ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

A Coupler with High Directivity and Strong Coupling Using Coupled Lines

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Manuscript Info

Manuscript History:

Received: 15 June 2014
Final Accepted: 25 July 2014
Published Online: August 2014

Key words:
High Directivity, Strong Coupling, Microstrip, Coupled line, Advance Design System

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Abstract

A new symmetrical coupler with high directivity and strong coupling is proposed using microstrip coupled lines. It can be used in a various RF combining, power splitting and sampling applications. The proposed coupler structure is very simple to fabricated using single-layer PCB. This coupler is designed using RT/duroid material having dielectric constant 2.2. The operating frequency is chosen as 2.1 GHz. The simulation has been done using Advance Design System (ADS) software. The simulated results show that it has good return loss, high directivity and good coupling.

Introduction

Microstrip coupled-line couplers are widely used for the designs of various balanced power amplifiers, mixers, modulators, measurement systems, circularly polarized antennas, beam-forming array antennas, etc [1].

Generally, traditional microstrip coupled-line couplers provide very low coupling and very poor directivity. To achieve a strong coupling and high directivity in microstrip coupled-line couplers, several methods have been studied. But these methods put extra burden such as extra connecting wires, extra capacitor and inductors on the circuit and do not provide strong coupling and high directivity together [2]-[5].

In this paper, a novel coupled-line coupler with strong coupling coefficient and high-directivity is proposed. It can be fabricated using single layer PCB.

I. COUPED LINE COUPLER

Couplers are passive devices which couple a part of the transmission power by a fixed amount out through another port, often by using two transmission lines placed close together such that energy flowing through one transmission line is coupled to the other transmission.

When two unshielded transmission lines are in close proximity, power can be coupled from one line to the other due to the interaction of the electromagnetic fields. Such lines are referred to as coupled transmission lines [6]. These coupled lines can be used to design couplers and this type of coupler is called coupled line coupler. In this paper the coupler is designed using microstrip lines.

The following quantities are commonly used to characterize a coupler

$$\text{Coupling} = \text{C (dB)} = -20\log S_{31}\ \text{dB}$$

$$\text{Isolation} = \text{I (dB)} = -20\log S_{41}\ \text{dB}$$

$$\text{Directivity} = \text{D (dB)} = 20\log\frac{S_{31}}{S_{41}}\ \text{dB}$$

$$\text{Insertion Loss} = \text{IL (dB)} = -20\log S_{21}\ \text{dB}$$

Here S_{21}, S_{31}, S_{41} are scattering parameters. S_{21} shows output from the port 2 when we apply signal on port 1. S_{31} shows output at port 3 when signal is applied on the port 1. S_{41} shows output at port 4 when we apply signal at port 1.

II. DESIGN AND SIMULATION

A. Designing of coupler

The proposed coupler has single layered structure and does not require any bonding wires, any capacitance and inductance to improve directivity or coupling. So it is easy to fabricate. For designing this coupler we have chosen a substrate RT/duroid, which have dielectric constant 2.2 and thickness 2 mm. The proposed coupler has two coupled line section one in vertical direction and other in horizontal direction.

This coupler has symmetry along the horizontal and vertical directions. So we can calculate even and odd characteristic impedance of each section of coupled by even–odd decomposition method described in [7] and [8].

In *even mode*, the currents in the strip conductors are in the same direction and equal in amplitude and in *odd mode*, the currents in the strip conductors are equal in amplitude but in opposite directions.

The designing steps for this coupler are as follows:

1) Find the power-dividing coefficient and the center frequency required for the design [1].
2) Choose even and odd mode characteristic impedance of first section of coupled line (horizontal) and electrical length of second section of coupled line (vertical) [1].
3) Calculate even and odd mode characteristic impedance of second section of coupled line (vertical) using equations given in reference number [1].
4) Convert all these electrical parameters into physical dimensions using line calculator in ADS and simulate the scattering parameters and phase information by using ADS.
5) l_n is the length of the 50Ω port and can be chosen freely as per requirements of the design[1].
6) Tune the physical dimensions including w_1, w_2, and S to obtain high directivity without affecting the coupling and matching performance.

The physical dimensions of the coupler are:
$w_1 = 2.8$ mm,
$w_2 = 1.8$ mm ,
$w_n = 5.4$ mm ,
$l_1 = 25$ mm ,
$l_2 = 14$ mm ,
$l_n = 18$ mm ,
$S = 0.4$ mm

III. RESULTS

The simulated results show that the return loss is around 60dB, coupling is 5 dB, and directivity is around 52 dB at 2.124 GHz. The phase difference between the two output ports is about 90^0 over a wide range from 1.8 to 2.4 GHz.

For this coupler we got highest directivity around 55 dB at 2.13 GHz and strongest coupling 4.965 dB at 2.199 GHz.

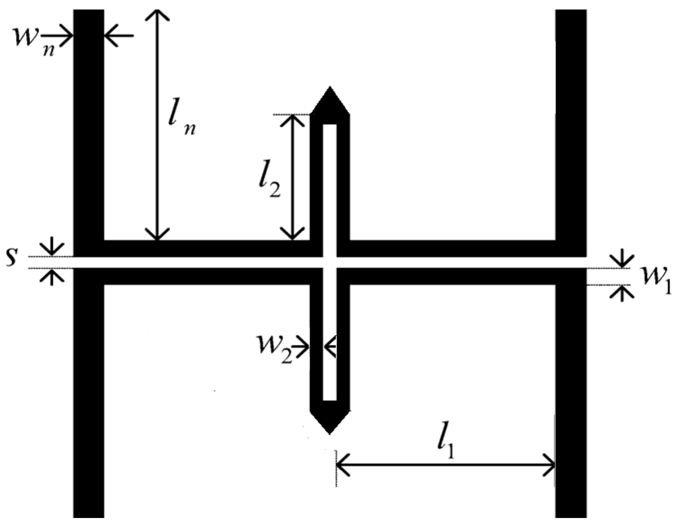

Fig. 1 Layout of the Proposed Coupler

A. Simulation of Coupler

Simulation of the coupler is done using Advance Design System (ADS) software.

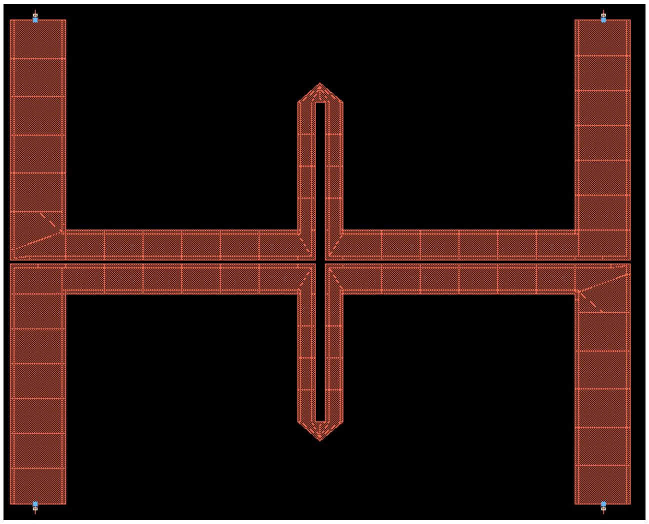

Fig. 2 Layout of Proposed Coupler in ADS

After simulation of proposed coupler using Advance Design System (ADS) software, we get following simulation results:

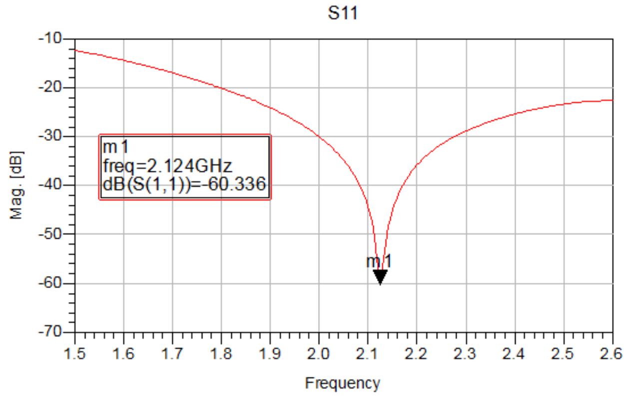

Fig. 3 Rerurn Loss of Coupler

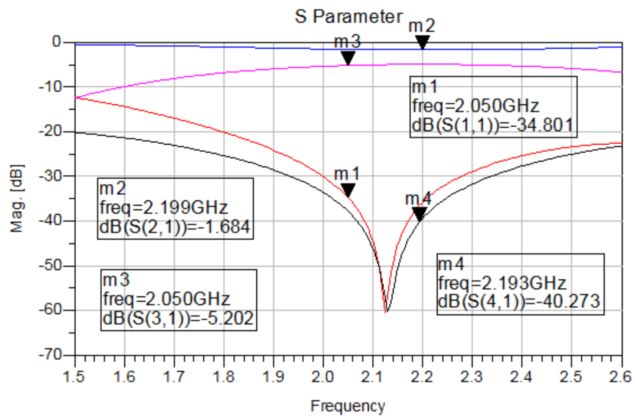

Fig. 4 S Parameters of Proposed Coupler

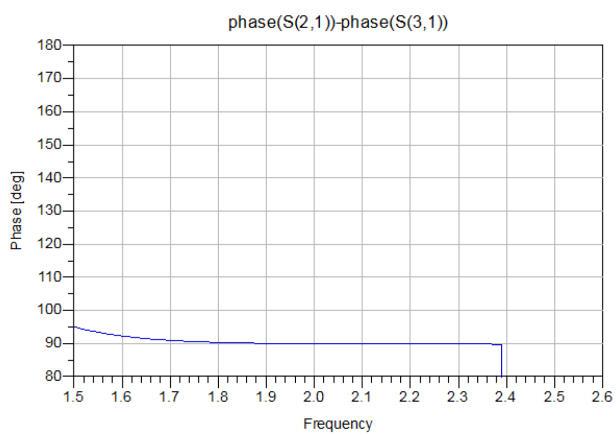

Fig. 5Phase Difference between two output ports of
Proposed Coupler

IV. CONCLUSION

A new coupler using coupled-line has been proposed in this paper. The simulated results show that return loss, coupling, and directivity are good. The highest simulated return loss is around 60 dB, coupling around 5 dB and directivity is 52 dB at 2.1 GHz. This frequency is used in Universal Mobile Telecommunications System. So this coupler can be used in mobile communication. The circuit structure of this coupler is very simple and easy to fabricate.

ACKNOWLEGMENT

The authors would like to thank Dr. Priyanka Jain, Assistant Professor, Department of Electronics and Communication, Delhi technological University, Delhi for her support and encouragement.

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