

DESIGN OF SLOT X-POLARIZED MICROSTRIP PATCH ANTENNA AT ISM
BAND

MUHAMMAD SAUFI BIN ISMAIL

This Report Is Submitted In Partial Fulfillment Of Requirement For The Bachelor of
Electronic Engineering (Telecommunication Electronic) With Honours

Faculty of Electronic and Computer Engineering

Universiti Teknikal Malaysia Melaka

MAY 2011



UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : DESIGN OF SLOT X-POLARIZED MICROSTRIP PATCH
ANTENNA AT ISM BAND

Sesi Pengajian :

1	0	/	1	1
---	---	---	---	---

Saya MUHAMMAD SAUFI BIN ISMAIL 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 (\checkmark) :

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

Disahkan oleh:

(TANDATANGAN PENULIS)

(COP DAN TANDATANGAN PENYELIA)

Tarikh: 18 Mei 2011

Tarikh: 18 Mei 2011

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

Signature :
Name : MUHAMMAD SAUFI BIN ISMAIL
Date : 18 MAY 2011

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

Signature :

Supervisor's Name : MOHAMAD ZOINOL BIN ABD. AZIZ

Date : 18 MAY 2011

ACKNOWLEDGEMENT

All praises and thanks be to Allah (S.W.T), who has guided us to this, never could we have found guidance, were it not that Allah had guided us.

Words cannot express my gratitude towards my supervisor, Mr. Mohamad Zoinol Bin Abd. Aziz for the patience, humble supervision and fatherly advice I received from him in the course of this project. May the sky be your limits in all your future endeavors and may jannatul-firdaus be your abode in the hereafter.

Also, I would like to heartily thank the technician in the PSM Laboratory and Microwave Laboratory for constantly being helping hands during my laboratory sessions and of course to the rest of the staff, academic and non-academic wise.

Finally, my acknowledgement will be incomplete if I keep my family on support and help I received from all my friends.

ABSTRACT

This project is about design of slot X-polarized microstrip patch antenna at ISM band. Microstrip patch antenna is widely used in wireless communication system due to its advantages such as low electromagnetic coupling to human head and low cost. Due to the rapid development in various wireless communication systems, several methods have proposed to develop antenna with reduced size and enhanced frequency bandwidth to achieve the efficiency requirement of mobile systems. One of the methods proposed to increase the bandwidth is insert slot on the microstrip patch. This project will analyze the effects of slot when placed on the microstrip patch antenna. The parameter will be analyzed such as bandwidth, gain, directivity and radiation pattern. These parameters will show the performance of microstrip patch antenna when slot has inserted.

ABSTRAK

Projek ini adalah tentang merekabentuk antena slot X-polarized microstrip patch. Antena microstrip patch digunakan secara meluas dalam sistem telekomunikasi masakini disebabkan kelebihannya seperti kesan elektromagnetik rendah dan murah. Disebabkan pengembangannya semakin pesat dalam pelbagai sistem telekomunikasi, banyak kaedah dan teknik dicadangkan untuk mencipta antena dengan saiz yang kecil dan jalur lebar yang besar untuk mencapai kecekapan sistem telekomunikasi. Salah satu cara yang dicadangkan adalah meletakkan slot ke atas antena microstrip patch. Projek ini akan mengkaji kesan slot yang diletakkan ke atas microstrip patch. Parameter antena yang akan dikaji untuk melihat prestasi dan pencapaian antena X-polarized microstrip patch apabila diletakkan slot di atas microstrip patch adalah penggandaan, jalur lebar, directiviti dan corak radiasi.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	PROJECT TITLE	i
	STATUS REPORT CONFIRMATION FORM	ii
	APPROVAL SHEET	iii
	DECLARATION SHEET	iv
	ACKNOWLEDGEMENT	v
	ABSTRACT	vi
	ABSTRAK	vii
	TABLE OF CONTENTS	viii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS / SYMBOLS	xvi
	LIST OF APPENDICES	xvii
I	INTRODUCTION	1
	1.1 BACKGROUND	1
	1.2 PROBLEM STATEMENT	2
	1.3 OBJECTIVES	2
	1.4 SCOPE OF WORKS	3
	1.5 PROJECT METHODOLOGY	3

II	LITERATURE REVIEW	6
2.1	PARAMETER OF ANTENNA	6
2.1.1	Radiation Pattern	6
2.1.2	Directivity	10
2.1.3	Gain	10
2.1.4	Bandwidth	11
2.1.5	Polarization	12
2.1.5.1	Linear Polarized	13
2.1.5.2	Circular Polarized	14
2.1.5.3	Elliptical Polarized	15
2.2	MICROSTRIP PATCH ANTENNA	16
2.3	RECTANGULAR MICROSTRIP PATCH	21
2.4	QUARTER WAVELENGTH TRANSFORMER	24
2.4.1	Single Section	25
2.4.2	Multiple Section And Binomial Design	25
2.5	SLOT TYPES OF MICROSTRIP PATCH ANTENNA	26
2.5.1	U-Slot	27
2.5.2	C-Slot	28
2.5.3	Multiple Slots	29
2.5.4	Diamond Slot	29
2.5.5	Slot Loaded	30
2.5.6	Dual Slot	31
2.6	ISM BAND	31
III	METHODOLOGY	33
3.1	FLOW OF METHODOLOGY	33
3.2	MICROSTRIP PATCH ANTENNA DESIGN	33
3.2.1	Single Microstrip Patch Antenna	33

3.2.2	Microstrip Feed Line	34
3.2.3	Inset Feed	35
3.2.4	$\pm 45^0$ Polarized Microstrip Patch Antenna	36
3.2.5	X-Polarized Microstrip Patch Antenna	37
3.2.6	Slot Microstrip Patch Antenna	38
3.3	SIMULATION	41
3.4	FABRICATION PROCESS	45
3.5	MEASUREMENT PROCESS	46
IV	RESULT ANALYSIS AND DISCUSSION	47
4.1	RESULT ANALYSIS	47
4.2	SIMULATION	47
4.2.1	Single Microstrip Patch Antenna	47
4.2.2	$\pm 45^0$ Polarized Microstrip Patch Antenna	49
4.2.3	Slot Single Microstrip Patch Antenna	53
4.2.3.1	Vertical Slot Microstrip Patch	53
4.2.3.2	Horizontal Slot Microstrip Patch	54
4.2.3.3	Slant Slot Microstrip Patch	56
4.2.3.4	Double Slot Microstrip Patch	57
4.2.4	X-Polarized Microstrip Patch Antenna	59
4.2.5	Slot X-Polarized Microstrip Patch Antenna	61
4.2.5.1	X-Slot X-Polarized Microstrip Patch Antenna	61
4.2.5.2	T-Slot X-Polarized Microstrip Patch Antenna	63
4.2.5.3	Simulation Result For T-Slot X-Polarized Microstrip Patch Antenna	66

4.3	MEASUREMENT	68
4.3.1	X-Polarized Microstrip Patch Antenna	68
4.3.2	T-Slot X-Polarized Microstrip Patch Antenna	69
V	CONCLUSION AND RECOMMENDATION	71
5.1	CONCLUSION	71
5.2	RECOMMENDATION	72
	REFERENCES	73
	APPENDICES	77

LIST OF TABLES

TABLE	TITLE	PAGE
2.6	Frequency band in ISM band	32
3.2.6	Dimension microstrip patch	40
4.2.2	Comparison simulation result for single microstrip patch and $\pm 45^0$ polarized microstrip patch antenna	52
4.2.4	Simulation result for X-polarized microstrip patch antenna	61
4.2.5.3	Simulation result for T-slot X-polarized microstrip patch antenna	67
4.3.1	Measurement result for X-polarized microstrip patch antenna	69
4.3.2	Measurement result for T-slot X-polarized microstrip patch antenna	70

LIST OF FIGURES

FIGURE	TITLE	PAGE
1	Flow of methodology	5
2.1.1 (a)	Field pattern in linear scale	7
2.1.1 (b)	Power pattern in linear scale	7
2.1.1 (c)	Power pattern in dB scale	8
2.1.1 (d)	Radiation pattern	9
2.1.1 (3)	Linear plot of power pattern	9
2.1.4	Bandwidth	12
2.1.5	Propagation of wave	13
2.1.5.1	The propagation wave of linear polarized	14
2.1.5.2	The propagation wave of circular polarized	15
2.1.5.3	The propagation wave of elliptical polarized	16
2.2 (a)	Microstrip patch antenna	17
2.2 (b)	Side view	17
2.2 (c)	Shape radiating patch	18
2.2 (d)	Typical feeds for microstrip patch antennas	20
2.2 (e)	Equivalent for typical feeds	20
2.3 (a)	Single microstrip patch antenna	22
2.3 (b)	Microstrip feed line	23
2.3 (c)	Inset feed length	24
2.4	The quarter wavelength transformer	25
2.4.2	N-section $\lambda/4$ transformer	26

2.5.1	U-slot design	28
2.5.2	C-slot design	28
2.5.3	Multiple slots	29
2.5.4	Diamond slot design	30
2.5.5	Slot loaded design	30
2.5.6	Dual slot design	31
3.2.4	$\pm 45^0$ polarized microstrip patch antenna	37
3.2.5	X-polarized microstrip patch antenna	38
3.2.6 (a)	Slot single microstrip patch antenna with various shapes	39
3.2.6 (b)	Slot X-polarized microstrip patch antenna	41
3.3 (a)	Microstrip patch antenna	42
3.3 (b)	Port structure in CST	43
3.3 (c)	$\pm 45^0$ polarized microstrip patch in CST	43
3.3 (d)	Side view in CST for X-polarized microstrip patch	44
3.3 (e)	Bottom view in CST for X-polarized microstrip patch	44
3.3 (f)	Front view in CST for X-polarized microstrip patch	45
3.5	Measurement setting	46
4.2.1 (a)	Single microstrip patch antenna	48
4.2.1 (b)	Simulation result single microstrip patch antenna	49
4.2.2 (a)	$\pm 45^0$ polarized microstrip patch antenna	50
4.2.2 (b)	Simulation result $\pm 45^0$ polarized microstrip patch antenna	52
4.2.3.1 (a)	Vertical slot microstrip patch	54
4.2.3.1 (b)	Result for bandwidth and gain when length slot, L_s is varied	54
4.2.3.2 (a)	Horizontal slot microstrip patch	55
4.2.3.2 (b)	Result for bandwidth and gain when width slot, W_s is varied	55
4.2.3.3 (a)	Slant slot microstrip patch	56
4.2.3.3 (b)	Result for bandwidth and gain when length slot, L_s is varied	56
4.2.3.4 (a)	Double slot microstrip patch	57
4.2.3.4 (b)	Result for bandwidth and gain when length slot, L_{s1} and L_{s2} are varied	58
4.2.3.4 (c)	Result for bandwidth and gain when length slot, L_{s1} and L_{s2}	58

	are varied	
4.2.4 (a)	X-polarized microstrip patch antenna	59
4.2.4 (b)	Simulation result for X-polarized microstrip patch antenna	60
4.2.5.1 (a)	X-slot X-polarized microstrip patch antenna	62
4.2.5.1 (b)	Result for bandwidth and gain when length slot, L_{s1} and L_{s2} is changed	63
4.2.5.2 (a)	T-slot X-polarized microstrip patch antenna	64
4.2.5.2 (b)	Result for bandwidth and gain when length slot, L_{s2} is changed	65
4.2.5.2 (c)	Result for bandwidth and gain when width slot, W_{s1} is changed	65
4.2.5.3	Simulation result for T-slot X-polarized microstrip patch antenna	67
4.3.1	Measurement result for X-polarized microstrip patch antenna	68
4.3.2	Measurement result for T-slot X-polarized microstrip patch antenna	70

LIST OF ABBREVIATIONS / SYMBOLS

DPS	-	Direct Broadcast Satellites
PCS	-	Personal Communication System
UMTS	-	Universal Mobile Telecommunication System
WLAN	-	Wireless Local Area Network
GPS	-	Global Positioning Satellites
PEC	-	Perfect Electric Conductor
ISM	-	Industrial, Scientific and Medical
FR4	-	Flame Resistant 4
dB	-	Decibel
ϵ_r	-	Dielectric Constant Of Material
ϵ_{eff}	-	Effective Dielectric Constant
λ_g	-	Waveguide Wavelength
λ	-	Wavelength In Free Space
μ_0	-	Permeability of vacuum
ϵ_0	-	Permittivity of vacuum
RF	-	Radio Frequency
PCB	-	Printed Circuit Board
CST	-	Computer Simulation Technology
f_r	-	Resonance frequency

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Slot single microstrip patch antenna	77
B	Slot X-polarized microstrip patch antenna	79
C	Real antenna after fabrication process	81

CHAPTER 1

INTRODUCTION

1.1 Background

Currently electronic devices are becoming very significant in people life and popular in computer systems, communication systems and wireless application. Due to the rapid development in various wireless communication systems, a lot of method have suggested to develop antenna with reduced size and enhanced frequency bandwidth to achieve the efficiency requirements of mobile systems such as mobile cellular, mobile cordless, direct broadcast satellites (DPS), personal communication system (PCS), universal mobile telecommunication system (UMTS), wireless local area network (WLAN), global positioning satellites (GPS) and other next generation wireless system [1].

Microstrip patch antennas are widely used in wireless communication system. This is due to its advantages such as low electromagnetic coupling to the human head, increased mechanical reliability, low cost and capability to maintain high performance over wideband of frequencies. In communication system, wide bandwidth is a main element requirement to make the patch antenna can be used in multipurpose application and operate more efficiency. Narrow bandwidth is a major disadvantage for microstrip patch antenna [2]-[4].

Several techniques have been proposed by researchers previously to increase the bandwidth. The conventional method is by using parasitic patches either in another layer (stacked geometry) or same layer (coplanar geometry). Both methods will increase the antenna size. Air gap will also increase the bandwidth but this method requires adjusting the air gap width mechanically, which is not an easy task in practice. Another method which is can be used to increase the bandwidth is increasing patch height over ground plane, using a lower substrate permittivity and cut the slot on the patch [5][6].

1.2 Problem Statement

Microstrip patch antenna has a lot of disadvantages such as narrow bandwidth, low gain and low power handling capabilities. Besides, it is also has narrow transmission signal. The polarization of wave radiated in conventional microstrip antenna is linear polarized. This type polarization will introduce losses because mismatch signal will occur during transmission signal. A narrow bandwidth is a main disadvantage of microstrip patch antenna in practical application normally a few per cent around 2% - 3%. Therefore, many methods have proposed to enhance the performance of microstrip patch antenna especially bandwidth. The narrow bandwidth will limits the function of microstrip antenna in the present modern communication system.

1.3 Objectives

The main objective for this project is to design, simulate and fabricate of slot X-polarized microstrip patch antenna at ISM band frequency. The operating frequency for this device operates in ISM band is 2.4 GHz. Another goal in this project is to enhance the bandwidth than conventional microstrip patch antenna and high gain and investigate the effects of slot on bandwidth when placed into the microstrip patch antenna.

1.4 Scope of work

This project will focus to the X-polarized microstrip patch antenna by inserting slot on the patch. This project has designed and simulated by using CST 2009 software to obtain the return loss, radiation pattern, gain and bandwidth. The operating frequency for this microstrip patch antenna used in ISM band application is 2.4GHz. The material applied for the substrate of the patch antenna is FR4 which is the dielectric constant is 4.4, thickness is 1.6mm and tangent loss is 0.019. Etching method has used to fabricate this antenna. For measurement return loss, radiation pattern, gain and bandwidth of patch antenna will be measured.

1.5 Project Methodology

All information about the microstrip patch antenna and slot types patch antenna are gathering from several sources such as journal, reference book and paper which is can obtain any website. But the most popular to obtain the information about the microstrip patch antenna and slot microstrip patch antenna are from IEEE explore. In this procedure, the information how to improve the characteristic of microstrip patch antenna such as bandwidth and gain has been investigated and proposed. From the literature review, the method to design slot was shown by using parametric study.

The design for this project is according to the design and characteristic of conventional microstrip patch antenna, X-polarized microstrip patch antenna and slot microstrip patch antenna. All information is obtained from literature review. Several methods can be used to design antenna such as calculation, parametric study and empirical approach. In this project, calculation and parametric study will be used to design the microstrip patch antenna. Dimension patch, inset feed and microstrip line can be calculated and designed using approximate equation from literature review. Slot shape can be designed any shape such as horizontal slot, X slot, double vertical slot and T slot. There has not approximate equation to determine dimension of slot. Therefore parametric study method used to determine dimension of slot. Slot is designed in single

microstrip patch and X-polarized microstrip patch antenna to analyze the effects of slot on bandwidth and gain by varying W_s (width) and L_s (length) slot.

This project has been simulated in the microwave application software, CST 2009. In this software, the parameter of antenna can be observed. This parameter is important to ensure that the antenna is operating well, efficient and in good condition before continue to fabricating process. The parameter antenna such as radiation pattern, return loss, gain, directivity and bandwidth is commonly analyzed.

In fabricating process, design from simulation is converted to *dxf* file and print out on the transparency paper. This transparency paper is patched on the substrate before fabricate. Several type substrate materials can be used to fabricate. In this project, FR4 substrate has selected. This substrate has dielectric constant is 4.4, thickness substrate is 1.6mm and tangent loss is 0.019. This substrate will be etching using chemical in the laboratory.

For measurement, it has been done in the laboratory. Network Analyzer, Spectrum Analyzer and Antenna Trainer are used for measurement. By using Network Analyzer, bandwidth, return loss and resonance frequency of antenna will be measured. To measure radiation pattern, gain and directivity Antenna Trainer is used.

This is the final step in this project. All information about literature review, design, simulation, fabricate and measurement has been collected and saved in this final report writing. The result for simulation and measurement is analyzed and compared. The suggestion for the future work to improve the efficiency and performance this project also included in this final report writing. Figure 1 is illustrated the flow of methodology during doing this project.

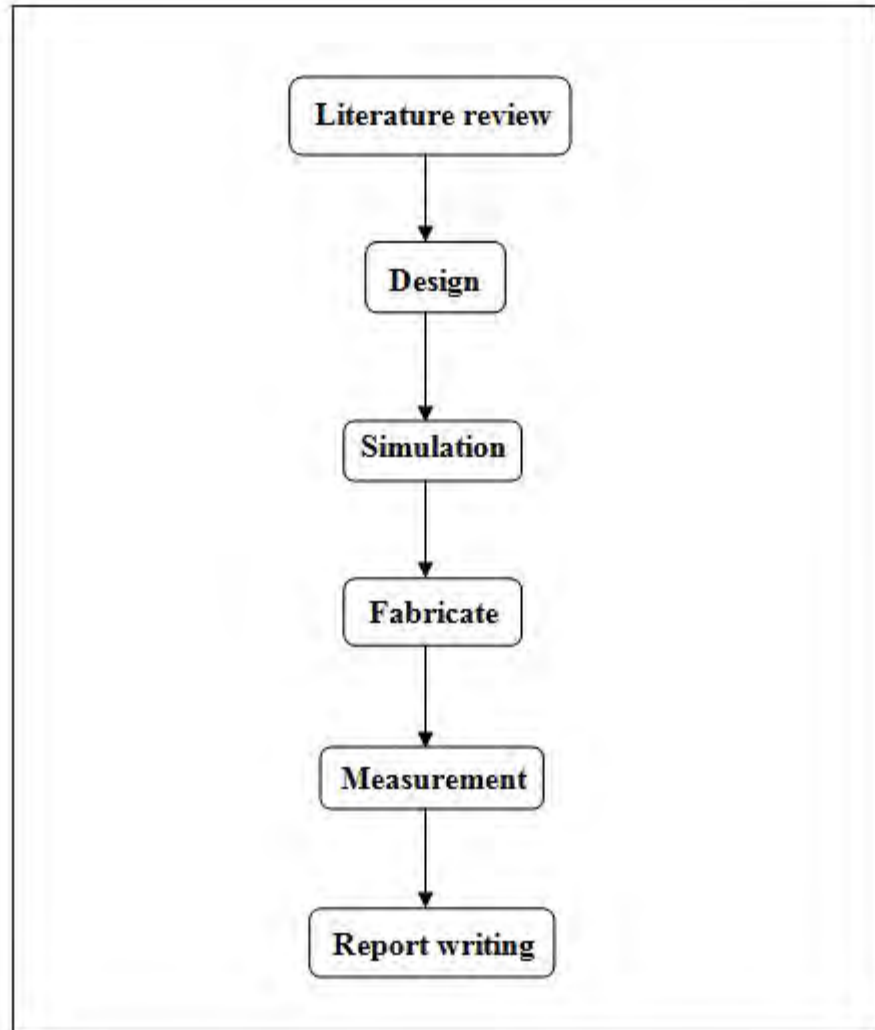


Figure 1: Flow of methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Parameters of the antenna

Parameter of the antenna is used to describe the performance and operation of the antenna. This parameter can be used to ensure that the antenna is operating well. The parameters of the antenna such as radiation pattern, radiation power density, radiation intensity, beamwidth, directivity, numerical techniques, antenna efficiency, gain, beam efficiency, bandwidth, polarization, input impedance, antenna radiation efficiency and antenna temperature. The parameter commonly used is radiation pattern, gain, bandwidth and polarization [7].

2.1.1 Radiation pattern

Radiation pattern can be defined as a graphical representation of the radiation properties of the antenna as a function of space coordinates. The radiation pattern can determine the far field region. The properties of radiation pattern such as power flux density, radiation intensity, field strength, directivity and polarization. A trace of the received electric or magnetic field at a constant radius is called the amplitude field

pattern and a graph of the spatial variation of the power density along a constant radius is called an amplitude power pattern. Usually, the field and power patterns are normalized with respect to their maximum value. The power pattern is usually plotted in decibels (dB) [7].

Field pattern in linear scale indicated in Figure 2.1.1 (a) normally represents a plot of the magnitude of the electric or magnetic field as a function of the angular space. Power pattern in linear scale illustrated in Figure 2.1.1 (b) normally represents a plot of the square of the magnitude of the electric or magnetic field as a function the angular space. Power pattern in dB scale indicated in Figure 2.1.1 (c) represents the magnitude of the electric or magnetic field as a function of the angular space [7].

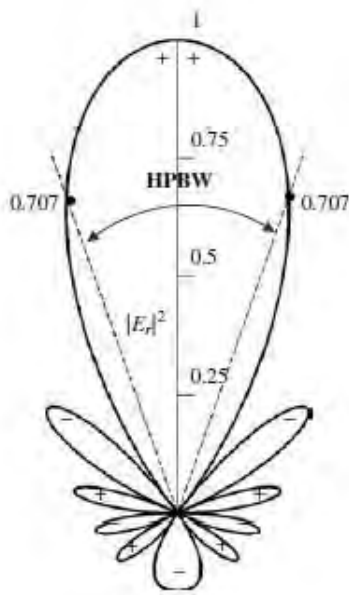


Figure 2.1.1 (a): Field pattern in linear scale

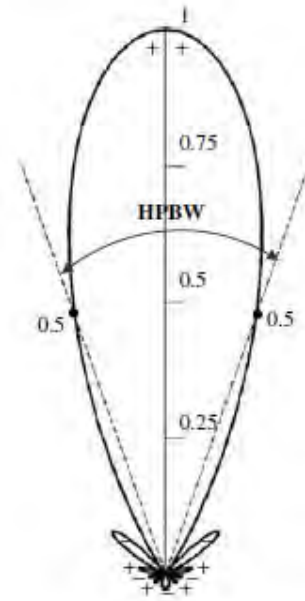


Figure 2.1.1 (b): Power pattern in linear scale