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Research Article

A Survey on Different Feeding Techniques of Rectangular Microstrip Patch Antenna

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Abstract

In this paper describe the different feeding technique for wireless microstrip antenna, which are microstrip line feed, coaxial plane feed, proximity coupled feed and aperture couple feed. Microstrip line and coaxial probe feeds are contacting scheme, in which RF power directly to the radiating patch. Proximity and Aperture coupled feeds are non contacting schemes ,in which electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. Feeding techniques are govern by many factors like efficient transfer of power between the radiation structure, feeding structure and their impedence matching .These techniques give a better understanding of design parameters of an antenna and their effect on return losses ,bandwidth ,VSWR and resonant frequency .

Keywords: *VSWR,Return Loss,Aperture Feed ,Coaxial Feed ,Microstrip feed, Proximity Feed.*

1. Introduction

There is an increase in demand for microstip antennas with improved performance for wireless communication applications are widely used for this purpose because of their planer structure, low profile, light weight moderate efficiency and ease of integration with active device.Almost all the important wireless applications lie in the band starting from 900 MHz to 5.8 GHz (Amit kumar *et al*). Broadband microstrip patch antennas for the 2.45 GHz ISM band and possible implementation using adhesive copper tape in research scenarios. In the course of the project, two broadband microstrip patch antennas were manufactured to adequately cover the 2.4- 2.5 GHz frequency band (Salman *et al*, 2003).The mechanism of coupling energy,equivalent circuit diagram and relative merits are discussed in this paper. Feeding techniques are govern by many factors like efficient transfer of power between the radiation structure, feeding structure and their impedence matching . Alongwith impedence matching are stepped impedence bends,stub function,transition which removes spurious radiation & surface wave loss.These radiation may increase the side lobe & cross polarization amplitude of radiation pattern.Most important factor is to remove the spurious radiation and it effect on radiation pattern is use to evaluate feed. Some feed structures are tends to better performance because of the large no of parameters available.

Advantages of Microstrip Antennas

Low profile (can even be "conformal") easy to fabricate (use etching and phototlithography) , Easy to feed (coaxial cable, microstrip line, etc.) , Easy to use in an array or incorporate with other microstrip circuit elements, Patterns are somewhat hemispherical with a moderate directivity (about 6-8 dB is typical) .

Disadvantages of Microstrip Antennas:

Low bandwidth (but can be improved by a variety of techniques). Bandwidths of a few percent are typical. Efficiency may be lower than with other antennas. Efficiency is limited by conductor and dielectric losses, and by surface-wave loss.Conductor and dielectric losses become more severe for thinner substrates.Surface-wave losses become more severe for thicker substrates (unless air or foam is used).

2. Methodology

Microstrip patch antenna can be fed by a variety of methods (Ojha *et al*,2011) 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 noncontacting 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 scheme).

2.1. Rectangular Patch

This model represents the microstrip antenna by two slots of width W and height h, separated by a transmission line of length L in figure 1(A) (K. Praveen Kumar, *et al*, 2013),

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(Devan Bhalla *et al*,2013). The microstrip is essentially a nonhomogeneous line of two dielectrics, typically the substrate and air. The purpose of manufacturing a narrowband rectangular patch was to gain some of the insights to the patch design process. Based on the measurements acquired from the narrowband rectangular antenna, the broadband antennas were designed. Especially to calculate the probe feed coordinates and the iterative process involved. The linearly polarized narrowband antenna was designed to operate at 2.45 GHz with input impedance of 50 ohms, using G10 fiberglass substrate. The rectangular slot excited by microstrip line feed gives an impedance bandwidth of 14.76% . When the rectangular slot is excited by a coplanar waveguide (CPW), it gives an impedance bandwidth of 26.61% (D. Mitra *et al*,2012).

The width W is usually chosen to be larger than L (to get higher bandwidth). However, usually $W < 2L$. $W = 1.5L$ is typical In order to operate in the fundamental TM10 mode, the length of the patch must be slightly less than $\lambda/2$ where $\boldsymbol{\lambda}$ in the dielectric medium and is equal to $\boldsymbol{\lambda}_0/\sqrt{\varepsilon_{reff}}$.

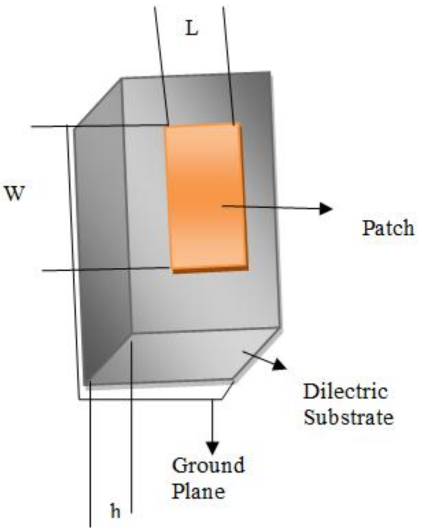


Figure 1 (A) Diagram of Rectangular Microstrip Patch Antenna

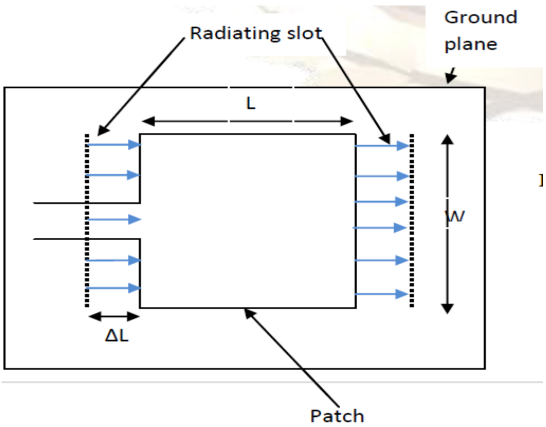


Figure 1 (B) Shows The Basic Microstrip Patch Geometry

Figure 1 (B) shows the basic microstrip patch geometry (Amit kumar *et al*,2013). The length of the patch is denoted by L and width of the patch is denoted by W. Because the dimensions of the patch are finite along the length and width, the fields at the edges of the patch undergo fringing. Since some of the waves travel in the substrate and some in air, an effective dielectric constant ε_{reff} is introduced to account for fringing and the wave propagation in the line. The dimension the patch along its length has been extended by a distance ΔL due to the fringing field which is a function of effective dielectric constant (Amit kumar *et al*, 2013, K. Praveen Kumar, *et al*, 2013 ,Brajlata Chauhan *et al*,2013). Hence the effective length is increased by 2ΔL as shown. $\Delta L \approx 0.5$ h. Various formulas for designing a microstrip patchantenna are written below. The expression for effective dielectric constant is

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

ε_{reff}= Effective dielectric constant, ε_r = Dielectric constant of substrate

h = Height of dielectric substrate, W =Width of the patch

2.1.1 Length

The length of the patch determines the resonant frequency thus it is a critical factor because it is a narrowband patch. The equation shown below was used to calculate the length of the patch. Since the fringing field cannot be accounted for accurately none of the results are definite.

$$L = L_{eff} - 2\Delta L \qquad (2)$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \qquad (3)$$

$$\Delta L = 0.412\, h \frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \qquad (4)$$

For Frequencies below 2 GHz, the variation in L with h is almost negligible. This is approximation, as long as resonant frequency (f_r) is less than 2GHz. The ΔL is the length extension due to the fringing field and can be calculate.

2.1.2 Width

The width is critical in terms of power efficiency, antenna impedance and bandwidth. It is largely dependent on the operating frequency and the substrate dielectric constant. The equation below was used to workout the width of the patch (Vishwakarma *et al*,2011). Other widths could have been used but if it is too small then radiator efficiency will suffer and if it is too large higher order modes will be excited, resulting in field distortions.

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}} \qquad (5)$$

2.1.3 Ground plane dimensions

$L_g = 6h + L$ (6)

$W_g = 6h + W$ (7)

2.1.4 Characteristics impedance (Z_0)

When W/h ≥1

$$Z_0 = \frac{120\,\pi}{\sqrt{\varepsilon_{reff}}[\left(\frac{W}{h}\right)+1.393+\frac{2}{3}\ln\left\{\left(\frac{W}{h}\right)+1.449\right\}]} \quad (8)$$

2.1.5 VSWR (Voltage Standing Wave Ratio)

The VSWR is basically a measure of the impedance mismatch between the feeding system and the antenna. The higher the VSWR the greater is the mismatch. The minimum possible value of VSWR is unity and this corresponds to a perfect match.

$$VSWR=\frac{1+|\Gamma|}{1-|\Gamma|} \quad (9)$$

$$\Gamma = \frac{Vr}{V_i} = \frac{Z_{in}-Zs}{Zin+Zs} \quad (10)$$

Z_{in} = Input impedance of the antenna, Z_s = Source impedance, Γ = reflection coefficient
Vr = Amplitude of the reflected wave, v_i = Amplitude of the incident wave

2.1.6 Return Loss

RL is a parameter similar to the VSWR to indicate how well the matching is between the feeding system, the transmission lines, and the antenna. The RL is

$$RL = - 20 \log | \Gamma | (dB) \quad (11)$$

To obtain perfect matching between the feeding system and the antenna, Γ = 0 is required and therefore, from equation (11), RL = infinity. In such a case no power is reflected back. Similarly at Γ = 1, RL = 0 dB, implies that all incident power is reflected. Usually return losses ranging from 10 dB to 12 dB are acceptable [5]. For practical applications a VSWR of 2 is acceptable and this corresponds to a return loss of 9.54 dB.

2.1.7 Bandwidth

The bandwidth is usually specified as the frequency range over which the VSWR is less than 2 (which corresponds to a return loss of 9.5 dB or 11 % reflected power). Sometimes for stringent applications, the VSWR requirement is specified to be less than 1.5 (which corresponds to a return loss of 14 dB or 4 % reflected power).

$$BW = \frac{VSWR-1}{Q\sqrt{VSWR}} \quad (12)$$

2.1.8 Resonance Frequency

Many models have been proposed notably by Sengupta (1983), HAMMERSTED (1975) and James et al (1981), the simplest are those HAMMERSTED and JAMES et al, where these models replace the dielectric substrate with finite thickness by homogeneous medium with effective dielectric constant ε_{eff} given by the formula (1) of Schneider (1969):

$$f_r = \frac{f_{r0}\left[1-\frac{2.h}{\varepsilon_{eff}(L).W.\alpha\pi}\right]}{1+\frac{2.h}{\varepsilon_{eff}(L).W.\alpha\pi}\ln\left[\frac{2.W.\sqrt{\varepsilon_{eff}(L)}}{\gamma.h}\right]} \quad (13)$$

Where $f_{r0} = \frac{C}{2W\sqrt{\varepsilon_{eff}(L)}}$

$\alpha = 1+1.393\frac{h}{L} + 0.667\frac{h}{L}\ln(\frac{L}{h} + 1.444)$
$\gamma = 1.78107$

3. Feeding Technique

3.1. Coaxial Probe Feed

3.1.1 Advantages: Simple, easy to obtain input match.

3.1.2 Disadvantages

Difficult to obtain input match for thicker substrates, due to probe inductance, significant probe radiation for thicker substrates.

The coaxial feed or probe 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.

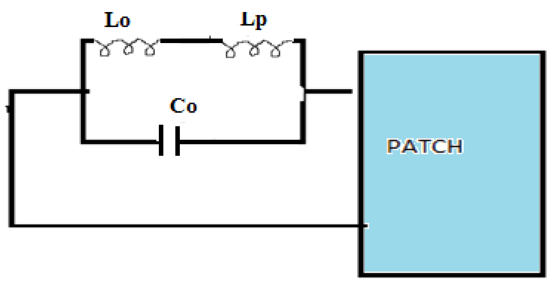


Figure 2 Circuit Diagram Of Coaxial Feed

However, its major drawback is that it provides narrow bandwidth of 2-5% 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. Also for thicker substrate the increased probe length makes the input impedence more inductive leading to matching problems. For a thick dielectric substrate, which provides broad bandwidth? The microstrip line feed and the coaxial feed suffer from numerous disadvantages. To reduce these type of disadvantages, we will study non conducting schemes. Excitation of patch occurs principally through the coupling of the feed current J_z to the E_z field of the patch mode. Coupling constant can be obtained as:

Coupling $= \iiint J_z E_z \, dv = \cos(\pi x_0/L)$ (14)

Where L is the resonant length of the patch and x_0 is the offset of the feed point from the patch edge.equation (13) shows that coupling is maximum for a feed located at a radiating edge of the patch (x_0= 0 or L) . Resulting impedance can be made by an equivalent circuit as shown in figure 2.

3.2. Microstrip Line Feed

3.2.1 Advantages

Simple, allows for planar feeding, easy to obtain input match.

3.2.2 Disadvantages

Significant line radiation for thicker substrates, for deep notches, pattern may show distortion.

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch. The conducting strip is smaller in width as compared to the patch . This kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planer structure. However increase the thickness of the dielectic substrate being used surface waves and spurious feed radiation also increases, which hampers the bandwidth 2-5% of the antenna. This feed radiation also leads to undesired cross polarized radiation. This method is advantageous due to its simple planar structure.

Coupling formula is same as coaxial probe feed. The edge-coupled microstrip feed can be modeled by means of the step in width or impedance junction. The equivalent circuit diagram is shown in figure 3.

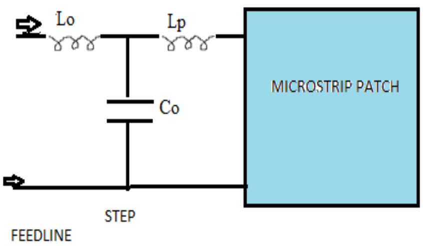


Figure 3 Circuit Diagram Of Micro strip Feed

3.3. Proximity Couple Feed (Electromagnetic Coupling Scheme)

3.3.1 Advantages

Allows for planar feeding, less line radiation compared to microstrip feed.

3.3.2 Disadvantages

Requires multilayer fabrication**,** alignment is important for input match.

The two dielectric substrates are used such that the feed line is between the two substrate and radiating patch is on the top of upper substrate and feed line end under the patch. It is also known as electromagnetic coupled microstrip line .Coupling between the patch and microstrip has capacitive in nature .The equivalent circuit diagram of this feed is shown in figure 3. Coupling capacitor C_c is in series with the parallel R-L-C resonant circuit representing the patch. Requirement of this coupling is to match the impedance and tuning of the bandwidth. The open end of the microstrip feed gives stud and stud parameters which help in improving bandwidth. By using this feeding technique 13 % of Bandwidth is achieved (Devan Bhalla et al, 2013). It is effective to use two layers as it increase the bandwidth and reduce spurious radiation, but it is difficult to form right alignment of the patches. Advantages are that it allows planer feeding & less line radiation than microstrip feed.

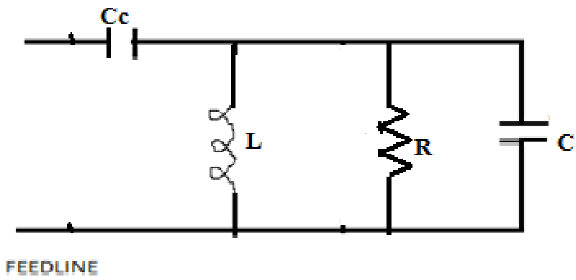


Figure 4 Circuit diagram of proximity feed

3.4. Aperture Coupled Feed

3.4.1 Advantages

Allows for planar feeding , feed radiation is isolated from patch radiation and higher bandwidth, since probe inductance problem restriction is eliminated and a double-resonance can be created. Allows for use of different substrates to optimize antenna and feed-circuit performance.

3.4.2 Disadvantages

Requires multilayer fabrication and alignment is important for input match.

In this type of feed technique the radiating patch and the microstrip feed line are separated by the ground plane as shown in figure 4 (A). Coupling between the patch and feed line is made through a slot or an aperture in the ground plane (D.M. Porzar *et al*,1987 C.A.Balanis *et al*,2001, Ramesh Garg, *et al*,2001). Variations in the coupling will depend upon the size i.e.length and width of the aperture. To optimize the result for wider bandwidths and better return losses.The coupling aperture is usually centred under the patch leading to lower cross-polarization due to symmetry of the configuration. Since the ground plane separates the patch and the feed line so spurious radiation is minimized.

Aperture coupled feeding is attractive because of advantages such as no physical contact between the feed and radiator, wider bandwidths of 21%, and better isolation between antennas and the feed network. Furthermore, aperture coupled feeding allows independent optimization of antennas and feed networks by using substrates of different thickness or permittivity.

The coupling slot is nearly centered with respect to the patch where the magnetic field of the patch is maximum. This is done purposely to enhance magnetic coupling between the magnetic field of the patch and equivalent magnetic current near the slot. The coupling amplitude can be determined from the following equation (14).

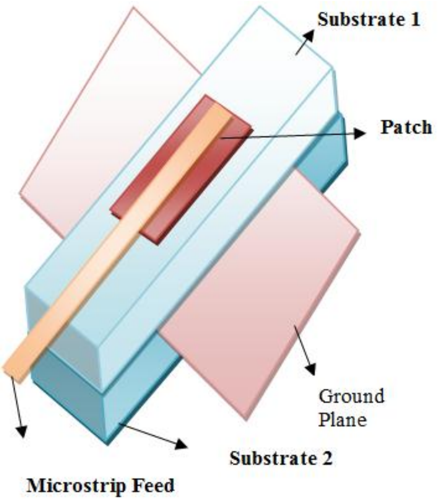


Figure 5 (A) of Aperture feed

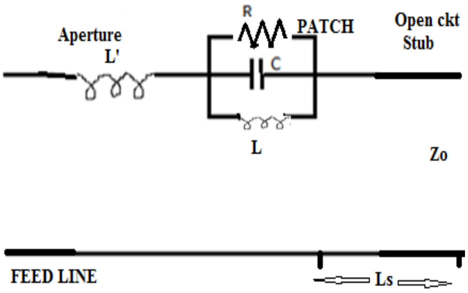
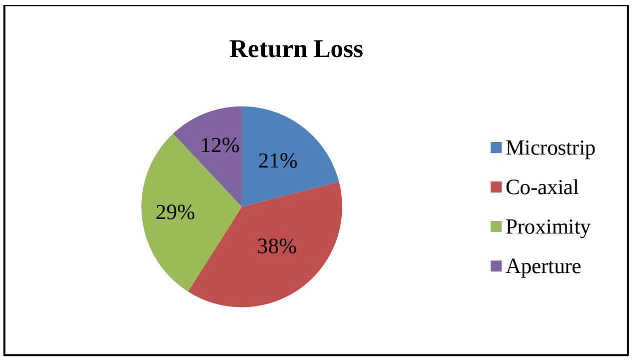
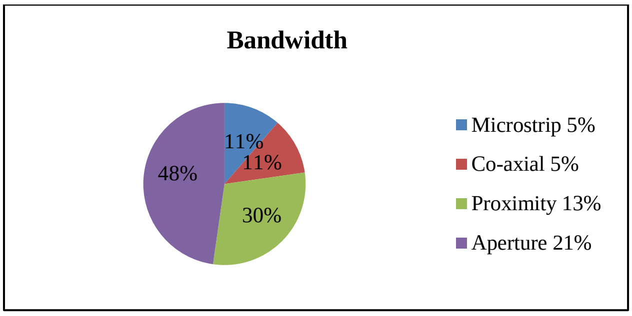


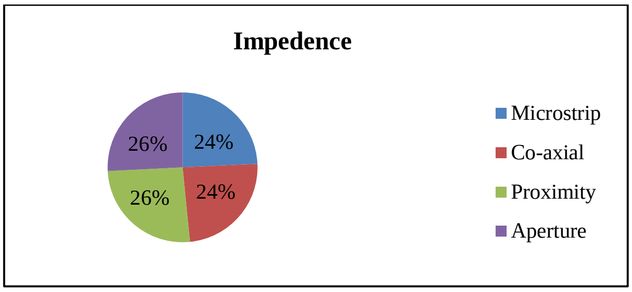
Figure 5 (B) Circuit diagram of Aperture feed

4. Comparison of Different Feeding Techniques

We can obtain the approximate result of Return Loss, Bandwidth and Impedence of all feeding techniques .Those feeding techniques are Microstrip Line ,Co-axial, proximity and Aperture which describe the comparision of Return Loss , Bandwidth and Impedence .These feeding techniques are given below.







Characteristic	Micro strip feed	Coaxial feed	Proximity feed	Aperture feed
Return loss	Less	More	More	Less
Resonant frequency	More	Less	Highest	Least
VSWR	Lower than 1.5	Between 1.4 to 1.8	Less than 1.23	Approx equal to 2
Spurious Feed Radiation	More	More	More	More
Polarization Purity	Poor	Poor	Poor	Excellent
Ease of Fabrication	simple	Soldering and Drilling Needed	Alignment Required	Alignmen t Required
Reliability	Better	Poor Due soldering	Good	Good
Impedence Matching	Easy	Easy	Easy	Easy
Bandwidth	2 -5 %	2-5 %	13 %	21 %

Conclusions

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- We can see that selection of the feeding technique for a microstrip patch antenna is an important decision because it affects the bandwidth, return loss, VSWR patch size and smith chart .
- A microstrip patch antenna excited by difffrent excitation techniques gives different bandwidth ,different gain and different efficiency etc.
- The maximum bandwidth can be achieved by aperture coupling .proximity coupling gives the best impedence matching and radiation efficiency.
- Coaxial feeding technique gives the least bandwidth .We can also conclude that by changing the feed point where matching is perfect.
- The high return loss can be achieved at the resonant frequency.
- Various microstrip patch antennas with each different feeding techniques are present the various parameters like return loss ,radiation pattern ,smith chart, electric field and VSWR.All these parameters are plotted for each antenna.The performance properties are analyzed for the optimized dimensions and proposed antenna

works well at the required (5.25-5.85) GHz Wimax frequency band.

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