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Modified Double Box Branch Line Coupler By Utilizing Quasi T-Shape Stub

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Abstract - In This paper presents the simulated and fabricated results of a broadband microstrip branch line coupler. In order to reduction size and increase bandwidth of the proposed broad band branch line coupler utilized from open stub line. The compactness of the system is depending on the replacement of branched transmission lines instead of ordinary transmission lines. Small and easy to fabricate microstrip layout topology for the hybrid have been designed and constructed relying on a low cost dielectric material, the well-known FR4. The proposed hybrid exhibits couplings and phase errors within −3.75 ± 1 dB and 4° over a 58% bandwidth with a center frequency at 2.4 GHz.

I. Introduction

Nowadays, demands for fully integrated and miniaturized RFIC (Radio Frequency Integrated Circuits) have increased in wireless microwave communication system. Passive components such as coupler, divider and filters are always fabricated in outside of ICs due to their bulky sizes, which have been a great barrier to a realization of a fully integrated design. To solve this problem, miniaturization of passive components is one of the big issues at the present time. This paper shows the development of two important microwave passive components, quadrature hybrid and rat-race couplers for LTE lower (698-960 MHz) and higher (1.71-2.70 GHz) frequency bands, which are obtained by replacing quarter-wave (λ/4) transmission line of a conventional coupler by their equivalent coupled line, resulting in significant size reduction.

The trend of any sophisticated electrical technology is toward small size, lighter weight, lower cost, and increase complexity. Microwave technology has been moving in this direction for last few decades, with the development of microwave integrated circuits [1]. With fast development of multifunctional technology and the miniaturization of wireless communication systems, compact radio frequency (RF) and microwave components and circuits have become increasingly popular. The quadrature hybrid and rat race coupler are among the most fundamental building blocks of RF circuits and microwave integrated circuits [2]. They are commonly used in antenna feeds, frequency discriminators, balanced mixers, image-reject mixers, modulators, balanced amplifier, power amplifier combiners, phase shifters, mono-pulse comparators, automatic signal level control, and signal monitoring [3] - [6]. Several techniques and approaches have been proposed and developed to miniaturize quadrature hybrid coupler in [7] - [19]. The miniaturization process has completed 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 rat race coupler in [11], [13] – [14], [20], where high and low impedance resonator cells, heptagonal rat-race 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 rat race coupler. Many of them meet the performance requirements while miniaturization was their main consideration. Though, performance requirements depend on application.

Therefore, this report introduces a compact quadrature hybrid and rat race coupler utilizing coupled line technique which is described in [9] - [20]. The presented structure is simple as it can be fabricated on a single layer printed-circuit board. These hybrids are designed to cover the frequency band for LTE applications. Utilizing the proposed multiple shunted open stubs shown in Fig. 1, which can be realized with either high or low impedance, can easily miniaturize four quarter-wavelength transmission lines of the conventional branch-line couplers or can be used in conventional broadband branch-line couplers which are shown in Fig. 1. The fabricated couplers not only occupy 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

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broadband Butler Matrix networks to feed an array antenna. Good agreements between the results of the conventional and proposed branch-line coupler are observed. (The related results of the conventional type are not included.)

II. *Branch line coupler*

Single and double branch line coupler was introduced in [1-4] which have narrow BW. To enhance the bandwidth, a double-box branch line coupler as a quadrature hybrid circuit is used. 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. 3, 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 $0 \leq \theta_S \leq \theta_0 \leq 90°$. A transmission line with the characteristic impedance Z_0 and electrical length θ_0 as a unit line section is demonstrated in Fig. 1(a), and its T-equivalent circuit model is presented in Fig. 1(b). Each open stub is then subbed by a plicate open stub with equal characteristic impedance Z_P and total electrical length θ_P (i.e. $\theta_P = \theta_P' + \theta_P''$) to reduce the size of the circuit as shown in Fig. 1(c). In order to achieve more size reduction, one of the folded stubs can be flipped vertically as shown in Fig. 1(d). Finally, a compact structure of the transmission line is obtained by using its balanced T-equivalent with quasi H-equivalent stubs and is called H-shaped equivalent as shown in Fig. 1. The simulation results shows that this structure has acceptable frequency response within the operating bandwidth with attention to size reduction.

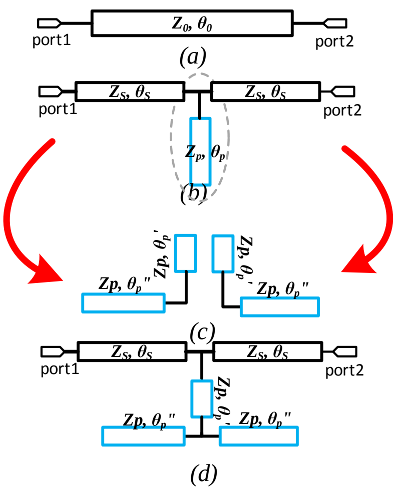

Fig. 1. (a) A conventional transmission line, (b) π-equivalent transmission line of the conventional type, (c) flipped vertically and folded equivalent structure of the open stub, and (d) H-shaped equivalent structure of the conventional transmission line.

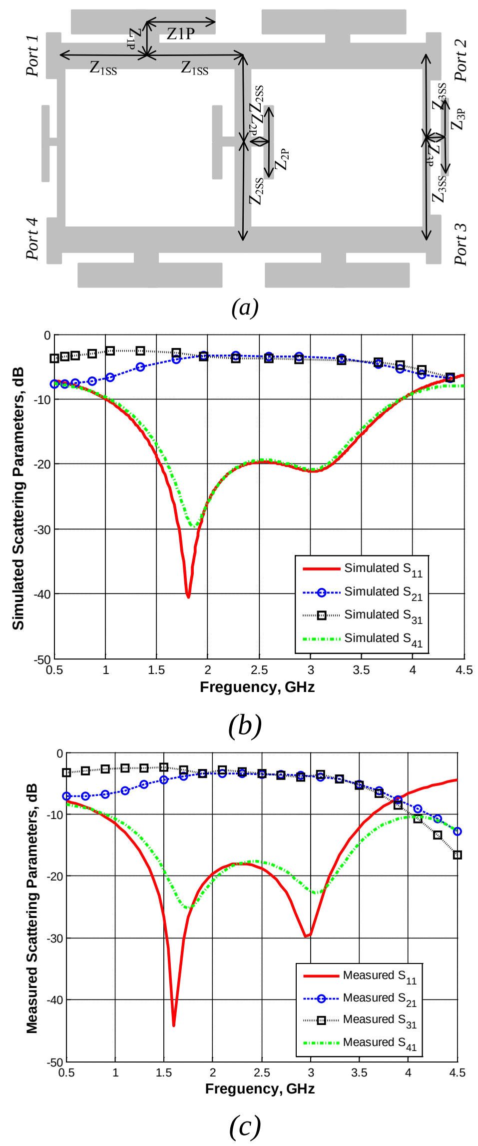

Fig. 2. (a)The proposed broadband branch-line coupler with L-shaped equivalent structure of the conventional transmission line. (b) Magnitude of Simulated scattering parameters (c) Magnitude of measured scattering parameters

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. 2(a) are as follows:

$Z_{1S}=74\Omega$, $\theta_{1S}=36°$, $Z_{1P}=70\Omega$, $\theta_{1P}=57°$, $Z_1'=74\Omega$, $\theta_1'=9°$, $Z_{2S}=102.5\Omega$, $\theta_{2S}=33°$, $Z_{2P}=115.5\Omega$, $\theta_{2P}=32.5°$, $Z_2'=102.5\Omega$, $\theta_2'=14.5°$, $Z_{3S}=137\Omega$, $\theta_{3S}=32°$, $Z_{3P}=137\Omega$, $\theta_{3P}=21°$, $Z_3'=137\Omega$, $\theta_3'=14°$.

The simulation results of the scattering parameters for the proposed branch-line coupler are indicated in Fig. 2(b) and phase difference are shown in Fig. 2(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 -15 dB over a 83.3% bandwidth (from 1.4 GHz to 3.4 GHz). Table I summarizes the recently published

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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. 3.

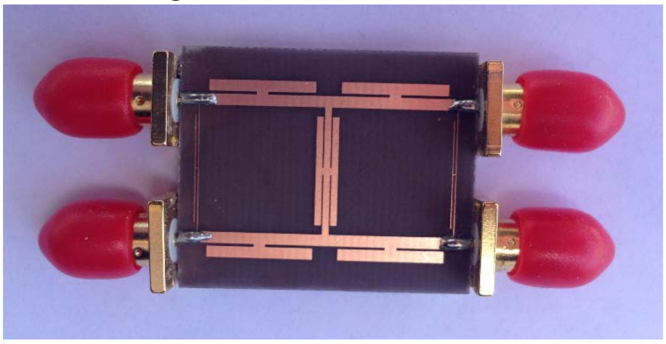

Fig. 3. *photograph of fabricated coupler*

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

Ref.	*Phase Error (degree)*	*Substrate*	*f_0 (GHz)*	*BW (GHz)*	*Size Reduction Ratio*
[15]	~5	RO4003	0.9	0.3 (0.75~1.05)	0.12
[16]	~2	FR4	0.825	0.15 (0.75~0.9)	0.26
[17]	~4	FR4	2.3	0.6 (2~2.6)	0.54
[18]	>5	RO4003	2.4	0.4 (2.2~2.6)	0.76
[19]	>5	FR4	2.4	0.8 (2~2.8)	0.29
[20]	~5	RO4003	5	2 (4~6)	0.5
This Work	~3	FR4	5.5	2.4 (1.7~3.1)	~0.3

III. Conclusions

In this paper, the conventional broadband branch-line coupler (cascaded branch-line coupler) with seven sections of the quarter-wavelength transmission lines has been miniaturized easily by using the proposed quasi-H-equivalent structure. 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 structure is an effective approach to miniaturize the circuit size of a branch-line coupler with regard to wideband performance. The proposed branch line coupler exhibits couplings and phase errors within −3.75 ± 1 dB and 3° and return loss and isolation better than -15 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.

References:

[1]David. M. ozar, “Microwave Engineering,” John Wiley ons, Inc. 2 5.

[2]He-Xiu Xu, Guang-Ming Wang, and Ke Lu, ‘‘Microstrip rat race coupelers,’’ IEEE microwave magazine, 2011.

[3]Kai Chang, ‘‘RF and Microwave Wireless ystem,’’ I N -471-35199-7, John Willy & Sons.

[4]M. Aikawa and H. Ogawa, ‘‘Double-sided MICs and their applications,’’ Microwave Theory and Techniques, IEEE Transactions, volume 37, pp.406-413, Feb.1989

[5]P. Slonen, P. Jokinen, M. keskilammi, ‘‘Analysis of 2.45GHz 4-bit hybrid coupled phase shifter for phased arrays,’’ in roc. IEEE 1 International conference on Electrical and Electronic Technology, Singapore, volume 2, page 529-534, August 2001.

[6]Gary reed, ‘‘Transmission line and lumped element quadrature coupler’’ High Grequncy electronics, November 2009.

[7]K.-K. M. Cheng and F.-L. Wong, “A novel approach to the design and implementation of dual-band compact planar 90 branch-line coupler”, IEEE Trans. Microw. Theory Tech., vol. 52, no. 11, pp. 2458–2463, Nov.2004.

[8]C. Collado, A. Grau and F.D. Flaviis, “Dual band planar quadrature hybrid with enhanced bandwidth response,” IEEE Trans. Microw.Theory Tech., vol. 54, no. 1, pp. 180–188, Jan. 2006.

[9]antanu Dwari and . anyal, “ ize reduction and harmonic suppression of microstrip branch-linecoupler using defected ground structure,” Microwave and Optical technology Letters, vol.48, no. 10, pp. 1966 – 1969, Oct. 2006.

[10]T. Hirota, A. Mina awa, and M. Muraguchi, “Reduced-size branch-line and rat-race hybrids for uniplanar MMICs,” IEEE Trans. Microwave Theory Tech., vol. 38, pp. 270–275, Mar. 1990.

[11]K.-K. M. Cheng and F.-L. Wong, “Dual band rat race coupler design using tri-section branch-line,” Electronic Letters, vol. 43, no. 6, March. 2007

[12]K.C.Gupta, A. ingh, ‘‘Microwave Integrated Circuits’’, 1st ed. Wiley, 14.

[13]Kuo-Sheng Chin, Ken-Min Lin, Yen-Hsiu Wei, Tzu-Hao Tseng, and Yu-Jie Yang ‘‘Compact Dual-Band Branch-Line and Rat-Race Couplers With Stepped-Impedance- tub Lines’’, IEEE Trans. Microw. Theory Tech, Vol. 58, no. 5, May 2010

[14]Kimberley W. Eccleston, Sebastian H. M. Ong ‘‘Compact planar microstrip line ranch-Line and Rat-Race Couplers’’, IEEE Trans. Microw. Theory Tech, ol. 51, No. 1 , October 23

[15]D. de Castro Gal´an, L. E. Garc´ıa Mu˜noz and D. egovia argas, ‘‘Diversity monopulse antenna based on a dual-frequency and dual mode CRLH rat race coupler’’, Progress In Electromagnetics Research B, Vol. 14, 87–106, 2009.C. H. Tseng, and C. L. Chang, “A Rigorous Design Methodology for Compact Planar Branch-Line and Rat-Race Couplers with Asymmetrical T-Structures,” IEEE Transactions on Microwave Theory and Techniques, Vol. 60, No. 7, July 2012.

[16]K. Y. Tsai, H. S. Yang, J. H. Chen, and Y. J. E. Chen “A Miniaturized 3 dB Branch-Line Hybrid Coupler with Harmonics Suppression,” IEEE Microwave and Wireless Components Letters, Vol. 21, No. 10, October 2011.

[17]C. W. Tang, and M. G. Chen “Synthesizing Microstrip Branch-Line Couplers With Predetermined Compact Size and Bandwidth,” IEEE Transactions On Microwave Theory And Techniques, Vol. 55, No. 9, September 2007.

[18]C. W. Tang, M. G. Chen, and J. W. Wu "Realization of Ultra-Compact Planar Microstrip Branch-Line Couplers with High-Impedance Open Stubs," Microwave Symposium, 2007 IEEE.

[19]S. S. Liao, and J. T. Peng "Compact Planar Microstrip Branch-Line Couplers Using the Quasi-Lumped Elements Approach With Nonsymmetrical and Symmetrical T-Shaped Structure," IEEE Transactions On Microwave Theory And Techniques, Vol. 54, No. 9, September 2006.

[20]C. Chen, H. Wu, and W. Wu "Design and Implementation of A Compact Planar 4×4 Microstrip Butler Matrix for Wideband Application," Progress in Electromagnetics Research C, Vol. 24, 43-55, 2011.