PERFORMANCE ANALYSIS OF RECTANGULAR PATCH ANTENNA USING QUARTER WAVE FEED LINE AND COAXIAL FEED LINE METHODS FOR C- BAND RADAR BASED APPLICATIONS

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Abstract: Microstrip antenna has various attractive features like light weight, low cost, easy fabrication, etc. Microstrip antenna can be fed in a variety of ways. This paper is focused on the enhancement of gain of the rectangular patch antenna at 7.5 GHZ for two different feeds and compare their results. The two types of feed are coaxial cable feed and quarter wave feed. Antenna design has been simulated using HFSS tool. Comparative study of simulated parameters like Gain, Bandwidth, Directivity and Radiation pattern for these two feeding methods have been done and presented in this paper.

***Index Terms*— Microstrip patch antenna, Quarter wave inset feed, Coaxial cable feed, Gain, Bandwidth, Directivity, Radiation pattern.**

I. INTRODUCTION

Microstrip antennas are relatively inexpensive to manufacture and design because of the simple 2-dimensional physical geometry. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency. Different feeding methods used for Microstrip patch antenna are:

- *Microstrip line inset feed:*

Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be considered as an extension of patch. It is simple to model and easy to match by controlling the inset position. Since the current is low at the ends of a half-wave patch and increases in magnitude towards the center, the input impedance (Z=V/I) could be reduced if the patch was fed closer to the center. One method of doing this is by using an inset feed (a distance R from the end) as shown in Figure 1.

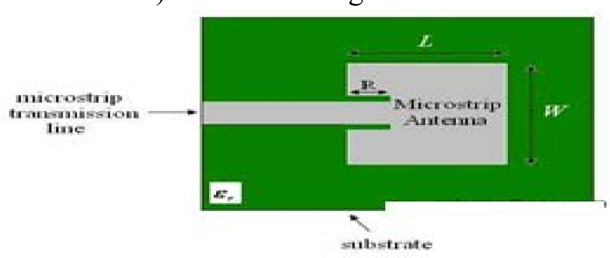


Figure 1: Inset feed

- *Quarter wavelength transmission line*

The microstrip antenna can also be matched to a transmission line of characteristic impedance Z_0 by using a Quarter-wave transmission line of characteristic impedance Z_1 as shown in below Figure 2.

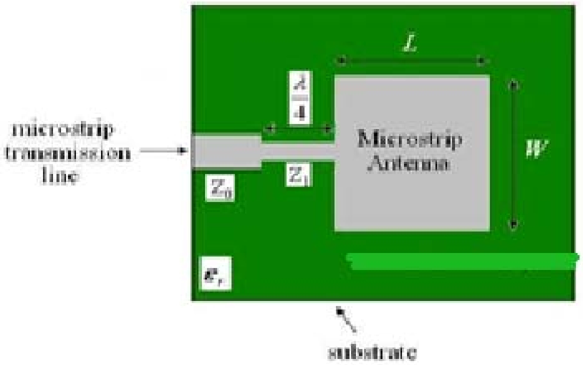
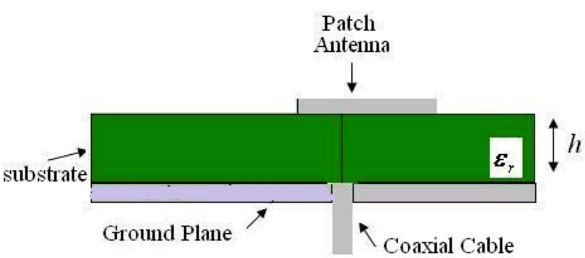


Figure 2: *Quarter wavelength transmission line*

- *Coaxial cable feed*

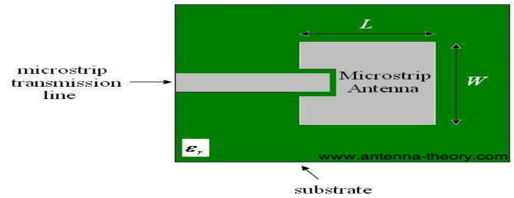
Microstrip antennas can also be fed from underneath via a probe as shown in Figure 3. The outer conductor of the coaxial cable is connected to the ground plane, and the center conductor is extended up to the patch antenna. The position of the feed can be altered as before (in the same way as the inset feed, above) to control the input impedance.



The coaxial feed introduces an inductance into the feed that may need to be taken into account if the height h gets large (an appreciable fraction of a wavelength). In addition, the probe will also radiate, which can lead to radiation in undesirable directions.

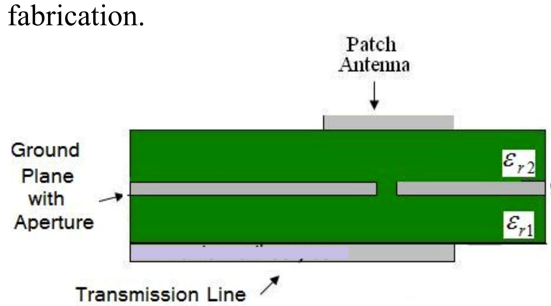
- *Coupled feed*

The feeds above can be altered such that they do not directly touch the antenna. For instance, the probe feed in Figure 3 can be trimmed such that it does not extend all the way up to the antenna. The inset feed can also be stopped just before the patch antenna, as shown in Figure 4. The advantage of the coupled feed is that it adds an extra degree of freedom to the design. The gap introduces a capacitance into the feed that can cancel out the inductance added by the probe feed.



- Aperture feed

Another method of feeding microstrip antennas is the aperture feed. In this technique, the feed circuitry (transmission line) is shielded from the antenna by a conducting plane with a hole (aperture) to transmit energy to the antenna, as shown in Figure 5. The upper substrate can be made with a lower permittivity to produce loosely bound fringing fields, yielding better radiation. The lower substrate can be independently made with a high value of permittivity for tightly coupled fields that don't produce spurious radiation. The disadvantage of this method is increased difficulty in fabrication.



II. ANTENNA GEOMETRY

The structure of the proposed antenna is shown in Figure 2 below. For a rectangular patch, the length L of the patch is usually 0.3333_o<L<0.5_o is the free wavelength. The patch is selected to be very thin such that t>>_o.the height h of the dielectric is usually 0.003_o<= h<=0.05_0.thus, a rectangular patch of dimension 40.1mm*31mm is designed on one side of the an FR4 substrate of thickness 1.6mm and relative permittivity 4.4 and the ground plane is located on the other side of the substrate with dimension 50.32mm *41.19mm.The antenna plate is fed by standard coaxial of 50_ at feeding location of 11.662mm by 20.286mm on the patch. This type of feeding scheme can be placed at any desired location inside the patch in order to match with the desire input impedance and has low spurious radiation.

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III. DESIGN REQUIREMENT

There are three essential parameter for design a coaxial feed rectangular microstrip patch antenna. Firstly, the resonant (fo) or the antenna must be selected appropriately. The frequency range used is from 2 GHZ-2.5GHZ and the design antenna must be able to operate within this frequency range. The resonant frequency selected for this design is 2.25GHZ with band width of 46MHz.

Secondly, the dielectric material of the substrate selected for this design is FR4 Epoxy which has a dielectric for this design of 4.4 and loss tangent equal to 0.002. The dielectric constant of the substrate material is an important design parameter. Low dielectric constant is used in the prototype design because it gives better efficiency and higher bandwidth, and lower quality factor Q. The low value of dielectric constant increases the fringing field at the patch periphery and thus increase the radiated power. The proposed design has patch size independent of dielectric constant. So the way of reduction of patch size is by using higher dielectric constant and FR4 Epoxy is good in this regard. The small loss tangent was neglected in the simulation.

Lastly, substrate thickness is another important design parameter. Thick substrate increases the fringing field at the patch periphery like low dielectric constant and thus increases the radiated power. The height of dielectric substrate (h) of the microstrip patch antenna with coaxial feed is to used in S-band range frequencies. Hence, the height of dielectric substrate employed in this design of antenna is h=1.6mm.

IV. ANTENNA STRUCTURE

Patch antenna design with Quarter wave line feed

i. Width (**W**):

$$W = \frac{c}{2fr\sqrt{\frac{(\epsilon r+1)}{2}}}$$

where;

c - free space velocity of light, 3×10^8 m/s

ii. Effective dielectric constant ($\boldsymbol{\varepsilon_{reff}}$):

$$\varepsilon reff = \frac{(\varepsilon r+1)}{2} + \frac{(\epsilon r-1)}{2}[1+12\frac{h}{w}]^{-1/2}$$

Where,

εr - dielectric constant

W - width of the patch

h - Height of dielectric substrate

iii. Effective length (**Leff**):

$$Leff = \frac{c}{2fr\sqrt{\varepsilon reff}}$$

iv. Patch length extension (**ΔL**):

$$\Delta L = 0.412h\frac{(\varepsilon reff+0.3)[\frac{W}{h}+0.264]}{(\varepsilon reff-0.258)[\frac{W}{h}+0.8]}$$

v. Actual length of patch (**L**):

$$L = Leff - (2\Delta L)$$

Equations for impedance Matching

$Z=(60/\sqrt{(\varepsilon_{reff})} * \ln[(8*h/w + w/4h)]$ (6)

Where, $Z=Z_0$=impedance of the port feed =50 **Ω**.

$\lambda g= \lambda_0/\sqrt{\varepsilon_{reff}}$ (7)

λ_0=Free space wavelength

ε_{reff}=Effective permittivity of the microstrip

Patch antenna design with Coaxial line feed

The position of the coaxial cable can be obtained by using equation for same rectangular micro strip patch antenna.

$X_f=L/(2\sqrt{\varepsilon_{reff}})$ (8)

Where Xf is the desire input impedance to match the coaxial cable and εreff is the effective dielectric constant.

$Y_f=W/2;$ (9)

So (X_f ,Y_f,Z) represent the coordinate on patch for 50Ω impedance point in patch .

The impedance with 50Ω coaxial wire is given by equation

$Z_0=138*\log_{10}(D/d)/\sqrt{\varepsilon_{reff}}$ (10)

V. EXPERIMENTAL RESULTS

- ***Results for Patch antenna with Quarter wave line feed.***

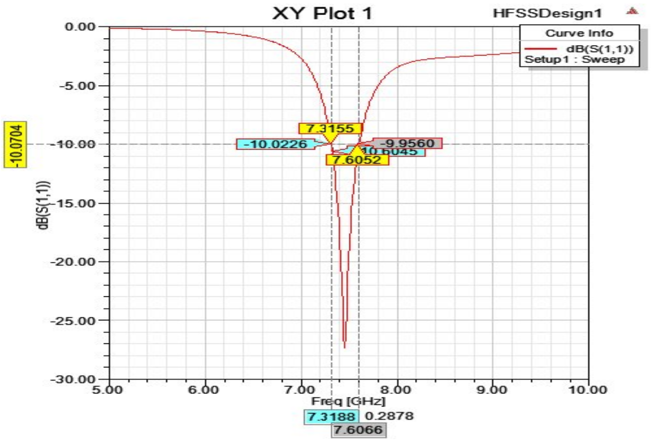

Fig6: Return loss = -27.5 dB (Centre frequency f_r=7.5GHz, BW=0.2878GHz)

Fig7: Voltage Standing Wave Ratio

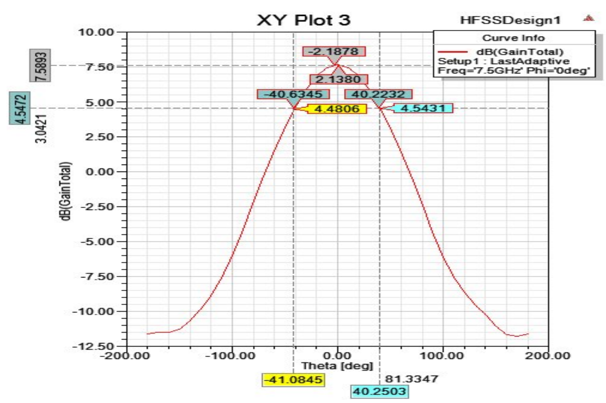

Fig8: Gain plot

- ***Results for Patch antenna with Coaxial line feed***

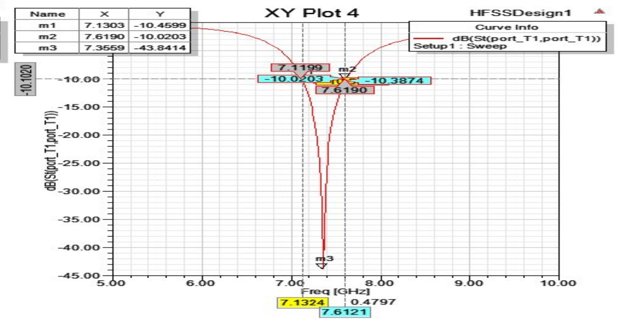

Fig9: Return loss = -43.8414 (Centre frequency f_r=7.5GHz, BW=0.2878GHz)

Fig10: Voltage standing wave ratio=1.0615

Fig: Gain = 6.927 dB

Table 1 Comparison of radiation properties two methods.

Parameter	Microstrip line feed	Co-axial probe feed
Resonant frequency	7.5 GHz	7.5GHz
Return loss	-27.5 dB	-39 dB
VSWR	1.2	1.05
Gain	7.69 dB	8.54dB
Directivity	7.625 dB	8.5 dB

VI. CONCLUSION

In this paper, we have designed a rectangular microstrip patch Antenna covering the 7.5 GHz frequency spectrum. It has been observed that there is 40 % improvement in the Bandwidth in case of a coaxial line feed compared with microstrip line feed and there is also an improvement in the VSWR in case of coaxial feeding technique. There is a 9 % improvement in the Gain and 11% increase in the Directivity which shows that there are radiation losses and losses within the feed system and it is difficult to achieve impedance matching for Microstrip line feeding technique.

VII. ACKNOWLEDGMENT

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