Dual-Band Patch Hybrid Coupler

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***Abstract*—Patch hybrid couplers are used to provide arbitrary power division ratio over two frequency bands. The coupler is designed using three main topologies. They are Branch-line, Coupled-line and Patch. Branch-line and Coupled-line provides equal power division ratio over two frequency bands. Patch structure provides arbitrary power division ratios. The patch hybrid coupler is the rapid development of communication topologies, it has become a trend to make a wireless component workable in multiple frequency bands. Complementary split ring resonators (CSRRs) are loaded onto each quadrant of a patch hybrid coupler to enable dual-band operation. The unique property of CSRR was found to give different power division ratios over the two frequency bands, which is difficult to implement using conventional approaches. The complementary split ring resonator is designed using microstrip components which operates in the frequencies of 1.2GHz and 2.4GHz.**

Keywords—Arbitrary power division ratios, complementary split ring resonator (CSRR), dual-band hybrid coupler, metamaterial, patch hybrid coupler.

I. INTRODUCTION

Hybrid couplers are generally 3 dB directional couplers with specific phase relation between the outputs. If the phase difference is 90° then the hybrid is called quadrature or 90° hybrid, if it is 180° then that hybrid is called 180° hybrid and if the phase difference is 0° then it is called Wilkinson power divider. Generally, hybrids are four port networks with one port as an isolated port, but the wilkinson power divider is a three-port network and its fourth port is imbedded. Hybrid couplers find their applications in various microwave circuits. 3 dB hybrid junctions, such as magic-T or hybrid ring are used in the design of single balanced mixer.

Coupler is one of the most popular passive circuits used in microwave and millimeter-wave applications. It gives equal amplitude and phase outputs within the designed operating frequencies. These passive components are commonly used in variety of application such as mixers, phase shifters, power amplifiers and bridging many microwave circuits. The hybrid couplers are designed using three main topologies. They are branch-line, coupled-line and patch-line structure. Each topologies has its own advantages and disadvantages. In a branch-line structures stubs are loaded on the conventional branch line sections to realize dual-band operation. In other way, additional pairs of cross coupling and transmission line sections are to be added to the conventional branch line coupler to enable dual-band operation. The left handed transmission lines can be used to replace conventional branch lines to realize dual-band operation. The coupled line sections are commonly used to implement a broadband coupler. As a novel design, three coupled line sections are employed to form a dual-band coupler with a wide range of identical power division ratio. Patch configuration, open stubs are loaded onto the rectangular patch to realize dual-band operation with an enhancement bandwidth. All these previous configurations can only provide equal power division over the two bands. Patch structure gives different power division ratios at two operating bands are often needed by some applications, such as the dual-band Doherty amplifier. To overcome this a novel stepped impedance section with open stubs is used to imitate the quarter wave-length section, and it has successfully achieved different power division ratios at the two operating bands. However, this methodology is confined to the branch line based configuration, and cannot be applied to the patch based configuration. It is obvious that there exists a need for a new patch hybrid coupler that is able to provide dual-band operation but with distinct power division ratios.

The complementary split ring resonator (CSRR) was first introduced as a new metamaterial resonator in and has been proven to exhibit negative permittivity characteristics. Finally, the CSRR has been widely applied in antennas, microstrip lines and substrate integrated waveguides. Most of the reported applications of CSRR in patch configuration are found to be related to size minimization of patch antennas no work has been reported in literature regarding the application of CSRR to patch-type circuits for performance enhancement.

In this paper, a novel CSRRs loaded patch hybrid coupler is investigated both theoretical and simulated results for dual-band operation. The proposed dual-band patch hybrid coupler offers a few advantages over existing designs. First, the patch configuration is simpler in structure, meaning that it is easy and low in cost to fabricate especially for high-frequency applications. On top of that, the proposed patch hybrid coupler can provide different power division ratios at two operating frequency bands due to the flexibility of the loading CSRRs.

II. DESIGN PROCEDURE

A. Configuration

The patch hybrid coupler based on multiple sector patches is shown in Fig. 1. The patch hybrid coupler consists of four circular sectors with different radii (R_1 and R_2) and angles ($\theta_1 = \theta_2 = \theta_3 = \theta_4 = 90°$). This circular sector patch hybrid coupler has been found to provide arbitrary coupling coefficient while maintaining phase characteristic.

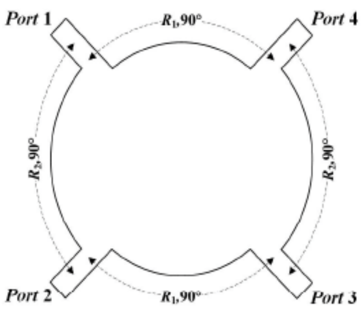

Fig. 1 Configuration of circular sector patch hybrid coupler.

The patch hybrid coupler can be divided into four sectors subsections where R is the radius of circular sector patch, θ is the angle of the circular sector patch subsection in degree. The configuration of single circular CSSR is shown in Fig. 2. Four CSRRs with the same dimensions are loaded onto the circular sector patch for size miniaturisation.

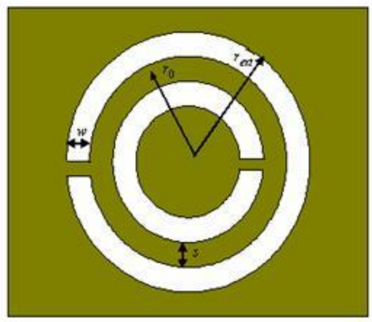

Fig. 2 Configuration of CSRR

B. Circular Sector Patch Hybrid Coupler Loaded with CSRRs

The working principle for the proposed dual-band hybrid coupler were already explained in the previous section. From the analysis, it can be found that a dual-band quadrature hybrid coupler can be implemented by assigning appropriate values. To realize the desired dual-band operation, the component values can be simply be tuned. However this cannot be directly applied to the patch element. The analysis of this patch hybrid coupler can be conducted using the proposed equations, but the effects of the circuit parameters are not easily predictable. Therefore, a relevant study that can provide the necessary information for the design procedure of a dual-band patch hybrid coupler has been conducted. Design of the dual-band coupler is investigated by studying the effects of different dimensional parameters on the operation frequencies and power division behavior.

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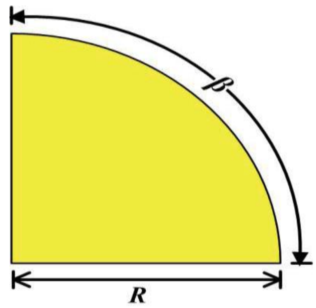

Fig. 3. Configuration of a circular sector patch.

First, a conventional single-band circular sector patch hybrid coupler operating at 1.2 GHz and 2.4GHz was obtained by determining the radii (R_1 and R_2). Four CSSRs with the same dimensions are loaded onto the circular sector patch. The detailed dimensional parameters are $R_1 = R_2 = 18$ mm, $r_{ext} = 6$ mm, $r_{int} = 4.5$ mm, g = 1 mm and $p_1 = p_2 = 12$ mm. The CSRRs loaded patch hybrid coupler was found to operate at frequencies $f_1 = 1.2$ GHz and $f_2 = 2.4$ GHz as shown in Fig. 4

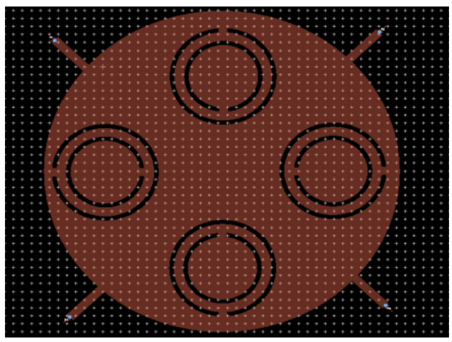

Fig. 4. Configuration of the multi-band patch hybrid coupler loaded with CSSRs.

The result for this design was shown in Fig.5. The circuit is designed using FR_4 substrate with dielectric constant ratio of $\varepsilon_r = 4.4$ mm and thickness of $h = 1.5$ mm.

Fig.5 (a) S_{11} Input Fig. 5 (b) S_{21}Throughput

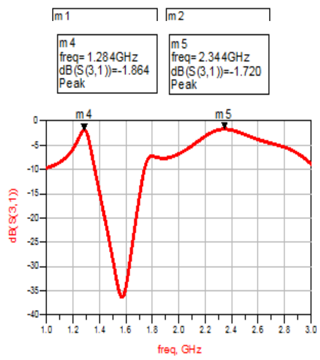

Fig. 5(c) S_{31} Coupled

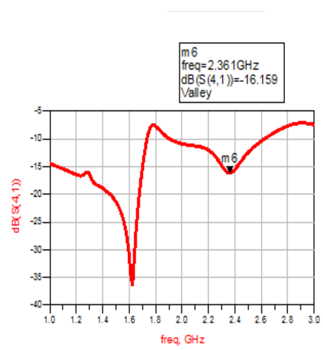

Fig. 5(d) S_{41} Isolation Port Factor

The results shows that S_{11} is the input port, S_{21} is the throughput nothing but the input power is delivered to the output, S_{31} is defined as some portion of the power is delivered to the coupled port. S_{41} is the isolation factor.
The proposed CSRRs loaded patch configuration, which was designed at frequencies 1.2GHz and 2.4GHz provides an efficient bandwidth.
The S-parameters are
Return loss S_{11} = -16.8 dB and -28.0 dB
Insertion loss = -1.72 dB and -1.75 dB
Coupling Factor S_{31} = -1.7 dB and -1.7dB
Throughput S_{21} = -19.4 dB and -8.7 dB
Isolation Factor S_{41} = -16.0 dB and -16.1 dB

III. RESULTS AND DISCUSSION

The designed results for two dual-band patch hybrid couplers were designed and simulated. The circuit was designed using FR_4 substrate with dielectric constant ratio of ε_r = 4.4 and h = 1.5mm. The proposed CSSRs loaded patch configuration, which was designed at frequencies 1.2GHz and 2.4GHz provides an efficient bandwidth. The simulated curves including the return loss and insertion loss for different radius R_2 with a fixed R_1. It can be observed that, as R_2 increases, the two optimum operating frequencies decrease. On the other hand, the corresponding coupling coefficient S_{21} increases, but the coupling coefficient S_{31} decreases at the two operating frequencies.

IV. CONCLUSION

The proposed CSRRs loaded patch configuration which was designed at the frequencies 1.28GHz and 2.4GHz provides a high power division ratio with efficient bandwidth than the coupled-line and branch-line structures. The proposed configuration has the S-Parameter of (Return Loss) S_{11} = -13.8 dB and -25.7 dB, (Insertion Loss) S_{12} = -11.4 dB and -5.7 dB, (Isolation Factor) S_{14} = -34.0 dB and -15.1 dB, (Coupling Factor) S_{13} = -2.6 dB and -2.2 dB.

The Coupling factor, Isolation factor and Power division results can be further improved by matching the conductance effectively. Also the size can be further reduced by applying the fractal methods. It also used to design a Doherty amplifier. These frequencies are also used in Amateur Satellite up-links and Radar applications.

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