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Analysis and Design of Rectangular Microstrip Patch Antenna using HFSS

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Abstract

The efficiency of a method of moments procedure for microstrip antennas is strongly dependent on the convergence of the Inverse Fourier Transformation (IFT) from the spectral to the spatial domain.In the cylindrical case, the calculation of the two-dimensional Green's functions stays inherently time-consuming. In the planar case, Green's function can be reduced to a one-dimensional function.In HFSS gives the three dimension and bending technigues is very easy compared to the other softwares.It can be used to calculate the s parameter and resonant frequency .

Keywords: microstrip antenna,inverse fourier transform,green function ,HFSS(high frequency structure stimulaor)
Reviewed by* **ICETSET'16 *organizing committee*

1. Introduction

An antenna is an electrical conductor or a system of conductors which is "that part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves"**[1].** A Microstrip antenna consists of a thin metallic conductor which is bonded to thin grounded dielectric substrates. 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. The size miniaturization of Microstrip patch antenna is crucial in many of the modern day practi1cal applications, like that of Wireless local area networks(WLAN's), mobile cellular handsets, global position satellites (GPS) and other upcoming wireless terminals. Patch antennas play a very significant role in today's world of wireless communication systems.

2. Microstrip patch antenna:

2.1 Description And Design Principle

Microstrip patch antennas possess a very high antenna quality factor (Q) which represents the losses associated with the antenna where a large Q would lead to a narrow bandwidth and low efficiency. The factor Q can be reduced by increasing the thickness of the dielectric substrate but as the thickness will increase there will be a simultaneous increase in the fraction of the total power delivered by the source into a surface wave which can be effectively considered 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 which is a collection of homogeneous antennas oriented similarly to get greater directivity and gain in a desired direction. The inset-fed microstrip antenna provides impedance control with a planar feed configuration.

The structure of the Micro strip patch antenna consists of a thin square patch on one side of a dielectric substrate and the other side having a plane to the ground. In its most fundamental form, a Micro strip antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on other side as shown in the figure below. The patch is generally made of conducting material such as copper or gold. The basic antenna element is a strip conductor of length L and width W, on a dielectric substrate. The thickness of the patch being *h* with a height and thickness *t* is supported by a ground plane. The rectangular patch antenna is designed so that it can operate at the resonance frequency. The length of the patch for a rectangular patch antenna normally would be $0.333\lambda<L<0.5\lambda$

Where, λ being the free space wavelength. The thickness of the patch is selected to be in such a way that is $t<<\lambda$. The length of the patch can be calculated by the simple calculation from **[2,7]**

$L \approx 0.49\ \lambda d = \varepsilon\lambda 49.0$ ---------- Eq. (1.1)

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 $2.2 \leq \varepsilon r \leq 12$.The performance of microstrip antenna depends on its dimension,operating frequency, radiation efficiency, directivity, return loss and other parameters are also influenced. For an efficient radiation,the practical width of the patch can be written as

$$W = \frac{1}{2f_r\sqrt{\mu_o\varepsilon_o}} * \sqrt{\frac{2}{\varepsilon_r+1}} \text{------------ (1.2)}$$

and the length of antenna becomes

$$L=\frac{1}{2f_r\sqrt{\varepsilon_{eff}}\sqrt{\mu_o\varepsilon_o}} - 2\Delta L \text{ ---------- (1.3)}$$

$$\Delta L=0.41h\frac{\varepsilon_{eff}+0.3}{\varepsilon_{eff}-0.258}*\frac{\frac{W}{h}+0.264}{\frac{W}{h}+0.8}\text{---------(1.4)}$$

Where

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+\frac{h}{w}}} \text{ ------ (1.5)}$$

Where λ is the wavelength, $f_r$is the resonant frequency, L and W are the length and width respectively and $\varepsilon_r$is the dielectric constant.

2.2 Waves On Microstrip

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. 1.1) 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.

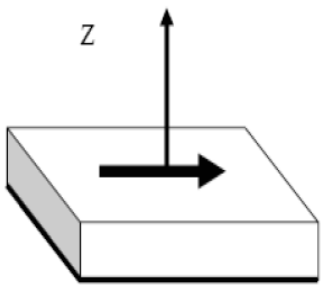


Fig. 1 ertz diole on a microstrip substrate

2.3 Surface Waves

The waves transmitted slightly downward, having elevation angles θ between π/2and π - arcsin (1/√ε*r*), meet the ground plane, which reflects them, and then meet the dielectric-to-airboundary, which also reflects them (total reflection condition). The magnitude of the fieldamplitudes builds up for some particular incidence angles that leads to the excitation of a discrete setof surface wave modes; which are similar to the modes in metallic waveguide.The fields remain mostly trapped within the dielectric, decaying exponentially above theinterface (fig1.2). The vector α, pointing upward, indicates the direction of largest attenuation. Thewave propagates horizontally along β, with little absorption in good quality dielectric. With twodirections of α and β orthogonal to each other, the wave is a non-uniform plane wave.

Surface wavesspread out in cylindrical fashion around the excitation point, with field amplitudes decreasing withdistance (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 theintended user. The signal’s amplitude is thus reduced, contributing to an apparent attenuation or decrease in antenna efficiency. Additionally, surface waves also introduce spurious coupling between different circuit or antenna elements. This effect severely degrades the performance ofmicrostrip filters because the parasitic interaction reduces theisolation in the stop bands.

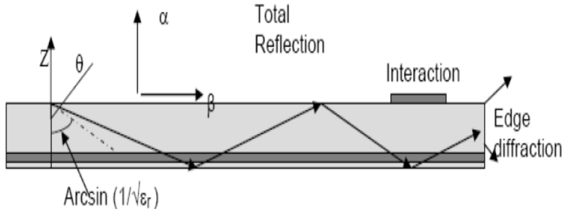


Fig 2 surface waves

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 particulardirections (blind spots). This is due to a resonance phenomenon, when the surface waves excite insynchronism the Floquet modes of the periodic structure. Surface waves reaching the outer boundaries of an open microstrip structure are reflected anddiffracted by the edges. The diffractedwaves provide an additional contribution to radiation, degrading the antenna pattern by raising theside lobe and the cross polarization levels. Surface wave effects are mostly negative, for circuits andfor antennas, so their excitation should be suppressed if possible.

2.4 Leaky Waves

Waves directed more sharply downward, with θ angles between π - arcsin (1/√ε*r*) and π,are also reflected by the ground plane but only partially by the dielectric-to-air boundary. Theyprogressively leak from the substrate into the air (Fig 1.3), hence their name laky waves, andeventually contribute to radiation. The leaky waves are also non-uniform plane waves for which theattenuation direction α points downward, which may appear to be rather odd; the amplitude of thewaves increases as one moves away from the dielectric surface. This apparent paradox is easilyunderstood by looking at the figure 1.3; actually, the field amplitude increases as one move awayfrom the substrate because the wave radiates from a point where the signal amplitude is larger. Sincethe structure is finite, this apparent divergent behavior can only exist locally, and the wave vanishes abruptly as one crosses thetrajectory of the first ray in the figure.

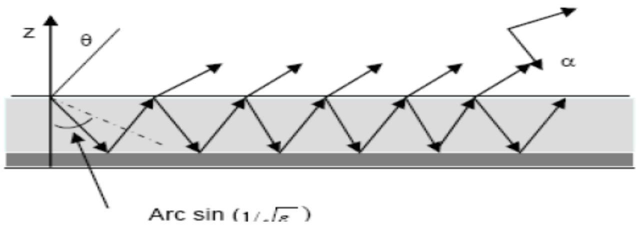


Fig .3 leaky waves

In more complex structures made with several layers of different dielectrics, leaky wavescan 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 notexcited in some other multilayer structures.

2.5 Guided Waves:

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 thedielectric located under the upper conductor bounce back and forth on the metal boundaries, whichform a parallel plate waveguide. The waves in the metallic guide can only exist for some Particularvalues of the angle of incidence, forming a discrete set of waveguide modes. The guided wavesprovide the normal operation of all transmission lines and circuits, in which the electromagneticfields are mostly concentrated in the volume below the upper conductor. On the other hand, thisbuildup of electromagnetic energy is not favorable for patch antennas, which behave like resonatorswith a limited frequency bandwidth.

3.Antenna Characteristics

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

- Antenna radiation patterns
- Power Gain
- Directivity
- Polarization

3.1 Description:

In its most fundamental form, a Microstrip Patch antenna consists of a radiating patch on oneside of a dielectric substrate which has a ground plane on the other side as shown in Figure 3.1. The patch is generally made ofconducting material such as copper or gold and can take any possible shape. The radiating patch and the feed linesare usually photo etched on the dielectric substrate.

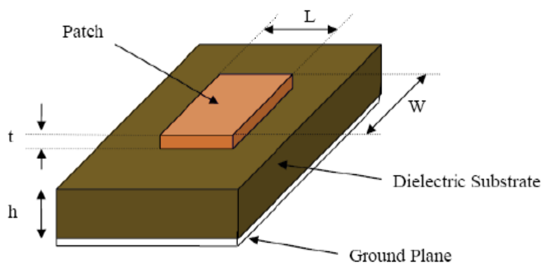


Fig .4 Structure of a Microstrip Patch Antenna

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 3.2.For a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\ \lambda o$, where $\lambda o$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

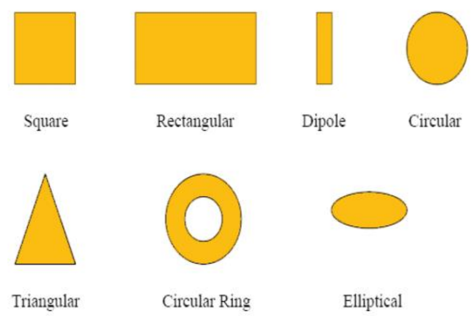


Fig .5 Common shapes of microstrip patch elements

4. Advantage

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structureThe 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 discussed by Kumar and Ray **[9]** are given below:

- 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.

5. Feed Techniques

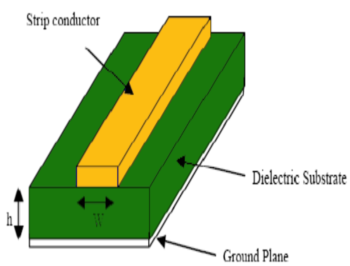
Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch [4]. 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).

6. 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 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.

6.1Transmission 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.



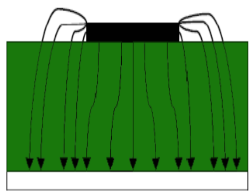


Fig. 6 Microstrip Line Fig . 7 Electric Field Lines

Hence, as seen from Figure 3.4, 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-electricmagnetic (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 $\varepsilon_{reff}$is slightly less then$\varepsilon_r$because the fringaing 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 3.4 above. The expression for $\varepsilon_{reff}$is given by Balanis **[12] as**:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad \text{-------- (1.6)}$$

Where

ε_{reff}= Effective dielectric constant

ε_r= Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

Consider Figure 3.5 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.

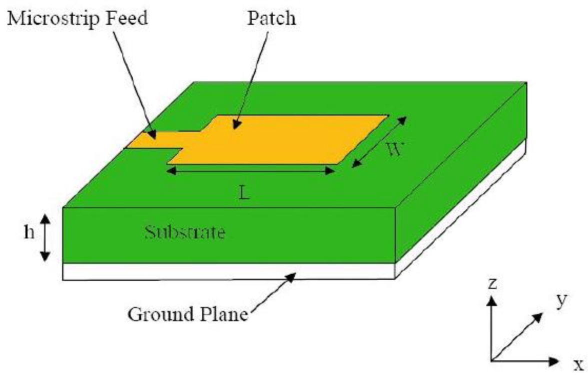


Fig. 8 Microstrip Patch Antennas

In order to operate in the fundamental *TM*10 mode, the length of the patch must be slightlyless than λ/2 where λ is the wavelength in the dielectric medium and is equal to $\lambda o/\sqrt{\varepsilon reff}$where λoisthe free space wavelength. The*TM*10 mode implies that the field varies one λ/2 cycle along thelength, and there is no variation along the width of the patch. In the Figure3.6 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.

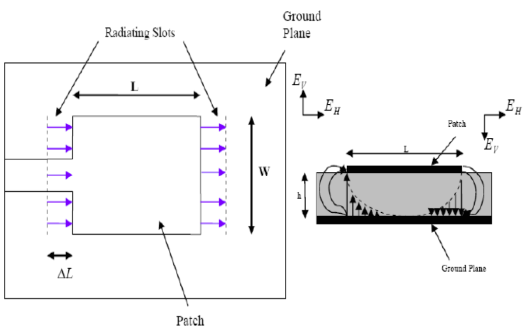


Fig. 9 TopViewofAntenna

It is seen from Figure 3.7 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 3.8), 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 itslength have now been extended on each end by a distance ΔL, which is given empirically by

Hammerstad [13] as:

$$\Delta L = 0.412h \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)}$$ ------ (1.7)

The effective length of the patch Leff now becomes

Leff=L+2ΔL

For a rectangular microstrip patch antenna,the resonance frequency for any TM mod mode is given by james and hall as,

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}}$$ --------------- (1.8)

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

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

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$ -------------- (1.9)

6.2Cavity Model

Although the transmission line model discussed in the previous section 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 basis for this assumption is the following observations for thin substrates ($h << \lambda$) [10].

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

• The electric field is *z* directed only, and the magnetic field has only the transverse components *Hx*and

*Hy*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.

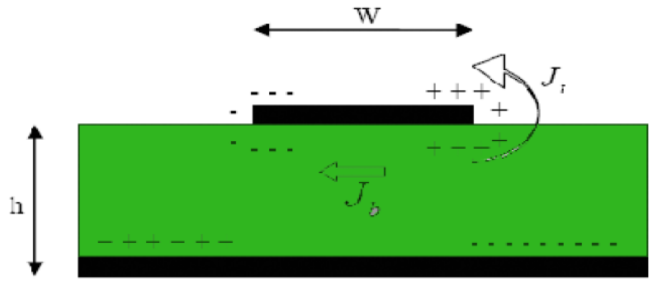


Fig. 10 Charge distribution and current density creation on the microstrip patch

Consider Figure 3.9 shown above. When the microstrip patch is provided power, a chargedistribution is seen on the upper and lower surfaces of the patch and at the bottom of the groundplane. This charge distribution is controlled by two mechanisms-an attractive mechanism and arepulsive mechanism as discussed by Richards [11Since the walls of the cavity, as well as the material within it are lossless, the cavity wouldnot radiate and its input impedance would be purely reactive. Hence, in order to account for radiationand a loss mechanism, one must introduce a radiation resistance *RR* and a loss resistance *RL*. A lossycavity would now represent an antenna and the loss is taken into account by the effective loss tangentδ*eff*which is given as:

$$\delta_{eff}=\frac{1}{Q_J}\text{--------(2.1)}$$

$Q_J$is the total antenna quality factor and has been expressed by [4] in the form:

$$\frac{1}{Q_T}=\frac{1}{Q_d}+\frac{1}{Q_c}+\frac{1}{Q_r}\text{--------(2.2)}$$

$Q_d$represents the quality factor of the dielectric and is given by :

$$Q_d=\frac{\omega_r W_T}{P_d}=\frac{1}{\tan\delta}\text{--------(2.3)}$$

Where

$\omega_r$is the angulr resonany frequency.

W_T is the total energy stored in the patch

P_d is the dielectric loss

$\tan\delta$is the loss tangent of the dielectric.

$Q_c$represents the quality factor of the conductor and is given by :

$$Q_d=\frac{\omega_r W_T}{P_d}=\frac{h}{\Delta}\text{-------- (2.4)}$$

Where

P_c is the conductor loss.

Δ is the skin depth of the conductor.

h is the height of the substrate.

Q_r represents the quality factor for radiation and is given by :

$$Q_r = \frac{\omega_r W_T}{P_r} \text{---------(2.5)}$$

Where P_r is the power radiated from the patch.
Hence

$$\delta_{eff} = \tan\delta + \frac{\Delta}{h} + \frac{P_r}{\omega_r W_T} \text{--------(2.6)}$$

Thus, the above equation describes the total effective loss tangent for the microstrip patch antenna.

7.Rectangular Patch Antenna

7.1.Introduction:

Microstrip antennas are among the most widely used types of antennas in the microwavefrequency 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, andother types of antennas such as wire antennas dominate). Also called patch antennas, microstrippatch antennas consist of a metallic patch of metal that is on top of a grounded dielectric substrate ofthickness *h*, with relative permittivity and permeability εr and μr as shown in Figure 4.1 (usually μr=1). The metallic patch may be of various shapes, with rectangular and circular being the most common.

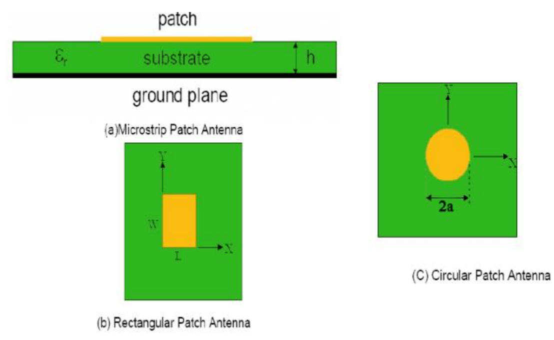


Fig. 11 Rectangular & Circular Patch Antenna

Most of the discussion in this section will be limited to the rectangular patch, although the basicprinciples are the same for the circular patch. (Many of the CAD formulas presented will applyapproximately for the circular patch if the circular patch is modeled as a square patch of the samearea.) Various methods may be used to feed the patch, as discussed below. One advantage of themicrostrip antenna is that it is usually low profile, in the sense that the substrate is fairly thin. If thesubstrate is thin enough, the antenna actually becomes “conformal,” eaning that the substrate canbe bent to conform to a curved surface (e.g., a cylindrical structure). A typical substrate hickness isabout 0.02 λ0. The metallic patch is usually fabricated by a photolithographic etching process or amechanical milling process, making the construction relatively easy and inexpensive (the cost ismainly that of the substrate material). Other advantages include the fact that the microstrip antenna isusually lightweight (for thin substrates) and durable.

7.2Basic Principles Of Operation:

The metallic patch essentially creates a resonant cavity, where the patch is the top of thecavity, the ground plane is the bottom of the cavity, and the edges of the patch form the sides of thecavity. The edges of the patch act approximately as an open-circuit boundary condition. Hence, thepatch 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 thepatch antenna, as well as in understanding its behavior. Inside the patch cavity the electric field isessentially *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 electricfield has the form

$$E_z(x,y) = A_{mn}\cos\left(\frac{m\pi x}{L}\right)\cos\left(\frac{n\pi y}{W}\right) \quad \text{------------ (2.7)}$$

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

$$J_{sx}(x) = A_{10}\left(\frac{\pi / L}{j\omega\mu_0\mu_r}\right) \quad \text{---------- (2.8)}$$

For this mode the patch may be regarded as a wide microstrip line of width *W*, having aresonant 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. (Thewidth 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 radiatorwhen the substrate is electrically thin, since the patch current in (2) will be effectively shorted by theclose proximity to the ground plane. If the modal amplitude wasconstant, the strength of theradiated 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 modalfield at resonance is inversely proportional to h. Hence, the strength of the radiated field from aresonant patch is essentially independent of h, if losses are ignored.

7.3 Resonant Frequency

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

$$f_0 = \frac{c}{2L_e\sqrt{\varepsilon_r}} \quad \text{---------} \ (2.9)$$

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

Le= L + 2ΔL ------- (2.10)

The Hammerstad formula for the fringing extension is [1]

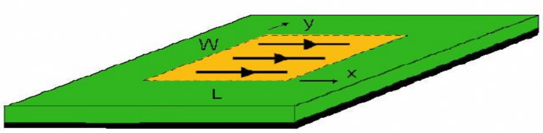
$$\frac{\Delta L}{h} = 0.412\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right) \quad \text{------} \ (2.11)$$

where

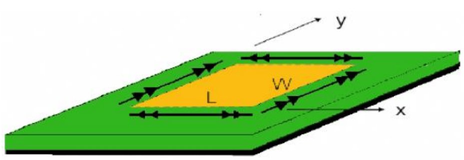
$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-1/2} \quad \text{-------} \ (2.12)$$

7.4Radiation Patterns:

The radiation field of the microstrip antenna may be determined using either an “electric currentmodel” or a “magnetic current model”. In the electric current model, the current in (2) is useddirectly to find the far-field radiation pattern. Figure 4.2a shows the electric current for the (1, 0)patch mode. If the substrate is neglected (replaced by air) for the calculation of the radiation pattern,the pattern may be found directly from image theory. If the substrate is accounted for, and isassumed infinite, the reciprocity method may be used to determine the far-field pattern [5].



(a)Electric Current for (1,0) patch



(b) Magnetic Current for (1,0) patch

Fig. 4.2 / Electric & Magnetic Current Distribution .In the magnetic current model, the equivalence principle is used to replace the patch by a magneticsurface current that flows on the perimeter of the patch. The magnetic surface current is given by

$$\bar{M}_s = -\hat{n} \times \bar{E}$$ -------- (2.13)

Where **E** is the electric field of the cavity mode at the edge of the patch and **n** is the outward pointingunit-normal vector at the patchboundary. Figure 3b shows the magnetic current for the (1, 0) patchmode. The far-field pattern may once again be determined by image theory or reciprocity, dependingon whether the substrate isneglected or not [4]. The ominant part of the radiation field comes fromthe “radiating edges” at $x = 0$ and $x = L$. The two non-radiating edges do not affect the pattern in theprinciple planes (the E plane at φ = 0 and the H plane at φ = π/2), and have a small effect for otherplanes.

If the substrate is neglected, the agreement isonly approximate, with the largest difference being near the horizon.According to the electric current model, accounting for the infinite substrate, the far-fieldpattern is given by [5]

$$E_i(r,\theta,\phi) = E_i^h(r,\theta,\phi)\left(\frac{\pi WL}{2}\right)\left(\frac{\sin\left(\frac{k_y W}{2}\right)}{\frac{k_y W}{2}}\right)\left(\frac{\cos\left(\frac{k_x L}{2}\right)}{\left(\frac{\pi}{2}\right)^2-\left(\frac{k_x L}{2}\right)^2}\right)$$ ---- (2.14)

Where

$kx = k0\ sin\theta cos\varphi$

$ky = k0\ sin\theta sin\varphi$

and$E_{i\,h}$ is the far-field pattern of an infinitesimal (Hertzian) unit-amplitude *x*- directed electricdipole at the centre of the patch. This pattern is given by [5]

Where

$$E_\theta^{\,h}(r,\theta,\varphi) = E_0\cos\varphi G(\theta)$$
$$E_\varphi^{\,h}(r,\theta,\varphi) = -E_0\sin\varphi F(\theta)$$

Where

$$E_0 = \left(\frac{-j\omega\mu_0}{4\pi r} \right) e^{-jk_0 r}$$

$$F(\theta) = \frac{2\tan(k_0 h N(\theta))}{\tan(k_0 h N(\theta)) - j\dfrac{N(\theta)}{\mu_r}\sec\theta}$$

$$G(\theta) = \frac{2\tan(k_0 h N(\theta))\cos\theta}{\tan(k_0 h N(\theta)) - j\dfrac{\varepsilon_r}{N(\theta)}\cos\theta}$$

And

$$N(\theta) = \sqrt{n_1^2 - \sin^2\theta}$$

$$n_1^2 = \varepsilon_r \mu_r$$

The radiation patterns (E- and H-plane) for a rectangular patch antenna on an infinite substrate of permittivityεr= 2.2 and thickness h /λ0= 0.02 are shown in Figure 4.3. The patch is resonant with W / L = 1.5. Note that the E-plane pattern is broader than the H-plane pattern. The directivity is approximately 6 dB.

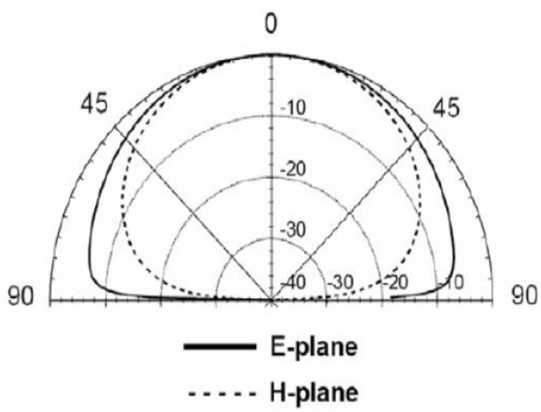


Fig. 12 Radiation Pattern (E & H plane)

7.5 Radiation Efficiency

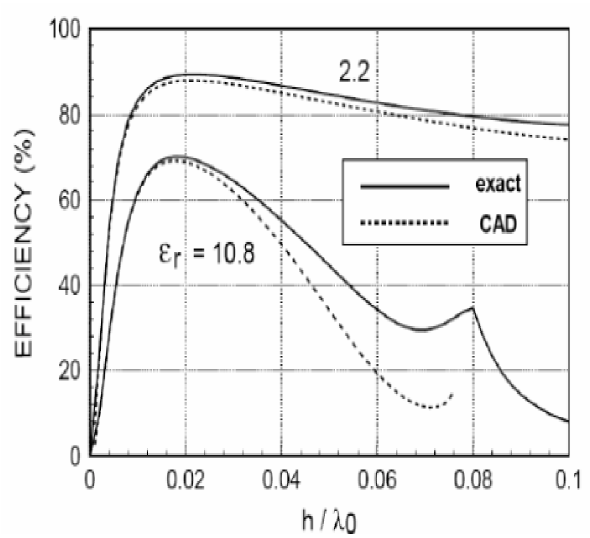
The radiation efficiency of the patch antenna is affected not only by conductor and dielectric closses, but also by surface-wave excitation - since the dominant TM0 mode of the grounded substrate will be excited by the patch. As the substrate thickness decreases, the effect of the conductor and dielectric losses becomes more severe, limiting the efficiency. On the other hand, as the substrate thickness increases, the surface-wave power increases, thus limiting the efficiency. Surface-wave excitation is undesirable for other reasons as well, since surface waves contribute to mutual coupling between elements in an array, and also cause undesirable edge diffraction at the edges of the ground plane or substrate, which often contributes to distortions in the pattern and to back radiation. For anair (or foam) substrate there is no surface-wave excitation. In this case, higher efficiency is obtained by making the substrate thicker, to minimize conductor and dielectric losses (making the substrate too thick may lead to difficulty in matching, however, as discussed above). For a substrate with a moderate relative permittivity such as ε*r*= 2.2, the efficiency will be maximum when the substrate thickness is approximately λ0 = 0.02. The radiation efficiency is defined as

$$e_r = \frac{P_{sp}}{P_{Total}} = \frac{P_{sp}}{P_c + P_d + + P_{sw} + P_{sp}}$$ --------- (2.15)

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

The efficiency may also be expressed in terms of the corresponding Qfactors as

$$e_r = \left(\frac{Q_{sp}}{Q_{Total}}\right)^{-1}$$ ---------- (2.16)



However, a specified frequency is necessary to determine conductor loss.) For *h* / λ0 < 0.02, the conductor and dielectric losses dominate, while for *h* /λ0 < 0.02, the surface-wave losses dominate. (If there were no conductor or dielectric losses, the efficiency would approach 100% as the substrate thickness approaches zero.)

7.6 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. A CAD formula for the bandwidth (defined by SWR < 2.0) is

$$BW = \frac{1}{\sqrt{2}}\left[\tan\delta_d + \left(\frac{R_s}{\pi\eta_0\mu_r}\right)\left(\frac{1}{h/\lambda_0}\right) + \left(\frac{16}{3}\right)\left(\frac{pc_1}{\varepsilon_r}\right)\left(\frac{h}{\lambda_0}\right)\left(\frac{W}{L}\right)\left(\frac{1}{e_r^{sw}}\right)\right] \quad - \ (2.17)$$

Where the terms have been defined in the previous section on radiation efficiency. The result shouldbe multiplied by 100 to get percent bandwidth. Note that neglecting conductor and dielectric lossyields a bandwidth that is proportional to the substrate thickness *h*.

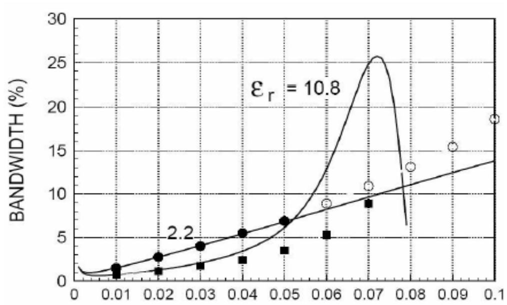
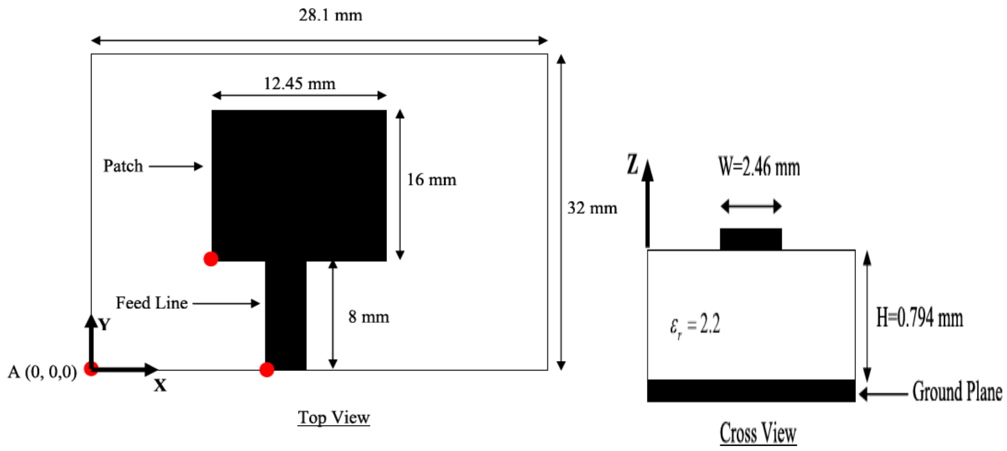


Fig. 13 Calculated & Measured Bandwidth

8.Proposal Method

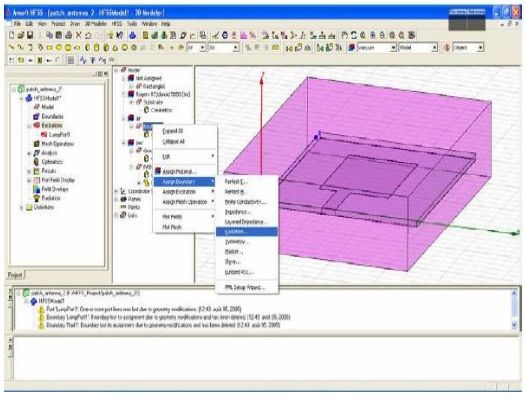
8.1Microstrip Antenna Using Hfss

The procedure for designing a rectangular microstrip patch antenna is explained. Next, a compact rectangular microstrip patch antenna is designed for use in cellular phones. Finally, the results obtained from the simulations are demonstrated.

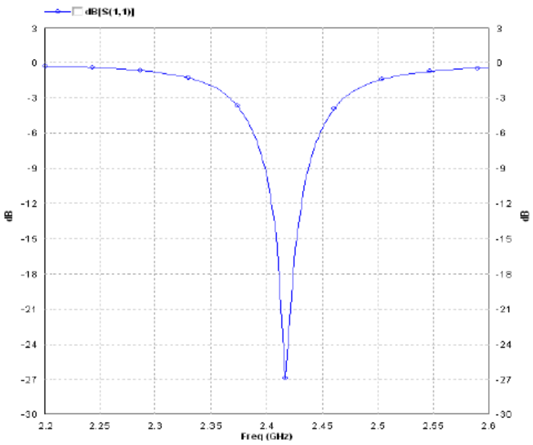


8.2Simulation And Output:

HFSS Software: By taking advantage of the modeling capability of HFSS, it is easy to simulate the bend situation. In particular, there are two features which facilitate this kind of modeling greatly: 1) Sweep - sweep a line to form a sheet, sweep a sheet to form a solid 2) Thicken **-** a sheet can be thickened to form a solid with an assigned thickness



s-parameter display



9. Conclusion

The study of microstrip patch antennas has made great progress in recent years. Compared with conventional antennas, microstrip patch antennas have more advantages and better prospects. They are lighter in weight, low volume, low cost, low profile, smaller in dimension and ease of fabrication and conformity. Moreover, the microstrip patch antennas can provide dual and circular polarizations, dual-frequency operation, frequency agility, broad band-width, feedline flexibility, beam scanning omnidirectional patterning. In this paper we discuss the microstrip antenna, types of microstrip antenna, feeding techniques and application of microstrip patch antenna with their advantage and disadvantages over conventional microwave antennas.

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