Int. J. Electron. Commun. (AEÜ) 69 (2015) 856–860

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

A novel miniaturized Gysel power divider using lowpass filter with harmonic suppression

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ARTICLE INFO

Article history:
Received 15 May 2014
Accepted 10 February 2015

Keywords:
Compact power divider
Gysel power divider
Harmonic suppression
Lowpass filter

ABSTRACT

This paper presents a new design of a compact Gysel power divider with harmonic suppression. It is comprised of the six similar lowpass filters instead of the six conventional transmission lines in the Gysel power divider. The proposed power divider not only effectively reduces the occupied area to 35%, but also features the higher order harmonic rejection. Simulation and measurement results show good insertion loss, return loss, isolation, and wide stopband bandwidth, while maintaining high-power handling capability over the Wilkinson power divider.

1. Introduction

Power dividers and combiners are the basic parts of microwave systems, such as feeding network for an antenna array, power amplifier and mixer. Prevalent types of power dividers are low-power and small-sized Wilkinson power divider [1] and high-power and large-sized Gysel power divider [2–4]. However, both of these dividers suffer from the presence of odd harmonic responses in as much as they adopt λ/4 lines. Although the Gysel power divider has some merits over the Wilkinson power divider, its enormous size in comparison to Wilkinson divider has limited its applications. Therefore, having a compact power divider with harmonic suppression and high-power handling capability simultaneously is still an ongoing challenge. There are numerous studies about miniaturization and suppression of spurious responses on the Wilkinson power divider [5–8]. Defected ground structure (DGS) [5,6], electromagnetic band gap (EBG) [7,8], resonator cell [9,10], additional stubs and extended line [11], and lumped element [12] are some diverse methods to achieve a compact power divider with harmonic suppression. In this paper, a compact Gysel power divider with suppression of spurious responses is proposed. Six similar lowpass filter cells which contribute to the extreme size reduction as well as striking harmonic rejection of Gysel power divider are employed.

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http://dx.doi.org/10.1016/j.aeue.2015.02.004
1434-8411/

2. Lowpass design

Fig. 1(a) shows the structure of the proposed lowpass filter, which is composed of two modified T-shaped resonators, a L-shaped resonator and transmission line. The structure has good response for designing power divider. The equivalent LC circuit of the lowpass filter is shown in Fig. 1(b), so that L1, L2, L6 and L7 are inductances of high-impedance lossless line. C1, C4 and C5 denote the sum of equivalent capacitances of open-end and high-impedance lossless line and L3, L4, L5, C2 and C3 are the sum of equivalent inductances and capacitances of high-impedance lossless line and bend respectively. The values of these parameters can be extracted by using the methods discussed in [1].

The filter dimensions of Fig. 1 are $W_1 = 0.6$, $W_2 = 0.2$, $W_3 = 2.1$, $W_4 = 7.7$, $W_5 = 1.4$, $W_6 = 5.7$, $A_1 = 5.7$, $A_2 = 8.9$, $A_3 = 4.5$, $A_4 = 6.9$, $A_5 = 0.9$, $A_6 = 9.6$, $A_7 = 4.4$, $A_8 = 1.8$ and $g_1 = 0.4$ (all in millimeters).

A high and low-impedance lossless line terminated at both ends with relatively low impedance lines can be presented by a Π-equivalent circuit, as shown in Fig. 2. The values of inductors and capacitors can be attained as:

$$l_s = \frac{1}{\omega} \times z_s \times \sin\left(\frac{2\pi}{\gamma_g} l\right) \quad (1)$$

$$c_s = \frac{1}{\omega} \times \frac{1}{z_s} \times \tan\left(\frac{\pi}{\gamma_g} l\right) \quad (2)$$

Formulas of open-end are discussed in [1]. Also the structure and equivalent circuit are shown in Fig. 3.

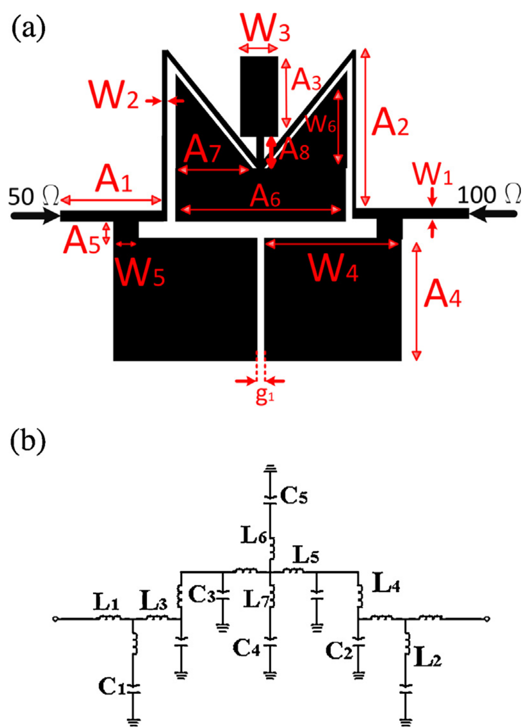

Fig. 1. (a): Layout of the proposed lowpass filter and (b): L-C equivalent circuit.

Formulas of bend are investigated and expressed here [1] and its structure and equivalent circuit are shown in Fig. 4.

$$C = 0.00137h\frac{\sqrt{\varepsilon_{re1}}}{Z_{cl}}\left(1-\frac{W_1}{W_2}\right) \times \left(\frac{\varepsilon_{rel}+0.3}{\varepsilon_{rel}-0.258}\right)\left(\frac{W_1/h+0.264}{W_2/h+0.8}\right)(pF) \quad (3)$$

$$L_1 = \frac{L_{w1}\times L}{L_{w1}\times L_{w2}}, \quad L_2 = \frac{L_{w2}\times L}{L_{w1}\times L_{w2}} \quad (4)$$

$$L_{ni} = Z_{ci}\sqrt{\varepsilon_{rei}/c} \quad (5)$$

$$L = 0.000987h\left(1-\frac{Z_{c1}}{Z_{c2}}\sqrt{\frac{\varepsilon_{re1}}{\varepsilon_{re2}}}\right)(nH) \quad (6)$$

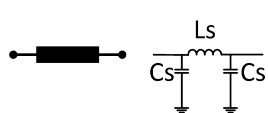

Fig. 2. Layout and equivalent LC circuit of high and low-impedance lossless line.

Fig. 3. Layout and equivalent LC circuit of open-end.

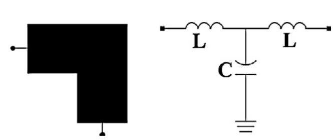

Fig. 4. Layout and equivalent LC circuit of bend.

Table 1
Calculated values for LC equivalent circuit. (Units: C, pF; L, nH).

Parameters	C1	C2	C3	C4	C5	L1
Optimized	0.1	2.1	1.5	0.2	0.1	3.9
Parameters	L2	L3	L4	L5	L6	L7
Optimized	0.3	4.3	0.3	5.3	1.7	4.3

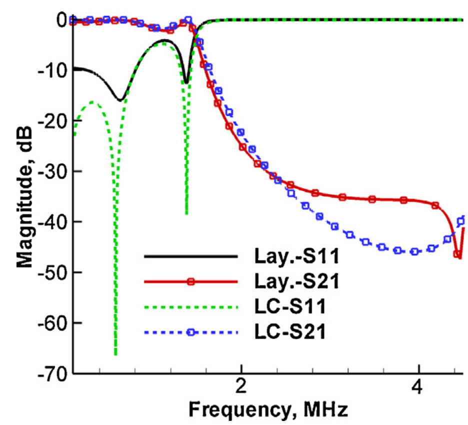

Fig. 5. Frequency responses of layout and LC equivalent circuit of lowpass filter. Lay: Momentum EM simulation response; LC: equivalent circuit response.

The calculated and optimized values for LC equivalent circuit are summarized in Table 1. (Units: C, pF; L, nH).

Fig. 5 shows the frequency response of the proposed lowpass filter and LC equivalent circuit.

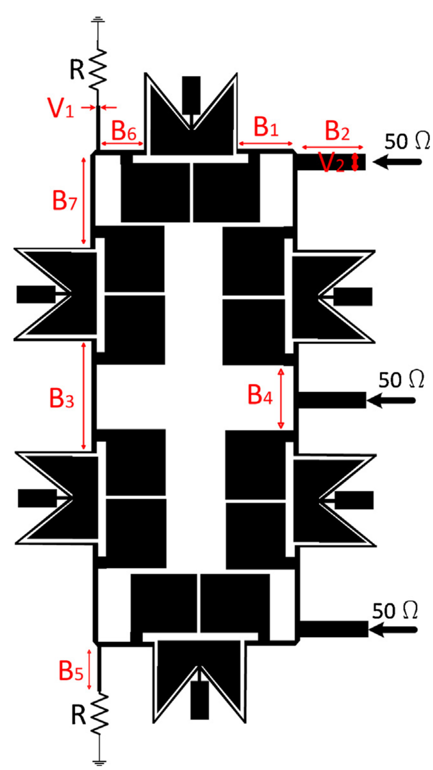

Fig. 6. Layout of the proposed Gysel power divider.