1.1 MICROSTRIP PATCH ANTENNA

Microstrip antennas has been considered as the most exciting development in the history of electromagnetics in the 1950s due to their numerous advantages like simplicity, light weight, easy fabrication, low cost, low profile, integrability with millimeter and microwave circuits. The conventional microstrip antenna consists of a pair of parallel conducting layers separated by a dielectric medium, known as substrate. In this configuration, the upper conducting layer “patch” is the source of radiation where electromagnetic energy fringes off the edges of the patch and into the substrate. The lower conducting layer acts as a perfectly reflecting ground plane, bouncing energy back through the substrate and into free space. Physically, the patch is a thin conductor that is an appreciable fraction of a wavelength in extent. The patch which has resonant behaviour is responsible to achieve adequate bandwidth. Conventional patch designs yield few percent bandwidths. In most practical applications, patch antenna is rectangular or circular in shape however, in general any geometry is possible [1].

![Figure 1.1 Structure of microstrip patch antenna](image-url)
Microstrip antenna should be designed so that its maximum wave pattern is normal to the patch. This is accomplished by proper choice of mode of excitation beneath the patch. Generally, patch of microstrip antenna thickness is very thin in the range of $t << \lambda_o$ ($\lambda_o$ is free space wave length) and the height $h$ of dielectric material is between $0.003\lambda_o < h < 0.05\lambda_o$. For a rectangular path, the length $L$ of the element is usually $\lambda_o/3 < L < \lambda_o/2$. There are numerous substrate that can be used for the design of microstrip antenna and their dielectric constants are usually in the range of $2.2 < \varepsilon_r < 10$, where $\varepsilon_r$ is relative dielectric constant. The substrate whose size is thick and dielectric constant is in the range of lower end provides better efficiency and bandwidth but at the expense of large element size.

There are several techniques available to feed or transmit electromagnetic energy to a microstrip antenna. The four most popular feeding methods are the microstrip line, coaxial probe, aperture coupling and proximity coupling. In microstrip line feed, a conducting strip is connected directly to the edge of microstrip patch as shown in Figure 1.2.

![Figure 1.2 Microstrip line feeding rectangular microstrip antenna](image)

The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy
feeding scheme, since it provides ease of fabrication and simplicity in modelling 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 [1].

The coaxial feed or probe feed is a very common technique used for feeding microstrip patch antennas. As seen from Figure 1.3, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02\lambda_o$). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages.

![Figure 1.3 Coaxial feed rectangular microstrip antenna](image)

In aperture coupled feed technique, the radiating patch and microstrip feed line are separated by the ground plane as shown in Figure 1.4. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane. The coupling aperture is usually centred under the patch, leading to lower cross polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is
determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for the bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth (up to 21%).

![Diagram of Aperture coupled feed rectangular microstrip antenna](image)

Figure 1.4 Aperture coupled feed rectangular microstrip antenna

The proximity coupled feed technique is also called as the electromagnetic coupling scheme. As shown in Figure 1.5, 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 choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances. Matching can be achieved by controlling the length of the feed line and the width-to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment. Also, there is an increase in overall thickness of the antenna.
1.2 ADVANTAGES OF MICROSTRIP PATCH ANTENNA

The present-day portable wireless systems are versatile devices and need microstrip patch antennas operating at different frequencies for various transmission functions such as Bluetooth, Wi-Fi, GPS along with voice based services and high data rate transmission. Some of the key advantages of patch antennas are as follows:

- Small size
- Low profile
- Light weight
- Planar configuration
- Superior portability
- Less fabrication cost, hence can be manufactured in large quantity
- Easily integrable with monolithic and microwave integrated circuits
- Supports both, linear as well as circular polarization
- Capable of multi frequency operation
- Suitable for arrays
1.3 LIMITATIONS OF MICROSTRIP PATCH ANTENNA

The limitations of conventional microstrip patch antenna are:

- Narrow bandwidth
- Low gain
- Low efficiency
- Single operating band behaviour
- Cross polarization radiations
- Extraneous radiation from feeds and junctions
- Surface wave excitation

1.4 OBJECTIVE OF THE THESIS

The contemporary microstrip antennas must have wide impedance and axial ratio bandwidth, good radiation characteristics, better gain, improved polarization and multiband frequency operation with compact size. The objective of the thesis is to improve the limitations of conventional microstrip patch antenna. In the current work, several circularly polarized microstrip antennas are presented for modern wireless applications. These antennas are theoretically analyzed, designed and fabricated. The main objectives of the thesis are:

- To design and fabricate circularly polarized microstrip antennas for modern wireless applications
- To present equivalent circuit model of circularly polarized microstrip antenna
- To increase the impedance bandwidth of microstrip antenna
- To increase the axial ratio bandwidth of circularly polarized microstrip antenna
- To increase the gain of microstrip patch antenna
- To reduce the dimension of microstrip patch making compact antenna size
- To provide polarization diversity in microstrip antenna
- To design wideband circularly polarized microstrip antenna
- To design multiband circularly polarized microstrip antenna
• To reduce mutual coupling effect
• To provide frequency agility in microstrip patch antenna

1.5 ORGANIZATION OF THE THESIS

The overall thesis is organized into seven chapters. Chapter 1 provides a brief introduction about the microstrip patch antenna along with objectives of the thesis.

Chapter 2 provides the literature review and the theory involved in the research work. Literature available about the circularly polarized microstrip antennas is given and application of circularly polarized antennas in the field of wireless communication is presented.

Chapter 3 presents analysis of circularly polarized square patch antenna. Theoretical analysis using equivalent circuit approach and modal expansion cavity model is developed for L-slot circularly polarized square patch antenna and results are verified with simulated and experimental results.

Chapter 4 provides an in-depth design procedure for compact circularly polarized microstrip antennas. The prototype or the reference antenna and the design of its several variants are mentioned in this chapter. A superstrate loaded circularly polarized microstrip antenna for wireless applications is also presented in this chapter. The dielectric superstrate loading protects the antenna against environmental conditions such as rain, snow and fog with wider impedance bandwidth, improved efficiency and better gain characteristics.

Investigation of single-feed dual-band circularly polarized patch antenna with small-frequency ratio is presented in chapter 5. Theoretical analysis is presented for stacked microstrip antenna for multi-band wireless applications.

Chapter 6 presents stacked circularly polarized microstrip antennas for dual-band characteristics. Simulation and measurement results have been mentioned for the proposed structures. The antennas are presented for S and C band applications.
Chapter 7 summarizes all the important observations and results from previous chapters. Potential future work is also put forth.