A Performance Enhanced Power Divider Structure

Vahdettin Tas[1,2], Abdullah Atalar[1]
[1]Department of Electrical and Electronics Engineering, Bilkent University, Ankara, Turkey
[2]Power Amplifier Technologies Divison, REWIS, Aselsan Inc., Ankara, Turkey
vtas@ee.bilkent.edu.tr, aatalar@bilkent.edu.tr

***Abstract*—We analyze the bandwidth capability of a divider with a series RLC circuit at the isolation arm. Analytical expressions for optimal component values are given. Bandwidth limiting effect of the pad capacitances of the chip resistors is analyzed. These parasitic capacitors are compensated by the proposed structure. Broadband characteristic of the new divider is verified by experimental results.**

Index *Terms*—wideband power divider, isolation resistor parasitics, pad capacitance.

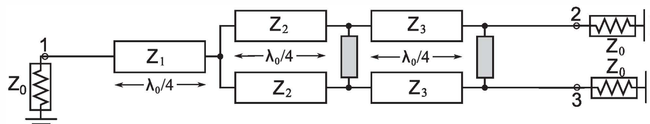

Fig. 1. A symmetrical 2-way power combiner/divider network. White boxes are quarter-wave transmission lines. Gray boxes represent the lossy isolation arms. Possible contents of a gray box: Symmetrical lossless components with isolation resistors in the middle.

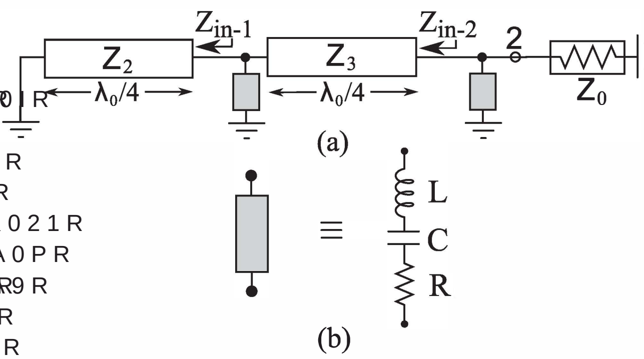

Fig. 2. a) Odd mode equivalent circuit of the divider in Fig 1. b) Possible content of a gray box for wideband operation: Series RLC network.

II. Analysis and Design of the Divider

$$2Z_1Z_2 = 2Z_0^2 \quad (1)$$

$$\frac{Z_2^2\,2Z_0}{4Z_1^2} = Z_0\frac{1+\Gamma_e}{1-\Gamma_e} \quad (2)$$

$$\frac{Z_1}{Z_2} = \sqrt{\frac{1-\delta}{2(1+\delta)}} \approx \frac{1}{\sqrt{2}}\left(\frac{1-\delta/2}{1+\delta/2}\right) \quad (3)$$

978-1-4799-3869-8/14/$31.00 ©2014 IEEE

(G < A 9 R A 1 R Z_1 R . A 1 Z_2 R . F 2 0 R > 0 K > . G 2 1 R

$$\frac{Z_1}{Z_0} = 2^{-1/4}(1-\delta/2)$$

$$\frac{Z_2}{Z_0} = 2^{1/4}(1+\delta/2)$$

' : 2 R B 1 1 @ R B 1 2 R K < L . 9 2 A 0 R K G R B M < A R 9 R 0 R 2

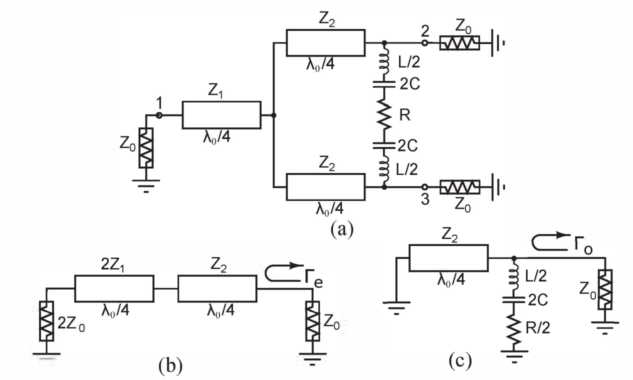

Fig. 3. a) Broadband 2-way divider. b) Even-mode equivalent circuit. c) Odd-mode equivalent circuit.

. A 1 R F 2 G B A I R 2 R A 1 0 R 2 A I 2 F R

$$\frac{1}{\sqrt{LC}} = 2\pi f_0$$

I f_0, M 2 < R @ C B $|\Gamma_o|$ 2 = δ. & B R R 0 . A I R = 2 R M B L R > K 2 R G = R $2Z_0(1 \pm \delta)/(1 \mp \delta)$. ' : 2 R G @ . > B 2 F R G K < A B M R < 1 2 . F A R 1 R G < A I 0 : 2 R 2 G < G 0 I B < @ 2 C R B A 9 2 A G R @ < A M A < I I R 2 G C I 2 B 0 R R I : 2 G R : B F I I 2 1 A R G @ < G < G A 2 B A R 2 6 R A 1 R

$$\frac{R}{Z_0} = 2\frac{1-\delta}{1+\delta} \approx 2(1-2\delta)$$

' B R 0 . > 0 K > . I 2 A R 1 R . A . > P I < 0 M 2 R B > R B M R C C F B . 0 : R < A, R- * R 2 R 1 2 6 A I 2 R R A 1 M < 1 0 I B A 1 < I B 3 $|\Gamma_e|$ R < δ . G R $f_0(1-k) < f < f_0(1+k)$. & < A Z_1 2 R A 1 Z_2 R . F 2 0 R > 0 K > . I 2 1 R K G < A 9 R A 1 R k R < G R A B M C A R . @ 2 ' I 2 R @ R N < @ I < Q 2 R B L 2 F / > A 1 R M < 1 M : 2 R G G K @ 2 I R 2 $|\Gamma_o|$ < δ 0 B A 1 < I < B A R 0 B L 2 I F 2 G R . @ 3 2 R 2 E K 2 F A A 9 . A R 1 0 R > 0 K > R I 2 R

$$\frac{w_0 L}{Z_0} = \frac{(1-k)(b+\sqrt{b^2-4ac})}{ak(2-k)}$$

M : 2 F 2 R

$$a = 1 + t^2\sqrt{2}(1+\delta) \quad , \quad b = 2^{5/4}t(1+\delta/2)$$

$$c = 1 - 4\delta \quad , \quad t = \tan(\pi/2 - k\pi/2)$$

< 9 R G : B M I G 2 R R A 1 M < 1 C I 2 F 3 B F @ B 3 A R 0 2 R R < L < 1 2 F 2 I M 2 2 I A 2 R R F 2 E K 2 A 0 < A G R R I : 2 R . F . @ 2 I $|S_{11}|$, G R $|S_{22}|$, $|S_{32}|$ G I . P 2 R > B I M 2 R R F 2 G 0 R < C 2 1 F R @ 2 2 L 2 R > 9 R R < G R C > B I 3 R R 2 R 2 E K < 0 F 2 @ R C B A L 2 A K R 2 G R 0 : < 2 L I 2 2 R R / . A 1 M < I I . A R 9 2 G R F 2 G G A G R 2 9 1 R R

' : 2 R < @ C > 2 @ 2 A B 3 I R < B 0 A R F 0 K G I R R 5 0 K 1 > K R B I R 2 R C . F . G < B 3 0 R 2 R K @ C 2 B 1 @ C B A 2 L 1 2 A I R 2 G @ . C > 1 R R 0 . C . 0 < I B B R G R B K A B 3 I R 2 G 2 F < 0 . B @ R C B A 0 G A 9 0 A R < 6 0 . A I > 2 P R < L < 1 G 2 F R K 0 K A R 2 R 1 K A R 9 R R M . G R @ C > 2 @ 2 A I 2 1 R . 4 2 0 I I R 2 C R 2 F 3 B F @ < A 9 0 R G R B M R G R 3 R F 2 E K 2 @ A B 1 P R 3 B A . R R G K / G I R M < 2 R R : < 0 = A 2 G R G R @ @ < R 9 R . R 0 : < E 2 R G < G B B R 2 R L 2 @ R B 1 2 : 2 R B @ C B A Z_1 2 A I R G R I R G : B M I G 2 R : B I B 3 R 2 1 R < L < 1 2 F M R G G < 9 I A B 2 R I R 2 B 1 2 F R

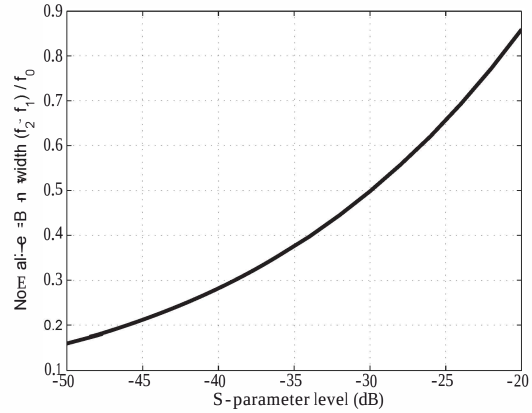

Fig. 4. Achievable bandwidth versus the desired S-parameter level for the divider in Fig. 3. The bandwidth is normalized with the center frequency.

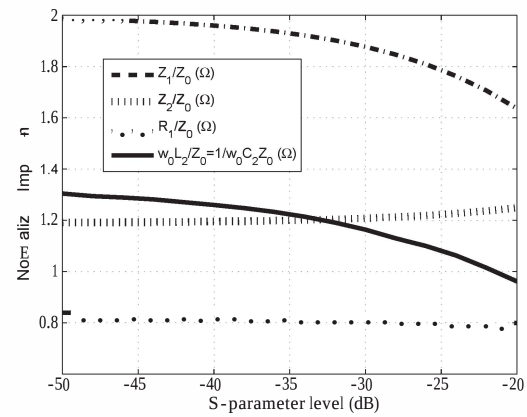

Fig. 5. The component values to achieve the bandwidth ranges expressed in Fig. 4.

. F 2 A R B < A R 2 G R < 0 I K / F 2 R 2 G R . 1 0 R C . 0 < I . A D 0 R 2 R G K < A I R G R C . I I B R 2 9 R F B K M A 1 < R 0 1 : R 9 F . 1 I 2 2 G R A 1 M < C I 2 R 3 B F @ . A 0 2 R B 3 R 2 1 R < L < 1 2 E F R 2 B R A < I G D R R : B K / 2 1 R R A 2 B 1 K R B R F I R < G R C K F C B M G 2 R F R B C B : G 2 R F K 0 K A R 2 9 R R M : 2 F 2 D R G K R A 2 B K K R G < A R G R B F I I 2 F 1 A R G @ < G < G A Z_2 B A R 2 R < A 1 K 0 I B f_1 R < G R @ C > 2 @ 2 M A < I I 2 R R 9 < R @ C 2 1 . A F 0 . 2 R G @ < G < G A Z_3 B A R I : . I . R > G 0 B B R @ C 2 A G : . 2 R G F R G < B 3 R 2 0 R C . 0 < I B R : 2 R A 2 M 0 R B A 6 9 K F B 3 I R 2 A R G B > . I F B @ A R 2 0 I . G R G I B 2 R L 2 A R @ B 1 0 < R F 0 K 2 R A G 2 F > I B B A G R R I R 2 R 2 G < G G I B R F R 1 2 1 R / P G R > . 0 < A I R R 2 @ < C B < A 2 < R 2 4 R 2 0 I < 1 2 G R A R R 2 R L 2 A R @ B 1 2 : 2 A R 2 I M B < F A = R < R G B > . I F B @ A B R G . I < @ < B 2 R 2 A 1 R A 0 2 R I : 2 R A 1 M < B 3 I R 2 < R A C K F 2 R K > F B A G R G R 2 > . G R R 2 R K I C K I R F 2 I K > F B A G A G 1 R G B > . I < B G 2 R R F I 2 9 F B 2 3 R F 2 2 1 . B > @ R M G R I : 2 < R A C K F I . R A G @ < G < G A Z_4 B R R 2 R > < @ < A . A 2 1 P R B 3 G R I : 2 G F 2 2 R G K M > G 2 R R F 2 G 2 A < I A 2 R R N I 2 A 1 2 1 R B 2 3 F R G G R A R C . C 2 F R

R + # % ' R % & (' & R

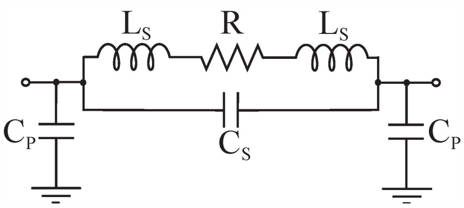

Fig. 6. Equivalent circuit of a chip resistor.

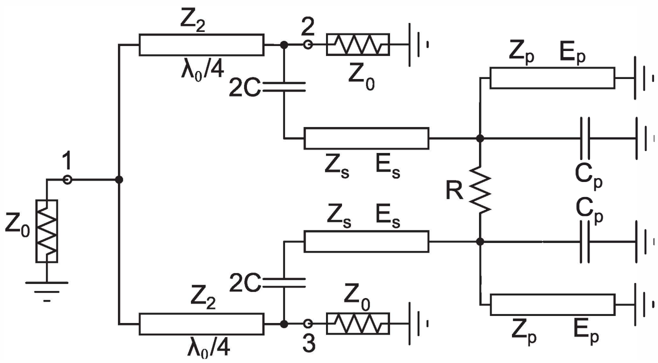

Fig. 7. Schematic diagram of a 2-way divider with symmetric transmission lines in the isolation arm to enhance the band and to compensate the parasitics of the resistor.

1 R< G B > . I A BFA2 R K > F B A G R G A R 2 / R A 1 B 3 R Q R
< 9 G R A 1 R G : B M : R @ 2 . G K F 2 G R % 2 G K F B A G R > K 2 G R
. F 2 / R I J 2 F . R R 1 R A R / . A 1 M < 1 B 3 R Q R A R
. R M < 1 2 . F A R I R 2 < R G B > . < G B R A 2 F 1 R R N I F < A G 2 F I < B A R > B G G R
< G B M 2 : F . A R 1 R A 1 I R 2 . R @ C > < I K 1 2 R @ 2 < I G M @ 2 1 A 2 R R
B K I C K B F < G B M 2 : F . A R ? 1 R

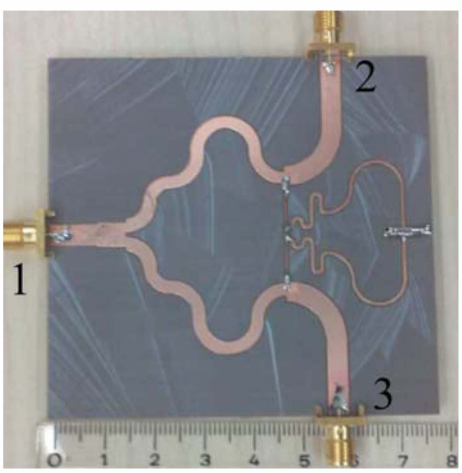

Fig. 8. Implemented 2-way power divider (Fig. 7).

) R" (& " &R

R G 2 F $ 2 G R < F 0 < K R R > < Q 2 R 2 R G B > . I F @ B A R R
* < > = < A G B A R 1 B R @ C F B L 2 R A 1 M < 1 # I : F R G < G < K A R I R
0 . C . 0 < I . A B 2 R G R G B > . F 2 G A R G 4 2 F I G R 2 F 3 B F @ . A 2 R
A 2 9 . I < L' 2 > 2 R 2 0 < I 2 R < @ < A . G 2 < 1 A 2 R M C B M 2 F R < 1 2 F R

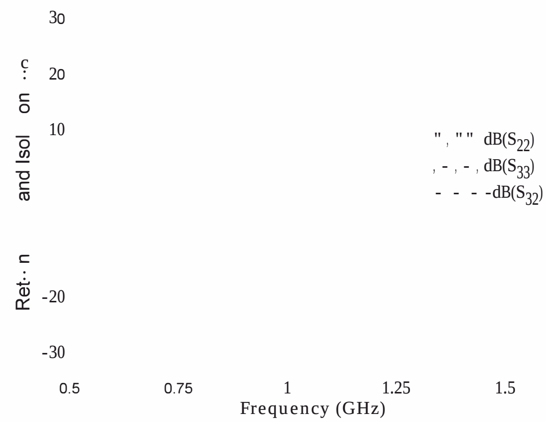

Fig. 9. Measured return loss and isolation characteristic of the divider in Fig. 8.

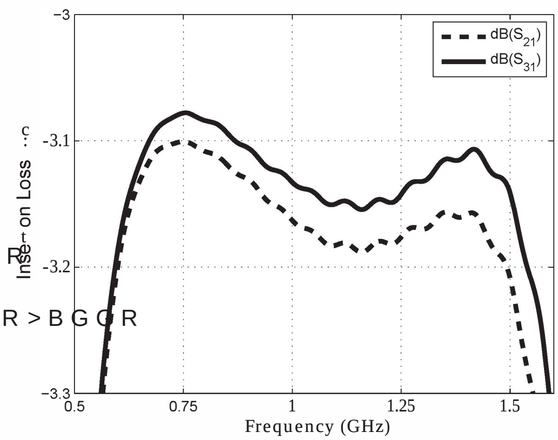

Fig. 10. Measured insertion loss characteristic of the divider in Fig. 8.

G I F K 0 I K A F 2 M R < 1 F 2 R G C B B A 3 G R 2 1 R < L < 1 < 2 G F R R B @ < 3 G B < F A P R
M < 1 / 2 A R 1 . R C C > < 0 . I < B A G R

REFERENCES

[1] E. Wilkinson, "An N-way hybrid power divider," IRE Trans. on Microwave Theory and Techniques, vol. 8, no. 1, pp. 116–118, 1960.

[2] S. Cohn, "A class of broadband three-port TEM-mode hybrids," IEEE Trans. on Microwave Theory and Techniques, vol. 19, no. 2, pp. 110–116, Feb. 1968.

[3] H. Oraizi and A.-R. Sharifi, "Design and optimization of broadband asymmetrical multisection Wilkinson power divider," IEEE Trans. on Microwave Theory and Techniques, vol. 54, no. 5, pp. 2220–2231, May 2006.

[4] J-c. Chieh and A.-V. Pham, "Development of a broadband Wilkinson power combiner on liquid crystal polymer," in Microwave Conference, 2009. APMC 2009. Asia Pacific, 2009, pp. 2068–2071.

[5] T. Kawai, 1. Yamasaki, Y Kokubo, and I. Ohta, "A design method of dual-frequency Wilkinson power divider," in Asia-Pacific Microwave Conference, 2006, pp. 913–916.

[6] X. Wang and I. Sakagami, "Generalized dual-frequency Wilkinson power dividers with a series/parallel rlc circuit," in Proc. of 2011 IEEE MTT-S International, 2011, pp. 1–4.

978-1-4799-3869-8/14/$31.00 ®2014 IEEE

[7] Y Wu, Y Liu, and S. Li, "Unequal dual-frequency Wilkinson power divider including series resistor-inductor-capacitor isolation structure," IET Microwaves, Antennas Propagation, vol. 3, no. 7, pp. 1079–1085, 2009.

[8] J.-c. Kao, Z.-M. Tsai, K.-Y Lin, and H. Wang, "A modified Wilkinson power divider with isolation bandwidth improvement," IEEE Trans. on Microwave Theory and , vol. 60, no. 9, pp. 2768–2780, 2012.

[9] S. B. Cohn, "Optimum design of stepped transmission-line transformers," IRE Transactions on Microwave Theory and Techniques, vol. 3, no. 3, pp. 16–20, 1955.

978-1-4799-3869-8/14/$31.00 ®2014 IEEE