Design of Slot Patch Antenna and Comparative Study of Feeds For C-Band Applications

Jitendra Velip
PG Student
Department of Electronics and Telecommunication Engineering
Goa College Of Engineering

Dr. H. G. Virani
Professor
Department of Electronics and Telecommunication Engineering
Goa College Of Engineering

Abstract

This research work presents design, simulation and comparison of microstrip patch antenna designed using different feed techniques. The Microstrip feed techniques are microstrip line feed, inset feed, coaxial feed, aperture coupled feed and proximity coupled feed. We have chosen to compare co-axial feed and microstrip inset feed due to the advantage that it can be easily fabricated and simplicity in modelling as well as impedance matching. The objective of this paper is to design a rectangular microstrip patch antenna which operates in C-band at 5.2 GHz. Microstrip antennas are most suited for aerospace and mobile applications etc. They can be designed in variety of shapes. Therefore, method of moments based IE3D software is used to design a Microstrip Patch Antenna with enhanced gain and bandwidth. IE3D is an integrated full-wave electromagnetic simulation and optimization package for the analysis and design of 3D and planar microwave circuits. The IE3D has become the most versatile, easy to use, efficient and accurate electromagnetic simulation tool. It computes most of the useful quantities of interest such as radiation pattern, input impedance and gain etc. The microstrip patch antenna is designed and simulated using high frequency simulation software IE3D and it is designed to operate in C-band frequency range (4GHz-8GHz). These antennas are designed using RT-duroid dielectric substrate with the permittivity $\varepsilon_r=2.2$. In this analysis, we have compared the antenna parameters such as gain, impedance, reflection coefficient, VSWR and further the performance of these two feed techniques discussed. The antenna has been designed for the range 5-6 GHz; hence this antenna is highly suitable for C-band applications wimax applications, and other wireless systems.

Keywords: C-Band, IE3D, Micro strip Patch, Wimax, WLAN

I. INTRODUCTION

In this paper the design of Rectangular Microstrip Patch antenna which operates at 5.2 GHz has been discussed in details. Microstrip patch antenna has been received tremendous attention since the last two decades in Wimax applications. Microstrip antenna is a printed type antenna consisting of a dielectric substrate sandwiched in between a ground plane and a patch. In this project Microstrip patch antenna technology is used for designing of the antenna suitable for Wimax because of its commercial reality with applications in wide variety of microwave systems, Personnel communication system(PCS), wireless local area network (WLAN) etc. These are preferred over other types of radiators because of its low profile and light weight but its major drawback is its narrow bandwidth and low gain[1]. This is one of the problems that researchers around the world have been trying to overcome.

Modern wireless communication system requires low profile, light weight, high gain, and simple structure antennas to assure reliability, mobility, and high efficiency characteristics [1, 2]. The key features of a microstrip antenna are relative ease of construction, light weight, low cost and either conformability to the mounting surface or, an extremely thin protrusion from the surface [2, 3]. This antenna provides all of the advantages of printed circuit technology. These advantages of microstrip antennas make them popular in many wireless communication applications such as satellite communication, radar, medical applications, etc [3]. Choosing the design parameters (dielectric material, height and frequency, etc) is important because antenna performance depends on these parameters. Radiation performance can be improved by using proper design structures. The use of high permittivity substrates can miniaturize microstrip antenna size. Thick substrates with lower range of dielectric offer better efficiency and wide bandwidth but it requires larger element. And it depends on the feeding technique the parameters like VSWR return loss bandwidth will vary [1].

This research provides a way to choose the effective feeding technique between transmission lines and Microstrip patch antenna. It also compares the characteristics of pin feed and inset feed techniques. By comparing the antenna parameters the best feeding technique will be selected for the design of microstrip patch array antenna. These designed antennas are potential candidate for the C-band wireless applications due to the simplicity in structure, ease of fabrication, high gain and high efficiency [4].Various parameters of the microstrip patch antennae, design considerations, performance of different feed techniques are discussed in the subsequent sections.
II. MICROSTRIP PATCH ANTENNA

Microstrip antenna consists of very small conducting patch built on a ground plane separated by dielectric substrate. The patch is generally made of conducting material such as copper or gold and can take any possible shape [1]. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. Some of the other configurations used are complex to analyze and require large numerical computations. In its most fundamental form, a microstrip patch antennae consist of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side [1] is illustrated in figure 1.

![Fig. 1: Structure of Microstrip Patch Antenna](image)

Microstrip patch antennae radiate primarily because of the fringing fields between the patch edge and the ground plane. For a rectangular patch, the length $L$ of the patch is usually $0.3333\lambda_0 < L < 0.5 \lambda_0$, where $\lambda_0$ is the free space wavelength [1]. The patch is selected to be very thin such that $t << \lambda_0$ (where $t$ is the thickness of patch). The height $h$ of the dielectric substrate is usually $0.003 \lambda_0 \leq h \leq 0.05 \lambda_0$. The dielectric constant of the substrate is typically in the range $1.2 \leq \varepsilon_r \leq 12$.

III. FEED TECHNIQUES

Microstrip patch antennae can be fed by a variety of different methods [1]. The four most popular feed techniques used for the microstrip patch are:

1) Microstrip inset feed
2) Coaxial probe feed
3) Aperture coupling
4) Proximity coupling

A. Microstrip Inset Feed Design:

In this type of feeding technique, a conducting strip connected directly to the edge of the microstrip patch. 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 on the same substrate to provide a planar structure. 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. However, this method of feeding is very widely used because it is very simple to design and analyze, and very easy to manufacture.

![Fig. 2: Geometry Of Microstrip Antenna With Inset Feed](image)
B. **Coaxial Feed (Pin Feed) Design:**

The Coaxial feed or pin feed is a very common technique used for feeding Microstrip patch antennas. 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 λ0) [1]. Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems.

![Image](image.png)

**Fig. 3: Geometry of Microstrip Antenna with Probe Feed**

**IV. DESIGN CONSIDERATIONS**

Microstrip patch antenna consists of very thin metallic strip (patch) placed on ground plane where the thickness of the metallic strip is restricted by t<< λ0 and the height is restricted by 0.0003λ0 ≤ h ≤ 0.05λ0. The microstrip patch is designed so that its radiation pattern maximum is normal to the patch. For a rectangular patch, the length L of the element is usually λ0 /3 <L< λ0 /2 [1].

### A. Design of Microstrip Patch Antenna:

The dimensions of the proposed antenna are calculated by using transmission line model. The effective relative dielectric constant (εeff) of the substrate is given by

\[
ε_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + \frac{12 + \frac{H}{W}}{\sqrt{2}}\right)
\]

(1.1)

Where,

\( W \) - Width of the patch
\( H \) - Height of the substrate

The width of the patch element is given by

\[
W = \frac{v_0}{2fr} \sqrt{\frac{2}{\varepsilon_{\text{eff}} + 1}}
\]

(1.2)

Where,

\( fr \) - Resonance frequency
\( v_0 \) - Free space velocity

The length of the patch element is given by

\[
L = \frac{v_0}{2fr\sqrt{\varepsilon_{\text{eff}}}} - 2ΔL
\]

(1.3)

Where,

\( L \) = Length of the patch

The extension length of the patch element given as,

\[
ΔL = H \times 0.412 \frac{(ε_{\text{eff}} + 0.31)(\frac{W}{H} + 0.264)}{(ε_{\text{eff}} - 0.258)(\frac{W}{H} + 0.8)}
\]

(1.4)

### B. Return Loss:

A frequency range of 5-6 GHz is chosen as the resonant frequency which is suitable for C-band applications. Figure 4 shows return loss plot for the inset feed technique. From the figure it is clear that the return loss at the resonant frequency 5.2 GHz is -21 dB.
Fig. 4: Return Loss for Inset Feed

The figure below shows the return loss plot for pin feed technique. The return loss achieved here at the resonant frequency 5.2 GHz is -32 dB. Hence, it is clear that the losses associated with inset feed is more compared to pin feed technique.

Fig. 5: Return Loss for Pin Feed

C. Radiation Pattern Plots:
Since a microstrip patch antenna radiates normal to its patch Surface, the elevation pattern for $\varphi = 0$ and $\varphi = 90$ degrees would be important. Figure 6 and Figure 7 shows the gain plot for inset feed technique and Pin feed technique respectively. From the below figures it is clear that gain is maximum for pin feed technique and its gain 5 dB. Generally the gain should be above 6 dB which will be achieved when we use array of antenna.

Fig. 6: Gain of Microstrip Patch Antenna Inset Feed Is At F=5.2 Ghz
Fig. 7: Gain of Microstrip patch antenna probe feed is at f=5.2 GHz

D. Impedance:
The theory of maximum power transfer states that for the transfer of maximum power from a source with fixed internal impedance to the load, the impedance of the load must be the same of the source. The following are the impedance plot. Figure 8 and Figure 9 shows impedance plot for the inset feed and pin feed technique respectively.

Fig. 8: Input Impedance of Inset Feed At 5.2ghz Is 48.88

Fig. 9: Input Impedance of Probe Feed At 5.2ghz Is 48.0288

From the above figures we can infer that impedance is close to perfectly matched in case of pin feed and inset feed at the resonant frequency.
E. VSWR:
When a transmitter is connected to an antenna by a feed line, the impedance of the antenna and feed line must match exactly for maximum possible energy transfer from the feed line to the antenna. When an antenna and feed line do not have matching impedances, some of the electrical energy cannot be transferred from the feed line to the antenna. Energy not transferred to the antenna is reflected back towards the transmitter. It is the interaction of these reflected waves with forward waves which causes standing wave patterns. Ideally, VSWR must lie in the range of 1-2 [1]. Figure 10 and Figure 11 shows the VSWR plot for Line feed and pin feed respectively. It is clear that in both cases the VSWR value lies in the acceptable range.

![VSWR Plot](image)

**Fig. 10: VSWR of Microstrip Patch Antenna Inset Feed Is 1.19 at F=5.2 Ghz**

![VSWR Plot](image)

**Fig. 11: VSWR Of Microstrip Patch Antenna Probe Feed Is 1.05 At F=5.2 Ghz**

Table 1 shows the comparative for line feed and Pin feed technique which gives simulated values for the parameters like return loss, gain, impedance, VSWR. In which the pin feed technique has high gain, good impedance and high VSWR.

<table>
<thead>
<tr>
<th>Patch parameters</th>
<th>Inset feed</th>
<th>Pin feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return loss</td>
<td>-21 dB</td>
<td>-32 dB</td>
</tr>
<tr>
<td>Gain</td>
<td>4.48</td>
<td>5</td>
</tr>
<tr>
<td>Impedance</td>
<td>48.88Ω</td>
<td>48.028Ω</td>
</tr>
</tbody>
</table>
V. CONCLUSION

The unique feature of this microstrip antenna is its simplicity to get higher performance. In many applications essentially in radar and satellite communication, it is necessary to design antennas with very high directive characteristics to meet the demand of long distance communication. The inset feed and pin feed microstrip patch antennae has been designed and simulated using high frequency simulation software IE3D. The simulation results show that the pin feed excitation technique provides more gain and better VSWR compared to inset feed excitation technique. Also the main advantage of this feeding technique is that feed can be given anywhere inside the patch which makes easier fabrication compared to inset feed technique. In future microstrip patch antenna array will be designed for the same operating frequency range in order to achieve the maximum gain which is highly suitable for C-band applications.

REFERENCES