Analysis on the effect of change in inset feed length of a circular patch antenna on return loss and current distribution

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Abstract: **This paper presents a circular microstrip antenna resonant at S-Band. Operating frequency (2.4 GHz) fed using transmission line model. The position of Microstrip line feed is varied and their effect on the current distribution and return loss has been observed. The antenna is of the radius of 17 mm. The substrate is of rectangular shape with dimensions 60 mm by 50 mm. Maximum gain of the antenna reaches above 5 dB. It is observed that the position of feed has a significant effect on return loss, gain and forward distribution. Height of the substrate is 1.6 mm and dielectric constant of the substrate material is 4.4 (FR4_Epoxy). The length of the inset feed is varied as 12 mm, 13 mm and 14 mm.**

Keywords: **Inset Feed, return loss, current distribution, transmission line model, input impedance.**

1. Introduction

The performance of the antenna does not depend only on its frequency response but rather its characteristic impedance of transmission line. So it is necessary to get better response of antenna, the input impedance of transmission line must be proper match to characteristic impedance of the antenna. There are various methods of feeding a patch antenna.

A. Micro strip line
B. Coaxial probe
C. Aperture coupling

A. Microstrip line feed

In this type of feeding technique, the patch of the micro strip antenna can be directly fed by feeding line. It is a conducting strip. For this type of feeding technique the width of feeding line is much smaller than the micro strip patch. It is very simple to model because of its easy to match by controlling the inset position.

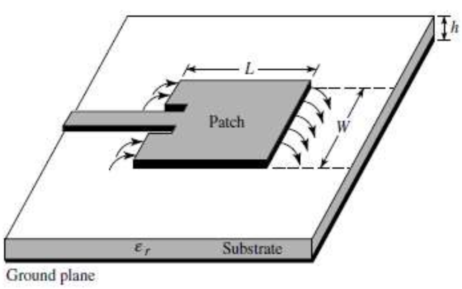

Fig. 1 Microstrip fed patch antenna (courtesy [1])

B. Coaxial probe

This type of feeding technique is also simple and easy to fabricate. In this type of feeding technique, the inner conductor of the coaxial wire is attached to the radiation patch and the ground plane is connected to the outer conductor of the coaxial wire

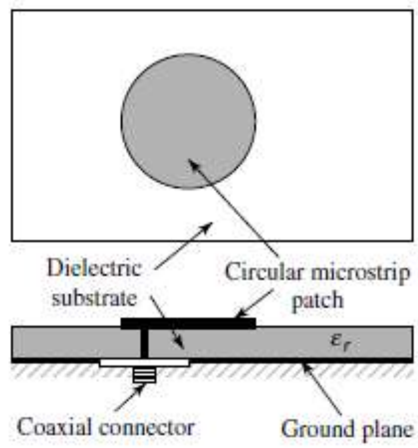

Fig. 2 Coaxial feed (courtesy [1])

C. Aperture coupling

In this type of feeding technique, there are two substrates which are separated by ground plane. Here the micro strip line feed which is put on the bottom side on the lower substrate is used and its energy is coupled on the patch by using the slot on the ground plan. The value of the dielectric material which is used on the bottom substrate is high and the value of top substrate is low.

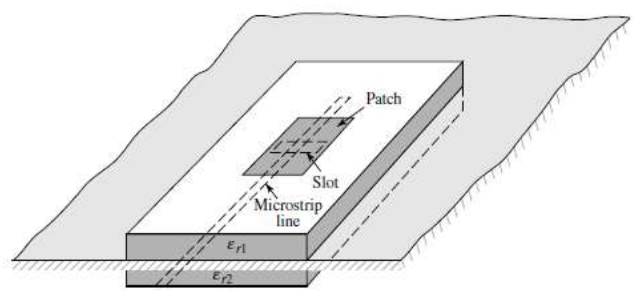

Fig. 3 Aperture coupling (courtesy [1])

Among these feeding techniques Microstrip line feeding is the easiest and the most famous. The reason is its simplicity. The microstrip-line feed is easy to fabricate, simple to match by controlling the inset position and rather simple to model. However, as the substrate height increases, surface waves and spurious radiation increase, which results in limiting the bandwidth typically by 2–5%.

2. Inset Feed and input impedance

If the microstrip line feeds the patch antenna at the edge it leads to high input impedance. Since practically the wire used even to feed the microstrip line is a coaxial cable the input impedance of the antenna cannot be high. It should match with the characteristic impedance of the coaxial wire (50 ohms). Since the current is low at the edges of a half wave patch and large in magnitude toward the centre, the input impedance could be reduced if the patch was fed closer to the centre [4].

One method is to move the feed point inside the patch by cutting a slot that is slightly greater than the width of the transmission line.

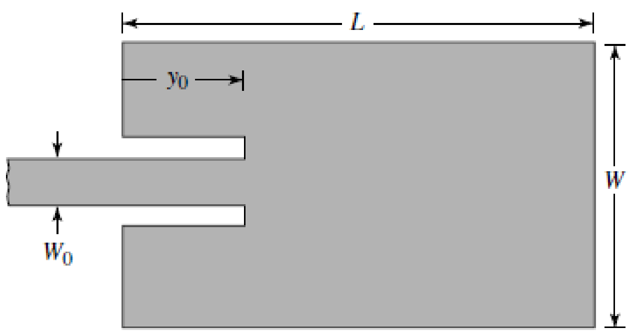

Fig. 4 Inset feed

Input impedance of the patch antenna can be calculated using the expression given below [1]

$$Z_{in} = \frac{1}{2G1}$$

G1 is the conductance of the patch antenna.
G1 can be calculated by the expression below

$$G1 = \begin{cases} \frac{1}{90}\left(\frac{W}{\lambda_0}\right)^2 & W \ll \lambda_0 \\ \frac{1}{120}\left(\frac{W}{\lambda_0}\right) & W \gg \lambda_0 \end{cases}$$

W is the width of the patch and λ_0 is the operating frequency. G1 actually gives input resistance at the edge of the antenna. HFSS can also be used to calculate by simulation the input impedance of the designed antenna.

The depth of the inset y_0 can be calculated using the formula below [3]

$$Zin(y = y_0) = \frac{1}{2G1}\left(\cos\left(\frac{\pi}{L} y_0\right)\right)^2$$

Width of the feedline is 3 mm and height of substrate is 1.6 mm resulting W_0/H ratio of 1.875 (>1). To obtain the characteristic impedance of 50 ohms following equation is used [2]:

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}} \times \left[\frac{W_0}{h} + 1.393 + \frac{2}{3}\ln\left(\frac{W_0}{h} + 1.444\right)\right]}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W_0}\right]^{\frac{1}{2}}$$

ε_{eff} is the effective dielectric constant. W_0 is the width of the feed line and h is the height of the substrate from the ground plane.

3. Design methodology

Designing the circular antenna is easier than designing a rectangular patch antenna. There is only one dimension of control i.e. radius. Changing radius does not change the order of modes but it does change the resonant frequency. Following is the design formula for a circular patch antenna [1]

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}}$$

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}}$$

F is the factor that is affected by the resonant frequency and the dielectric constant of the substrate.
The radius of the antenna is a.

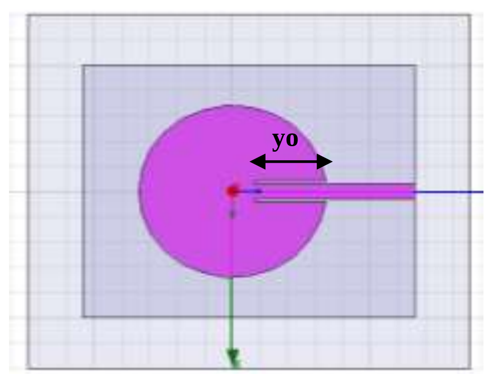

Fig. 5 Proposed antenna

4. Simulation results

Design and simulation are done on HFSS 11.1.1. It is one of the many standard EM-CAD tools.

A. *Return loss (S11)*

The inset length yo is varied and return loss is observed in table 1.

Table 1 Return loss vs Inset length

Inset Length y0 (mm)	Return loss (dB)
12	-17.42
13	-25.10
14	-14.16

It is observed that the inset length of 13 mm in our case gives the lowest value of return loss. Increasing or decreasing it results in increase of return loss.

(a)
(b)
(c)

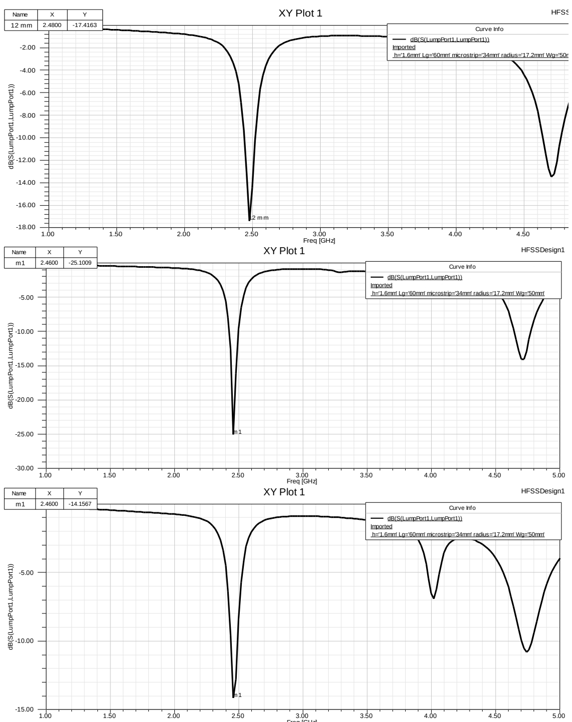

Fig. 6 Return loss y0 (a) 12 mm (b) 13 mm (c) 14 mm

B. *Current Distribution*

Antenna performance and efficiency of radiation highly depends upon the how the supplied current is distributed on the surface of the patch antenna. Since the edges of the antenna usually contribute most towards the radiation, the current should reach towards the edges as far as possible.

Fig. 7 shows the current distribution on the antenna for different inset lengths

(a)
(b)
(c)

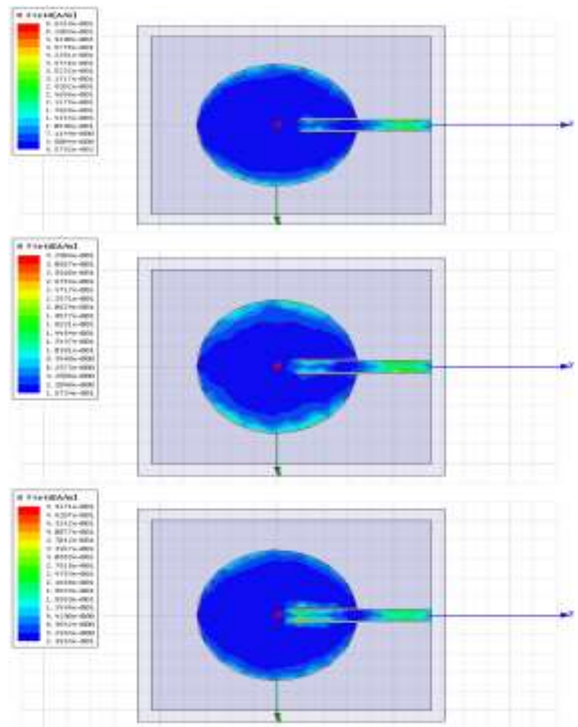

Fig. 7 Current distribution A/m (a) 12 mm (b) 13 mm (c) 14 mm

It is apparent from the figure 7 that when the inset length is kept as 13 mm the current is highest at the edges as compared to y0 = 12 mm or y0 = 14 mm.

5. Conclusion

The work presented here successfully asserts that the formula present in various books and literatures can be used successfully to calculate the inset feed length. The simulated and the calculated results match to a high degree.

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