Differential Unequal Power Divider with Bandpass Response

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***Abstract* – In this paper, a differential unequal power divider with bandpass response has been for the first time proposed. With suitable design of the inverters' impedances, power dividing ratio of the differential power divider could be assigned and realized. A differential, filtering 4:1 power divider has been realized and measured. Bandwidth of return loss is 8%. The input return loss is better than 15 dB at the center frequency and in-band isolation is better than 20 dB. Wideband common-mode rejection of 30 dB is also obtained.**

***Index Terms* — Bandpass response, differential, power divider, unequal power dividing.**

1. Introduction

Differential circuits has better immunity against environment noise than their single-ended counterparts. To alleviate insertion loss, equal and unequal differential power divider with good common-mode rejection have been presented for the first time to avoid the use of baluns [1], [2]. An equal-power differential power divider with filter function has also been developed for good stopband rejection [3]. Based on [3], a differential unequal power divider with bandpass characteristic was firstly presented in this paper.

2. Structure and Design Method

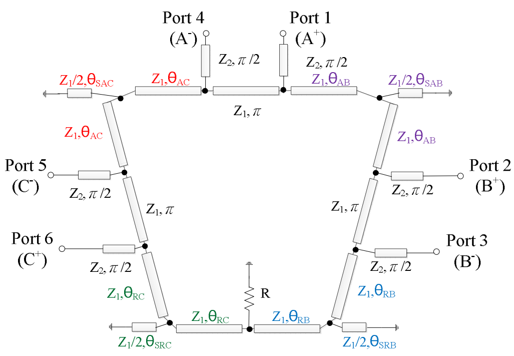


Fig. 1. Structure of the differential unequal power divider with bandpass response.

The proposed differential unequal power divider shown in Fig.1 has three full-wavelength (1λ) resonators and one half-wavelength (λ/2) resonator, and could be derived from its equal-power counterpart [3]. A transmission line with shorted ends and characteristic impedance of Z_1 is utilized to form the resonator. Adjacent resonators are coupled by *K* inverters realized by short-circuited stubs with line impedance of $Z_1/2$. The power divider has three differential ports, denoted Ports A, B, and C. Ports 1 and 4 (2 and 3, 6 and 5) represent the positive and negative single-ended terminals of Port A (B, C), respectively. Each single-ended terminal is tapped on the corresponding 1λ resonator through a λ/4 transformer of impedance Z_2. The tapped points between each pair of positive and negative terminals are λ/2 apart for good common-mode rejection [3]. A lump resistor of resistance *R* is connected at the center of the λ/2 resonator for good isolation.

To have unequal power division, the inverter impedances in [3] should be modified. Let $k = \left| S_{BA}^{dd} / S_{CA}^{dd} \right|$ be the ratio of insertion loss in the differential mode. Let K_{AB} (K_{AC}) denote inverter impedance of the *K* inverter between resonators on which Ports A and B (A and C) are tapped, and K_{RB} (K_{RC}) represent inverter impedance of the *K* inverter between resonators to which the resistor and Port B (and C) are connected. Inverter impedances are calculated by (1) and (2):

$$K_{AB} = kK_{AC} = \frac{kM}{\sqrt{k^2+1}} X_f \tag{1}$$

$$K_{RC} = kK_{RB} = \frac{kM}{\sqrt{k^2+1}} \sqrt{X_f X_h}, \tag{2}$$

where *M* is the coupling coefficient of a second-order bandpass filter and $X_f = \pi Z_1$ ($X_h = \pi Z_1/2$) is the reactance slope of a 1λ (λ/2) resonator. The electrical length θ_{spq} (*pq* denotes *AB*, *AC*, *RB*, or *RC*) of the short-circuited stub used to realize the *K* inverter of impedance K_{pq} could be determined [4]. The electrical length θ_{pq} of the transmission-line segment is then calculated by $\theta_{pq} = 90° - \tan^{-1}(K_{pq}/Z_1)$. Let *Q* be the external quality factor of the second-order bandpass filter. Impedance of the transformer and the resistance *R* for isolation are then derived as [3]

$$R = \frac{Z_2^2}{Z_0} = \frac{2Z_1 Q}{\pi} \tag{3}$$

where $Z_0 = 50\ \Omega$ is the port impedance in this design.

3. Simulation and Measurement

A differential 4:1 ($k = 2$) power divider operating at 2.45 GHz with a fractional bandwidth (FBW) of 10% is designed. For a second-order Chebyshev bandpass filter of in-band ripple = 0.043 dB and FBW = 10%, $M = 0.1327$ and $Q = 8.334$ are obtained. $Z_1 = 60$ is chosen so that $Z_1/2 = 30\ \Omega$ and $Z_2 = 112.84\ \Omega$ are realizable using microstrip line technology. A surface-mounted resistor of R = 255 Ω is used. The electrical lengths are found to be θ_{SAB} = 50°, θ_{SAC} = 26.2°, θ_{SRB} = 36.5°, θ_{SRC} = 18.7°, θ_{AB} = 65°, θ_{AC} = 76.9°, θ_{RB} = 71.8°, θ_{RC} = 80.6°. A RO4003C substrate with dielectric constant of ε_r = 3.55, thickness of h = 20 mil, and loss tangent of tanδ = 0.0028 has been used. Layout of the power divider is shown in Fig. 2 where parameters are (unit = mm): W_1=0.8, W_2=0.18, W_3=1.11, L_1=4.1, L_2=8.54, L_3=5.75, L_4=2.81, L_5=2.0, L_6=18.17, L_7=15.76, L_8=14.18, L_9=14.06, L_{10}=16.68, L_{11}=37.52, L_{12}=4.0, L_{13}=0.46, S_1=0.77.

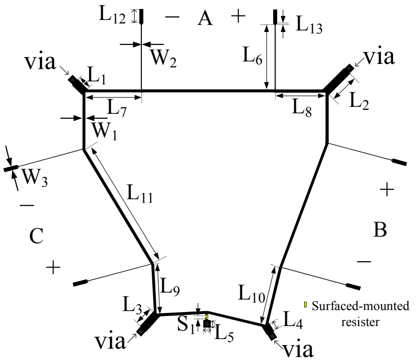
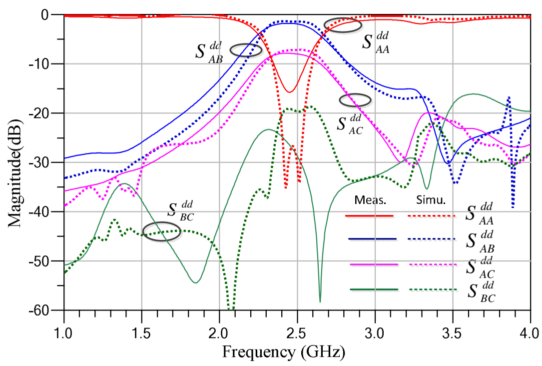
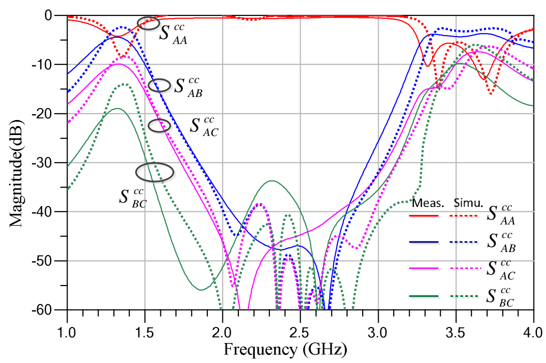


Fig. 2. Layout of the differential 4:1 power divider with bandpass response.



(a)



(b)

Fig.3. Simulated and measured differential-mode and common-mode S parameters. (a) Differential mode. (b) Common mode.

Measured and simulated S parameters of the implemented power divider are compared in Fig. 3. In Fig. 3(a), the measured differential-mode return loss is better than 10 dB from 2.35 GHz to 2.55 GHz corresponding to a fractional bandwidth of 8.2%. The measured and simulated differential-mode insertion losses of $1/S_{AB}^{dd}$ are 1.8 and 1.4 dB, respectively. The discrepancy may be caused by fabrication tolerance. To be more precise, it may be severely influenced by fabrication of the high-impedance λ/4 transformers. The measured and simulated differential-mode insertion losses of $1/S_{AC}^{dd}$ are 7.9 and 7.2 dB, respectively. The measured power dividing ratio is 6.1 dB which is close to the theoretical ratio of 6.02 dB. The in-band amplitude imbalance is within 0.048 dB. The measured differential-mode isolation between Ports B and C is better than 20 dB in the frequency range from 1 GHz to 3.47 GHz.

In Fig. 3(b), the measured common-mode return loss of S_{AA}^{cc} is –0.186 dB. The measured S_{AB}^{cc}, S_{AC}^{cc} and S_{BC}^{cc} are lower than –30 dB from 1.8 GHz to 2.9 GHz. Wideband common-mode rejection is obtained. S parameters of cross-mode conversion was also measured and simulated which are not shown for simplicity. Cross-mode conversion less than –18 dB from 1.5 GHz to 3 GHz are measured.

Table 1. Summary of results

	simulation	measurement
Bandwidth (%)	10	8
Power ratio (dB)	5.9	6.1
Return loss, S_{AA}^{dd} (dB)	>26	>15
Isolation, S_{BC}^{dd} (dB)	>18	>23

4. Conclusion

A differential 4:1 power divider with filtering response has been realized in the paper. Measured results as well as simulated data verify the design. Wideband isolation and common-mode rejection are also obtained.

Acknowledgment

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