Miniaturised Inkjet-printed Quadrature Hybrid Couplers for Multiband Wireless Systems

Oludotun Olukoya, Andrzej Tarczynski and Djuradj Budimir
Wireless Communications Research Group,
University of Westminster, London, W1W 6UW, UK
d.budimir@wmin.ac.uk

Abstract— **A miniaturised multiband inkjet printed Quadrature Hybrid Coupler is proposed in this paper. The design and flexibility characterization of an inkjet-printed coupler on a flexible 50 µm polyimide film (Kapton) substrate is presented. Kapton is chosen due to its good balance of physical, chemical and electrical properties with a low loss factor of 0.0021. The coupler is designed to operate at 1.5 GHz, 4.5 GHz, 6.0 GHz, 7.5 GHz and 9.0 GHz. The circuit was simulated and the simulation results are presented. The coupler will be fabricated and test results will be presented. The proposed QHC size is 78% smaller than the conventional QHC.**

Keywords—quadrature hybrid couplers; inkjet printing; multiband couplers.

I. INTRODUCTION

Quadrature Hybrid Couplers (QHCs) or branch-line couplers are commonly used in are widely used in numerous Sensing, RFID, wireless systems, RF and micro-/mm-wave circuits such as mixers, amplifiers, phase shifters, antenna array feed networks and beam-forming networks [1]. Conventional quadrature hybrid couplers with quarter wavelength transmission lines operate at a fundamental frequency and its odd harmonics. Inkjet printing technology is excellent candidate for low-cost circuit realization. Using inkjet printing technology, several advantages such as faster fabrication, waste decrease and low fabrication costs, reduction in material quantity can be achieved over conventional etching technology. In last few years several inkjet-printed couplers have been implemented in a wide range of applications [2]-[3]. To overcome the problem of complexity and increase in size, a U-shaped transmission line is proposed to replace the four quarter wavelength transmission lines of the conventional couplers.

In this paper, a novel U-shaped transmission line (USTL) is proposed for the quadrature hybrid coupler to maintain high performance whilst reducing size. One of such structures is proposed in this paper with a total reduction of about 78% in its occupied size when compared to its conventional equivalent. The structure also gives good return and insertion loss performance at multiband frequencies. In Section II a brief description of the proposed coupler is given. Section III presents the obtained results and the conclusion is given in Section IV.

II. PROPOSED QUADRATURE HYBRID COUPLER

Principal schematic of a conventional quadrature hybrid coupler is shown in Figure 1. Characteristic impedances and electrical length of all transmission lines related to our design, shown in Figure 1, are given in Table I. Also Table I gives physical dimensions of transmission lines in branch line coupler.

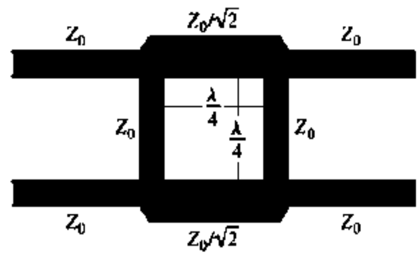

Fig. 1. Schematic of a conventional quadrature hybrid coupler

TABLE I. BLC DESIGN PARAMETERS

Characteristics impedance (Ω)	Width (mm)	λ_g (mm)	Length (λ_g/4) (mm)
50 (Z0)	0.11	122.28	30.57
35.35(Z0/√2)	0.19	119.52	29.88

The conventional coupler has a total size (LxW) of 91.10 x 31.14 mm^2. Figure 2 shows the proposed compact quadrature hybrid coupler. It is implemented using inkjet printing technology. In order to reduce the size of the coupler, U-shaped transmission line units shown in Figure 3 are used instead of λ/4 transmission lines.

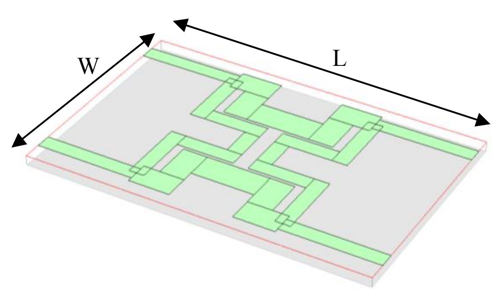

Fig. 2. Proposed QHC structure

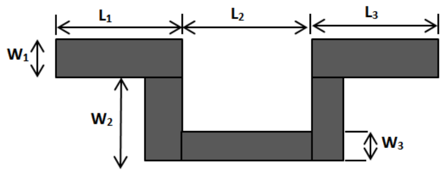

Fig. 3. Proposed U-shape transmission line unit (USTL).

The $\lambda_g/4$ Transmission lines are replaced with USTL shown in Figure 3.The dimensions of the proposed coupler structure are shown in Table II.

TABLE II. USTL PARAMETERS

Characteristics impedance (Ω)	W1 (mm)	W2 (mm)	W3 (mm)	L1 (mm)	L2 (mm)	L3 (mm)
50 (Z0)	0.32	8.7	0.32	6.0	5.3	6.0
35.35(Z0/√2)	0.54	5.2	0.54	5.5	7	5.5

Branch line coupler is designed as microstrip structure. Metal lines should be printed on substrate foil of 50 µm thickness and relative dielectric permittivity of $\varepsilon_r = 3.4$. Kapton is chosen because it fulfils the required properties and has a low loss factor of 0.0021. Silver nanoparticles thickness of 1 µm for inkjet printing was chosen in order to reduce losses in metal. The proposed coupler was simulated using full 3D electromagnetic simulation software, *em* Sonnet.

III. Results

The proposed a multiband inkjet-printed quadrature hybrid coupler was designed and simulated using *em* Sonnet software. The coupler has a total compact size (L x W) of 34.4 x 17.84 mm^2. The simulated S-parameters are shown is given in Figure 4.

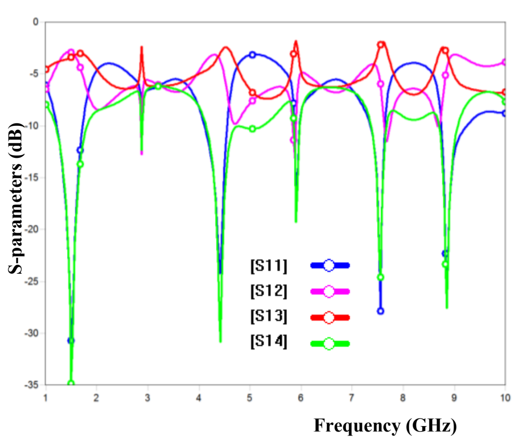

Fig. 4. Simulated S-parameters of a multiband coupler.

The scattering parameter S11 is lower than −20 dB at all bands. Even better results are with isolation parameter S41 is lower than −25 dB at all bands. Also, the transmission parameter S21 and coupling parameter S31 are close to −3 dB.

The phase difference of a branch line coupler between ports 2 and 3 at both bands is around 90 degrees (89.93 + 0.02 = 89.96), as shown in Figure 5.

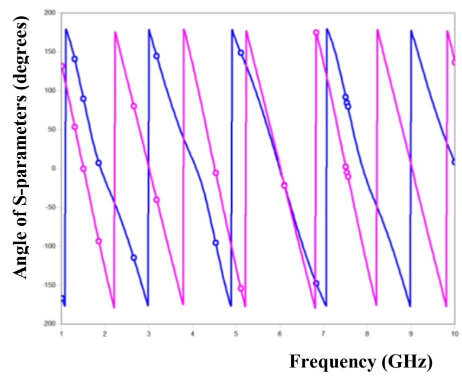

Fig. 5. Simulated results of angles of S21 (red) and S31 (blue) parameter of a proposed coupler.

IV. Conclusion

In this paper, a compact multiband inkjet-printed Quadrature Hybrid Coupler has been proposed and designed. The design of an inkjet-printed coupler on a flexible 50 µm Kapton substrate is simulated. The coupler was simulated and the simulation results were presented. The insertion loss of a proposed coupler was about −3 dB. The simulated return loss and isolation loss were better than −15 dB and −20 dB, respectively at at 1.5 GHz, 4.5 GHz, 6.0 GHz, 7.5 GHz and 9.0 GHz, respectively. The proposed inkjet-printed QHC size is 78% smaller than the conventional inkjet-printed QHC. The coupler will be fabricated and test results will be presented.

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