

Certificate

This is to certify that the dissertation titled “*Design of Microstrip Line Coupler with Improved Directivity*” is the authentic work of **Ms. Ayushi Barthwal** under my guidance and supervision in the fulfillment of requirement towards the degree of Master of Technology in Microwave and Optical Communication Engineering, jointly under the Deptt. of Electronics and Communication Engineering and Deptt. of Applied Physics in Delhi Technological University. The contents of this thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

Dr. Priyanka Jain
Supervisor
Assistant Professor
Deptt. of ECE
Delhi Technological University

Prof. Rajeev Kapoor
HOD
Deptt. of ECE
Delhi Technological University

Acknowledgement

The completion of this project has come through the overwhelming help that came from many people. I wish to express my sincere gratitude to all the people who offered their kind help and guidance throughout my project period.

The foremost special thanks should be dedicated to my supervisor, Dr. Priyanka Jain, who has continuously supported me to research in the new areas related to microwave. She always encourages and advises me to solve many technical problems and tries to provide me with best research environment.

I would also like to express my sincere gratitude to Prof. Rajiv Kapoor, HOD Electronics & Communication Department and Prof. R.K. Sinha, HOD Applied Physics Department for giving me invaluable expert knowledge and intelligence about the field.

I would like to thank Dr. Ajeet Kumar, Applied Physics department for constantly monitoring my thesis work.

Finally I express my deep sense of gratitude to my parents and almighty God for their blessings without which this project was not possible.

Ayushi Barthwal

M.Tech (MOC)

01/MOC/2010

Table of Contents

Certificate	ii
Acknowledgement	iii
Table of contents	iv
List of figures	vi
List of symbols	viii
Abstract	x
Chapter 1	
Introduction	
1.1 Thesis Outline	2
Chapter 2	
Review of Microstrip Lines	
2.1 Planar Transmission Structures	3
2.2 Two Port Parameters	
2.2.1 The Scattering Matrix	5
2.2.2 The Transmission (ABCD) Parameters	8
2.3 Microstrip Line	
2.3.1 The Quasi-TEM Mode of Propagation	9
2.3.2 Static-TEM Parameters	10
2.3.3 Effect of Finite Microstrip Thickness on Characteristic Impedance	14
2.3.4 Losses in Microstrip Lines	16
Chapter 3	
Parallel Coupled Microstrip Lines and Directional Coupler	
3.1 Introduction	19
3.2 General Analysis of Coupled Lines	
3.2.1 Methods of Analysis	20
3.2.2 Coupled Line Theory	21
3.2.3 Coupled Mode Approach	23

Chapter 4	
Design of Directional Coupler and Its Directivity Improvement	
4.1 Design of Directional Coupler	35
4.2 Parameters of Directional Coupler	40
4.2 Improvement in Directivity of Directional Coupler	41
Chapter 5	
Design and Simulation of Microstrip Directional Coupler	
5.1 Design Specifications	44
5.2 Calculations and Schematic Diagram	45
5.3 Layout of Directional Coupler	49
5.4 Design of Modified Directional Coupler	51
Chapter 6	
Conclusion	54
References	55
Appendix	58

List of Figures

Figure	Title	Page
2.1	Microstrip Line	3
2.2	Slotline	4
2.3	Coplanar waveguide	4
2.4	Coupled Microstrip Line	4
2.5	Incident and Reflected voltages in two port network	5
2.6	ABCD parameters of two-port network	8
2.7	Microstrip transmission line	
	(a) Geometry	9
	(b) Electric and Magnetic field lines	9
2.8	Changes in the distribution of electric field (transverse cross-section) as a thickness of microstrip is altered	14
3.1	A pair of parallel edge-coupled microstrip line	19
3.2	Even and Odd mode analysis of Coupled Microstrip Lines	20
3.3	Equivalent Diagram of Coupled Microstrip Lines	22
3.4	Even Mode Excitation	22
3.5	Odd Mode Excitation	23
3.6	Parameters of coupled transmission lines. (a) The total voltages that result when port 1 is excited by an input signal. (b) the even mode voltages, and (c) the odd mode voltages	28
3.7	Electric field lines shown in the Even-mode and Odd Mode for parallel coupled microstrip transmission lines	29
3.8	Parameters for terminated transmission line	30
4.1	A typical Wiggly Line Coupler	42
5.1	Dimensions calculated using Agilent ADS Linecalc	45
5.2	Schematic Diagram for the Physical Parameters calculated	46
5.3	Simulation results of designed directional coupler	46
5.4	(a) Tuning of parameters	47
	(b) Simulation results of tuned coupler	47

5.5	Updated Schematic	48
5.6	Layout of Directional Coupler with specified Physical Parameters	49
5.7	Defining Substrate Parameters	49
5.8	Simulation Control Window	50
5.9	S-parameters of the coupler designed	50
5.10	Physical Dimensions shown of the modified Directional Coupler	51
5.11	Layout of Modified Directional Coupler	52
5.12	Coupling and Isolation of Modified Directional Coupler	52
5.13	Forward Transmission parameter S_{21} of directional coupler	53
5.14	S_{21} and S_{42} parameter of modified directional coupler	53

List of Symbols

ABCD	A, B, C, D transmission parameters of two port network
c	velocity of light
C	Capacitance per unit length
C	coupling in dB
C_e	even mode capacitance of coupled microstrip line
C_o	odd mode capacitance of coupled microstrip line
C_p	parallel plate capacitance
C_f	fringing capacitance
D	Directivity
f	operational frequency
G	conductance per unit length
h	height of substrate
I_n	current at port n
I	Isolation of Directional Coupler
l	length of microstrip
L	inductance per unit length
q	filling factor
S	S-parameters
s	Space between coupled microstrip lines
t	thickness of strip
v_p	phase velocity of wave
V_n	Terminal voltage of port n
w	width of microstrip
w_e	effective width of microstrip when thickness of strip is finite
Y	characteristic admittance
Z_{01}	terminal impedance of microstrip in the absence of air
Z_0	characteristic impedance
Z_{0e}	even mode impedance
Z_{0o}	odd mode impedance

α	attenuation of medium
ϵ_r	relative permittivity
ϵ_0	permittivity of free space
ϵ_{eff}	effective microstrip permittivity
λ	operational wavelength
θ	electrical length of microstrip line
ω	angular frequency
μ	permeability of conductor
μ_0	permeability of free space
σ	conductivity of medium

Abstract

In this project, a symmetrical microstrip line directional coupler has been designed using the synthesis technique. The introduced design procedure does not require the prior knowledge of the physical geometry of the coupler and requires only the information of the port impedances, coupling level, and operational frequency. The width of coupled microstrip lines, spacing between them and length of the coupler is then determined.

The directivity of the conventional coupler designed is improved by bringing the changes in the physical geometry of the coupler by phase velocity compensation, which utilizes the coupled microstrip with square wiggles on its inner edges.

In this project, a directional coupler has to be designed at the operational frequency of 1.5GHz with the coupling of -15dB. The width, length and spacing of coupled microstrip line are calculated with the help of Agilent ADS linecalc and then S-parameters of this coupler are calculated. The layout is plotted down in the layout window and is simulated. Then, the changes in the geometry of the coupler are made in order to improve the isolation and thus the directivity. The change in geometry raises the odd mode inductance more strongly than that of even mode and this results in phase velocity compensation between even- and odd-modes.

The coupler is designed on Rogers-R03210 substrate with dielectric constant of 10.2 and thickness of 0.5mm. The simulations are carried out with the help of software *Agilent Advanced Design System 2008*.