A New Type of Microstrip Coupler with Complementary Split-Ring Resonator (CSRR)

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Abstract — A new type of microstrip Coupler with Complementary Split-Ring Resonator (CSRR) is proposed. The characteristic impedance of the even mode can be enhanced by etching CSRR structure in the grounded plane of a conventional microstrip double-line coupler. This results in a higher degree of coupling. Based on the analysis of the odd and even modes, a new type of microstrip coupler was designed. The results of simulation and measurement show that the new coupler achieves a high degree of coupling (3 dB coupling) over a wide frequency band (38.1% relative bandwidth).

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1. INTRODUCTION

A well-known problem of the conventional microstrip parallel-coupled couplers is their difficulty to achieve tight backward coupling because of the excessive small lines-gap required [1]. Alternative components include non-coupler-line couplers such as the branch-line or rat-race, however, these couplers are inherently narrowband (no more than 15% bandwidth) circuit. The Lange coupler [2] is a solution widely used in the MMIC industry for broadband 3-dB coupling, but it has the disadvantage of requiring bonding wires. In the past few years, there has been a great interest in the emerging field of meta-materials and more specially left-handed (LH) structures. Couplers based on LH transmission lines (TL) was proposed by some authors [3, 4]. This couplers, which composed of one or two LH-TL constituted of series interdigital capacitors and shunt shorted-stub inductors, can provide arbitrary loose/tight coupling levels. But designing this coupler is too complicated.

Very recently, Complementary Split-Ring Resonator (CSRR), which is the negative image of Split-Ring Resonators (SRR) [5] (see Fig. 1), have been reported by some authors [6]. It has been demonstrated that CSRR etched in the ground plane or in the conductor strip of planar transmission media (microstrip or CPW) provide a negative effective permittivity to the structure. CSRR has been successfully applied to the narrow band filters and diplexer with compact dimensions [7, 8].

(a) (b)

Figure 1: (a) Topology of the SRR, (b) Topology of CSRR (Metal regions are depicted in gray).

In this paper, a novel coupled-line backward coupler based on CSRR is presented. The characteristic impedance of the even mode can be enhanced by etching CSRR structure in the grounded plane of a conventional microstrip double-line coupler. This results in a higher degree of coupling. The results of simulation and measurement show that the new coupler achieves a high degree of coupling (3 dB coupling) over a wide frequency band (38.1% relative bandwidth).
2. ODD AND EVEN MODES ANALYSIS

The electric fluxline of coupling microstrip of odd mode and even mode are showed in Fig. 2. In odd mode, the E-field is asymmetric and continuous even in the presence of CSRR slot. Signal does not slow down just as the one without CSRR. In even mode, the E-field is discontinuous along the middle line of coupler. The CSRR act as open circuit for the even mode.

![Electric fluxline of coupling microstrip](image)

Figure 2: Electric fluxline of coupling microstrip. (a) odd mode, (b) even mode.

The odd and even modes S-parameters of the coupler of Fig. 3 were computed by full-wave simulation, and are showed in Fig. 4. Table 1 shows the odd and even characteristic impedances.

![Structure of conventional directional coupler and CSRR-based directional coupler](image)

Figure 3: (a) Structure of conventional directional coupler, (b) Structure of CSRR-based directional coupler.

![Magnitude of the S-parameters for the two structures](image)

Figure 4: Magnitude of the S-parameters for the two structures showed in Fig. 3 obtained by simulation. (a) odd mode, (b) even mode.
Table 1: Odd and even impedance for the two structures showed in Fig. 3 at the central frequency (2.1 GHz).

<table>
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<th>$Z_{eo}$</th>
<th>$Z_{ee}$</th>
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<tbody>
<tr>
<td>Conventional coupler</td>
<td>38.7 Ω</td>
<td>69.6 Ω</td>
</tr>
<tr>
<td>CSRR coupler</td>
<td>38.2 Ω</td>
<td>240 Ω</td>
</tr>
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</table>

at the frequency of 2.1 GHz computed from the odd and even S-parameters, using the general formula

$$Z_{ci} = Z_0 \sqrt{\frac{(\Pi_i - 1)}{(\Pi_i + 1)}}$$

with

$$\Pi_i = \frac{(S_{21i}^2 - S_{11i}^2 - 1)}{(2S_{11i})}.$$ 

It is demonstrated that the characteristic impedance of the even mode can be enhanced by CSRR structure. This results in a higher degree of coupling.

3. DESIGN OF CSRR-BASED 3 DB DIRECTIONAL COUPLER

The structure of CSRR-based directional coupler is showed in Fig. 5. The parameter of substrate is $\varepsilon_r = 2.65$, $h = 1.5$ mm. The characteristic impedance at the ports is set to $Z_0 = 50$ Ω. The results obtained by full-wave simulation and measurement are showed in Fig. 6. The performances of the 3-dB coupler are the following: $3.7 \pm 0.5$ dB backward coupling, return loss smaller than $-18$ dB and isolation better than 25 dB over the 1.7 to 2.5 GHz range (38.1% fractional bandwidth).

![Figure 5: Structure of CSRR-based directional coupler.](image)

![Figure 6: (a) Magnitude of the S-parameters for the coupler of Fig. 4 obtained by simulation (Ansoft-Design) (b) Magnitude of the S-parameters for the coupler of Fig. 4 obtained by measurement.](image)
ACKNOWLEDGMENT
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REFERENCES