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Modified Double Box Branch-Line Coupler with Reduction Size by Embedding Double Stub

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Abstract – **In This paper to reduction size and increase bandwidth of the proposed double box broadband branch line coupler utilized from π-shape open stub line. The size decreasing of the structure is depending on the replacement of branched transmission by ordinary transmission lines. Small and easy fabrication of microstrip layout topology for the hybrid have been designed and fabricated relying on a low cost dielectric material, the well-known FR4.**

I. INTRODUCTION

3-dB branchline coupler is an important component widely applied in microwave circuit design. They typically use resonant quarter-wave length transmission line elements as their circuit building blocks. Example implementations are branch-line couplers, Lange couplers, and coupled-line couplers [1]–[3]. However, the dimensions of those hybrids are too large to be realized on monolithic microwave integrated circuits (MMIC). Therefore, in terms of application where size reduction is required, lumped or semi-lumped element devices requiring only a small area are very attractive [4]–[6]. Hitherto, many techniques and approaches have been presented and developed to miniaturize quadrature hybrid coupler in [7] - [19]. The miniaturization procedure has accomplished utilizing shunt lumped capacitors with short high-impedance transmission lines, two-step stubs, high and low impedance open stubs, stepped impedance stub lines, artificial transmission line, distributed capacitor inside the area of coupler, planner transformer coupling method, discontinuous microstrip lines for quadrature hybrid coupler. Also, several miniaturization techniques have been presented for coupler in [11], [13] – [14], [20], where high and low impedance resonator cells, heptagonal coupler and photonic band gap cells, shunt stub based transmission line, meander curves, multiple open stubs, low impedance section are used method to shrink the size of the coupler. Many of them meet the performance requirements while miniaturization was their main consideration. Though, performance requirements depend on application. In this paper, by embedding two open stub on conventional quarter wavelength line, moreover reduces size of line causes to increase branch line coupler in branch line coupler. Only engross small space, but also reveal good circuit performances compared with that of the conventional branch-line type, and it can be used as an element of phase array feed an array antenna and also other MMIC structure. Good agreements between the results of the conventional and proposed branch-line coupler are experiential.

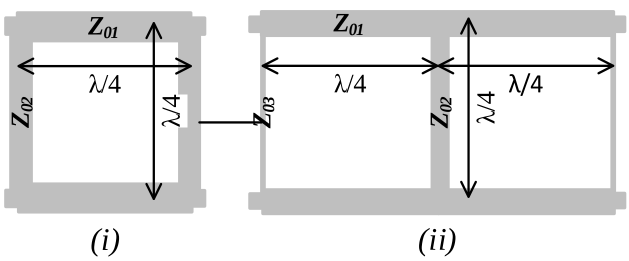
II. BRANCH LINE COUPLER

As illustrated in Fig. 1(a (i)), the branch-line coupler which is known to have a narrow-band characteristic is presented. To enhance the bandwidth, a double-box branch line coupler as a quadrature hybrid circuit is used (Fig. 1a (ii)). However, it requires a large circuit area. The stub line is a favorite method to reduce the size of transmission-line circuits. A transmission line and its L-shaped equivalent circuit are shown in Fig. 2 (b, c), and the design equations can be defined as follows [8]:

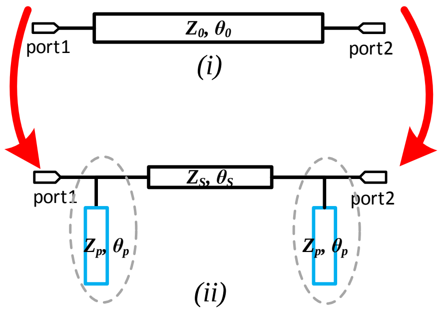
$$\frac{\tan\theta_p}{Z_p} = \frac{\cos\theta_s - \cos\theta_0}{Z_0 \sin\theta_s} \quad (1),$$

$$Z_s = \frac{Z_0 \sin\theta_0}{\sin\theta_s} \quad (2)$$

Where $0 \le \theta_S \le \theta_0 \le 90°$.A transmission line with the characteristic impedance Z_0 and electrical length θ_0 as a unit line section is demonstrated in Fig. 1(b, c (i)), and its π-equivalent circuit model is presented in Fig. 1(b, c (ii)). Each open stub is then subbed by a plicate open stub with equal characteristic impedance Z_P and total electrical length θ_P to reduce the size of the circuit as shown in Fig. 1(b, c (ii)). Finally, a compact structure of the transmission line is obtained by using its balanced π-equivalent with quasi L-equivalent stubs and is called π -shaped equivalent as shown in Fig. 2(a). The simulation results shows that this structure has acceptable frequency response within the operating bandwidth with attention to size reduction.



(a)



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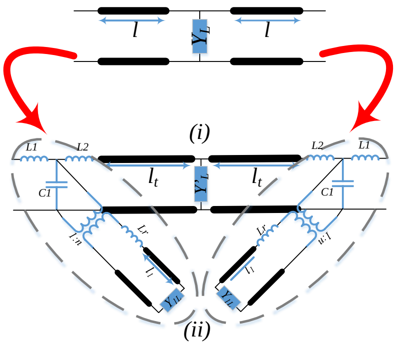
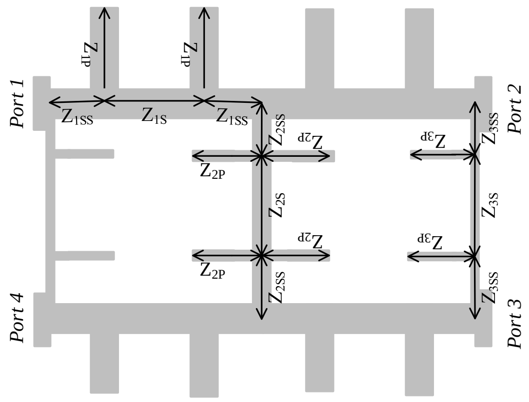
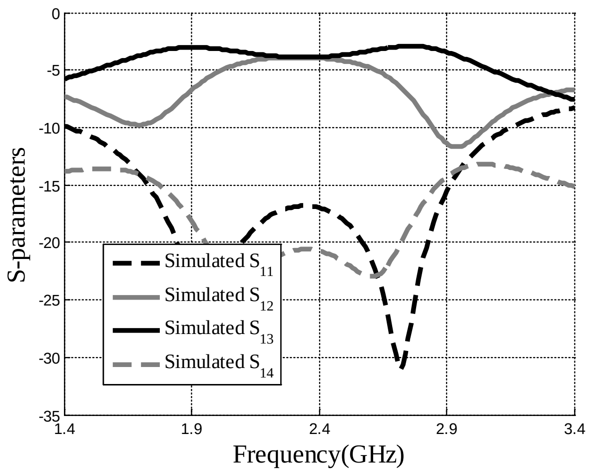


(c)

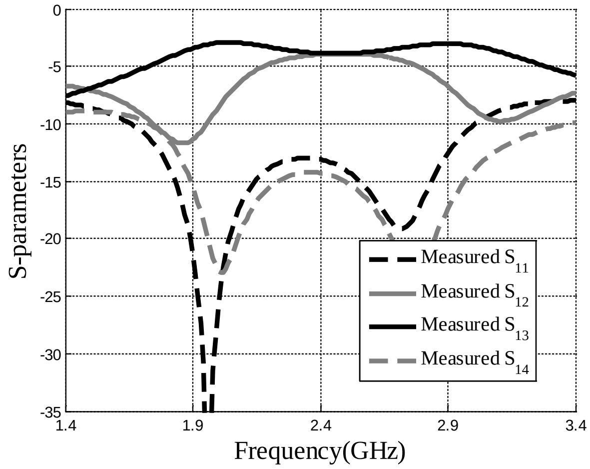
Fig. 1. (a (i)) Formal 90° branch-line coupler, (a (ii)) formal double box broadband 90° branch-line coupler. (b, c (i)) A conventional transmission line, (b, c (ii))



(a)



(b)



(c)

Fig. 2. (a)The proposed broadband branch-line coupler with L-shaped equivalent structure of the conventional transmission line. (b) Magnitude of Simulated scattering parameters (c) Magnitude of measured scattering parameters

The proposed circuit is represented in Fig. 2 and each formal transmission line has been replaced by an L-shaped equivalent structure. Impedance and electrical length of each transmission line lettered in Fig. 4(a) are as follows: Z_{1S}=74Ω, θ_{1S}=36°, Z_{1P}=70Ω, θ_{1P}=57°, Z_1'=74Ω, θ_1'=9°, Z_{2S}=102.5Ω, θ_{2S}=33°, Z_{2P}=115.5Ω, θ_{2P}=32.5°, Z_{3S}=137Ω, θ_{3S}=32°, Z_{3P}=137Ω, θ_{3P}=35°,

The simulation results of the scattering parameters for the proposed branch-line coupler are indicated in Fig. 4(b) and phase difference are shown in Fig. 4(c). At the designed frequency of 2.4 GHz, the insertion loss is -3.25±0.1 dB, the isolation is about -20 dB, and the phase difference is 89°. In addition, these figures show that the performance of the proposed coupler has approximately coupling and phase errors within -3.25 ± 0.1 dB and 3°.Return loss and isolation are better than -10 dB over a XXXXXX bandwidth (from 1.4 GHz to 3.4 GHz). Table I summarizes the recently published branch-line hybrid couplers with reduced wavelength in transmission line and the results obtained in this work. In addition, it shows significant improvement in size reduction with wide bandwidth performance. Photograph of fabricated broadband branch line coupler is shown in Fig. 4.

TABLE I. Comparison of Published Compact Branch-Line Couplers and This Works.

Ref.	Phase	Substrate	f_0	BW (GHz)	Size
[8]	~5	RO4003	0.9	0.3	0.12
[9]	~2	FR4	0.825	0.15	0.26
[10]	~4	FR4	2.3	0.6 (2~2.6)	0.54
[11]	>5	RO4003	2.4	0.4	0.76
[12]	>5	FR4	2.4	0.8 (2~2.8)	0.29
This	~3	FR4	2.4	0.6 (2.2-	~0.3

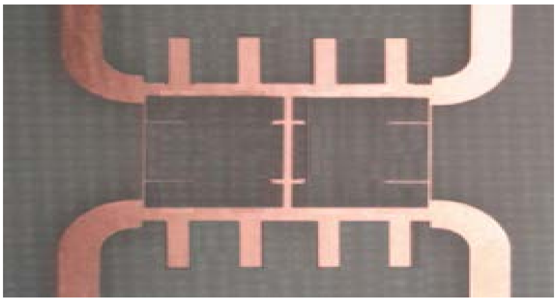


Fig. photograph of fabricated coupler

III. CONCLUSIONS

In this paper, the conventional broadband branch-line coupler by quasi-π-equivalent structure is presented. The corresponding design equations and equivalent structures and their simulated results are presented as well. Table I reveals that using the proposed quasi-π-equivalent double box is an in effect attitude to reduce the circuit size of a branch-line coupler with regard to wideband performance. The proposed branch line coupler displays couplings and phase errors within −3.65 ± 1 dB and 4° and return loss and isolation superior than -10 dB over frequency from (1.4 GHz ~ 3.4 GHz) with a center frequency at 2.4 GHz. Moreover, these couplers can be fabricated using a standard printed circuit board process, which is easily applicable to the design of microwave integrated circuits, such as broadband Butler Matrix Networks.

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