DESIGN, FABRICATION AND PERFORMANCE ANALYSIS OF MICROSTRIP PATCH ANTENNAS FOR WIRELESS APPLICATIONS

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DECLARATION

I, Richa, hereby certify that the work which is being presented in this thesis entitled "Design, Fabrication and Performance Analysis of Microstrip Patch Antennas For Wireless Applications" by me in partial fulfillment of the requirements for the award of degree of Master of Engineering in Electronics and Communication Engineering from Thapar University (Deemed University), Patiala, is an authentic record of my own work carried out under the supervision of **Mrs. Jaswinder Kaur, Assistant Professor (ECED).** The matter presented in this thesis has not been submitted in any other University/Institute for the award of any other degree.

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ABSTRACT

Wireless communications has been developed widely and rapidly in the modern world especially during the last two decades. The future development of the personal communication devices will aim to provide image, speech and data communications at any time, and anywhere around the world. This indicates that the future communication terminal antennas must meet the requirements of multi-band or wideband operations to sufficiently cover the possible operating bands. However, the difficulty of antenna design increases when the number of operating frequency bands increases within a single antenna. The aim is to study and design various rectangular microstrip patch antennas for wireless communication systems and study the effect of various antenna parameters like patch length (L), patch width (W), substrate relative dielectric constant, substrate thickness etc. Here CPW feed and microstrip line feed methods have been used to excite the patch antenna.

The CPW-fed ‘U’ shaped Dual band Microstrip patch antenna has been designed resonating at the frequency 2.23 GHz and 5.27 GHz. The design is successfully simulated using CST Microwave Studio software. The return loss for 2.23 GHz and 5.27 GHz is -20.02 dB and -46.12 dB respectively and corresponding bandwidth is 839 MHz (1.95 GHz-2.79 GHz) and 1.07 GHz (4.86 GHz-5.93 GHz) respectively.

CPW-fed ‘E-G’ shaped Triple band Microstrip patch antenna has been designed by resonating at the frequency 2.2 GHz, 3.37 GHz and 5.84 GHz. The return loss for 2.2 GHz, 3.37 GHz and 5.84 GHz is -20.48 dB, -18.56 dB and -35.93 dB respectively and corresponding bandwidth is 567 MHz (1.98GHz-2.54 GHz), 439 MHz (3.19 GHz-3.63GHz) and 1.17 GHz(5.35 GHz-6.52 GHz) respectively.

Microstrip-fed monopole Triple band antenna using DGS has been designed which is resonating at the frequency at 2.4 GHz, 3.48 GHz and 5.46 GHz. The return loss is -25.42 dB, -16.98 dB and -24.94 dB and corresponding bandwidth is 347 MHz (2.27 GHz-2.61 GHz), 580 MHz (3.15 GHz-3.73 GHz) and 833 MHz (5.17 GHz-6 GHz) respectively.

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CPW	Coplanar Waveguide
DGS	Defected Ground Structures
MMIC	Monolithic Microwave Integrated Circuits
MPA	Microstrip Patch Antennas
PCB	Printed Circuit Board
Q	Quality Factor
RFIC	Radio Frequency Integrated Circuits
RFID	Radio Frequency Identification
S	Scattering (return loss)
TEM	Transverse Electric-Magnetic
TM	Transverse Magnetic
VSWR	Voltage Standing Wave Ratio
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

Chapter 1

INTRODUCTION

This chapter gives the brief introduction and history about wireless communication and different wireless standards of wireless communication. This chapter also defines the objectives and organization of thesis.

1.1 Overview

Satellite communication and Wireless communication has been developed rapidly in the past decades. Today world's communication depends on wireless links. In the last few years, the development of WLAN represented one of the principal interests in the information and communication field. Thus, the current trend in commercial and government communication systems has been to develop low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a large spectrum of frequencies. This technological trend has focused much effort into the design of MPA.
MPA are well suited for WLAN/WiMAX application systems and having some disadvantages, like narrow bandwidth, low gain etc. Broad banding is the main problem, for solving this problem we proposed new structures for devices that require more than one frequency band of operation [3]. Dual-band wireless phones have become popular recently because they allow using the one phone in two networks that have different frequencies. Tri-band phones have also gained popularity. Still, there exist more than three frequency bands used for wireless applications. Table 1-1 lists a few useful wireless applications and their operating frequencies. The systems having multi-band operation require antennas that resonate at the specified frequencies. This only adds complexity to the antenna design problem.

1.2 Brief history of wireless communication

The first wireless networks are developed in Pre-industrial age. For these systems information transmitted over line of sight distances. Early communication networks were replaced first by telegraph networks, which are invented by Samuel Morse in 1838 .In

1895 telephone was invented, Marconi demonstrated the first radio transmission. Then the radio technology advances rapidly to enable transmissions over larger distances with better quality and less power cheap device.

True radio communications were of course based on the work of Maxwell and Experiments of hertz. The first use of radio to transmit coded information was proposed by Tesla in 1880's. Early radio systems transmitted analog signals. But today's radio system use digital signals for transmission of data in binary form. In 1985 the Federal communication commission (FCC) enables the commercial development of wireless LAN's by authorizing the public use of the Industrial, Scientific, and Medical bands for wireless LAN products, but due to poor performance of these products, new generation WLAN were formed.

The current generation of the wireless LAN's based on family IEEE 802.11 standards have better performance, but still low data rates. These are providing few applications such as e-mail and web browsing that are not sufficient applications today's users. For many applications we need wide band and wide band are formed by using many designing techniques. Different types of antenna are used to get wide band for many applications. The generations 1G, 2G, 3G and 4G for wireless communication with brief view are:

1.2.1 The First Generation:

It can also be a good choice for long range communication. The main difference between two succeeding mobile telephone systems, 1G and 2G, is that of the radio signals that 1G networks use are analog, while 2Gnetworks are digital. Although both systems use digital signaling to connect the radio towers to the rest of the telephone system, the voice itself during a call is encoded to a digital signal in 2G whereas 1Gis only modulated to higher frequency, typically 150 MHz and up. The technology used here (AMPS) which is 2G standards using frequency at 800MHz. It could accommodate 5 to 10 times more users than IMTS by dividing an area into smaller cells hence the term 'cellular network' came into existence. The first generation (1G) analog cellular systems supported voice communication with limited roaming E.g. AMPS.

1.2.2 The Second Generation:

Second Generation (2G) wireless cellular services was a step ahead of First Generation (1G) services by providing the facility of short message service(SMS) unlike 1G that had its prime focus on verbal communication. A typical 2G G.S.M network (TDMA-based) which is service ranges from 800/900MHz or 1800/1900MHz spectrum. 2G networks were mainly for voice services and slow data transmission, but are considered by the general public to be 2.5G or 2.75G services. The bandwidth of 2G is 30-200KHz. E.g. GSM, GPRS.

1.2.3 The Third Generation:

In 3G, Wide Brand Wireless Network is used with which the clarity increases and gives the perfection as like that of a real conversation. The data are sent through the technology called Packet Switching. Voice calls are interpreted through Circuit Switching. It is a highly sophisticated form of communication that has come up in the decade. In addition to verbal communication it includes data services, access to television/video, categorizing it into triple play service. 3G operates at a range of 2100MHz and has a bandwidth of 15-20MHz. High speed internet service, video chatting are the assets of 3G. E.g. CDMA

1.2.4 The Fourth Generation of Mobile Wireless Communication System:

A successor of 2G and 3G, 4G promises a downloading speed of 100Mbps and is yet to shower its wonders on. Then with the case of Fourth Generation that is 4G in addition to that of the services of 3G some additional features such as Multi-Media Newspapers, also to watch T.V programs with the clarity as to that of an ordinary T.V. Unlike 3G, which is based on two parallel infrastructures consisting of circuit switching and packet switching network nodes, 4G will be based on packet switching only. This will require low latency data transmission. In addition, we can send data much faster that of the previous generations. It is expected to provide a comprehensive and secure all IP based solutions.

1.3 IEEE standard for WLAN

The IEEE 802.11 standard was proposed in 1997 for WLANs application. After few year new standard was proposed, operating on the 2.4 GHz ISM band (2.4 - 2.484 GHz), is called 802.11b or 802.11 HR (High Rate), which provides a data rate up to 11 Mbps. The IEEE 802.11a standard was approved in 1999, operating on the 5 GHz ISM bands (5.15 - 5.35GHz and 5.725 -5.825GHz). The change of band shows that 802.11a and 802.11b products are not compatible. Therefore, the IEEE proposed 802.11g standard which is compatible with both 802.11b and 802.11a technology. The 802.11g standard was accepted in 2003[4].

Since 802.11b and 802.11g are using 2.4 GHz frequency band while 802.11a uses 5 GHz frequency band so a dual band antenna is requirement for WLAN applications. The popularity of WLAN is increased due to high-speed transfer rate. This increased the development of broadband antennas [4].

1.4 IEEE standard for WiMAX

WiMAX technology is based on the IEEE 802.16 standard also called Broadband Wireless Access. The name WiMAX was created by the WiMAX forum which was formed in June 2001 to promote conformity and interoperability of the standard. The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL". There is no uniform global licensed spectrum for WiMAX, although the WiMAX Forum has published three licensed spectrum profiles: 2.5 GHz (2.5-2.69 GHZ), 3.5 GHz (3.4-3.69 GHZ) and 5.5 GHz (5.25-5.85 GHZ). WiMAX provide the data rate upto70 Mbps over 50 Km. IEEE 802.16-2004 is often called IEEE 802.16d, since that was the working party that developed the standard. It is also frequently referred to as "fixed WiMAX" since it has no support for mobility. It replaced IEEE Standards 802.16-2001, 802.16c-2002, and 802.16a-2003. 802.16e-2005 is an amendment to 802.16-2004 and is often referred to in shortened form as 802.16e. It introduced support for mobility, amongst other things and is therefore also known as "mobile WiMAX" [4].

Table 1-1 Various type of wireless applications and its frequency band

Wireless Applications		Frequency Band (MHz)	Bandwidth (MHz)
GSM	GSM 900	890-960	70
	GSM 1800	1710-1805	95
	GSM 1900	1850-1990	140
IMT		2300-2400	100
		2700-2900	200
		3400-4200	800
		4400-4900	500
WLAN		2400-2484	84
		5150-5350	200
		5725-5825	100
Bluetooth		2400-2500	100
WiMAX		2500-2690	190
		3400-3690	290
		5250-5850	600

1.5 Objectives of the Thesis

The objectives of thesis is divided into three parts:

- Design and simulation of CPW-fed 'U' shaped dual band MPA for 2.4/5.2/5.8 GHz WLAN and 2.5/5.5 GHz WiMAX applications is done and fabrication and testing of the designed antenna is done.

- Design and simulation of CPW-fed 'E-G' shaped triple band MPA from CPW-fed 'U' shaped dual band MPA for 2.4/5.8 GHz WLAN applications and 3.5/5.5 GHz WiMAX applications is done and the parameters variations are also studied.

- Design and simulation of Microstrip line fed triple band MPA using DGS for 2.4/5.2/5.8 GHz WLAN applications and 2.5/3.5/5.5 GHz WiMAX applications is done and the parameters variations are also studied.

1.6 Organization of the Thesis

This thesis is divided into five chapters and organized as follows:

Chapter 2 deals with the literature survey. The brief introduction of research papers are given for the various antenna design based on wireless application.

Chapter 3 gives the overview of patch antenna including advantages and disadvantages, various feed model techniques, analysis model, antenna parameters and applications for MPA.

Chapter 4 proposes the geometry of a CPW-fed 'U' shaped dual band MPA as well as the geometry of a CPW-fed 'E-G' shaped triple band MPA and its parametric analysis of how geometrical parameters affect the performance of the optimized antenna with the results and discussion for proposed antenna structure.

Chapter 5 proposes Microstrip-fed triple band MPA using DGS and various parameters are also studied.

Chapter 6 The antenna studied in chapter 4 is fabricated and tested.

Chapter 7 ends with the concluding remarks and future scope for further research and development purposes.

Chapter 2

LITERATURE SURVEY

2.1 Introduction

Prior to starting of my thesis, it is important to have a deep understanding on the existing pages of Microstrip antenna. The main sources of information for the dissertation are books, journal, thesis and dissertations and the internet. There are major areas of reading in the literature review, which are antenna design, methods for improving performance of microstrip patch antenna and related simulation software. This chapter includes the research paper literature review.

2.2 Research paper literature Review

In order to start the thesis, the first step is to study the research papers that have been performed previous by other researches. Papers related to this work are chosen and studied. With the help of literature review, it becomes clearer to perform this project.

The concept of Microstrip radiators was first proposed by Deschamps in 1953. A patent was issued in France in 1955 in the names of Gutton and Baissinor. However 20 years passed before practical antenna ware fabricated. Development during 1970's was accelerated by the availability of good substrate with low loss tangent and attractive thermal and mechanical properties, improved photolithographic techniques, and better theoretical models. The first practical antenna was developed by Howell [1] and Munson [2]. Since then extensive research and development on microstrip antennas aimed at exploiting their advantages.

2.2.1 Analysis of coplanar waveguide-fed microstrip antenna [5]

The literature survey for multi-band MPA using CPW feed line. This includes the multilayer stacked-patch antennas using circular, annular, rectangular, and triangular patches. The CPWS-fed antenna have been widely used for wireless communications owing to their many attractive features such as wide bandwidth, simplest structure of a single metallic layer, no soldering points, easy integration with MMICs, etc.

2.2.2 Dual-Frequency Patch Antennas [6]

A dual frequency patch antenna provide a large-bandwidth planar antennas, In applications in which large bandwidth is really needed. Here single antenna operated at two separate transmit- receive bands. When the two operating frequencies are far apart, a dual-frequency patch structure can be conceived to avoid the use of separate antennas. This paper discusses about various antenna. Orthogonal mode dual-frequency patch antennas, Multi-patch dual frequency antennas and Reactively loaded dual-frequency patch antennas.

2.2.3 A CPW Fed E-Shaped Reconfigurable Antenna with Frequency Diversity [7]

A new CPW fed E-shaped reconfigurable Antenna with frequency diversity is designed and analyzed in this paper. The basic antenna consists of CPW fed E-shaped Patch antenna which operates at 5.8GHz which falls in IEEE 802.11 WLAN/RFID applications. The reconfigurability in frequency is obtained by connecting the switches in basic antenna by use of PIN diodes. By controlling the switches the antenna can be operated at three different frequencies namely 8.5GHz, 6.18GHz and 8.76GHz. The return loss of -28dB, -28.2dB, -33.07dB and -38.17dB are observed at 5.8GHz, 8.5GHz, 6.18GHz and 8.76GHz respectively. Two dimensional radiation patterns with elevation angles, gain, and efficiency of about 70% are also obtained.

2.2.4 CPW-fed Slot Patch Antenna for 5.2/5.8GHz WLAN Application [8]

This paper represent CPW-fed patch antenna with slots. The antenna consists of patch structure with two rectangular slots on it. The physical size of the proposed antenna is 30mm x 24mm. The impedance bandwidth of the proposed antenna is 4.1GHz ranging from 4.8GHz to 8.9GHz and has a fractional bandwidth of 60%. The proposed CPW-fed slot patch antenna produces a 30% higher bandwidth compared to the conventional CPW-fed patch antenna. The antenna is resonating at 5.5GHz and gives monopolar radiation pattern at this frequency. This antenna can be used in 5.2GHz/5.8GHz WLAN application.

2.2.5 Design of a Broadband CPW-Fed Monopole Antenna for WLAN operations [9]

A novel broadband design of a CPW-fed planar monopole antenna with double plus shape slots is proposed. The design considerations for achieving broadband operation of the proposed plus sign slot antenna are discussed, and theoretical results are presented. The antenna operates in single wide frequency bands from 4.789 GHz to 6.318 GHz covering WLAN bands with a total bandwidth of 1.529 GHz. The overall size of the antenna is 44.53 mm × 35.87 mm × 1.6 mm including the finite ground CPW feeding mechanism and total volume of the antenna is 2.56 cm^3. The parametric study is performed to understand the characteristics of the proposed antenna. Also, good antenna performances such as radiation patterns and antenna gains over the operating bands have been observed. The maximum gain of the proposed antenna is 2.51 dBi at 5.49 GHz band.

2.2.6 Design and Simulation of CPW-FED Printed Antenna for Ultra Wide Band (UWB) and Wireless LAN (WLAN) Applications [10]

This paper proposed design and simulation of CPW-fed printed antenna for UWB and WLAN applications. The return loss, gain and directivity and current distribution for the different frequencies are explored, It is shown proposed antenna has good gain and directivity. The antenna design configuration simulation using a commercially available Advanced System Design (ADS). The simulated results -15 dB at 3.9GHz and -24.5 dB at 5.78 GHz, efficiency of the proposed antenna is 92%.

2.2.7 Design and Development of CPW-FED Microstrip antenna for WLAN/WiMAX Applications [11]

This paper represents a novel broadband monopole antenna with an extended rectangular shaped slot based on CPW-fed. The antenna composed of a planar rectangular patch element embedded with slots, capable of generating two separate resonant modes with good impedance matching. The parametric study is performed to understand the characteristics of the proposed antenna. The total volume of the antenna is 1.49 cm3. The antenna operates in broad frequency bands from 3.424GHz to 6.274GHz covering WLAN and WiMAX bands. The maximum gain of the proposed antenna is 5.51 dBi at 4.78GHz frequency band. The proposed antenna's radiation characteristics are also observed.

2.2.8 Microstrip Patch Antenna with Skew-f Shaped DGS for Dual Band Operation [12]

The goal of this paper is to use DGS in microstrip antennas for dual band operation at microwave frequencies. The soft nature of the DGS facilitates improvement in the performance of microstrip antennas. A design study on microstrip patch antenna with specific DGS slot has been presented. A SMPA has been designed for broadband behaviour, and then skew-F shaped DGS has been integrated with a detailed study of possible DGS slots in a small area for dual band operation.

2.2.9 Characterization of the Input Impedance of the Inset-Fed Rectangular Microstrip Antenna [13]

This paper discuss about the input impedance and radiation pattern of the inset-fed rectangular microstrip patch antenna. It is concluded that a shifted cosine-squared function describes well the variation of the resonant input resistance with the feed location (point of contact between the microstrip feed line and the notch) for a given patch and substrate geometry. The parameters of the shifted cosine-squared function depend on the notch width, for a given patch and substrate geometry.

2.2.10 Dual Broadband Slit-Loaded CPW-Fed Monopole Antenna for Wireless Communication [14]

This paper represent a slit-loaded CPW-fed monopole antenna comprises a planer patch element with a sided L-shaped slit and is capable of generating two separate resonant modes with good impedence matching conditions, it is a single layer slit-loaded monopole antenna based on 50 Ω CPW-fed technology and is suitable for spatial-diversity operation in WLAN.

2.2.11 Dual-band CPW-Fed G-shaped Monopole Antenna for 2.4/5 GHz WLAN Applications [15]

A ‘G’ shaped monopole antenna designed by combining two folded strips and is fed by a CPW transmission line achieves the impedence bandwidth of 9.7% and 62.8% at band of 2.43 and 4.3 GHz, respectively, which cover the 2.4/5.2/5.8 GHz WLAN bands, it shows to obtain good dual band impedance matching by controlling the current distribution on the G-shaped stripline and compensation between the capacitive and inductive effects caused from the electromagnetic coupling effects of the finite ground planes and both the feeding line and the G-shaped stripline at the desired various operating bands, the overall antenna gain is in the range of 3.0-7.0 dBi with small gain variation around 5 GHz band.

2.2.12 CPW-Fed Compact Monopole Antenna for Dual-band WLAN Applications [16]

A multiband slot antenna with modifying fractal geometry fed by CPW transmission model, it is designed by modifying an inner fractal patch of the antenna to operate at multiple resonant frequencies, which effectively supports the digital communication system (DCS 1.71-1.88 GHz), WiMAX, IMT advance system or fourth generation mobile communication system (3.40-4.2 GHz), and WLAN (5.15-5.35 GHz) and the radiation patterns at each operating frequency are almost similar to bidirectional which is an advantage of the fractal concept over the conventional multiband antenna, CPW-fed dual band monopole antennas have been proposed in this paper where the two resonant modes are exited primarily owing to the longer and shorter current paths.

2.2.13 CPW-Fed Compact Meandered Patch Antenna for Dual Band Operation [17]

The key design configurations in order to meet this dual-band operation include a monopole antenna fed with a meandered (CPW), by inserting slit at the edge of a rectangular patch printed in a single layer and fed by coplanar waveguide transmission line, a novel compact dual frequency antenna is obtained, can operate at both 2.0 and 5.32 GHz bands and provide sufficient bandwidths for the UMTS and WLAN systems.

2.2.14 A New Triple Band CPW-Fed Monopole Antenna for WLAN and WiMAX Applications [18]

In this paper a ‘T’ shaped monopole with a trapezoid ground plane and two parasitic elements to generate a triple band for WLAN and WiMAX operations. The use of trapezoid ground plane and parasitic elements has generated different resonant frequency very remarkably to sufficiently cover the 2.4/5.2/5.8 GHz WLAN bands 2.5/3.5/5.5 WiMAX bands.

2.2.15 Investigations on a Dual-Frequency Micro strip Antenna for Wireless Applications [19]

This paper discuss about the design of a MPA be operated at GPS (Global Positioning System) and Bluetooth frequencies. The antenna structure consists of a very thin microstrip patch excited by a co-axial connector and a thin parasitic patch, separated by a certain distance and coupled to the driven patch. The bandwidths of the antenna at both the frequencies were narrow. This problem of narrow bandwidth may be solved by using thick substrate. From the parametric studies, it is found that relative position between the driven patch and the parasitic patch is important to achieve impedance matching and maximum gain at both the frequencies.

2.2.16 A Connected E-Shape and U-Shape Dual Band Patch Antenna for Different Wireless Applications [20]

This paper gives an idea about dual operation E-shape and U-shape Patch Antenna feed by transmission line. The proposed antenna is designed on two-layer (FR4 & Air) substrate with an area of 35 mm by 40 mm. The dual operation frequencies are 4.7 GHz and 5.4 GHz. The impedance bandwidth for the dual band is 4.6% and 4.3% respectively. E-plane and H-plane for the dual operation frequencies is satisfactory within this bandwidth.

2.2.17 Bandwidth and Gain Increment of Microstrip Patch Antenna With Shifted Elliptical Slot [21]

This paper describes the increment in Bandwidth and Gain of Rectangular Microstrip Patch antenna with Shifted Elliptical slot. First we have designed a Rectangular microstrip patch antenna. After that an elliptical slot is cut inside a rectangular patch which is shifted towards right. The results of both the designs are compared and it was found that an increase in the bandwidth of 21% and gain of 7.21 dBi is being achieved as that of a simple RMPA. The Slot dimension, feed point variations are the parameters that should be optimized for maximum bandwidth and gain.

2.2.18 Improving Bandwidth Rectangular Patch Antenna Using Different Thickness of Dielectric Substrate [22]

MPA has some drawbacks of low efficiency, narrow band and surface wave losses. In this paper the solution method was used different thickness of dielectric substrate (h = 4, 6 and 8) mm to increase bandwidth. The simulated results for rectangular give bandwidth of (200 MHz) in case (h = 6mm), a rectangular microstrip patch antenna that meets the requirement of operation at (2.4 GHz) and for substrate thickness (4mm) had a (155.1) MHz bandwidth (6.46 % of central frequency). But when the thickness was used (6mm), the bandwidth increased to be (200) MHz.

2.2.19 A Compact Dual-Band Patch Antenna for WLAN Application [23]

A compact dual-band patch antenna is proposed and measured in this paper. The proposed antenna employs a U-shaped slot and two mitered corners to provide a lower band of 2.40GHz-2.48GHz and an upper band of 5.15GHz-5.80GHz radiation, which will meet the WLAN requirements. Moreover a fabricated prototype which has compact dimensions of 20.0mm x 25mm x 1mm is fabricated and measured.

2.2.20 Compact Broad Band Dual Frequency Slot Loaded Microstrip Patch Antenna with Defecting Ground Plane for Wi-MAX and WLAN [24]

A dual frequency, compact microstrip patch antenna with enhanced bandwidth is presented in this paper. Microstrip antenna with bandwidth of 31% is also been designed for Wi-MAX application by defecting the ground plane. The single layered antenna has been designed to resonate in dual frequencies for Wi-MAX and WLAN with enhanced bandwidth of more than 12%. Microstrip patch antenna with inset feed.

2.2.21 Broadband Microstrip Patch Antenna [25]

This paper explains the enhancing bandwidth and size reduction mechanism that improves the performance of a conventional microstrip patch antenna on a relatively thin substrate (about 0.01 0λ). The design adopts contemporary techniques: L-probe feeding, inverted patch structure with air-filled dielectric, and slotted patch. The simulated impedance bandwidth of the proposed antenna is about 22%. The design is suitable for given frequency of 1.84-2.29 GHz.

2.2.22 Multiband Rectangular Ring Microstrip Antenna for UWB Wireless Applications [26]

In this paper, Rectangular Ring Microstrip Antenna for UWB (3.1GHz-10.6GHz) wireless applications. The beauty of this antenna is the use of single patch which make it easy to fabricate and cost of antenna becomes cheaper. Tri-band antenna is designed which have resonance frequency 4.49GHz, 6.17GHz and 9.64GHz and this antenna have 13.5%, 24.42%, and 6% impedance bandwidth respectively. Return loss at all three centre frequency have less than -24 dB and antenna efficiency at all center frequencies are more than 95%.Here, two type of rectangular patches are used, one patch are rectangular ring and other are small rectangular patch. Rectangular ring patch is used for radiation and small rectangular patch is used for coaxial probe feed.

2.2.23 A Planar Compact Triple-Band Monopole Antenna for WLAN/WIMAX Applications [27]

A planar triple-band monopole antenna with a U-shaped stripline and a L slot is presented. The antenna is very compact with a size of 20 × 30 ×1.5 mm^3 and fed by a 50-microstrip line with a defected ground. The measured -10 dB impedance bandwidth of the proposed antenna covers 2.33GHz-2.51GHz, 3.25GHz-3.82GHz, and 4.83GHz-8.4GHz, respectively, which meets the specifications of WLAN 2.4/5.2/5.8GHz and Wi-MAX 3.5/5.5GHz. The radiation characteristics show a monopole-like pattern.

2.2.24 A Compact High-Gain Microstrip Patch Antenna for Dual Band WLAN Applications [28]

This paper describes a High-gain, dual band L- shaped MPA is printed on a FR-4 substrate for WLAN systems, and has dimensions of 60 × 70 ×1.6mm3 with a ground plane .The dual-band operation is obtained by embedding a pair of L-shaped slots. This proposed antenna is simulated using a CST MWS suite TM 2010. The simulated results shown the proposed MPA achieves a frequency range from 5.0 GHz to 6.0 GHz (return loss less than -10dB), so maximum gain with the values of 8.4 and 7.1 dB are achieved in the lower and higher frequency band respectively.

2.2.25 A 2.45 GHz Microstrip Patch Antenna with Defected Ground Structure for Bluetooth [29]

In this paper, a RMPA with DGS has been analyzed and simulated for the wireless applications. The proposed antenna has been simulated at 2.45 GHz frequency. This compact antenna fed by Quarter Transformer feeding. This type of feeding is mostly used for impedance matching purposes. The defect in a ground is one of the unique techniques to reduce the antenna size and provide improved returning loss, VSWR bandwidth, gain of the antenna as compared to the conventional antenna. Here the rectangular patch antenna designed with swastik structure DGS shows gain of 7 dB.

2.2.26 Comparative Analysis of Microstrip Patch Antenna With Different Feeding Techniques [30]

A single band MPA for wireless communication is presented. In this paper, direct microstrip line feed and coaxial feed techniques are integrated. This antenna offers low profile, narrow bandwidth, high gain, and compact antenna element. The comparison of the feeding techniques is shown in paper and it is proved that the coaxial feeding is better impedance matching technique than microstrip line feeding to improve the gain, return loss and bandwidth.

2.2.27 Comparisons of Circular and Rectangular Microstrip Patch Antennas [31]

The most commonly used Microstrip patch antennas are rectangular and circular patch antennas. These patch antennas are used as simple and for the widest and most demanding applications. Dual characteristics, circular polarizations, dual frequency operation, frequency agility, broad band width, feed line flexibility, beam scanning can be easily obtained from these patch antennas. It is evident that the directivity of circular patch antenna is more when compared with rectangular patch antenna for same given parameter. So we have concluded that circular MPA is better when compared to the other MPA that is rectangular patch antenna.

2.2.28 Inset Microstrip-Line Fed Dual Frequency Microstrip Pacth Antenna [32]

This paper explains analysis, design, and simulation of microstrip-fed dual band antenna. A novel single feed dual frequency microstrip patch antenna with proper selection of slot loading and inset feed. A dual frequency operation of patch antenna with a frequency ratio between 1.03 - 1.2 can be achieved, with maintaining an input impedance of 50ohm at both frequencies. The main advantage of this design is that it can be fed directly through the use of a 50ohm inset microstrip feed line. Input impedance of 50 ohm at both frequencies.

2.2.29 Dual Band Microstrip Patch Antenna Using Dual Feed for Wireless Applications [33]

This paper present analysis, design, and simulation of dual feed microstrip patch antenna for dual band WLAN applications. Dual frequency operation in the antenna is achieved by two rectangular patches on a single substrate and giving them individual feed to each patch. There should be appropriate dual feed arrangements should be in the antenna system to ensure that individual antenna can work successfully in their operating frequency. The proposed antenna consist of two frequencies a) 2.4 GHz for Bluetooth and Wi-fi applications b) 5 GHz for other high frequency wireless applications. Due to its compactness and easy fabrication, the proposed antenna is useful for commercial wireless communication applications.

2.2.30 Design of Triple-Frequency Microstrip-Fed Monopole Antenna Using Defected Ground Structure [34]

This paper represents a novel triple-frequency microstrip-fed planar monopole antenna for multiband operation. Defected ground structure (DGS) is used in this antenna, which has a rectangular patch with dual inverted L-shaped strips and is fed by a cross-shaped stripline, for achieving additional resonances and bandwidth enhancements. The designed antenna has a small overall size of 20 ×30mm^2, and operates over the frequency ranges, 2.14–2.52 GHz, 2.82–3.74 GHz, and 5.15–6.02GHz suitable for WLAN 2.4/5.2/5.8 GHz and WiMAX 3.5/5.5 GHz applications.

Chapter 3

INTRODUCTION OF MICROSTRIP PATCH ANTENNA

In this chapter, an introduction to the MPA, its advantages and disadvantages, some feed modeling techniques and method of analysis are discussed. Next antenna parameters and applications of microstrip antennas are discussed.

3.1 Introduction

A MPA consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 3.1.The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

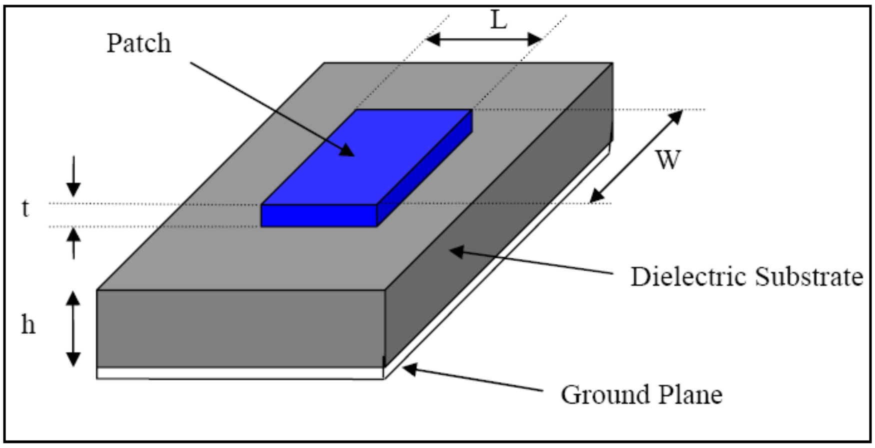


Figure 3.1 Structure of microstrip patch antenna [35]

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular and elliptical or some other common shape as shown in Figure 3.2. For a rectangular patch, the length L of the patch is usually $0.3333\,\lambda_0 < L < 0.5\,\lambda_0$ where λ_0 is the free-space wavelength. The patch is selected to be very thin such that $t << \lambda_0$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\,\lambda_0 \leq$

$h \leq 0.05\,\lambda_0$. The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$.

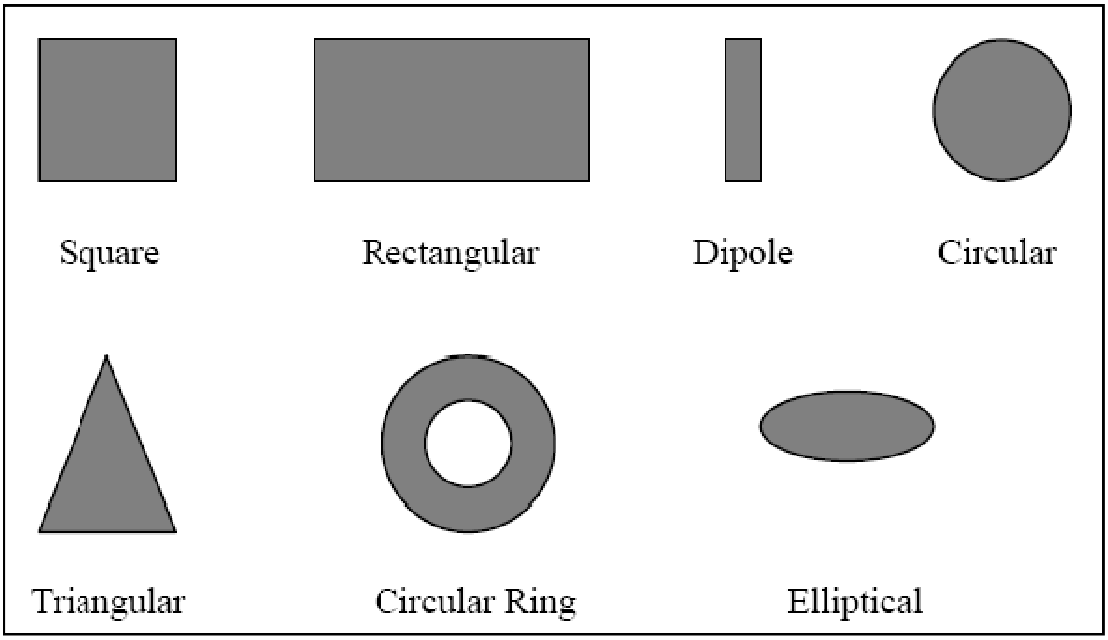


Figure 3.2 Common shapes of microstrip patch elements [35]

MPA radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact MPA, higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a compromise must be reached between antenna dimensions and antenna performance [35].

3.2 Advantages and Disadvantages

MPA are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc. Some of their principal advantages discussed are given below:

- ❖ Light weight and low volume.

- ❖ Low profile planar configuration which can be easily made conformal to host surface.
- ❖ Low fabrication cost, hence can be manufactured in large quantities.
- ❖ Supports both, linear as well as circular polarization.
- ❖ Can be easily integrated with microwave integrated circuits (MICs).
- ❖ Capable of dual and triple frequency operations.
- ❖ Mechanically robust when mounted on rigid surfaces.

MPA suffer from a number of disadvantages as compared to conventional antennas. Some of their major disadvantages are given below:

- ❖ Narrow bandwidth
- ❖ Low efficiency
- ❖ Low Gain
- ❖ Extraneous radiation from feeds and junctions
- ❖ Poor end fire radiator except tapered slot antennas
- ❖ Low power handling capacity.
- ❖ Surface wave excitation

MPA have a very high antenna Q and it represents the losses associated with the antenna and a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics. Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements [35].

3.3 Feed Techniques

MPA can be fed by a variety of methods. These methods can be classified into two categories-contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch [35]. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

3.3.1 Microstrip line feed

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in Figure 3.3. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching.

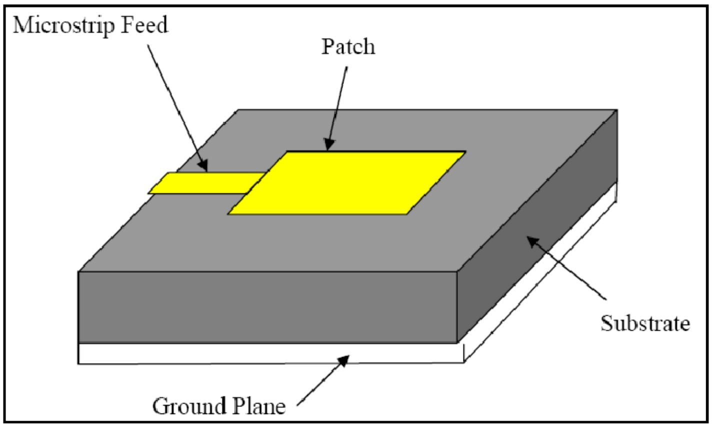


Figure 3.3 Microstrip line feed [35]

However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna [35]. The feed radiation also leads to undesired cross polarized radiation.

3.3.2 Coaxial feed

The Coaxial feed or probe feed is a very common technique used for feeding MPA. As seen from Figure 3.4, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

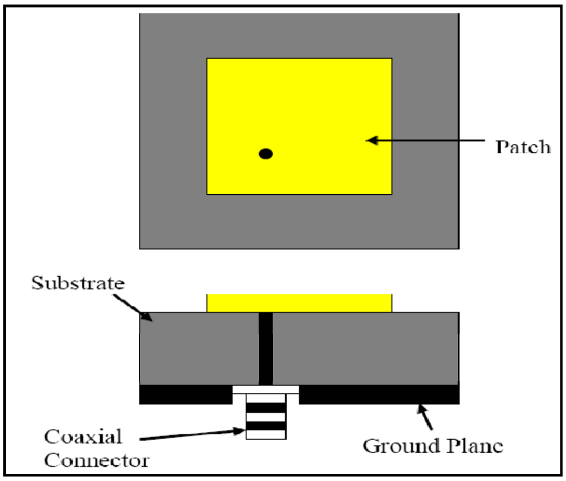


Figure 3.4 Probe fed rectangular microstrip patch antenna [35]

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02\lambda o$). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages [35].

3.3.3 Aperture coupled feed

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure 3.5. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane.

The coupling aperture is usually centered under the patch, leading to lower cross polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture.

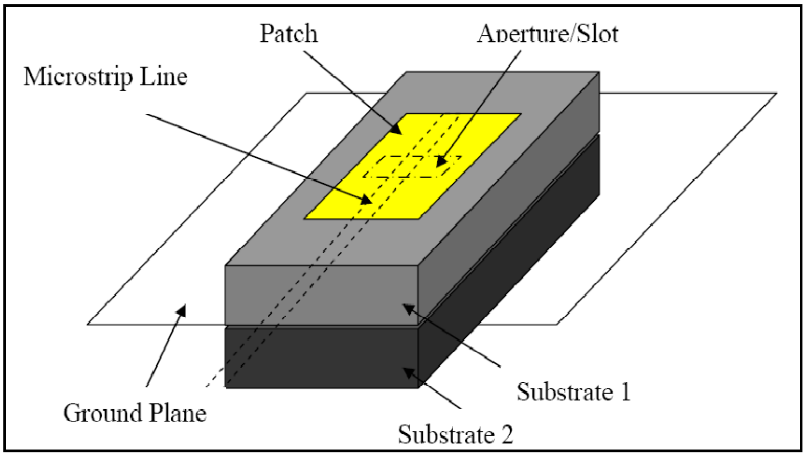


Figure 3.5 Aperture-coupled feed [35]

Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for the bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth [35].

3.3.4 Proximity coupled feed

This type of feed technique is also called as the electromagnetic coupling scheme. As shown in Figure 3.6, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%) [35], due to overall increase in the thickness of the MPA. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

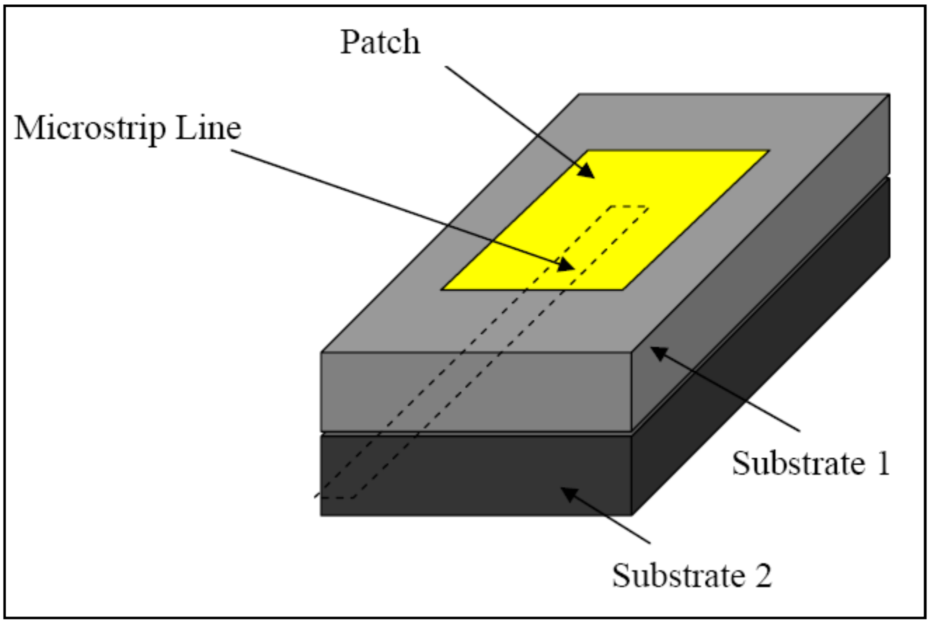


Figure 3.6 Proximity-coupled feed [35]

Matching can be achieved by controlling the length of the feed line and the width-to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate Microstrip Line Patch because of the two dielectric layers which need proper alignment. Also, there is an increase in the overall thickness of the antenna.

3.3.5 Coplanar Waveguide Feeding

Coplanar waveguide is a transmission line system consisting of a central current-carrying trace on the top of a substrate, coplanar with side grounds extending beyond a symmetric gap to either side of trace. A CPW is the preferred transmission line for microwave monolithic integrated circuits (MMIC). Both CPW and microstrip antennas belong to the planar geometry. Therefore, for integrating microstrip antennas with CPW, it is desirable to feed the microstrip antenna with a CPW. The coplanar waveguide (CPW) fed antenna have been widely used for wireless communications owing to their many attractive features such as wide bandwidth, simplest structure of a single metallic layer, no soldering points, easy integration with MMICs, etc.

Table 3.1 Comparison of the characteristics for different feed techniques

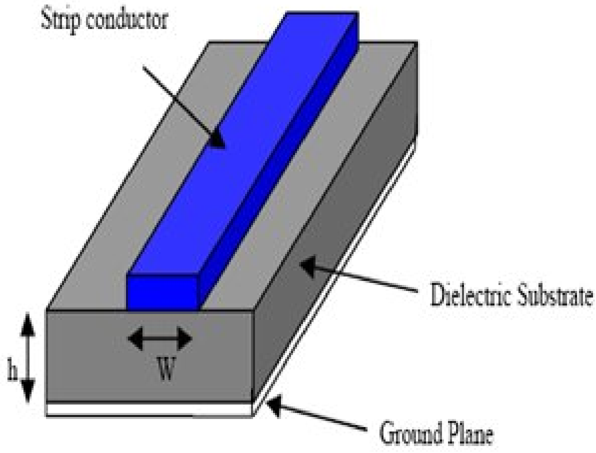
Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed Radiation	More	More	Less	Minimum
Reliability	Better	Poor due to Soldering	Good	Good
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with impedance matching)	2-5%	2-5%	2-5%	2-5%

3.4 Methods of Analysis

The most popular models for the analysis of Microstrip patch antennas are the transmission line model, cavity model, and full wave model (which include primarily integral equations/Moment Method) [35]. The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. The cavity model is more accurate and gives good physical insight but is complex in nature.

Transmission line model

This model represents the microstrip antenna by two slots of width W and height h, separated by a transmission line of length L. The microstrip is essentially non-homogeneous line of two dielectrics, typically the substrate and air.



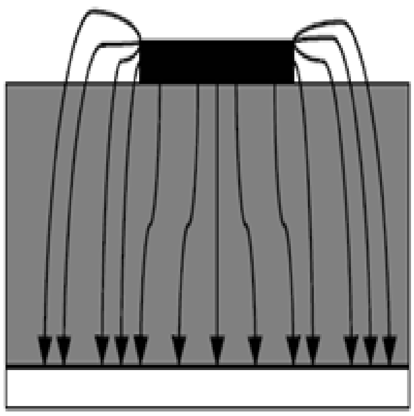


Figure 3.7 Microstrip line [35] **Figure 3.8 Electric field lines [35]**

Hence, as seen from Figure 3.8, most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse electric-magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less than ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in Figure 3.8 above. The expression for ε_{reff} is given in [35] as:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2}$$

Where ε_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

w = Width of the patch

Consider Figure 3.9, which shows a rectangular microstrip patch antenna of length L, width W resting on a substrate of height h. The co-ordinate axis is selected such that the length is along the x direction, width is along the y direction and the height is along the z direction.

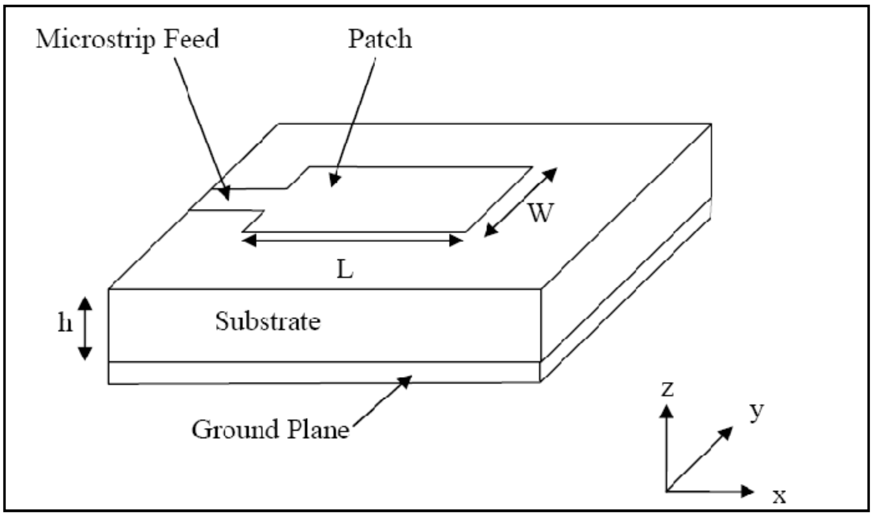


Figure 3.9 Microstrip patch antenna [35]

In order to operate in the fundamental TM_{10} mode, the length of the patch must be slightly less than λ / 2 where λ is the wavelength in the dielectric medium and is equal to $\lambda_0/\varepsilon_{reff}$ where λ_0 is the free space wavelength. The TM_{10} mode implies that the field varies one λ / 2 cycles along the length, and there is no variation along the width of the patch. In the Figure 3.10 shown below, the microstrip patch antenna is represented by two slots, separated by a transmission line of length L and open circuited at both the ends. Along the width of the patch, the voltage is maximum and current is minimum due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane. It is seen from Figure 3.11 that the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is λ / 2 long and hence they cancel each other in the broadside direction. The tangential components (Figure 3.11), which are in phase, means that the resulting fields combine to give maximum radiated field normal to the surface of the structure.

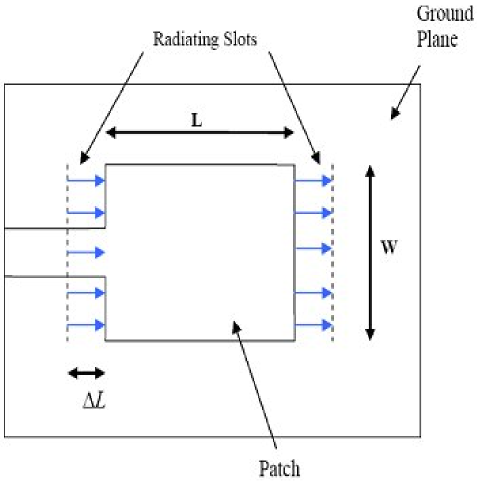


Figure 3.10 Top view of antenna [35]

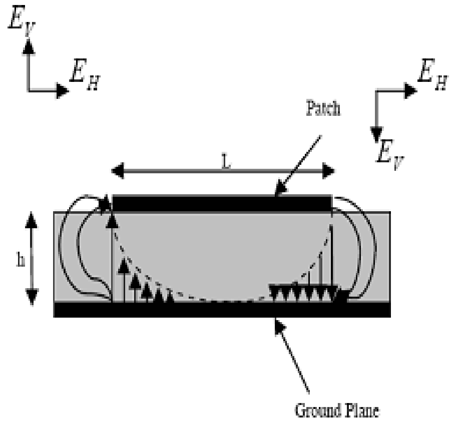


Figure 3.11 Side view of antenna [35]

Hence the edges along the width can be represented as two radiating slots, which are λ / 2 apart and excited in phase and radiating in the half space above the ground plane. The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions.

3.5 ANTENNA PARAMETERS

In a simple way we can say that "an antenna is the transitional radio b/w free space and a guiding device" [35]. For designing a perfect antenna there are certain parameters that are to be considered that define the configuration of the antenna.

3.5.1 Return Loss

This is the best and convenient method to calculate the input and output of the signal sources. It can be said that when the load is mismatched the whole power is not delivered to the load there is a return of the power and that is called loss, and this loss that is returned is called the 'Return loss'.

This Return Loss is determined in dB as follows: [35]

$$R_L = -20log|\Gamma| \ (dB)$$

$$here\ |\Gamma|\ is\ \frac{V_0^-}{V_0^+} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$|\Gamma|$ = is the reflection coefficient

V_0^- = is the reflected voltage

V_0^+ = is the incident voltage

Z_L and Z_0 are the load and characteristic impedence.

3.5.2 Radiation Pattern

MPA has radiation patterns that can be calculated easily. The source of the radiation of the electric field at the gap of the edge of the Microstrip element and the ground plane is the key factor to the accurate calculation of the pattern for the patch antenna.

Simply it can be said that the power radiated or received by the antenna is the function of angular position and radial distribution from the antenna [36]. In the Figure 3.14 below we can see the side view of the rectangular Microstrip element associated with source, and also the radiating of E fields.

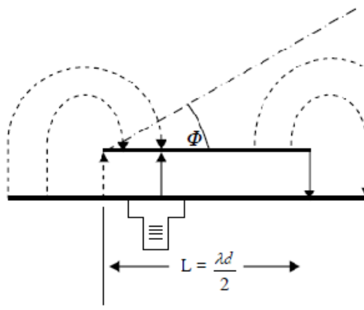


Figure 3.12: Side view of the rectangular Microstrip element and associated radiation [36]

The radiation pattern of a generic dimensional antenna can be seen below, which consist of side lobe, black lobes, and are undesirable as they represent the energy that is wasted for transmitting antennas and noise sources at the receiving end.

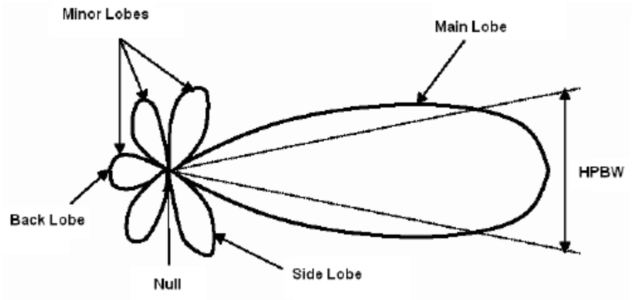


Figure 3.13: Radiation Pattern of a generic dimensional antenna [36]

3.5.3 Gain & Directivity

The gain of the antenna is the quantity which describes the performance of the antenna or the capability to concentrate energy through a direction to give a better picture of the radiation performance. This is expressed in dB, in a simple way we can say that this refers to the direction of the maximum radiation [36].

The expression for the maximum gain of antenna is as follows

$$G = \eta \, x \, D$$

η = The efficiency of the antenna
D = Directivity
In order to receive or transmit the power it can be chosen to maximize the radiation pattern of the response of the antenna in a particular direction.
The directivity of an antenna can be defined as the ratio of radiation intensity in a given direction from the antenna to the radiation intensity averaged in all the directions. And the gain can be known as the ratio between the amounts of energy propagated in these directions to the energy that would be propagated if there is an Omni-directional antenna.
The directivity of the antenna depends on the shape of the radiation pattern. The measurement is done taking a reference of isotropic point source from the response. The quantitative measure of this response is known as the directive gain for the antenna in given direction.

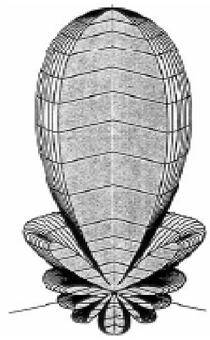


Figure 3.14: Directivity of an antenna [35]

3.5.4 Polarization

The polarization of the electric field vector of the radiated wave or from source Vs time the observation of the orientation of the electric fields does also refer to the polarization. It is defined as" the property of an electromagnetic wave describing the time varying direction and relative magnitude of the electric filed vector"[36].

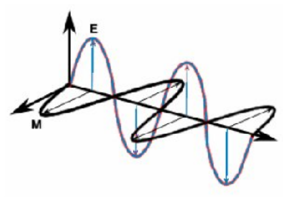


Figure 3.15: A linearly polarized wave [36]

3.5.5 Reflection Coefficient |Γ| and Characteristic Impedance (Z_0)

There is a reflection that occurs in the transmission line when we take the higher frequencies in to consideration. There is a resistance that is associated with each transmission line which comes with the construction of the transmission line. This is called as character impedance (Z_0). The standard value of this impedance is 50 Ω. Always the every transmission line is being terminated with an arbitrary load Z_L and this is not equivalent to the impedance i.e. Z_0. Here occurs the reflected wave.

The degree of impedance mismatch is represented by the reflection coefficient at that load and is given by:

$$\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

We can observe here that the reflection coefficient for the shorted load Z_L=0, there is a match in the load Z_L=Z_0 and an open load Z_L= ∞ are -1, 0, +1 [22]. Hence we can say that the reflection coefficient ranges from 0 to +1.

3.5.6 Voltage Standing Wave Ratio

There should be a maximum power transfer between the transmitter and the antenna for the antenna to perform efficiently. This happens only when the impedance Z_{in} is matched to the transmitter impedance, Z_S.

In the process of achieving this particular configuration for an antenna to perform efficiently there is always a reflection of the power which leads to the standing waves, which is characterized by the Voltage Standing Wave Ratio (VSWR).
This equation is given by [35].

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1 + |\Gamma|}{1 - |\Gamma|} = \frac{1 + S_{11}}{1 - S_{11}}$$

As the reflection coefficient ranges from 0 to 1, the VSWR ranges from 1 to ∞.

3.5.7 Input Impedance

This is the ratio of the voltage to current at the pair of terminals or the ratio of the appropriate components of the electric fields to the magnetic fields at a point. Or in other words we can say it is the impedance presented by the antenna at the input terminal.

$$Z_{in} = (R_{in} + jX_{in})$$

R_{in} – the real part, representing the power dissipated though heat or through radiation losses.
X_{in} – Imaginary part, representing the reactance of the antenna & the power stored in the near field of the antenna [36].

3.5.8 Bandwidth

Bandwidth can be said as the frequencies on both the sides of the centre frequency in which the characteristics of antenna such as the input impedance, polarization, beam width, radiation pattern etc are almost close to that of this value. As the definition goes [35] “the range of suitable frequencies within which the performance of the antenna, w.r.t some characteristic, conforms to a specific standard”.

The bandwidth is the ratio of the upper and lower frequencies of an operation, expressed as

$$BWbroadband = \frac{f_H}{f_L}$$

$$BWnarroband(\%) = \left[\frac{f_H - f_L}{f_C}\right]100$$

When the ratio of $f_H/f_L = 2$, the antenna is said to be broadband. We can judge the antenna’s performance by operating the antenna at high frequency by observing VSWR, when VSWR ≤ 2 (RL≤ -9.5 dB) the antenna is said to have performed well.

3.6 Dimension Parameters

Here we take a short tour of the dimensions of the Microstrip patch antenna i.e. Length (L), width (W).

3.6.1 Length

The length of the rectangular patch antenna, the resonate length, it determines the resonate frequency and is λ/2 for a rectangular patch in its fundamental mode.
The length is calculated as

$$L \approx 0.49\,\lambda_d = 0.49\,\frac{\lambda_0}{\sqrt{\varepsilon_r}}$$

λ_0-Wave length of free space
L-Resonant length
λ_d-Wavelength of PC board
ε_r-dielectric constant

3.6.2 Width

As we know that the dimensions of the patch antenna effects in the results as the main part, especially length (L) and the width (W).

$$Width = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

c = Speed of light

f_r= the resonant frequency which is equal to 1 GHz

3.6.3 Length Extension (ΔL)

The calculation of the extension of the length is given by a very popular relation for the normalized extension of the length is [35]:

$$\Delta L = 0.412h\frac{\left[\varepsilon_{reff} + 0.3\right]\left[{}^{W}/_{h} + 0.264\right]}{\left[\varepsilon_{reff} - 0.258\right]\left[{}^{W}/_{h} + 0.8\right]}$$

h = height

w = width of patch

ε_{reff}= Effective dielectric constant

3.7 Applications of Microstrip Patch Antenna

The Microstrip patch antennas are well known for their performance and their robust design, fabrication and their extent usage. The advantages of this Microstrip patch antenna are to overcome their de-merits such as easy to design, light weight etc., the applications are in the various fields such as in the medical applications, satellites and of course even in the military systems just like in the rockets, aircrafts missiles etc. the usage of the Microstrip antennas are spreading widely in all the fields and areas and now they are booming in the commercial aspects due to their low cost of the substrate material and the fabrication. It is also expected that due to the increasing usage of the patch antennas in the wide range this could take over the usage of the conventional antennas for the maximum applications.

Some of the applications for the Microstrip Patch Antenna are as follows [36]

- Radio altimeters
- Command and control system
- Remote sensing and environmental instrumentation
- Feed element in complex antennas
- Satellite navigation receivers
- Mobile radio
- Integrated antennas
- Doppler and other radars
- Satellite communication and direct broadcast services (DBS)

Chapter 4

DESIGN OF CPW-FED MICROSTRIP ANTENNA FOR WLAN AND WiMAX APPLICATIONS

The present chapter describes CPW-fed 'U' shape dual band microstrip antenna satisfying WLAN and WiMAX applications. This design is described as follows.

4.1 CPW-fed 'U' shaped dual band microstrip patch antenna for WLAN and WiMAX applications :

CPW-fed 'U' shaped microstrip patch antenna consists of U- shape patch element, capable of generating two separate bands with good impedance matching conditions. This antenna can achieve dual band performance to simultaneously cover the most commonly used 2.4 GHz/5.2 GHz/5.8 GHz WLAN bands and 2.5 GHz/5.5 GHz Wi-MAX bands. CST microwave studio version 10 has been used to model and simulate the 'U' shaped MPA. For the feeding of antenna, a 50 Ω CPW line has been designed by analyzing the effects of various design parameters on characteristic impedance of the line. After that, design of 'U' shaped microstrip antenna has been discussed including effects of various geometry parameters on the performance of antenna.

4.1.1 Antenna Geometry and Working Principle

Figure 4.1 shows the geometrical configuration of the proposed CPW-fed planar monopole antenna. The antenna is printed on only one side of an FR4 microwave substrate with the substrate thickness of 1.6 mm and the dielectric constant of 4.4. The main structure of the proposed antenna comprises two folded strips, a CPW feeding line. The strips have a fixed strip width of 'S' and are folded to resemble the antenna in 'U' shape. The major function of the two folded strips of equal lengths is to produce two different current paths and thus expected to effectively excite dual resonant modes. A 50 ohm CPW feeding line with a fixed signal strip thickness of 'W_f' and a gap distance of 'g' between the signal strip and ground is used for centrally feeding the U-shaped antenna from its bottom edge. Two equal finite ground planes, each with dimensions of width 'W_g' and length 'L_g', are situated symmetrically on each side of the CPW feeding line. In this to obtain good dual band impedance matching by controlling the current distribution on the U-shaped stripline and compensation between the capacitive and inductive effects caused from the electromagnetic coupling effects of the finite ground planes and both the feeding line and the U-shaped stripline at the desired various operating bands.

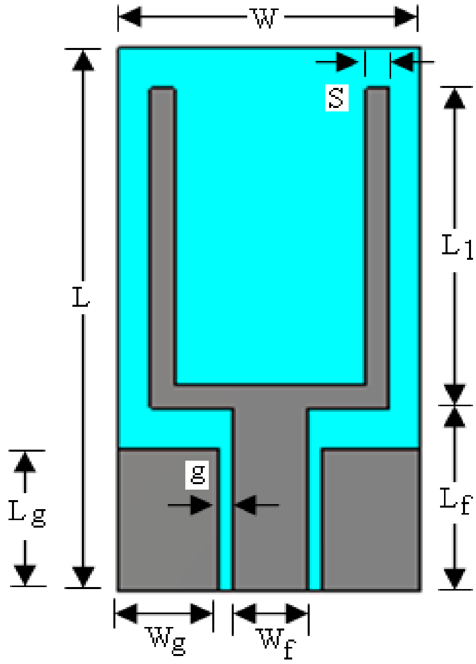


Fig. 4.1: Geometrical configuration of CPW fed U-shaped microstrip antenna

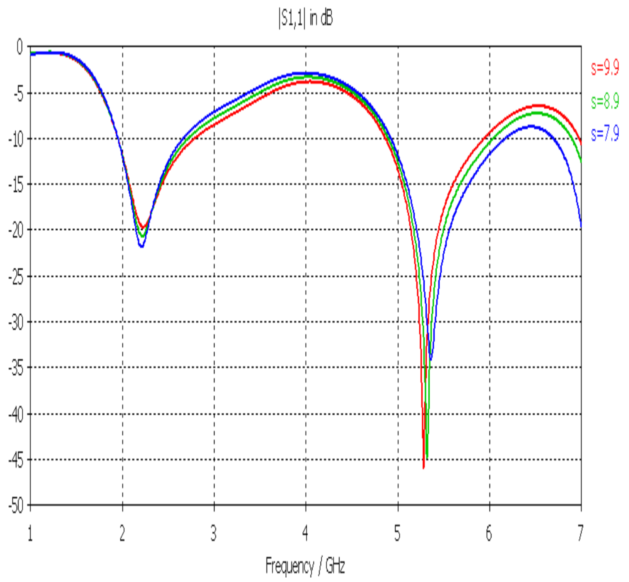
4.1.2 Effect of Geometrical Parameters

Design of 50 Ω CPW line for the feeding of antenna the optimal values of 'W_f', 'W_g' and' *g* ' were obtained as 6.26 mm, 12.62 mm, 1.09 mm respectively. The width of both strip in 'U' shape is kept 2 mm which is represent by 'S'. In order to study the effect of the various geometrical parameters on the antenna performance, the parameters were varied one at a time keeping the others fixed at the value given in Table 4.1.

Table 4.1 Geometry parameters of the antenna and CPW-line (all dimensions in mm)

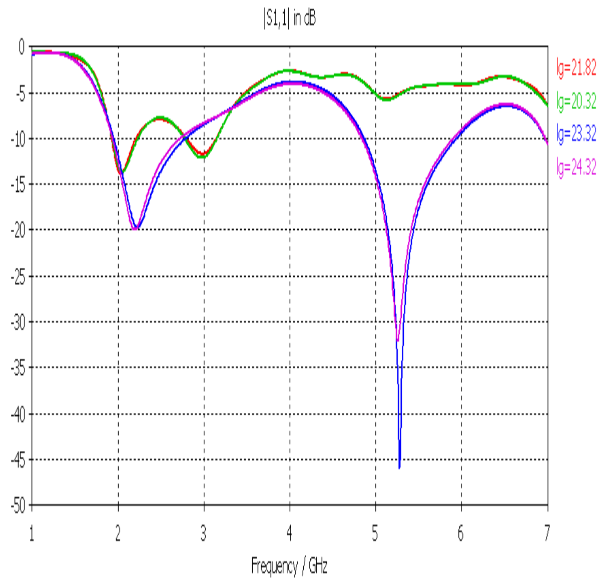
W	L	S	L_1	L_f	g	W_g	W_f	L_g
25	48.32	2	28.4	16.32	1.095	8.275	6.26	12.62

Effect of S variation (Fig. 4.2): As 'S' varies, higher resonating frequency moves upward with decrease in the return loss and there is no significant change in lower frequency band. The value S = 2 mm gives the optimized result which is shown below by red color graph.



Effect of s variation on return loss

Fig. 4.2

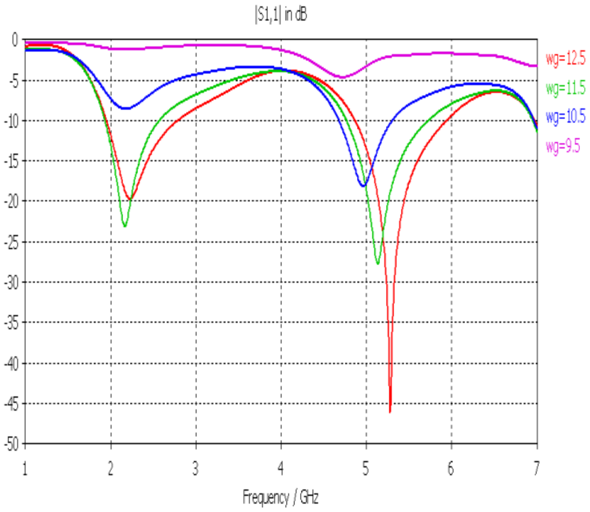


Effect of L_g variation on return loss

Fig. 4.3

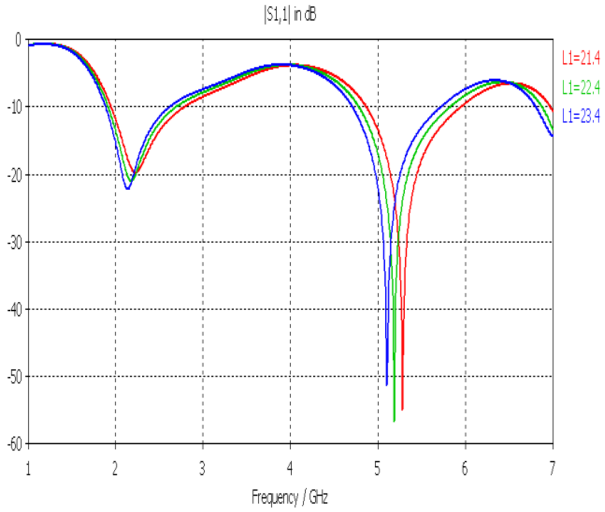
Effect of L_g variation (Fig. 4.3): As 'L_g' increases, the return loss of higher resonating frequency decreases and no significant change in lower resonating frequency. If L_g decreases then higher frequency response becomes very poor and lower resonating frequency appears but with small value of return loss. The graph shown in blue color shows the optimized results.

Effect of W_g variation (Fig. 4.4): Decreasing the value of 'W_g', the higher resonant frequency moves downwards and slight change occur in lower resonating band. The curve shown in red color gives the optimized result.



Effect of W_g variation on return loss

Fig. 4.4



Effect of L_1 variation on return loss

Fig. 4.5

Effect of L_1 variation (Fig. 4.5): Increasing the value of 'L1' causes the higher resonating frequency shifts downward with small change in the value of return loss. There is no significant change occur in lower resonating frequency.

4.1.3 Results and Discussion for CPW-fed 'U' shaped Dual band MPA

Return loss

The simulated return loss results are shown in Figure 4.6. The designed antenna resonates at 2.23 GHz and 5.27 GHz respectively. The return loss for 2.23 GHz is -20.02 dB and the return loss for 5.27 GHz is -54.98 dB which covers the minimum required value of return loss of -10 dB.

The bandwidth of the proposed patch antenna is 839 MHz (1.95 GHz-2.79 GHz) for 2.23 GHz frequency and 1.08 GHz (4.86 GHz-5.93 GHz) for 5.28 GHz frequency. This antenna covers 2.4/5.2/5.8 GHz WLAN standard and 2.5/5.5 GHz WiMAX standard.

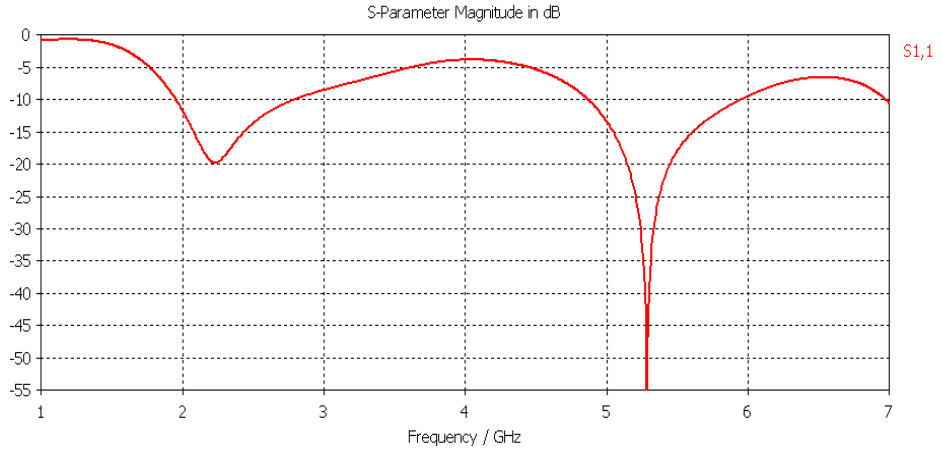


Fig. 4.6 Return loss vs frequency curve

Smith Chart

The Smith Chart plot represents that how the antenna impedence varies with frequency. The achieved antenna impedance is 50 ohm as shown in Figure 4.9, which is equal to the required impedance of 50 ohm.

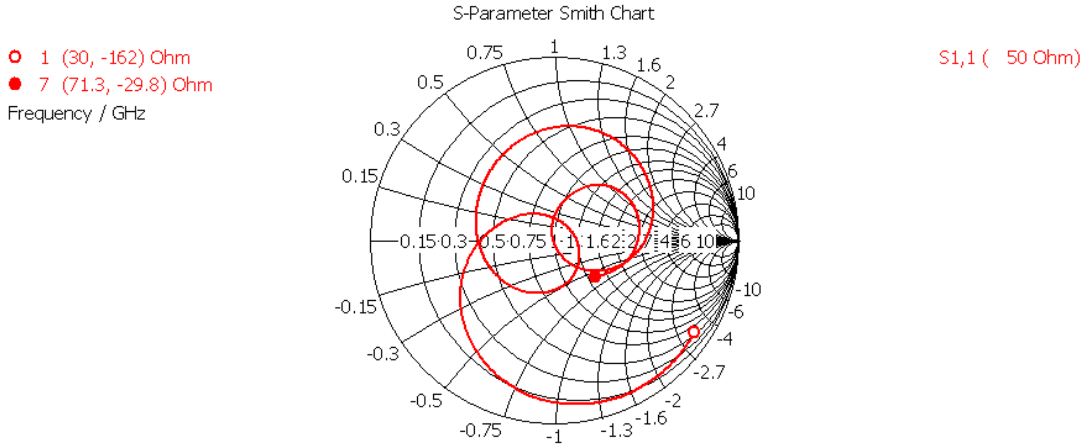


Fig. 4.7 Smith Chart of CPW-fed Dual Band Microstrip Patch Antenna

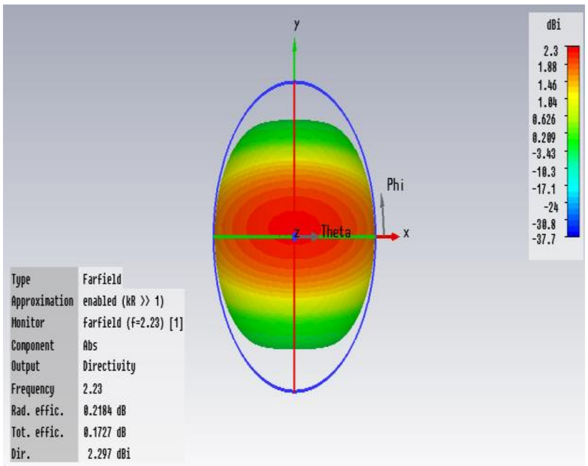
Voltage Standing Wave Ratio (VSWR)

Ideally, VSWR must lie in the range of 1-2 which has been achieved for 2.23 GHz and 5.27 GHz frequency, near the operating frequency value. The VSWR ratio at 2.23 GHz and 5.27 GHz frequency is 1:1.231 and 1:1.012 respectively.

Radiation Pattern

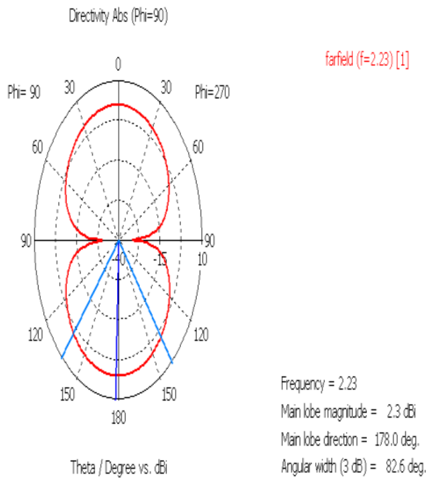
The radiation pattern showing the directivity (3D view) for the designed antenna has been shown in Figure 4.8 and Figure 4.10 for 2.23 GHz and 5.27 GHz respectively and in polar view in Figure 4.9 and 4.11 for 2.23 GHz and 5.27 GHz respectively. The directivity for 2.23 GHz frequency is 2.296 dBi and for 5.27 GHz frequency is 4.612 dBi. The directivity plot represent amount of radiation intensity and it can be represent by red color.

Also from polar plot view of the directivity, it can be seen that at frequency of 2.23 GHz, radiation pattern obtained with main lobe directed at an angle of 178 degree with the magnitude 2.3 dBi and having angular beam width of 82.6 degree. Similarly for the frequency 5.27 GHz, radiation pattern obtained with main lobe directed at an angle of 32 degree with the magnitude 4.6 dBi and having angular beam width of 46.2 degree.



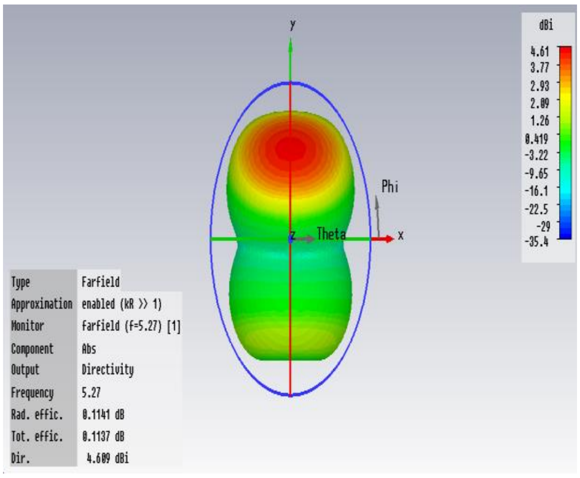
Directivity (3D view) at 2.23 GHz

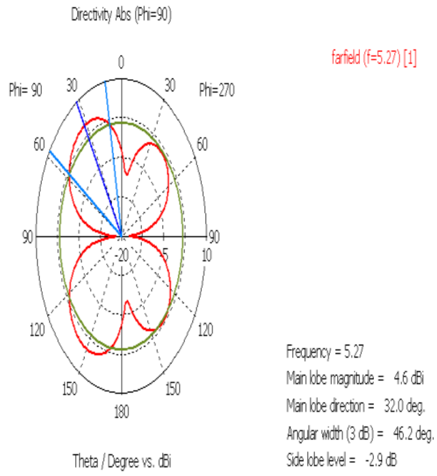
Fig. 4.8



Directivity (Polar plot) at 2.23 GHz

Fig. 4.9





Directivity (3D view) at 5.27 GHz **Directivity (Polar plot) at 5.27 GHz**

Fig. 4.10 **Fig. 4.11**

Total Field Gain

The average antenna gain of proposed antenna for frequencies across the dual band is measured and is shown in Figure 4.12 and Figure 4.13. The ranges of antenna gain at the higher operating band (4.86 GHz-5.95 GHz) is about 5.09-5.13 dB and the average gain is 4.86 GHz around 5.27 GHz. The ranges of antenna gain for lower band is about 2.3-3.03 dB and the average gain is 2.64 dB around 2.23 GHz.

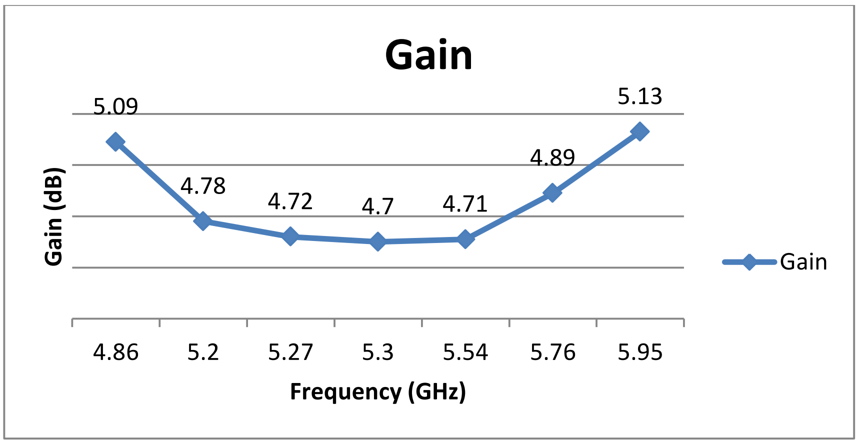


Fig. 4.12 Gain at higher frequency band resonating at 5.27 GHz

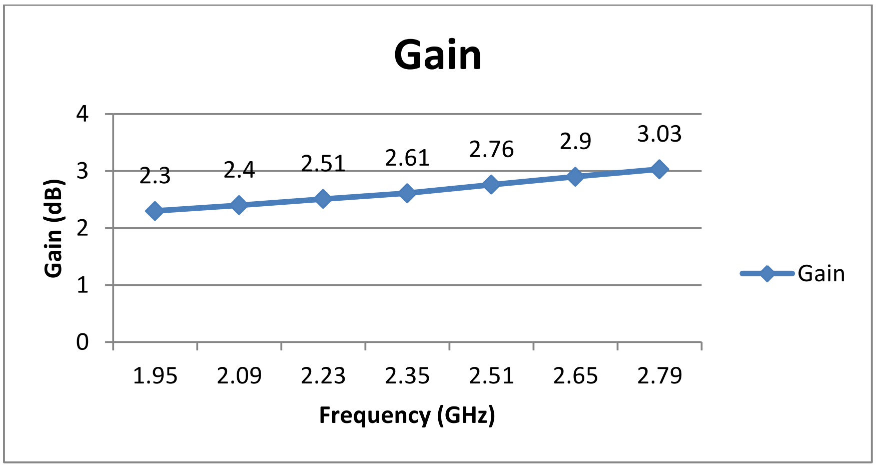
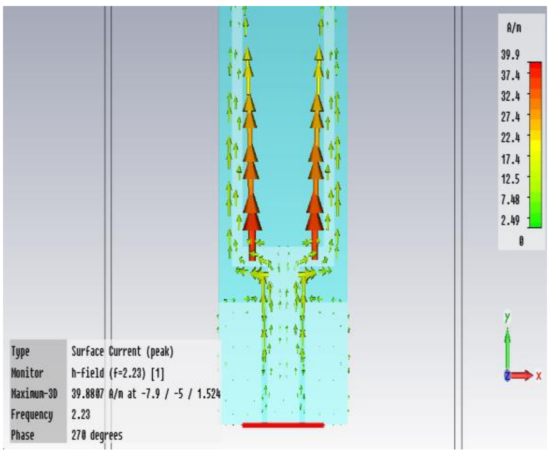
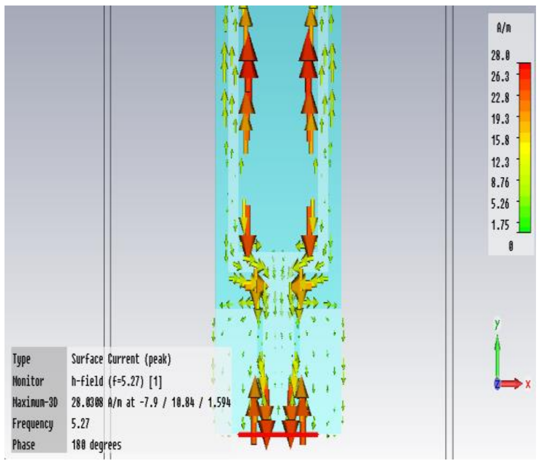


Fig. 4.13 Gain at lower frequency band resonating at 2.23 GHz

Current Distribution at resonant frequencies of operation

The current distributions at both of the frequency are given in Figure 4.14 and Figure 4.15. The surface current at 2.23 GHz is highest near the parallel strips of 'U' shaped patch which is responsible for covering the lower frequency band (1.95 GHz-2.79 GHz) and the maximum value of surface current is 37.4 A/m.





Current distribution at 2.23 GHz

Fig. 4.14

Current distribution at 5.27 GHz

Fig. 4.15

The surface current at 5.27 GHz is highest near gap 'g' between feed line and ground and along the parallel strips of 'U' shaped patch antenna which is responsible for covering the higher frequency band (4.86 GHz-5.95 GHz). The maximum value of surface current at 5.27 GHz is 27.9 A/m.

4.2 Design of CPW-fed 'E-G' shaped Microstrip antenna for WLAN and WiMAX Applications

In this chapter, A CPW-fed 'E-G' shaped monopole antenna with triple band is presented for simultaneously satisfying wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. The initial U-shaped antenna is modified so that 'E-G' shape is formed. The main advantage of inserting the slit is that it is easy to achieve triple band with more bandwidth. This antenna can achieve triple band performance to simultaneously cover the most commonly used 2.4 GHz/5.8 GHz WLAN bands and 3.5 GHz/5.5 GHz Wi-MAX bands. CST MWS simulator has been used to model and simulate the 'E-G' shaped microstrip antenna. After that, design of microstrip antenna has been discussed including effects of various geometry parameters on the performance of antenna. The multiband or broadband antennas are used high interest in recent years for application to multimode communication systems. Because of low cost and process simplicity, monopole antennas are very popular candidates for these applications. This design generally needs to consider many dimensional parameters.

4.2.1 Antenna Geometry

Figure 4.18 shows the geometrical configuration of the proposed CPW-fed planar monopole. The antenna is printed on only one side of an FR4 microwave substrate with the substrate thickness of 1.6 mm and the dielectric constant of 4.4. The main structure of the proposed antenna comprise of three folded strips. A 50 Ω CPW feeding line with a fixed signal strip thickness of 'W_f' and a gap distance of 'g' between the signal strip and ground is used for centrally feeding the 'E-G'-shaped antenna from its bottom edge. Two equal finite ground planes, each with dimensions of width 'W_g' and length 'L_g', are situated symmetrically on each side of the CPW feeding line.

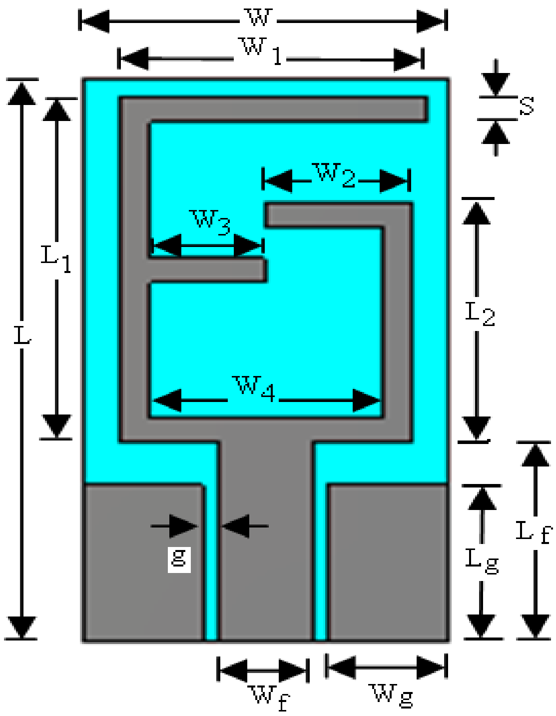


Fig. 4.16 Geometrical configuration of CPW-fed 'E-G' shaped MPA

4.2.2 Design Parameters of Antenna

Design of 50 Ω CPW line for the feeding of antenna the optimal values of W_f, W_g and g were obtained as 6.26 mm, 8.275 mm, 1.09 mm respectively.

Effect of Geometrical Parameters

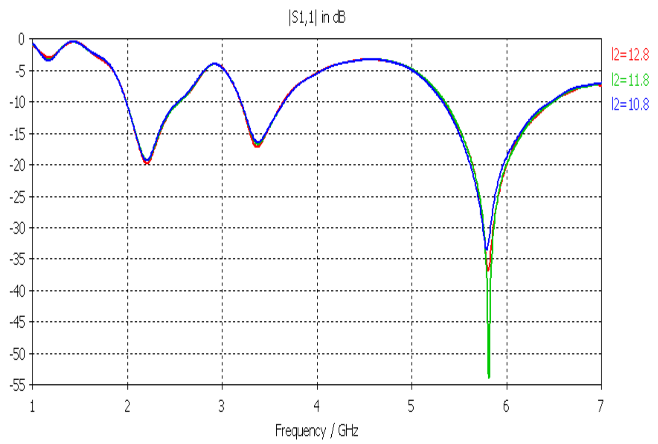
In order to study the effect of the various geometrical parameters on the antenna performance, the parameters were varied one at a time keeping the others fixed at the value given in Table 4.2.

Effect of L_2 variation (Fig. 4.17): Decreasing the value of L_2, the return loss of higher resonating frequency increases sharply. There is slight change occur in lower resonating frequency.

Table 4.2 Geometry parameters of the antenna and CPW-line (all dimensions in mm)

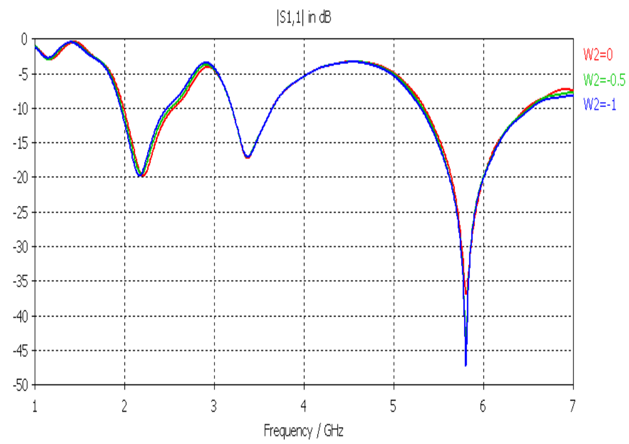
L	L_1	W	L_2	W_1	W_2	W_3	W_4	S	G	L_f	W_f	L_g	W_g
46.32	28.4	25	19.8	20.8	9.9	7.9	15.8	2	1.09	16.32	6.26	12.82	8.275

Effect of W_2 variation (Fig. 4.18): As the value of W_2 increases, the return loss of higher resonating frequency increases sharply. The Second lower resonating frequency remains unchanged.



Effect of L_2 variation on return loss

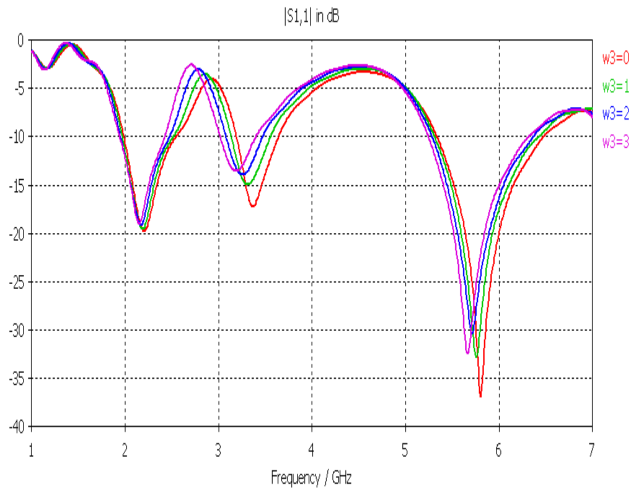
Fig. 4.17



Effect of W_2 variation on return loss

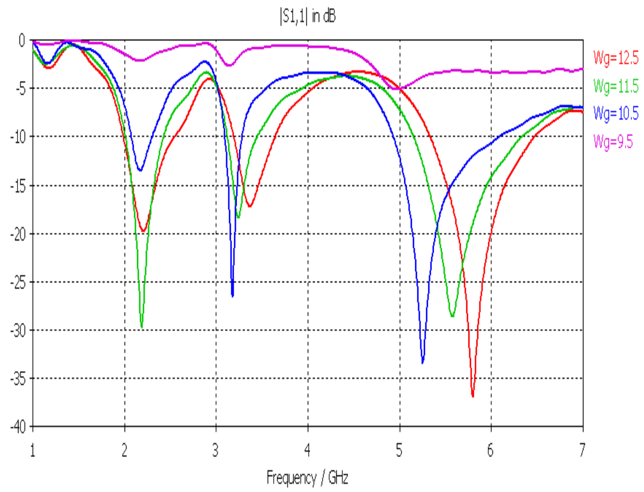
Fig. 4.18

Effect of W_3 variation (Fig. 4.19): Increasing the value of W_3, causes shifting of lower resonating frequency downwards with poor impedance matching. The return loss of higher resonating frequency varies rapidly with increasing W_3.



Effect of W_3 variation on return loss

Fig. 4.19



Effect of W_g variation on return loss

Fig. 4.20

Effect of W_g variation (Fig. 4.20): Decreasing the value of W_g , causes the shifting of second and third higher resonating frequency downwards. The return loss of first lower resonating frequency changes sharply.

Effect of W_f variation (Fig. 4.21): As the value of W_g decreases, all the resonating frequency shifts downward and the first lower resonating frequency greatly effects with poor impedance matching. The return loss of second resonating frequency varies sharply.

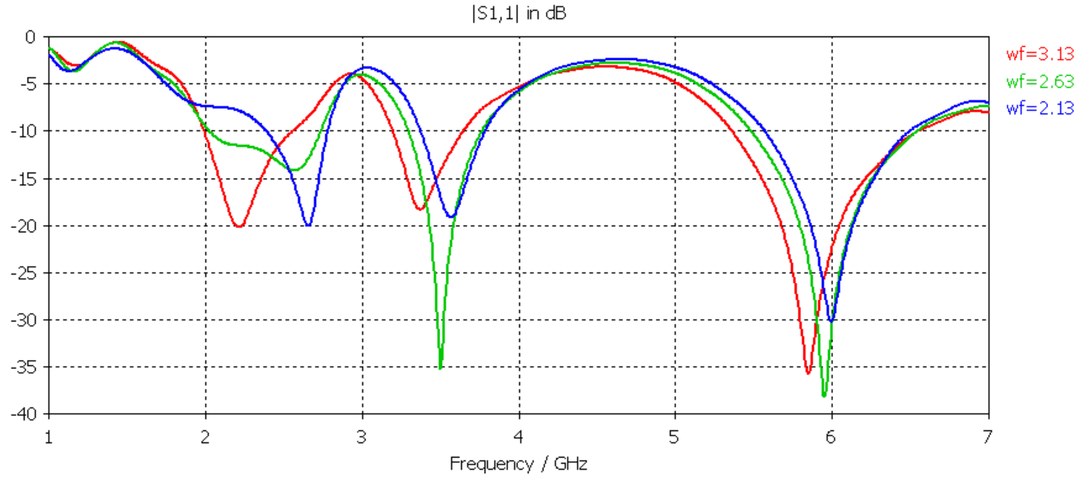


Fig. 4.21 Effect of W_f variation on return loss

4.2.3 Results and Discussion for CPW-fed 'E-G' shaped Triple band Microstrip patch antenna

The geometrical parameters of the antenna were changed one by one and after several cycle of changes, the optimized values for these parameters were obtained. Table 4.2 lists the values of optimized parameters of the antenna and CPW-line.

Return loss

The designed antenna resonates at 2.20 GHz, 3.37 GHz and 5.84 GHz respectively. The return loss for 2.2 GHz, 3.37 GHz and 5.84 GHz is -20.48 dB, -18.56 dB and -35.93 dB respectively. The return loss versus frequency curve is shown in Figure 4.22. The bandwidth of the proposed patch antenna is 567 MHz (1.98 GHz-2.54 GHz) for 2.2 GHz frequency and 439 MHz (3.19 GHz-3.63 GHz) for 3.37 GHz frequency and 1.17 GHz (5.35 GHz-6.52 GHz) for 5.84 GHz respectively.

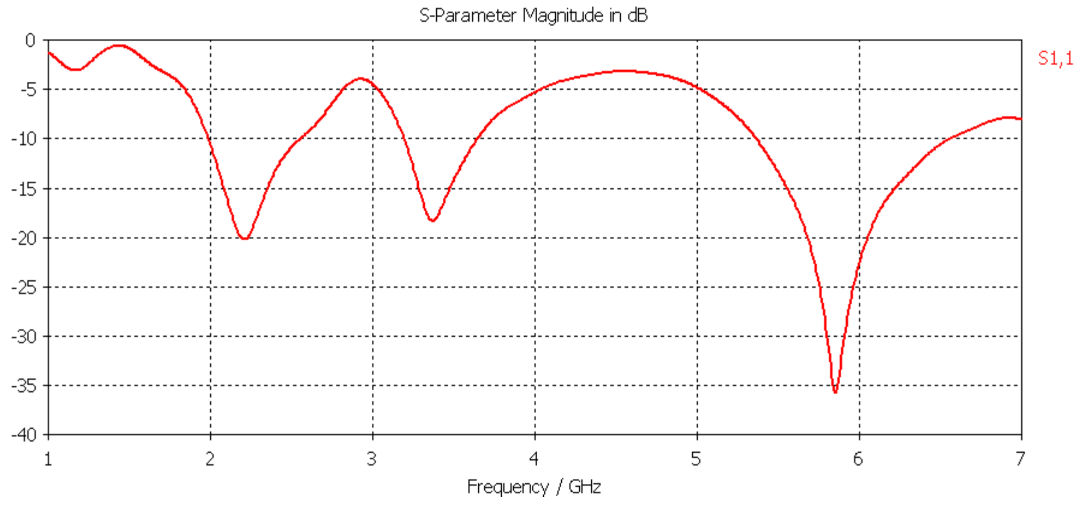


Fig. 4.22 Return loss vs Frequency curve

Smith Chart

The Smith Chart plot represents that how the antenna impedence varies with frequency. The achieved antenna impedance is 50 ohm as shown in Figure 4.23, which is equal to the required impedance of 50 ohm.

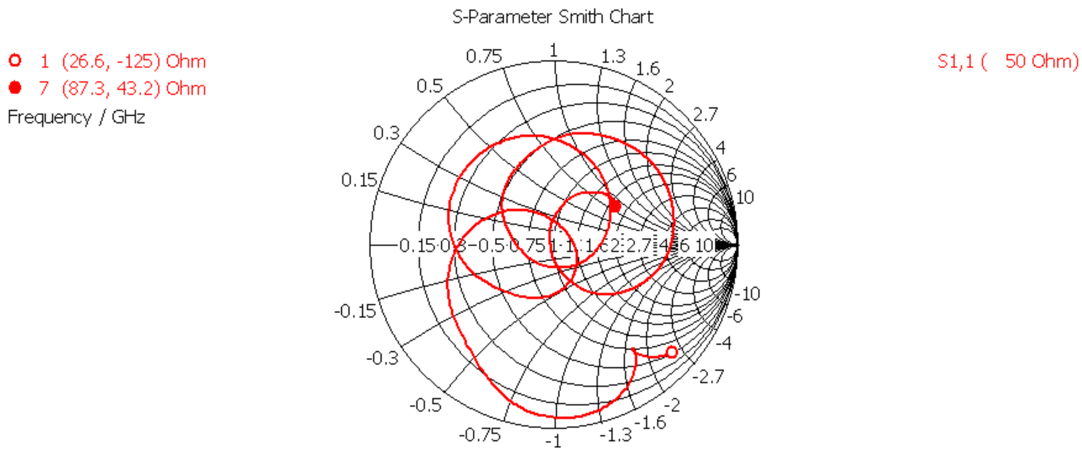


Fig.4.23 Smith Chart of CPW-fed ‘E-G’ shaped Triple Band MPA

Radiation Pattern

The radiation patterns showing the directivity for the designed antenna for 2.2 GHz, 3.37 GHz and 5.84 GHz have been shown in Figure 4.24, Figure 4.25 and Figure 4.26 respectively. The radiation pattern shows directivity (polar view) is 2.287 dBi, main lobe direction is 178 degree and angular beam width is 83.6 degree for 2.2 GHz frequency. The radiation pattern obtained for 3.37 GHz frequency shows directivity is 2.796 dBi and main lobe direction is 180 degree having angular beam width of 91.3 degree and for 5.84 GHz frequency directivity is 3.582 dBi with main lobe direction 152 degree and having angular beam width of 54.2 degree

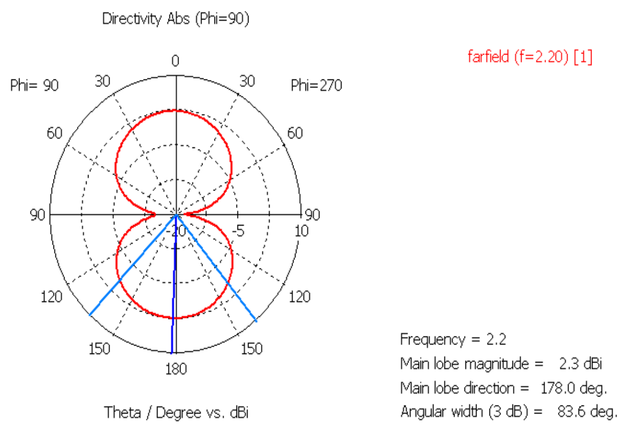
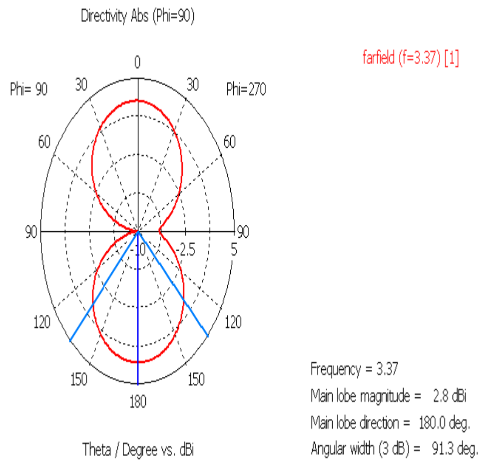


Fig. 4.24 Directivity (Polar plot) at 2.2 GHz



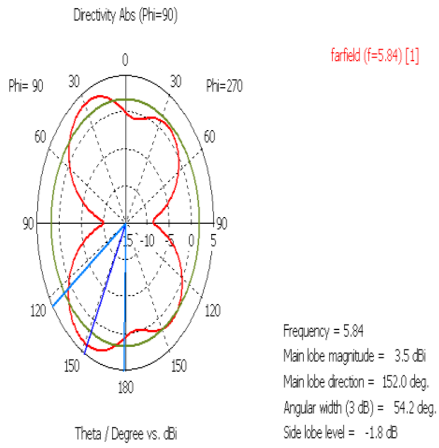


Fig. 4.25 Directivity at 3.37 GHz

Fig. 4.26 Directivity at 5.84 GHz

Voltage Standing Wave Ratio (VSWR)

Ideally, VSWR must lie in the range of 1-2 which has been achieved for 2.20 GHz, 3.37 GHz and 5.84 GHz frequency, near the operating frequency value. The VSWR ratio at 2.20 GHz, 3.37 GHz and 5.84 GHz frequencies is 1:1.217, 1:1.276 and 1:1.033 respectively

Total Field Gain

The average antenna gain of proposed antenna for frequencies across the triple band is measured and is shown in Figure 4.27. The ranges of antenna gain at the first lower frequency band (1.98 GHz-2.54 GHz) is about 2.48-2.9 dB and the average gain is 2.63 GHz around 2.2 GHz. The ranges of antenna gain for second lower frequency band (3.19 GHz-3.63 GHz) is about 2.56-3.5 dB and the average gain is 3.02 dB around 3.37 GHz and for higher frequency band (5.35 GHz-6.52 GHz) is about 3.85-3.39 dB respectively. The average gain is 3.57 around 5.84 GHz.

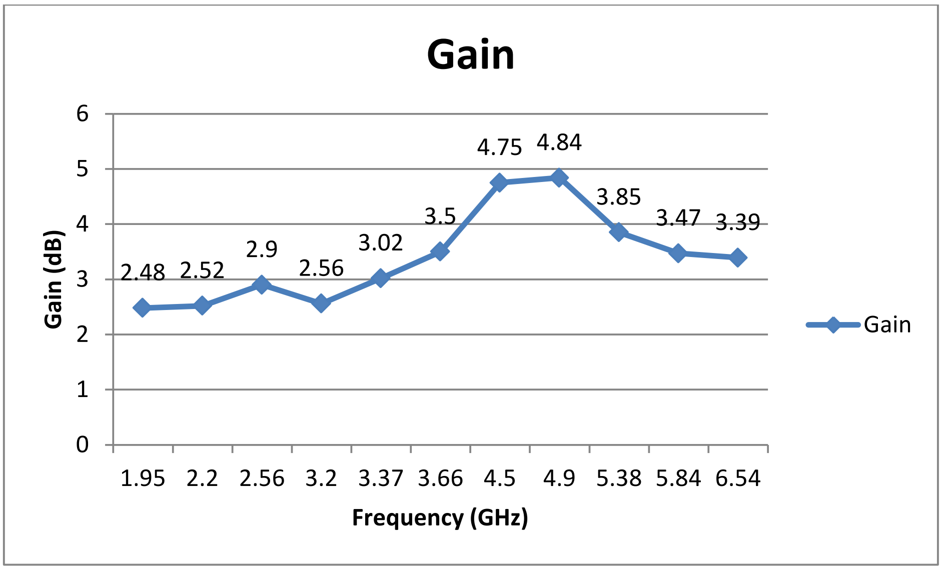
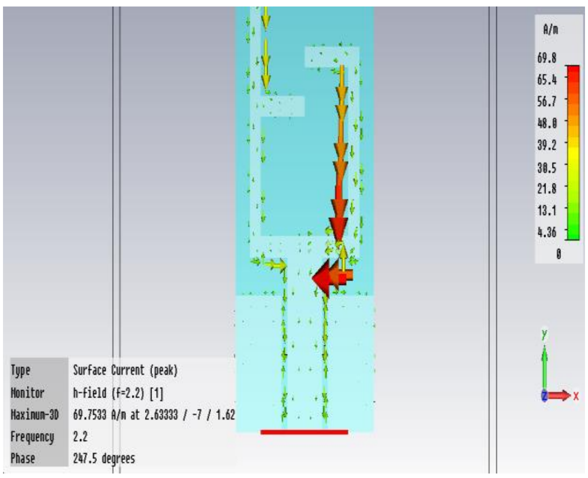


Fig. 4.27 Gain versus frequency curve

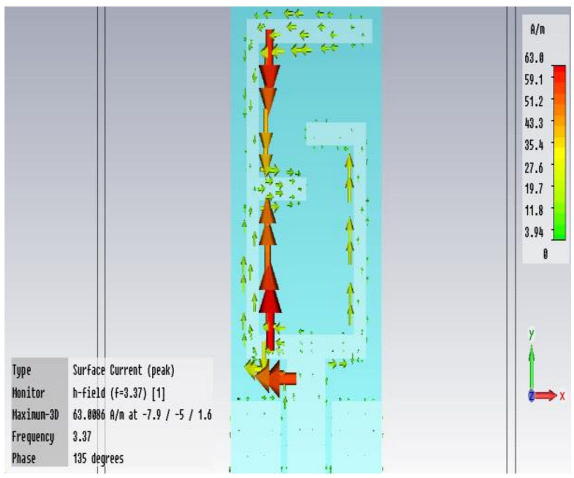
Current Distribution at resonant frequencies of operation

The current distributions at both of the frequency are given in Figure 4.28 and Figure 4.29 and Figure 4.30. The surface current at 2.2 GHz is highest near the ‘L_2’ strip of ‘E-G’ shaped patch which is responsible for covering the first lower frequency band (1.98 GHz-2.54 GHz) and the maximum value of surface current is 69.75 A/m.



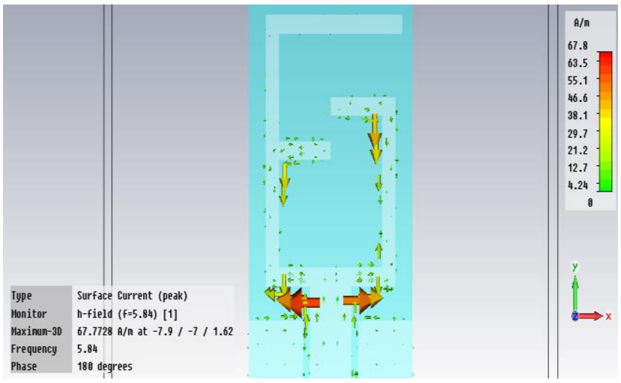
Current distribution at 2.2 GHz

Fig. 4.28



Current distribution at 3.37 GHz

Fig. 4.29



Current distribution at 5.84 GHz

Fig. 4.30

The surface current at 3.37 GHz is highest near gap 'g' between feed line and ground and along the strip 'L_1' which is responsible for covering the second lower frequency band (3.19 GHz-3.63 GHz). The maximum value of surface current at 5.27 GHz is 63 A/m. The surface current at 5.84 GHz is highest near gap 'g' between feed line and ground and its maximum value is 67.77 A/m.

Chapter 5

DESIGN OF MICROSTRIP-FED MONOPOLE ANTENNA USING DEFECTED GROUND STRUCTURE FOR WLAN AND WiMAX APPLICATIONS

In this chapter a triple frequency microstrip-fed planar monopole antenna for multiband operation is presented. Defective ground structure is used in this antenna which has a rectangular patch with dual inverted staircase L-shaped strips and is fed by a cross-shaped stripline for achieving additional resonance and bandwidth enhancements. This antenna can achieve triple band performance to simultaneously cover the most commonly used 2.4 GHz/5.2 GHz/5.8 GHz WLAN bands and 2.5GHz/3.5 GHz/5.5 GHz WiMAX bands. CST Microwave Studio simulator has been used to model and simulate the microstrip patch antenna using DGS (Defective Ground Structure). After that, design of microstrip antenna has been discussed including effects of various geometry parameters on the performance of antenna.

The multiband or broadband antennas are used high interest in recent years for application to multimode communication systems. Because of low cost and process simplicity, monopole antennas are very popular candidates for these applications. This design generally needs to consider many dimensional parameters.

5.1 Defected Ground Structure

A Defected Ground Structure (DGS) is an etched lattice shape, which locates on the ground plane. Defected ground structure (DGS) is realized by etching defects in the backside metallic ground plane under a microstrip line. A basic and widely used DGS cell is composed of two wide defected areas and a narrow connecting slot such as H shape narrow at middle or U shape with narrow at bottom. The name for this technique simply means that a “defect” has been placed in the ground plane, which is typically considered to be an approximation of an infinite, perfectly-conducting current sink. DGS allows the designer to place a notch (zero in the transfer function) almost anywhere [38]. DGS is an etched periodic or non-periodic cascaded configuration defect in ground of planar transmission line (e.g., microstrip, coplanar and conductor backed coplanar wave guide) which disturbs the shield current distribution in the ground plane cause of the defect in the ground. This disturbance will change characteristics of a transmission line such as line capacitance and inductance. In a word, any defect etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance [37].

5.2 Antenna Geometry

Figure 5.1 and Figure 5.2 shows the geometrical configuration of the proposed microstrip-fed monopole antenna using defected ground structure for WLAN and WiMAX application. The microstrip antenna has a planar geometry and consists of a defected ground, substrate, patch and cross-shaped feed. The defected ground structure has 'I' shape and radiating element is loaded with staircase L-shaped strips and it is fed with cross shaped stripline.

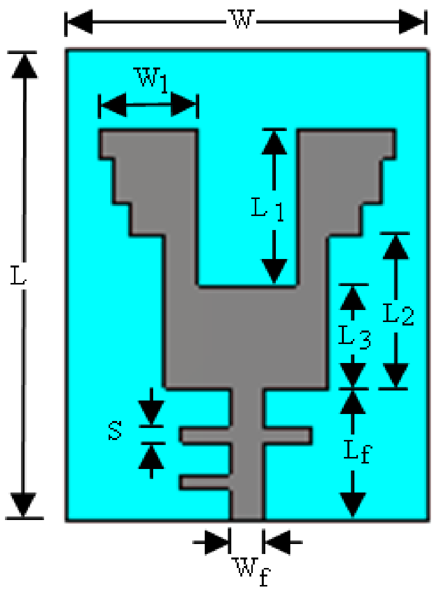


Fig. 5.1 Geometrical configuration of Front view of microstrip-fed monopole antenna for WLAN/WiMAX applications

The patch and ground plane are etched on the opposite sides of a substrate with a dielectric constant of 4.4 and thickness of 1.6 mm. The WLAN and WiMAX standards can be achieved by properly selecting the dimensions of the proposed antenna.

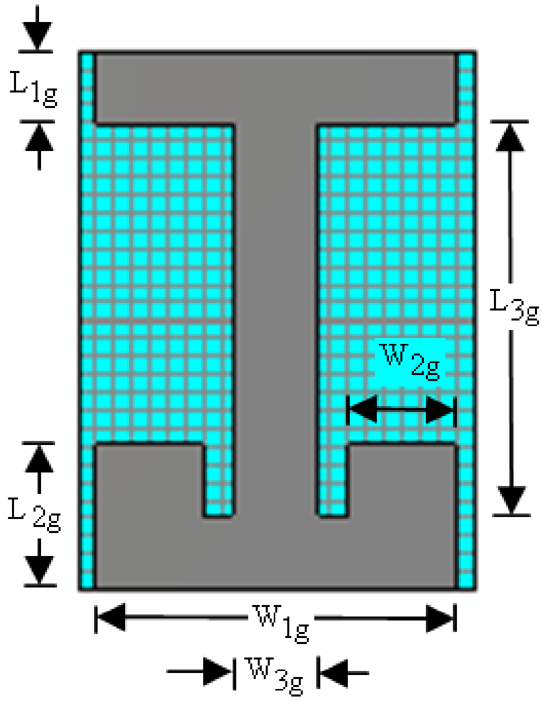


Fig. 5.2 Geometrical configuration of Back view of microstrip-fed monopole antenna for WLAN/WiMAX applications

5.3 Design Parameters of Antenna

Design of cross shaped microstrip line feed for the feeding of antenna the optimal values of ‘L_f’, ‘W_f’ and ‘S’ were obtained as 9 mm, 2 mm and 1 mm respectively.

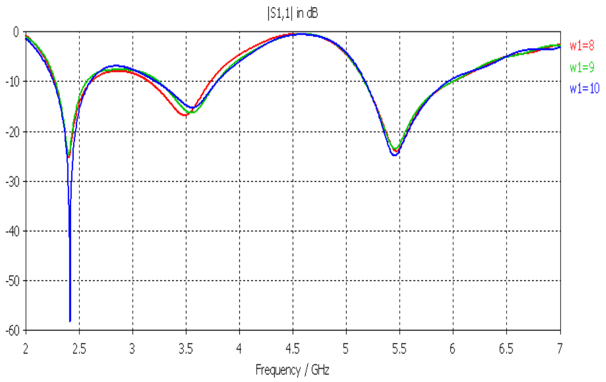
Effect of Geometrical Parameters

In order to study the effect of the various geometrical parameters on the antenna performance, the parameters were varied one at a time keeping the other fixed the value is given in Table 5.1.

Table 5.1 Geometry parameters of the antenna and microstrip line (all dimensions in mm)

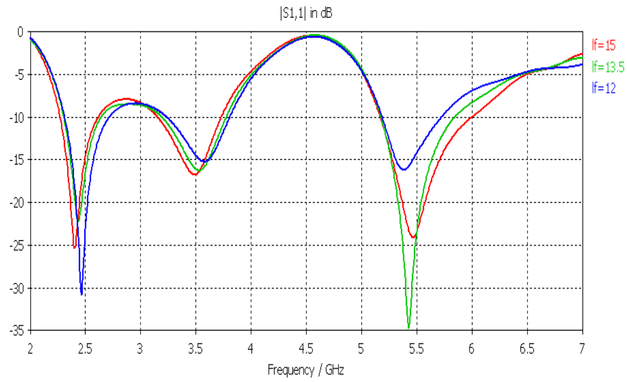
L	W	L_f	W_f	S	L_1	L_2	L_3	L_{1g}	W_{1g}	L_{2g}	W_{2g}	L_{3g}	W_{3g}
30	22	9	2	1	10	9.7	6.5	4.11	20	8.1	6	21.78	4.8

Effect of W_1 variation (Fig.5.3): As the value of W_1 increases, the return loss of first lower resonant frequency varies sharply and there is no effect on second and third resonating frequency. The optimized curve is shown in red color curve.



Effect of W_1 variation on return loss

Fig. 5.3



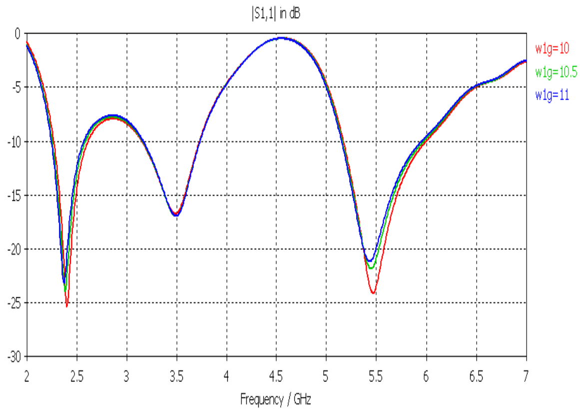
Effect of L_f variation on return loss

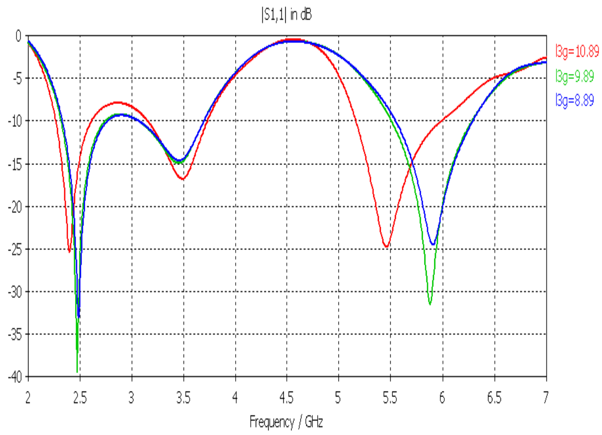
Fig. 5.4

Effect of L_f variation (Fig. 5.4): As the value of L_f decreases, first and second lower resonating frequency shifts towards right side. The higher resonating frequency shifts downward with good impedance matching.

Effect of W_{1g} variation (Fig. 5.5): Increasing the value of W_{1g}, the return loss of first lower resonating frequency increases. There is no change occur in second lower resonating frequency. The higher resonating frequency shifts downward. The curve shown in red color shows the optimized results.

Effect of L_{3g} variation (Fig. 5.6): As the value of L_{3g} decreases, the higher resonating frequency shifts upward and the return loss of first resonating frequency increases sharply. The curve shown in red color gives the optimized value of 'L_{3g}'.





Effect of W_{1g} variation on return loss **Effect of L_{3g} variation on return loss**

Fig. 5.5 **Fig. 5.6**

5.4 Results and Discussion for Microstrip-fed Triple band Monopole Microstrip patch antenna

The geometrical parameters of the antenna were changed one by one and after several cycle of changes, the optimized values for these parameters were obtained. Table 5.1 lists the values of optimized parameters of the antenna and CPW-line.

5.4.1 Return loss

The simulated return loss results are shown in Figure 5.7. The designed antenna resonates at 2.4 GHz, 3.48 GHz and 5.46 GHz respectively.

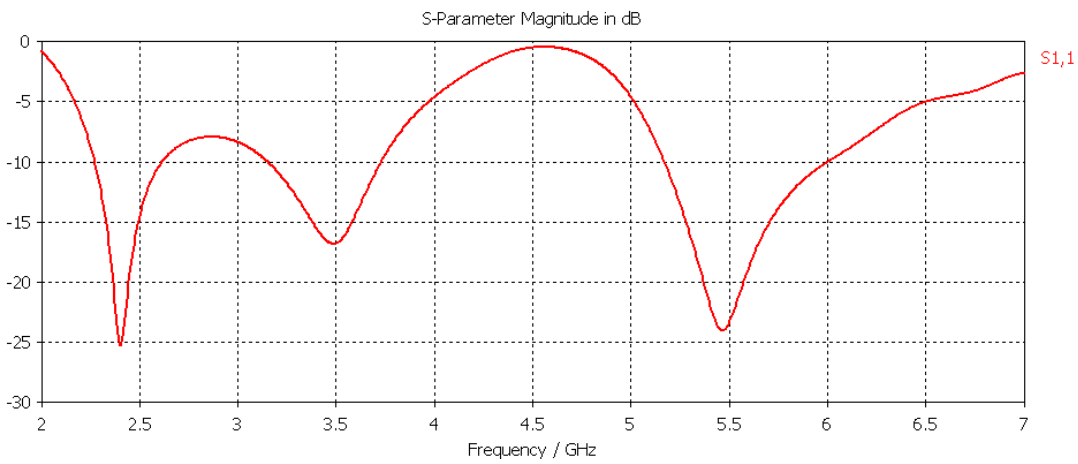


Fig. 5.7 Return Loss of Microstrip-fed Triple Band Monopole MPA

The return loss for 2.4 GHz is -25.42 dB and the return loss for 3.48 GHz is -16.98 dB and the return loss for 5.46 GHz is -24.94 dB which covers the minimum required value of return loss of -10 dB. The bandwidth of the proposed patch antenna is 347 MHz (2.27 GHz-2.61 GHz) for 2.40 GHz frequency and 580 MHz (3.15GHz-3.73 GHz) for 3.48 GHz frequency and 833 MHz (5.17 GHz-6 GHz) for 5.46 GHz.

5.4.2 Smith Chart

The Smith Chart plot represents that how the antenna impedence varies with frequency. The achieved antenna impedance is 50 ohm as shown in Figure 5.8, which is equal to the required impedance of 50 ohm.

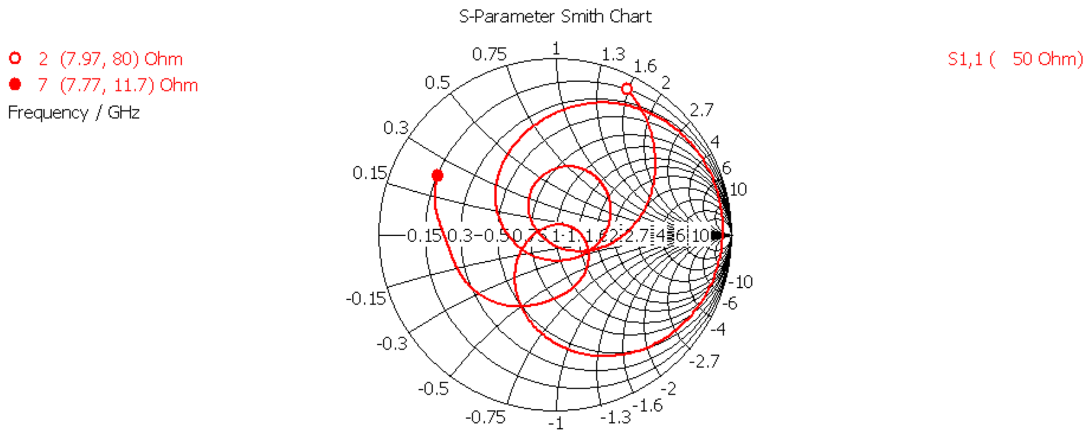


Fig. 5.8 Smith Chart of Microstrip-fed Triple Band Monopole MPA

5.4.3 Voltage Standing Wave Ratio (VSWR)

Ideally, VSWR must lie in the range of 1-2 which has been achieved for 2.40 GHz, 3.48 GHz and 5.46 GHz frequency, near the operating frequency value. The VSWR ratio at 2.40 GHz frequency is 1:1.115, at 3.48 GHz frequency and 5.46 GHz frequency is 1:1.339 and 1:1.123 respectively.

5.4.4 Radiation Pattern

The radiation patterns showing the directivity for the designed antenna for 2.4 GHz, 3.48 GHz and 5.46 GHz have been shown in Figure 5.9, Figure 5.10 and Figure 5.11

respectively. The radiation pattern shows directivity (polar view) is 2.1 dBi, main lobe direction is 0 degree and angular beam width is 86.2 degree for 2.4 GHz frequency.

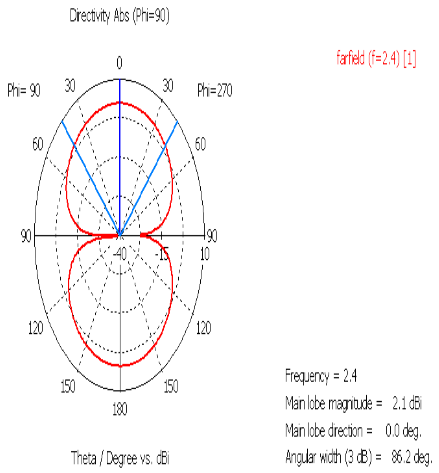


Fig. 5.9 Directivity at 2.4 GHz

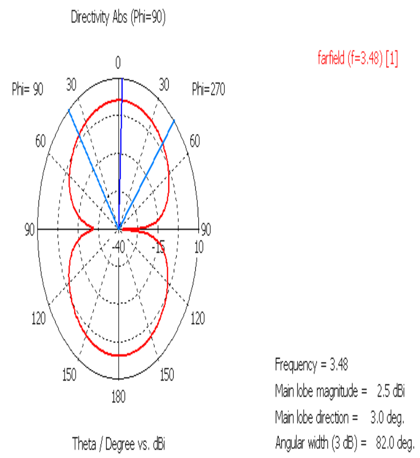


Fig. 5.10 Directivity at 3.48 GHz

The radiation pattern obtained for 3.48 GHz frequency shows directivity is 2.5 dBi and main lobe direction is 3 degree having angular beam width of 82 degree and for 5.46 GHz frequency directivity is 3.2 dBi with main lobe direction 12 degree and having angular beam width of 74.7 degree.

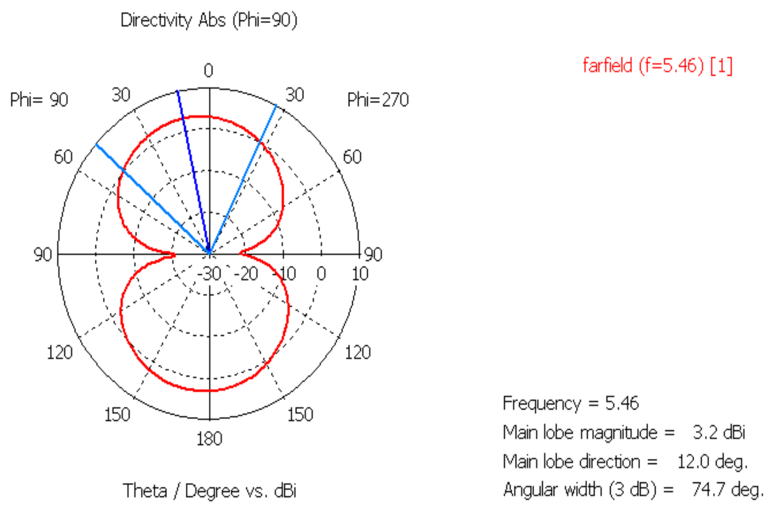


Fig. 5.11 Directivity at 5.46 GHz

5.4.5 Total Field Gain

The average antenna gain of proposed antenna for frequencies across the triple band is measured and is shown in Figure 5.12. The ranges of antenna gain at the first lower frequency band is about 1.68-2.28 dB and the average gain is 1.98 GHz around 2.4 GHz. The ranges of antenna gain for second lower frequency band is about 2.41-2.46 dB and the average gain is 2.43 dB around 3.48 GHz and for higher frequency band is about 3.16-3.18 dB respectively. The average gain is 3.15 dB around 5.46 GHz.

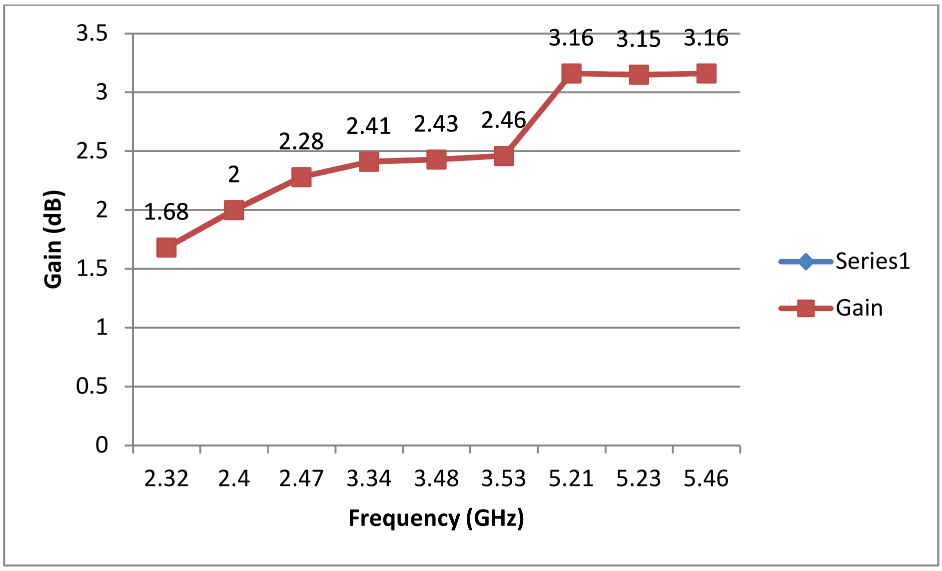


Fig. 5.12 Gain versus frequency curve

Chapter 6

FABRICATION AND TESTING

This chapter describes the fabrication and testing of CPW-fed 'U' shaped dual band microstrip patch antenna. The material used for fabrication of antenna is PEC (copper) of height 0.07 mm with FR4 substrate of dielectric constant 4.4 and thickness 1.524 mm. The fabricated antenna is shown in Figure 6.1.

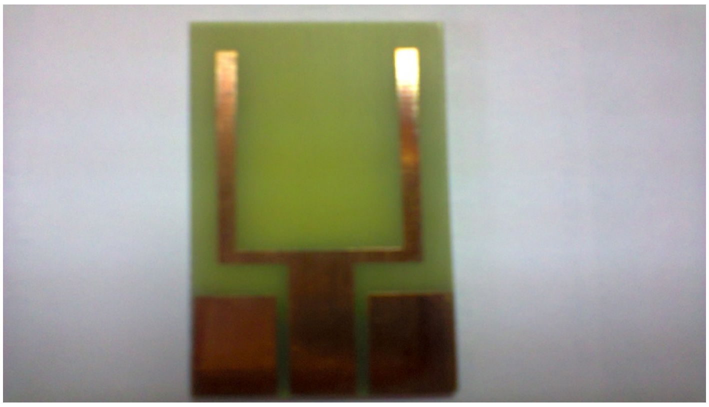


Fig. 6.1 Front view of CPW-fed dual band MPA

6.1 Testing of Structure on VNA

The CPW-fed 'U' shaped dual band microstrip patch antenna was designed using the CST2010 studio suite software. But practically, these were tested using VNA model no : E5071C, frequency range is 9KHz-8.5GHz and is shown below :

Fig. 6.2 Instrument used for testing

Figure 6.3 shows the simulated and measured return loss curve. It shows that the measured value of return loss is -17.25 dB for lower frequency band and -40.12 dB for higher frequency band whereas the simulated value of return loss is -20.02 dB and -54.98 dB for lower frequency band and higher frequency band respectively.

The simulated bandwidth of this antenna also reduced for the both resonating frequency. The measured value of the bandwidth is 33 MHz (2.23 GHz-2.56 GHz) for lower frequency band and 49 MHz (5.64 GHz-5.15 GHz) for higher frequency band.

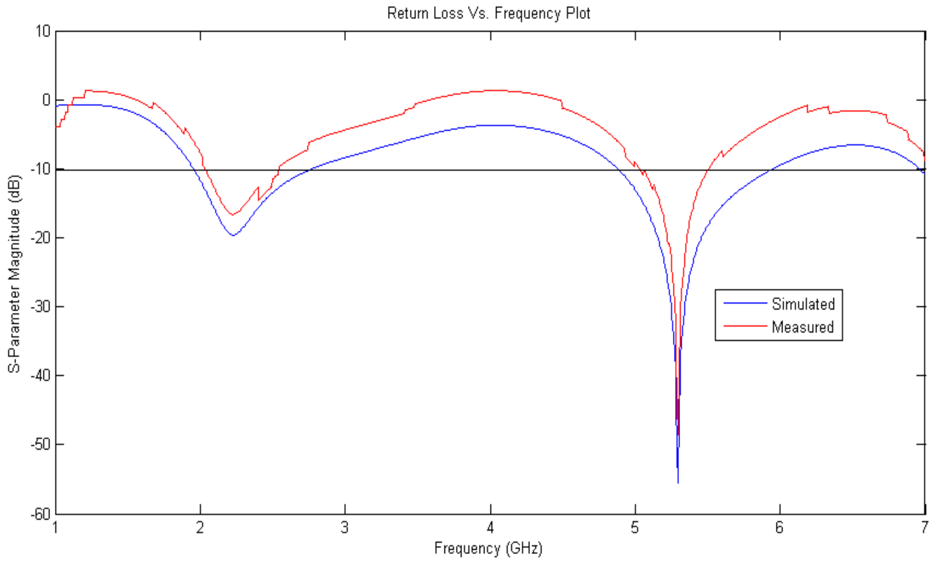


Fig. 6.3 Return loss versus frequency curve of CPW-fed dual band MPA

Chapter 7

CONCLUSION AND FUTURE WORK

7.1 Conclusion

This chapter sums up all the work presented in this thesis, and then obtain a conclusion that would help in the development of this work and finally preset the future work.

Firstly a CPW-fed 'U' shaped dual band microstrip patch antenna has been designed. The obtained -10 dB impedance bandwidth for 'U'-shaped dual band antenna is 37.66% and 20.30% at the bands of 2.23 GHz and 5.27 GHz respectively, sufficiently covering the bandwidth requirement of WLAN system and WiMAX system in the 2.4/5.2/5.8 GHz standard and in 2.5/5.5 GHz standard respectively. CPW feeding has been used because of its many advantages such as wide bandwidth, simple single metallic layer and easy integration with MMIC devices.

Further by modifying this antenna, a CPW-fed 'E-G' shaped triple band microstrip patch antenna has been designed which covers 2.4/5.8 GHz WLAN standard and 3.5/5.5 GHz WiMAX standard. The obtained -10 dB impedance bandwidth for CPW-fed 'E-G' shaped triple band antenna is 25.45%, 13.05% and 20.03% at the bands of 2.20 GHz, 3.37 GHz and 5.84 GHz respectively.

A Microstrip-fed triple band monopole antenna using defected ground structure has been designed which covers 2.4/5.2/5.8 GHz WLAN standard and 2.5/3.5/5.5 GHz WiMAX standard. The obtained -10 dB impedance bandwidth for this antenna is 14.16%, 16.66% and 15.20% at the bands of 2.4 GHz, 3.48 GHz and 5.46 GHz respectively/

Monopole-like radiation pattern observed which fulfills the condition of radiation pattern for a better WLAN and WiMAX system.

7.2 Future Work

- ❖ In this thesis, optimization of parameters has been done manually. One can use inbuilt optimizer to optimize the parameters using optimization techniques. One can optimize the parameters via. Writing the program using MATLAB to optimize the various parameters, then calibrating MATLAB with CST.

- The proposed Microstrip patch antennas have small value of gain and it can be enhanced by using photogenic band gap (PBG) structure and by applying the planar metamaterial structure on upper patch and bottom ground of dielectric substrate.
- Wideband and ultra-wideband patch antenna can be designed which is helpful in telecommunication, and high speed data transmission systems.

REFERENCES

[1] Howell, J. Q., "*Microstrip Antenna*", IEEE AP-S int. Symp. Digest, pp 177-180, 1972.

[2] Munson, R.E., "*Conformal Microstrip antennas and microstrip phased arrays*", IEEE transaction on antennas and propagation, Vol. -AP22, pp74-78, 1974.

[3] Kin-Lu Wong, Wen-Hsiu Hsu, "*A Broad-band Rectangular Patch Antenna with a Pair of Wide Slits*", IEEE Transaction on Antennas and Propagation, Vol. 49, pp 1345-1347, 2001.

[4] http:en.wiki .edia.org/wiki/Wimax/Wlan.

[5] Sheng-Ming, M. –D. Wu and P. Hsu, "*Analysis of coplanar waveguide-fed microstrip antenna*", IEEE Transaction on Antennas and Propagation Letters, Vol. 43, No. 7, July 1995.

[6] S. Maci and G. BifJi Gentili, "*Dual Frequency Patch Antenna*", IEEE Antennas and Propagation Magazine, Vol. 39, No. 6, December 1997.

[7] Ch. Sulakshana and L. Anjaneyulu, "*A CPW Fed E-Shaped Reconfigurable Antenna with Frequency Diversity*", International Journal of Information and Electronics Engineering, Vol. 2, No. 2, march 2012.

[8] Vepuri Niranjan, Alok Kumar and KUMAR Vaibhav Srivastava, "*CPW-fed Slot Patch Antenna for 5.2/5.8GHz WLAN Application*" PIERS Proceedings, Kuala Lumpur, Malaysia, march 27-30, 2012.

[9] Davinder Prakash and Rajesh Khanna, "*Design of a Broadband CPW-Fed Monopole Antenna for WLAN operations*" MIT International Journal of Electronics and Communication Engineering Vol. 1, No. 1, pp(5-7), Jan 2011.

[10] P.Prabhu, C. Poongodi, R.Ranjith Kumar and K. Prabhakaran, "*Design and Simulation of CPW-FED Printed Antenna for Ultra Wide Band (UWB) and Wireless LAN (WLAN) Applications*", International Journal of Electronics and Computer Science Engineering, ISSN-2277-1956, Vol. 2, No. 2, pp 434-442.

[11] D.Prakash and R. Khanna, "*Design and Development of CPW-FED Microstrip antenna for WLAN/WiMAX Applications*", Progress In Electromagnetic Research, Vol. 17, pp 17-27, 2010.

[12] A. K. Arya and A. Patnaik, "*Microstrip Patch Antenna with Skew-f Shaped DGS for Dual Band Operation*", Progress In Electromagnetic Research M, Vol. 19, pp 147-160, 2011.

[13] Ying Hu, David R. Jackson and Jeffery T. Williams, "*Characterization of the Input Impedence of the Inset-Fed Rectangular Microstrip Antenna*", Antenna and Propagation, IEEE Transaction, Vol. 56, No. 10, Oct. 2008.

[14] Wen-Chung Liu and Chao-Ming Wu, "*Dual Broadband Slit-Loaded CPW-Fed Monopole Antenna for Wireless Communication*", IEEE ISIE 2005.

[15] W.C. Liu and C. Wu, "*Dual-band CPW-Fed G-shaped Monopole Antenna for 2.4/5 GHz WLAN Applications*", PIERS Online, Vol. 3, No. 7, 2007.

[16] T. H. Kim and D. C. Park, "*CPW-Fed Compact Monopole Antenna for Dual-band WLAN Applications*", Electronic Letter., Vol. 41, March 2005, pp. 291-293.

[17] W. C. Liu and W. R. Chen, "*CPW-Fed Compact Meandered Patch Antenna for Dual-band Operation*" Electronic Letter, Vol. 40, No. 18, pp. 1094-1095, Sept. 2004.

[18] Y. Y. Cui Y.-Q. Sun. H.-C. Yang. C.-L. Ruan, "*A New Triple Band CPW- fed Monopole Antenna for WLAN and WiMAX Applications*", PIERS m, Vol. 2, pp 141-151, 2008.

[19] A.Sen, J.S. Roy and S.R. Bhadra Chaudhuri, "*Investigation on A Dual Frequency Microstrip Antenna for Wireless Application*", IEEE, ISSN: 978-1-4244-4396-3/09/25.00 ©2009.

[20] H. F. AbuTarboush, H. S. Al-Raweshidy, "*A Connected E-Shape and U-Shape Dual-Band Patch Antenna for Different Wireless Application*", IEEE, Vol.4. 2001.

[21] Isha Puri and Archana Agarwal, "*Bandwidth and Gain Increment of Microstrip Patch Antenna With Shifted Elliptical Slot*", IJEST, ISSN : 0975-5462, Vol.3, No. 7, July 2011.

[22] Ali Dheyab and Karim Hamad, "*Improving Bandwidth Rectangular Patch Antenna Using Different Thickness of Dielectric Substrate*", ARPN Journal of Engineering and Applied Sciences, Vol. 6, No. 4, April 2011.

[23] Y. Zhuo and L. Yan, "*A Compact Dual-Band Patch Antenna for WLAN Application*", Progress in Electromagnetic Research Letters, Vol. 26, pp. 153-160.

[24] Avisankar Roy and Sunandan Bhunia, "*Compact Broad Band Dual Frequency Slot Loaded Microstrip Patch Antenna with Defecting Ground Plane for Wi-MAX and WLAN*", International Journal of Soft Computing and Engineering (IJSCE), ISSN: 2231-2307, Volume-1, Issue-6, January 2012.

[25] Mohammad Tariqul, "*Broadband Microstrip Patch Antenna*", European Journal of Scientific Research, ISSN: 1450-216X, Vol. 27, No.2 (2009), pp.174-180, 2009.

[26] Sangam Kumar Singh and Arun Kumar Singh, "*Multiband Rectangular Ring Microstrip Antenna for UWB Wireless Applications*", Progress In Electromagnetic Research Symposium, Beijing, China, pp 23-27, march 2009.

[27] J. Cao, X. Zhao and C. Liu, "*A Planar Compact Triple-Band Monopole Antenna for WLAN/WIMAX Applications*", Progress In Electromagnetic Research Letters, Vol. 29, 15-23, 2012.

[28] Bharath Kelothu, K.R.Subhashini and G.Lalitha, "*A Compact High-Gain Microstrip Patch Antenna for Dual Band WLAN Applications*", IEEE ISSN: 978-1-4673-0455-9/12/$31.00 © 2012.

[29] Rajeshwar Lal Dua and Himanshu Singh, "*2.45 GHz Microstrip Patch Antenna with Defective Ground Structure for Bluetooth*", IJSCE, ISSN: 22312307, Vol. No. 1, 2012.

[30] Gurdeep Singh and Jaget Singh, "*Comparative Analysis of Microstrip Patch Antenna With Different Feeding Techniques*", International Conference on Recent Advances and Future Trends in Information Technology (iRAFIT2012) proceedings published in International Journal of Computer Applications (IJCA).

[31] T. Durga Prasad and K. V. Satya Kumar, "*Comparisons of Circular and Rectangular Microstrip Patch Antennas*", International Journal of Communication Engineering Applications-IJCEA, Vol. 02, ISSN: 2230-8520; e-ISSN-2230-8539. July 2011.

[32] M. Elsdon, A. Sambell and S.C. Gao, "*Inset Microstrip Line Fed Dual Frequency Microstrip Patch Antenna*", IEE Michael Faraday House Six Hill Way SG1 2AY.

[33] Vidhi Sharma and Dwejendra Arya, "*Dual Band Microstrip Patch Antenna Using Dual Feed for Wireless Applications*", IJECSE, ISSN-2277-1956/V1N2-230-238.

[34] Wen-Chung Liu and Chao-Ming Wu, "*Design of Triple-Frequency Microstrip-Fed Monopole Antenna Using Defected Ground Structure*", IEEE Transactions on Antennas and Propagation, Vol. 59, No. 7, July 2011.

[35] C. A. Balanis, "*Antenna Theory (Analysis and Design)*", Second Edition, John Wiley & Sons.

[36] Ramesh Garg, Prakash Bhartie, Inder Bahl, Apisak Ittipiboon, "*Microstrip Antenna Design Handbook*", pp. 1-68, 253-316 Artech House Inc. Norwood, MA 2001.

[37] L. H. Weng, Y. C. Guo, X. W. Shi, and X. Q. Chen, "*An Overview on Defected Ground Structure*". Progress In Electromagnetic Research B, Vol. 7, pp 173-189, 2008.

[38] Gary Breed, "*An Introduction to Defected Ground Structures in Microstrip Circuits*", High Frequency Electronics Copyright © 2008 Summit Technical Media, LLc, Nov. 2008.

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