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Effect of Change in Feedpoint on the Antenna Performance in Edge, Probe and Inset-Feed Microstrip Patch Antenna for 10 GHz

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ABSTRACT

In this paper, we present the simulations results of three types of rectangular patch antenna feeding for 10 GHz. The conception of this patch antenna is realized by software HFSS "Ansoft-High Frequency Structure Simulator". The first feeding uses a quarter wavetransformer to connect the patch to the feed line,the second uses the coaxial feed line and the third one is a microstrip line feed with notch. The aim of our study is to determine the optimal position decreasing the return loss and to make a comparison between feeding methods to show the improvement in directivity, bandwidth and impedance matching.

Keywords:
Patch antenna,Bandwidth, Return Los, Directivity,Coaxial feeding, Inset feeding, Edge feeding, HFSS v13.

INTRODUCTION

Because of the great demand in wireless communication system and UHF applications, microstrip patch antennas have attracted much interest due to their low profile, light weight, ease of fabrication and compatibility with printed circuits. Microstrippatch antenna in its simplest form consists of a radiating patch (of different shapes) which is made up of a conducting material like Copper or Gold on one side of a dielectric substrate and a ground plane on the other side. It is used in communication systems due to simplicity in structure, conformability, low manufacturing cost, and very versatile in terms of resonant frequency, polarization, pattern and impedance at the particular patch shape and model [1], it can be used for high frequency and high speed for data transfer.

However, they also have some drawbacks, such as narrow bandwidth, low gain, and spurious feed radiation limited power handling capacity. To overcome their inherent limitation of narrow bandwidth and low gain, many techniques have been proposed and investigated. When we change the shape of a microstrip antenna, the feeding method and the position of the feeding point, its properties are changed which may seriously degrade or upgrade the antenna performance.

Microstrip patch antennas can be fed in a variety of ways.1.Contacting 2.Non-Contacting.In contacting method the RF power is fed directly to the radiating patch using a connected element, they are microstripfeed and coaxial feed [8].In Non Contacting method, electromagnetic coupling is done to transfer the power between the feed line and the radiating patch, they are Aperture coupled feed and Proximity coupled feed [9].

In this paper it is shown that we can change the position of feed point for each contacting feeding method which shows the improvement in return losses (S11 parameter), bandwidth, directivity & impedance matching without changing the patch size.

DESIGN OF MICROSTRIP PATCH ANTENNA

A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. Thisconcept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970 [1]. After that many authors have described the radiation from the ground plane by a dielectric substratefor different configurations.

The patch antenna consists of a metallic conductor wide arbitrary shape called radiating element and depositedon a dielectric substrate. The lower face is completely metalized to provide a ground plane as shown in Fig. 1.

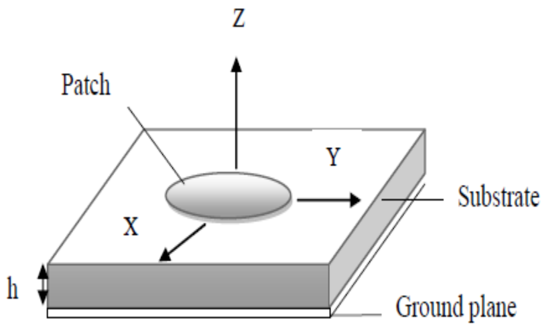

Fig. 1: Microstrip antenna configuration

1. *Rectangular patch antenna*

The rectangular microstrip patch antenna is the simplest microstrip patch configuration. We can describe the antenna as a strip conductor of dimension (L×W) on a dielectric substrate of dielectric constant εr and thicknessh backed by a ground plane. Fig. 2

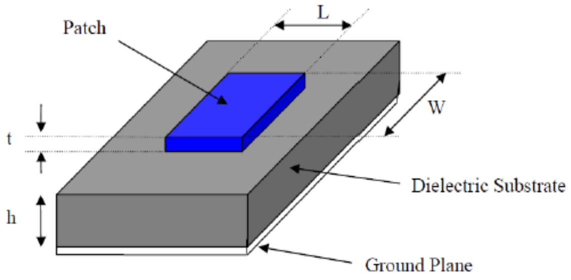

Fig. 2: Rectangular microstrip patch antenna configuration

When the patch is excited, a charge distribution is established on the underside of the patch metallization and ground plane. At a particular moment, the underside of patch is positively charged while the ground plan is negatively charged. This tends to hold a large percentage of the charge between the two surfaces. However, the repulsive force between positive charges on the patch pushes some of these charges toward the edges, resulting in large charge density at the edges. These charges are the source of fringing field and the associated radiation [2].

2. *Methods of Analysis*

There are several methods for the analysis of patch antennas, but the transmission line model is the simplest and most commonly used in the literature since it gives a good understanding of physics, however, there areother models such as cavity model and full wave model.

In Transmission line model the microstrip radiator element is viewed as a transmission lineresonator with no transverse field variations. In the cavity model, the region between the patch and the ground plane is treated as a cavity that is surrounded by magnetic walls around the periphery and by electric walls from the top and bottom sides. The full wave model for analyzing the MSA is an extension of the cavity model. In this method, the electromagnetic fields underneath the patch and outside the patch are modeled separately [3].

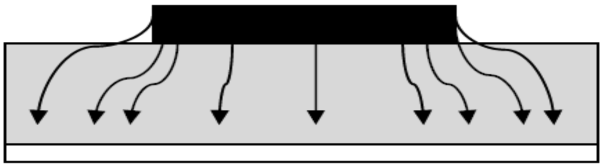

Fig.3: Fringing field between patch and ground plane

Considering fig.3which represents the model of transmission line we notice that most of the electric field lines move through the substrate except of a few lines out into the air. Therefore the transmission line cannot support pure transverse electric magnetic (TEM) mode of transmission, since the phase of velocities would be different in the air and the substrate. Instead the dominant mode of propagation is quasi-TEM mode. Therefore, an effective dielectric constant should be obtained to take account of the fringe and the wave propagation in the line.

$$\varepsilon_{ref} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-0.5}$$

Where, $\boldsymbol{\varepsilon_{eff}}$ is the effective dielectric constant, **h** is the height of dielectric substrate and **W** is the width of the patch.

The width of the rectangular MSA is given by

$$W = \frac{c}{2f_r\sqrt{\frac{2}{\epsilon_r + 1}}}$$

The normal component of the electric field at the two edges along the width is 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 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 and by a distance ΔL:

$$\Delta L = 0.412h \frac{\varepsilon_{ef+0.30}}{\varepsilon_{ef-0.258}} \left(\frac{W/_{h} + 0.264}{W/_{h} + 0.813} \right)$$

The effective length of the patch:

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

Where **c** is the velocity of Light, **$\mathbf{f_r}$**is the antenna frequency

The length of the patch is:

$$L = L_{eff} - 2\Delta L$$

3. Contacting feeding techniques

Patch feeding can broadly be classified as either contacting or non-contacting. In the contacting method, either amicrostrip line or coaxial cable is used to directly excite the radiating patch. This makes this techniques easy tofabricate and simple to model. The main advantage of these techniques is that impedance matching is relatively easysince the probe or microstrip line can be placed at any desired position, either we can use a quarter wave transformers to adapt the feed line to the patch.

3.1 Edge feeding

The feed line is connected to the patch by a quarter wave transformer to achieve the impedance matching.This scheme has the advantage that the feed line and the radiating patch can be etched on the samesubstrate, however, conflicting substraterequirement for feed line and radiating element results in reduced system efficiency.

3.2 Probe feeding

This scheme involves drilling a hole through the ground plane and the substrate and extending the inner conductor ofa coax through the hole. This conductor is then soldered to the radiating patch while the outer conductor of the coaxis connected to the ground plane. Control of the input impedance is achieved by positioning of the probe. Thismethod result in minimal spurious radiation but is very complicated since it involves precise drilling both on theground plane and the substrate in terms of position and size.

3.3 Inset feeding

This is a variation of the edge feeding where the fed line is in direct contact with one of the radiating edges of thepatch. Impedance control is achieved by cutting out a notch from the radiating edge and extending the feed line intothe notch. This scheme has the advantage that the feed line and the radiating patch can be etched on the samesubstrate making design and realization easier and highly suited for array design.

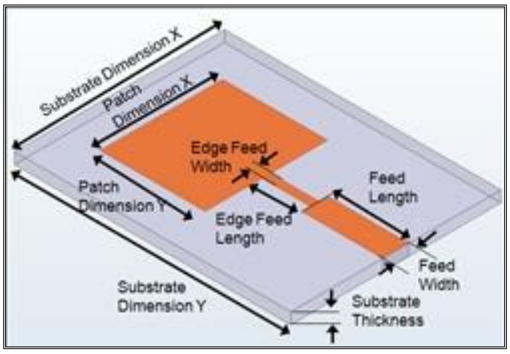

Fig. 4: Edge feeding microstrip patch antenna

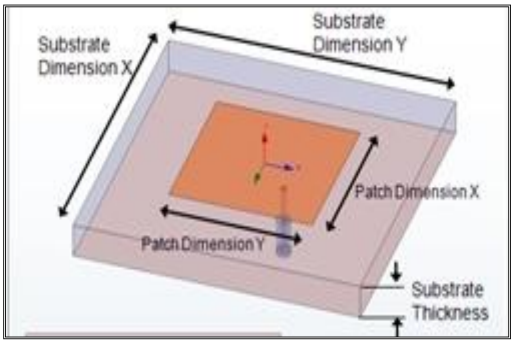

Fig. 5 : Probe feeding microstrip patch antenna

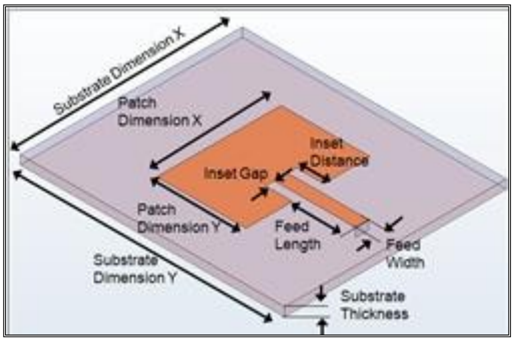

Fig. 6 : Inset feeding microstrip patch antenna

Fig.4, 5 and 6shows respectively edge, probe and insetfeedingmicrostrip patch antenna configuration.

4. *Design Parameters of the proposed antennas*

S.N°	**Symbol**	**Parameter**	**Inset-fed**	**Probe-fed**	**Edge-fed**
1	Ls	Substratelength	27.93	27.93	27.93
2	Ws	Substratewidth	35.58	35.58	35.58
3	H	Substratethickness	0.79	0.79	0.79
4	W	Patch width	11.86	11.86	11.86
5	L	Patch length	9.31	9.31	9.31
6	W_f	Feedlinewidth	2.408	-	2.408
7	W_{qw}	Quarter wavelengthtransformerwidth	–	–	0.5

Table 1: Patch antenna dimensions

Substrate dimensions are tabulated in Table 1 above for a frequency of 10 GHz. The substrate employed in this design isRogers RT/duroid 5880 (tm) with a dielectric constant =2.2 loss tangent tanδ=0.0009.

RESULTS & DISCUSSION

The software used to model and simulate the microstrip patch antenna is HFSS v13 [4]. HFSS is a full-waveelectromagnetic simulator based on finite element method, and is essential for the design of high frequency and high speed component design.

Below is the description of how the simulations were carried out for all three feeding schemes, by changing the coordinates of the feed point (X_0,Y_0).

1. *Edge-feed patch antenna*

Fig. 4 shows the patch geometry of an Edge-feed rectangular patch antenna, where thefeed line is connected to the patch by a quarter wave transformer for impedance matching.

The results tabulated in table 2 are obtained aftervarying the feed location along the width of the patchfrom the origin (centre of patch) to its left most edge.The coordinates of the feeding point are given by (X0; Y0) where Y0 is set to L/2. Frequency rangeof 9.94 GHz to 9.98 GHz was selected.

Return loss is the difference, in dB, between the forward and reflected power measured at a given point in an RF system. A mismatched antenna reflects some of the incident power back toward the transmitter and since this reflected wave is traveling in the opposite direction as the incident wave, there will be some points along the cable where the two waves are in phase and other points where the waves are out of phase.The centre frequencyis selected as the one at which the return loss isminimum. The bandwidth was calculated from thereturn loss (RL) plot. The bandwidth of the antenna canbe said to be those range of frequencies over which theRL is less -10dB. (-10dB corresponds to a VoltageStanding Wave Ratio (VSWR) of 2 which is anacceptable figure). The impedance is evaluated from impedance magnitude plot and gain in directivityis evaluated from radiation pattern.

Feed location (X_0;Y_0=L/2) (mm)	Centre frequency (GHz)	Return loss (dB)	Bandwidth (MHz)	Impedance (Ω)	Gain in Directivity (dBi)
(0; L/2)	9.98	-28.61	250	46.62	8.59
(1; L/2)	9.96	-29.18	250	48.14	8.55
(2; L/2)	9.96	-29.42	250	48.84	8.54
(2.1; L/2)	9.96	-30.66	250	47.16	8.55
(2.2; L/2)	9.96	-27.65	250	46.10	8.54
(3; L/2)	9.96	-23.59	250	43.80	8.52
(4; L/2)	9.94	-20.51	250	42.15	8.46
(5; L/2)	9.96	-29.26	250	46.69	8.47

Table 2: Effect of feed location on center frequency, return loss, bandwidth, impedance and directivity for Edge-feed patch antenna

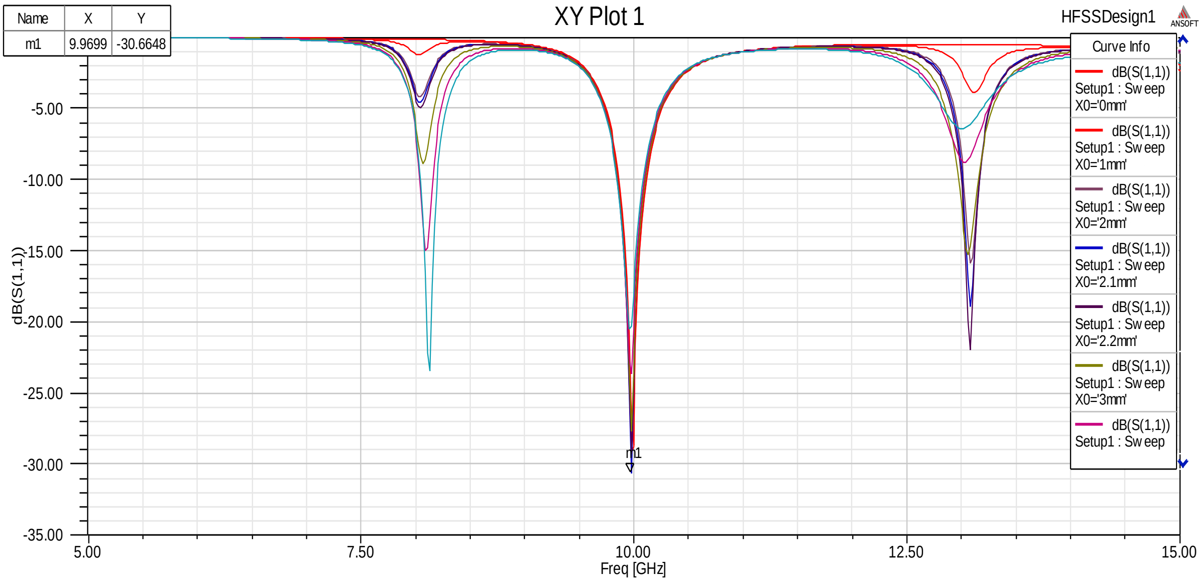

Fig. 7: the return loss versus frequency at different Edge feed point locations.

According to the table 2, it was observed that with the variation of feed point location along the width of the patch; theresonant frequency does not shift much;it remains almost fixed at 9.96 GHz. Even the bandwidth does not show anyconsiderable change. The bandwidth was almost constant i.e. 250 MHz.The gain of directivity was also observed andfound to be varying between 8.46dB to 8.59dB which is a remarkable value. The parameter which has shown a considerable variationwith the change in feed point locationis return loss, it is observed to be -30.66dB for(X_0,Y_0) = (2.1; L/2) which is the optimum feed point.

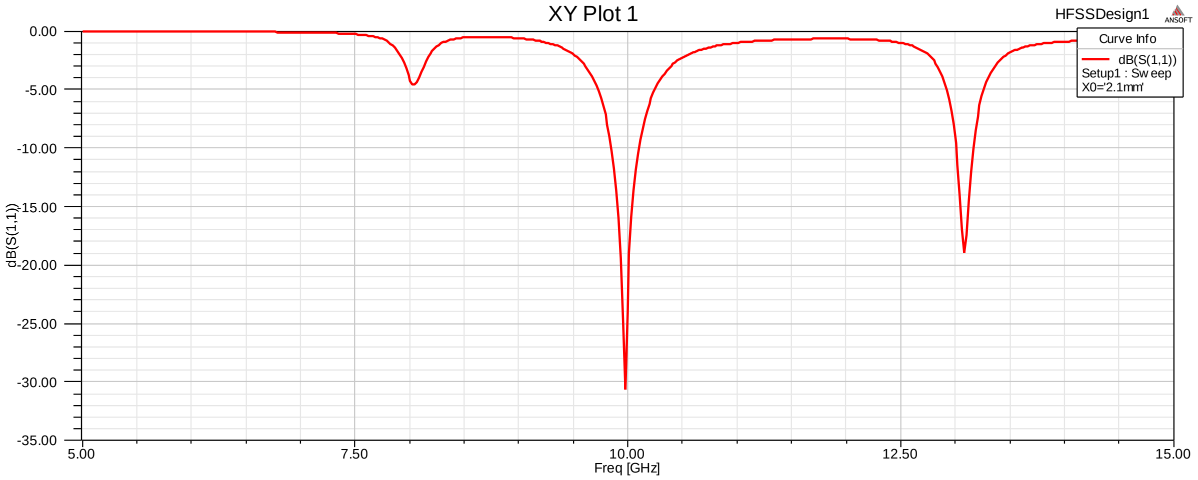

Fig.8: Return loss for Edge feed point located at (X_0, Y_0) = (2.1; L/2)

Since a microstrip patch antenna radiates normal to its patch surface, the elevation pattern for φ = 0 and φ = 90 degrees would be important. Fig.9 below shows the directivity pattern of the patch antenna at φ = 0 degrees for different feed points location.

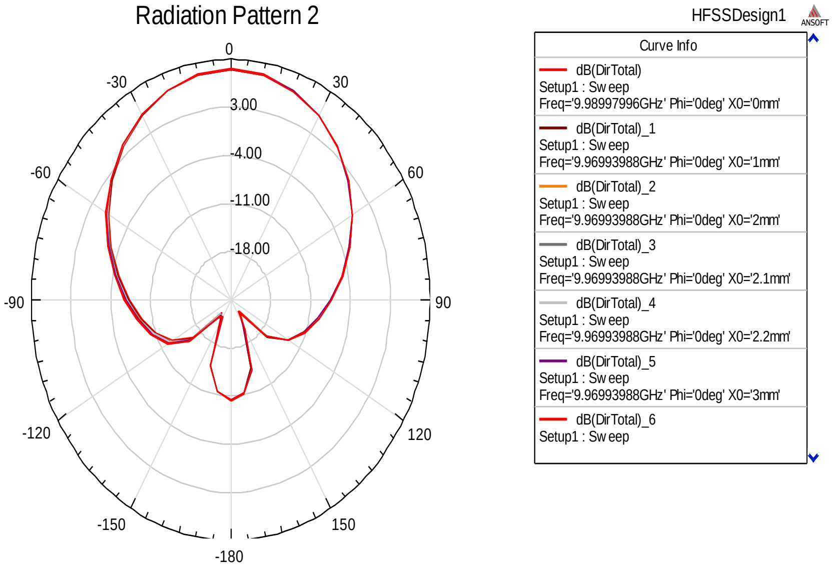

Fig.9: Directivity pattern for φ = 0 for different edge-feed points location

From fig. 9 we see that even when changing the position of the feed line the directivity pattern is almost the same. We note also that the radiation pattern of the edge-feed patch antenna is directional (8.55 dB).

2. Probe-feed microstrip patch antenna

Fig. 5 shows the patch geometry of a probe-feed rectangular patch antenna, the coaxial probe feed usedis designed to have a radius of 0.5mm.

Through the same way, the position of the coaxial feed takes different values according to the table below:

Feed location (X_0;Y_0) (mm)	Centre frequency (GHz)	Return loss (dB)	Bandwidth (MHz)	Impedance (Ω)	Gain in directivity(dBi)
(0; 1.5)	9.94	-11.18	110	51.85	8.45
(0; 2)	10.03	-30.09	310	48.63	8.49
(0; 2.1)	10.05	-32.25	310	47.95	8.49
(0; 2.2)	10.05	-25.50	330	50.34	8.50
(0; 2.4)	10.9	-18.23	330	48.15	8.50
(0; 2.5)	10.11	-16.12	330	48.50	8.50
(0; 3)	10.19	-11.16	200	47.11	8.51
(0; 3.5)	10.27	-9.01	-	44.97	8.51
(0; 4)	10.33	-8.03	-	42.86	8.51
(0.3; 2.1)	10.05	-32.91	310	48.30	8.48
(0.5; 2.1)	10.05	-33.45	330	48.88	8.49
(0.7; 2.1)	10.03	-31.29	310	51.48	8.48
(1; 2.1)	10.03	-29.65	330	50.93	8.48
(1.5; 2.1)	10.03	-25.27	330	52.19	8.49
(2; 2.1)	10.03	-22.27	180	50.49	8.49
(3; 2.1)	9.98	-18.12	350	56.08	8.50
(4; 2.1)	9.98	-16.72	350	56.04	8.50
(5; 2.1)	9.96	-17.51	370	57.57	8.50

Table 3: Effect of feed location on centre frequency, return loss, bandwidth, impedance and directivity for probe-feed patch antenna

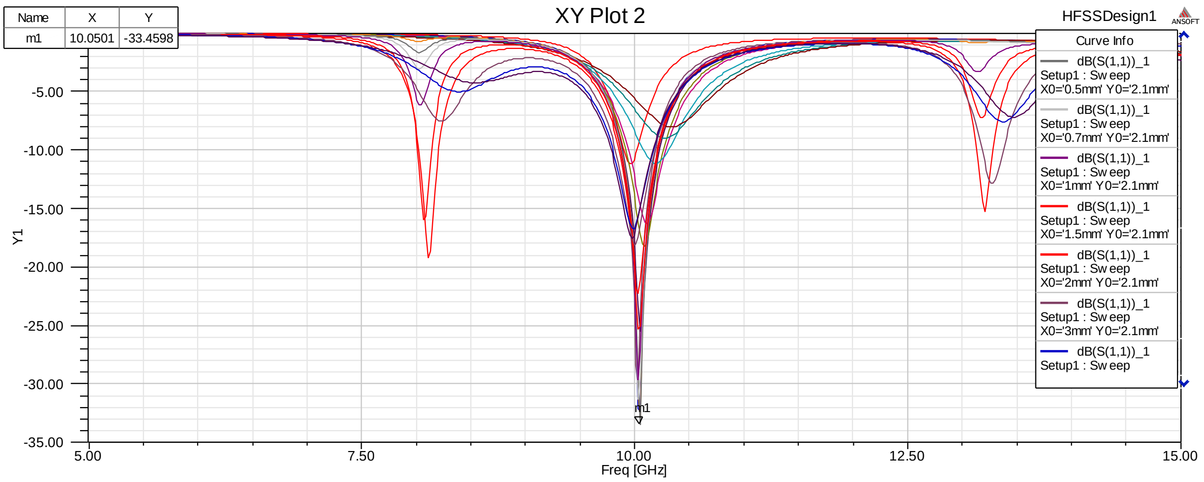

Fig.10: the return loss versus frequency at different probe feed point locations

After analyses the S11 parameter simulation result from table 3 for the coaxial feed line, The result has shown that the minimal value of return loss is -35.15 dB for (X0,Y0) = (0.5; 2.1); with a resonance frequency of 10.05 GHz, fig.10. The bandwidth of the antenna for this feed point is330MHz and the directivity is about 8.5 which are also an important values.

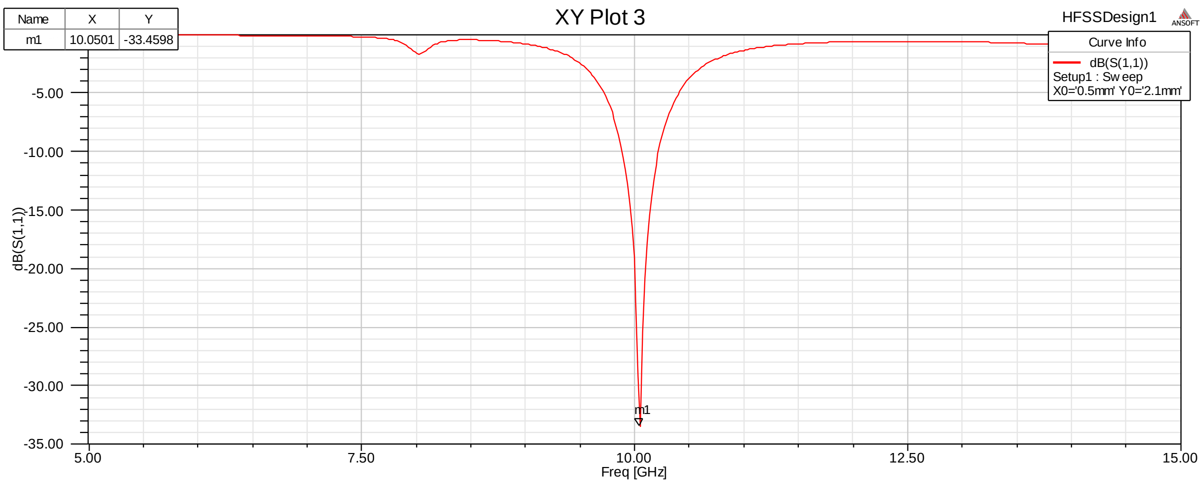

Fig.11: Return loss for probe feed point located at (X_0, Y_0) = (0.5; 2.1)

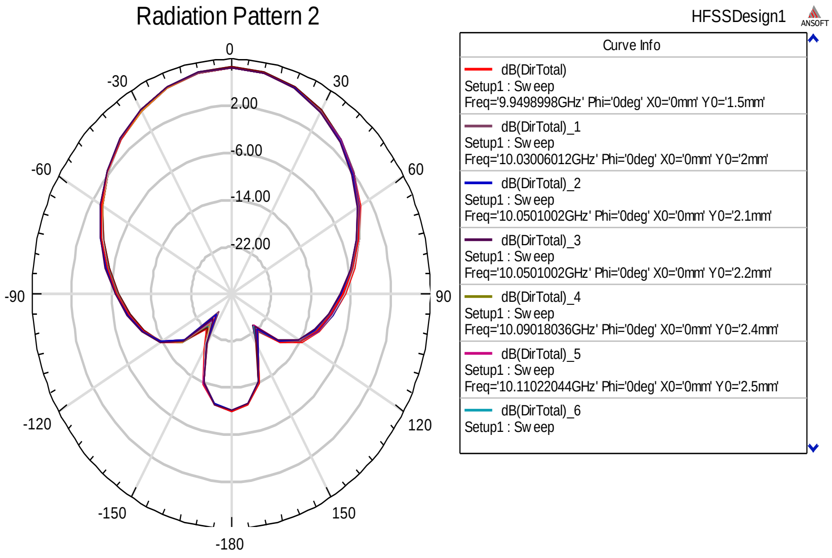

Fig.12: Directivity pattern for φ = 0 for different probe-feed points location

From fig.12 we see that even when changing the position of the probe feed line the directivity pattern is almost the same with an important value of 8.49 dB.

3. Inset-feed microstrip patch antenna

Figure 6 shows the patch geometry of an inset-feed rectangular patch antenna, where the inset gap ‘g’ is located symmetrically along the width of the patch.The value of ‘g’ is taken equal to W_f.

The results tabulated in table 4 are obtained aftervarying the feed location along the length and the width of the patchfrom the origin (centre of patch) to its left most edge.Frequency rangeof 10 GHz to 11GHz was selected.

Feed location (X_0;Y_0) (mm)	Centre frequency (GHz)	Return loss (dB)	Bandwidth (MHz)	Impedance (Ω)	Gain in Directivity (dBi)
(0; 1.5)	10.25	-1.2	-	72.25	6.81
(0; 2)	10.59	-6.97	-	63.24	7.54
(0; 2.1)	10.61	-9.26	-	59.91	7.68
(0; 2.2)	10.67	-11.89	120	56.17	7.71
(0; 2.25)	10.69	-13.39	160	55.5	7.72
(0; 2.3)	10.71	-15.32	200	53.45	7.74
(0; 2.35)	10.73	-17.54	220	51.26	7.76
(0; 2.4)	10.73	-21.05	240	53.15	7.82
(0; 2.45)	10.75	-25.91	260	52.34	7.83
(0; 2.5)	10.77	-32.49	260	52.15	7.83
(0; 2.6)	10.79	-24.45	300	50.32	7.89
(0.5; 2.5)	10.79	-35.15	320	48.42	7.85
(0.7; 2.5)	10.81	-29.29	300	47.65	7.85
(1; 2.5)	10.83	-23.56	280	48.56	7.87
(2; 2.5)	10.97	-13.56	280	45.07	7.86
(3; 2.5)	11.01	-11.69	220	42.32	7.86

Table 4: Effect of feed location on centre frequency, return loss, bandwidth, impedance and directivity for inset feed patch antenna

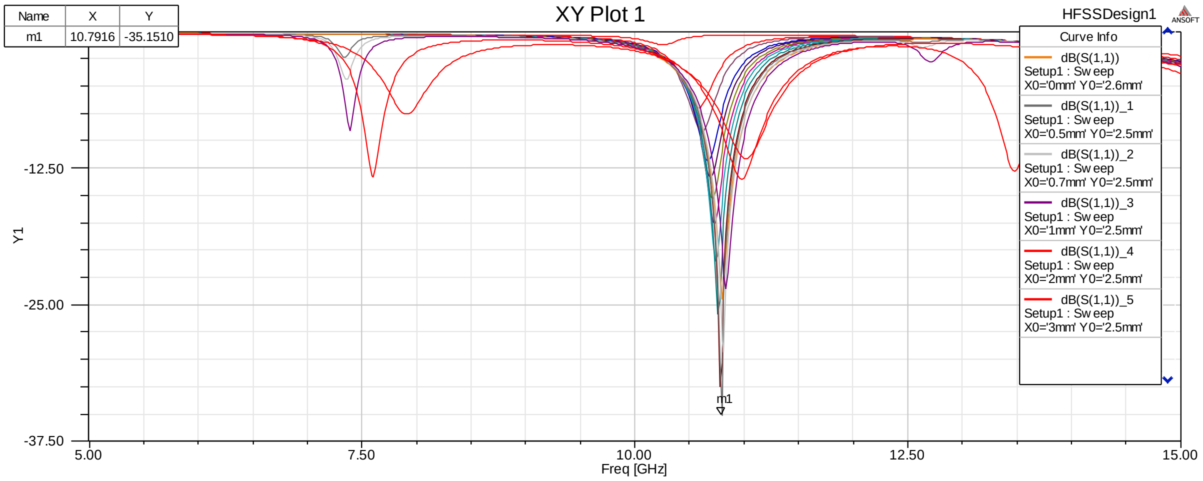

Fig.13: the return loss versus frequency at different inset feed point locations.

After analyses the S11 parameter simulation result from table 2, the optimum inset feed point location is found to be at(X_0,Y_0) = (0.5;2.5) where RL of -35.15 dB is obtained. Thebandwidth of the antenna for this feed point is300MHz and the centre frequency is 10.79 GHz which is veryclose to the desired design frequency of 10 GHz. Results are presented by the fig.13above.

Wehave observed that as the feed point moves away fromthe centre of the patch, the centre frequencychangesslightly; this variation is as a result of change inthe input impedance.It is also seen that the directivity has a negligible change when we varied the feed point location.

Now we vary the inset gap in proportion of feed line width and observe the variation of patch antenna performance, we note that the feed point is fixed at (X_0,Y_0) = (0.5; 2.5):

Inset gap g (mm)	W_f	0.75 * W_f	0.9 * W_f	1.1 * W_f
Centre frequency (GHz)	10.79	10.67	10.73	10.85
Return loss (dB)	-35.15	-21.09	-27.09	-37.80
Bandwidth (MHz)	320	280	280	300
Impedance (Ω)	48.42	48.64	48.44	49.40
Gain in Directivity (dBi)	7.85	8.1	7.98	7.74

Table 5: Performance analysis as a function of inset gap

It was observed that with the variation in inset gap, theresonant frequency does not shift much. Even the bandwidth shows alow change. The gain in directivity was also observed and found to be varying between 7.74 dB to 8.1 dB.The parameter which has shown a considerable change with the change in inset gap is return loss and input impedance. The inset gap was varied in proportion of feed line width 'W_f '.When the inset gap was equal toW_f the return loss was observed to be -35.15dB. The return loss for inset gap wider than $W_f$was lesser so we increase the notch width so that the return losses can be further decreased. As we increased the inset gap the value of return loss started to decrease and it became maximum negative (-37.80 dB) at inset gap equal to 1.1 * $W_{f,}$ Fig. 14.as this feedingpoint shows a good impedance matching.

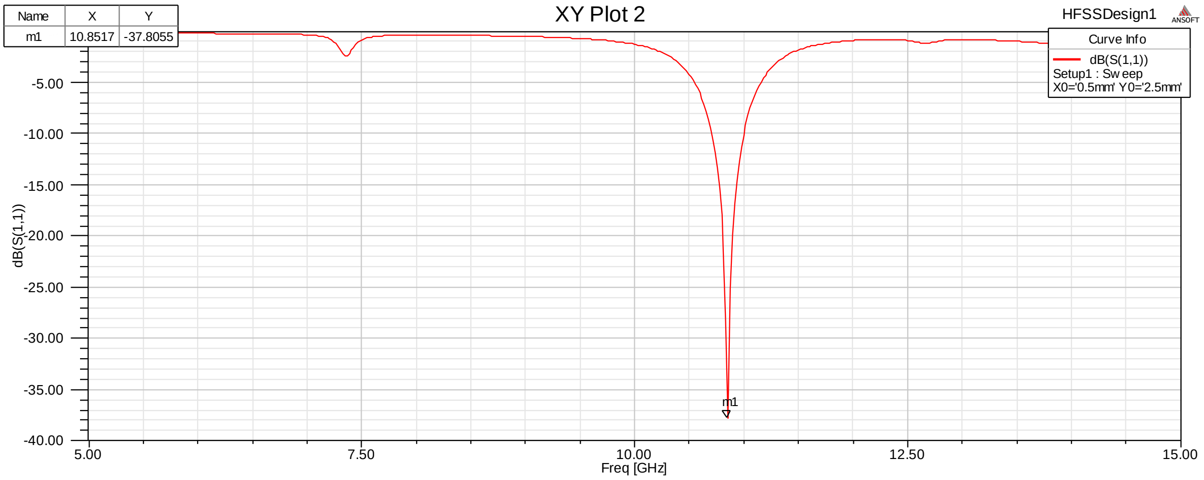

Fig.14: Return loss for inset feed point located at (X_0, Y_0) = (0.5; 2.5) and g = 1.1*W_f

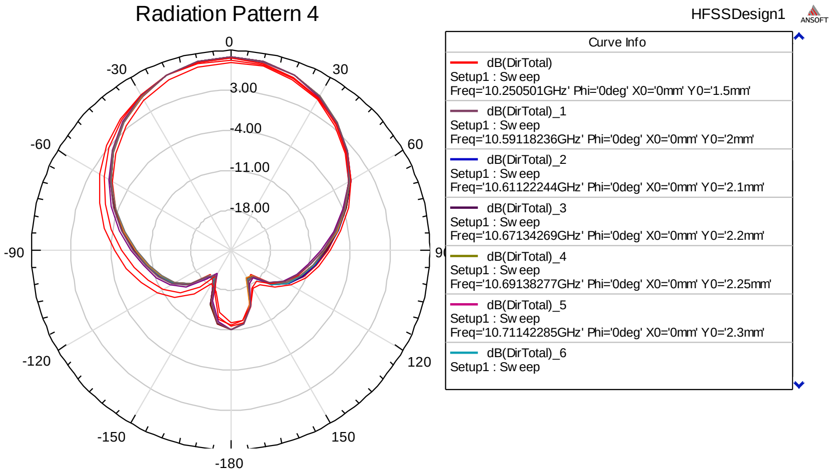

Fig.15: Directivity pattern for φ = 0 for different inset-feed points location

We observe that the directivity pattern changes slightly with the variation of the feed point location but generally its value remains important (7.74 dB) for the optimum feed point. Fig 15

CONCLUSION

In this work, the aim was targeted at investigating the effect of feeding methods and feed location on the performance parameters of rectangular patch antenna such as center frequency, return loss, bandwidth, directivity and impedance matching. We have selected different feed points for each feeding method and that for thesamepatchsize, the simulated results compared and the best location adopted and implemented for a frequencyof 10 GHz.

In the edge-fed patch antenna, the return loss is minimum in the position (X0; Y0) = (2.1; L/2)which is equal to -30.66, the advantages of this feeding method is that the resonance frequency, bandwidth and directivity are fixed while changing the feed location, also it gives a good value of directivity (8.55 dB).

Coaxial feeding is giving a good value of return loss, -33.45 in the position (X0; Y0) = (0.5; 2.1), and bandwidth (330 MHz), the problem with it is its design complexity.

Inset feeding is giving the best value of return loss -37.80 dB in the position (X0; Y0) = (0.5; 2.5) and inset gap g = 1.1*Wf .it achieves a good impedance matching. The inset and edge feeding are easier in construction. From the tables, it is clearly shown that, feed point location can affect the performance of rectangular patch antenna.

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