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Research Article

Design of Coupled Line Based Wide Band Branch Line Coupler

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Abstract: This research work discusses a design of a coupled line based wide band branch line coupler. The coupler gives 3 dB coupling and achieves a bandwidth of 25 percent at the frequency of 2 GHz. The proposed design gives a size reduction up to 81 percent of the 3 dB conventional broad band microstrip branch line coupler.

Key words: Coupled Line, Bandwidth, Size Reduction

1. INTRODUCTION

One of the important components used in the microwave integrated circuits and millimeter wave integrated circuits is a directional coupler [1]. For usage with balanced type components such as amplifiers and mixers, the branch line couplers with equal power split are recommended. However, these have the issue of narrower bandwidth. The issue of narrow bandwidth can however be reduced by using additional sections in the coupler [2-4], e.g., an additional branch line coupler, quarters wavelength lines or matching circuits of L type. One of the disadvantages associated with branch line couplers and wide band branch line couplers is their larger size as far as printed circuit boards are concerned. Lately, various methodologies have been devised for size reduction of branch line couplers [5-9]. In the under-hand research work, a coupled line-based branch line coupler has been designed which offers increased bandwidth up to an extent of 25 percent. The said functionality has been achieved with addition of a matching circuit along with the coupled lines. The performance comparison of proposed coupler with the conventional one with dual quarter wavelength lines in each port has been depicted in Fig. 1.

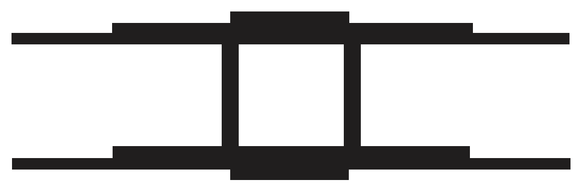

Fig. 1. Wide band conventional branch line coupler with dual quarter wavelength lines in each port

2. THEORETICAL BACKGROUND

Figure 1 depicts the conventional branch line coupler with dual quarter wavelength lines in each port. Theis helps in achieving increased bandwidth. The introduced quarter wavelength lines may be further divided into two transmission lines with electrical lengths of θ_0 and $90° - \theta_0$. Same is depicted in Fig. 2.

The transmission line with electrical length $\theta' = 90° - \theta_0$ may further be replaced with dual transmission lines each with electrical length θ_1 and a characteristic impedance Z_1 which is connected to the coupled line having an electrical

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length of θ_2, an even impedance of Z_e and an odd impedance Z_o. Same has been shown in Fig. 3.

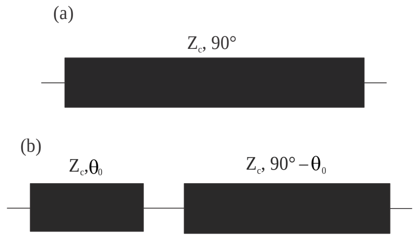

Fig. 2. (a) Quarters wavelength (b) Division of quarters wavelength line into two parts

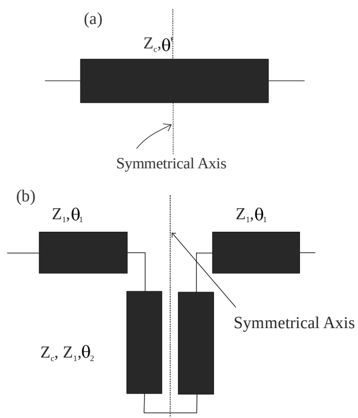

Fig. 3. (a). Quarter wavelength transmission line (b) Equivalent circuit (Proposed)

After application of even and odd mode analysis to the proposed design equivalent circuit as depicted in Fig. 3(b), the design equations may be written as:

$$MNt_2 + Mt_1 + Nt_1t_2t_3 = 1 \quad (1)$$

$$t_2 + Kt_1 + Mt_1t_2t_3 = KMt_3 \quad (2)$$

The variables used in Eq. 1,2 are described below:

$$t_1 = \tan\theta_1$$
$$t_2 = \tan\theta_2$$
$$t_3 = \frac{\tan\theta'}{2}$$
$$M = \frac{Z_c}{Z_1}$$
$$N = \frac{Z_1}{Z_e}$$
$$K = \frac{Z_1}{Z_o}$$

The values of θ_1 and θ_2 may be easily calculated from Eq. 1 and 2 provided the values of θ_c, M, N, and K are known. In a 3 dB branch line coupler, the characteristic impedance of coupled and through branches are chosen to be 50Ω and 30Ω, respectively. Therefore, following may be chosen:

$$\theta_c = 0^o$$
$$M = \frac{35}{Z_1}$$
$$M = \frac{50}{Z_1}$$

3. RESULTS AND DISCUSSION

This section deals with two types of wide band branch line couplers. The substrate used is Rogers RT Duroid 2870 with dielectric constant ε_r = 2.33 and thickness = 0.254 mm. The design and simulations have been carried out in Advanced Design System Electromagnetic Simulator.

Table 1 depicts the values of characteristic impedances and electrical lengths for the wide band branch line coupler shown in Fig. 4 with θ_1 = 0° for equivalent circuits of quarter transformers in matching circuits.

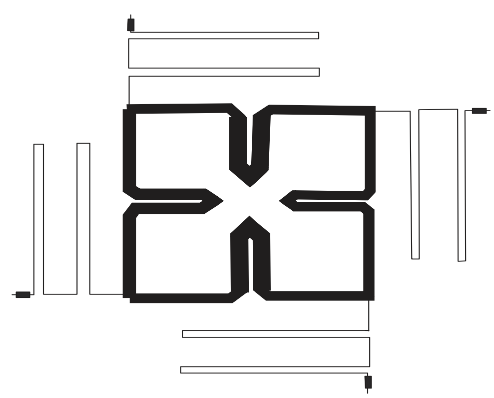

Fig. 4. The proposed wide band branch line coupler

Likewise Fig. 5 depicts the scattering parameters of branch line couplers shown in Fig.1 and Fig. 4. It may be observed that both the configurations exhibit same performance. The size comparisons are elaborated in Table 2.

It is evident from the figures depicted that the designed wide band branch line coupler has an 81 percent reduced size in comparison to the conventional branch line coupler which has dual quarters wavelength transmission lines in each port.

Table 1. Characteristic impedances & electrical lengths of proposed branch line coupler

Zc (Ω)	Zc (Ω)	Zc (Ω)	Zc (Ω)	θ_0 (°)	θ_1 (°)	θ_2 (°)	S (mm)
50	52.5	44.6	59.2	-	24.5	17.04	0.2
35	36.9	43.2	56.9	-	24.5	17.04	0.2
69.7	-	71.3	99.4	8.5	0	45.8	0.23
73.6	-	75.2	105.7	8.5	0	45.8	0.23

Table 2. Size comparisons

Branch Line Coupler	Size (mm²)
Figure 1	[26 + 2 × 27 + 2 × 27] × 26 = 3484
Figure 4	[2 × 7.1 + 0.2 + 4 × (0.23 + 2.5)] × [2 × 7.1 + 0.2 + 4 × (0.23 + 2.5)] = 641.1

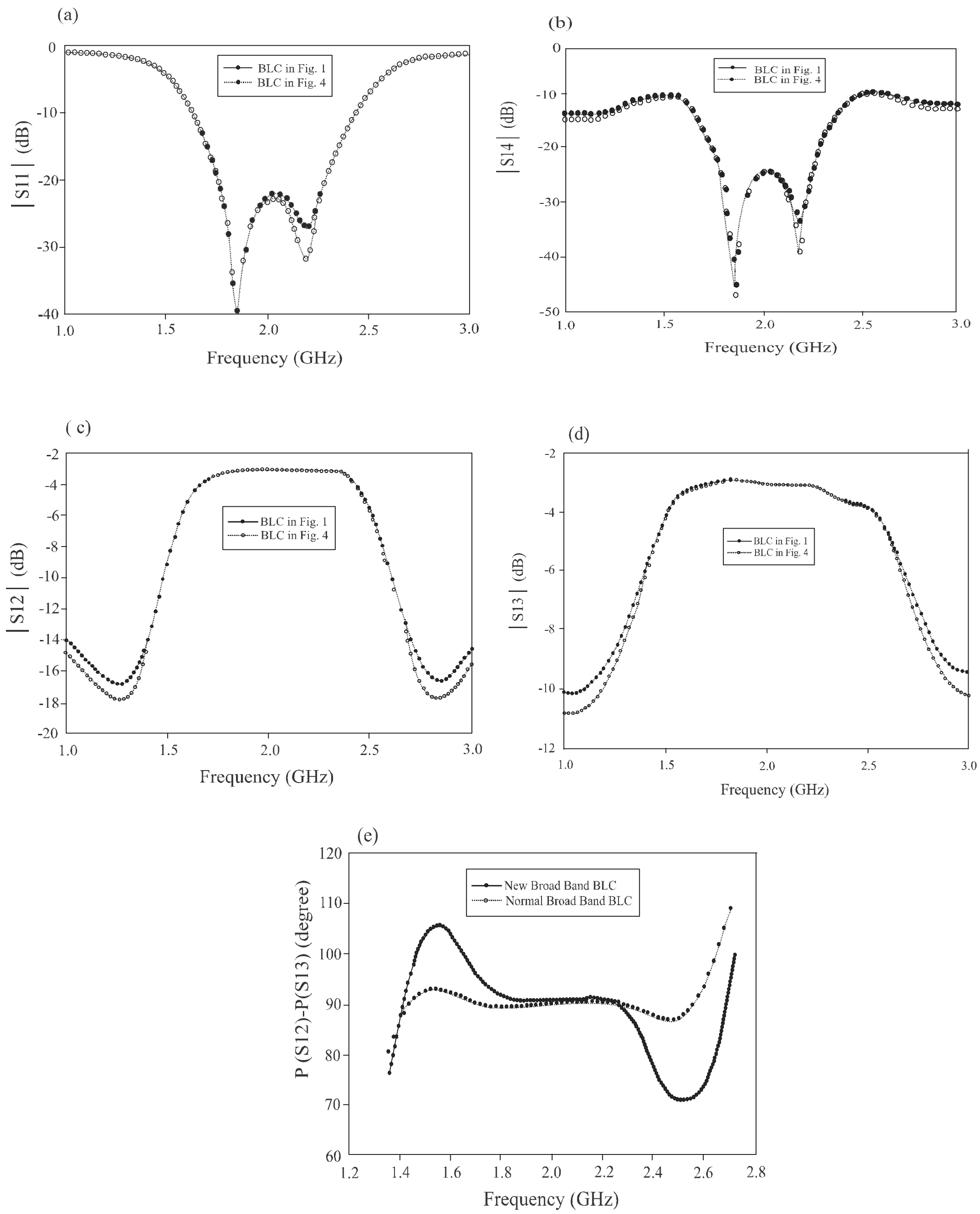

Fig. 5. (a) Reflection at port 1, (b) Isolation between port 1 & port 4, (c) Through port, (d) Coupling port and (e) Phase difference between through and coupling ports

4. CONCLUSION

The research work has exhibited design of a wide band branch line coupler with 81 percent reduced size in comparison to the conventional branch line coupler which has dual quarter wavelength lines in each port. Moreover, the performance parameters have been found to be same in both cases.

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