Chapter 1

Introduction

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CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION TO MICROSTRIP ANTENNA

In its simplest form a microstrip antenna is a dielectric substrate panel sandwiched in between two conductors. The lower conductor is called ground plane and upper conductor is known as patch. Commonly used frequencies for microstrip antenna is in between 1ghz to 100ghz. The radiating patch can be design in various shapes according to the desired characteristics but circular, square and rectangular shapes are common due to ease of fabrication and analysis. patches are normally made of material such as gold or copper and design in to any shapes. These conducting metals are the main choice because of their low resistivity, resistance to oxidation, solderable and adhere well to substrate. The feed line and radiating patch is printed photo etched on the substrate.

Matching is usually required between the antenna and the feed lines because input impedance differ from customary 50 ohm line impedance. An appropriately selected port location will provide matching between the antenna and its feed line. The first step in designing the microstrip antenna is to select an appropriate substrate. The substrate characteristics involved the dielectric constant and loss tangent and their variation with temperature and frequency, dimensional stability with processing. In order to give support and protection for the patch element the dielectric substrate must be strong and able to endure high temperature during soldering process and has high resistant towards chemical that are used in fabrication process. Substrate thickness and permittivity determine the electrical characteristic of the antenna. Thicker substrate will increase the bandwidth but it will cause the surface waves to propagate and spurious coupling will happen. This problem can be reduced by using a suitably low permittivity substrate.
Patch antenna have a very thin patch that is placed a small fraction of a wavelength above a conducting ground plane. The ground and patch are apart by dielectric substrate bearing low dielectric loss. The important characteristic of microstrip antennas is their inherent ability to radiate efficiently despite of their low profile. A typical patch antenna is shown in fig.1.1.
1.3.1 Shape of Patches

Through decades of research it was identified that the performance and operation of a microstrip antenna is driven mainly by the geometry of the printed patch and the material characteristics on to which the antenna is printed. Over the years there have been many conductor shapes proposed and investigated for a microstrip patch antenna. The patch geometries are generally rectangular but square, circular and triangular patches are also possible. Depending upon the characteristics of the transmitted electromagnetic energy, the radiating element may be square, rectangular, triangular elliptical or circular in shape and must be separated by a finite distance from the ground plane. Thin sheet of dielectric substrate is introduced between these two conducting layers. Schematic diagrams of few common patch geometrics are shown in figure 1.2.

Among the geometries mentioned below, rectangular and square patches [figs. 1.2(a) and 1.2(b)] are probably the most utilized patch conductor geometries.

![Fig 1.2 some common shapes of Microstrip patch antennas.](image-url)
1.3.2 Advantages and Drawbacks of microstrip Antennas

Low profile which can be Conformable to planar and non-planar surfaces
Matching networks and Feed lines are simultaneously fabricated along with the antenna structure.
Low fabrication cost
Occupied less space and having little weight
Easy of fabrication.
Linear and circular polarization is possible with simple feed.
Integrated easily with MICs.
Dual and triple frequency response is possible. The antennas have low scattering cross section.
Mechanically robust when mounted on rigid surfaces.
Resistant to shock and vibration.

Drawbacks of MSA

Low efficiency and low gain.
Low power handling capacity.
low isolation between radiating elements and feed.
Possibility of excitation of surface waves.
bandwidth is too narrow
1.3.3 Review of Literature on Microstrip Antenna

With the advancement of modern mobile and wireless communication systems, need for small size antennas with improved performance were realized. Since normal microstrip antennas in their original shape may not be applied in these systems, extensive work to amend these geometries started and several amended geometries were proposed with improved performance. A good number of research papers published in journals during past two decades on these antennas shows the importance gained by these geometries. The microstrip antennas are the present day antenna designer’s choice. Prior to starting the work carried by us, it is important to have a deep understanding on the existing work on microstrip patch antennas. A brief detail of work carried out by different workers during past ten years is reported here. However to maintain the continuity of work, some old references are also reported in the coming section.

Deschamps [1953] was the first to give the concept of microstrip radiators but as was the case with most scientific breakthroughs of that time, the first patented documentation of microstrip antennas was in the name of Gutton and Baissinot [1955] of France. Munson et al. [1972] firstly introduced the microstrip patch antenna after twenty years to Deschamps in a symposium paper. Notably, the original patent on the microstrip antennas obtained by Munson. These papers presented the rectangular patch and wraparound microstrip antenna. Later, Munson et al. [1974] reported their work on conformal microstrip antennas and arrays. That work described a wrap-around strip element fed from multiple points by means of a corporate power divider, which was suitable for application on the surface of missiles. The antenna had an Omni directional pattern in the plane perpendicular to the missile axis. This was clearly an important step in simplifying the radiation elements, where weight and aero dynamical properties were important. During the same period, Howell [1972] published the first experimental results on rectangular and circular patch. Lo et al [1979] published many canonical microstrip antenna shapes. At that point, there had been enough work accumulated to set up the stage for the first professional meeting devoted to microstrip antennas at New Mexico in 1979. Carver and mink [1981] presented an excellent review on microstrip antenna developments and their modeling

Revankar and Kumar [1991] experimentally investigated the broadband behavior of a three-layer electromagnetically coupled circular microstrip antenna and the effects of interlayer spacing and the thickness of the parasitic layers on the impedance bandwidth. Lee and Nalbandian [1992] discussed the dual-band MSA using air gap and reported that the radiation characteristics were unaffected by the modification for the dual-frequency or dual polarization operation. Zhong et al. [1994] developed the improved model of transmission line for input impedance of rectangular MSA with multi-dielectric layers. Sanad [1995] presented a very compact wide band microstrip antenna for cordless telephones. In this antenna both the driven and the parasitic elements were partially shorted, double C-patches on a very small ground plane. Maci et al. [1995] analyzed a patch antenna which provided dual-frequency operation by means of two slots placed close to the radiating edges of a patch. Kumar et al. [1996] presented dual port microstrip antenna for dual frequency operation, having intersection of two circles of the same radius giving wide bandwidth and good isolation between its ports. Zhang et al. [1997] investigated experimentally microstrip patch antenna with probe fed on a very high permittivity super-substrate configuration at 1.8 GHz. The prototype presented was much smaller and had about the same gain as a conventional microstrip patch. Huang et al [1998] implemented a compact rectangular microstrip antenna with enhanced gain and wider bandwidth using the loading of
high permittivity super substrate layer and chip resistor. Sze and Wong [2000] proposed a slotted rectangular MSA by embedding modified U shaped slot and a pair of right angle slots in a rectangular patch for increasing the bandwidth.

Kuo and Wong [2001] demonstrated a novel compact microstrip antenna design by inserting meandering slots in the antenna’s plane and analyzed that resonant frequency of the MSA was significantly lowered, which led to size reduction of an antenna for a fixed frequency band. Paul et al. [2002] presented a compact multiband octagonal-shaped msa used for blue tooth and mobile communication application. Karmakar [2002] presented circular cavity-enclosed circular-patch antenna and derived an formula to find its resonant frequency. Gan et al. [2004] presented an enhanced cavity model for analyzing microstrip patch antenna. Theoretical results of the enhanced model were compared with some commonly used models to determine their range of validity. Shackelford et al. [2003] designed a L-probe-fed patch and U-slot patch antenna with wide-bandwidth and described several techniques that might be utilized to reduce the resonant length of these MSA patch. Denidni [2004] summarized the design, construction and experimental results for a new wideband miniaturized antenna operating in the 1.9GHz band using shorting pins at the zero-potential plane. This antenna was intended for handset applications and was also used as an element in a large array. Deshmukh and kumar [2005] proposed a broadband E-shaped microstrip antenna and further increased its bandwidth by cutting a pair of tapered slots using the even-mode symmetry. Ooi and Ang [2005] investigated a new wideband flower-shaped semicircle-fed microstrip patch antenna. The broadband characteristic was achieved by introducing flower petals at the four sides of a rectangular patch. Alameddine et al. [2006] presented an electromagnetically coupled feeding structure technique for bandwidth enhancement of microstrip patch antennas abd-alhameed [2006] proposed and investigated the design for low profile and small broadband antennas for 3G frequency band by embedding different types of slot in the ground plane with substrate of high permittivity. Kan and Waterhouse [2007] presented a probe-fed patch antenna that generated low cross-polarized radiated fields. Bhardwaj et al. [2007] presented a notch square patch antenna on FR4 substrate and found that on reducing the notch angle from 180° to 164°, the best performance with the
proposed geometry might be achieved. Yang et al. [2008] studied by simulation and experimental analysis the performance of circularly polarized microstrip antennas with truncated corner on different substrate thickness and analyzed that there is enhancement in axial ratio bandwidth due to thicker substrate. Khodaei et al. [2008] presented an asymmetric U-slot patch antenna with low probe diameter and reported that reduction in probe diameter caused reduction in bandwidth. Krishna et al. [2008] presented a compact dual frequency microstrip antenna on super substrate with slotted circular patch used to lowered the resonant frequency and improved the bandwidth. H. F. Abu Tarboush et al. [2009] proposed a technique to enhance the bandwidth by using stacked patches and inserting slot in the ground plane and getting bandwidth up to 25%. Chi and Wong [2009] proposed a very-small-size printed loop antenna for mobile phone application which had a loop strip of length 62.0mm only, which was folded into an L-shape and occupied a small area of 96.5mm on the top no-ground portion of the system circuit board of the mobile phone. By incorporating a simple matching circuit formed by a chip capacitor and a chip inductor, both in series, the loop antenna generated three resonant modes at about 925 MHz, 1800 MHz and 2200 MHz.

Kumar et al. [2009] presented the effect of slots in ground plane and patch on resonant frequency, impedance bandwidth, gain and side lobes. It was observed that size reduction of slotted patch antenna was more than that for slotted ground plane applications. this chip antenna is attractive to mobile devices as it doesnot require a guard region to separate by circuit components. M. T. Islam et al.[2009] presented a technique for broadband microstrip antenna to enhance gain and band width by modifying the patch with the use of L-probe feed and E-H microstrip patch. The antenna has achieved 30% impedance bandwidth from 1.76 GHz to 2.38 GHz and a maximum gain of 9.37 dbi. Techniques for microstrip broad banding, size reduction, high gain and stable radiation pattern are carried out and experimentally verified .Chen et al. [2010] demonstrated a E-shaped microstrip patch antenna by introducing a method of distributed LC circuit for enhancement of bandwidth. Singh et al. [2010] proposed a Ultra-Wideband folded asymmetric antenna structure for application of Mobile Phone. The antenna Covered UTMS (Universal Mobile Telecommunication System) (1927-2121 MHz) and ISM (2348-2830 MHz)
frequency bands and was constructed by folding the metal plate dipole antenna with meandered ground plate and occupied a small volume of 90mmX36mmX9mm. D. Parkash and Rajesh Khanna [2010] proposed a msa antenna for WIMAX / WLAN applications by using CPW fed technique. Anil Kumar et al. [2011] presented a notched rectangular msa for WLAN applications with increase bandwidth and good gain Using stacking method. Author obtained the desired band by changing the dimensions of stacked patches and notches. Amit A.Deshmukh et al.[2012] presented a broad band microstrip antenna by fabricating the patch on thicker substrate having lower dielectric constant. The simpler proximity feeding techniques increases the antenna bandwidth for substrate thickness greater than 0.06 $\lambda_0$. Here author obtain a large bandwidth of nearly 350 mhz by gap coupling of RMSAs and 500 MHz with arrays. Chandan et al. [2012] presented a elevated CPW- fed slotted microstrip antenna for ultra-wideband application. P. A. Ambresh [2012] demonstrated a compact microstrip patch antenna for dual frequency band using slits in the patch. The antenna is fabricated on FR4 dielectric material which is suitable for applications like wi-max, w-lan and satellite communication. The experimental result shows that compactness of antenna is achieve by 78% and bandwidth of 170 MHz operating at dual frequency 2.05 GHz and 3.72 GHz in S-band. Sarthak Singhal. [2012] In this paper Author design a microstrip patch antenna which is gap coupled with two parasitic elements to its non radiating and radiating edge. This design is giving an impedance Bandwidth of 4.967 GHz and operating at center frequency 14.3 GHz. The Author presented here a gap coupled method to increase the Bandwidth of Patch antenna. Xianglong Liu[2013] proposed a CPW fed antenna with circularslot in ground plane. A double band notched characteristics is obtain by introducing L shape branches in ground plane. Antenna find application in 3.3 to 5.8 ghz UWB band. Guihang [2013] design a elliptical shaped antenna which uses three folded capacitive line to obtain three bands for UWB application 3.1 ghz to 10.6ghz. R, zim[2013] presented a UWB edge fed annular ring antenna for DSRC- dedicated short range communication and wireless LAN which consists of a rectangular slot in ground plane and annular ring patch.
1.4 FEEDING TECHNIQUES

The feed guides the electromagnetic energy from the source to the region under the patch. Some of this energy crosses the boundary of the patch and radiated into space. There are several methods to feed the radiating patch. These include coaxial feed, microstrip feed (feed line), aperture coupling feed, proximity coupling feed and Coplanar wave guide feeding (CPW). With different feeding methods, different antenna properties are constructed such as bandwidth, radiation pattern, polarization, gain and impedance. In practice, the coaxial and microstrip feed are the most commonly used feeding method. In this thesis coaxial feed and CPW feeding techniques are used to increase bandwidth. A brief description of each of these feeding methods is given here.

1.4.1 Microstrip Line Feed

This method is the easiest to fabricate as this feeding arrangement and radiating patch can be printed on same dielectric substrate. Fig. 1.3 shows a diagram of patch feed by this technique. Due to this advantage a large arrays may be designed using edge-fed patches.

![Fig 1.3 Microstrip Line Feed](image)
1.4.2 Probe Feed / Coaxial Cable Technique

In this technique MSA patch is fed from underneath through a coaxial cable probe as shown in fig. 1.4. This is a feeding method in which center conductor of the coaxial cable is soldered to the patch. The position of the feed placed at any location inside the patch used to control the input impedance. The main advantages associated with coaxial probe feed are ease of fabrication and ease to match with radiating element and it also has low spurious radiation.

![Coaxial cable or Probe feed Technique](image)

Fig 1.4 Coaxial cable or Probe feed Technique.
1.4.3 Aperture Coupling Feed Technique

In an aperture coupling the field is coupled from the feed line to the resonating patch through slot in the ground structure as shown in fig 1.5, which is placed between the two substrate. On bottom substrate feed line is there and on top substrate radiating patch.

Fig 1.5 Aperture coupling feed Technique.
1.2.4 Proximity Coupled Feed Technique

This feeding method contains two dielectric layers i.e. one is a radiating patch layer and on lower layer feed line is fabricated with a ground plane on back side. the patch is electromagnetically coupled to feed line..This method has the widest bandwidth and low radiation. However this method is difficult to fabricate.

Fig 1.6 Proximity Coupled Feed Technique.
1.2.5 Coplanar wave guide feeding (CPW)

The coplanar waveguide feed is shown in figure 1.1, has also been used to excite the msa. In this method, the coplanar waveguide is printed on the ground surface of the patch. The line is excited by a coaxial feed and is terminated by a slot, whose length is chosen to be between 0.25 and 0.29 of the slot wavelength the main disadvantages of this method is the high radiation from the rather longer slot, leading to the poor front to back ratio. This ratio is improved by reducing the slot dimension and modifying its shape in the form of a loop. The CPW fed antenna have been widely used for wireless communications due to its many features such as wide band width, simple structure, a single metallic layer, less numbers of soldering points, and easily compatible with other circuits etc.

![Figure 1.7- coplanar waveguide feed](image-url)
1.5 THESIS ORGANIZATION

The main challenge in microstrip patch antenna is to achieve wide bandwidth in which conventional one has as fewer percent. These antennas in their original form resonate at a single resonance frequency corresponding to their dominant mode. For modern communication systems, antenna capable of resonating two or more frequencies simultaneously are preferred and hence development in these geometries is desired if they have to be apply in future communication systems. Looking these requirements, work in this direction is started as in this thesis. The whole work done for this thesis has been divided into six chapters as given below:

First chapter deals with a brief introduction of microstrip antennas, along with its characteristics, feeding techniques used to excite the antenna, advantages and its disadvantages which is followed by a various review literature for the microstrip antennas.

The second chapter of thesis presents the design, development and analysis of compact, modified rectangular patch antenna. In veracity, a rectangular antenna is a poor radiator having narrow bandwidth and low gain. In this chapter rectangular patch is modified by introducing a truncation on opposite corners of rectangular patch and later by introducing slots which are gap coupled. The radiation parameters are simulated using IE3D software. By varying the dimension of slots and air gap between the patches the performance of these geometries is optimized to achieve best performance. It is established that by the introduction of truncated corners it not only improves the performance of antenna to great extent in terms of tuning of axial ratio bandwidth but with such modification, antenna now resonates efficiently at two different frequencies which can be control by changing the parameters of patch antenna to achieve broader bandwidth.

Next chapter three describes TRMSA with H slot loaded on thick substrate to increase the bandwidth. It is realized that by using thicker substrate there is a good enhancement in impedance bandwidth. The Truncated rectangular microstrip patch antenna with H slot on thick substrate gives good increment in impedance band width but other characteristics like gain and
efficiency are not improved much so to enhance the overall performance of patch a technique with defected ground structure is applied to achieve further improvement in impedance bandwidth and other characteristics. It was reported that defected ground structure was used to suppress higher order harmonics and to increase impedance bandwidth. In next step a novel approach is used to enhance the bandwidth of MSA patch using thick substrate and by inserting U slot and H slot in the truncated rectangular microstrip antenna. It is realized that the gain and directivity is improved to a large extent as compared to previous design. The obtained bandwidth and radiation pattern results suggest that proposed antenna geometry can be considered as a useful candidate for wireless communication system if its gain is somehow improved further.

Chapter four discuss the performance of a stacked TRMSA with horizontal slot in lower patch and vertical slot in upper patch to achieve wide bandwidth due to its multi resonance nature. In the next part radiation characteristics of stacked with defected ground structure is presented. From simulation study it is realized that with the introduction of slot in the ground plane the performance of antenna is significantly improved, improvement in wide impedance bandwidth almost twice as that of stacked truncated rectangular microstrip patch antenna covering the Wi-Max band of communication and gain is marginally improved. The radiation pattern is also found stable and the direction of maximum radiation is directed normal to patch geometry.

Fifth chapter presents a broadband monopole antenna with half U cut slot in rectangular patch on a coplanar wave guide (CPW) fed and radiation performance of parasitic patches gap couple with rectangular antenna with CPW fed are discuss and compared. Presently a single layer CPW fed antenna is widely used for wireless communications due to its many features such as wide band width, simple structure, a single metallic layer, less numbers of soldering points, and easily compatible with other circuits etc.

The results of simulator show that the designed antenna having very wide bandwidth, good gain & stable radiation characteristic which covers the bands for WLAN and WMAX applications.
Last Sixth chapter of this thesis gives the conclusion drawn from the presented work and suggestions for future research on microstrip patch antennas. At the end of this thesis a detailed bibliography deals with recently reported work in microstrip antenna fields is included.