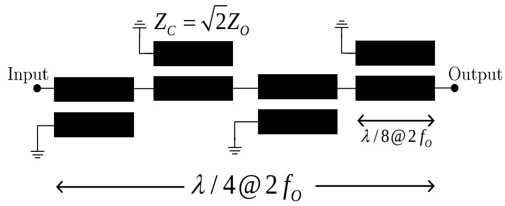


(b)

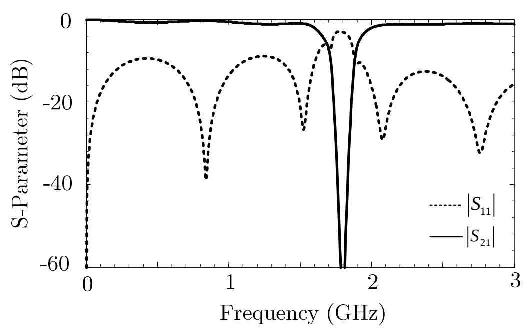
Fig. 1 *(a) The conventional the Gysel PD; (b) The proposed Gysel PD technique.*

2.2 The parallel-coupled lines BSF

In the paper presented that the parallel-coupled lines BSF as show in Fig. 2 (a) schematics of BSF. The BSF are important components in microwave and millimeter-wave applications to reject higher harmonics and spurious passbands. Maximun coupling to the resonator is achieved when only a $\lambda/4$ length of the resonator is microstrip parallel – coupled line. The general parallel coupled-lines of BSF design equations of the proposed divider [7] can be written as



(a)



(b)

Fig. 2 *(a) The schematics BSF and (b) simulation results BSF.*

$$Z_{0ei} = Z_0[1 + Z_0 J_i + (Z_0 J_i)^2] \quad (1)$$

$$Z_{0ei} = Z_0[1 + Z_0 J_i + (Z_0 J_i)^2] \quad (2)$$

Where $i = 1,2,3.....N$, and the impedance-scaled BPF as

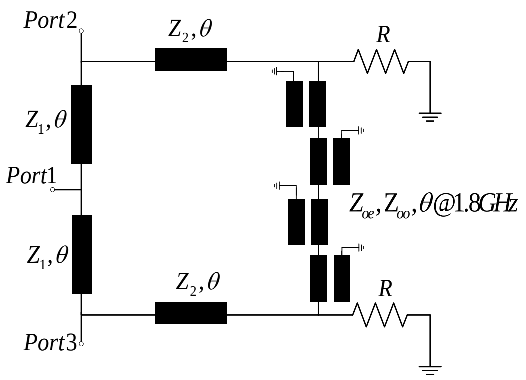
$$Z_{01} = 4Z_0 / \pi g_1 \Delta \quad (3)$$

$$Z_{02} = 4Z_0 / \pi g_2 \Delta \quad (4)$$

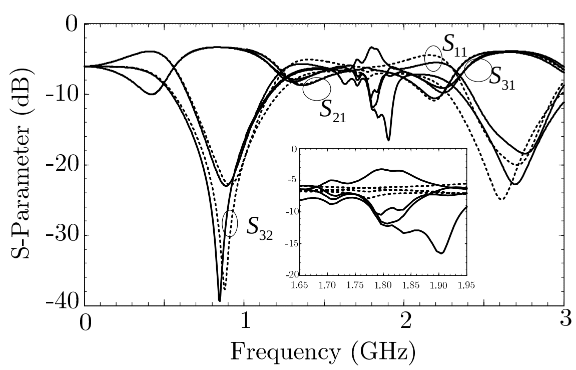
where $\Delta = (\omega_2 - \omega_1)/\omega_0$ is the fractional bandwidth of the filter and g_n is the lumped element values for BSF prototype. It is easy to show that the general result for the characteristic impedances of BSF is

$$Z_{0n} = 4Z_0 / \pi g_n \triangle \quad (5)$$

In this paper, a simple design of compact BSF using parallel-coupled lines as shown in Fig. 2 (a) is proposed. To suppress the 2nd harmonic frequency response and provide 90 degree phase shift between input and output signal of Gysel PD, the proposed BSF is designed and implemented by using two $\lambda/8$ electrical length parallel-coupled lines at the operating frequency f_0. The function of Gysel PD in the proposed BSF is used to widen the suppression performance bandwidth (S_{21}) at the operating frequency. Simulations of the proposed topology are performed. Fig. 3(b) shows the simulated results of frequency response (S_{21}) and input return loss (S_{11}) performances of the proposed BSF parallel-coupled lines.



(a)

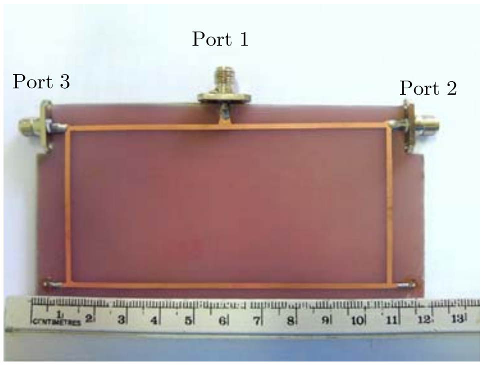


(b)

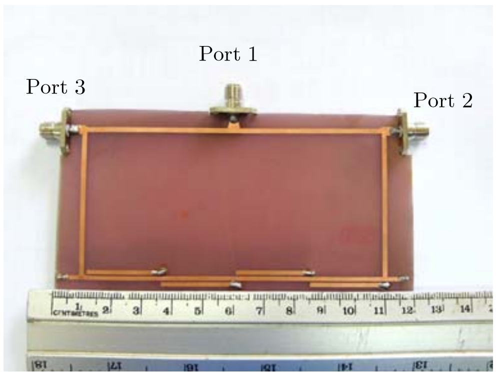
Fig. 3 *(a) The proposed Gysel PD, (b) the simulated results (------) conventional, ( ) proposed.*

3. DESIGN AND EXPERIMENTAL RESULTS

The design of proposed Gysel PD technique based on parallel-coupled lines deigned at f_0 of 0.9 GHz. The circuit prototype were designed and fabricated on FR4 substrate (ε_r = 4.55, h = 1.6 mm, tanδ = 0.02). In the proposed Gysel PD were the parameter values: $Z_O = 50\Omega$, $Z_1 = 70.7\Omega$, $Z_2 = 70.7\Omega$ $R = 100\Omega$, And the BSF were synthesized from -10 dB coupling factor with electrical parameters $Z_C = 70.7\Omega$, $Z_{oe} = 90.09\Omega$, $Z_{oo} = 50.95\Omega$, and $\theta = \lambda/4$ of 1.8 GHz respectively that show in Fig. 3 (a). Then the simulated results of conventional and the both proposed Gysel PD technique were shown in Fig. 3 (b) respectively. The electromagnetic (EM) simulator was done by Sonnet-Lite™ [8], the prototype were measured by E5062A Vector Network Analyzer and Matlab® data processing and display.



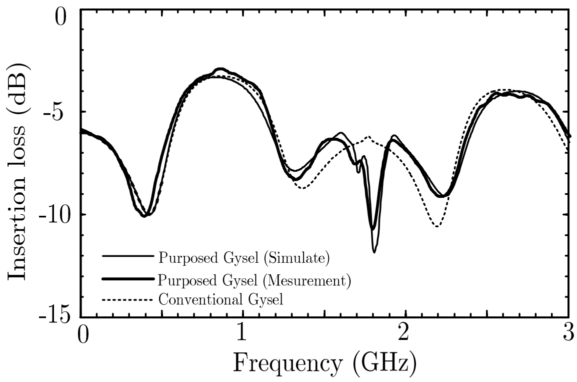
(a)



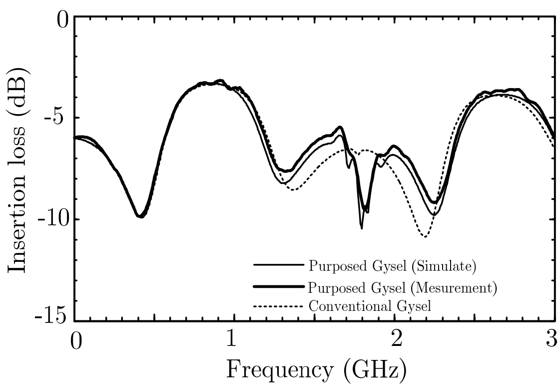
(b)

Fig. 4 *(a) The prototype the conventional Gysel PD and (b) the proposed Gysel PD.*

The fabricated circuits are shown in Fig. 4 (a) and (b), the conventional and both the proposed Gysel PD. Fig. 5 shows the measured S-parameter of the conventional and the purposed Gysel PD. Fig. 5 (a) depict the purposed and conventional Gysel PD achieved the insertion loss (S_{21}) 2.98 dB at centre frequency, and the second harmonics is less than 10 dB respectively. And the bandwidth of is 655 MHz around 0.9 GHz. The insertion loss (S_{31}) at port 3 measurement show that in Fig 5 (b) were 3.05 dB, 9.8 dB at the centre and second harmonics respectively. Fig 5 (c) depict of the return loss (S_{11}) values are more than 20 dB around centre frequency and the return loss 2.23 dB of the second harmonics. When considering of the isolation loss (S_{32}) more than 30 dB at the centre frequency and the second harmonic of the isolation loss more than 10 dB as show in Fig. 5 (d). However, when compared the measured results of the improved the purposed technique and conventional Gysel PD as shown in Fig 5 (a-d) have the harmonic suppression at the $2f_o$ to improve the BSF of the parallel-coupled microstrip lines. Finally, considering the result of the proposed Gysel PD based on parallel-couple line BSF, the insertion, return, and isolation loss performances from around 1.65-1.95 GHz better than the conventional Gysel PD respectively.

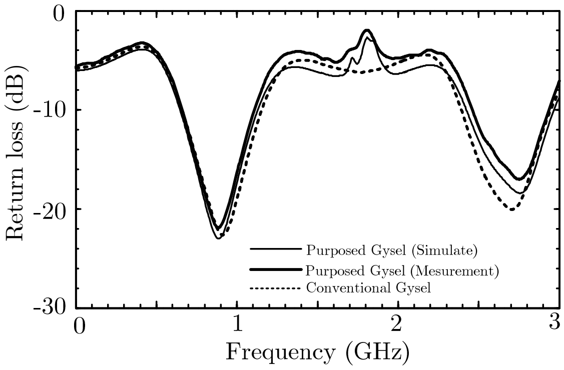


(a) Insertion loss (S_{21})

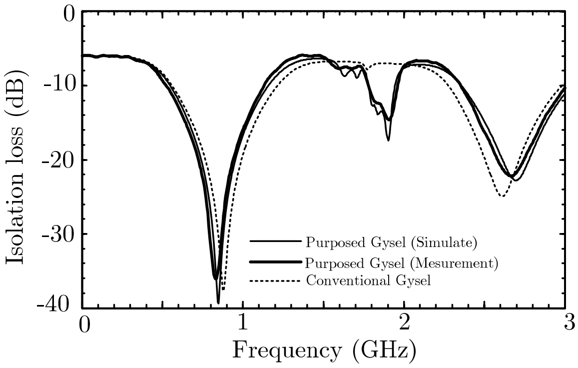


(b) Insertion loss (S_{31})

Fig. 5 *Measured the conventional Gysel PD and the proposed Gysel PD (cont.).*



(c) Return loss



(d) Isolation loss (S_{32})

Fig. 5 *Measured the conventional Gysel PD and the proposed Gysel PD.*

4. CONCLUSIONS

The Gysel PD techniques are proposed to enhance the insertion loss 3 dB, return loss more than 20 dB, and isolation loss 36 dB of microstrip parallel-coupled lines BSF at $2f_o$. The techniques are very simple to design and fabricated, since its all microstrip structures, and achieved in our experiments. Specifically, the experimental results are in agreement between the conventional Gysel PD and the proposed results. The proposed couplers are suitable to use in many wireless and microwave applications.

5. ACKNOWLEDGEMENTS

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REFERENCES

[1] Wilkinson, E.J. An N-way hybrid power divider. *IRE Trans. Microw. Theory Tech*, 8, pp. 116-188., 1960.

[2] Gysel, U.H. A new N-way power divider/combiner suitable for high power applications. *IEEE MTT-S Int. Microwave Symp*., Palo Alto, CA, USA, pp 116-118, 1975.

[3] Ardemagni, F., An optimized L-band eight-way gysel power divider-combiner. *IEEE Transactions on Microwave Theory and Techniques*, 31, pp 491- 495, 1983.

[4] Zhengu Sun and et al., Modified Gysel Power Divider for Dual-Band Applicatons. *IEEE Microwave and Wireless Components Letters*., Vol. 21, No. 1, January 2011.

[5] D. Betancourt and C. del Rio Bocio, “A novel methodology to feed phased array antennas,” *IEEE Trans. Antennas Propag.* , vol. 55, no. 9,pp. 2489–2494, Sep. 2007.

[6] Y. Saito, D. Fontaine, J. Rollin, and D. Filipovic, “Micro-coaxialKa-band Gysel power dividers,” *Microw. Opt. Technol. Lett.*, vol. 52, no. 2, pp. 474–478, Feb. 2010

[7] D. M. Pozar, “Microwave Engineering” 4 edition, John Wiley & Sons, 2012.

[8] http://www.sonnetsoftware.com

N. Angkawisittpan**,** photograph and biography not available at the time of publication.

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