

A Microstrip Coupler With Improving the Characteristic Transmission

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Abstract— In this paper, a new miniaturized microstrip coupler at the center frequency of 3.26 KHz is proposed. Meander line allowed for reducing the size of the component. The coupler demonstrates a coupling level of 2.29 dB, a reflection level of 25.39 dB and an isolation level as 42.41 dB. The meandered coupler have the compact sizes of 23×34.6 mm², and a characteristic impedance Z_0 of 50.60 Ω . in order to validate our model, the compact coupler is designed and fabricated using microstrip technology on FR4 substrat. Good agreement is achieved between the simulated and measured results

I. INTRODUCTION

The telecommunications was initially restricted to public and military services, later they became commonplace in recent years.

Driven by the enthusiasm of the public, wireless communications systems are experiencing tremendous growth worldwide, they became cheaper and faster and the microwave components became miniaturized. The use of directional couplers [1,2] has become commonplace in radio frequency systems and the modern optical communications systems. It therefore becomes important to present this "coupler" in the microwave research.

Directional and hybrid couplers are passive components that allow signals to be split or combined.

The perfect integration of the coupler in the design of RF and digital circuits requires the miniaturization of the device, which naturally leads to define the new design methodologies associated with new hardware and software tools which gives a novel enhanced and miniaturized coupler which is presented in [3-5].

This article presents a concrete case of realization of a directional coupler with meander transmission line in the microstrip technology.

This study led us to conceive, simulate, realize and characterize a compact meandered coupler.

The manipulation (electromagnetic simulations and measurements) guided us to determine the influence of the geometry on the transmission *characteristics* and to deduce all the parameters and rules of behavior.

Objectives of the study

- to highlight a design rule and a reliable process which aims to describe a geometric dimensioning
- To ensure a miniaturization of the component without having a performance degradation.

II. PARAMETERS CHARACTERISTICS OF A COUPLER

The concept of the planar transmission line was proposed from 1950, According to Pozar, from the 1960s, much thinner substrates began to be used, which promotes microstrip lines for microwave integrated circuits. Different waveguide couplers were invented and characterized at the MIT Radiation Laboratory in the 1940s [6].

The concept of couplers in microstrip technology has been proposed since 1950, but it was not possible to achieve them effectively until 1960, when low-loss dielectrics arrived on the market [6]. Since then, research in this field has continued to intensify to exploit the many advantages of directional couplers:

A. Advantages:

- Simple to realize, suitable for two-layer circuits
- Simple connectivity,
- low-loss connector

Unfortunately, these components also have disadvantages ;

B. disadvantages

- Inhomogeneous propagation environments
- Sensitivity to electromagnetic disturbances
- Larger losses, only the substrate that is chosen
- Controlled phase shift

State space can be equivalent to the form showed Fig. 1 and the following functional form:

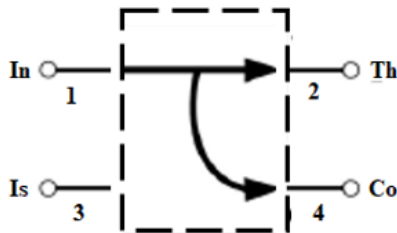


Figure 1. Functional definitions of a classical coupler with Input (In), through (Th), isolation (Is) and coupled port (Co).



Figure 2. Three types of COD directional couplers with Input, through, isolation and coupled port.

The simplest coupler to study is probably given in Fig. 2 which is defined by:

- **Its transmission characteristics:** S-parameters, S11 (reflection coefficient), S21 (isolation), S31 and S41 (characteristics transmission: coupled and through).
- **Its usage parameters:** the resonance frequency f_1 , its input impedance and its bandwidth B.
- **Its internal parameters:** The first step is the choice of the substrate and the conductor for which the characteristics to be known are:

✓ **For the substrate:** its relative permittivity and the dielectric losses of the substrate $\tan \delta$, and its thickness h.

✓ **For the conductor:** its conductivity σ and its thickness t.

The baseline design of coupler consists to determine: the S-parameters, input impedance which must be adapted and the phase difference between the Coupler Output Ports of 90 degree.

In this article only one type feeding is presented. It's about an microstrip line excitation.

In order to formalize our design optimization, the following specification is provided:

- FR4 epoxy glass substrates (it is chosen for cost reasons): relative permittivity $\epsilon_r = 4,6$, $\tan \delta = 0,018$, $h = 1,6mm$
- The conductor: it is copper, $t = 35 \mu m$.
- The type of excitation chosen is the Wave Port for simulation in HFSS.
- The resonance frequency is $f_1 = 3.26$ GHz.

The S31 and S41 (characteristics transmission: coupled and through) are given by:

$$S_{41} = \frac{\sqrt{1-k^2}}{\sqrt{1-k^2} \cdot \cos(\theta) + j \sin(\theta)} \quad (1)$$

$$S_{31} = \frac{jk \sin \theta}{\sqrt{1-k^2} \cdot \cos \theta + j \sin \theta} \quad (2)$$

The maximum amount of coupling between ports 1 and 3 (or between ports 2 and 4) occurs when [7] :

$$\theta = \beta l = \frac{\pi}{2} \text{rads} \quad (3)$$

Or

$$l = \frac{\pi}{2\beta} = \frac{\lambda_g}{4} \quad (4)$$

$\theta = \beta l$ denotes the electrical length of the coupler and β is the frequency bandwidth ratio of a directional coupler (single- or multisection) is defined in [7].

k is given by :

$$k = \frac{Z_{0e} - Z_{0o}}{Z_{0e} + Z_{0o}} \quad (5)$$

where Z_{0e} and Z_{0o} denote the characteristic impedance of the even-mode and odd mode of symmetrical coupled lines respectively, which verify this condition [7] :

$$Z_{0e} Z_{0o} = Z_0^2 \quad (6)$$

We can write Z_{0e} / Z_{0o} in terms of a voltage coupling coefficient k as [7]:

$$\frac{Z_{0e}}{Z_{0o}} = \frac{1+k}{1-k} \quad (7)$$

If the coupling from port 1 to port 3 is given as C dB (where C is a positive quantity), then k is related to C as [7]:

$$k = 10^{-C/20} \quad (8)$$

The geometric parameters: given in the figure below:

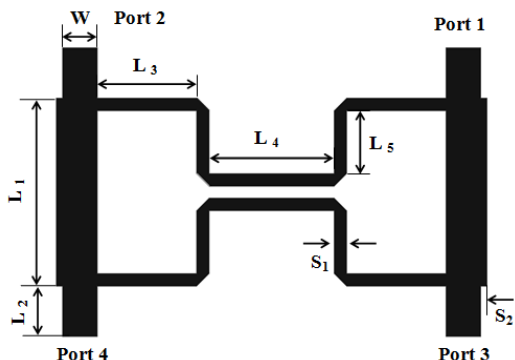


Figure 3. Geometry and dimension of the proposed coupler with:
 $L_1=15\text{mm}$; $L_2= 4\text{mm}$; $L_3= 8\text{mm}$; $L_4= 10\text{mm}$; $L_5= 5\text{mm}$; $S_1= 1\text{mm}$;
 $S_2= 0.5\text{mm}$; and $W= 1.8\text{mm}$.

Fig. 1 shows the schematic coupler design with dimension of the transmission-line sections.

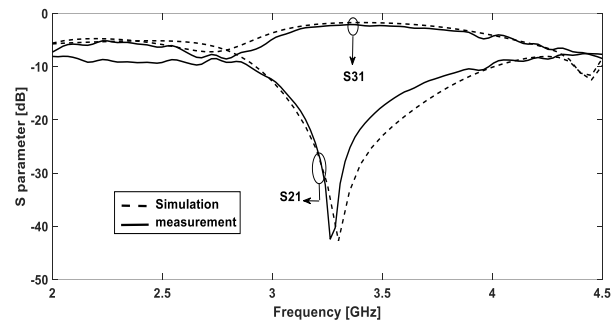
The simulations were performed using the high-frequency structure simulator (HFSS) software who owns an electromagnetic simulator. It is based on Finite Element Method (FEM), also it requires the use of mesh patterns.



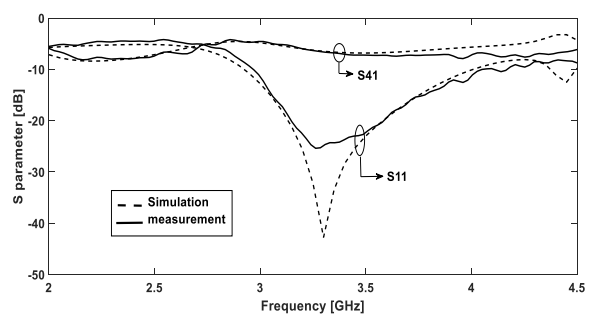
Figure 4. (left) Measurement setup: a network analyzer E5071C being used for S -parameter measurement, (right) component under test.

The coupler Measurement setup is shown on Fig 4. This stage of coupler measures validates the simulation steps.

These measurements are made using Vector Network Analyzers E5071C being used for S -parameter.



(a)



(b)

Figure 5. Simulated and measured S -parameters: (a) S_{31} and S_{21} , and (b) S_{11} and S_{41} .

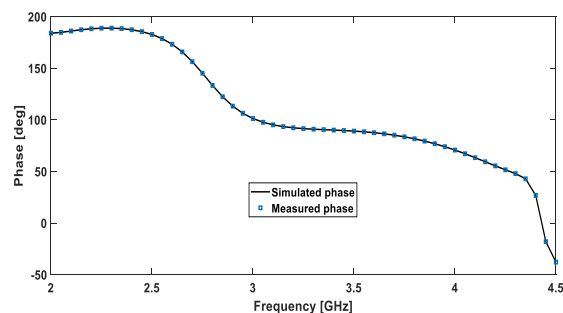


Figure 6. Measured phase difference between Port 3 and Port 4.

Fig 6 gives the measured responses of the coupler. The measurement results shows that the branch line coupler can operate at $f = 3.26$ GHz which are selected as the operating frequency.

The comparison of the performances of the proposed coupler is summarized in Table 1.

Table 1 Performance of Branch line meandered Coupler.

| | Frequency GHz | S21 dB | S31 dB | S41 dB | S11 dB | Phase Diff | $ S_{41} - S_{31} $ $\leq \pm 1dB$ |
|-------------|------------------|-----------|-----------|-----------|-----------|---------------|---|
| Simulation | 3.30 | -33.04 | -1.74 | -6.45 | -42.74 | -90.87° | 4.71 |
| Measurement | 3.26 | -42.41 | -2.29 | -6.40 | -25.39 | -91.22° | 4.11 |

The frequency shifting may be caused by weld of SMA connectors.

At the center frequency of 3.26 GHz, the return loss S11 is -25.39 dB and the isolation S21 is -42.41 dB.

In the range of bandwidth, the insertions losses and S31 is -2.29 dB, it is under -3 dB and S41 is - 6.40 dB. Above all, the fabricated coupler only occupies 23×34.6 mm² which work at the center frequency of 3.26 GHz. Measured phase difference between Port 3 and Port 4 is 91.22° at operating bandwidth, shown in Fig. 6.

This study proves that we improved the transmission characteristic that can reach -1.74 dB. For miniaturization, the design and manufacture of the device operating in 3.30 GHz has been completed for WLAN applications.

we allowed ourselves to compare our work with that presented in [8]. this study was published in 2017. The following table shows the results of the comparison:

Table 2. Comparison between our results and those published in [8].

| Reference | [20] | This work |
|-------------------------------------|---------|-----------|
| Operating frequencies (GHz) | 2.52 | 3.26 |
| Isolation (dB) - | > 20 dB | - 42.41 |
| Insertion loss (dB) | -4.5 | -2.29 |
| Coupling loss (dB) | -2.8 | -6.40 |
| Phase difference | -92.8° | -91.86° |
| Perfect transmission characteristic | medium | better |
| Perfect impedance matching | No | Yes |

we can notice that the results obtained in this work is better than those cited in [8].

III. CONCLUSION

In this paper, a new miniaturized compact coupler is proposed. The main purpose of this study is used meander

transmission-line to replace the shunt arms of the classical coupler. The performance of the coupler was measured for 3.26 GHz operating frequency. The model of meander line was investigated for miniaturization.

The simulated and measured results are agreement which demonstrates the efficiency of numerical simulation using the HFSS. This work made it possible to highlight the feasibility of the realized microwave coupler

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