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Design of Cavity Model Microstrip Patch Antenna

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Abstract

Design and realization of LINEARLY POLARIZED AND DUAL FREQUENCY RECTANGULAR MICROSTRIP PATCH ANTENNA in S band at 2.42 GHz is reported in this project paper. It is shown that the design adopted for different antennas is quite accurate. By using the conventional MIC fabrication technology compact, light weight microstrip antennas can be realized. The desired narrow band is achieved for the microstrip antennas. Antennas are designed and fabricated on the substrate of dielectric constant 4.22 and thickness 1.6mm. Simulation is done using the microwave software to achieve the desired results.At a frequency of 2.42 GHZ return loss is -27.0 dB. Also from smith chart it is seen that at a frequency of 2.42 GHz impendence offered by the antenna is resistive as well as inductive. From VSWR plot it is seen that VSWR offered by the antenna is 1.1 at a frequency of 2.42 GHz.

Keywords: Cavity model, VSWR, return loss, smith chart.

INTRODUCTION

na consists of conducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations. The early work of Munson on micro strip antennas for use as a low profile flush mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years, on these antennas shows the importance gained by them. The micro strip antennas are the present day antenna designer's choice.

Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. Other configurations are complex to analyze and require heavy numerical computations. A microstrip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. Various parameters of the microstrip antenna and its design considerations were discussed in the subsequent chapters. The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna.

Microstrip patch antenna used to send onboard parameters of article to the ground while under operating conditions. The aim of the thesis is to design and fabricate an inset-fed rectangular Microstrip Patch Antenna and study the effect of antenna dimensions Length (L) , Width (W) and substrate parameters relative Dielectric constant (εr), substrate thickness (t) on the Radiation parameters of Bandwidth and Beam-width.

Antenna Characteristics

An antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves. There are several important antenna characteristics that should be considered when choosing an antenna for your application as follows:

- Antenna radiation patterns
- Power Gain
- Directivity
- Polarization

The application of this type of antennas started in early 1970's when conformal antennas were required for missiles. Rectangular and circular micro strip resonant patches have been used extensively in a variety of array configurations. A major contributing factor for recent advances of microstrip antennas is the current revolution in electronic circuit miniaturization brought about by developments in large scale integration. As conventional antennas are often bulky and costly part of an electronic system, micro strip antennas based on photolithographic technology are seen as an engineering breakthrough.

Introduction

In its most fundamental form, a Microstrip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 2.1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

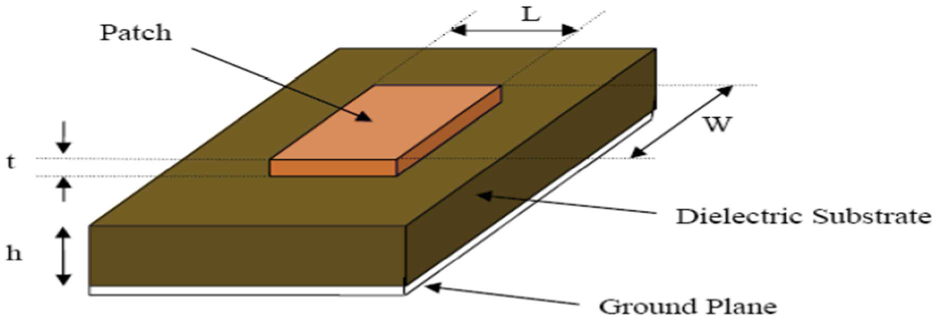

Figure 2.1 Structure of a Microstrip Patch Antenna

Microstrip antennas are attractive due to their light weight, conformability and low cost.These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. The radiation properties of micro strip structures have been known since the mid 1950's.

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape as shown in Figure 2.2.

For a rectangular patch, the length L of the patch is usually $0.3333\lambda o< L < 0.5\ \lambda o$, where λo is the free-space wavelength. The patch is selected to be very thin such that $t << \lambda o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\ \lambda o \leq h \leq 0.05\ \lambda o$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$.

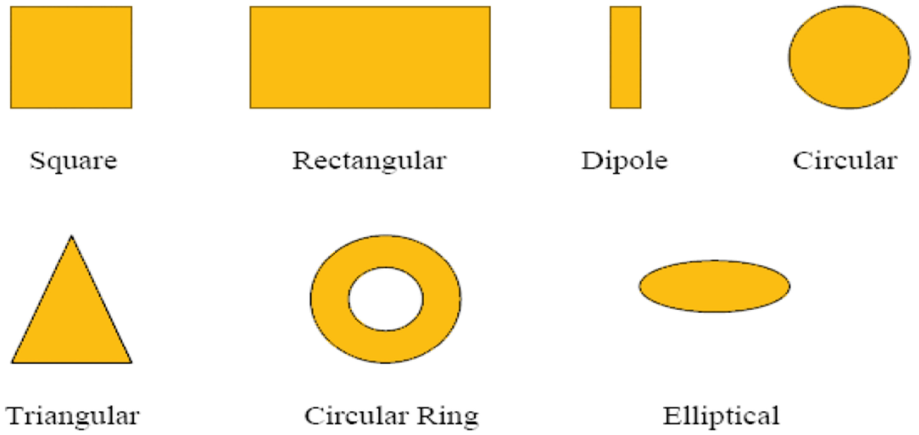

Figure 2.2 Common shapes of microstrip patch elements

Microstrip 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 [5]. However, such a configuration leads to a larger antenna size. In order to design a compact Microstrip 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.

Advantages and Disadvantages

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc... The telemetry and communication antennas on missiles need to be thin and conformal and are often in the form of Microstrip patch antennas. Another area where they have been used successfully is in Satellite communication. Some of their principal advantages are given below:

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

Microstrip patch antennas suffer from more drawbacks as compared to conventional antennas. Some of their major disadvantages are given below:

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

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

Feed 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 microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch [5]. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling(both non-contacting schemes).

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- Power Gain
- Directivity
- Polarization

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Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch as shown in Figure 2.3. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

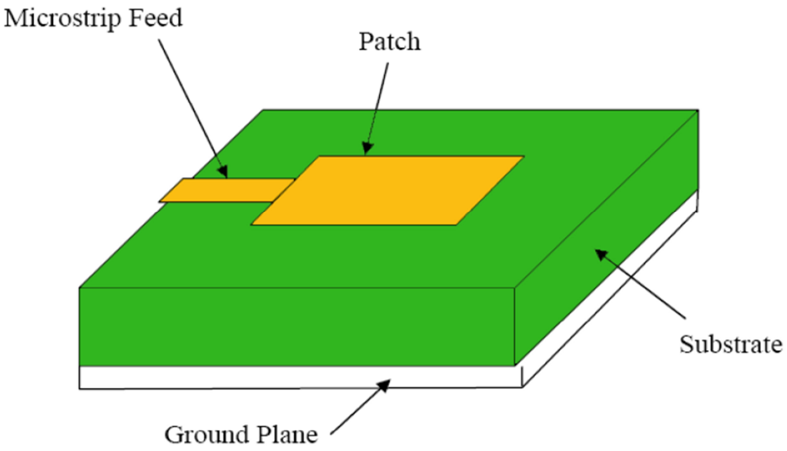


Figure 2.3 Microstrip Line Feed

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 [5]. The feed radiation also leads to undesired cross polarized radiation.

Coaxial Feed

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure 2.4, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

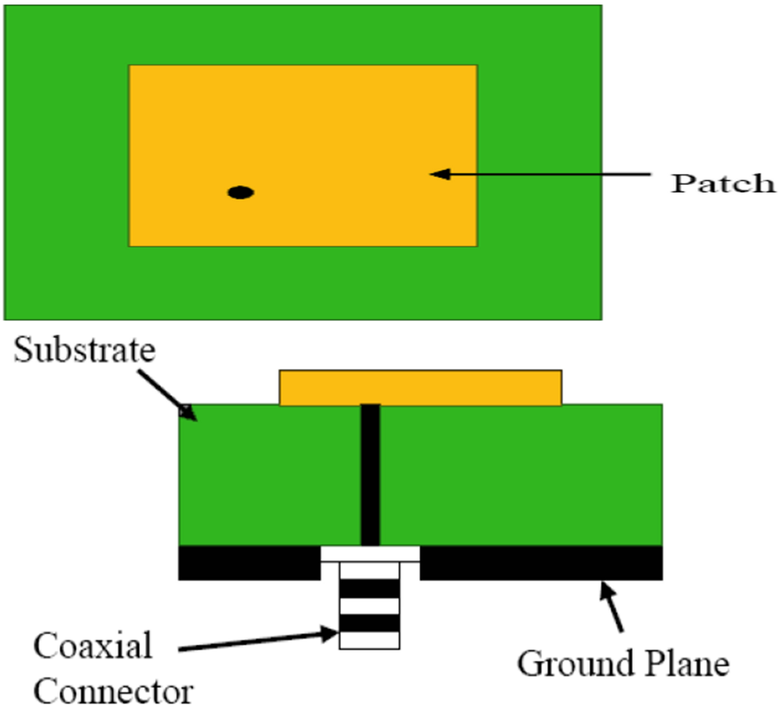


Figure 2.4 Probe fed Rectangular Microstrip Patch Antenna

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, a 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 >0.02λo). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems [9]. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these issues.

Methods of Analysis

The preferred models for the analysis of Microstrip patch antennas are the transmission line model, cavity model, and full wave model [5] (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 treatsingle 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.

In order to operate in the fundamental $TM10$ 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 $TM10$ 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 2.10 shown below, the microstrip patch antenna is represented by two slots, separated by a transmission line of length L and open circuited at both the ends. Along the width of the patch, the voltage is maximum and current is minimum due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane.

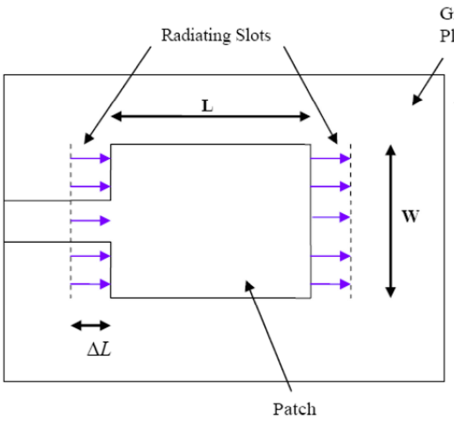


Figure 2.10 Top View of Antenna

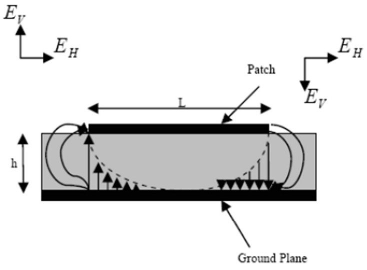


Figure 2.11 Side View of Antenna

It is seen from Figure 2.11 that the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is λ/2 long and hence they cancel each other in the broadside direction. The tangential components (seen in Figure 2.11), 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 Hammerstad [13] as:

$$\Delta L = 0.412h\frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)}$$

The effective length of the patch L_{eff} now becomes:

$$L_{eff} = L + 2\Delta L$$

For a given resonance frequency f_o, the effective length is given by [9] as:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

For a rectangular Microstrip patch antenna, the resonance frequency for any TM_{mn} mode is given by James and Hall [14] as:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}}$$

Where m and n are modes along L and W respectively.

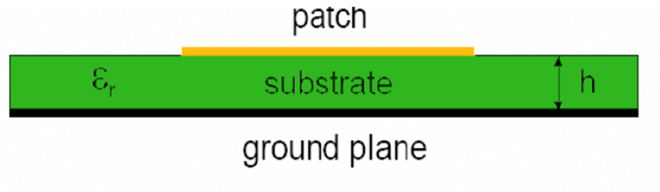
For efficient radiation, the width W is given by Bahl and Bhartia [15] as:

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

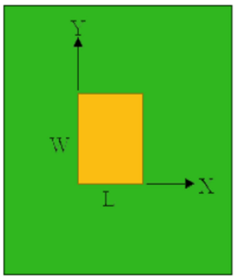
The cavity model assumes that the height to width ratio (i.e. height of substrate and width of the patch) is very small and as a result of this the attractive mechanism dominates and causes most of the charge concentration and the current to be below the patch surface. Much less current would flow on 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 [5].

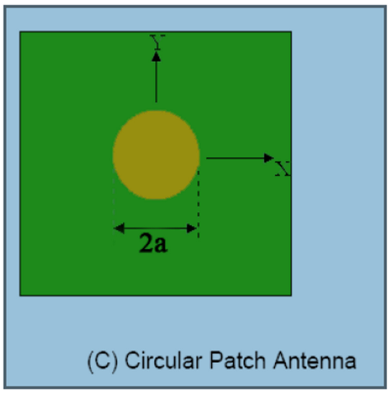
RECTANGULAR PATCH ANTENNA

Microstrip antennas are among the most widely used types of antennas in the microwave frequency range, and they are often used in the millimeter-wave frequency range as well [1, 2, 3].(Below approximately 1 GHz, the size of a microstrip antenna is usually too large to be practical, and other types of antennas such as wire antennas dominate). Also called patch antennas, microstrip patch antennas consist of a metallic patch of metal that is on top of a grounded dielectric substrate of thickness *h*, with relative permittivity and permeability εr and μr as shown in Figure 3.1 (usually μr=1). The metallic patch may be of various shapes, with rectangular and circular being the most common, as shown in Figure 3.1.



(a)Microstrip Patch Antenna





(C) Circular Patch Antenna

Fig. 3.1/ Rectangular & Circular Patch Antenna

Most of the discussion in this section will be limited to the rectangular patch, although the basic principles are the same for the circular patch. (Many of the CAD formulas presented will apply approximately for the circular patch if the circular patch is modeled as a square patch of the same area.) Various methods may be used to feed the patch, as discussed below. One advantage of the microstrip antenna is that it is usually low profile, in the sense that the substrate is fairly thin. If the substrate is thin enough, the antenna actually becomes "conformal," meaning that the substrate can be bent to conform to a curved surface (e.g., a cylindrical structure). A typical substrate thickness is about 0.02 λ0. The metallic patch is usually fabricated by a photolithographic etching process or a mechanical milling process, making the construction relatively easy and inexpensive (the cost is mainly that of the substrate material). Other advantages include the fact that the microstrip antenna is usually lightweight (for thin substrates) and durable.

Disadvantages of the microstrip antenna include the fact that it is usually narrowband, with bandwidths of a few percent being typical.

Basic Principles of Operation

The metallic patch essentially creates a resonant cavity, where the patch is the top of the cavity, the ground plane is the bottom of the cavity, and the edges of the patch form the sides of the cavity. The edges of the patch act approximately as an open-circuit boundary condition. Hence, the patch acts approximately as a cavity with perfect electric conductor on the top and bottom surfaces, and a perfect "magnetic conductor" on the sides. This point of view is very useful in analyzing the patch antenna, as well as in understanding its behavior. Inside the patch cavity the electric field is essentially *z* directed and independent of the z coordinate. Hence, the patch cavity modes are described by a double index (*m*, *n*). For the (*m*, *n*) cavity mode of the rectangular patch the electric field has the form

$$E_z(x,y) = A_{mn}\cos\left(\frac{m\pi x}{L}\right)\cos\left(\frac{n\pi y}{W}\right)$$

Where *L* is the patch length and *W* is the patch width. The patch is usually operated in the (1, 0) mode, so that *L* is the resonant dimension, and the field is essentially constant in the *y* direction. The surface current on the bottom of the metal patch is then x directed, and is given by For this mode the patch may be regarded as a wide microstrip line of width *W*, having a resonant length *L* that is approximately one-half wavelength in the dielectric. The current is maximum at the centre of the patch, $x = L/2$, while the electric field is maximum at the two "radiating" edges, $x = 0$ and $x = L$. The width *W* is usually chosen to be larger than the length ($W = 1.5\ L$ is typical) to maximize the bandwidth, since the bandwidth is proportional to the width. (The width should be kept less than twice the length, however, to avoid excitation of the (0,2) mode.)

At first glance, it might appear that the microstrip antenna will not be an effective radiator when the substrate is electrically thin, since the patch current in (2) will be effectively shorted by the close proximity to the ground plane. If the modal amplitude $A10$ were constant, the strength of the radiated field would in fact be proportional to h. However, the Q of the cavity increases as h decreases (the radiation Q is inversely proportional to h). Hence, the amplitude $A10$ of the modal field at resonance is inversely proportional to h.

Resonant Frequency

The resonance frequency for the (1, 0) mode is given by

$$f_0 = \frac{c}{2L_e\sqrt{\varepsilon_r}}$$

where c is the speed of light in vacuum. To account for the fringing of the cavity fields at the edges of the patch, the length, the effective length Le is chosen as

$Le = L + 2\Delta L$

The Hammerstad formula for the fringing extension is [1]

Where

Where

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2}$$

$$\frac{\Delta L}{h} = 0.412\left(\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right)$$

$$e_r = \frac{P_{sp}}{P_{Total}} = \frac{P_{sp}}{P_c + P_d + + P_{sw} + P_{sp}}$$

Where $P\ sp$ is the power radiated into space, and the total input power $P\ total$ is given as the sum of Pc - the power dissipated by conductor loss, Pd- the power dissipated by dielectric loss, and Psw - the surface-wave power.

The dielectric and conductor Q factors are given by

$$e_r = \left(\frac{Q_{sp}}{Q_{Total}}\right)^{-1}$$

Where tanδd is the loss tangent of the substrate and Rs is the surface resistance of the patch and ground plane metal at radian frequency $\omega = 2\pi f$, given by where ζ is the conductivity of the metal.

The space-wave Q factor is given approximately as [6]

$$Q_{sp} = \frac{3}{16}\left(\frac{\varepsilon_r}{pc_1}\right)\left(\frac{L}{W}\right)\left(\frac{1}{h/\lambda_0}\right)$$

Where

$$c_1 = 1 - \frac{1}{n_1^2} + \frac{2/5}{n_1^4}$$

$$p = 1 + \frac{a_2}{10}(k_0W)^2 + \left(a_2^2 + 2a_4\right)\left(\frac{3}{560}\right)(k_0W)^4 + c_2\left(\frac{1}{5}\right)(k_0L)^2$$
$$+ a_2c_2\left(\frac{1}{70}\right)(k_0W)^2(k_0L)^2$$

with a_2= − 0.16605, $a4$=0.00761, and $c2$ = - 0.0914153.

The surface-wave Q factor is related to the space-wave Q factor as where *ersw* is the radiation efficiency accounting only for surface-wave loss.

This efficiency may be accurately approximated by using the radiation efficiency of an infinitesimal dipole on the substrate layer [6].

A plot of radiation efficiency for a resonant rectangular patch antenna with W / L = 1.5 on a substrate of relative permittivity ε*r* = 2.2 or ε*r* = 10.8 is shown in Figure 2.5. The conductivity of the copper patch and ground plane is assumed to be ζ = 3.0×10^7 [S/m] and the dielectric loss tangent is taken as tanδd = 0.001. The resonance frequency is 5.0 GHz. (The result is plotted versus normalized (electrical) thickness of the substrate, which does not involve frequency

Bandwidth

The bandwidth increases as the substrate thickness increases (the bandwidth is directly proportional to *h* if conductor, dielectric, and surface-wave losses are ignored). However, increasing the substrate thickness lowers the *Q* of the cavity, which increases spurious radiation from the feed, as well as from higher-order modes in the patch cavity. Also, the patch typically becomes difficult to match as the substrate thickness increases beyond a certain point (typically about 0.05 λ0). This is especially true when feeding with a coaxial probe, since a thicker substrate results in a larger probe inductance appearing in series with the patch impedance. However, in recent years considerable effort has been spent to improve the bandwidth of the microstrip antenna, in part by using alternative feeding schemes. The aperture-coupled feed is one scheme that overcomes the problem of probe inductance, at the cost of increased complexity.

Lowering the substrate permittivity also increases the bandwidth of the patch antenna.

However, this has the disadvantage of making the patch larger. Also, because the *Q*of the patch cavity is lowered, there will usually be increased radiation from higher-order modes, degrading the polarization purity of the radiation.

By using a combination of aperture-coupled feeding and a low-permittivity foam substrate, bandwidths exceeding 25% have been obtained. The use of stacked patches (a parasitic patch located above the primary driven patch) can also be used to increase bandwidth even further, by increasing the effective height of the structure and by creating a double-tuned resonance effect.

Neglecting conductor and dielectric loss yields a bandwidth that is proportional to the substrate thickness *h*.

Input Impedence

A variety of approximate models have been proposed for the calculation of input impedance for a probe-fed patch. These include the transmission line method [9], the cavity model [10], and the spectral-domain method [11]. These models usually work well for thin substrates, typically giving reliable results for *h* / λ0 < 0.02. Commercial simulation tools using FDTD, FEM, or MoM can be used to accurately predict the input impedance for any substrate thickness. The cavity model has the advantage of allowing for a simple physical CAD model of the patch to be developed, as shown in

MICROSTRIP PATCH ANTENNA DESIGN AND RESULTS

Design Specifications

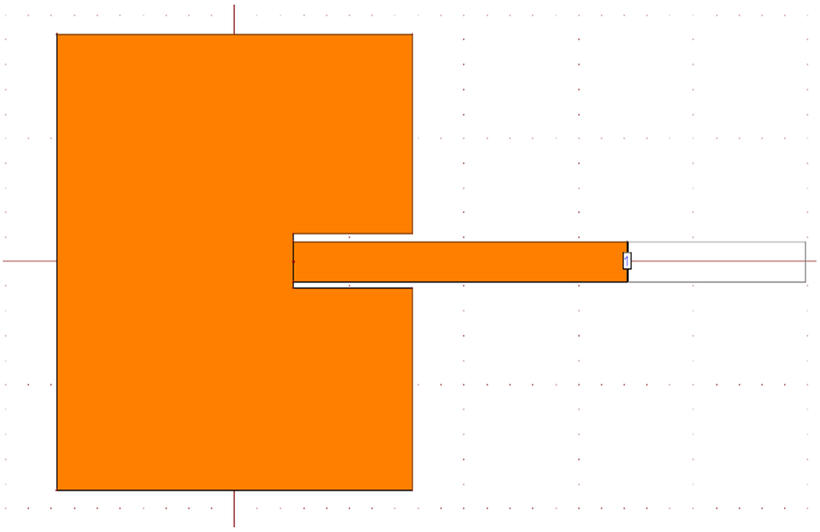
The three essential parameters for the design of a rectangular Microstrip Patch Antenna:

- Frequency of operation (*fo*): The resonant frequency of the antenna must be selected appropriately. The Mobile Communication Systems uses the frequency range from 2100-5600 MHz. Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for my design is 2.4 GHz.
- Dielectric constant of the substrate (ε*r*): The dielectric material selected for our design is RT Duroid which has a dielectric constant of 2.45. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.
- Height of dielectric substrate (*h*): For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.58 mm.

Hence, the essential parameters for the design are:

- *fo* = 2.4 GHz
- ε*r* = 2.45
- *h* = 1.58mm

Microstrip patch antenna designed using IE3D



Step 1: Calculation of the Width (*W*):

The width of the Microstrip patch antenna is given as:

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Substituting *c* = 3.00e+008 m/s, ε*r* = 2.45 and *fo* = 2.4 GHz, we get:

***W* = 0.0475 m = 47.5 mm**

Step 2: Calculation of Effective dielectric constant (ε*reff*):

The effective dielectric constant is:

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

Substituting ε*r* = 2.45, *W* = 47.5 mm and *h* = 1.58 mm we get:

ε*reff* = **2.3368**

Step 3: Calculation of the Effective length (*Leff*):

The effective length is:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

Substituting $\varepsilon reff$ = 2.3368, c = 3.00e+008 m/s and fo = 2.4 GHz we get:
$Leff$ = **0.**0406 m = 40.625 mm

Step 4: Calculation of the length extension (Δ*L*):
The length extension is:

$$\Delta L = 0.412h\frac{\left(\varepsilon_{reff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)}$$

Substituting $\varepsilon reff$ = 2.3668, W = 47.5 mm and h = 1.58 mm we get:
Δ*L* = 0.81 mm

Step 5: Calculation of actual length of patch (*L*):
The actual length is obtained by:
Substituting $Leff$ = 40.625 mm and Δ*L* = 0.81 mm we get:
***L* = 39 m = 39 mm**

Step 6: Calculation of the ground plane dimensions (*Lg* and *Wg*):
The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown by [9] that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:
Lg = 6*h* + L = 6(1.5) + 39 = 48 mm
Wg = 6*h* + W = 6(1.5) + 47.5 = 56.5 mm

Step 7: Determination of Inset feed depth (y0):
An inset-fed type feed is to be used in this design. As shown in Figure 4.1, the feed depth is given by y0. The feed point must be located at that point on the patch, where the input impedance is 50 ohms for the resonant frequency. Hence, a trial and error method is used to locate the feed point.

In this case we use PSO to obtain the optimum feed depth, where the return loss (R.L) is most negative (i.e. the least value). According to [5] there exists a point along the length of the patch which gives the minimum return loss.
Rin (y = y 0) = Rin (y = 0) cos4 (π*y0/L)
Where, Rin (y=0) = 0.5 * (G1 ± G12)

$$Z_c = \begin{cases} \dfrac{60}{\sqrt{\epsilon_{reff}}}\ln\left[\dfrac{8h}{W_0}+\dfrac{W_0}{4h}\right], & \dfrac{W_0}{h}\le 1 \\[2ex] \dfrac{120\pi}{\sqrt{\epsilon_{reff}}\left[\dfrac{W_0}{h}+1.393+0.667\ln\left(\dfrac{W_0}{h}+1.444\right)\right]}, & \dfrac{W_0}{h}>1 \end{cases}$$

Where,

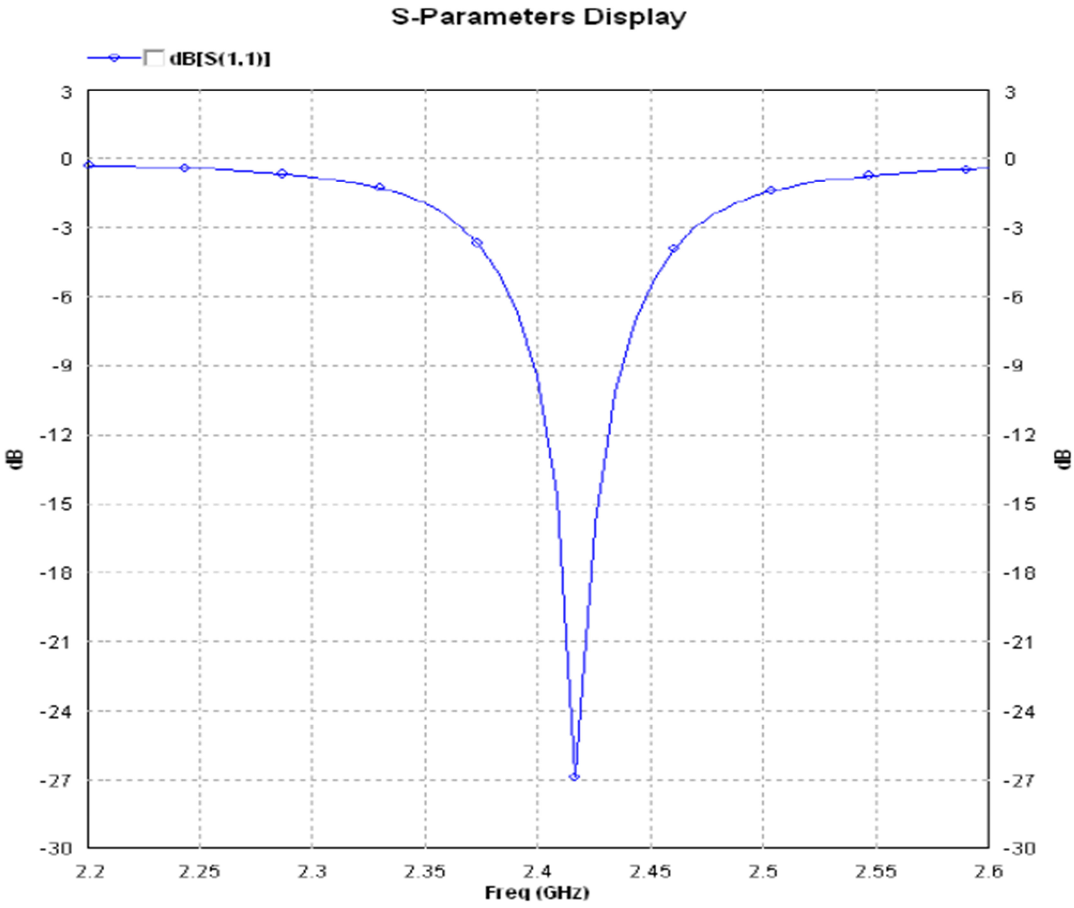
$$G_1 = \begin{cases} \dfrac{1}{90}\left(\dfrac{W}{\lambda_0}\right)^2 & W \ll \lambda_0 \\[2ex] \dfrac{1}{120}\left(\dfrac{W}{\lambda_0}\right) & W \gg \lambda_0 \end{cases}$$

$$G_{12} = \frac{1}{120\pi^2} \int_0^{\pi} \left[\frac{\sin\left(\frac{k_0 W}{2} \cos\theta\right)}{\cos\theta} \right]^2 J_0\left(k_0 L \sin\theta\right) \sin^3\theta \, d\theta$$

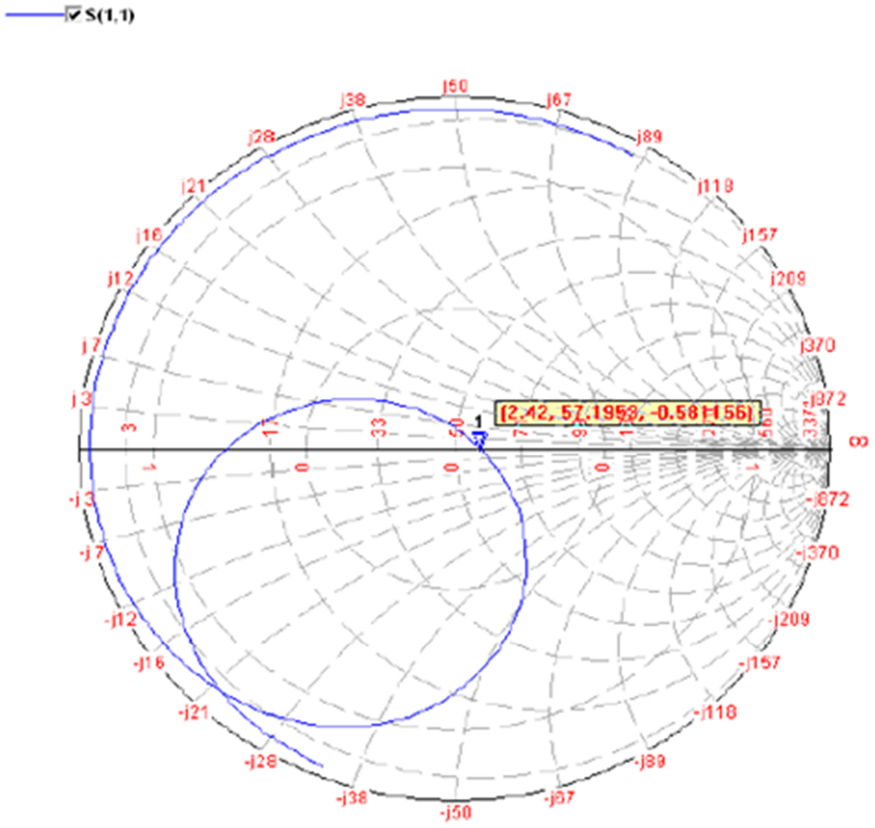
Using the first equation (assuming that ZC in the second equation is 50 Ω) where Rin (y=y0) = 50 Ω we get:
y0 = 13 mm

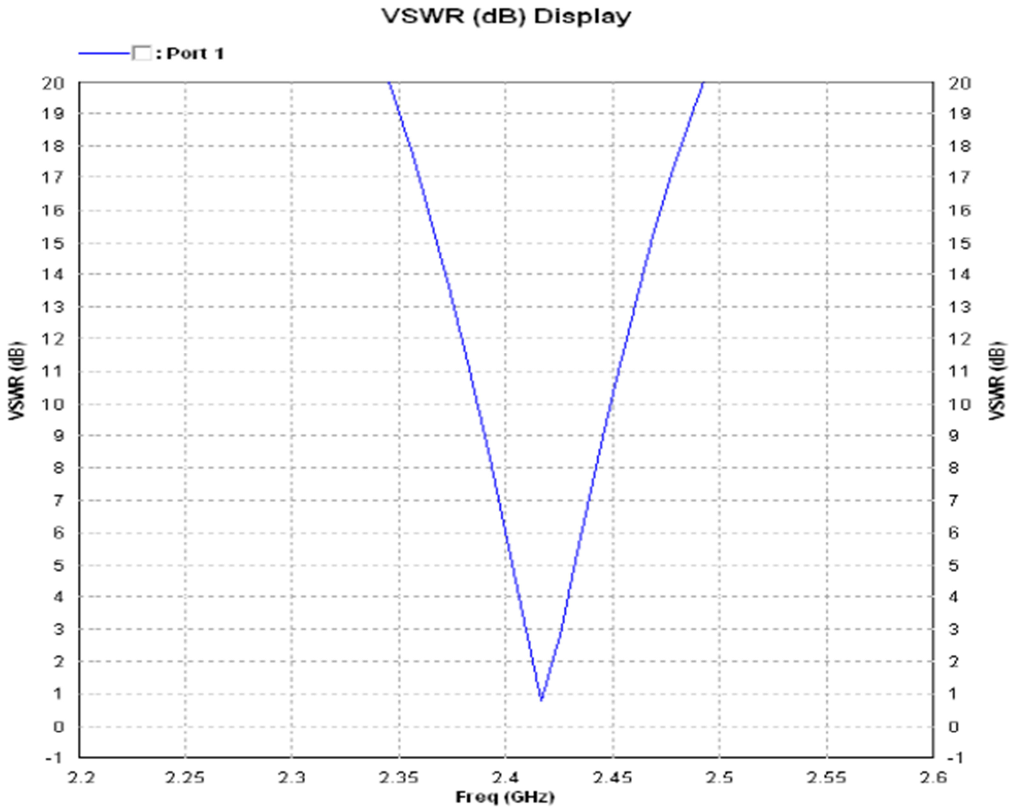
4.2 Simulation Setup and Results

The software used to model and simulate the Microstrip patch antenna is Zeland Inc's IE3D. IE3D is a full-wave electromagnetic simulator based on the method of moments. It analyzes 3D and multilayer structures of general shapes. It has been widely used in the design of MICs, RFICs, patch antennas, wire antennas, and other RF/wireless antennas. It can be used to calculate and plot the *S*11 parameters, VSWR, current distributions as well as the radiation patterns.



Smith Chart display





CONCLUSION

The optimization of the Microstrip Patch is partially realized. The future scope of work revolves around increasing the efficiency of the antenna. Realization of results can be concluded with the fabrication of the patch of the Microstrip Patch Antenna. Microstrip antenna one of the most innovative topics in Antenna theory today. As started earlier microstrip antenna find use in airborne and spacecraft systems mainly owing to their low profile, conformal nature and easy integration with microwave integrated circuits. This trend is likely to continue because of the characteristics of microstrip antenna quake tem very appealing from a system perspective. There has been research and development in recent years that has gone towards improved the dielectrical characteristic of microstrip antenna.

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