Dual-band Wilkinson Power Divider and Its Miniaturization Using Coupled Line Sections

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***Abstract* — In this paper, a generalized two-way dual-band Wilkinson power divider (WPD) with four open-circuited stubs is discussed. A coupled line section is introduced to reduce circuit size based on the assumption of linear phase characteristics. A normal size WPD and its miniaturized WPD were fabricated. Experimental results were in good agreement with predicted ones.**

***Index Terms* — Dual-band, Wilkinson power divider, open-circuited stub, coupled-line section, miniaturization.**

I. Introduction

Dual-band Wilkinson power dividers (WPDs) using open/short circuited stubs were presented in [1]-[3]. A two-way two-section dual-band WPD with open-circuited stubs was presented in [4] together with its arbitrary power division responses. In this paper, a generalized planar two-way dual-band WPD which consists of four open-circuited stubs, two transmission lines and an absorption resistor is discussed. The frequency ratio of the lower and upper bands is around three. Coupled line sections are introduced to miniaturize single transmission lines and open-circuited stubs based on assumptions of linear phase characteristics and equal phase velocities of the even- and odd-modes.

II. Design Equations

Fig. 1 shows a generalized dual-band Wilkinson power divider, where Z_b, Z_c, Z_{bopen} and Z_{copen} are characteristic impedances, θ is the electrical length and R stands for an absorption resistor. R_a, R_b and R_c are terminal loads.

Input signals applied to the port 1 are divided and delivered to ports 2 and 3 with an arbitrary power dividing ratio K^2 at lower frequency f_1 and upper frequency f_2. θ_1 and θ_2 are the electrical length at f_1, and f_2, respectively. The design equations can be summarized as follows:

$$\theta_1 = \frac{\pi}{1 + f_2/f_1} \tag{1}$$

$$Z_b = \frac{\sqrt{(1+K^2)R_aR_b}}{\sin\theta} \tag{2}$$

$$Z_c = \frac{\sqrt{\frac{1+K^2}{K^2}R_aR_c}}{\sin\theta} \tag{3}$$

$$Z_{bopen} = \frac{\sin\theta}{\cos^2\theta}\sqrt{(1+K^2)R_aR_b} \tag{4}$$

$$Z_{copen} = \frac{\sin\theta}{\cos^2\theta}\sqrt{\frac{1+K^2}{K^2}R_aR_c} \tag{5}$$

When $R_a = R_b = 50\ \Omega$ and $R_c = 25\ \Omega$, the design parameters can be determined using (1)-(5) as shown in Fig. 2.

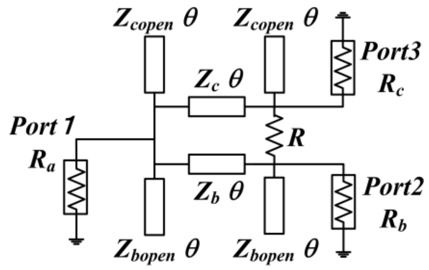


Fig. 1. An arbitrary power division Wilkinson power divider with open-circuited stubs.

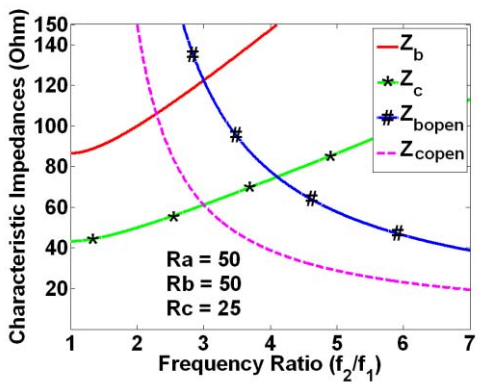


Fig. 2. Design chart for characteristic impedances.

III. Miniaturization

As shown in Fig. 3, coupled line sections are used to miniaturize the divider shown in Fig. 1. $Z^{ev}{}_i$, $Z^{ev}{}_{copen}$ and $Z^{od}{}_i$, $Z^{od}{}_{copen}$ ($i = b, c$) are the even- and odd-mode characteristic impedances. Assuming equal phase velocities of the even- and odd-modes, the phase shift of a coupled line section can be given by

$$\varphi_N = \arctan(\tan\theta_C \sqrt{\frac{1-C}{1+C}}) \quad (6)$$

where C and θ_C are coupling coefficient and electrical length of the coupled line length, respectively.

The total phase φ_{tot} that corresponds to that of single transmission lines of Z_b and Z_c is given by

$$\varphi_{tot} = 2\varphi_N + 2\theta_S \quad (7)$$

For dual-band operation, phase characteristics of coupled line section have been discussed in [5]. In this paper, φ_{tot} is adjusted to be 112.5° at f_r = 1.25f_0, where average frequency $f_0 = (f_1 + f_2)/2$.

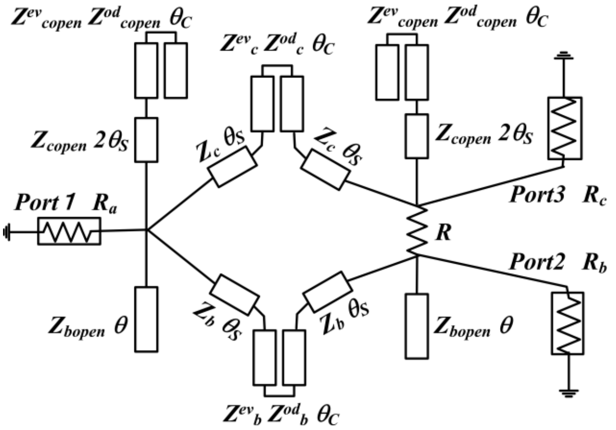
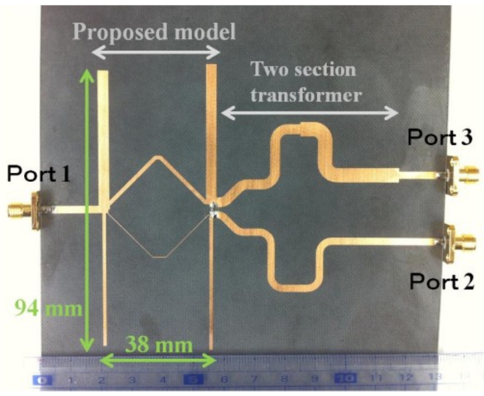


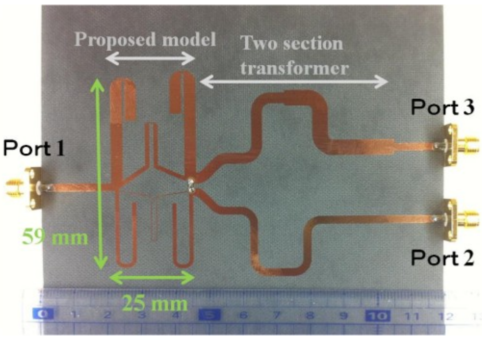
Fig. 3. Miniaturization using coupled line sections.

IV. Experimental Results

The circuit topologies shown in Fig. 1 and 3 were fabricated on a Roger RT/5880 substrate as shown in Fig. 4 (a) and (b). Because of $Z_{bopen} > Z_{copen}$ from Fig. 2, meandering lines are applied to the open-circuited stubs of Z_{bopen}. The data for the substrate are: ε_r = 2.2, tanδ = 0.0009, thickness of dielectric layer = 0.787 mm and conductor thickness = 0.018 mm. Design conditions are: $R_a = R_b$ = 50 Ω and R_c = 25 Ω, f_1 = 0.5 GHz and f_2 = 2 GHz. The couplings of the four coupled line sections were set to be 20 dB. The design parameters for two circuits are shown in Table I and II, respectively. In Fig. 4 (a) and (b), the circuit areas are 94mm×38mm and 59mm×25mm, respectively, and the ratio of size-reduction was 41%.



(a) Normal size



(b) Miniaturization

Fig. 4. Photos of the fabricated Wilkinson power dividers.

TABLE I
Line impedances, line width and line length of the proposed divider (normal size).

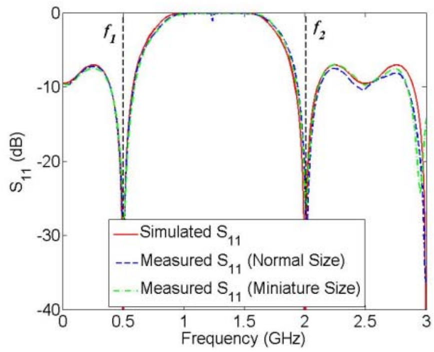
Defination	Characteristic impedance (Ω)	Line width (mm)	Line length (mm)
Z_b	147.30	0.23	46.19
Z_c	73.67	1.26	44.62
Z_{bopen}	77.77	1.14	44.75
Z_{copen}	38.89	3.44	43.29
Z_{st1}	40.59	3.25	43.37
Z_{st2}	30.80	4.71	42.87

TABLE II
Line impedances, line width and line length of the proposed divider (miniature size).

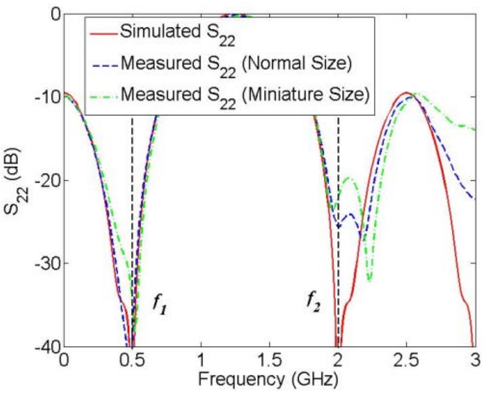
Defination	Characteristic impedance (Ω)	Line width (mm)	Line length (mm)	Spacing (mm)
$Z^{ev}{}_b$	162.85	0.21	13.87	1.36
$Z^{od}{}_b$	133.24			
$Z^{ev}{}_c$	81.45	1.24	13.47	1.21
$Z^{od}{}_c$	66.64			
$Z^{ev}{}_{copen}$	42.99	3.37	13.08	0.82
$Z^{od}{}_{copen}$	35.18			
Z_b	147.30	0.23	10.27	-
Z_c	73.67	1.26	9.91	-
Z_{bopen}	77.77	1.14	44.75	-
Z_{copen}	38.89	3.45	19.23	-

θ_C = 33.86° and θ_S = 25° at f_r = 1.25f_0. $f_0 = (f_1 + f_2)/2$ = 1.25 GHz.

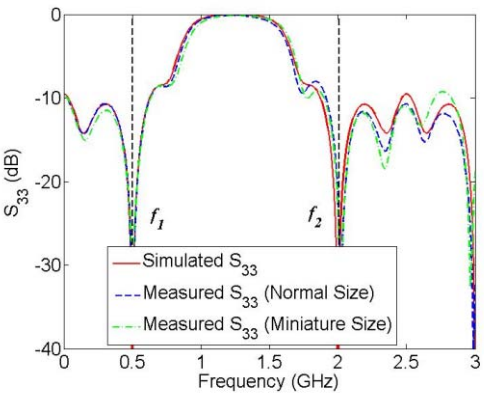
Schematic simulation in ADS 2008U2 was applied for the two circuits. Figs. 5 give the simulated and measured performance for the two circuits shown in Fig. 4 (a) and (b).



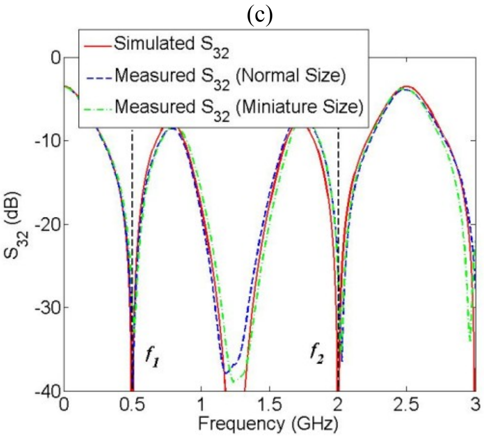
(a)



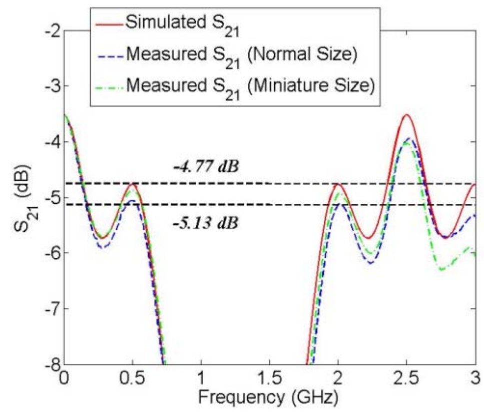
(b)



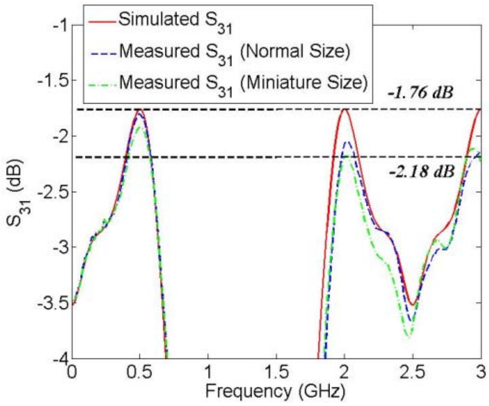
(c)



(d)



(e)



(f)

Fig. 5. Experimental results for the proposed and miniaturized circuits.

VII. Conclusion

A generalized dual-band Wilkinson power divider with open-circuited stubs and a size-reduction technique using a coupled line section have been discussed.

The ratio of size reduction of an experimental divider was over 50%. Good agreement between simulation and experiment results were achieved.

Coupled lines at open circuited stubs will be discussed in the near future.

Acknowledgement

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