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An Analysis of Microstrip Patch Antenna with Feed Techniques

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ABSTRACT

In this paper, use of different feeding techniques of Microstrip patch antennas with different spiral defected ground structures are presented in different way. Microstrip patch antennas can be fed by a variety of methods. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a Microstrip line.

Keywords: Antenna, Microstrip, Feed, Low Power, Costing, Coaxial.

1. Introduction

Microstrip antennas are used in a wide range of applications because of their advantageous features in terms of low profile, low cost, light weight and easy fabrication. A Microstrip patch antenna (MPA) consists of an on ducting patch of any planar or non-planar geometry a one side of a dielectric substrate with a ground plane on other side. Due to their many attractive features, Microstrip antenna has drawn the attention of researchers over the past work [1]. Microstrip antennas are used in n increasing number of applications, ranging from biomedical diagnosis to wireless communications.

2. 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 [2]. 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 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

$$Ez(x,y) = Amn\ \mathrm{Cos}\ ()\ \mathrm{Cos}\ ()\ \text{---------------------------------}\ 1.1$$

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 will be effectively shorted by the close proximity to the ground plane [3]. 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. Hence, the strength of the radiated field from a resonant patch is essentially independent of h, if losses are ignored. The resonant input resistance will likewise be nearly independent of h. This explains why a patch antenna can be an effective radiator even for very thin substrates, although the bandwidth will be small.

3. 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. 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).

3.1. 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 1. 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.

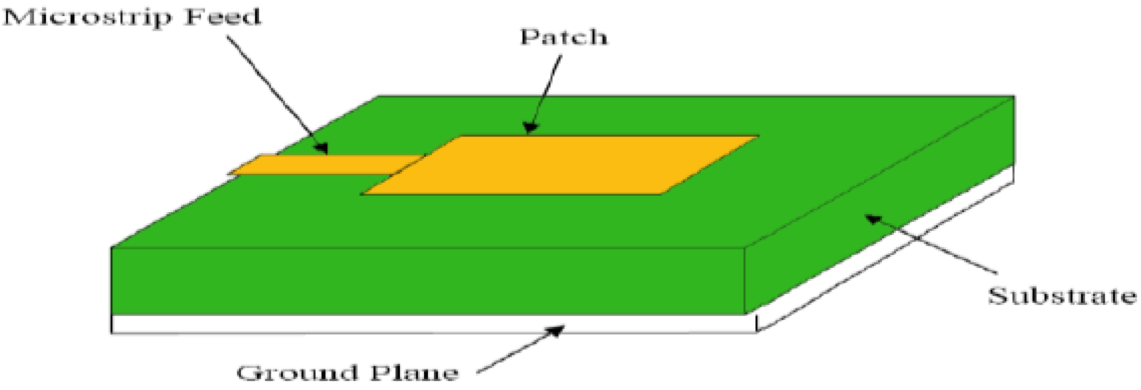


Figure 1: Microstrip Line Feed

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

3.2. Coaxial Feed

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas.

As seen from Figure 2, 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.

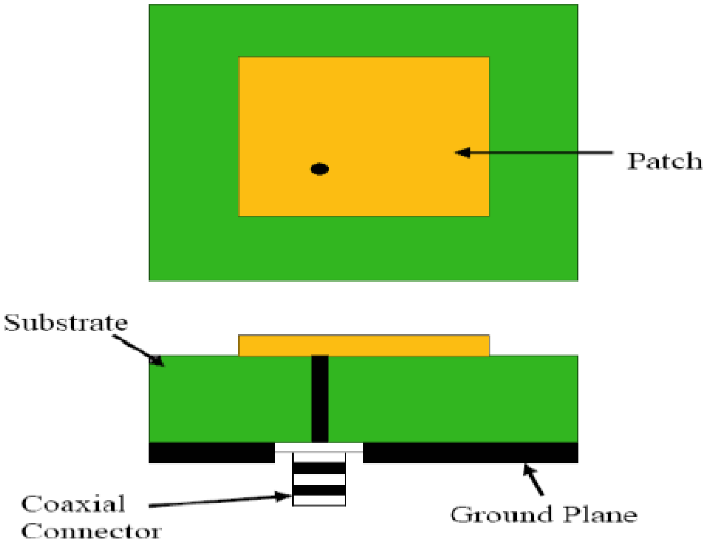


Figure 2: Probe fed Rectangular Microstrip Patch Antenna

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 arrow 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 [11]. 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.

3.3. Aperture Coupled Feed

In this type of feed technique, the radiating patch and the Microstrip feed line are separated by the ground plane as shown in Figure 3. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane.

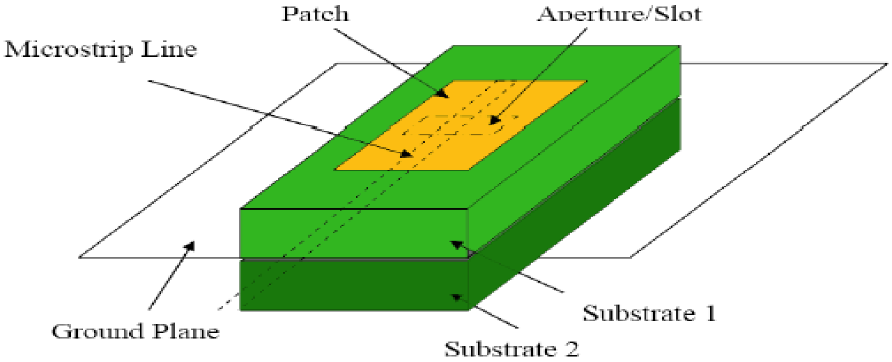


Figure 3: Aperture coupled feed

The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to symmetry of the configuration [5]. 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 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.

4. Proximity Coupling

This type of feed technique is also called as the electromagnetic coupling Scheme. As shown in figure 4, 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. 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..

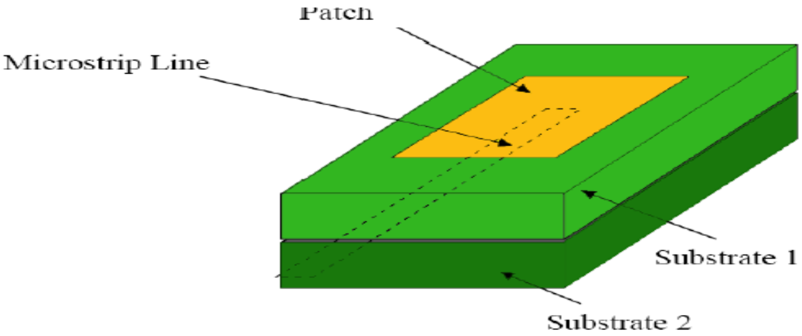


Figure 4: Proximity Feed Technique

5. Methods Of Analysis

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

5.1. Transmission 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.

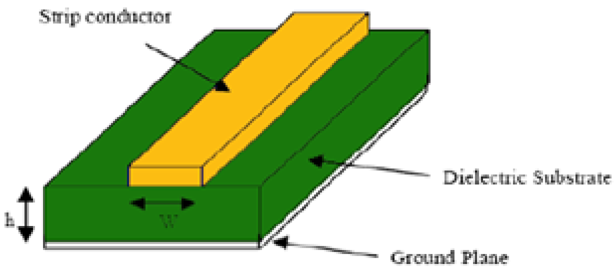


Figure 5: Microstrip line

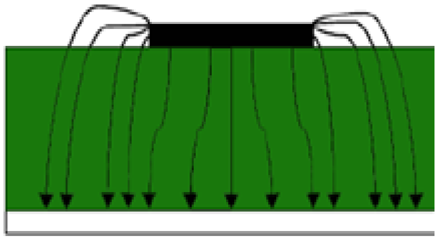


Figure 6: Electric field lines

Hence, as seen from Figure 6, 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-electromagnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate [6]. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε*eff*) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε*eff* is slightly less then ε*r* because the fringing 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 2.6 above. The expression for ε*reff* is given by Balanis as:

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

------1.2

Where:

E*reff* = effective dielectric constant.

E*r* = dielectric constant of substrate

h = height of dielectric substrate

W = width of the patch.

Consider Figure 6 above, 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.

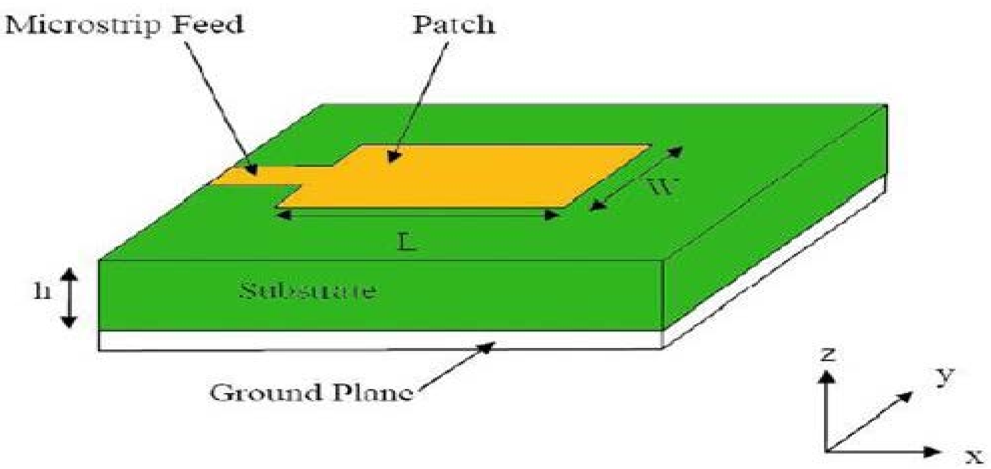
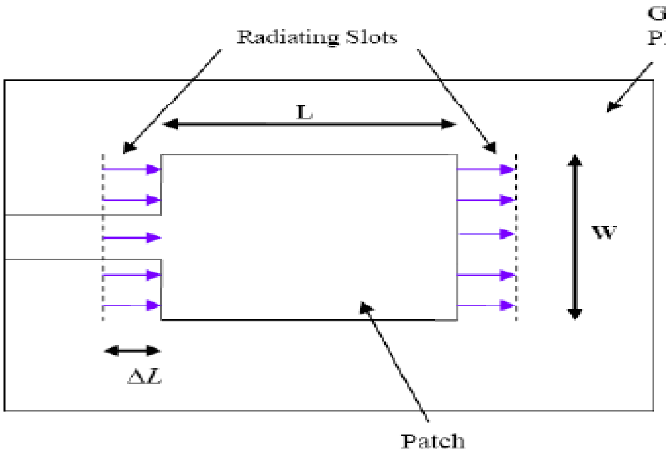


Figure 7: Microstrip patch antenna

In order to operate in the fundamental *TM*10 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 *λo*/√*εreff* where *λo* is the free space wavelength. The *TM*10 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 8 (a) 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.



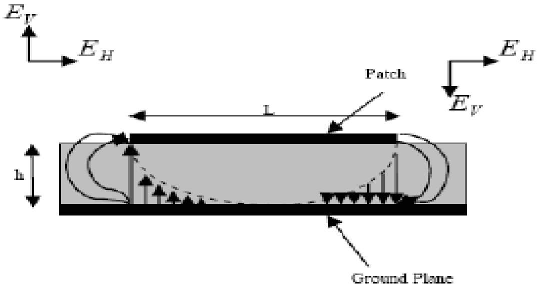


Figure 8: Top view

Figure 9: Bottom view

It is seen from Figure 9 (b) 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 9 (b) , 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 Δ*L*, which is given empirically by

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad \text{---------1.3}$$

Where

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2}$$ --------1.4

The effective length of the patch Leff now becomes

Leff = L +2ΔL --1.5

For a given resonance frequency fr , the effective length Leff is given by [4] as

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}}$$ --1.6

where m and n are modes along L and W respectively.
for efficient radiation , the width W is given as

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_{reff}+1}} = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_{reff}+1}}$$ -----------1.7

Where C is the free space velocity of *light***.**

5.2. Patch Antenna Materials

In the wide range of antenna models there are different structures of Microstrip antennas, but on the whole we have four basic parts in the antenna [5]:

They are:

- The patch
- Dielectric Substrate
- Ground Plane
- Feed Line

A thin metallic region which has different shapes and sizes id the patch where the ground plane is usually of the same material. The common operation that we should be aware of that is that the RF supplies the power to the patch. The dielectric material is commonly known as ‘substrate’ there is features that are to be considered in the selection of the substrate such as dielectric constant [7], cost of the material, dielectric loss tangent, the surface adhesion properties for the conductor coatings, and the ease of fabrication. We have a wide range of materials for the substrate selection which are in use for the planar and also for the conformal antenna configurations. The dielectric constant for the materials range from 1.17 to ≈ 25. In this research the dielectric materials for Design 1 with εr=9.8(alumina), which is the well known to have the high unloaded Q material the substrates patch antennas and the dielectric resonators [20] and for the Design 2 εr=2.32 has been used. The material εr=9.8(alumina) requires a sintering temperature that is higher than 16000c the alumina processes a quality factor of 333,000 at 15000c for 5 hours.

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