Letters

Comments on “A Symmetrical Four-Port Microstrip Coupler for Crossover Application”

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In the above paper [1], the authors demonstrate a four-port coupler for crossover application. In their eigenmode model analysis, the entire circuit is decomposed into tapers and two rings with four external arms. In formulation, the eigenadmittance of the inner substructure is taken account as the load of that of the outer one. A cascade of P short sections is then used to approximate the taper and incorporated into the model of the composite structure by successively applying the input admittance formula of a loaded transmission line. Finally, one prototype circuit solution obtained by an optimization process is demonstrated.

In this letter, the transmission line theory is applied to the circuit analysis. It is found that the circuit structure is so versatile for the crossover application that infinite numbers of solutions can be simply obtained by solving two simultaneous equations. In addition, the tapers for input/output matching can be saved, leading not only to circuit area reduction, but also to formulation simplification. A microstrip coupler is fabricated and measured for confirmation.

Fig. 1 shows the crossover coupler in [1]. The characteristic impedances of the inner and outer rings are Z_3 and Z_1, and their circumferences are $4\theta_3$ and $8\theta_1$, respectively. The counterparts of the sections connecting the two rings are Z_2 and θ_2. In analysis, both PP' and QQ' planes can be either an electric or a magnetic wall since the whole structure possesses bisymmetry. Four reflection coefficients can be readily derived and all the S-parameters can be formulated [2]. These reflection coefficients are the eigenvalues of the eigenadmittances of the composite structure in [1]. Note that two of the four coefficients are identical since the two reduced structures with one electric and one magnetic wall have the same input admittances. This reflects the fact that the four-port circuit supports three instead of four eigenmodes. After some algebraic manipulation, on the basis of [1, eq. (1)], the following two simultaneous equations can be used to determine the six structure parameters

$$R = 2t_2 s_3 \tag{1}$$

$$2z_2(Rt_3+2t_2)(z_1^2t_1^2-2t_1^2+2) = z_1t_1(Rt_2t_3-2)(z_1^2t_1^2+4) \tag{2}$$

where $R = Z_3/Z_2$, $z_i = Z_i/Z_o$ $(i = 1, 2,$ and $3)$ denotes the characteristic impedances of the θ_i sections normalized with respect to the termination impedance Z_o (50 Ω), $t_i = \tan\theta_i$, and $s_3 = \tan(\theta_3/2)$.

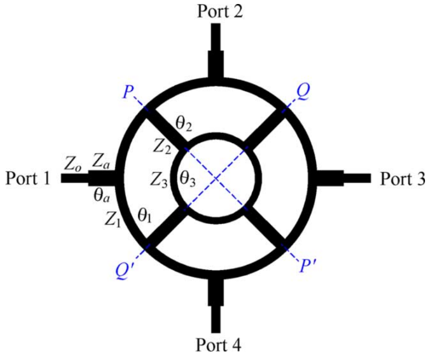

Fig. 1. Crossover coupler in [1].

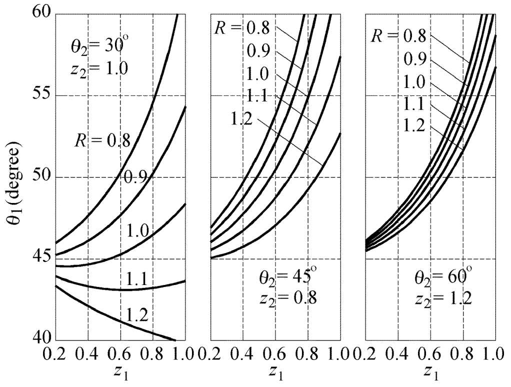

Fig. 2. Some solutions in term of θ_1 versus z_1 for various R, θ_2, and z_2.

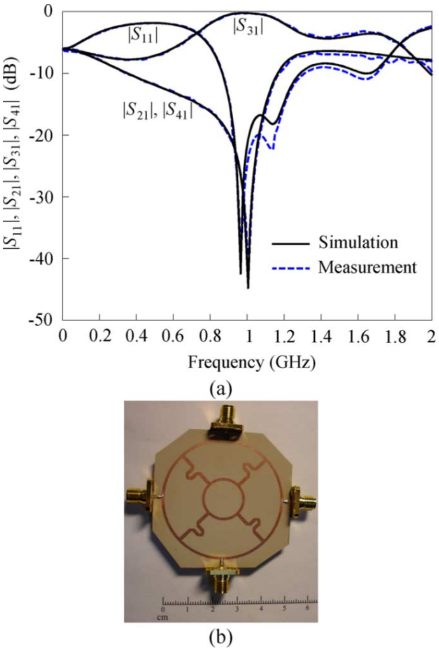

Fig. 3. (a) Simulation and measured results of the coupler. (b) Photograph of the fabricated circuit. Geometric parameters: $z_1 = 1$, $z_2 = 0.88$, $z_3 = 1$, $\theta_1 = 59.21°$, $\theta_2 = 57.35°$, $\theta_3 = 40°$, and $\theta_a = 0$.

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Here, θ_i denotes electric length of the corresponding section at the design frequency.

Fig. 2 plots some solutions in a form of variation of θ_1 versus change of z_1, given $\theta_2 = 30^\circ$ and $z_2 = 1.0$, $\theta_2 = 45^\circ$ and $z_2 = 0.8$, and $\theta_2 = 60^\circ$ and $z_2 = 1.2$. In each case, five curves with $R = 0.8, 0.9, \ldots, 1.2$ are presented. Note that θ_3 can be simply determined by (1) once θ_2 and R are known. As shown in Fig. 2, all θ_1 values decrease as R is increased. When $\theta_2 = 45^\circ$ and 60°, θ_1 increases when z_1 is increased.

For each of the three cases shown above, we have validated the solutions sampled at $z_1 = 0.3$, and 0.8 and $R = 0.8$ and 1.2 by a circuit simulator. Fig. 3(a) compares the simulation and measured results of a fabricated circuit designed at $f_o = 1$ GHz. The substrate has a relative constant $\varepsilon_r = 10.2$ and thickness $h = 1.27$ mm. The software package IE3D [3] is used for simulation. The measured $|S_{11}|$, $|S_{21}| = |S_{41}|$, and $|S_{31}|$ are -25, -40, and -0.1 dB, respectively. Based on the definition in [1], the experimental bandwidths of $|S_{11}|$, $|S_{21}|$, and $|S_{31}|$ are 22%, 18% and 18%, respectively. Good agreement between simulation and measured results can be observed. Fig. 3(b) shows a photograph of the experimental circuit. Note that the fabricated circuit has $\theta_a = 0$.

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