DESIGN ANALYSIS OF SHORTING PIN MICROSTRIP PATCH ANTENNA FOR C-BAND APPLICATION

Submitted in partial fulfillment for the award of the degree

of

DOCTOR OF PHILOSOPHY

In

ELECTRONICS AND COMMUNICATION ENGINEERING

By

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CERTIFICATE

Certified that the Thesis entitled **"Design Analysis of Shorting PIN microstrip patch antenna for C- band application"** submitted to Department of Electronics and Communication Engineering, Shepherd Institute of Engineering & Technology in Sam Higginbottom University of Agriculture, Technology and Sciences, Naini, Allahabad, in partial fulfillment of the requirement for the degree of **Doctor of Philosophy in Electronics and Communication Engineering** in Shepherd Institute of Engineering & Technology is a bonafide record of thesis report carried out by Mr. **Rakesh Kumar Singh** (ID No. **13PHEC204**) under my supervision and guidance.

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I, Rakesh Kumar Singh ID No. 13PHEC204 declare that the work presented in this thesis entitled "Design Analysis of Shorting pin Microstrip Patch Antenna for C-band Application" submitted to the Department of Electronics and Communication Engineering, in the Faculty of Engineering and Technology, **Sam Higginbottom University of Agriculture, Technology and Sciences, Naini, Allahabad,** for the award of the Doctor of Philosophy degree in Electronics and Communication is an original work. I have neither copied nor submitted the same work for the award of any other degree. In case this Undertaking is found incorrect, my degree may be withdrawn unconditionally by the University.

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ABSTRACT

In this work, a multi frequency microstrip antenna (MSA) for wireless applications is designed. The proposed MSA comprised of elliptical patch antenna with shorting pin. This antenna is fed by coaxial probe. The design parameters are major and minor axis of elliptical patch, the position of shorting pin and feeding point of probe are mentioned in table-1. The proposed antenna can provide optimized multi frequency by varying the above design parameters. FR-4 substrate with dielectric constant 4.4 is chosen. The multi frequencies are 4.49 GHz, and 6.69GHz, which covers the applications such as satellite communications, for full-time satellite TV networks.

And for the second case, the work is as a novel design of a Pentagonal shaped patch antenna is presented for ultra wideband wireless communication applications. Designed Microstrip patch antenna consists of a pentagonal patch which is found to resonant at frequency 4.8571 GHz, with return loss -19.65 dB having satisfactory radiation properties. The proposed antenna is a compact design of 30mm × 20mm area on the FR4-epoxy substrate with dielectric constant of 4.4 and thickness of 1.8 mm. The designed antenna structure with 3.45 dB gain is planar, simple and compact hence it can be easily embedded for wireless communication systems and integrated with microwave circuitry for low manufacturing cost.

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LIST OF ABBRIVATIONS

PPDR	Public Protection and Disaster Relief
PMR	Professional Mobile Radio, Private Mobile Radio
PAMR	Public Access Mobile Radio
EPIRBs	Emergency Position Indicating Radio Beacons
ISM	Industrial, Scientific and Medical
PMSE	Programme Making and Special Events
MFCN	Mobile/Fixed Communications Networks
GSM	Global System for Mobile communications
IMT	International Mobile Telecommunications
MCV	Mobile Communication Services on Board Vessels
RFID	Radio Frequency Identification
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
T-DAB	Terrestrial Digital Audio Broadcasting
MSS	Mobile Satellite Service
MCV	Mobile Communication Services on Board Vessels
MCA	Mobile Communications Services on Board Aircraft
DECT	Digital Enhanced Cordless Telecommunication
DA2GC	Direct to Air Ground Communications
MBANS	Medical Body Area Network Systems
UWB	Ultra-Wideband
BWA	Broadband Wireless Access
ESV	Earth Stations on board Vessels
BBDR	Broad Band Disaster Relief
MLS	Microwave Landing System
BFWA	Broadband Fixed Wireless Access
TTT	Transport and Traffic Telematics
FSS	Fixed Satellite Service
ITS	Intelligent Transport Systems

AES	Aircraft Earth Stations
HEST	High E.i.r.p. Satellite Terminals
LEST	Low E.i.r.p. Satellite Terminals
VSAT	Very Small Aperture Terminal
AGA	Air Ground Air
GBSAR	Ground Based Synthetic Aperture Radar System
GSO ESOMPs	Geo Stationary Orbit and Earth Stations On Mobile Platforms
NGSO ESOMPs	Non Geo Stationary Orbit and Earth Stations On Mobile Platforms
SRR	Short Range Radar
MWS	Multimedia Wireless System
HAPS	High Altitude Platform Systems
VSWR	Voltage Standing Wave Ratio
SAR	Specific Absorption Rate
TWT	Traveling Wave Tube
MSA	Micro-Strip Antenna
HIPERLAN	High-Performance Local Area Network
MMIC	Monolithic Microwave Integrated Circuit
LTCC	Low Temperature Co-fired Ceramics
SPS	Satellite Positioning System
ISM	Industrial, Scientific and Medical
LTE	Long-Term Evolution
MIMO	Multiple-Input and Multiple-Output
EBG	Electromagnetic band-gap
SMA	Sub Miniature version A

CHAPTER-I

INTRODUCTION

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

The first digital wireless system, which consists of two of the best-known antennas: the dipole and loop. For this reason, the dipole antenna is also called the Hertz (dipole) antenna. After a decade, Guglielmo Marconi's (1874-1937) an Italian inventor, developed and commercialized wireless technology by introducing a radiotelegraph system and Karl Ferdinand Braun 'in recognition of their contributions to the development of wireless telegraphy'. Monopole antennas were widely used in Marconi's experiments; thus vertical monopole antennas are also called Marconi antennas. At that time, the invention of horn antenna by J. C. Bose for the radio communication links. To give the Allies an edge, British and American scientists developed radar technology to 'see' targets from hundreds of miles away, even at night. The research resulted in the rapid development of high-frequency radar antennas, which were no longer just wire-type antennas. Some aperture-type antennas are reflector and horn antennas. John D. Kraus was the inventor of the helical antenna the workhorse of space communication. The corner reflector antenna is used by the millions for television reception and many other types of antennas.

The antenna family consists of different types of antenna such as point source antenna, monopole or dipole antennas, wire antennas, loop antennas, slot antennas, horn antennas, patch antennas, reflector antennas, lens antennas, helical antennas, wide band antennas and many more. Antenna can be classified on the basis of direction of radiation as isotropic or anisotropic. There is no difference in selection factors relating to transmitting and receiving antennas, the same antenna may be used for transmission and reception or separate antennas can be used for transmission and reception.

The Microstrip antenna concept dates back about 26 years to work in the U.S.A. by Deschamps in 1953 [1]. Kaloi, who studied basic rectangular and square configurations, undertook additional studies in the late 1960's. Shortly thereafter, Lewin investigated radiation from strip line discontinuities [2]. However, other than the original Deschamps report, work was not reported in the literature until the early 1970's, when Byron described a conducting strip radiator separated from a ground plane by a dielectric substrate [3]. This half wavelength wide and several-wavelength long strip was fed by coaxial connections at periodic intervals along both radiating edges, and was used as an array for Project Camel. Shortly thereafter, a basic rectangular and circular microstrip patches were published by Munson and Howell and patented a microstrip element [4-5]. Weinschel developed several microstrip geometries for use with cylindrical S-band arrays on rockets. Sanford showed that the microstrip element could be used in conformal array designs for L-band communication from a KC-135 aircraft to the ATS-6 Satellite. The early work by Munson on the development of microstrip antennas for use as low-profile flush-mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems, and thereby gave birth to a new antenna industry.

In recent years, 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 microstrip (patch) antennas. With a simple geometry, patch antennas offer many advantages not commonly exhibited in other antenna configurations. For example, they are extremely low profile, lightweight, simple and inexpensive to fabricate using modern day printed circuit board technology, compatible with microwave and millimeter-wave integrated circuits (MMIC), and have the ability to conform to planar and non-planar surfaces [6]. In addition, once the shape and operating mode of the patch are selected, designs become very versatile in terms of operating frequency, polarization, pattern, and impedance. The variety in design that is possible with microstrip antennas probably exceeds that of any other type of antenna element.

Despite the many advantages of patch antennas, they do have some considerable drawbacks [6]. One of the main limitations with patch antennas is their inherently narrowband performance due to its resonant nature. With bandwidths as low as a few percent, broadband applications using conventional patch designs are limited. Other characteristics of patch antennas include low efficiencies, limited power capacity, spurious feed radiation, poor polarization purity, and manufacturing tolerance problems. For over two decades, research scientists have developed several methods to increase the bandwidth of a patch antenna. Many of these techniques involve adjusting the placement and/or type of element used to feed (or excite) the antenna. The first, simplest and most direct, approach is to increase the thickness of the substrate, while using a low dielectric substrate. Using thick dielectric substrate material on the other hand has the ability to produce undesired surface wave which likely reduces the antenna efficiency, gain, bandwidth, increases the side-lobes and antenna loss in general. The second technique to increase bandwidth is decreasing the relative permittivity, which has an obvious limitation based on size. Therefore, there should be different techniques that are capable to reduce the surface wave excitation while keeping the antenna parameters at the desired level. In addition various techniques have also been reported by authors in order to improve antenna parameters such as shorting pin, defected ground, introduction of slots and notches on the radiating patch, shorting of walls via conducting plate, stacking of layers, gap coupled patches and utilization of metamaterial concept.

Microstrip Patch antenna is a type of radio frequency antenna with its low profile, that can mounted on a flat surface. It consists of a flat rectangular sheet or patch of metal, mounted under a larger area of substrate called a ground plane. Patch antennas are different names such as shorted patch antenna, printed antennas, microstrip patch antennas etc. Microstrip antenna shapes may be square, rectangular, circular and elliptical but any continuous shapes are possible. Some patch antennas do not use a dielectric substrate and instead are made of a metal patch mounted above ground plane using dielectric spacers; the resulting structure is less rugged but has a wider bandwidth, this type antennas have a low cost, low profile, and mechanically rugged and it can be shaped as curve of a vehicle, and also mounted on the exterior of satellite, missile applications aircraft and spacecraft. Microstrip patch antennas are often used where there thickness and conformability to the host surface are key requirements. Since the patch antennas can be directly printed onto a circuit board, so these are becoming popular day by day the mobile phone market.

Reconfigurable antenna is an antenna that capable to reconfigure the radiation pattern, bandwidth, and polarization to adapt the environment. Frequency reconfigurable may adjust dynamically their frequency of operation. Frequency reconfiguration is achieved by modifying physically or electrically the dimensions of antennas using RF-switches, impedance loading as well as tunable materials. In present days the reconfigurable antenna are attaining great attention specially in wireless communication systems due to its ability to reduce front end system and allow pre filtering at the receiver. The reconfigure antennas also contain so many other features due to which it is introduced in future wireless communication system such as its reconfigurable low cost, multipurpose, and size miniaturization etc.

A microstrip patch antenna has been one of the most innovative topics in antenna theory and design. They are used in wide range of wireless applications because of their simplicity and compatibility with printed-circuit board technology. Various techniques have been utilized in antenna research to reduce size and to achieve wide-band characteristics through various modifications.

1.2 DEVELOPMENT OF SINGLE BAND ANTENNA

In 2001, A broadband single layer annular ring microstrip patch antenna fed by L-shaped probe feeding is reported [7]. The proposed antenna configuration generated at two resonant modes TM11 and TM12. The bandwidth and peak gain for both modes was obtained 33% (7.5 dBi) and 27% (10.3 dBi) respectively.

In 2002, A U-slot gap coupled patch antenna with T-shaped microstrip line is proposed [8]. Authors were obtained that the measured bandwidth 76.8% along with the relatively good radiation characteristics.

In 2003, Authors [9] analyzed the two concentric annular ring patch antenna using planar waveguide model in order to compare the bandwidth characteristic of the antennas that was gap-coupled and annular ring antennas, calculations were made for VSWR 1.5:1 and 2:1 respectively.

In 2004, Authors [10] designed a novel broadband antenna was achieved the linearly polarized characteristics using an H-shaped coupled to a microstrip line via a ring slot in the ground plane. They were also found that a 54% bandwidth with 6.6 dBi gain,

In 2005, Authors [11] presented a meandering probe fed stacked patch antenna and they were achieved the wide bandwidth upto 37% and gain 9.0 dBi.

In 2006, Authors [12] proposed a broadband printed coplanar waveguide (CPW) fed circular slot antenna. The proposed design offered an ultrawide bandwidth of 143.2% (from 2.3 to 13.9 GHz).

In 2007, Authors [13] proposed a wideband U-shaped parasitic patch antenna. The antenna was fabricated on a FR4 substrate and achieved the bandwidth of 27.3% at 5.5 GHz centre frequency with peak gain 6.4 dBi and 5.2 dBi at each resonant frequency.

In 2008, a novel broadband square slot antenna fed by an asymmetric coplanar waveguide for circular polarization was proposed by authors [14]. With an additional pair of grounded strips integrated in the slot, the 3 dB axial ratio BW and VSWR < 2 impedance bandwidth was achieved greatly raised to be high as 30 and 35% respectively.

In 2009, Authors [15] reported a wide bandwidth and beamwidth micro strip antenna loaded with gaps and stubs. This antenna was based on a two layer-stacked electromagnetic coupling antenna and found the impedance bandwidth up to 34.6%.

In 2010, the two printed wide-slot antennas with E-shaped patches and slots for broadband operation were proposed by authors [16] and they achieved the 136% impedance bandwidth at the range from 2.86 GHz to 18.2 GHz.

In 2011, Author [17] studied a very wideband microstrip antenna and that obtained the impedance bandwidth upto 128% from 1.80 GHz to 8.23 GHz. Moreover, the non-correlative current path on the driven elements provided the independence of band adjustment.

In 2012, Author [18] proposed a printed wide-slot antenna with a parasitic patch fed by microstripline for bandwidth enhancement. The designed antenna was achieved the 80% impedance bandwidth ranging from 2.23 to 5.35 GHz, and also stable and omnidirectional radiation pattern was obtained within the operating bandwidth.

In 2013, a high gain wideband U-shaped patch antenna with two equal arms on poly tera fluaro ethylene (PIFE) substrate was presented by authors [19] and they were obtained the maximum impedance BW of 86.79% and highest gain of 4.1 dBi with circular shaped ground plane.

In 2014, Authors [20] proposed a compact ultra wideband antenna fed by a coplanar waveguide. They were obtained the measured impedance bandwidth from 3 to 18 and 2 to 13 GHz (146.67%).

In 2015, Authors [21] designed a new concept of planar magneto-electro-dielectric waveguide meta-materials (MED-WG-MTM) loaded antenna was reported to manipulate the effective permeability and the effective permittivity. The designed antenna was advanced in many aspects such as compact dimension with a 42.53% miniaturization, broadband with 207% bandwidth and comparable radiation performances relative to its conventional counter parts.

In 2016, A wideband dual-polarized array antenna for K/Ka-band wireless communication is reported [22]. Improved bandwidth of 21.4% from 25 GHz to 31 GHz has been achieved, with a gain more than 20 dBi and an isolation more than 30 dB for the orthogonal polarizations throughout the whole band

In 2017, A compact microstrip line fed wide band MIMO antenna with high isolation, dual notch bands with high gain and low correlation coefficient is proposed [23]. U-shape slots are etched on radiating element and on feed line to achieve decent band rejection capability.

1.3 DEVELOPMENT OF DUAL BAND ANTENNA

In 2001, Authors [24] discussed a new compact dual-polarized antenna and they were provided an area reduction of 70% as compare to a standard rectangular patch antenna.

In 2002, Authors [25] proposed a dual-frequency quarter-wave U-shaped patch antenna with two unequal arms built on FR4 substrate. They were obtained the measured impedance bandwidths at operating frequency 900 MHz were 7%, 10% and 18% respectively.

In 2003, a compact dual-band planar inverted F antenna suitable for the mobile communication was implemented by authors [26].

In 2004, a rectangular slot antenna for dual broadband operation was proposed by authors [27] and they were obtained the measured bandwidths of 10.6% and 33.8% using U-shaped strip.

In 2005, a rectangular patch loaded planar monopole antenna for PCS/WLAN systems was introduced by authors [28] and they were obtained the measured impedance bandwidths of 14.4% and 34.1%.

In 2006, Authors [29] designed a novel circularly polarized antenna for dual-band operation. The measured impedance bandwidths of 20.1% (895 MHz) and 8.9% (2397 MHz) were achieved.

In 2007, Authors [30] proposed a coplanar waveguide (CPW)-fed monopole antenna with a cross slot for 2.1/5.2/5.8 GHz WLAN communication systems and they were found that the measured bandwidths of 13.7% and 28.3% at the resonant frequencies of 2.48 and 5.23 GHz respectively.

In 2008, a slot loaded shorted rectangular microstrip antenna for dual-band operation was theoretically and experimentally investigated by authors [31].The frequency ratios of about 3.0 for the two operating frequencies were obtained. They were also observed that the reduced the size up to 37% by loading the slot and shorting pin on the rectangular patch.

In 2009, Authors [32] designed a novel circularly polarized CPW-fed slot antenna loaded with two spiral slots and the frequency ratio 1.375 of the proposed antenna was obtained.

In 2010, Authors [33] proposed a coplanar waveguide (CPW) loaded antenna for dual-band operation which was very compact and suitable for 2.4/5.2/5.8 WLAN operations.

In 2011, Authors [34] presented a simple new design method to achieve a dual-band micro strip fed slot antenna. This model was validated with a prototype antenna that operates at 4.22 GHz and 5.26 GHz, which were commonly used as the downlink and uplink in satellite communications

In 2012, a bridged V-shaped patch antenna for dualband operation was designed and fabricated by authors [35].

In 2013, Authors [36] reported a dual-band circularly polarized antenna fed by four apertures, which meet the requirement of global navigation satellite system (GNSS) applications.

In 2014, Authors [37] proposed an antenna system comprising two closely chip antennas for dual-band wireless LAN uses.

In 2015, Authors [38] studied a design approach for microstrip antenna to achieve reconfigurable dual-band operation with tunable frequency ratio from 1.45 to 1.93 with a capacitance range from 0.31 to 0.74 pF.

In 2016, A design for dual-band circularly polarized microstrip antennas with different radiation patterns is described [39]. The proposed structure was designed for GPS and WLAN applications.

In 2017, Authors [40] proposed a compact dual band slot loaded multilayered patch antenna. Patch antenna is designed for WLAN and WiMAX applications. The antenna parameters such as return loss, radiation pattern, gain, frequency ratio, VSWR, efficiency, group delay and beam-width are presented. Enhanced -10dB impedance bandwidth of 9.53 % and 6.53% was reported for lower and upper resonating frequency respectively.

Pentagonal and elliptical shaped radiating patch antenna design is not explored by many researchers. Authors have used pentagonal shape for the radiating patch and ground plane in the design of coplanar antennas. Pentagonal geometry is one of the various shapes for microstrip antennas capable of circular polarization and linear polarization. For pentagonal patch antenna is considered with thickness of the substrate for enhancing bandwidth of antenna with a simple configuration and the characteristics of the pentagonal patch antennas are analyzed.

There is a need for optimization of this type antenna so as to conveniently integrate within the compact communication equipment and devices. This has opened large interest for developing the compact antennas and their miniaturized techniques. There are so many techniques that has proposed and applied to design microstrip patch antenna such as using dielectric substrate of high permittivity, slot on the radiating patch, defected ground structure at the ground plane or a combination of them.

With the recent advancement in modern wireless communications, the need for microstrip antennas in compact size with multiple antenna characteristics has greatly increased. Electronic equipment has rapidly reduced in physical size due to the development of integrated circuits; therefore, the demand for the smaller antennas becomes quite necessary. The microstrip antenna (MSA) is one of the most preferable antennas because it has many advantages such as lightweight, small volume and that they can be made conformal to the host surface. In addition, MSAs are manufactured using printed-circuit technology, so that mass production can be achieved at a low cost. Therefore, microstrip antennas have been fruitfully engaged in many wireless applications such as cellular and satellite communications, radars and GPS receivers, mobile communications, remote sensing and many defense equipments. Apart from many advantages, it has some serious drawbacks such as narrow bandwidth with single band and this restricts its applications. Several techniques exist to achieve the multiband/dualband/wideband with broad bandwidth behavior of the antenna. In the present endeavor, therefore the author has made an attempt to design and analyze the different structure of microstrip antenna for multiband, dual-band and broadband operations.

In this research work, a new design of pentagonal shape and elliptical shape of patch antenna is proposed and design is simulated by electromagnetic simulation tool High Frequency Structure Simulator (HFSS). Performance of proposed structures is analyzed in terms of return loss, VSWR, antenna gain, directivity and radiation pattern. Detail discussion of thesis work is presented in foregoing sections.

1.4 THESIS OBJECTIVES

- To survey the different type of microstrip patch antenna
- To design pentagonal shaped patch with shorting pin microstrip patch antenna
- To analyze the characteristics of pentagonal microstrip patch antenna
- To design elliptical shaped patch antenna with shorting pin microstrip patch antenna
- To analyze the characteristics of elliptical microstrip patch antenna

CHAPTER-II
REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

2.1 REVIEW OF LITERATURE

Wireless communications have progressed very rapidly in recent years, and many wireless devices are becoming smaller and smaller. To meet the miniaturization requirement, the antennas employed in devices terminals must have their dimensions reduced accordingly. Planar antennas, such as microstrip and printed antennas have the important features of low profile, small size and conformability to mounting host and are very promising candidates for satisfying these design consideration. For this reason, broadband, dual-band and multiband designs techniques for planar antennas have attract much attention from antenna researchers. Very recently, especially after the year 2000, planar antennas are also attractive for applications in modern communication devices for 5.2/5.8 GHz wireless local area network (WLAN) standards of IEEE 802.11a (5.15-5.35 GHz and 5.725-5.825 GHz), 2.4 GHz IEEE 802.11b/g (2.4-2.484 GHz), 3.5 GHz worldwide interoperability for microwave access (WiMAX) standards of IEEE 802.16 (3.4-3.6 GHz), 5.5 GHz high performance radio local area network (HIPERLAN) standards of IEEE 802.16 (5.47-5.725 GHz) and wireless personal area networks (WPANs) standards of IEEE 802.15.1 due to its wide range of usability in almost all commercial communication devices. Even, before the year 2000 many research papers on this topic have been presented and cited these papers are the base of the microstrip antenna research. Primarily, the antennas need to have high gain, small physical size, broad bandwidth, versatility, embedded installation etc. In particular, as can be seen that the broad bandwidth for impedance, polarization or axial ratio, radiation pattern and gain are becoming the most important factors that affect the application of antennas in contemporary and future wireless communication systems. The antennas used must have the required performance over the relevant operating frequency range. Antennas are used for fixed applications such as cellular base stations and wireless access points should have high gain and stable radiation coverage over the operating range. Antennas are also used in portable devices such as smart phones, personal digital assistants (PDAs), laptop, tablets and computers should be embedded which are efficient in radiation and omnidirectional in coverage. Most importantly, the antennas should be well impedance-matched over the operating frequency range. Many novel planar antenna designs to satisfy specific bandwidth specifications of present-day mobile cellular communication systems, including the global system for mobile communication (GSM; 890-960 MHz) band, centered at 900 MHz; the digital communication system (DCS; 1710-1880 MHz) band, centered at 1800 MHz; and the personal communication system (PCS; 1850-1990 MHz) band, centered at 1900 MHz and the universal mobile telecommunication system (UMTS; 1920-2170 MHz) band, centered at 2 GHz, have been developed and published in the open literature. In all wireless systems, antenna is front end.

The three factors influencing the design of antenna for wireless communications are: (1) performance and (2) physical size and cost (3) substrate materials over which radiating patch is designed. In literature different techniques have been reported by authors to improve the impedance bandwidth, radiation efficiency and antenna gain. Chapter 2 is devoted for literature review in which several past research works are presented for understanding of current challenges in the field of micro strip patch antenna.

[41]Egashira *et al.* (1996) focused on an approach to improve the gain and the bandwidth of the microstrip antenna, basically an antenna had been designed which had two parasitic elements. One element improves the gain and other improves the bandwidth.

[42]Maci *et al.* (1997) proposed their work on dual-frequency microstrip patch antennas which provided replacement to large-bandwidth antennas. A dual frequency structure could be obtained if two operating frequencies were independent of each other and this will help to avoid the need of separate antennas. Dual frequency multi patch antennas, Dual-frequency patch antennas which were reactively loaded; Dual-frequency orthogonal antennas were discussed.

[43]Herscovici et al. (1998) focused on an antenna where a single-layer patch was a narrow band element printed on a dielectric substrate. For better efficiency and low cost the substrate taken should not be very thick. Additional resonators of different combinations and different configurations were used in order to improve the bandwidth of microstrip elements which was generally slots and parasitic elements etc. The widest bandwidth of microstrip antenna element was nearly 40–50%. The patch was supported by a pin which was non-conductive and etched on the ground plane. The feeding was done through three-dimensional transition which was connecting the patch of antenna and a perpendicular connector. This element had a typical bandwidth of 90%.

[44]Jui-Han Lu et al. (1999) proposed Single-Feed Slotted Equilateral-Triangular Microstrip Antenna for Circular Polarization. It has been demonstrated that by embedding a narrow slot or a cross slot of unequal slot lengths in the triangular patch, circularly polarized radiation of microstrip antennas has been achieved using a single probe feed. The required antenna size has been smaller for the proposed antenna for performing CP radiation as compared to a conventional circularly polarized triangular microstrip antenna at a fixed operating frequency. The electrical thickness of the substrate has been reduced due to the lower operating frequency

[45]Horri *et al.* (1999) focused on the single band micro strip antenna which had photonic band gap structure (PBG) in the ground plane and also discussed the effect of photonic band gap structure to suppress the resonance of the antenna at the different harmonic frequencies. The experimental study showed that at harmonic frequencies the radiation patterns were drastically diminished when PBG structure was used. At the third harmonic frequency the radiation forward to the photonic band gap antenna was at more than 15 dB.

[46]Gao *et al.* (2001) focused on a dual-polarized micro strip patch antenna which was capable to achieve a high isolation, low backward radiation levels, wide bandwidth and low cross-polarization levels. The coupling aperture used was H-shaped. It used a stacked aperture coupled micro strip square patch which was easy to integrate with active devices and gave wide bandwidth. The return loss had bandwidth of 20.9% and over this bandwidth the isolation was better than 36 dB. Front-to-back ratio and cross-polarization levels were also good.

[47]Sung *et al.* (2003) focused on a paper in which defected ground structure was used in micro strip patch antenna which would suppress the higher order harmonics. An H-shaped defect was cut in the ground plane which had one or more unit lattices and produced band stop characteristics. The radiated power in the defected ground structure antenna had been highly decreased at harmonic frequencies as compared to micro strip antenna without DGS.

[48]Row et al. (2004) proposed a design of the circular polarization (CP) for an annular-ring antenna operated at its TM11 and TM12 modes. The CP Radiations of this design are achieved by placing an L-shaped strip connected to two orthogonal sides of the inner boundary of the annular patch. The annular-ring patch is fabricated on an FR4 substrate of thickness 0.8 mm and permittivity 4.4 and has the inner and outer radii of a and b, respectively. An extended strip with the dimensions of d and w is connected to the inner boundary of the annular-ring patch, and a coaxial probe feed of radius 0.6 mm is located at the end of the strip. The 10 dB input-impedance bandwidths centered at 1.243 and 3.871 GHz are 2.9% (36 MHz) and 4.9% (191 MHz) for the TM11 and TM12 modes, respectively. The radiation patterns are measured at 1.25 and 3.88 GHz.

[49] Geo *et al.* (2005) focused on Characteristics of a single-layer, dual-frequency micro strip patch antenna, which used a T-strip loaded rectangular micro strip patch. This antenna was easy to achieve good impedance matching at both frequencies by tuning the feed position and other design parameters. Further advantageous aspect was that it had high polarization effect. A detailed parameter study was performed and the theoretical analysis was based on the finite-difference time-domain (FDTD) method. The FDTD programs were developed and validated by measurement results. The effects of different antenna parameters on multi-resonant frequencies, frequency ratio, and radiation pattern characteristics of the antenna analyzed and discussed. It was the various frequency ratios (1.5–2.49) could be obtained by varying the design parameters of this antenna. Similar radiation patterns with same polarization were obtained at two resonant frequencies. Several design curves were presented.

[50]Cai et al. (2006) proposed a design dual-frequency microstrip patch antenna that can produce dual circular polarization. This microstrip antenna has an annular-ring patch and is excited by an L-shaped microstrip line through the coupling of a ring slot in the ground plane. The annular-ring patch with outer radius 25mm and inner radius 8mm is printed on an FR4 substrate of thickness 0.6 mm and permittivity 4.4. The radiation patterns are measured at 2075 and 2735MHz. The peak gain is about 6.5 dBi for LHCP radiation and 6 dBi for RHCP radiation.

[51]Lu *et al.* (2006) focused on a stacked patch antenna which was wide band and aperture-coupled circularly polarized. The three-stub hybrid coupler, aperture coupled feed and one stacked patch was used in combination. Due to this both the 3 dB axial ratio bandwidth and the impedance bandwidth had been improved. This design had axial ratio bandwidth of nearly 40.3% and -10 dB return loss bandwidth of nearly 37% which was operating in X band. The maximum gain of this design was 8.4dBi. Since this antenna had simple structure and good performance therefore used in many applications.

[52]Dimitrios et al. (2005) proposed a frequency reconfigurable multiband antenna. The antenna operating conditions are controlled by RF-MEMS switches. RF-MEMS Radio frequency Micro electro mechanical switch. MEMS switches have shown good RF characteristics and can be used at both low and high frequency applications. The antenna's adjacent triangular patches are connected with 4 series cantilever rhombic contact RF-MEMS switches for obtain the re-configurability of antenna. Using the switches, a bowtie mode of operation all switches are OFF and a MEMSenabled (i.e. fractal) mode of operation which was all switches ON obtained. Since the 'fractal' mode's active structure consists of one iteration, we anticipate two widely-spaced resonant frequencies. Two more non symmetric configurations may also be obtained by setting one switch ON and one OFF on each arm. The result is a total of 4 different paths for the currents to flow and hence 4possible antenna configurations. The antenna was made of same material as the metal layer of switch. The antenna was fabricated monolithically with the MEMS switches on the same substrate. The insertion loss when the switch is ON is around 0.2 dB at 15 GHz, while the additional 0.2 dB measured loss is due to the transmission line used in the measurement. The isolation around 18 dB is reported at 15 GHz when the switch is OFF. The overall switch performance reveals that it can be used in antenna applications for frequencies up to 40 GHz. The reconfigurable multiband antenna that resonates primarily at 14 GHz and that can resonate on-demand, at two more frequency bands, preferably around 8 GHz and 24 GHz. The simulated antennas exhibited radiation patterns similar to that of a planar dipole at their respective resonances, while different applications may require different antenna designs. At 8 GHz, antennas with bow angles between 20 and 80 degree are suitable for our application. At14 GHz, it seems that any antenna with a bow-angle from 10 to 90 degree would suffice as well. For the third resonance at 24 GHz, the antenna with bow-angle between 50 and 80 degree, but the input impedance for these angles was not acceptable as the return loss was greater than 15 db.

[53]Mandal *et al*. (2007) presented a paper in which a compact filter which was low pass filter (LPF) with high selectivity and wide stop band was considered on the feed line of micro strip patch antenna. Suppressions of harmonics were an important element for micro strip antennas which were radiating harmonic frequencies. The stop band of 15 dB low pass filter exists over 10 GHz. The operating frequency falls in the pass band of low pass filter of the fundamental antenna.

[54]Roy *et al.* (2007) focused on the investigations on two new short-circuited micro strip patch antennas, which were able to radiate dual frequencies at GPS and Bluetooth frequency bands, were reported. One of these antennas was combination of two square patch sections and the other was combination of two circular patch sections, both of which were grounded by shorted pins. Using these antennas, by properly choosing the positions of shorted pins, good impedance matching could be obtained at both the frequencies. The dual frequency natures of the shorted patches, theoretically obtained using IE3D software were verified by measurement.

[55]Singh *et al.* (2008) focused on a novel design of the antenna using Defected Micro strip Structure & Defected Ground Structure which reduced the size of patch antennas and did not degrade the performance characteristics as bandwidth and efficiency etc. It had also another application of suppressing the harmonics without establishment of huge attenuation in the fundamental frequency.

[56] Arya *et al.* (2008) worked on an antenna in which there was improvement in efficiency and reduction in size. Mutual coupling reduction and cross polarization reduction etc. were also some of the advantages of using Defected ground structure. DGS was considered as an identical LC resonator circuit. The size and area of the defect determined the value of capacitance and inductance. The efficiency of micro strip patch antenna was increased by 10% using a cavity backed structure, where patch was surrounded by the electric walls.

[57] Pradeep et al. (2009) presented a paper that contained technical review with recent advances of the microstrip antennas having shorting posts. The size of the antenna was considerably reduced by a single shorting post. Effects of different parameters of shorting posts on short-circuit microstrip patch antenna was also discussed in this paper.

[58] Xu et al. (2008) presented a novel design of an antenna with an array of slots, radiating circularly polarized conical beam. The structure of the antenna was simple and suitable for mass production. The radiation characteristics such as radiation pattern and directivity were found to be conical beam radiation, which was Omni-directional in the circumferential direction. The polarization characteristics were investigated to perform the circularly polarized radiation. At the operation frequency 35 GHz, the antenna got a circularly polarized Omni-directional radiation pattern at theta=77deg, the gain was about 1.70-5.08 dB, and the axial ratio was less than 3 dB in the azimuthally plane.

[59] Geng *et al.* (2009) observed that a paper in which a series of micro strip patch antenna with DGS for multiband applications had been discussed. These antennas had wide radiation beam much smaller in size and found suitable in different conditions for WLAN applications. The defected ground structure made in the ground plane of the Micro strip patch antenna was used to achieve small size, gain enhancement for multiband applications.

[60]Mishra *et al.* (2009) presented that notch loaded shorted micro strip patch antenna had been analyzed using cavity model. The proposed antenna showed dual band operation which depends on notch dimensions as well as shorting wall. The frequency ratio was found to be 1.5278 for the notch loaded rectangular patch, while in notch loaded shorted patch the frequency ratio varied from 2.9764 to 2.725 for increasing value of notch width and it was almost invariant with notch depth. Further a slot loaded shorted patch antenna showed the dual frequency nature with the frequency ratio 1.7. The theoretical results were compared with IE3D simulation as well as reported experimental results.

[61] Han et al. (2010) presented single probe-fed reconfigurable monopole patch antenna with frequency diversity. The proposed antenna had a rectangular patch with two shorting pins. Four open stubs were attached to the rectangular patch through four pin diodes, and the ability of switching the antenna operating frequency was achieved by using dual in-line package switches to control the states of the diodes, whereby eight different operating bands over a wide range of frequencies can be switched. Moreover, the radiation patterns of the proposed antenna were stable in each operating band.

[62] Cai et al. (2010) proposed A Frequency-Reconfigurable Quasi-Yagi Dipole Antenna. It consists of a driven dipole element with two varactors in two arms, a director with an additional varactor, a truncated ground plane reflector, a microstrip to coplanar stripline (CPS) transition, and a novel biasing circuit. The effective electrical length of director element and the driven arms were adjusted together by changing the biased voltages. A 35% continuously frequency-tuning bandwidth, from 1.80 to 2.45 GHz, is achieved. This covers a number of wireless communication systems, including 3G UMTS, US WCS, and WLAN. the gain varies from 5.6 to 7.6 dBi

[63] Row et al. (2010) proposed a design of Frequency-Reconfigurable microstrip Patch Antennas with Conical radiation. Several shorting strips are symmetrically placed along the circumference of the radiating patch to vary its resonant frequency. This antenna is made on copper-clad FR4. Good impedance matching has been achieved for each case, and their measured resonant frequencies are 6.05, 7.04, and 7.25 GHz, respectively.

[64]Kathleen et al. (2010) Proposed planer inverted-F antennas. This antenna integrated with SDMC circuit in order to create an impedance match for a diverse set of frequency. SDMC- Software Defined Match Control. The SDMC is a microstrip circuit with tuning diode that are adjusted to tune the input impedance of the antenna. PIFA antenna was work at 2.45 GHz with a 13.6% bandwidth. The reconfigurable filter was designed to provide a broadband match for a diversity of frequency-dependent loads over the 1710–2170 MHz frequency range. The two individual parts of the circuit were then combined to provide the overall software-defined RF front-end system. The PIFA consists of a lower ground plane, a top plate, a wire feed that connects to a coaxial cable on the ground plane, and a shorting strip. The top plate of the 2.45 GHz PIFA is 4.74 mm high, 9.4mm wide and 22.32 mm long. The ground plane is 18.96 mm wide and 42.66 mm long. The shorting strip is 1.84 mm wide. The frequency-dependent input impedance of the antenna is used as a load in the ADS model of the filter. The integrated software defined match control circuit shows an excellent range of tuning to various target frequencies of operation. The results show that the integrated design can achieve good tuning performance at frequencies that are beyond the primary design frequencies of either the antenna or the filter. This avoids have to package several different antennas for different standards on a single device. The SDMC can also be used for new wireless standards after the system is designed and fabricated.

[65] Nasimuddin et al. (2010) proposed a design Dual-Band Circularly Polarized - Shaped Slotted Patch Antenna with a Small Frequency-Ratio. The S-shaped slot was cut at the center of a square patch radiator for dual-band operation. The 10-dB return loss bandwidths for the lower and upper-bands are 16% (1.103–1.297 GHz) and 12.5% (1.444–1.636 GHz), respectively. The 3-dB axial-ratio (AR) bandwidth is 6.9% (1.195–1.128 GHz) for the lower-band and 0.6% (1.568–1.577 GHz) for the upper-band. The gain is more than 5.0 dBover both the bands. The frequency-ratio was 1.28.

[66]Singh et al. (2011) proposed a design of frequency reconfigurable microstrip patch antenna. In this antenna design a rectangular patch antenna with slots at the Centre frequency 10 GHz that can be reconfigured in the frequency range of 10-10.5 GHz. The reconfiguration is done by switching the diodes ON/OFF. The simulated return loss is -13 dB at the resonance frequency 10.5 GHz. The simulated return loss is -19 dB for resonance frequency 10.3 GHz. The simulated return loss is -42 dB for resonance frequency 10.2 GHz.

[67]Mahendra et al. (2011) proposed a new design of compact elliptical microstrip patch antenna which was applicable for Ku-band. The antenna design consists of an elliptical patch on RO3001 substrate followed by a thin foam substrate as dielectric and a ground plane. A square slot was cut just below the elliptical patch. Various parameters like reflection coefficient, gain and radiation characteristics of the designed antenna were discussed. The simulation results showed return loss (S11) better than 22.98 dB at resonant frequency 14.6 GHz with the impedance bandwidth 33.56% or 3.95 GHz (12.9 GHz to 16.85 GHz) for VSWR<2 and 98.71% or 12.41 GHz (6.15 GHz to 18.18 GHz) for VSWR≤ 2.The presented antenna has nearly uniform radiation patterns across the frequency band with VSWR<2. This proposed antenna can be used for satellite application where larger bandwidth is required.

[68]Sharma et al. (2011) presented the radiation performance of a modified elliptical patch antenna that has three orthogonal sector slots, the results obtained from the experiment were compared to the simulation performance for a deeper study and better understanding. It was found that by using the slots, the patch size was reduced to na extent but the antenna performance was significantly improved. Impedance bandwidth and gain both were improved. The radiation patterns were stable and the direction of maximum radiations was directed normal to path geometry. This modified antenna meets the bandwidth requirements for the IEEE 802.11 a5 wireless local area network (WLAN) applications.

[69] Hoseini *et al.* (2010) proposed a paper in which a micro strip slot antenna using E-shaped aperture was considered. The various parameters of antenna were discussed. It was shown that the antenna could be made for dual band characteristic, high gain and quad band characteristic by making variations in the dimensions of stub length and E-shaped slot.

[70] Challal *et al.* (2011) proposed that the effect of introducing a defected ground structure of rectangular shape in the ground plane of simple micro strip patch antenna. After varying the dimensions of defected ground structure in the ground plane and also on locating the defect at proper position the performances of conventional rectangular micro strip antenna were characterized.

[71]Dheyab *et al.* (2011) focused on a method of using dielectric substrate of different value to enhance the bandwidth. Generally Micro strip antennas had some drawbacks like low gain, low efficiency, narrow bandwidth and more surface wave losses. The biggest drawback had been removed by increasing the bandwidth of micro strip antenna. The micro strip antenna when operating at 2.4 GHz and substrate thickness 4 mm was considered the bandwidth comes out to be 155.1 MHz and when the substrate thickness of 6mm was used the bandwidth comes out to be 200 MHz. Therefore it was shown that on increasing the thickness of substrate the bandwidth also increases.

[72] Halappa *et al.* (2011) demonstrated the paper in which they discussed their design of rectangular micro strip antenna. They considered the substrate of dielectric constant 4.4 and height 1.6mm and the name of this substrate was glass epoxy substrate. At the top right of patch the half circular shape slot was etched as DMS and in the ground plane two circular slots were etched as DGS. The Defected ground structure shifts the resonant frequency to required frequency. They showed defected ground structure was considered to reduce the size and to improve the bandwidth of micro strip patch antenna and the gain achieved was 4.65 dBi**.**

[73] Zheng *et al.* (2011) presented a miniaturized dual-band printed square quadrifilar helix antenna (QHA) for global navigation satellite systems (GNSS) receiver applications. The antenna consists of four printed helices forming a cube with a very small size of 1 cm^3 only. It could cover both L1 and L2 bands, centered at 1.575 and 1.227 GHz, respectively, with good impedance matching and circularly polarized radiation patterns. To prove the concept, a prototype was developed, fabricated and measured. Both measured and simulated results were presented and discussed. Because of its advantages of compact size, low mass and low cost, the antenna was useful for GNSS receiver onboard small satellites, and mobile terminals on the ground.

[74]Cai et al. (2012) proposed a frequency reconfigurable printed yagi-uda dipole antenna for cognitive radio applications. A 46% of continuous frequency tuning bandwidth has been obtained by loading the driver dipole arms and four directors with varactor diodes.a new frequency reconfigurable high-gain printed Yagi-Uda dipole antenna, operating over the 478–741 MHz UHF TV band, is proposed for cognitive radio applications. This frequency band is particularly important in Asia and Australasia where a concerted TV switchover has been planned. Compared to a broadband quasi-Yagi antenna, a frequency reconfigurable design maintains an end-fire high-gain pattern over a wide operating frequency range. It offers frequency selective functionality and spatial filtering capability.

[75]Mrinmoy et al. (2012) proposed a rectangular microstrip patch antenna with slots. When the slots and DGS were not defined in the antenna design, the structure was found to resonate at 5.22 GHz but when slots and DGS were introduced there was found to be a frequency shift from 5.22 GHz to 1.56 GHz and a size reduction of about 91% was achieved with 60 MHz bandwidth and return loss of -20dB making the antenna useful for wireless communication systems. The antenna was designed and simulated using Ansoft designer software.

[76] Singh *et al*. (2012) proposed an antenna in which two techniques called micro strip line feed technique and coaxial feed technique were combined. They discussed the high gain, low profile, small size and narrow bandwidth of the antenna. When both feeding techniques were compared it was shown that better impedance matching technique was coaxial feeding.

[77]Dua *et al.* (2012) focused on the rectangular micro strip patch antenna in which defect taken was swastika in shape. In this design patch area was much smaller in comparison to the simple micro strip antenna without defective ground structure. So, this type of antenna design using defected ground structure not only helps to improve the antenna parameters but it also helps to reduce the size of radiating patches which further reduces the overall size of the antenna.

[78]Bao *et al.* (2012) focused on several novel compact circularly-polarized probe-fed annular-ring micro strip patch antennas were examined experimentally and numerically. In order to reduce the antenna size and provide a suitable input impedance match, two techniques were employed; the insertion of strips into the annular ring and placing a cross-slot into the ground plane.

The annular-ring patch with a cross-slotted ground plane yielded much smaller size for a given frequency. This novel patch antenna could effectively be reduced by about 55 percent in size compared to conventional annular-ring patch antennas. The antenna displayed wide bandwidth and good circular polarization characteristics. The results of a parametric study for three novel strip-loaded annular-rings patch antennas and for the compact circular patch antenna augmented by a narrow annular ring with a cross-slotted ground plane were discussed.

[79] Majid et al. (2012) proposed design of Frequency-Reconfigurable Narrowband Microstrip Slot Antenna. This antenna is capable of frequency switching at six different frequency bands between 2.2 and 4.75 GHz. The five p-i-n diode switches were placed in the slot to achieve frequency re-configurability. The feed line and the slot are bended to reduce 33% of the original size of the antenna. Switches using RF p-i-n diode BAR 64-02 are located in the slot of the antenna, which can control the effective length of the slot, thereby producing six different frequencies covering from 2.2 to 4.75 GHz.

[80] Aneesh *et al.* (2013) proposed on S-shape micro strip patch antenna was investigated for wideband operation using circuit theory concept based on modal expansion cavity model. It was found that the antenna resonates at 2.62 GHz. The bandwidth of the S-shape micro strip patch antenna 21.62 % (theoretical) and 20.49% (simulated). The theoretical results were compared with IE3D simulation as well as reported experimental results and they were in close agreement.

[81] Ridhi et al. (2013) presented a paper that described, by using shifted elliptical slot there is an increment in bandwidth and gain of rectangular microstrip patch antenna. Firstly they designed a rectangular microstrip patch antenna and then an elliptical slot was made on the patch which was made on the patch which was then shifted to the right side. The results of both designs were compared and were found that 21% of bandwidth was increased and gain was found to be 7.21 dBi when the slot was cut. This antenna was designed on Duroid 5880 substrate having dielectric constant 2.2. The antenna was fed by a co-axial probe feed and the design and performances of the antenna were analyzed by using software called Zealand IE3D.

[82] Roy et al. (2013) presented three different geometry shapes, the U, E and H are made from a rectangular patch of size 24mm*32mm. The proposed antenna was simulated by sonnet software and the results were compared to the conventional rectangular microstrip patch antenna. The results showed that the bandwidth of the conventional rectangular microstrip antenna can be improved from 4.81% (100 MHz) to 28.71% (610 MHz), 28.89% (630 MHz) and 9.13% (110 MHz) respectively by taking U, H and E patches on the substrate. Out of the three shaped patches, E shaped patch antenna had the greatest bandwidth then the U shaped patch followed by H shaped patch antenna. The material of substrate used in the antenna was Alumina 96% having dielectric constant 9.4 and loss tangent 4.0e-4. The designed antenna can be used for wireless local area network (WLAN) applications.

[83] Mishra *et al.* (2015) focused on a dual-band antenna was proposed for WLAN and WiMAX frequency bands. Two resonance frequencies were found to be 2.45 and 5.125 GHz and −10 dB bandwidth of lower and upper resonance frequencies were 4.13 and 8.82 % respectively. It was observed that frequency ratio was more sensitive with the dimensions of L-shaped slot. The frequency ratio of the antenna for a given dimension of L-slot was found to be 2.092 and gain of the antenna was 3.9 dBi for lower resonance whereas 6 dBi at upper resonance. The theoretical results were compared with the reported experimental result as well as simulated results obtained from IE3D simulation software which was in close agreement.

[84] Aneesh *et al.* (2014) worked on the parametric analysis of the slot-loaded micro strip line feed patch antenna was investigated using artificial neural network model. The bandwidths of the proposed antenna obtained at TM01, TM02, and TM03 frequency modes were 10.2 GHz, 13.6 GHz, and 17.2 GHz, respectively. The performance of the proposed antenna was analyzed using artificial neural network model. The changes obtained in bandwidth due to the position of slot length and slot width were reported. The antenna parameters such as return loss, VSWR, gain and efficiency were also calculated. The simulated results obtained with the help of IE3D simulation software were trained and tested using ANN. Theoretical results were compared with simulated and experimental ones, and they were in close agreement.

[85]Panusa *et al.* (2014) presented a quad-band U-slot micro strip patch antenna for wireless application. The proposed antenna operates at GPS/Bluetooth/Wi-Fi/WLAN frequency bands, had the substrate Rogers RO4232 with dielectric constant of 3.2 and dimensions $47 \times 57 \times 1.5$ mm^3 with the dielectric loss of 0.043. Coaxial feeding technique was used to feed the antenna with 50 ohm impedance. The antenna performance such as VSWR, return loss, radiation pattern and gain of the antenna is presented.

[86] Chiu et al. (2014) proposed a design of frequency-reconfigurable pixel slot antenna. The antenna makes use of a canonical switched slot element that is concatenated together to form various radiating structures. The resonant path of the pixel slot antenna can be a conventional slot or a slot plus a loop, so higher degrees of freedom in generating various resonant frequencies is achieved. The maximum resonance to minimum resonance achievable values of a demonstrated 4-switch single-pixel slot antenna were 3.30 GHz to 1.56 GHz in which the feed mechanism remains unchanged. The RF MEMS switches are then placed in the slots on the backside of the board and bond wired to the copper pads providing a short and open circuit to the slot, such that the slot length (path) is able to be controlled electronically, offering a frequency tuning effect. The DC control lines for the RF MEMS switches are also printed on the lower layer. As a result, the radiating slot and the switching elements associated with bias lines are separated by two different layers. This eliminates the crowded DC control lines laid on the ground plane and allows the construction of a more complicated 2x2 pixel matrix slot antenna. The re-configurability of the antenna is achieved by changing the radiating slot topology using RF MEMS switches. This design differs from the conventional pixel antenna because the radiation occurs from the slots between metallic pixels rather than directly from the pixel themselves. As the perimeter of the pixel is utilized in this antenna, a longer possible resonant length could be defined over that of a pixel patch antenna with the same number and size of pixels.

[87] Mansoul et al. (2014) proposed a design of Selective Frequency-Reconfigurable Antenna for Cognitive Radio Applications. The proposed antenna was capable of switching between a wide operating band of 2.63–3.7 GHz and four different sub bands, which allowed using for sensing the entire band and then adjusted its bandwidth to select sub-band and prefilter the other ones. The antenna was composed of a radiating element in the form of an inverted U fed by a microstrip line on its upper side. For a selective frequency reconfiguration, four horizontal slots with integrated p-i-n diode switches are incorporated in the ground plane to act as reconfigurable filter. For frequency reconfiguration that allows adjusting to the desired band and bandwidth, four horizontal slots with integrated switches are disposed in three rows and incorporated to the antenna ground plane. The upper slot and bottom slot were used to stop band filters in order to suppress the whole specified band. To be able to bias the p-i-n diodes in order to turn them ON/OFF, 0.4-mm-width slots are introduced in the ground plane to separate the two ports of the switches and be able to have a voltage difference between them. To maintain a dc separation and ensure an RF continuity of the ground plane, 100-pF surface-mount RF capacitors are used to bridge the slots, which provided almost a short circuit (≤0.6) at the operating frequencies. To operate the antenna in one of four sub-bands, six switches s1–s6 working by pairs have been integrated to the middle slots in order to control their electrical length. To operate the antenna in the wideband mode and cover the whole wide band, six other switches s7 –s12 are used to deactivate the effect of the four slots by disrupting them. by turning the different switches ON and OFF according to the configurations , the antenna can be operated over the whole considered band or in one of four sub-bands with a good in-band impedance matching.

[88] Divyanshu et al. (2014) presented the simulation analysis of small planar antennas by using various antenna miniaturization techniques. The techniques mentioned in the paper were used to reduce the physical size of antenna but to increase the bandwidth and efficiency. Different miniaturization approaches like introduction of slots, short meandering, slits and novel geometries like fractals or by taking dielectric constant which is high, were mentioned in the paper. Also the effect of miniaturization in different antenna parameters like radiation, gain, efficiency, and bandwidth were also discussed. And finally the paper reported a short description about miniaturization of antenna by using by using efficient and suitable methods that included the use of double layered substrate structure in the microstrip patch antenna.

[89] Swati et al. (2014) presented the design of a compact size, rectangular, single feed, single layer, circular and square shaped microstrip patch antennas applicable for WLAN and WiMAX. In this paper a comparative study has been done among the various parameters of these patch antennas with and without slots. It was found that in each case when slots were introduced a significant improvement was observed, return loss of more than -10 dB was fetched for each structures. There was found to be an increment of gain when slots were introduced, from 3.71 dBi to 4.43 dBi in circular patch and from 6.22

dBi to 6.43 dBi in square patch. The proposed structure was studied by using IE3D simulation software.

[90] Huda. et al. (2014) Proposed a design of frequency reconfigurable slot-patch antenna with reflector at the back of an Antenna is presented. Three switches are placed in the slot. The antenna was capable to reconfigure up to six different frequency bands i.e. from 1.7 GHz to 3.5 GHz. Three PIN diodes were positioned in the slot in order to obtain frequency reconfiguration. and the different radiation patterns were obtained at the higher and lower frequency bands whatever specified, a reflector was placed behind the antenna to produce directional radiation pattern at all frequency bands. This antenna is a combination of a microstrip patch and slot antenna. The size of the antenna is 80 mm × 60 mm, and the size of the reflector is 122 mm × 102 mm. This antenna was a combination of a microstrip patch and slot antenna. The slot is positioned at the ground plane underneath the patch. Three switches are used to reconfigure six different frequency bands. The microstrip patch antenna produces three reconfigurable frequency bands while the slot produces another three frequency bands at the lower frequency region. In order to produce directional radiation pattern at all frequency bands, a reflector is installed at the back of the frequency reconfigurable slot-patch antenna. The antenna is capable to switch between two modes which are the standard and half-slot mode. The standard mode operates when the PIN diode is switched on and varactor diode tuned to give five different frequency bands from 0.8 GHz to 1.48 GHz. The half-slot mode operates when the PIN diode is switched off and the varactor diode tuned to give four different frequency bands from 0.42 GHz to 0.96 GHz. The substrate material taconic RF35 with relative permittivity of 3.5 and substrate thickness of 3.04 wass used for the antenna design. The patch of the antenna is designed to operate at 4.13 GHz. Inset feed is used to match the impedance between the patch and the transmission line.

[91] Nisha et al. (2015) A new configurable circular patch antenna for Military applications fed by 50Ω impedance hybrid coupler feed was examined here. The dual fed circular polarized microstrip antenna was etched on a Rogers with dielectric substrate of 2.2 with the height of 0.16 mm. The effect of hybrid coupling was circular polarization and radiation around 360 degree. The thickness of Circular patch antenna was of 0.381mm. The antenna was designed to achieve high gain of 6dB at the operating frequency of 8GHz. Simulation results and the measured results characteristic were closely matches with each other.

[92] Gu. et al. (2015) proposed a design of circularly polarized patch antenna with frequency reconfiguration. The antenna consist a rectangular patch that was etched with a rectangular ring slot. Four pairs of varactor diodes are symmetrically placed along the slot. By varying the capacitance values of the varactor diodes with single DC voltage, the resonant frequencies of the two modes are simultaneously changed.

[93] Sharma et al. (2015) proposed a design of slot embedded dual-band patch antenna for WLAN and WiMAX applications. The antenna consist an aperture-fed square patch which was embedded with a narrow with symmetrical π-shape slot to generate a dual-band resonance. This antenna resonates at a lower frequency band which fully covers the 2.4–2.484 GHz WLAN band and 2.5–2.69 GHz WiMAX band. The higher-frequency resonance is 3.5 GHz in WiMAX band. This antenna geometry exhibited a wide impedance bandwidth of 18.07 and 8.28% in the two operating bands.

[94] Ajinkya et al. (2015) suggested an elliptical microstrip patch antenna for ultra wide band frequency ranging from 3.1 GHz to 10.6 GHz. Proposed design focused on bandwidth increment by using elliptical patch so as to cover many applications on a single patch antenna. The antenna was designed by using FR4 printed circuit board of dimensions 55mm*56mm*1.6mm. The designed antenna was found to have a good voltage standing wave ratio and return loss over the entire ultra wide band frequency range. The results of antenna were simulated by using HFSS version 13.0.0 software.

[95] Anuja et al. (2015) proposed an elliptical probe-fed antenna having double U-shaped slot for increasing the bandwidth. This proposed antenna was suited for multiband wireless communication systems and it achieved good impedance matching and gain in the entire band of operation. The antenna served well in radiating in all frequencies of operation with good radiation efficiency. The designed antenna was simulated and analyzed by using Ansoft HFSS software.

[96] Sumanpreet et al. (2015) implemented microstrip patch antennas with six different types of shapes like rectangular, hexagonal, square, pentagonal, circular and elliptical using Ansoft HFSS software. All the antennas were designed on the substrate Rodger RT/duroid 5880 having dielectric constant 2.2 and having the thickness 3.2mm. The operating frequency was taken to be 7.5 GHz for all these antennas. All antennas were excited by co-axial feeding. It was found that pentagonal microstrip patch antenna had better results at this frequency than all the other shapes.

[97] Vikram et al. (2015) presented the review paper on a survey which was conducted on techniques and design for the designing of efficient, low profile, small, compatible, and affordable microstrip patch antenna that is used to design wideband, multiband, and reconfigurable antennas. In this paper an initiator patch antenna design was given with some dimensions on which techniques has been applied for the analysis of different parameters of the antenna. By using the techniques given in this paper, some of the drawbacks of the conventional microstrip patch antenna characteristics were improved.

[98] Kavita et al. (2016) presented a project of a monopole ultra wide band elliptical antenna array at the transmitter to synthesize an array pattern for reducing the BER performance in an ultra wide band communication system and also to design and bandwidth optimization of ultra wide band antenna. As ultra wide band antennas has low profile, small size, and low manufacturing cost so the UWB antenna was found to be in more demand for wireless communication systems. In this paper the ground plane of the antenna was used as a radiator which resulted in the overall reduction of size but there was found to be an improvement in the operating bandwidth which was suitable for high speed and short range WPAN. The antenna performance was analyzed by using electromagnetic software MWS-CST (computer simulation technology simulator).

[99] Murugan et al. (2016) proposed a multi-frequency microstrip antenna design applicable for wireless communication. The antenna had an elliptical patch with a T-slot and was excited by co-axial feeding. It provided optimized multi-frequency by varying antenna design parameters like major and minor axis of elliptical patch, feeding points of the probe and length or width of the T-slot. The designed antenna was found to resonate at frequencies 1.57, 1.96, and 3.4 GHz which can be used in GPS and 4G LTE applications. Simulation of the antenna was done by using Ansoft HFSS. The antenna was fabricated and tested using vector network analyzer.

[100] Rishabh et al. (2016) proposed an elliptical patch antenna design for circular polarization. Ansoft HFSS was used for the analysis of the antenna design, HFSS modeling was developed to calculate the antenna dimensions for some given aspect ratio, height of substrate, resonant frequency and dielectric constant. After the HFSS simulation, the network showed high success rate.

[101]Gogoi et al. (2017) reported slots loaded rectangular patch antenna for C- band applications. Slots are incorporated in ground plane of a simple rectangular patch antenna over FR-4 substrate with dielectric constant $\varepsilon_r = 4.3$ and height, h = 1.5 mm. Ground slots changes resonating behavior of antenna and shows multi frequency characteristics with enhanced bandwidth and directivity as compared to simple patch antenna without modified ground plane. Antenna parameters are studied for both defected and simple ground structures. Two slots geometry shows three resonant frequencies with $S_{11} < -17$ dB and enhancement in −10 dB bandwidth of 11.74% at 5.96 GHz. In three slots geometry, two resonant frequencies are observed with $S_{11} < -20$ dB and enhancement in −10 dB bandwidth of 13.05% at 5.44 GHz.

[102] Rajagopal et al. (2016) proposed a modified elliptical shaped antenna for C- band wireless applications. Three different designs are created to analyze improved antenna performance in terms of radiation efficiency and bandwidth. Third design has same substrate and physical dimensions but controlled by the length of the slots and width of the feed. Third design is to yield unique performance in a single element and achieves the performance of enhanced radiation efficiency and bandwidth with the reconfigurable mechanism. Improved efficiency up to 87.09% and improved bandwidth up to 300MHz is achieved.

[103] Kaushal et al. (2017) reported a Vinayak slotted rectangular microstrip patch antenna 146 × 90 × 1.6 mm^3 for quad band resonance with significant characteristics to serve applications including radio determination, satellite, mobile, and space research is proposed. FR4 epoxy substrate is used as dielectric and a coaxial feeding mechanism is used for excitation. The simulation software HFSS-15 is used for analysis purpose and the design has been analyzed for its standard parameters including the reflection coefficient, bandwidth, radiation pattern, gain, VSWR, directivity, and distribution of fields. The experimental and the measured values are in close agreement.

[104]Wu et al. (2017) proposed a coupled-fed with dual-band (at 4.3 and 5.4 GHz) dual-mode (TM_{01} and TM_{10}) and dual-polarization (vertical and horizontal polarization) characteristics micro strip patch antenna for navigational system. The antenna consists of two symmetrical rectangular patches as radiators and a microstrip line as coupled feeding structure. The measured impedance bandwidth of 60 MHz at lower frequency band and 140 MHz at upper frequency band is observed. Antenna performance are analyzed in terms of reflection coefficients, impedance bandwidth and radiation pattern. The proposed antenna has advantages of simple structure, low cross polarization and low cost.

CHAPTER-III

MATERIALS AND METHOD

CHAPTER-3

MATERIALS AND METHOD

3.1 OVERVIEWOF MICROSTRIP ANTENNA

A microstrip antenna in its simplest configuration consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. The patch conductors, normally of gold and copper, can assume virtually any shape, but conventional shapes are generally used to simplify analysis and performance prediction ideally, the dielectric constant should be low, so to enhance the fringing field, which account for the radiation. Microstrip antennas have several advantages compared to conventional microwave antennas and therefore many applications cover the broad frequency range from 100MHz to 50GHz.

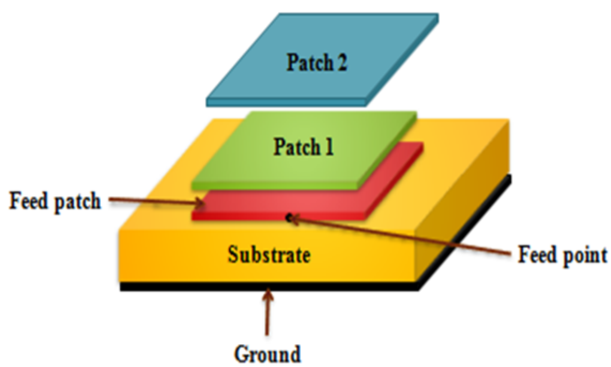

Figure 3.1 Basic geometry of microstrip patch antenna

In telecommunication, there are several types of microstrip antenna (also known as printed antenna) the most common of which is the microstrip patch antenna or patch antenna. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate with a continuous metal layer bonded to the opposite side of substrate which forms a ground plane. Common microstrip antenna radiator shapes are square, rectangular, circular, and elliptical, but any continuous shape is possible. Some patch antennas eschew a dielectric substrate and suspend a metal patch in air above a ground plane using dielectric spacers; the resulting structure is less robust but provides better bandwidth. Because such antennas have a very low profile, are mechanically rugged and can be conformable, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communication devices.

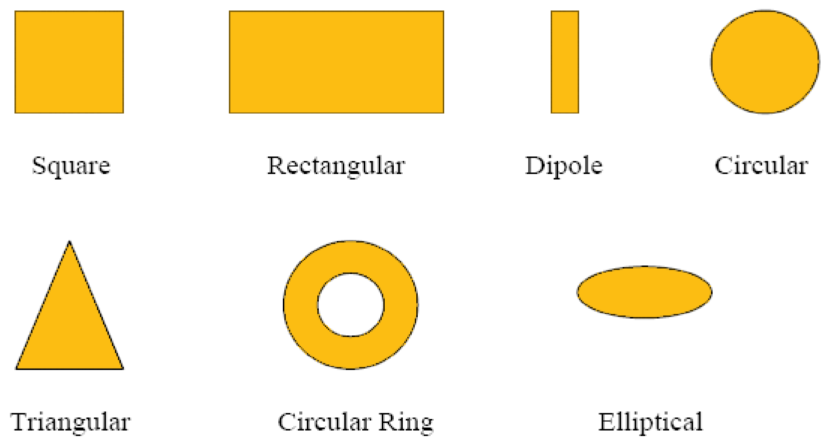

Figure: 3.2 Different structures of radiating patch

Microstrip antennas are also relatively inexpensive to manufacture and design because of the simple 2-dimensional physical geometry. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonance frequency. A single patch antenna can provide a maximum directive gain of around 6-9dBi. It is relatively easy to print an array of patches on a single (large) substrate using lithographic techniques. Patch arrays can provide much higher gain than a single patch at little additional cost; matching and phase adjustment can be performed with printed microstrip patch feed structures, again in the same operations that form the radiating patches. The ability to form high gain arrays in a low profile antenna is one reason that patch arrays are common on airplanes and in military applications.

Microstrip or patch antenna has less bandwidth but for practical applications increased bandwidth is demanded. Applications in mobile and wireless communication systems usually require reduced size antenna to meet the compact size demand of mobile system. Therefore, reduction in size and improved bandwidth are important design issues for practical application of microstrip antenna. Microstrip or patch geometries give electromagnetic radiation; this was first reported in 1950's. The idea of microstrip patch as a radiator was first offered by Deschamp in 1953. A patent was out flowed in France in 1955 in the name of great scientists Gutton and Baissinot . The first patch design can be assumed as a slim radiating metallic plane of any shape, placed apart from a metallic ground by a dielectric substrate. The microstrip patch antenna is termed as a resonant antenna, because the size of the patch based on the wavelength. General view for all resonant antennas is that the bandwidth is narrow, commonly only a few percent.

Radiation losses were the big concern with circuits implemented in microstrip patch antenna. Fortunately, antenna designers selected this unwanted effect and worked on the microstrip technique, in spite of the fact that it is a resonant device having relatively low operation bandwidth. Microstrip antennas have become the most emerging issue in antenna theory and design in recent years and are increasingly searching application in several modern wireless systems. A microstrip antenna made up of a very slim ($t \ll \lambda 0$, where't' refers to the thickness and '$\lambda 0$' refers to the free space wavelength) metallic strip or patch placed a small proportion of a wavelength ($h \ll \lambda 0$, usually $0.003\ \lambda 0 \leq h \leq 0.05\ \lambda 0$) above a metallic ground plane. A dielectric substrate placed apart the patch from the metallic ground plane. Microstrip antenna provides suitable shaped irregularities that are designed to radiate. The shaped irregularities represent sudden changes in the microstrip patch design e.g. a sudden change in width, an open end and a microstrips bend. The shaped irregularities change the electric and magnetic fields distributions. These produce in energy storage and also electromagnetic radiation at the irregularities. As long as the physical measurement and the relative dielectric constant of the microstrip patch remain stable, virtually no electromagnetic radiation occurs. But the irregularities introduced by the sudden change in the microstrip patch at the junction of the feed line and patches radiated. The other end of the patch where the metallic patch suddenly ends also radiates. Because of this change, electric field spreads out and it creates fringing fields at this edge. After this change the patch seems to be another microstrip line. The field propagates down this line until the other edge is reached. Here the sudden termination of the microstrip line generates the fringing fields for the open end irregularities. The fringing field store energy. The corner of antenna appears as the capacitor to metallic ground as the changes in the electric field are more than that of the magnetic field. Since the patch is much wider than the microstrip patch length, the fringing field also radiate, this may be considered as a conductance in shunt with the edge capacitance, which is accountable for the power lost because of radiation.

Selecting an appropriate dielectric substrate with optimum height (h) and loss tangent (tan δ) is a big concern in the microstrip patch antenna design. A relatively thicker substrate would improve impedance bandwidth. However, it would increase the size, weight, dielectric loss and surface wave loss.

The most commonly employed microstrip antenna is a rectangular patch shown in fig 3.2 below. The rectangular patch antenna is approximately a one-half wavelength long section of rectangular microstrip transmission line. When air is the antenna substrate, the length of the rectangular microstrip antenna is approximately one-half of a free-space wavelength. The resonant length of the antenna is slightly shorter because of the extended electric “fringing fields” which increase the electric length of the antenna slightly. The dielectric loading of a microstrip antenna affects both its radiation pattern and impedance bandwidth. The rectangular microstrip antennas are made of a rectangular patch with dimensions width W and length L over a ground plane with a substrate thickness h and dielectric constants ε_r.

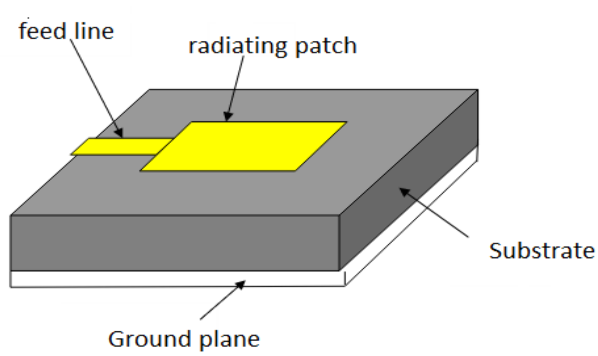

Figure: 3.3 Geometry of rectangular microstrip patch antenna

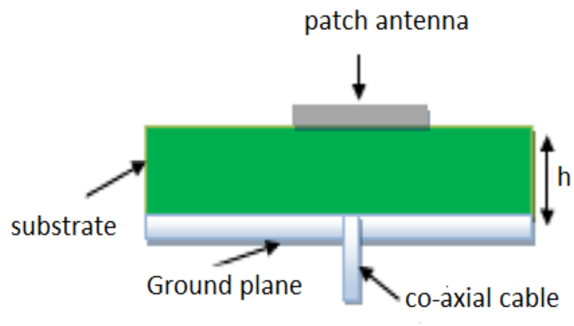

Figure: 3.4 Side view geometry of patch antenna

Dielectric constants are usually used in the range between 2.2 and 12. However, the most desirable ones are the dielectric constants at the lower end of this range together with the thick substrates, because they provide better efficiency and larger bandwidth, but at the expense of larger element size. Micro-strip is used extensively in both hybridand monolithic microwave integrated circuits, and it is by far the most popular medium for the design of components with active devices.

Figure 3.3 shows a cross section of rectangular micro-strip antenna. Although micro-strip is physically extremely simple, it is the most complex of all the transmission lines. Pure TEM mode propagation is impossible because of the mixed dielectric, the medium is dispersive, a multitude of higher order modes can propagate along it and being an open structure, it can radiate energy as well as conduct it. Nevertheless, its popularity is a result of ease with which one can chip components. The relatively good thermal dissipation properties of the medium and, above all, the ability to make adjustments to micro-strip circuits while operating at RF.

Micro-strip patch antennas 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 Micro strip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a trade-off must be realized between the antenna dimensions and antenna performance.

3.2 CHARACTERISTICS OF ANTENNA

3.2.1 Input Impedance:

For an efficient transfer of energy, the impedance of the radio, of the antenna and of the transmission cable connecting them must be the same. Transceivers and their transmission lines are typically designed for 50Ω impedance. If the antenna has impedance different from 50 Ω, then there is a mismatch and an impedance matching circuit is required.

3.2.2 Return loss:

The return loss is another way of expressing mismatch. It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line.

3.2.3 Bandwidth:

The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly. The antenna's bandwidth is the number of Hz for which the antenna will exhibit an SWR less than 2:1. The bandwidth can also be described in terms of percentage of the center frequency of the band.

3.2.4 Directivity and Gain:

Directivity is the ability of an antenna to focus energy in a particulardirection when transmitting, or to receive energy better from a particular direction when receiving. In a static situation, it is possible to use the antenna directivity to concentrate the radiation beam in the wanted direction. However in a dynamic system where the transceiver is not fixed, the antenna should radiate equally in all directions, and this is known as an omni-directional antenna.Gain is not a quantity which can be defined in terms of a physicalquantity such as the Watt or the Ohm, but it is a dimensionless ratio. Gain is given in reference to a standard antenna. The two most common reference antennas are the isotropic antenna and the resonant half-wave dipole antenna. The isotropic antenna radiates equally well in all directions. Real isotropic antennas do not exist, but they provide useful and simple theoretical antenna patterns with which to compare real antennas. Any real antenna will radiate more energy in some directions than in others. Since it cannot create energy, the total power radiated is the same as an isotropic antenna, so in other directions it must radiate less energy. The gain of an antenna in a given direction is the amount of energy radiated in that direction compared to the energy an isotropic antenna would radiate in the same direction when driven with the same input power. Usually we are only interested in the maximum gain, which is the gain in the direction in which the antenna is radiating most of the power. An antenna gain of 3 dB compared to an isotropic antenna would be written as 3 dBi. The resonant half-wave dipole can be a useful standard for comparing to other antennas at one frequency or over a very narrow band of frequencies. To compare the dipole to an antenna over a range of frequencies requires a number of dipoles of different lengths. An antenna gain of 3 dB compared to a dipole antenna would be written as 3dB.The method of measuring gain by comparing the antenna under test against a known standard antenna, which has a calibrated gain, is technically known as a gain transfer technique. Another method for measuring gain is the 3 antennas method, where the transmitted and received power at the antenna terminals is measured between three arbitrary antennas at a known fixed distance.

3.2.5 Radiation Pattern:

The radiation or antenna pattern describes the relative strength of the radiated field in various directions from the antenna, at a constant distance. The radiation pattern is a reception pattern as well, since it also describes the receiving properties of the antenna. The radiation pattern is three-dimensional, but usually the measured radiation patterns are a two dimensional slice of the three-dimensional pattern, in the horizontal or vertical planes. These pattern measurements are presented in either a rectangular or a polar format.

3.2.6 Beamwidth:

An antenna's beamwidth is usually understood to mean the half-power beamwidth. The peak radiation intensity is found and then the points on either side of the peak which represent half the power of the peak intensity are located. The angular distance between the half power points is defined as the beamwidth. Half the power expressed in decibels is -3dB, so the half power beamwidth is sometimes referred to as the 3dB beamwidth. Both horizontal and vertical beamwidths are usually considered. Assuming that most of the radiated power is not divided into sidelobes, then the directive gain is inversely proportional to the beamwidth: as the beamwidth decreases, the directive gains increases.

3.2.7 Side lobes:

No antenna is able to radiate all the energy in one preferred direction. Some is inevitably radiated in other directions. The peaks are referred to as sidelobes, commonly specified in dB down from the main lobe.

3.2.8 Nulls:

In an antenna radiation pattern, a null is a zone in which the effective radiated power is at a minimum. A null often has a narrow directivity angle compared to that of the main beam. Thus, the null is useful for several purposes, such as suppression of interfering signals in a given direction.

3.2.9 Polarization:

Polarization is defined as the orientation of the electric field of anelectromagnetic wave. Polarization is in general described by an ellipse. Two special cases of elliptical polarization are linear polarization and circular polarization. The initial polarization of a radio wave is determined by the antenna. With linear polarization the electric field vector stays in the same plane all the time. Vertically polarized radiation is somewhat less affected by reflections over the transmission path. Omnidirectional antennas always have vertical polarization. With horizontal polarization, such reflections cause variations in received signal strength. Horizontal antennas are lesslikely to pick up man-made interference, which ordinarily is vertically polarized. In circular polarization the electric field vector appears to be rotating with circular motion about the direction of propagation, making one full turn for each RF cycle. This rotation may be right hand or left hand. Choice of polarization is one of the design choices available to the RF system designer.

3.2.10 Polarization Mismatch:

In order to transfer maximum power between a transmit and a receive antenna, both antennas must have the same spatial orientation, the same polarization sense and the same axial ratio. When the antennas are not aligned or do not have the same polarization, there will be a reduction in power transfer between the two antennas. This reduction in power transfer will reduce the overall system efficiency and performance.

3.3 MERITS AND DEMERITS

3.3.1 Merits:

A microstrip patch antenna has small dimensions and light weight. It also provides ease of manufacturing, ease of fabrication (use etching and photolithography) and high level of integration with low cost. These are low profile antennas (can even be "conformal"), easy to feed (coaxial cable, micro-strip line, etc.) and also easy to use in an array or incorporate with other micro-strip circuit elements. The patterns of these antennas are somewhat hemispherical, with a moderate directivity (about 6-8 dB is typical).

3.3.2 Demerits:

But besides these entire merits microstrip patch antenna has some demerits as well like narrow bandwidth and low gain. They have low power handling capacity. Generation of surface wave at the air-dielectric interface is common. Also the overall efficiency is low due to dielectric losses. Micro-strip antenna elements can only operate effectively in the vicinity of resonant frequency.

Some notable system applications for which microstrip antennas have been developed include satellite, radar and mobile communication, defense applications and in biomedical radiator. They are also used as feed element in complex antennas.

3.4 SUBSTRATE MATERIALS

In the antenna design, the substrate material is a very big factor through which we can change the antenna's characteristics. The selection of the dielectric material depends on the area of the application that we have to use the antenna. The purpose of the substrate material of a microstrip antenna is primarily to provide mechanical support for the radiating patch elements and to maintain the required precision spacing between the patch and its ground plane. With higher dielectric constant of the substrate material, the patch size can also be reduced due to loading effect. Certainly, with reduced antenna volume, higher dielectric constant also reduces bandwidth. There is a variety of types of substrate materials. As discussed in above, the relative dielectric constant of these materials can be anywhere from 1 to 10.

Materials with dielectric constants higher than 10 are rarely used and need more care. They can significantly reduce the radiation efficiency by having small antenna volumes. The most popular type of material is Teflon-based with a relative dielectric constant between 2 and 3. This Teflon-based material, also named PTFE (polytetrafluoroethylene), has a structure form very similar to the fiberglass material used for digital circuit boards, but it has a much lower loss tangent or insertion loss. The selection of the appropriate material for a microstrip antenna should be based on the desired patch size, bandwidth, insertion loss, thermal stability, cost, etc. For commercial application, cost is one of the most important criteria in determining the substrate type. For example, a single patch or an array of a few elements may be fabricated on a low-cost fiberglass material at the L-band

Frequency, while a 20-element array at 30 GHz may have to use higher-cost, but lower loss, Teflon-based material. For a large number of array elements at lower microwave frequencies (below 15 GHz), a dielectric honeycomb or foam panel may be used as substrate to minimize insertion loss, antenna mass, and material cost with increased bandwidth performance.

Properties of different substrate materials are compared in terms of mass density, dielectric constant and loss of tangent in table 3.1.

Table 3.1 A comparative overview of different substrate materials [105].

Substrate materials	Mass density	Dielectric constant	Loss of tangent
FR4 Epoxy	1900	4.4	0.02
Duroid (tm)	0	2.2	0.0009
copper	8933	0.99991	0
Ferrite	4600	12	0
Foam	-	1.24	0.0213
Polyester	0	3.2	0.003
Rogers RO3003	0	3	0.0013
Teflon (tm)	2250	2.1	0.001
Polyflon-NorCLAD(tm)	0	2.55	0.0011

3.5 FEEDING TECHNIQUES

Microstrip patch antennas 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 micro-strip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the micro-strip line and the radiating patch. The four most popular feed techniques used are the micro-strip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

3.5.1 Micro-Strip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the Micro-strip patch as shown in Figure 3.5. 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.

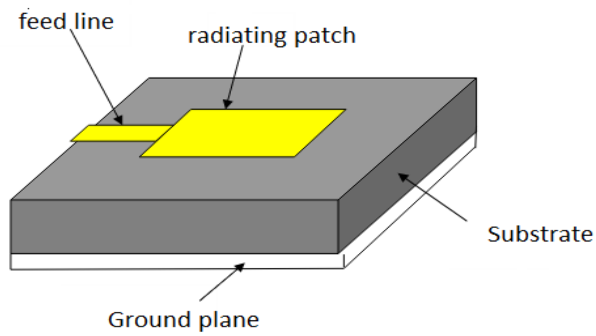

Figure: 3.5 Micro-strip transmission line feed

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. 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. The feed radiation also leads to undesired cross polarized radiation.

3.5.2 Coaxial Cable or Probe Feed

Micro-strip antennas can also be fed from underneath via a probe as shown in figure 3.6. The outer conductor of the coaxial cable is connected to the ground plane, and the center conductor is extended up to the patch antenna.

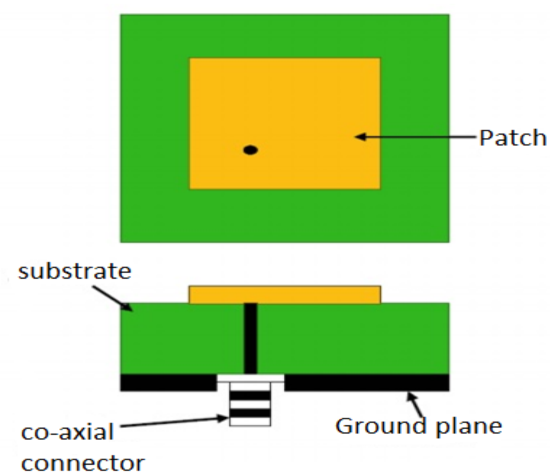

Figure: 3.6 Coaxial cable feed of patch antenna

The position of the feed can be altered as before (in the same way as the inset feed, above) to control the input impedance. The coaxial feed introduces an inductance into the feed that may need to be taken into account if the height *h* gets large (an appreciable fraction of a wavelength). In addition, the probe will also radiate, which can lead to radiation in undesirable directions.

The advantage of the coupled feed is that it adds an extra degree of freedom to the design. The gap introduces a capacitance into the feed that can cancel out the inductance added by the probe feed.

3.5.3 Aperture Feed

In this technique, the feed circuitry (transmission line) is shielded from the antenna by a conducting plane with a hole (aperture) to transmit energy to the antenna, as shown in figure 3.7.The upper substrate can be made with a lower permittivity to produce loosely bound fringing fields, yielding better radiation. The lower substrate can be independently made with a high value of permittivity for tightly coupled fields that don't produce spurious radiation. The disadvantage of this method is increased difficulty in fabrication.

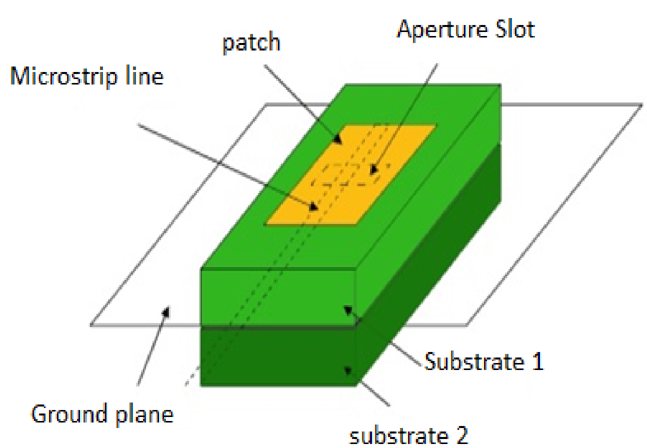

Figure: 3.7 Aperture coupled feed

3.5.4 Proximity Coupled Feed

This type of feed technique is also called as the electromagnetic coupling scheme. As shown in figure 3.8, 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%), due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choice between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

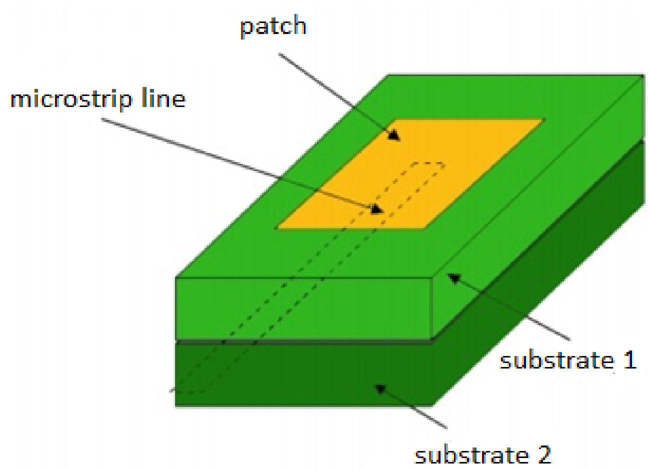

Figure: 3.8 Proximity-coupled feed

Table-3.2 Comparative analysis of different feeding techniques [106].

Characteristics	**Microstrip Line Feed**	**Coaxial Feed**	**Aperture Coupled Feed**	**Proximity Coupled Feed**
Spurious radiation from feed	More	More	Less	Minimum
Reliability	Better	Poor	Good	Good
Ease Of Fabrication	Easy	Soldering and drilling are required	Alignment required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Impedance bandwidth	2-5%	2-5%	2-5%	2-5%

3.6 ANALYSIS OF MODELS OF MICROSTRIP ANTENNA

The preferred 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). 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. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. These give less insight as compared to the two models mentioned above and are far more complex in nature.

3.6.1 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 a non - homogeneous line of two dielectrics, typically the substrate and air.

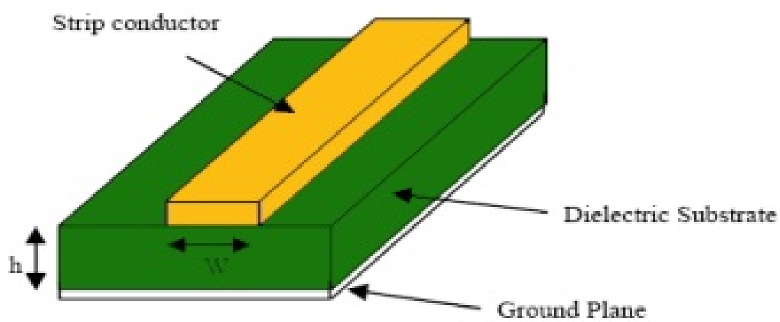

Figure: 3.9 Microstrip line feed

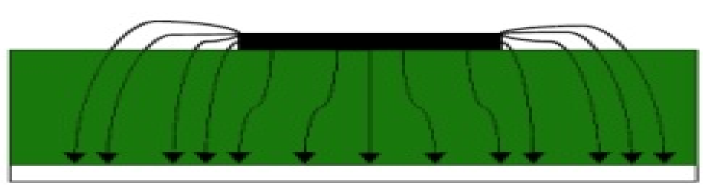

Figure: 3.10 Electric field lines distribution

Hence, as seen from figure 3.10, 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 3.10 above. Effective dielectric constant is given by

$$\varepsilon_{reff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \tag{3.1}$$

Consider figure 3.11 below, 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.

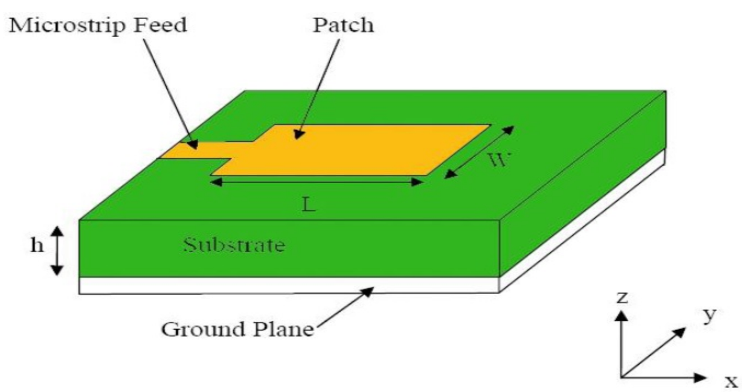

Figure: 3.11 Microstrip patch antenna in x-y-z Co-ordinate

In order to tolerate 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 $\lambda o/\sqrt{\varepsilon reff}$ where λo is the free space wavelength. The *TM*10 mode implies that the field varies one λ/2 cycle along the length, and there is no variation along the width of the patch. In the figure 3.12 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.

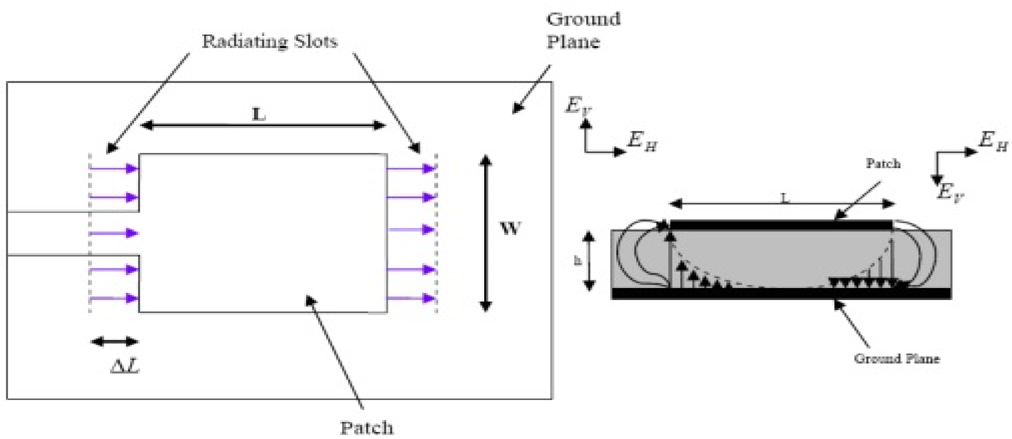

Figure: 3.12 Effective length of micro strip patch antenna

It is seen from figure 3.12, 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 (seen in Figure 3.12), which are in phase, means that the resulting fields combine to give maximum radiated field normal to the surface of the structure. 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. The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically by:

$$\frac{\Delta L}{h} = 0.412 \frac{\left(\varepsilon_{reff}+1\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)} \tag{3.2}$$

Where ΔL is the extension in length

The width and the length of patch are calculated through the formula given below:

$$\mathrm{W} = \frac{\mathrm{c}}{2\mathrm{f_r}}\sqrt{\frac{2}{(\varepsilon_r)+1}} \tag{3.3}$$

Where c is the free space velocity of light; ε_r is the dielectric constant of substrate; f_r is the antenna design frequency; W is the patch width and length of patch is given by:

$$\mathrm{L} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{3.4}$$

Hence, the length and width of ground plane can be calculated as follows:

$$Lg = 6(h) + L \tag{3.5}$$

$$Wg = 6(h) + W \tag{3.6}$$

Where,

c = velocity of light

ε_r = dielectric constant of the substrate

f_r = antenna design frequency

W = width of patch

L = length of patch

h = height of substrate

Δl = normalized extension of length of the patch

3.6.2 Cavity Model

Although the transmission line model discussed is easy to use, it has some inherent disadvantages. Specifically, it is useful for patches of rectangular design and it ignores field variations along the radiating edges. These disadvantages can be overcome by using the cavity model.

A brief overview of this model is given below. In this model, the interior region of the dielectric substrate is modeled as a cavity bounded by electric walls on the top and bottom. The bases for this assumption are the following observations for thin substrates (h<< λ) [106]:

• Since the substrate is thin, the fields in the interior region do not vary much in the direction, i.e. normal to the patch.

• The electric field is *z* directed only, and the magnetic field has only the transverse components H_x and H_y in the region bounded by the patch metallization and the ground plane. This observation provides for the electric walls at the top and the bottom.

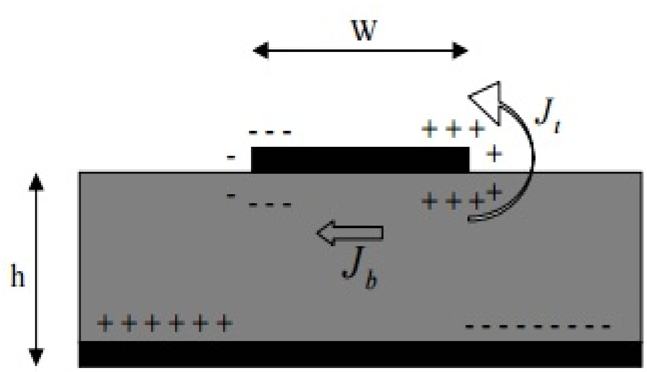

Figure: 3.13 Charge distribution and current density on the microstrip patch

Consider Figure 3.13 shown above. When the microstrip patch is provided power, a charge distribution is seen on the upper and lower surfaces of the patch and at the bottom of the ground plane. This charge distribution is controlled by two mechanisms; an attractive mechanism and a repulsive mechanism. The attractive mechanism is between the opposite charges on the bottom side of the patch and the ground plane, which helps in keeping the charge concentration intact at the bottom of the patch. The repulsive mechanism is between the like charges on the bottom surface of the patch, which causes pushing of some charges from the bottom, to the top of the patch. As a result of this charge movement, currents flow at the top and bottom surface of the patch. The cavity model assumes that the height to width ratio (i.e. height of substrate and width of the patch) is very small and as a result of this the attractive mechanism dominates and causes most of the charge concentration and the current to be below the patch surface. Much less current would flow on the top surface of the patch and as the height to width ratio further decreases, the current on the top surface of the patch would be almost equal to zero, which would not allow the creation of any tangential magnetic field components to the patch edges. Hence, the four sidewalls could be modeled as perfectly magnetic conducting surfaces. This implies that the magnetic fields and the electric field distribution beneath the patch would not be disturbed. However, in practice, a finite width to height ratio would be there and this would not make the tangential magnetic fields to be completely zero, but they being very small, the side walls could be approximated to be perfectly magnetic conducting. Since the walls of the cavity, as well as the material within it are lossless, the cavity would not radiate and its input impedance would be purely reactive.

3.6.3 Multiport network model

Multiport network model is a basically extension model of cavity model analysis in which electromagnetic fields are modeled separately for upper side the radiating patch and lower side the patch. The patch is analyzed as a two dimensional planar network with multiple number of ports located all around the patch. In multiport network model each port consist a small section of length of the patch as the electromagnetic fields may be assumed as uniform over small length [107]. Generally, four and five number of ports is usually considered for rectangular patch in the direction of radiating and non radiating edge respectively. Impedance matrix of the patch is calculated from Green’s function and the fields are incorporated by adding an equivalent edge admittance network. Lastly segmentation method is then used to find overall impedance matrix.

3.6.4 Full wave model

In the second group, the numerical methods are based on the electric current distribution on the patch conductor and the ground plane (similar to dipole antennas, used in conjunction with full-wave simulation/numerical analysis methods). Some of the full-wave techniques for anlyzing MSAs are listed as follows:

- The method of moments (MoM)
- The finite-elements method (FEM)
- The spectral domain technique (SDT)
- The finite-difference time domain (FDTD) method

The analytical techniques are used in conjunction with full-wave simulation and numerical analysis methods. These techniques have received lots of attention due to their rigor and high accuracy. The full-wave techniques are generally providing the most accurate solution for the impedance and radiation characteristics due to the effect of dielectric loss, conductor loss, surface wave and external coupling. These techniques are numerically typical and therefore require careful programming to reduce computation cost. It can be also used to analyze the arbitrary shaped, multilayered geometries of microstrip patch antennas and arrays, various types of feeding techniques, anisotropic substrate and active antennas.

Full wave analysis has following features:

- The full wave model primarily involves integral equations/methods.
- Extremely accurate
- Much complex in nature
- Gives less insight
- Versatile

3.5 TRAVELING WAVES IN MICROSTRIP PATCH ANTENNA

The mechanisms of transmission and radiation in a Microstrip can be understood by considering a point current source (Hertz dipole) located on top of the grounded dielectric substrate (fig. 3.14) This source radiates electromagnetic waves. Depending on the direction toward which waves are transmitted, they fall within three distinct categories, each of which exhibits different behaviors.

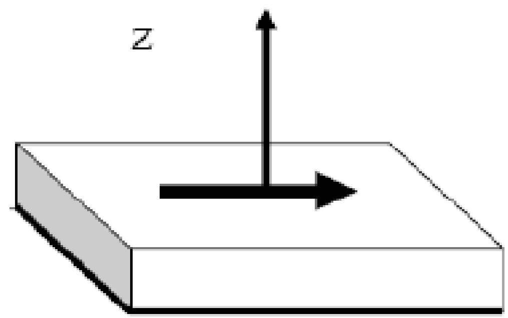

Figure: 3.14: Hertz dipole on a microstrip substrate

3.5.1 Surface Waves

The waves transmitted slightly downward, having elevation angles θ between $\frac{\pi}{2}$ and π-arcsin(1/$\sqrt{\varepsilon r}$), meet the ground plane, which reflects them, and then meet the dielectric-to-air boundary, which also reflects them (total reflection condition). The magnitude of the field amplitudes builds up for some particular incidence angles that leads to the excitation of a discrete set of surface wave modes; which are similar to the modes in metallic waveguide.

The fields remain mostly trapped within the dielectric, decaying exponentially above the interface (fig 3.15). The vector α, pointing upward, indicates the direction of largest attenuation. The wave propagates horizontally along β, with little absorption in good quality dielectric. With two directions of α and β orthogonal to each other, the wave is a non-uniform plane wave. Surface waves spread out in cylindrical fashion around the excitation point, with field amplitudes decreasing with distance (r), say1/r, more slowly than space waves. The same guiding mechanism provides propagation within optical fibers.

Surface waves take up some part of the signal's energy, which does not reach the Intended user. The signal's amplitude is thus reduced, contributing to an apparent attenuation or a decrease in antenna efficiency. Additionally, surface waves also introduce spurious coupling between different circuit or antenna elements. This effect severely degrades the performance of microstrip filters because the parasitic interaction reduces the isolation in the stop bands. In large periodic phased arrays, the effect of surface wave coupling becomes particularly obnoxious, and the array can neither transmit nor receive when it is pointed at some particular directions (blind spots). This is due to a resonance phenomenon, when the surface waves excite in synchronism the Floquet modes of the periodic structure. Surface waves reaching the outer boundaries of an open microstrip structure are reflected and diffracted by the edges. The diffracted waves provide an additional contribution to radiation, degrading the antenna pattern by raising the side lobe and the cross polarization levels. Surface wave effects are mostly negative, for circuits and for antennas, so their excitation should be suppressed if possible.

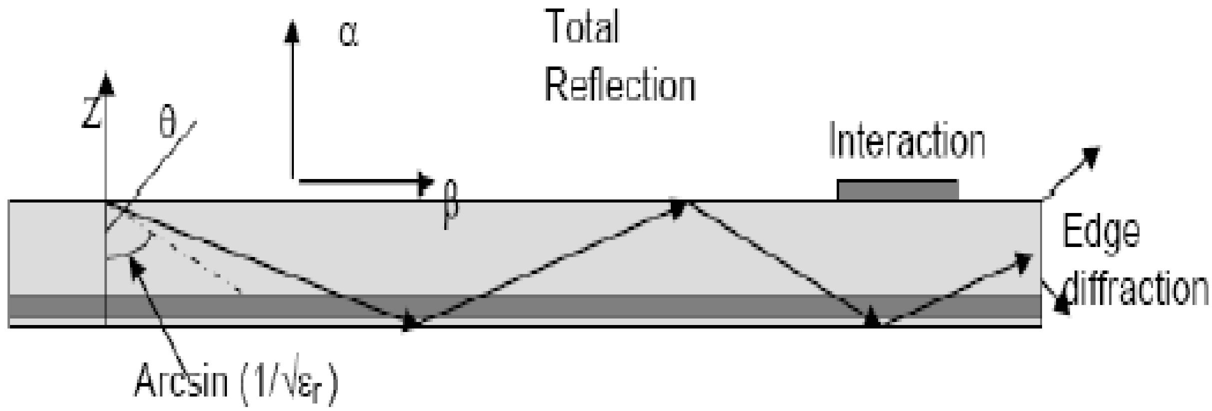

Figure: 3.15: Travelling surface wave

3.5.2 Leaky Waves

Waves directed more sharply downward, with θ angles between π – arcsin (1/εr) and π, are also reflected by the ground plane but only partially by the dielectric-to-air boundary. They progressively leak from the substrate into the air (figure 3.16), hence their name laky waves, and eventually contribute to radiation. The leaky waves are also non-uniform plane waves for which the attenuation direction α points downward, which may appear to be rather odd; the amplitude of the waves increases as one moves away from the dielectric surface. This apparent paradox is easily understood by looking at the (figure 3.16); actually, the field amplitude increases as one move away from the substrate because the wave radiates from a point where the signal amplitude is larger. Since the structure is finite, this apparent divergent behavior can only exist locally, and the wave vanishes abruptly as one crosses the trajectory of the first ray in the figure 2.7.

In more complex structures made with several layers of different dielectrics, leaky waves can be used to increase the apparent antenna size and thus provide a larger gain. This occurs for favorable stacking arrangements and at a particular frequency. Conversely, leaky waves are not excited in some other multilayer structures.

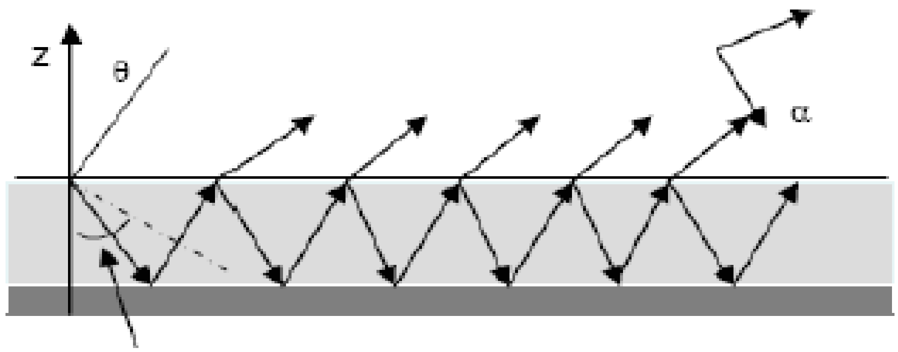

Figure: 3.16: Travelling leaky wave

3.5.3 Guided Wave

When realizing printed circuits, one locally adds a metal layer on top of the substrate, which modifies the geometry, introducing an additional reflecting boundary. Waves directed into the dielectric located under the upper conductor bounce back and forth on the metal boundaries, which form a parallel plate waveguide. The waves in the metallic guide can only exist for some Particular values of the angle of incidence, forming a discrete set of waveguide modes. The guided waves provide the normal operation of all transmission lines and circuits, in which the electromagnetic fields are mostly concentrated in the volume below the upper conductor. On the other hand, this buildup of electromagnetic energy is not favorable for patch antennas, which behave like resonators with a limited frequency bandwidth.

3.8 PROPOSED ANTENNA STRUCTURE

3.8.1 Proposed antenna design -1

The proposed antenna is shown in Figure-1 (top view) (front view). The elliptical patch of semi major axis ‘b’ and semi minor axis ‘a’ is printed on the FR-4 substrate (ε_r=4.4). A pin is inserted at (-7,3,0) in between patch and ground the diameter of the pin is 1mm. the eccentricity of elliptical patch e (= $\sqrt{1-(a|b)^2}$), where 'b' is the semi major axis of the elliptical patch, 'a' is semi minor axis of the elliptical patch, ε_r is dielectric constant of the substrate. The multi frequency resonance can be obtained by properly designing the length and width of the substrate, patch, and also the feed point of the probe all dimensions are given in table-3.3.

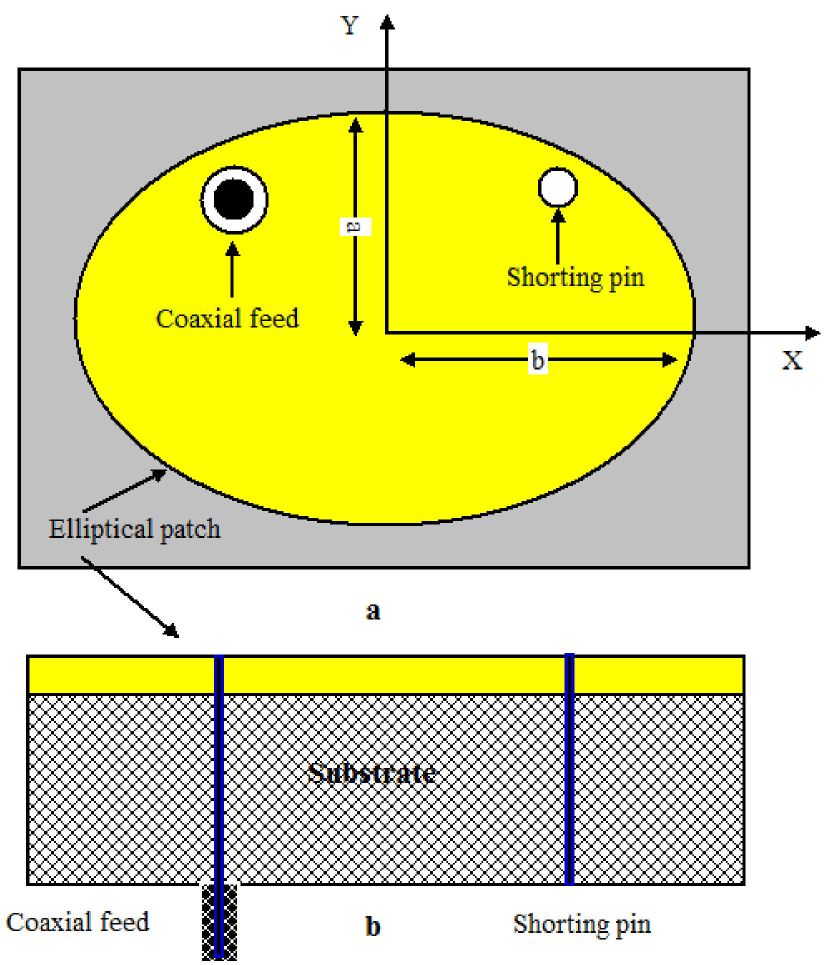

Figure: 3.17: Front and side view geometry of elliptical shape antenna

Table-3.3 Specification of the elliptical antenna

Design Parameters	Value
Substrate area	30mmX30mm
Semi major axis ‘b’	14mm
Semi minor axis ‘a’	5.6mm
Eccentricity ‘e’	0.92
Substrate type	FR4
Substrate thickness h	1.8mm
Dielectric constant ‘ε_r’	4.4
Shorting pin point	(7,1.5,0)
Feed point	(-7,3,0)
Patch Material	Copper
Patch thickness	0.017mm

3.8.2 Proposed antenna design -2

Substrate FR4-epoxy of dielectric constant 4.4 has been taken for this design. The antenna has been designed and simulated using ASYS HFSS. The radiating patch of pentagonal shape is considered with radius 10mm and a slot is made at the center of the pentagonal patch. The feeding point is taken at coordinate as (-5,0,0) . A shorting pin of material copper is also used in this design of height 1.8mm and radius 0.5mm. Various parameters considered are indicated in the table below.

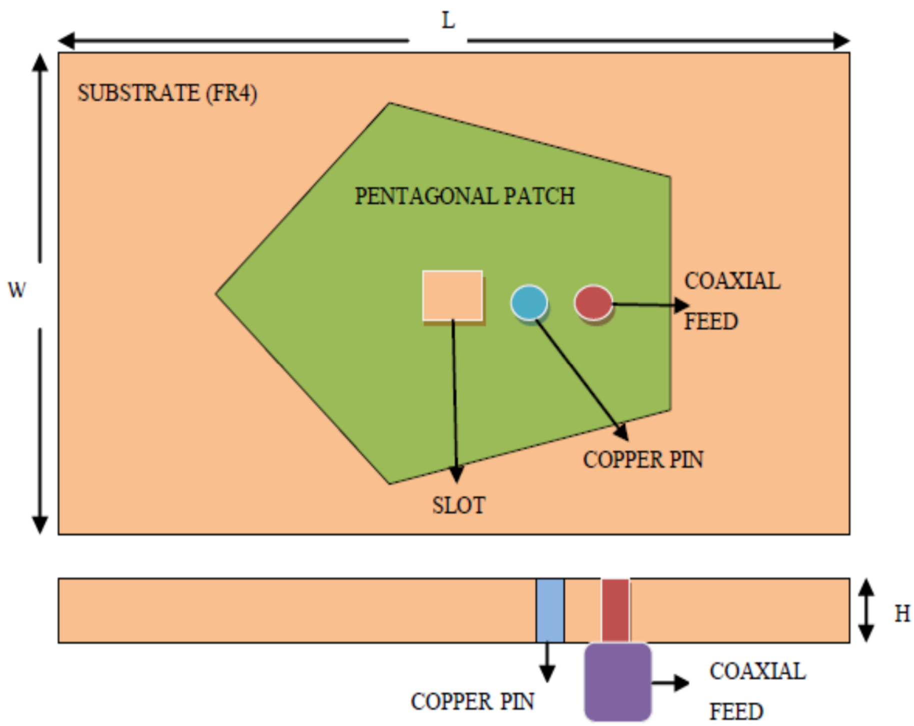

Figure: 3.18: Front and side view geometry of pentagonal shape antenna

Table 3.4 Antenna specifications

Antenna design Parameters	**Values**
Substrate material	FR4
Substrate thickness ‘H’	1.8mm
Length of Substrate ‘L’	30mm
Width of Substrate ‘w’	20mm
Dielectric constant	4.4
Dielectric loss tangent	0.02
Pentagonal Patch radius	10mm
Radius of the Coaxial Probe	0.5mm
Position of the coaxial Probe	(-5,0,0)
Material of the Shorting Pin	copper
Radius of the shorting pin	0.5mm
Position of the Shorting Pin	(-3,0,0)
Dimensions of slot (x-axis × y-axis)	2mm × 2 mm

CHAPTER-IV

RESULTS AND DESUSSION

CHAPTER-4
RESULTS AND DISCUSSION

4.1 ELLIPTICAL SHAPE ANTENNA USING SHORTING PIN

Antenna plays pivotal role in our day to day life. This is the reason for so many researches in field of antenna. There are number of ongoing researches intending to efficient and compact antennas. Proceeding with the same aim, we came across elliptical shape antennas. It is evident from [108] that with the application of elliptical slots on patch we can get better results. [108] proposes an antenna of different dimensions with three elliptical slots over the patch, and it is to be noted that their performance analysis was especially based on radiation pattern, bandwidth and return loss.

Considering [109], we see its overall dimension is 140×140 mm^2 fabricated with a substrate of relative permittivity of 3.48. Its resonating band and bandwidth is 0.41-8.86 GHz and 8.45, respectively. Having a peak gain of 4dBi, it is applicable in the field CST and SWB. Then again, we have [110] with the dimension of 25×28 mm^2 fabricated with FR4 Epoxy, resonating in the bandwidth of 3-11GHz with the bandwidth of 8GHz and peak gain of 5.48dBi, is applicable in HFSS/UWB fields. Now, referring [111], we come across another elliptical shape antenna with dimension of 75×75 mm^2, fabricated with FR4 epoxy, foam.[111] works in the resonating band of 3.21-4.05 GHz with the bandwidth of 0.84 GHz, and peak gain of 4.6dBi, which makes it efficiently applicable in the fields of IE3D and WiMax. Lastly, referring to [112], we witness an antenna of 30×35 mm^2, fabricated with FR4 epoxy, resonating in the band of 3.1-12GHz having bandwidth of 8.9GHz and peak gain of 6dBi, thus making it suitable for CST/UWB application.

In the thesis work elliptical and pentagonal shape of microstrip patch antenna is presented. Iintroducing of slots on the radiating patch is used to alter the resonating behavior of patch antenna. An improved performance is observed in both the geometry after shorting the radiating patch layer and conducting ground layer with conducting rod of 1mm diameter (d). A rectangular patch antenna is equivalent of parallel R, L, C circuit and resonate at specific frequency with fixed physical dimensions of antenna. By introducing the shorting pin on the patch, a parallel inductance L_s is added to the whole patch. The inductance value of shorting pin is calculated after [106] and is given by.

$$L_s = \frac{\eta_0 W\, L}{2\pi c}\left\{\ln\left[\frac{4c}{EW_p d\sqrt{\epsilon_r}}\right]\right\} \qquad \text{.......}4.1$$

where

L- Patch length

W- Patch width

d - Diameter of the shorting pin

E - Euler's constant = 0.5772

$\eta_0 = 120\pi$ and c is the velocity of light

The elliptical shape antenna shows better return loss i.e. -12.7893dB, and -20.4519dB at the first and second band of the frequencies 4.4898GHz and 6.6938GHz respectively, Increasing negative value of return loss implies good impedance matching with the reference of 50ohms characteristics impedance.

4.1.1 Gain

Antenna gain describes how much of the power is radiated in a given direction. The designed antenna has a good gain of 0.8742dB and 5.7829dB at a resonant frequency of 4.4898GHz and 6.6938 GHz respectively, which means the antenna is more efficient at this frequency.

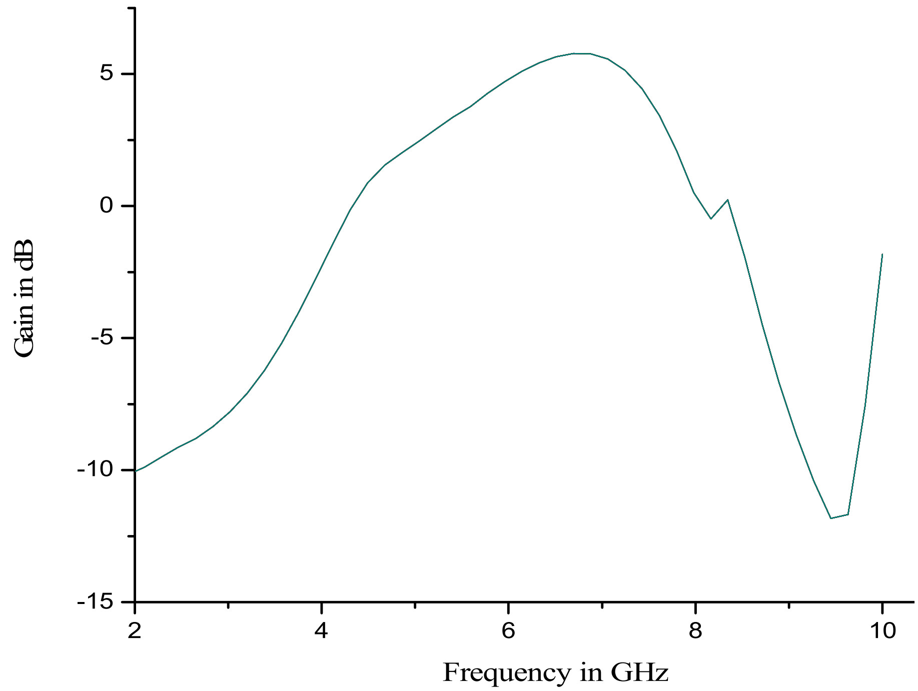

Figure: 4.1: Antenna gain Vs frequency plot

4.1.2 VSWR

The VSWR graph of proposed antenna shows the VSWR value are 4.0560 dB and 1.6549dB at frequency 4.4898GHz and 6.6938 GHz respectively. VSWR values imply the impedance matching between the source and the feed is good, which is an essential requirement for the proper working of the antenna.

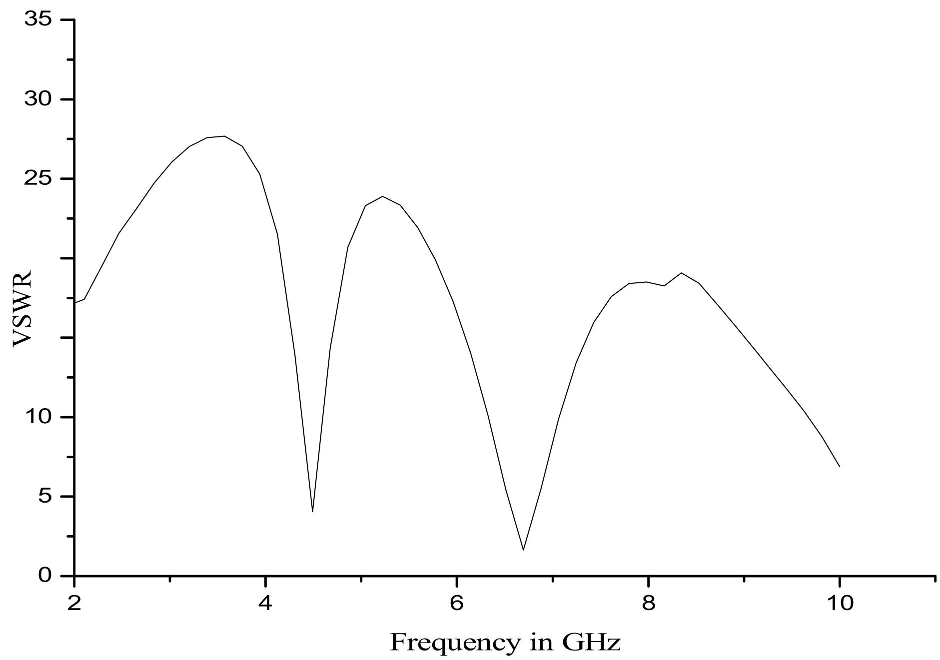

Figure: 4.2: VSWR Vs frequency plot

4.1.3 Return Loss

The designed antenna has a good return loss characteristic that is -12.7893dB, and -20.4519dB at resonant frequency 4.4898GHz and 6.6938 GHz respectively. Increasing negative value of return loss implies good impedance matching with respect to the reference impedance of 50ohms. Return loss could be further improved by using different feeding techniques.

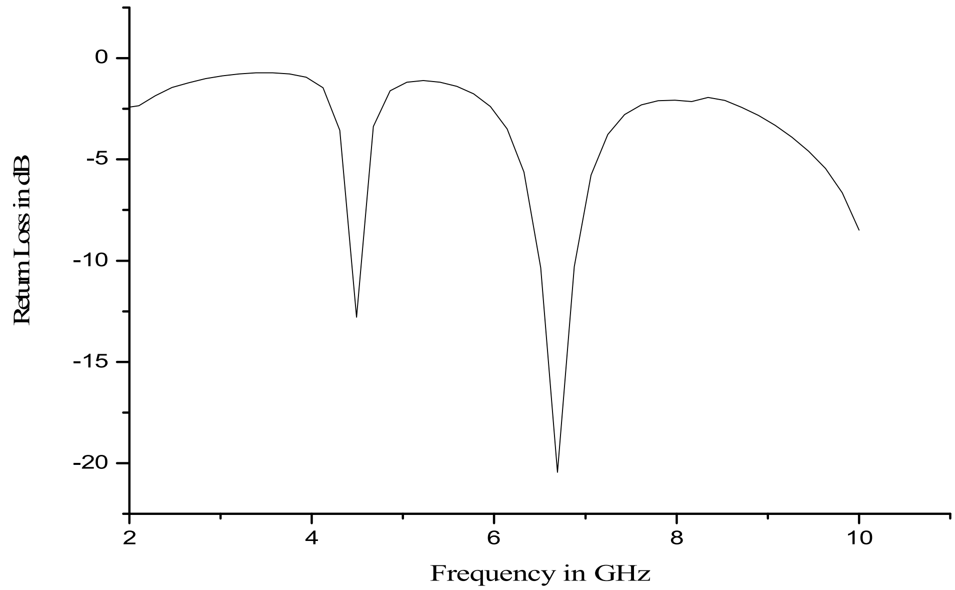

Figure: 4.3: Return loss response of elliptical shape antenna

4.1.4 Directivity

The directivity below shown as the maximum amount of radiation intensity that are equal to 3.2464 dB and 6.5826dB achieved at a resonant frequency of 4.4898GHz and 6.6938 GHz respectively. Directivity is nothing but the ability of antenna to radiate energy in a particular direction whether it is transmitting, or to be receiving the energy from a particular direction.

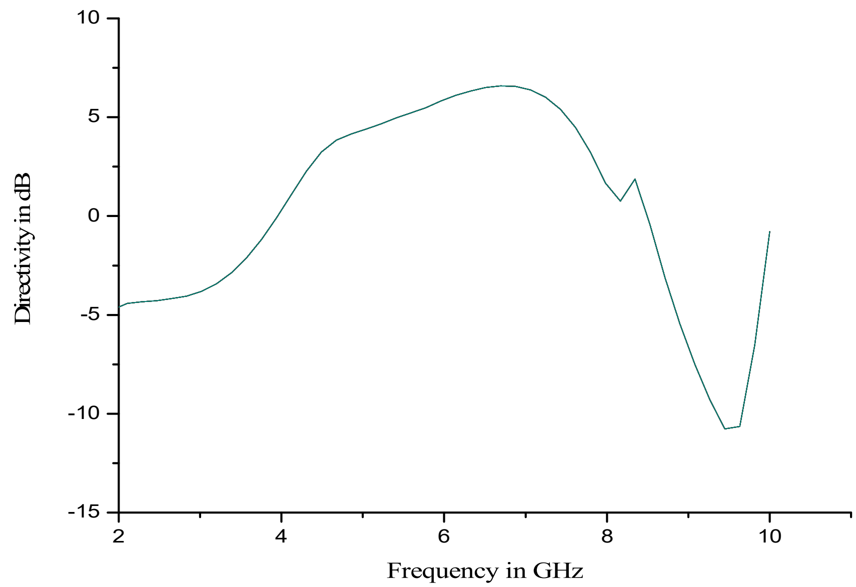

Figure: 4.4: Directivity of elliptical shape antenna

4.1.5 Radiation pattern

The 2-D radiation patterns for the elevation and azimuthal plane respectively of the proposed antenna is given in figures below. The radiation pattern is represented according to the radiation properties of the antenna as a function of whole space. Radiation pattern describes how the energy is radiated out into the space by the antenna or how it is received.

For the resonant frequency 4.4898GHz and 6.6938 GHz respectively, the radiation pattern is nearly omni-directional in the azimuthal and elevation plane for both resonant frequencies.

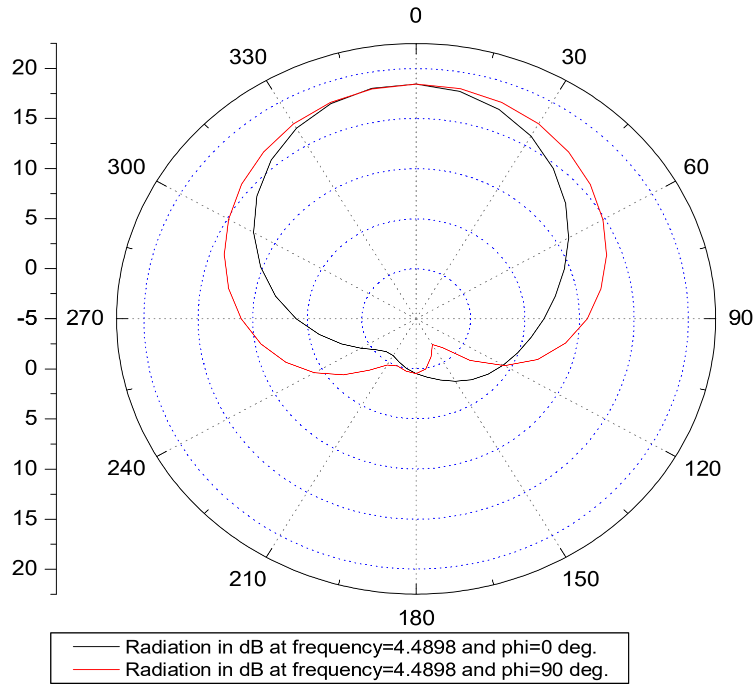

Figure: 4.5: Radiation pattern of elliptical shape antenna at frequency 4.4898GHz.

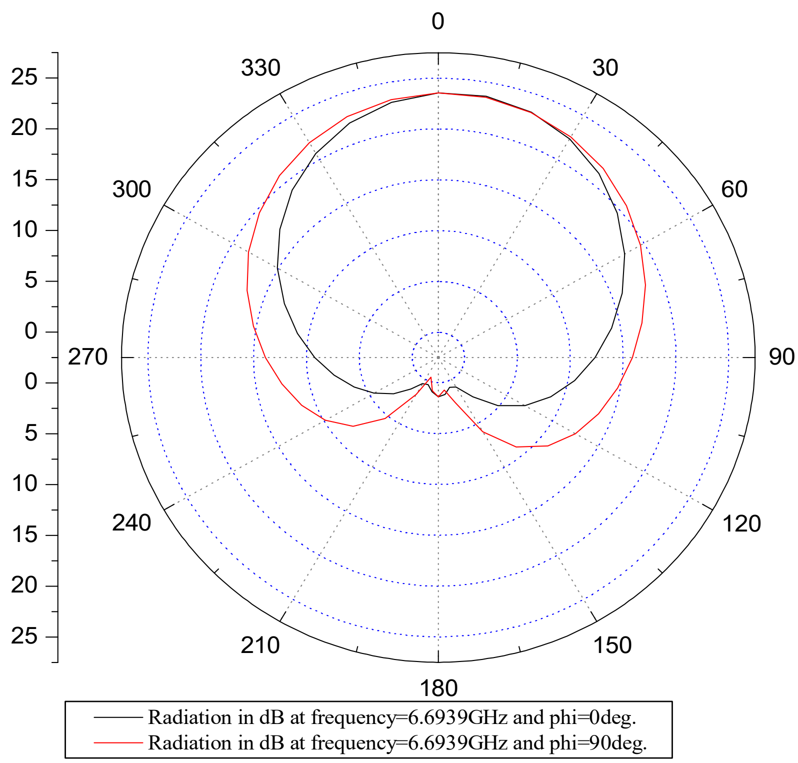

Figure: 4.6: Radiation pattern of elliptical shape antenna at frequency 6.6939 GHz

The VSWR of the proposed antenna shows 1.056 and 1.6549 at frequencies 4.4898GHz, and 6.6938 GHz respectively. This parameter implies the impedance matching between the sources to the feed is good, and it is essential requirement for the proper working of the antenna. VSWR value below 2 is successfully achieved for good antenna performance.

The designed antenna achieved good gain as 0.8742dB, and 5.7829 dB corresponding frequencies from lower to high.

Directivity of the antenna is the ability to focus energy in a particular direction when transmitting the power during the radiation, or to receive energy better from a particular direction. The directivity is achieved as 3.2464 dB and 6.5826 dB i.e. the maximum amount of radiation intensity at different corresponding frequencies as 4.4898GHz and 6.6938 GHz.

The 2D radiation patterns for the elevation and azimuthal plane respectively of the proposed antenna is given in figure-2 (e) and (f). Radiation pattern is the graphical representation of the radiation properties of the antenna as a function of space. Radiation pattern describes how the energy is radiated out into the space by the antenna and how it is received onto to antenna. For the band of the frequencies 4.4898 GHz, and 6.6938GHz, the radiation pattern is nearly omni-directional in the azimuthal and elevation plane.

Table 4.1 Performance of purposed antenna

Frequency in GHz	Return Loss in dB	VSWR in dB	Gain in dB	Directivity in dB
4.4898	-12.7893	4.056	0.8742	3.2464
6.6938	-20.4519	1.6549	5.7829	6.5826

4.2 PENTAGONAL SHAPE ANTENNA USING SHORTING PIN TECHNIQUE

As we all are well aware of various advancements going on in the field of antennas, it becomes important to do a keen study of various techniques that can be implied o meet the current needs of the user. Proceeding with this research, we here focus on the effect of pentagonal shaped antennas. A CPW fed pentagonal antenna mentioned in [113], shows that embedding pentagonal slot on the radiating patch enhances the impedance bandwidth.

An antenna of dimension 52.45×58 mm^2 fabricated with FR4 Epoxy, mentioned in [114], resonates in the band of 2.5-15GHz with bandwidth and peak gain of 12.5GHz, 8.7dBi, respectively, finds its application HFSS/medical imaging, radar, WLAN. Secondly, [115] discusses an antenna of 35.3×35.3 mm^2, having resonating band of 2.4-2.5GHz and bandwidth of 0.1GHz, this design has a peak gain of 4.54dBi, thus making it suitable for HFSS/Wireless sensor networks applications. Thirdly we have [116] with dimension of 30×30 mm^2 which resonates in the band of 3.28-4.75GHz and have bandwidth of 4.17GHz. It has peak gain of 4.24dBi and finds its application in WLAN, WiMAX and HIPERLAN. Lastly, we can refer [117] which has designed an antenna of dimension 50×80 mm^2 resonating in band of 2.65-11.3GHz with bandwidth of 8.65GHz having peak gain of 7.5dBi. This design witnesses its application in the fields of HFSS/Wireless communication systems.

In present work a new geometry of pentagonal shape antenna with introduction of slot is presented in order to overcome the drawbacks of patch antenna. Antenna results are presented in forgoing sections.

4.2.1 Return Loss

The proposed antenna shown which has return loss characteristic that is -19.6505 dB at resonant frequency 4.8571 GHz. Increasing negative value of return loss implies good impedance matching with respect to the reference impedance of 50ohms. Return loss can be further improved by using different feeding techniques.

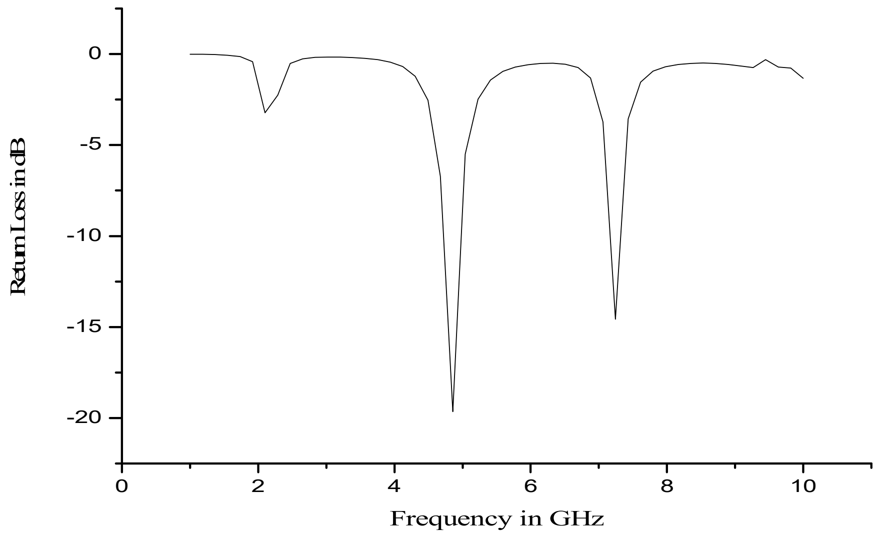

Figure: 4.7: Return loss Vs frequency plot of pentagonal shape antenna

4.2.2 VSWR

The VSWR graph of proposed antenna is shown in figure 4.2. The VSWR is 1.8151 at frequency 4.8571 GHz. VSWR imply as the voltage standing wave ratio and the impedance matching between the source and the feed is good, which is an essential requirement for the proper working of the antenna.

Figure: 4.8: VSWR Vs frequency plot of pentagonal shape antenna

4.2.3 Antenna gain

Antenna gain is the measure of power which is radiated in a given direction. The designed antenna has a good gain of 3.4529 dB at a resonant frequency of 4.8571 GHz, which means the antenna is more efficient at this frequency.

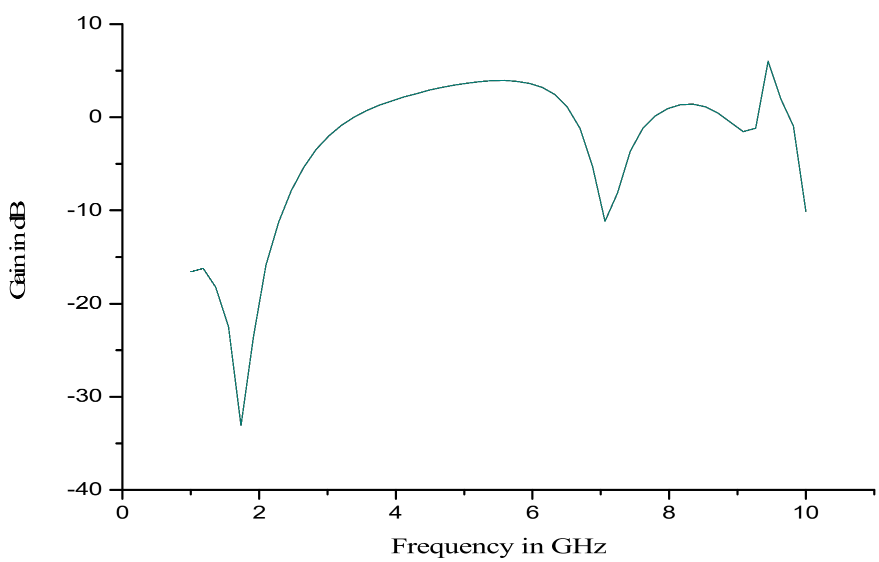

Figure: 4.9: Gain Vs frequency plot of pentagonal shape antenna

4.2.4 Directivity

The directivity graph shown below is the maximum amount of radiation intensity that is equal to 5.3160 dB is achieved at a resonant frequency of 4.8571 GHz. Directivity is nothing but the ability of antenna to radiate energy in a particular direction as it is transmitting, and if energy is receiving,this is also the capture area from a particular direction.

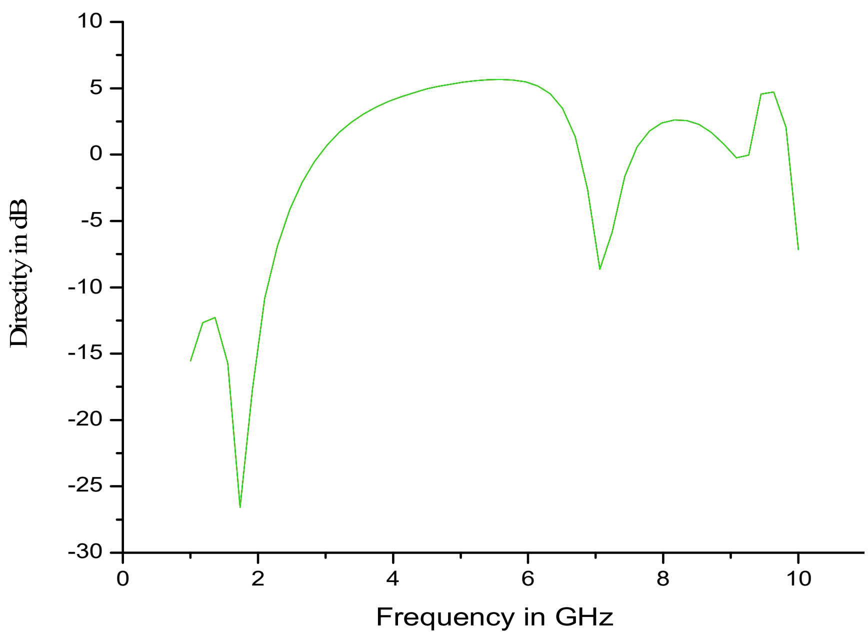

Figure: 4.10: Directivity Vs frequency plot of pentagonal shape antenna

4.2.5 Radiation Pattern

The 2D radiation patterns for the elevation and azimuthal plane respectively of the proposed antenna is given as shown in figures below. Radiation pattern is the representation of the radiation of antenna with the function of space. At the resonant frequency 4.8571 GHz, the radiation pattern is nearly omni-directional in the elevation plane and azimuthal angle.

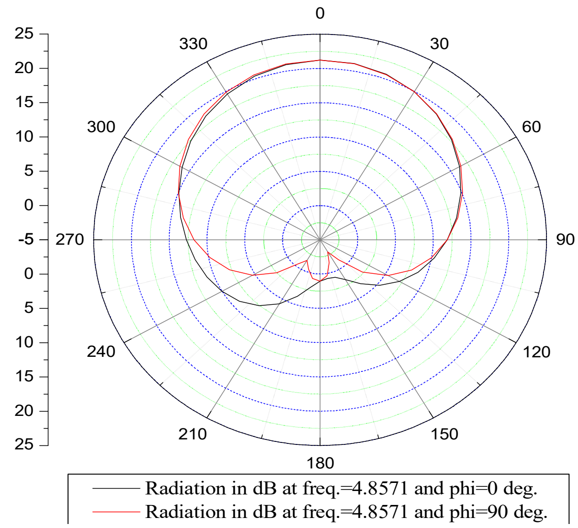

Figure: 4.11: Radiation pattern of pentagonal shape antenna at 4.8571 GHz

CHAPTER-V
CONCLUSION AND FUTURE SCOPE

CHAPTER-5
CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

Microstrip patch antenna is a short radiating structure that consists of dielectric substrate in between a metallic conducting patch and ground plane. The rapid development of modern communication systems such as mobile communication, wireless communication, satellite communication and radar applications are required for portable devices due to some important features including easy design, light in weight, reduction in size, compatibility with microwave, millimeter wave integrated circuits, low production cost and easy fabrication of microstrip antennas. However, single antenna has limitations that they can utilize for single application. In the endeavor an attempt has been made to achieve the dual-band with broad bandwidth operations for different radiating patch structures along with simulated results. Although various aspects of the patch antenna have been broadly discussed in above chapters by for the sake of convenience the entire investigations are summarized in this chapter.

The elliptical antenna has return losses -12.79dB, and -20.45dB at resonant frequencies 4.4898GHz and 6.6938GHz respectively, increasing negative value of return loss implies perfect impedance matching of the reference characteristics impedance of 50ohms. The designed elliptical antenna has a good gain of 0.8742dB and 5.7829dB at a resonant frequency of 4.4898GHz and 6.6938 GHz respectively, which means the antenna is more efficient at this frequency.

The VSWR of the elliptical antenna are 4.0560 dB and 1.6549dB at frequency 4.4898GHz and 6.6938 GHz respectively. The elliptical antenna has a good return loss as -12.7893dB, and -20.4519dB at resonant frequency 4.4898GHz and 6.6938 GHz respectively.The directivities i.e. the maximum amount of radiation intensities that is equal to 3.2464 dB and 6.5826dB at resonant frequencies of 4.4898GHz and 6.6938 GHz respectively.The radiation pattern of the elliptical shape antenna is uniformly distributed on broader side for the resonant frequency 4.4898GHz and 6.6938 GHz respectively.

The pentagonal antenna has return loss -19.6505 dB at resonant frequency 4.8571 GHz. Increasing negative value of return loss implies good impedance matching with the characteristics impedance of 50ohms. The VSWR of the pentagonal antenna is 1.8151 at frequency 4.8571 GHz and that reveals good impedance matching. The pentagonal antenna gain has 3.4529 dB at a resonant frequency of 4.8571 GHz, which means the antenna is more efficient at this frequency.

The directivity of the pentagonal antenna is the maximum amount of radiation intensity that is equal to 5.3160 dB is achieved at a resonant frequency of 4.8571 GHz. At the resonant frequency 4.8571 GHz, the radiation pattern of the pentagonal is nearly omni-directional in the elevation plane and azimuthal angle.

5.2 FUTURE SCOPE

As the time is passing, we are witnessing a new era of technology and all we want is a WIRELESS system. Wireless system is simply making the communication simpler, no need of wires, no need to worry about the connectivity, thus giving flexibility to the user. The key component of this system is ANTENNA and thus the proper knowledge of antenna is utmost important.

Talking about antennas then microstrip Patch antenna is an engineer's very first choice. Reason being, it is light weighted, ease of fabrication, ease of printing an array of patches on single substrate, etc. The efficiency of microstrip antennas also depends upon shapes of patch, thus we are proceeding with the scope of different shapes of patch antenna.

Triangular Patch Antenna

- WiMax
- WLAN
- Multiband application

Rectangular Patch Antenna

- Ku and K band application
- UHF application
- Military systems

- Medical application

Circular Patch Antenna

- Wireless and Satellite communication
- Applicable where compact antenna with circular polarization is required
- Global Positioning Satellite (GPS)
- Medical application
- L band application (1-2 GHz)

Pentagonal shape antenna

- Medical imaging
- Wireless sensor network
- RADAR
- Bluetooth

Elliptical shape antenna

- C-band wireless applications
- SWB applications
- Electronic warfare systems

So as to round off, different shapes of MPA does play pivotal role in different fields but here it is to be noted that even these antennas can be further modified by providing various slots.

CHAPTER-VI

REFERENCES

CHAPTER-6
REFERENCES

[1] G. A. Deschamps, “Microstrip microwave antennas,” *Present. third USAF Symp. Antennas*, vol. 1, no. 2, pp. 189–195, 1953.

[2] L. Lewin, “Spurious radiation from microstrip,” *Proc. Inst. Electr. Eng.*, vol. 125, no. 7, p. 633, 1978

[3] E.V. Byron, "A new flush-mounted antenna element for phased array applications," in Proc. Phased-Array Antenna Symp., pp. 187-192, 1970

[4] R. E. Munson, “Conformal microstrip antennas and microstrip phased arrays,” *IEEE Trans. Antennas Propag.*, vol. 22, no. 1, pp. 74–78, 1974.

[5] J. Q. Howell, “Microstrip antennas,” *IEEE Trans. Antennas Propag.*, vol. 23, no. 1, pp. 90–93, 1975.

[6] G. Kumar and K. P. Ray, *Broadband microstrip antenna*. Norwood, MA, 2003.

[7] Y. X. Guo, K. M. Luk and K. F. Lee, “L-probe proximity fed annular ring microstrip antennas,” *IEEE Transactions on Antennas and Propagation*, Vol. 49, pp. 19-21, January 2001.

[8] Y. W. Jang, “Broadband T-shaped microstrip fed U-slot coupled patch antenna,” *Electronics Letters*, Vol. 38, pp. 495-496, May 2002.

[9] B. K. Kanaujia and B. R. Vishvakarma, “Analysis of two- oncentric annular ring microstrip antenna,” *Microwave Optical Technology Letters* , Vol. 36, pp. 104-108, January 2003.

[10] Y. Qin, S. Gao, A. Sambell and E. Korolkiewicz, “Broadband patch antenna with ring slot coupling,” *Electronics Letters*, Vol. 40, pp. 5-6, January 2004.

[11] H. W. Lai and K. M. Luk, “Wideband stacked patch antenna fed by eandering probe,” *Electronics Letters*, Vol. 41, pp. 297-298, March 2005.

[12] T. A. Denidni and M. A. Habib, “Broadband printed CPW-fed circular slot antenna,” *Electronics Letters*, Vol. 42, pp. 135-136, February 2006.

[13] S.-H. Wi, Y.-S. Lee, and J.-G. Yook, “Wideband Microstrip Patch Antenna With U-Shaped Parasitic Elements,” *IEEE Trans. Antennas Propag.*, vol. 55, no. 4, pp. 1196–1199, Apr. 2007.

[14] J.-Y. Sze, J.-C. Wang, and C.-C. Chang, “Axial-ratio bandwidth enhancement of asymmetric-CPW-fed circularly-polarised square slot antenna,” *Electron. Lett.*, vol. 44, no. 18, p. 1048, 2008.

[15] Z.-S. Duan, S.-B. Qu, Y. Wu, and J.-Q. Zhang, “Wide bandwidth and broad beamwidth microstrip patch antenna,” *Electron. Lett.*, vol. 45, no. 5, p. 249, 2009.

[16] A. Dastranj and H. Abiri, “Bandwidth Enhancement of Printed E-Shaped Slot Antennas Fed by CPW and Microstrip Line,” *IEEE Trans. Antennas Propag.*, vol. 58, no. 4, pp. 1402–1407, Apr. 2010.

[17] S.-Y. Lin, “Very-wideband microstrip antenna for laptop applications,” *IET Microwaves, Antennas Propag.*, vol. 5, no. 6, p. 705, 2011.

[18] Y. Sung, “Bandwidth Enhancement of a Microstrip Line-Fed Printed Wide-Slot Antenna With a Parasitic Center Patch,” *IEEE Trans. Antennas Propag.*, vol. 60, no. 4, pp. 1712–1716, Apr. 2012.

[19] K. Mandal and P. P. Sarkar, “High Gain Wide-Band U-Shaped Patch Antennas With Modified Ground Planes,” *IEEE Trans. Antennas Propag.*, vol. 61, no. 4, pp. 2279–2282, Apr. 2013.

[20] T. M. Telsang and A. B. Kakade, “Ultrawideband slotted semicircular patch antenna,” *Microw. Opt. Technol. Lett.*, vol. 56, no. 2, pp. 362–369, Feb. 2014.

[21] T. Cai, G.-M. Wang, X.-F. Zhang, Y.-W. Wang, B.-F. Zong, and H.-X. Xu, “Compact Microstrip Antenna With Enhanced Bandwidth by Loading Magneto-Electro-Dielectric Planar Waveguided Metamaterials,” *IEEE Trans. Antennas Propag.*, vol. 63, no. 5, pp. 2306–2311, May 2015.

[22] J. Wu, Y. Jian Cheng, and Y. Fan, “Wide-band dual-polarized planar array antenna for K/Ka-band wireless communication,” *Microw. Opt. Technol. Lett.*, vol. 58, no. 10, pp. 2377–2381, Oct. 2016.

[23] V. Satam and S. Nema, “Dual notched, high gain diversity antenna for wide band applications,” *Microw. Opt. Technol. Lett.*, vol. 59, no. 5, pp. 1222–1226, May 2017.

[24] M. Paulson, S. O. Kundukulam, C. K. Aanandan, and P. Mohanan, “A new compact dual-band dual-polarized microstrip antenna,” *Microw. Opt. Technol. Lett.*, vol. 29, no. 5, pp. 315–317, Jun. 2001.

[25] Yong-Xin Guo, Kwai-Man Luk, Kai-Fong Lee, and R. Chair, “A quarter-wave U-shaped patch antenna with two unequal arms for wideband and dual-frequency operation,” *IEEE Trans. Antennas Propag.*, vol. 50, no. 8, pp. 1082–1087, Aug. 2002.

[26] Shih-Huang Yeh, Kin-Lu Wong, Tzung-Wern Chiou, and Shyh-Tirng Fang, “Dual-band planar inverted F antenna for GSM/DCS mobile phones,” *IEEE Trans. Antennas Propag.*, vol. 51, no. 5, pp. 1124–1126, May 2003.

[27] H.-M. Hsiao, J.-W. Wu, Y.-D. Wang, J.-H. Lu, and S.-H. Chang, “Novel dual-broadband rectangular-slot antenna for 2.4/5-GHz wireless communication,” *Microw. Opt. Technol. Lett.*, vol. 46, no. 3, pp. 197–201, Aug. 2004.

[28] W.-C. Liu and C.-F. Hsu, “Dual-band CPW-fed Y-shaped monopole antenna for PCS/WLAN application,” *Electron. Lett.*, vol. 41, no. 7, p. 390, 2005.

[29] H.-Y. A. Yim, C.-P. Kong, and K.-K. M. Cheng, “Compact circularly polarised microstrip antenna design for dual-band applications,” *Electron. Lett.*, vol. 42, no. 7, p. 380, 2006.

[30] C.-M. Wu, “Dual-band CPW-fed cross-slot monopole antenna for WLAN operation,” *IET Microwaves, Antennas Propag.*, vol. 1, no. 2, p. 542, 2007.

[31] A. Kumar Singh and M. Kumar Meshram, “Slot-loaded shorted patch for dual-band operation,” *Microw. Opt. Technol. Lett.*, vol. 50, no. 4, pp. 1010–1017, Apr. 2008.

[32] C. Chen and E. K. N. Yung, “Dual-Band Dual-Sense Circularly-Polarized CPW-Fed Slot Antenna With Two Spiral Slots Loaded,” *IEEE Trans. Antennas Propag.*, vol. 57, no. 6, pp. 1829–1833, Jun. 2009.

[33] K. G. Thomas and M. Sreenivasan, “Compact CPW-fed dual-band antenna,” *Electron. Lett.*, vol. 46, no. 1, p. 13, 2010.

[34] M. N. Mahmoud and R. Baktur, “A Dual Band Microstrip-Fed Slot Antenna,” *IEEE Trans. Antennas Propag.*, vol. 59, no. 5, pp. 1720–1724, May 2011.

[35] P. Borah, A. K. Bordoloi, N. S. Bhattacharyya, and S. Bhattacharyya, "Bridged 'V'-shaped patch antenna for dual-band communication," *Electron. Lett.*, vol. 48, no. 8, p. 419, 2012.

[36] Y.-Q. Zhang, X. Li, L. Yang, and S.-X. Gong, "Dual-Band Circularly Polarized Annular-Ring Microstrip Antenna for GNSS Applications," *IEEE Antennas Wirel. Propag. Lett.*, vol. 12, pp. 615–618, 2013.

[37] W.-J. Liao, S.-H. Chang, J.-T. Yeh, and B.-R. Hsiao, "Compact Dual-Band WLAN Diversity Antennas on USB Dongle Platform," *IEEE Trans. Antennas Propag.*, vol. 62, no. 1, pp. 109–118, Jan. 2014.

[38] A. Khidre, F. Yang, and A. Z. Elsherbeni, "A Patch Antenna With a Varactor-Loaded Slot for Reconfigurable Dual-Band Operation," *IEEE Trans. Antennas Propag.*, vol. 63, no. 2, pp. 755–760, Feb. 2015.

[39] J.-S. Yang and J.-S. Row, "Dual-band circularly polarized microstrip antenna," *Microw. Opt. Technol. Lett.*, vol. 59, no. 2, pp. 404–408, Feb. 2016.

[40] B. Mishra, V. Singh, and R. Singh, "Dual and wide-band slot loaded stacked microstrip patch antenna for WLAN/WiMAX applications," *Microsyst. Technol.*, vol. 23, no. 8, pp. 3467–3475, Aug. 2017.

[41] S. Egashira and E. Nishiyama, "Stacked microstrip antenna with wide bandwidth and high gain," *IEEE Trans. Antennas Propag.*, vol. 44, no. 11, pp. 1533–1534, 1996.

[42] S. Maci and G. B. Gentili, "Dual-frequency patch antennas," *IEEE Antennas Propag. Mag.*, vol. 39, no. 6, pp. 13–20, 1997.

[43] N. Herscovici, "A wide-band single-layer patch antenna," *IEEE Trans. Antennas Propag.*, vol. 46, no. 4, pp. 471–474, Apr. 1998.

[44] Jui-Han Lu, Chia-Luan Tang, and Kin-Lu Wong, "Single-feed slotted equilateral-triangular microstrip antenna for circular polarization," *IEEE Trans. Antennas Propag.*, vol. 47, no. 7, pp. 1174–1178, Jul. 1999.

[45] Y. Horii and M. Tsutsumi, "Harmonic control by photonic bandgap on microstrip patch antenna," *IEEE Microw. Guid. Wave Lett.*, vol. 9, no. 1, pp. 13–15, 1999.

[46] S. C. Gao, L. W. Li, P. Gardner, and P. S. Hall, "Wideband dual-polarised microstrip patch antenna," *Electron. Lett.*, vol. 37, no. 20, p. 1213, 2001.

[47] Y. J. Sung, M. Kim, and Y. S. Kim, “Harmonics reduction with defected ground structure for a microstrip patch antenna,” *IEEE Antennas Wirel. Propag. Lett.*, vol. 2, pp. 111–113, 2003.

[48] J.-S. Row, “Dual-frequency circularly polarised annular-ring microstrip antenna,” *Electron. Lett.*, vol. 40, no. 3, p. 153, 2004.

[49] S. Gao, L.-W. Li, and A. Sambell, “FDTD Analysis of A Dual-Frequency Microstrip Patch Antenna,” *Prog. Electromagn. Res.*, vol. 54, pp. 155–178, 2005.

[50] C.-H. Cai, J.-S. Row, and K.-L. Wong, “Dual-frequency microstrip antenna with dual circular polarisation,” *Electron. Lett.*, vol. 42, no. 22, p. 1261, 2006.

[51] Y. Lu, H. Wang, and D. Fang, “A Novel Wideband Aperture-Coupled Circularly Polarized Stacked Patch Antenna,” in *The 2006 4th Asia-Pacific Conference on Environmental Electromagnetics*, 2006, pp. 904–907.

[52] D. Peroulis, K. Sarabandi, and L. P. B. Katehi, “Design of reconfigurable slot antennas,” *IEEE Trans. Antennas Propag.*, vol. 53, no. 2, pp. 645–654, Feb. 2005.

[53] M. K. Mandal, P. Mondal, S. Sanyal, and A. Chakrabarty, “An improved design of harmonic suppression for microstrip patch antennas,” *Microw. Opt. Technol. Lett.*, vol. 49, no. 1, pp. 103–105, Jan. 2007.

[54] J. S. Roy and M. Thomas, “Investigations on a new proximity coupled dual-frequency microstrip antenna for wireless communication,” *Mikrotalasna Rev.*, vol. 13, no. 1, pp. 12–15, 2007.

[55] H. Singh, Y. K. Awasthi, and A. K. Verma, “Microstrip patch antenna with defected ground structure & defected microstrip structure,” in *2008 International Conference on Recent Advances in Microwave Theory and Applications*, 2008, pp. 937–938.

[56] A. K. Arya, M. V. Kartikeyan, and A. Patnaik, “Efficiency enhancement of microstrip patch antenna with defected ground structure,” in *2008 International Conference on Recent Advances in Microwave Theory and Applications*, 2008, pp. 729–731.

[57] P. Kumar, “Microstrip Antennas Loaded with Shorting Post,” *Engineering*, vol. 1, no. 1, pp. 41–45, 2009.

[58] Y. Xu and C. Ruan, “A Novel Design of Circularly Polarized Omni-directional Antenna for Ka Band,” in *2008 Global Symposium on Millimeter Waves*, 2008, pp. 378–379.

[59] J.-P. Geng, J. Li, R.-H. Jin, S. Ye, X. Liang, and M. Li, “The Development Of Curved Microstrip Antenna With Defected Ground Structure,” *Prog. Electromagn. Res.*, vol. 98, pp. 53–73, 2009.

[60] A. Mishra, P. Singh, N. P. Yadav, J. A. Ansari, and B. R. Vishvakarma, “Compact Shorted Microstrip Patch Antenna For Dual Band Operation,” *Prog. Electromagn. Res. C*, vol. 9, pp. 171–182, 2009.

[61] Liping Han, Wenmei Zhang, Xinwei Chen, Guorui Han, and Runbo Ma, “Design of Compact Differential Dual-Frequency Antenna With Stacked Patches,” *IEEE Trans. Antennas Propag.*, vol. 58, no. 4, pp. 1387–1392, Apr. 2010.

[62] Y. Cai, Y. J. Guo, and A. R. Weily, “A Frequency-Reconfigurable Quasi-Yagi Dipole Antenna,” *IEEE Antennas Wirel. Propag. Lett.*, vol. 9, pp. 883–886, 2010.

[63] J.-S. Row and T.-Y. Lin, “Frequency-Reconfigurable Coplanar Patch Antenna With Conical Radiation,” *IEEE Antennas Wirel. Propag. Lett.*, vol. 9, pp. 1088–1091, 2010.

[64] K. L. Melde, H.-J. Park, H.-H. Yeh, B. Fankem, Z. Zhou, and W. R. Eisenstadt, “Software Defined Match Control Circuit Integrated With a Planar Inverted F Antenna,” *IEEE Trans. Antennas Propag.*, vol. 58, no. 12, pp. 3884–3890, Dec. 2010.

[65] Nasimuddin, Zhi Ning Chen, and Xianming Qing, “Dual-Band Circularly Polarized S-Shaped Slotted Patch Antenna With a Small Frequency-Ratio,” *IEEE Trans. Antennas Propag.*, vol. 58, no. 6, pp. 2112–2115, Jun. 2010.

[66] G. Singh and M. Kumar, “Design of frequency reconfigurable microstrip patch antenna,” in *2011 6th International Conference on Industrial and Information Systems*, 2011, pp. 18–22.

[67] M. M. Sharma, S. Yadav, A. Kumar, Y. Ranga, and D. Bhatnagar, “Compact elliptical microstrip patch antenna with slotted ground for Ku-band applications,” in *2011 IEEE Applied Electromagnetics Conference (AEMC)*, 2011, pp. 1–3.

[68] V. Sharma, V. K. Saxena, K. B. Sharma, and D. Bhatnagar, “Radiation

performance of an elliptical patch antenna with three orthogonal sector slots," *Rom. J. Inf. Sci. Technol.*, vol. 14, no. 2, pp. 123–130, 2011.

[69] O. Hoseini Izadi and M. Mehrparvar, "A compact microstrip slot antenna with novel E-shaped coupling aperture," in *2010 5th International Symposium on Telecommunications*, 2010, pp. 110–114.

[70] M. Challal, A. Azrar, and M. Dehmas, "Rectangular Patch Antenna Performances Improvement Employing Slotted Rectangular shaped for WLAN Applications.," *Int. J. Comput. Sci. Issues* vol. 8, no. 3, pp. 1–5, 2011.

[71] A. A. D. Al-sajee and K. A. Hamad, "Improving Bandwidth Rectangular Patch Antenna Using Different Thickness of Dielectric Substrate," *ARPN Journal of Engineering and Applied Sciences.,* vol. 6, no. 4, pp. 16–21, 2011.

[72] H. R. Gajera, "The Microstrip Fed Rectangular Microstrip Patch Antenna (RMPA) with Defected Ground Plane for HIPERLAN /1," *InternatIonal Journal of Electronics & CommunicatIon technology*., vol. 7109, pp. 172–175, 2011.

[73] L. Zheng and S. Shichang Gao, "Compact dual-band printed square quadrifilar helix antenna for global navigation satellite system receivers," *Microw. Opt. Technol. Lett.*, vol. 53, no. 5, pp. 993–997, May 2011.

[74] Y. Cai, Y. J. Guo, and T. S. Bird, "A Frequency Reconfigurable Printed Yagi-Uda Dipole Antenna for Cognitive Radio Applications," *IEEE Trans. Antennas Propag.*, vol. 60, no. 6, pp. 2905–2912, Jun. 2012.

[75] M. Chakraborty, B. Rana, P. P. Sarkar, and A. Das, "Design and Analysis of a Compact Rectangular Microstrip Antenna with Slots using Defective Ground Structure," *Procedia Technol.*, vol. 4, pp. 411–416, 2012.

[76] G. Singh, "Comparative analysis of microstrip patch antenna with different feeding techniques," *Int. J. Comput. Appl.*, pp. 18–22, 2012.

[77] R. Dua, H. Singh, and N. Gambhir, "2.45 GHz Microstrip Patch Antenna with Defected Ground Structure for Bluetooth," *J. Soft Comput. Eng.*, no. 6, pp. 262–265, 2012.

[78] X. L. Bao and M. J. Ammann, "Comparison of Several Novel Annular-Ring Microstrip Patch Antennas for Circular Polarization," *J. Electromagn. Waves Appl.*, vol. 20, no. 11, pp. 1427–1438, Jan. 2006.

[79] H. A. Majid, M. K. A. Rahim, M. R. Hamid, and M. F. Ismail, "A Compact Frequency-Reconfigurable Narrowband Microstrip Slot Antenna," *IEEE Antennas Wirel. Propag. Lett.*, vol. 11, pp. 616–619, 2012.

[80] M. Aneesh, J. a Ansari, A. Singh, and S. S. Sayeed, "Analysis of S-shape Microstrip Patch Antenna for Bluetooth application," *Int. J. Sci. Res. Publ.*, vol. 3, no. 11, pp. 3–6, 2013.

[81] R. Gupta and S. Gurjar, "Shifted Elliptical Slot in Microstrip Patch Antenna for increasing bandwidth and gain," *International Journal of Advanced Research in Computer and Communication Engineering.,* vol. 2, no. 4, pp. 1687–1690, 2013.

[82] A. A. Roy, J. M. Môm, and G. A. Igwue, "Enhancing the Bandwidth of a Microstrip Patch Antenna using Slots Shaped Patch," *American Journal of Engineering Research (AJER).,* no. 9, pp. 23–30, 2013.

[83] A. Mishra, J. A. Ansari, K. Kamakshi, A. Singh, M. Aneesh, and B. R. Vishvakarma, "Compact dualband rectangular microstrip patch antenna for 2.4/5.12-GHz wireless applications," *Wirel. Networks*, vol. 21, no. 2, pp. 347–355, Feb. 2015.

[84] M. Aneesh, J. A. Ansari, A. Singh, Kamakshi, And S. S. Sayeed, "Analysis of Microstrip Line Feed Slot Loaded Patch Antenna Using Artificial Neural Network," *Prog. Electromagn. Res. B*, vol. 58, pp. 35–46, 2014.

[85] S. Panusa, "Quad-Band U-Slot Microstrip Patch Antenna," *International Journal of Scientific Research Engineering & Technology (IJSRET)*, vol. 3, no. 1, pp. 145–148, 2014.

[86] C.-Y. Chiu, J. Li, S. Song, and R. D. Murch, "Frequency-Reconfigurable Pixel Slot Antenna," *IEEE Trans. Antennas Propag.*, vol. 60, no. 10, pp. 4921–4924, Oct. 2012.

[87] A. Mansoul, F. Ghanem, M. R. Hamid, and M. Trabelsi, "A Selective Frequency-Reconfigurable Antenna for Cognitive Radio Applications," *IEEE Antennas Wirel. Propag. Lett.*, vol. 13, pp. 515–518, 2014.

[88] D. Upadhyay and R. P. Dwivedi, "Antenna miniaturization techniques for wireless applications," in *2014 Eleventh International Conference on Wireless and Optical Communications Networks (WOCN)*, 2014, pp. 1–4.

[89] S. Shrivastava and A. Bhargava, "A Comparative Study of Different Shaped Patch Antennas with and Without Slots," vol. 2, no. 3, pp. 3306–3312, 2014.

[90] H. A. Majid, M. K. Abd Rahim, M. R. Hamid, and M. F. Ismail, "Frequency Reconfigurable Microstrip Patch-Slot Antenna With Directional Radiation Pattern," *Prog. Electromagn. Res.*, vol. 144, pp. 319–328, 2014.

[91] A. S. A. Nisha, "Hybrid coupled feed circularly polarized patch antenna for military applications," *Indian J. Sci. Technol.*, vol. 8, no. 29, pp. 8–11, 2015.

[92] H. Gu, J. Wang, and L. Ge, "Circularly Polarized Patch Antenna With Frequency Reconfiguration," *IEEE Antennas Wirel. Propag. Lett.*, vol. 14, pp. 1770–1773, 2015.

[93] B. V. R. Reddy, A. Mittal, and A. K. Sharma, "Slot embedded dual-band patch antenna for WLAN and WiMAX applications," *Electron. Lett.*, vol. 51, no. 8, pp. 608–609, Apr. 2015.

[94] A. Pingale, A. Shende, A. Jadhav, C. Ghanote, and U. Sonare, "Design of Elliptical Microstrip Antenna for Ultra Wide Band Applications," no. 3, pp. 276–279, 2015.

[95] P.Surya Anuja, "Design of Elliptical Patch Antenna with Single & Double U-Slot \nfor Wireless Applications: A Comparative Approach," *Int. J. Mod. Eng. Res.*, vol. 4, no. 2, pp. 24–30, 2014.

[96] S. K. Sidhu and J. Singh Sivia, "Comparison of Different Types of Microstrip Patch Antennas," *Int. J. Comput. Appl.*, no. Icaet, pp. 975–8887, 2015.

[97] V. Thakur and S. Kashyap, "A Review Paper on Techniques and Design for Microstrip Patch Antenna,"*International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*., pp. 656–662, 2015.

[98] K. S. Alone and S. Prabha, "Design And B.W. Optimization Of UWB(Ultra Wideband) Antenna," *International Journal Of Engineering Sciences & Research Technology.,*no. 6, pp. 284–291, 2016.

[99] S. Murugan, B. Rohini, P. Muthumari, and M. P. Priya, "Multi-Frequency T-Slot Loaded Elliptical Patch Antenna for Wireless Applications," vol. 1, no. 7, pp. 212–215, 2016.

[100] R. Kumar and A. Saxena, "Elliptical Micro-strip Patch Antenna For Circular

Polarization Design Using HFSS," pp. 1408–1411, 2016.

[101] P. Jyoti Gogoi, D. Jyoti Gogoi, and N. S. Bhattacharyya, "Modified ground plane of patch antenna for broadband applications in C-band," *Microw. Opt. Technol. Lett.*, vol. 58, no. 5, pp. 1074–1078, May 2016.

[102] C. Rajagopal, S. Balakrishnapillai Suseela, N. Noorullakhan, and R. Sankararajan, "A novel performance diversity modified elliptical patch antenna for C-band applications," *Microw. Opt. Technol. Lett.*, vol. 59, no. 2, pp. 408–415, Feb. 2017.

[103] D. Kaushal and T. Shanmuganantham, "A Vinayak slotted rectangular microstrip patch antenna design for C-band applications," *Microw. Opt. Technol. Lett.*, vol. 59, no. 8, pp. 1833–1837, Aug. 2017.

[104] C. S. Wu, C. L. Lu, W. Q. Cao, and D. F. Guan, "A microstrip coupled-fed patch antenna with dual-band and dual-polarization characteristics," *Microw. Opt. Technol. Lett.*, vol. 59, no. 5, pp. 1065–1068, May 2017.

[105] High Frequency Structure Simulator (HFSS) Software, *ANSYS, Version. 13.*

[106] R. Garg, P. Bhartia, I. Bahl and A. Ittipiboon, "*Microstrip antenna design handbook,"* Norwood, MA: Artech House, 2001.

[107] J. R. James and P. S. Hall, "*Handbook of microstrip antennas,"* Peter Peregrinus Ltd., London, United Kingdom, 1989.

[108] V. Priyashman *et al.*, "2. 45 GHz of elliptical shape patch antenna," *IEEE Symp. Wirel. Technol. Appl. ISWTA*, pp. 126–129, 2012.

[109] S.-S. Zhong, X.-L. Liang, and W. Wang, "Compact elliptical monopole antenna with impedance bandwidth in excess of 21:1," *IEEE Trans. Antennas Propag.*, vol. 55, no. 11, pp. 3082–3085, Nov. 2007.

[110] R. Eshtiaghi, J. Nourinia, and C. Ghobadi, "Electromagnetically coupled band-notched elliptical monopole antenna for UWB applications," *IEEE Trans. Antennas Propag.*, vol. 58, no. 4, pp. 1397–1402, Apr. 2010.

[111] B. Shrama, V. Sharma, K. B. Sharma, and D. Bhatnagar, "Broadband semielliptical patch antenna with semicircular ring slot for WiMAX application," *Chinese J. Eng.*, vol. 2014, pp. 1–7, 2014.

[112] A. A. Adam, S. K. A. Rahim, K. G. Tan, and A. W. Reza, "Design of 3.1–12 GHz printed elliptical disc monopole antenna with half circular modified ground plane

for UWB application," *Wirel. Pers. Commun.*, vol. 69, no. 2, pp. 535–549, Mar. 2013.

[113] W. C. Liu, C. M. Wu, S. H. Chung, and J. La Jaw, "Notched CPW-FED pentagonal monopole antenna for dual wideband operation," *Microw. Opt. Technol. Lett.*, vol. 50, no. 12, pp. 3104–3108, 2008.

[114] R. Kumar and P. N. Choubey, "Design of pentagonal circular fractal antenna with and without notched-band characteristics," *Microw. Opt. Technol. Lett.*, vol. 55, no. 2, pp. 430–434, Feb. 2013.

[115] L. Bras, N. B. Carvalho, and P. Pinho, "Pentagonal patch-excited sectorized antenna for localization systems," *IEEE Trans. Antennas Propag.*, vol. 60, no. 3, pp. 1634–1638, Mar. 2012.

[116] P. N. Shinde and J. P. Shinde, "Design of compact pentagonal slot antenna with bandwidth enhancement for multiband wireless applications," *AEU - Int. J. Electron. Commun.*, vol. 69, no. 10, pp. 1489–1494, Oct. 2015.

[117] S. K. Rajgopal and S. K. Sharma, "Investigations on ultrawideband pentagon shape microstrip slot antenna for wireless communications," *IEEE Trans. Antennas Propag.*, vol. 57, no. 5, pp. 1353–1359, May 2009.

APPENDIX

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C-Band Multi-Frequency Shorting Pin Loaded Elliptical Patch Antenna

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***Abstract*-In this paper, a multi frequency microstrip antenna (MSA) for wireless applications is designed. The proposed MSA comprised of elliptical patch antenna with shorting pin. This antenna is fed by coaxial probe. The design parameters are major and minor axis of elliptical patch, the position of shorting pin and feeding point of probe are mentioned in table-1. The proposed antenna can provide optimized multi frequency by varying the above design parameters. FR-4 substrate with dielectric constant 4.4 is chosen. The multi frequencies are 4.49GHz, and 6.69GHz, which covers the applications such as satellite communications, for full-time satellite TV networks.**

***Keywords*-Coaxial feed, Elliptical patch, C-band, Shorting pin.**

I. Introduction

The microstrip antenna is one of the most preferred antenna structures for wireless applications and handheld devices. These antennas are light weight, small in size, and low volume. The design of the antenna along with its parametric studies and executed using a softs high-frequency structure simulator (HFSS). The design in x-band is verified experimentally with the prototypes etched on RT Duroid 5880[1-3]. Nearly double the element bandwidth has been achieved which may result in about 8% impedance bandwidth of a circular patch predicted and measured bandwidth of an identical conventional patch is about 4%. Although much larger impedance bandwidths of a microstrip element can be achieved by different techniques [5] like cutting slots on microstrip patch, introducing parasitic elements, or by reactively loading the patch [6], those methods usually involve rigorous design and fabrication processes. Moreover, most of those designs suffer from various distortions in radiation patterns, high cross-polarized levels, and decrease their efficiency [4]. Generally, the multi-frequency patch antennas are divided into two categories, (a) multi-resonator antennas and (b) reactively loaded antenna. The first category antennas are achieved by means of multiple radiating elements, and each radiating element supports strong currents and radiation phenomena at its resonant frequency [7].

It includes the multilayer stacked-patch antennas using circular, annular, rectangular and triangular patches [7-8]. Multi resonator antennas in coplanar structures can also be fabricated by using aperture-coupled parallel microstrip dipoles [9], as these antenna structures usually involve multiple substrate layers and these are high cost. The large size is the drawback of multi-resonator antenna, which is difficult to be installed in hand-held terminals. The second category is reactively load patch antenna, for multi frequency operation of the antenna such as multi-slotted patch, rectangular patch with two T-slots, truncated circular patch with double U-slot, square spiral patch antenna and pi-shaped slot on rectangular patch [10—15]. These structures involve complex calculation, design, higher frequency ratio and lower bandwidth as compared to proposed antenna. Therefore, the proposed antenna consists of a simple shorting pin with ground which is loaded on the elliptical patch antenna and it is fed by coaxial feed probe. The dimensions of the proposed antenna are optimized and simulated in such a way that it provides multi-frequency.

II. Antenna Design

The proposed antenna is shown in Figure-1 (top view) (front view). The elliptical patch of semi major axis 'b' and semi minor axis 'a' is printed on the FR-4 substrate ($\varepsilon_r = 4.4$). A pin is inserted at (-7, 3, 0) in between patch and ground the diameter of the pin is 1mm. the eccentricity of elliptical patch $e\ (= \sqrt{1-(a|b)^2})$, where 'b' is the semi major axis of the elliptical patch, 'a' is semi minor axis of the elliptical patch, $\boldsymbol{\varepsilon}_r$ is dielectric constant of the substrate. The multi frequency resonance can be obtained by properly designing the length and width of the substrate, patch, and also the feed point of the probe all dimensions are given in table-1.

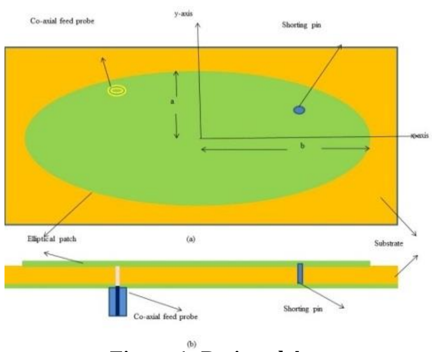
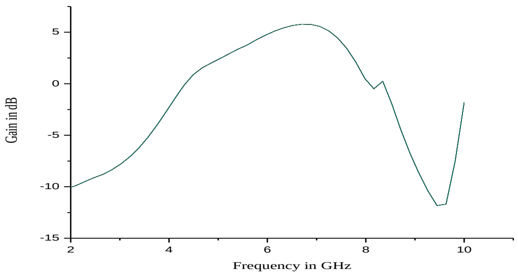


Figure-1: Designed Antenna

Table-1:
Specification of the elliptical antenna

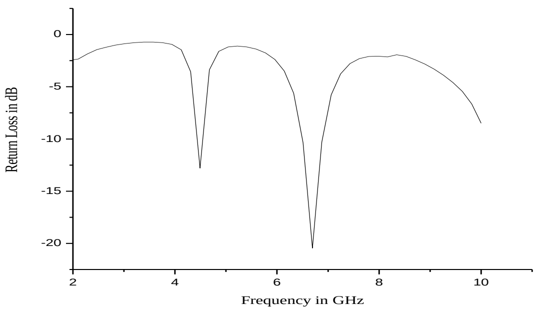
Design Parameters	Value
Substrate area	30mmX30mm
Semi major axis ‘b’	14mm
Semi minor axis ‘a’	5.6mm
Eccentricity ‘e’	0.92
Substrate type	FR4
Substrate thickness h	1.8mm
Dielectric constant ‘ε_r’	4.4
Shorting pin point	(7,1.5,0)
Feed point	(-7,3,0)
Patch Material	Copper
Patch thickness	0.07mm

The proposed antenna shows better return loss i.e. -12.7893dB, and -20.4519dB at the first and second band of the frequencies 4.4898GHz and 6.6938GHz respectively, Increasing negative value of return loss implies good impedance matching w.r.t the reference impedance of 50ohms.



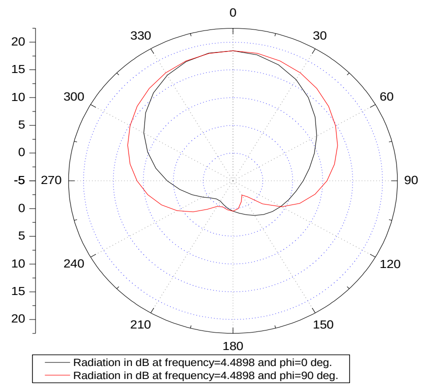
(a)

(b)

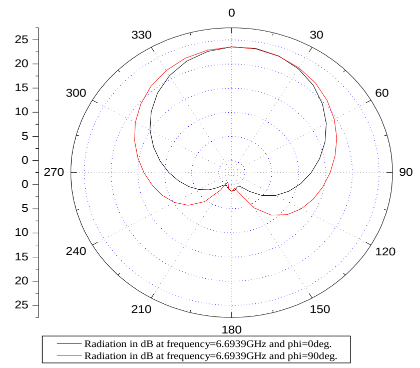


(c)

(d)



(e)



(f)

Figure-2: (a) Return loss, (b) VSWR, (c) Gain, (d) Directivity and (e) & (f) Radiation pattern

The VSWR of the proposed antenna shows 4.056dB and 1.6549dB at frequencies 4.4898GHz, and 6.6938 GHz respectively. This parameter implies the impedance matching between the sources to the feed is good, and it is essential requirement for the proper working of the antenna. VSWR value below 2 is successfully achieved for good antenna performance.

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The designed antenna achieved good gain as 0.8742dB, and 5.7829 dB corresponding frequencies from lower to high.

Directivity of the antenna is the ability to focus energy in a particular direction when transmitting the power during the radiation, or to receive energy better from a particular direction. The directivity is achieved as 3.2464 dB and 6.5826 dB i.e. the maximum amount of radiation intensity at different corresponding frequencies as 4.4898GHz and 6.6938 GHz. As shown in Figure-2: (a) Return loss, (b) VSWR, (c) Gain, (d) Directivity.

The 2D radiation patterns for the elevation and azimuthal plane respectively of the proposed antenna is given in figure-2 (e) and (f). Radiation pattern is the graphical representation of the radiation properties of the antenna as a function of space. Radiation pattern describes how the energy is radiated out into the space by the antenna and how it is received onto to antenna. For the band of the frequencies 4.4898 GHz, and 6.6938GHz, the radiation pattern is nearly omnidirectional in the azimuthal and elevation plane.

Table-2:
Performance of purposed Antenna

Frequency in GHz	Return Loss in dB	VSWR in dB	Gain in dB	Directivity in dB
4.4898	-12.7893	4.056	0.8742	3.2464
6.6938	-20.4519	1.6549	5.7829	6.5826

III. CONCLUSION

The compact elliptical microstrip patch antenna with shorting pin is proposed for C-band applications, shows that by using elliptical patch and shorting pin, antenna are able to resonate at frequencies 4.4898GHz, and 6.6938GHz. The designed antenna is appropriate for C-band applications. The obtained return loss, directivity, gain, and VSWR is good and radiation characteristics are also appropriate, different feeding techniques may also be used for increasing the efficiency of antenna.

REFERENCES

[1] Waterhouse R., April 13, 1995, “Small microstrip Patch antenna,” Electron. Lett., vol. 31, no. 8, pp. 604–605.

[2] Collins S. and AntarY. M. M.,March 2004, “Antenna size reduction using Yagi-Uda loops and shorted circular patches,” IEEE Trans. Antennas Propagat., vol. 52, no. 3, pp. 855–864.

[3] Waterhouse R., TargonskiS. D., Kokotoffand D. M., Nov. 1998, “Design and performance of small Printed antennas,” IEEE Trans. Antennas Propagat., vol. 46, no. 11, pp. 1629–1633.

[4] Wong K. L., 2002, Compact and Broadband Microstrip Antennas. New York: Wiley.

[5] GuhaD., Oct. 1–3, 2003, “Microstrip and printed antennas: recent trends and developments,” in Proc. Telecommu. Modern Satellite Cable and Broadcast. Serv. (TELSIKS 2003), Nis, Yugoslavia, pp. 39–44.

[6] Guha D. and SiddiquiJ. Y., 2002, “Simple Design of a novel broadband antenna: inverted Microstrip patch loaded with a capacitive post,” in Proc. IEEE Int. Symp. Antennas Propagat. vol. 2, pp. 534–537.

[7] Dahele J. S., Lee K. F., and Wong D. P., 1987, “Dual frequency stacked annular- ring microstrip Antenna,” IEEE Trans. Antennas Propagat., vol. AP-35, no. 11, pp. 1281-1285.

[8] Wang J., FralichR. Wu C., and Litva J., 1990, “Multifunctional aperture-coupled stacked antenna,” Electron. Lett., vol. 26, no. 25, pp. 2067-2068.

[9] Croq F. and Pozar D. M., 1992, “Multi frequency operation of microstrip antennas using aperture coupled parallel resonators,” IEEE Trans. Antennas Propagat., vol. 40, no. 11, pp. 1367-1374.

[10] NatarajamaniS., BeheraS. K., and Mishra R. K., 2009, “Design of multi slotted and multi frequency patch antenna,” Applied Electromagnetic Conference, Kolkata.

[11] De S., Samaddar P., Sarkar S., Biswas S., 2013, “Compact high gain multi frequency microstrip antenna,” International Journal of Soft Computing and Engineering, vol. 2, no. 6.

[12] Murugan S., Sathish E. Kumar, and Rajamani V., 2013, “Design and analysis of double U slot loaded dual frequency microstrip antenna,” Progress In Electromagnetic Research C, vol. 45, pp. 101-112.

[13] Keertana D. Ramya, Murthy M. V. S. D. N. N., YeswanthB, 2014, “A novel multi frequency rectangular microstrip antenna with dual T shaped slots for UWB applications,” IOSR Journal of Electronics and Communication Engineering, vol. 9, no. 1.

[14] Ghosal A., Majumdar A., Das S. Kumar, Das A., 2015, “Wideband and multi-frequency square spiralmicrostrip patch antenna,” International Journal of Innovative Research in Computer and Communication Engineering, vol. 3, no. 2.

[15] Das S., Sarkar P. P., and Chowdhury S. K., 2015, “Modified π-shaped slot loaded multi-frequency microstrip antenna,” Progress In Electromagnetics Research B, vol. 64, pp. 103-117.

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Slotted Pentagonal Shaped Patch Antenna with A Shorting Pin for C-Band Application

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***Abstract*— In this paper, a novel design of a Pentagonal shaped patch antenna is presented for ultra wideband wireless communication applications. Designed microstrip patch antenna consists of a pentagonal patch which is found to resonant at frequency 4.8571 GHz, with return loss -19.65 dB having satisfactory radiation properties. The proposed antenna is a compact design of 30mm × 20mm area on the FR4-epoxy substrate with dielectric constant of 4.4 and thickness of 1.8 mm. The designed antenna structure with 3.45 dB gain is planar, simple and compact hence it can be easily embedded for wireless communication systems and integrated with microwave circuitry for low manufacturing cost.**

***Keywords*—Pentagonal Patch, Microstrip Patch Antenna, shorting pin, slot.**

I. INTRODUCTION

With the rapid development and advancement of the wireless communication systems, antennas have become an essential part of any wireless communication [1]. Out of many types of miniature antennas, microstrip patch antennas have drawn the maximum attention of researchers over past few decades [2],[3],[4],[5] because they provide significant advantages like low profile, low weight, low manufacturing cost, polarization diversity, ease of fabrication etc [1].

A microstrip antenna can simply be defined as a sandwich of two parallel conducting layers separated by a dielectric substrate. The upper conductor is a metallic patch and the lower conductor is a ground plane [6, 7]. The efficiency of a microstrip antenna depends upon patch size, shape, substrate thickness, dielectric constant of substrate, feed point type and its location, etc. The patch of microstrip antenna can be of shapes like circular, elliptical, triangular, pentagonal, rectangular, etc. [8]. Since microstrip antenna has a drawback of narrow bandwidth, for this many solutions have been suggested including the use of different shapes of the patch, which covers multiple mode surface current waves, which causes resonance at multiband frequencies and finally widen the impedance bandwidth across UWB range. [6], [7].

The UWB operates over an ultra wide bandwidth with satisfactory radiation properties over the entire frequency range, a good impulse response with minimal distortion and low power utilization [9].

The pentagonal shaped radiating patch antenna design is not explored by many researchers. In [10, 11], authors have used pentagonal shape for the radiating patch and ground plane in the design of coplanar antennas. Pentagonal geometry is one of the various shapes for microstrip antennas capable of circular polarization and linear polarization [13, 18]. For this paper, pentagonal shaped patch antenna is considered using thick substrate for enhancing bandwidth of antenna with a simple configuration and the characteristics of the pentagonal patch antenna are analyzed.

There is a need for optimization of this type antenna so as to conveniently integrate within the compact communication equipment and devices. This has opened large interest for developing the compact antennas and their miniaturization techniques [14, 15]. There has been many techniques proposed and applied to microstrip patch antenna such as using dielectric substrate of high permittivity, slot on the radiating patch, defected ground structure at the ground plane or a combination of them [16,17]. In this paper, the pentagonal patch antenna is miniaturized using slotting technique on the radiating patch.

II. PROPOSED ANTENNA DESIGN

Substrate FR4-epoxy of dielectric constant 4.4 has been taken for this design. The antenna has been designed and simulated using Ansoft HFSS. The radiating patch of pentagonal shape is considered with radius 10mm and a slot is made at the center of the pentagonal patch. The feeding point is taken at coordinate as (-5, 0, 0). A shorting pin of material copper is also used in this design of height 1.8mm and radius 0.5mm. Various parameters considered are indicated in the table below.

TABLE I.
ANTENNA PARAMETERS

Antenna design Parameters	*Values*
Substrate material	FR4
Substrate thickness 'H'	1.8mm
Length of Substrate 'L'	30mm
Width of Substrate 'w'	20mm
Dielectric constant	4.4
Dielectric loss tangent	0.02
Pentagonal Patch radius	10mm
Radius of the Coaxial Probe	0.5mm
Position of the coaxial Probe	(-5,0,0)
Material of the Shorting Pin	copper
Radius of the shorting pin	0.5mm
Position of the Shorting Pin	(-3,0,0)
Dimensions of slot (x-axis X y-axis)	2mm X 2 mm

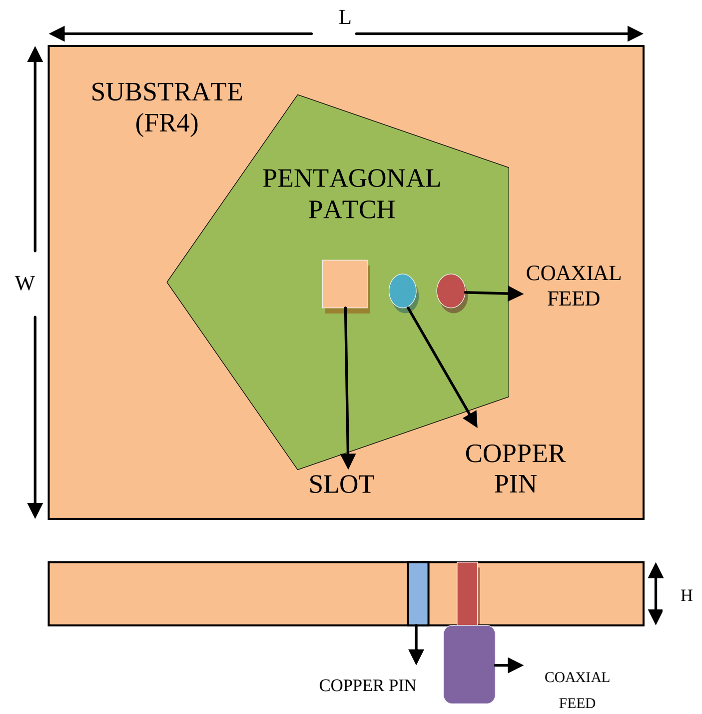

Figure1- Top view and Side view of the proposed antenna

III. Results And Discussions

A. Return Loss

The proposed antenna shows a better return loss characteristic that is -19.6505 dB at resonant frequency 4.8571 GHz. Increasing negative values of return loss implies good impedance matching with respect to the reference impedance of 50ohms. Return loss can be further improved by using different feeding techniques.

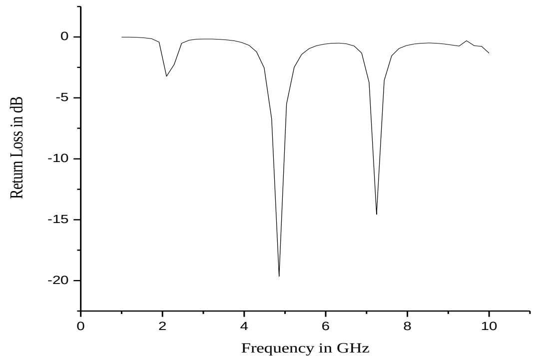

Figure 2- Return loss Vs Frequency

B. VSWR

The VSWR graph of proposed antenna shows the VSWR value is 1.8151 at frequency 4.8571 GHz. VSWR values imply the impedance matching between the source and the feed is good, which is an essential requirement for the proper working of the antenna.

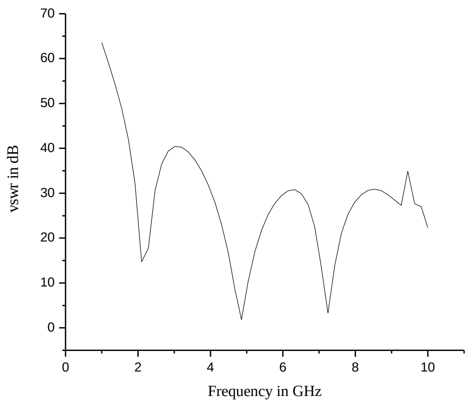

Figure 3- VSWR Vs Frequency

C. Gain

Antenna gain tells how much of the power is radiated in a given direction. The designed antenna has a good gain of 3.4529 dB at a resonant frequency of 4.8571 GHz, which means the antenna is more efficient at this frequency.

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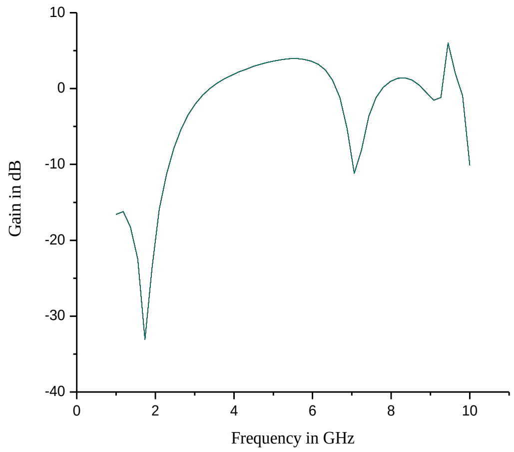

Figure 4- Gain Vs Frequency

D. Directivity

The directivity plot given below shows the maximum amount of radiation intensity that is equal to 5.3160 dB is achieved at a resonant frequency of 4.8571 GHz. Directivity is nothing but the ability of antenna to radiate energy in a particular direction whether it is transmitting, or to be receiving the energy from a particular direction.

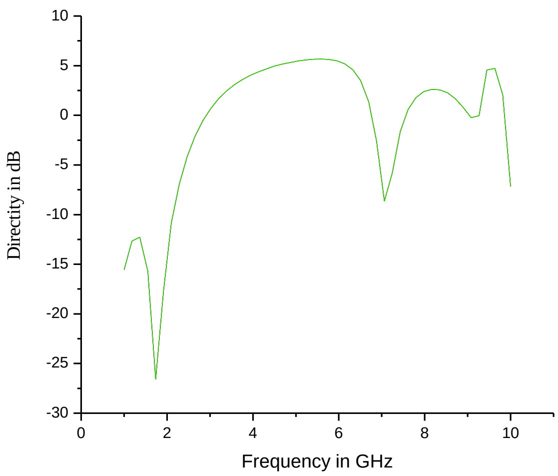

Figure 5- Directivity Vs frequency

E. Radiation Pattern

The 2D radiation patterns for the elevation and azimuthal plane respectively of the proposed antenna is given in figures below. Radiation pattern is the graphical representation of the radiation properties of the antenna as a function of space. Radiation pattern describes how the energy is radiated out into the space by the antenna or how it is received.

For the resonant frequency 4.8571 GHz, the radiation pattern is nearly omnidirectional in the azimuthal and elevation plane.

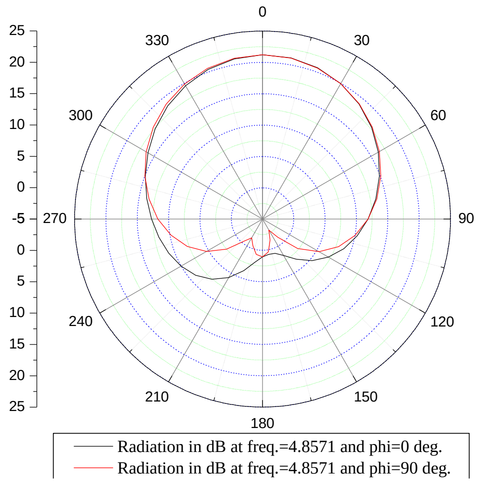

Figure 6- Radiation pattern at Frequency 4.8571 GHz

IV. CONCLUSION

The proposed compact pentagonal microstrip patch antenna design shows that by using pentagonal shaped patch with a slot and a shorting pin, antenna is able to resonate at frequency 4.8571 GHz. It is realized that with the introduction of the slot, the effective patch size is marginally reduced but the performance of antenna is significantly improved. The designed antenna is suitable for C-band applications. The obtained antenna characteristics are appropriate. The each characteristic such as Gain, return loss, and directivity have been discussed in this paper

REFERENCES

[1] A. B. Constantine, "Antenna Theory, Analysis and Design", Second Edition, John Wiley & Sons, pp. 1-23,724-726, 2009.

[2] N. Herscovici, "New considerations in the design of microstrip antennas." IEEE Transactions on Antennas and Propagation, AP-46, 6, June 1998, pp. 807-812.

[3] R.C. Keith, J.W. Mink, Microstrip Antenna Technology, IEEE Trans. On Antennas and Propagation, vol.AP-29 (1), 1981.

[4] D. Orban, G.J.K. Moernaut, The Basics Of Patch Antennas Update, RF Globalnet, 2009.

[5] J P Silver, Microstrip Patch Antenna Primer, RF,RFIC and microwave Theory, Design 2009.

[6] K.P. Ray, " Design Aspects of Printed Monopole Antennas for UWB Applications" , Hindawi Publishing Corp. International Journal of Antennas & Propagation Volume 2008.

[7] K. Baskaran, "A Compact Microstrip Antenna for Ultra Wideband Applications", European Journal of Scientific Research ISSN 1450-216X Vol.67 No.1, pp. 45-51 Euro Journals Publishing, Inc. 2011.

[8] S. K. Sidhu and J. S. Sivia," Comparison of Different Types of Microstrip Patch Antennas", International Journal of Computer Applications, ICAET 2015, pp 12-16.

[9] K. Sherdia," Microstrip Antenna Design for UWB Applications", International Journal of Advanced Research in Computer and Communication Engineering Vol. 2, Issue 10, October 2013.

[10] J. Jesmi, R. Anand, K. Sreedevi,"Study of Coplanar Pentagonal Antenna", 10th International Conference on Microwave, Antenna, Propagation and Remote Sensing, pp. 303-306, ICMARS Proceedings, 2014.

[11] J. Jesmi, R. Anand, K. Sreedevi,"A Coplanar Pentagonal antenna for wireless applications", 2nd International Conference on Signal Processing and Integrated Networks(SPIN-2015), pp. 303-306,IEEE Proceedings, 2015.

[12] R. Anand, J.A. Jose, A.M. Kaimal, S. Menon," Analysis of Dual Beam Pentagonal Patch Antenna", unpublished.

[13] M. Tecpoyotl-Torres and J. G. Vera-Dimas "Dual band Pentagonal Microstrip Antenna for Wi-Fi Applications" Electronics, Robotics and Automotive Mechanics Conference, pp 255, 2010.

[14] V. Kamboj, G. Saini and A. Saini, "Miniaturization of Microstrip Patch Antenna Using Slots for S Band", International Journal of Engineering Science and Computing, Volume 6 Issue No. 7, pp 2000-2003, July 2016.

[15] P. A Ambresh, A.A. Sujata, P. Jagadeesha, M. Hadalgi and P.V. Hunagund,"Design and Study of Pentagonal, Square Slotted Patch Antenna for Wireless Applications", International Journal on Emerging Technologies, pp 5-7, 2016.

[16] D. Upadhyay and R. P. Dwivedi,"Antenna Miniaturization Techniques for Wireless Applications", IEEE, 2014.

[17] M. Chakraborty, B. Rana, P.P. Sarkar, A. Das," Design and Analysis of a Compact Rectangular Microstrip Antenna with slots using Defective Ground Structure", SciVerse ScienceDirect, Procedia Technology 4, pp 411 – 416, 2012.

[18] Y. K Gupta, R. Yadava, R.K.Yadav, "Circularly polarized truncated pentagonal shaped microstrip patch antenna", International journal of microwaves applications, volume 2, no.6 pp 149-152, November-December 2013.