Abstract—In this paper, miniaturized branch-line couplers (BLC) is designed and simulated using FR4 substrate at the operating frequency 2.45 GHz in the ISM “Industrial Scientific Medical” band. High and low impedance open stubs are used to miniaturize the conventional BLC. After a theoretical study on the use of open stubs, we present the simulation results of this branch line coupler by using the ADS from Agilent technologies and CST Microwave Studio. The simulated results comparison gave good results and an agreement between ADS and CST, which confirms the theory and validates the proposed coupler design.

Keywords: Branch-line coupler, ADS, CST microwave Studio.

I. INTRODUCTION

Branch-line couplers with compact size and high-performance are demanded in many microwave communication systems. The branch-line coupler has several applications in the design of microwave devices such as balance amplifiers, balance mixers and phase shifters. The branch-line coupler employs quarter-wavelength transformers to realize a simple square-shaped configuration that is used for power dividing or power combining functions and is suitable for low-cost fabrication.

However, at the low frequencies the size of a conventional branch-line coupler is very large. Hence, the size reduction of this device is highly desirable for modern communication systems.

In order to reduce the size and volume of a branch-line coupler several techniques have been previously reported[1-6].

For example, combination of short high-impedance transmission-lines and shunt-lumped capacitors has been considered in [1, 3]. In [1] a size reduction of 60% is achieved compared with the conventional design by embedding series and shunt uniplanar stubs inside the main uniplanar line; and in [2] a size reduction of 55% is achieved using rectangular patches within the coupler arms.

The remainder of paper is organized as follows. Section II describes the design of conventional branch-line coupler. Section III describes the design of the proposed coupler. Its size and dimension are designed for ISM “Industrial Scientific Medical” technologies covering frequencies from 2 400 MHz to 2 483 MHz. After presenting its structure, the simulation results are shown to indicate its performance in section IV. Section V presents the comparison of dimension between the conventional and proposed coupler.

II. THEORICAL STUDY OF COUPLER

Coupels call “Branch-Line” as shown in figure 1,directional couplers are generally used for distribution to 3dB of energy, with a phase difference of 90° between the way “direct” and the way “coupled”[6-9]. This kind of coupler is commonly done in microstrip technology or Tri-plate, and is one of the couplers called “phase quadrature”:

![Figure 1: Branch Line Microstrip Structure](image)

According to figure.1 above, the power from the port 1 will be divided between the port 2 (direct path), and port 3 (channel coupled) with a phase difference of 90° between the outputs. No energy is transmitted to port 4 (isolated port ).
The directional coupler is characterized by three parameters:

- **Coupling:**  \( C_{db} = 10 \log \left( \frac{P_1}{P_3} \right) \)
- **Directivity:**  \( D_{db} = 10 \log \left( \frac{P_3}{P_4} \right) \)
- **Isolation:**  \( I_{db} = 10 \log \left( \frac{P_1}{P_4} \right) \)

We can observe that the coupler has a high degree of symmetry. Any port may be used as an input. This symmetry is reflected by examining the S-matrix, since each line can be obtained by transposing the first. So we can decompose this study on the even mode and odd mode analysis.

### III. DESIGN OF PROPOSED COUPLER

The traditional \( \lambda/4 \) microstrip branch-line coupler with branch line impedances 50 \( \Omega \) and 50/\( \sqrt{2} \) \( \Omega \), the proposed coupler is replaced \( \lambda/4 \) microstrip line by high and low impedances open stubs for the miniaturized of the conventional coupler.

The \( \lambda/4 \) microstrip line with impedance 50 \( \Omega \) is replaced by new transmission line of the combinational of two U-shaped and T-shaped [12-14-15] as shown in Figure 3.

![Figure 3: Equivalent quarter wave-length transmission line by using Combinational-shaped (T and π) with high-impedance stubs.](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Length ( L ) (mm)</th>
<th>Width ( W ) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L_4, W_4 )</td>
<td>12</td>
<td>1.5</td>
</tr>
<tr>
<td>( L_5, W_5 )</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>( L_6, W_6 )</td>
<td>4.1</td>
<td>0.8</td>
</tr>
</tbody>
</table>

The layout of the proposed coupler is shown in Figure 4, the coupler has the length \( L=20 \) mm and width \( W=12.9 \) mm as:

![Figure 4: Layout of the proposed Microstrip coupler](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Length ( L ) (mm)</th>
<th>Width ( W ) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L_1, W_1 )</td>
<td>9.1</td>
<td>1</td>
</tr>
<tr>
<td>( L_2, W_2 )</td>
<td>3</td>
<td>0.6</td>
</tr>
<tr>
<td>( L_3, W_3 )</td>
<td>5</td>
<td>0.4</td>
</tr>
</tbody>
</table>
IV. SIMULATION RESULTS AND ANALYSIS

After To see the performance of the proposed design, the return and insertion losses are evaluated by using ADS from Agilent Technologies [7] and CST microwave studio[8]. In the simulation , FR4 epoxy having dielectric constant 4.4, loss tangent 0.001 and thickness of 1.58 mm is used, the simulated S-parameters of the proposed coupler as following:

A. ADS results:

Figure 5: S-parameters amplitude versus frequency

According to the figure 5, it is observed that the isolation and reflection coefficient show better performance with S parameters amplitude remains below -10 dB over the entire frequency band and below -30 dB at the resonance frequency. For the direct path and coupled offer equal in magnitude in the resonance frequency, the amplitude of the coupled coefficient is of the order of -3.45 dB.

Figure 6: S-parameters in phase versus frequency

As shown in figure 6, The output signals of the direct and coupled channel represent a phase shift of about 91.5°.

B. CST results:

Figure 7: S-parameters amplitude versus frequency

As shown in figure 7, we have a good isolation and a good matching input impedance less than -30dB in the frequency band [2.1GHz,2.89GHz], with an insertion loss around -3dB.

Figure 8: S-parameters in phase versus frequency

The phase difference between the coupler’s output ports is depicted in figure 8, the phase difference is 91.2° at the resonance frequency 2.45 GHz. Finally, we can deduce that we have the same results obtained by ADS and CST.
V.  PERFORMANCE  THE  PROPOSED  COUPLER

Miniaturization is one of the most important issues that should be considered while designing a coupler, Table 3 shows a comparison between the proposed and conventional coupler as following:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>The conventional coupler</th>
<th>The proposed coupler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2.45 GHz</td>
<td></td>
</tr>
<tr>
<td>S11</td>
<td>-32.058 dB</td>
<td>-35.09 dB</td>
</tr>
<tr>
<td>S14</td>
<td>-36.519 dB</td>
<td>-30 dB</td>
</tr>
<tr>
<td>S21</td>
<td>-2.665 dB</td>
<td>-3.45 dB</td>
</tr>
<tr>
<td>S31</td>
<td>-3.355 dB</td>
<td>-3.45 dB</td>
</tr>
<tr>
<td>Phase difference</td>
<td>89.9°</td>
<td>91.35°</td>
</tr>
<tr>
<td>Size in mm²</td>
<td>21.7mm×17mm</td>
<td>20mm×12.9mm</td>
</tr>
</tbody>
</table>

VI. CONCLUSION

Recently, miniaturization of microwave circuits was the goal of many RF engineers in order to reduce the cost of microwave systems. To reduce the circuit size of the branch-line coupler, many compact designs have been introduced. Among these designs, we find the use of combinational-model (combinational of T and π model) with high and low impedance open circuit stub approach the branch-line couplers to achieve the optimum size-reduction. In this paper a new branch-line coupler (BLC) is designed and simulated by using FR4 substrate at the frequency 2.45 GHz in the ISM “Industrial Scientific Medical” band, a good agreement is found between simulated results by using ADS Agilent and CST microwave studio.

REFERENCES