

DESIGN OF GEOMETRICAL ARRAY MICROSTRIP ANTENNA

SHAH ERAWATI BINTI MOKHTAR

This report is submitted in partial fulfillment of requirements for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) with honours

Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka

April 2007



UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : DESIGN GEOMETRICAL ARRAY MICROSTRIP
ANTENNA
Sesi Pengajian : 2006/2007

Saya **SHAH ERAWATI BINTI MOKHTAR**
(HURUF BESAR)

mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan () :

SULIT*

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD*

(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD


(TANDATANGAN PENULIS)

Alamat Tetap: No. 50, Kg. Tersusun Batu 5,

Kg. Pengkalan Baru,

31300 Kg. Kepayang, Perak

Tarikh: 27 April 2007

Disahkan oleh:



(COP DAN TANDATANGAN PENYELIA)

Mohamad Zainol Abidin B Abd Aziz
Pensyarah
Fakulti Kejuruteraan Elektronik dan Komputer (FKEKK)
Universiti Teknikal Malaysia Melaka (UTeM)
Karung Bekunci 1200
Ayer Keroh 75450 Melaka

Tarikh:

14/05/07


"I hereby declare that this report is the result of my own work except for quotes as cited in the references".

Signature : 

Author : Shah Erawati Binti Mokhtar

Date : 27 April 2007

“I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of Bachelor of Electronic (Telecommunication Electronics) with honours”.

Signature : 

Supervisor's Name : Mohamad Zoinol Abidin Bin Abd Aziz

Date : 27 April 2007

To My Loving and Parents

ACKNOWLEDGEMENTS

My first thanks for my supervisor, Mr. Mohamad Zoinol Abidin Bin Abd. Aziz, whose constant support, patience and unbounded enthusiasm were of invaluable help. His devotion to the needs of the students and the encouragements have made working with him a true delight. Thanks for helping me to kick start this research by providing insights and his work as reference.

My sincere thankful to fellow friends in time spend sharing the similar research interests. I appreciated with the concern of helping me in enriching ideas in this project. My gratitude especially goes to Abd Syukur, Mohd Rifdi, and Jamunarani for many hours of discussions, as well as assistance during designing and fabrication process.

My sincere thanks to all those who is helping me in completely finish this thesis possible. Warmest regards to my mother, father, sister and brother for their seamless caring encouragement and moral support that has made this journey possible.

ABSTRACT

Wireless communication has experienced an enormous growth since it allows users to access network services. WLAN is the most rapid evolution and wide popularity in standard developed by IEEE (Institute of Electrical and Electronics Engineers). The 2.4 GHz and 5.2 GHz frequency is user in WLAN network. This project presents the design of geometrical array using microstrip antenna. The special of requirements microstrip antenna required it for designing the array concept. It is also one of the fastest growing segments in the telecommunication industry. It have proved that the microstrip antenna have their own unique characteristics that improved the telecommunication industry. Design geometrical array microstrip antenna can achieve the higher gain and broader bandwidth. The project design using three types of geometrical antenna, such as rectangular patch, triangle patch and circular patch antenna. The antenna is designed at the frequencies 2.4 GHz, 5.2 GHz, and 5.8 GHz. The behavior of each type antennas are investigate such as return loss, radiation pattern, bandwidth, half power bandwidth (HPBW), first null bandwidth (FNBW) and gain. The project are includes the simulation process, fabrication process and testing. According to the single element, triangle shapes show the efficiency of return loss of -27.02 dB and largest percentage of bandwidth. Circular shape shows the higher of gain. In array configuration, the 2 x 4 array of rectangular shows higher of return loss compare to 1 x 2 and 1 x 4 array configuration. The 1 x 2 and 1 x 4 array configuration shows that circular shape shows the good of return loss, higher in gain and percentage of bandwidth.

ABSTRAK

Komunikasi tanpa wayar mula berkembang sejak perkhidmatan rangkaian *access* diperkenalkan. Perkhidmatan Rangkaian Tempatan (WLAN) berkembang pesat dan meluas selaras dengan Institut Kejuruteraan Elektrik dan Elektronik (IEEE). Frekuensi yang digunakan dalam WLAN adalah 2.4 GHz, dan 5.2 GHz. Tajuk projek ini adalah rekabentuk *array* geometri menggunakan microstrip antenna. Keistimewaan microstrip antenna adalah dimana ia boleh direkabentuk dalam konsep *array*. Teknik ini merupakan teknik yang berkembang luas digunakan dalam industri telekomunikasi. Rekabentuk geometri *array* antenna boleh meningkatkan gandaan dan menghasilkan *bandwidth* yang luas. Rekabentuk projek ini menggunakan tiga bentuk geometri antenna iaitu bentuk segiempat tepat, segitiga dan sfera. Antenna ini di rekabentuk pada frekuensi 2.4 GHz, 5.2 GHz, and 5.8 GHz. Setiap antenna akan dikaji dari segi *return loss*, *radiation pattern*, *bandwidth*, *half power bandwidth (HPBW)*, *first null bandwidth (FNBW)* and *gain*. Projek ini mengandungi proses simulasi, proses fabrikasi dan ujikaji. *Single element antenna* menunjukkan bentuk segitiga menghasilkan kehilangan kuasa paling minimum iaitu pada -27.02 dan peratus lebar jalur paling tinggi (*bandwidth*). Bentuk sfera menghasilkan gandaan paling tinggi. Rekabentuk segiempat tepat gabungan 2 x 4 menghasilkan kehilangan yang minimum iaitu pada -17.5 dB berbanding bentuk gabungan 1 x 2. Rekabentuk segitiga gabungan 2 x 4 menghasilkan kehilangan paling minimum berbanding dengan rekabentuk struktur 1 x 2. Rekabentuk circular gabungan 1 x 2 dan 1 x 4 menghasilkan kehilangan yang minimum, gandaan yang tinggi dan peratus lebar jalur paling tinggi.

CONTENTS

CHAPTER	TITLE	PAGE
	TITLE	
	REPORT STATUS	
	DECLARATION	iii
	DECLARATION	iv
	DEDICATION	v
	ACKNOWLEDGEMENTS	vi
	ABSTRACT	vii
	ABSTRAK	viii
	TABLE OF CONTENTS	ix
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF APPEDICES	xvi
	LIST ABBREVIATIONS	xvii
I	INTRODUCTION	
	1.1 Introduction	1
	1.2 Objectives	1
	1.3 Scope of Work	2
II	BACKGROUND STUDY	
	2.1 Introduction	3
	2.2 Basic Microstrip	3

2.3	Feeding Technique	6
2.4	Analysis of Microstrip Antenna	7
2.4.1	Rectangular Patch	7
2.4.2	Triangle Patch	10
2.4.3	Circular Patch	11
2.5	Array	12
III	METHODOLOGY	
3.1	Designing Process	18
3.2	Single Element Antenna Design	21
3.3	Array Antenna Design	30
3.4	Fabrication Process	36
3.5	Design Flow Chart	39
IV	RESULT ANALYSIS & DISCUSSION	
4.1	Introduction	40
4.2	Single Element Antenna	41
4.2.1	Rectangular Patch Parameter	41
4.2.2	Triangle Patch Parameter	47
4.2.3	Circular Patch Parameter	53
4.3	Array Microstrip Antenna	60
4.3.1	The 1 x 2 Array Configuration Microstrip Antenna	60
4.3.2	The 1 x 4 Array Configuration Microstrip Antenna	66
4.3.3	The 2 x 4 Array Configuration Microstrip Antenna	70
4.3.4	The 4 x 4 Array Configuration Microstrip Antenna	73
V	DISCUSSION AND CONCLUSION	

5.1	Discussion	75
5.2	Conclusion	75
5.3	Future Works	76
	REFERENCES	77
	APPENDIX A	81
	APPENDIX B	93

LIST OF TABLES

TABLE	DESCRIPTION	PAGE
3.1	Calculated dimensions of the rectangular patch	23
3.2	Calculated dimensions of the triangle patch	26
3.3	Calculated dimension of circular patch antenna	28
3.4	Width and Length using the Wilkinson Power Divider	31
4.1	Calculated dimensions of the rectangular patch	41
4.2	Modified dimension of the rectangular patch	42
4.3	Analysis the rectangular patch antenna	42
4.4	Measurement of return loss	46
4.5	Calculated dimensions of the triangle patch.	47
4.6	Modified dimensions of the triangle patch.	48
4.7	Analysis of triangle patch antenna characteristics	48
4.8	Measurement of return loss	52
4.9	Calculated dimensions of the circular patch.	53
4.10	Modified dimensions of the triangle patch.	53
4.11	Analysis for circular patch antenna	54
4.12	Measurement result of return loss	57
4.13	Analysis the 1 x 2 array	60
4.14	Measurement result	60
4.15	Analysis the 1 x 4 array	62
4.16	Measurement result	65
4.17	Analysis the 1 x 4 array configuration	67
4.18	Analysis the 1 x 4 of rectangular shape array configuration	71

LIST OF FIGURE

FIGURE	DESCRIPTION	PAGE
2.1	(a) Basic structure of microstrip	4
	(b) Electric field on microstrip line	4
2.2	Structure of Microstrip Patch Antenna	4
2.3	Representative shapes of microstrip patch antenna	5
2.4	Physical and effective lengths of rectangular microstrip patch	8
2.5	Layout of the rectangular patch	10
2.6	Layout of the triangle	10
2.7	Layout or the circle patch	11
2.8	An equal-split power divider in microstrip form	14
2.9	Equivalent transmission line circuit	16
3.1	Wilkinson power divider	19
3.2	The 1 x 2 microstrip patch antenna array	19
3.3	Setting the Substrate Information (a) Enclosure setting, (b) Dielectric Layer, (c) Boundaries and (d) View layout in 3D	20
3.4	Setting the range of frequency and measurement of graph	21
3.5	Width and length using the TXLINE	22
3.6	Layout of the rectangular patch	23
3.7	Rectangular Patch Antenna Parameter at frequency 2.4 GHz.	24
3.8	Return Loss at -14.43 dB	24
3.9	Layout of the triangle	25

3.10	Triangle Schematic View	26
3.11	Triangle Patch Antenna Design at Frequency 2.4 GHz	27
3.12	Layout of the circular patch antenna	28
3.13	Setting the parameter of Circular	29
3.14	Dimension of Circular Patch Antenna at frequency 2.4 GHz	29
3.15	(a) Array Element and (b) Array Structure of Wilkinson Power Divider	30
3.16	Calculation Width and Length at characteristics impedance (Z_0) at 50 ohm and 70.71 ohm.	31
3.17	Circuit Schematic in New Schematic Layout View	32
3.18	Wilkinson Power Divider Circuit Schematic	33
3.19	The -3 dB at frequency 2.4 GHz	34
3.20	Angle between output and input port	34
3.21	Array Structure (a) 1 x 2 array, (b) 1 x 4 array and (c) 1 x 4 Geometrical array	35
3.22	Ultra Violet Ray Exposed	36
3.23	Etching Machine	37
3.24	Stripper Machine	38
3.25	Project Methodology Flow Chart	39
4.1	Layout of the Rectangular Patch	41
4.2	Return Loss (a) 2.4 GHz, (b) 5.2 GHz and (c) 5.8 GHz	43
4.3	Radiation pattern at (a) 2.4 GHz, (b) 5.2 GHz and (c) 5.8 GHz	45
4.4	Layout of the triangle	49
4.5	Return Loss (a) 2.4 GHz, (b) 5.2 GHz and (c) 5.8 GHz	48
4.6	Radiation Pattern (a) 2.4 GHz, (b) 5.2 GHz and (c) 5.8 GHz	51
4.5	Layout the circle patch	53
4.6	Return Loss (a) 2.4 GHz, (b) 5.2 GHz, and (c) 5.8 GHz	55
4.7	Radiation pattern (a) 2.4 GHz (b) 5.2 GHz and (c) 5.8 GHz	56
4.8	Result of return loss by adjusting the width and length of rectangular patch antenna at frequency 2.4 GHz.	58

4.9	(a) Rectangular, (b) Triangle and (c) Circular in 1 x 2 Array Microstrip Antenna	61
4.10	Return loss of 1 x 2 array in (a) Rectangular, (b) Triangle and (c) Circular shape	63
4.11	Radiation pattern of 1 x 2 array (a) Rectangular, (b) Triangle and (c) Circular shape	64
4.12	(a) Rectangular, (b) Triangle and (c) Circular in 1 x 2 array antenna	66
4.13	Return loss of (a) Rectangular, (b) Triangle and (c) Circular in 1 x 2 array	68
4.14	Radiation pattern of 1 x 2 array (a) Rectangular, (b) Triangle Circular 1 x 4 array	69
4.15	Layout of 2 x 4 array configuration (a) Structure 1 (b) Structure 2	70
4.16	Return loss of 2 x 4 array (a) Structure 1 (b) Structure 2	71
4.17	Radiation pattern of 2 x 4 array (a) Structure 1 (b) Structure 2 configuration	72
4.18	Layout of 4 x 4 array configuration	73
4.19	Layout of 4 x 4 array configuration	73

LIST OF APPENDICES

APPENDIX	DESCRIPTION	PAGE
A	Microstrip antenna calculation	72
B	Gant Chart	84

LIST OF ABBREVIATIONS

SYMBOLS	DESCRIPTION
w	Width
h	Dielectric thickness
t	Copper thickness
ϵ_r	Dielectric Constant
Z_0	Characteristics impedance
ΔL	Dimensions of the patch along its length
w/h	Width-to-height ratio
ℓ	Inset feed
a	Radius
f_r	Frequency
IEEE	(Institute of Electrical and Electronics Engineering)
WLAN	Wireless Local Area Network
MW2004	Microwave Office 2004
FR4	Frame Resistance 4

CHAPTER 1

INTRODUCTION

1.1 Introduction

This project discussed the design of geometrical array antenna using microstrip technology. The microstrip antenna is one of the fastest growing segments in the telecommunication industry. Microstrip antennas are low profiles, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology. Microstrip antenna consists of dielectric substrate, radiated patch and antenna ground plane. The microstrip antennas have disadvantage which narrow bandwidth and low gain.

1.2 Objectives

The objective of this project is to study the concept of the basic geometrical array microstrip antenna. This project involved the designed and fabrication of the three geometrical shapes such as rectangular, triangle and circular. Each geometrical shape will be designed in single element and array technique. The antenna is design to have higher gain and broader bandwidth.

1.3 Scopes of work

The first scope of the project is to study the concept of microstrip array antenna of broad band communication. The calculation of the parameter for rectangular, triangle and circular patch antenna will be studied. The simulation processed has been done by using microwave 2004. Then, the comparison between calculation and simulation will be investigated. The calculation has been done at frequency 2.4 GHz, 5.2 GHz, and 5.8 GHz. Then, the antenna is designed at 1 x 2, 1 x 4 and 4 x 4 array. Finally, the characteristics of the antenna such as return loss, gain, bandwidth and radiation pattern will be investigated.

CHAPTER II

BACKGROUND OF STUDY

2.1 Introduction

Microstrip antenna was a simple antenna that consists of radiated patch component, dielectric substrate and ground plane. The radiated patch and ground plane is a thin layer of cuprum or gold which is good conductor. Each dielectric substrate has their own dielectric permittivity value. This permittivity will influence the size of the antenna. Microstrip antenna is a low profile antenna, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology. They have several advantages light weight, small dimension, cheap, conformability and easily to integrate with other circuit make it is chosen in many applications [6].

2.2 Basic Microstrip Antenna

Microstrip antennas received considerable attention starting in the 1970s, although the idea of a microstrip antenna can be traced to 1953 [1] and a patent in 1955 [2]. Figure 2.1 and Figure 2.2 show the basic structure of microstrip structure. Bottom

layer of dielectric substrate is fully covered by conductors that act as a ground plane. The thickness of substrate layer can increase the bandwidth and efficiency, but unfortunately it will generate surface wave with low propagation that cause lost of power. It is consists of a very thin metallic strip (patch) placed a small fraction of a wavelength above a ground plane [6].

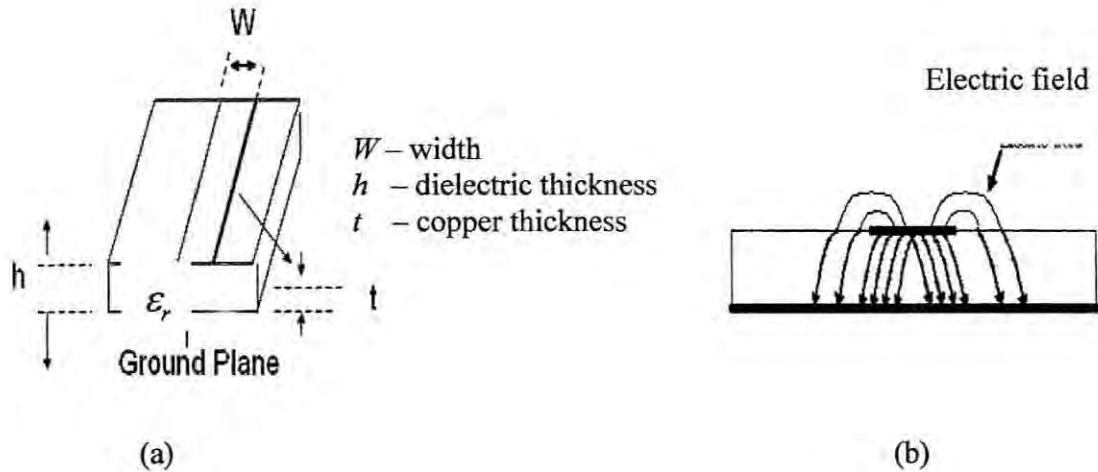


Figure 2.1 : (a) Basic structure of microstrip and (b) Electric field on microstrip line

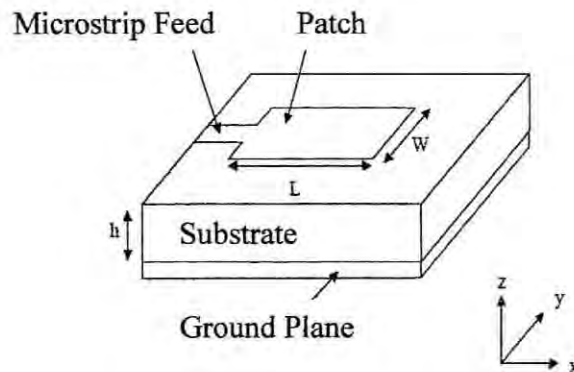


Figure 2.2 : Structure of Microstrip Patch Antenna

There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants (ϵ_r) are usually in the range of $2.2 \leq \epsilon_r \leq 12$. The ones that are most desirable for antenna performance are thick substrates whose

dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size [7].

Thin substrates with higher dielectric constant are desirable for microwave circuitry because they require tightly bound fields to minimize undesirable radiation and coupling, and lead to smaller element sizes. However, because of their greater losses, they are less efficient and have relatively smaller bandwidths [7]. Often microstrip antennas are also referred to as patch antennas. The radiating elements and the feed lines are usually photoetched on the dielectric substrate. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular or any other configuration as shown in Figure 2.3.

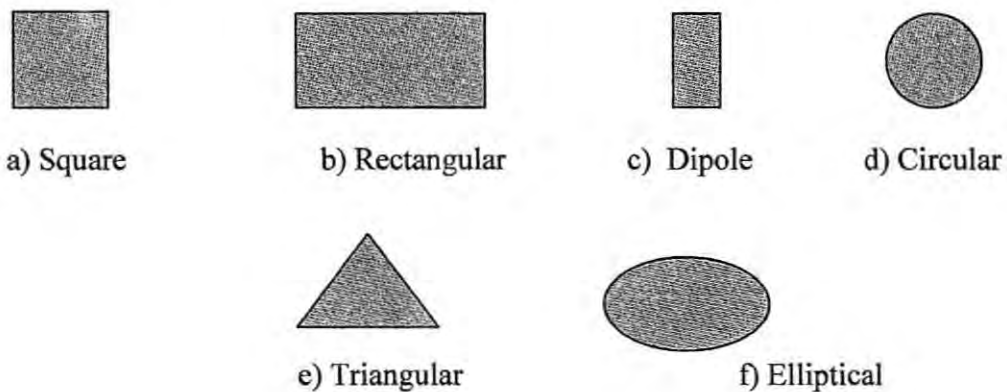


Figure 2.3 : Representative shapes of microstrip patch antenna

Square, rectangular, dipole (strip), and circular are the most common because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. Microstrip dipoles are attractive because they inherently possess a large bandwidth and occupy less space, which makes them attractive for arrays [8], [9]. Linear and circular polarizations can be achieved with either single elements or arrays of microstrip antennas. Arrays of microstrip elements with

single or multiple feeds, may also introduce scanning capabilities and achieve greater directivities.

The effective dielectric constant (ϵ_r), of a microstrip line is given approximately by [10]

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12 \left(\frac{d}{w} \right)}} \right) \quad 2.1$$

The effective dielectric constant (ϵ_r) can be interpreted as the dielectric constant of a homogeneous medium that replaces the air and dielectric regions of the microstrip given the dimensions of the microstrip line. The characteristics impedance (Z_0) can be calculated as [10];

$$Z_0 = \begin{cases} \frac{60}{\sqrt{\epsilon_{eff}}} \ln \left(\frac{8h}{w} + \frac{w}{4h} \right) & \text{For } w/h < 1 \\ \frac{120\pi}{\left[\frac{w}{h} + 1.393 + 0.667 \ln \left(\frac{w}{h} + 1.444 \right) \right] \sqrt{\epsilon_{eff}}} & \text{For } w/h > 1 \end{cases} \quad (2.2)$$

2.2 Feeding Techniques

Feeding techniques are important in designing the antenna to make sure antenna structure can operate at full power of transmission. Designing the feeding techniques for high frequency, need more difficult process. It is because of input loss on feeding increase depending on frequency, and finally given huge effect on overall design. There are a few techniques that can be used. The technique is used in this project is microstrip line feed. It is easy to fabricate, simple to match by controlling the inset position and rather simple to model. However as the substrate thickness increases surface waves and

spurious feed radiation increase, which for practical designs limit the bandwidth (typically 2-5%) [7], [11], [12].

2.3 Analysis of Microstrip Antenna

There has several approached to analyze microstrip antenna. Among the favorite are transmission-line, cavity model, and full-wave analysis. Transmission line model are simple to analysis. It gives good interior behavior even though less precisely. In this project, the transmission line is used. The transmission line model is easiest of all, it gives good physical insight, but is less accurate and it is more difficult to model coupling [7], [8], [12].

2.4.1 Rectangular Patch

The rectangular patch is by far the most widely used configuration. It is easy to analyze using both the transmission-line and cavity models, which are most accurate for thin substrates [6], [13].

2.4.1.2 Transmission-Line Model

a) Fringing Effects

The dimensions of the patch are finite along the length and width so, the fields at the edges of the patch undergo fringing. Fringing process is making the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant is introduced to account for fringing and the wave propagation in the line.