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Inset Fed Microstrip Patch Antenna for X-Band Applications

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***Abstract*— Microstrip antennas play an important role in RF Communication. They are available in different configurations for various applications. In this paper, patch antenna with inset feed configuration is designed which works at 10GHz frequency mainly for X-band communication. The antenna is designed using HFSS tool to determine its dimensions and evaluate performance parameters. The antenna substrate thickness is 1.588mm RT Duroid with a dielectric constant of 2.2. The antenna performance parameters such as return loss, VSWR, gain, directivity, bandwidth are found from the simulation.**

Index Terms:— Inset fed, HFSS, X-band, dielectric constant, VSWR, directivity.

INTRODUCTION

1.Microstrip patch antenna

Microstrip patch antennas are of printed kind of antennas used for wireless applications. Its features like compact size, less weight, simpler design makes it to be used in satellite & mobile communications and military applications. The patch antenna is commonly used type which can be used in array configuration also. It is a narrowband & widebeam antenna which is constructed easily by fabrication steps like etching process. It has a metal structure on one side of the dielectric substrate and on the other side ground plane is present. Microstrip antenna has abundant of advantages like cost effective, large scale production, dual polarization principle & easier integration with other complex circuits. Some of the drawbacks include less bandwidth, less gain, gives rise to surface waves & radiation from the edges.

The Fig.1 shows the construction of the microstrip patch antenna. The larger dimension is the length L which causes resonance at its half-wavelength frequency. Radiation occurs at the ends of the width W which gives rise to cross-polarization.

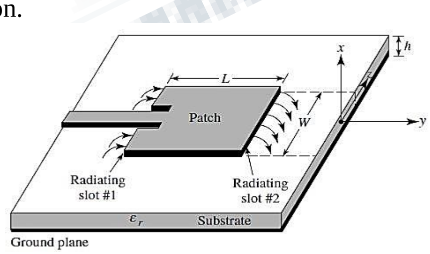

Fig.1: Construction of Microstrip Patch Antenna.

The Fig.2 shows the side view of patch. The E-field lines are normal to the ground plane. They change direction due to half-wave nature of patch. They propagate normal to the substrate. Figure shows the fringing fields at the edges of length L. The H-field lines are in circular fashion. Since the field lines are exposed to air & in dielectric region, effective permittivity is determined for further mathematical analysis.

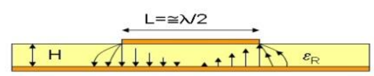

Fig.2: Side view of the patch.

The Fig.3 shows the variation of E-field & H-field along the length of the patch. The H- field lines are normal to the E-field lines as reference to Maxwell's field equations. The magnetic field is zero at the edges & maximum at the centre whereas the electric field strength is zero at the centre & tends to maximum at edges. The ratio of E to H field gives the impedance. The feed point must be properly located between centre & edge for better impedance match.

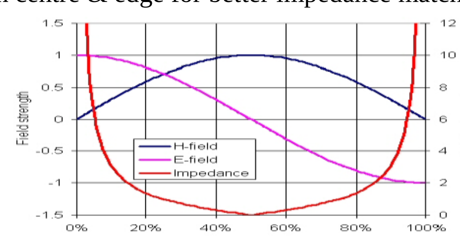

Fig.3:E & H Fields and impedance(Z) variation v/s length of the patch.

2. X-Band

X-band is mainly used for radar applications, phased arrays, in civil, military, and government institutions for weather monitoring, air traffic control, defence tracking and vehicle speed detection.

X-band is a portion of RF microwave region of the electromagnetic spectrum. The most commonly specified frequency range is 8.0 to 12.0 GHz as per IEEE.

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3. Design Methodology

Microstrip patch antenna comprises of metal patch usually made of copper & a feed line above the dielectric. This is done by photo etching. The other side of the substrate is the very thin ground plane. These antennas mainly radiate due to the fringing fields at the edges of length of patch. The antenna is fed by various mechanisms. They are broadly categorised in to two types viz contacting and non-contacting methods. The contacting methods are microstrip line & probe feed where the RF power is directly fed to patch. The non-contacting methods include electromagnetic field coupling, proximity feeding and aperture feeding where power is fed by coupling action.

4. Feeding Mechanism

Inset feeding technique of microstrip antenna is simple to implement & easy to know the behavior of the antenna, which is controlled by the inset gap and inset length. Impedance of the antenna can be controlled by this feeding method due to planar structure.

A notch due to inset feed provides a junction capacitance which in turn influence the resonance frequency of the antenna. As the feed point shifts towards the centre of the patch from the edge, the input impedance decreases and tends to zero at the centre. In this paper, the value of inset feed distance y0 is 3.126mm.

Since the feed location determines the antenna input impedance, so to achieve 50Ω impedance, the following relation is used.Fig.4 shows the inset fed microstrip antenna.

$$R_{in}(y = y_o) = R_{in}(y = 0)\cos^2\left(\frac{\pi y_o}{L}\right) \qquad (1)$$

where $R_{in}(y = 0)$ is the input impedance at the leading radiating edge of the patch and $R_{in}(y = y_0)$ is the desired input impedance (50 Ω).

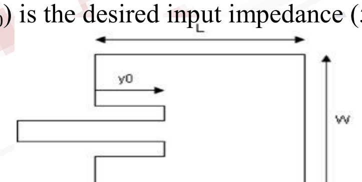

Fig.4:Inset fed microstrip antenna.

II. LITERATURE REVIEW

Microstrip antennas are designed using various feeding techniques to get better impedance match & achieve the desired results. Inset feeding is the most commonly used practice for patch antenna design for many applications. This section gives a brief literature survey on inset fed microstrip antenna.

In paper [1], the authors designed a slotted rectangular patch antenna for ISM band. The bandwidth of the patch antenna is improved by optimizing the feed offset position, but with a slight trade-off in gain was noticed.

In paper [2], the authors designed inset fed rectangular patch antenna to operate at frequency of 2.45 GHz for wireless applications with a lower value of dielectric constant of the substrate material is used. This enhances the efficiency, bandwidth and radiated power. The patch size was independent of the dielectric constant & loss tangent was neglected.

In paper [3], the authors designed inset fed patch antenna for RFID applications as it does not require much bandwidth for operation & accordingly improving the quality factor.

In paper [4], the authors examined & compared the variation in parameters by varying both the inset gap and inset length. It was noticed that the performance of the antenna depends more on inset gap rather than inset length.

In paper [5], the Transmission line model(TLM) was used for analyzing the microstrip antenna and also presented a curve fit formula to locate the exact inset length. The comparison was made between the results obtained using the TLM method and by EM simulator.

In paper [6], the investigation was done on the optimum result of different feeding techniques of patch antenna for Wimax applications. The bandwidth was achieved maximum by aperture coupling. Proximity coupling gave the best impedance matching and radiation efficiency. Coaxial feeding technique gave the least bandwidth.

III. ANTENNA DESIGN PROCESS

The "Transmission Line Model" is used for antenna design. In this model, microstrip antenna width W_p and height h will be separated by a transmission line of length L_p. The microstrip antenna is comprised of three layers namely ground plane, substrate and a patch in rectangular shape. The minimum required height of substrate above the ground plane is $0.333\lambda_0 \leq h \leq 0.5\lambda_0$, where λ_0 is the free space wavelength.

A. Substrate

The substrate plays a vital role in antenna design. Normally the substrates should have permittivity of $2.2 \leq \varepsilon_r \leq 12$. Low loss tangent reduces the dielectric power losses in the antenna.

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So substrate with low loss tangent can be used for patch antenna design. RT-Duroid substrate has a least dielectric constant of ε_r = 2.2 and permissible loss tangent.

B. Patch dimensions

The physical dimensions of the patch influence on the antenna performance. To construct the antenna, the following design equations are used.

1). Patch Width

The bandwidth & impedance characteristics of the antenna are mainly dependent on patch width.

$$W_p = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (2)$$

c = free space velocity of light
f_r = resonating frequency
ε_r = Dielectric constant of substrate

2).Effective dielectric constant

This is considered due to the presence of E & H-field lines partially in air and substrate.

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{W_p}}}\right)$$
(3)

3).Extension of patch length

This is due to fringing effects in the patch.

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{W_p}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W_p}{h}+0.8)}$$
(4)

4).Patch length

$$L_p = L_{eff} - 2\Delta L$$
(5)

where the effective length of the patch is

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}}$$
(6)

5).Ws/h ratio

The relation between width (Ws) of strip line and thickness (h) of the dielectric layer is given by

$$\frac{W_s}{h} = \begin{cases} \frac{2}{\pi}\left[B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{2X\varepsilon_r}X\left\{\ln(B-1)+0.39-\frac{0.61}{\varepsilon_r}\right\}\right], & for\ \frac{W_s}{h} > 2 \\ \frac{8xe^A}{e^{2xA}-2}, & for\ \frac{W_s}{h} \le 2 \end{cases}$$
(7)

$$A = \frac{Z_o}{60}X\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r-1}{\varepsilon_r+1}X(0.23X\frac{0.11}{\varepsilon_r})$$
(8)

$$B = \frac{377\pi}{2Z_o\sqrt{\varepsilon_r}}$$
(9)

For the present design, the characteristics impedance = 50**Ω.** The length of the strip is $\frac{\lambda_g}{4}$,

where $\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_r}}$
(10)

λ_o= Free-space wavelength
λ_g= Guide Wavelength

6).Inset length

The inset length of microstrip antenna is calculated by

$$l_f = 10^4(0.001699\varepsilon_r^{\ 7} + 0.13671\varepsilon_r^{\ 6} - 6.1783\varepsilon_r^{\ 5} + 93.187\varepsilon_r^{\ 4} - 682.69\varepsilon_r^{\ 3} + 2561.9\varepsilon_r^{\ 2} - 4031\varepsilon_r + 6697)\frac{L_p}{2}$$
(11)

7).Excitation Port

Lumped port is used for better impedance matching.

IV. PROPOSED PATCH ANTENNA

The proposed antenna is designed with following specifications:

A. Design Parameters

- ✓ Operating Frequency, f_o = 10GHz
- ✓ Fractional Bandwidth > 1% and VSWR < 2%
- ✓ Input Impedance, Z_{in} = 50 ohms
- ✓ Linear Polarization
- ✓ Half-Power-Beam-Width (HPBW) > 120 degrees

B. Substrate Parameters

- ✓ Lossy material of RT Duroid 5880
- ✓ Relative Dielectric Permittivity, ε_r = 2.2
- ✓ Substrate Thickness, h = 1.588 mm
- ✓ Conductor Thickness (Copper), t = 0.035 mm
- ✓ Substrate Dielectric Loss Tangent, $tan\delta$ = 0.025

An air box is used so that the radiation from the structure is absorbed and not reflected back. The air box should be a quarter-wavelength long of the wavelength of interest in the direction of the radiated field. For this design, air box of

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length of 71.21mm, width of 19.62mm and height of 43.65mm is taken. The dimensions of microstrip antenna calculated are shown in Table1.

Table.1: Antenna dimensions.

Dimensions	Values in mm
Length of the patch $\mathbf{L_p}$	9.06
Width of the patch $\mathbf{W_p}$	11.86
Length of the feed line $\mathbf{L_f}$	23.59
Width of the feed line $\mathbf{W_f}$	4.84
Width of the gap $\mathbf{W_{sf}}$	5.44
Inset feed distance $\mathbf{Y_o}$	3.126
Length of the ground plane $\mathbf{L_g}$	50
Width of the ground plane $\mathbf{W_g}$	50

The layout of inset fed microstrip antenna and the designed antenna structure simulated using HFSS tool are shown in Fig.5 and Fig.6 respectively.

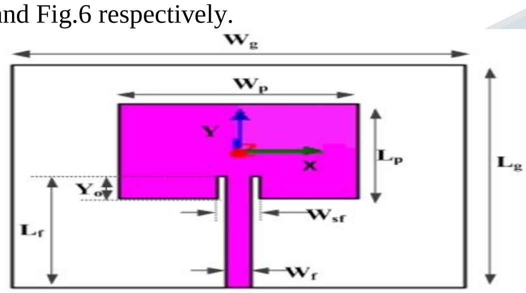

Fig.5: Layout.

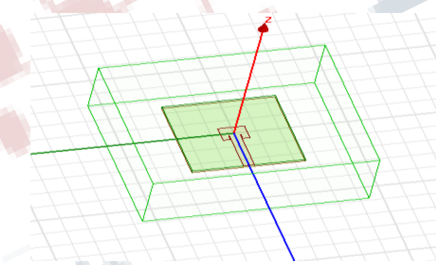

Fig.6: Designed Inset fed microstrip patch antenna.

V. RESULTS

The designed antenna is simulated using HFSS tool.
The percentage bandwidth of antenna is given by

$$BW(\%) = \frac{f_{max} - f_{min}}{f_r} X100\% \qquad (12)$$

Where, f_{max} and f_{min} are determined at -10dB. f_r is the resonant frequency. The simulated value at -10dB is f_{max} = 10.9GHz, f_{min} = 10.3GHz, BW = 600MHz and the percentage bandwidth is 5.66%. The Fig.7 shows the bandwidth calculation.

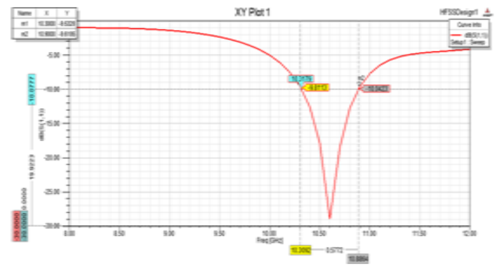

Fig.7: -10dB Bandwidth from return loss plot.

The return loss of -29dB is obtained as shown in Fig.8.

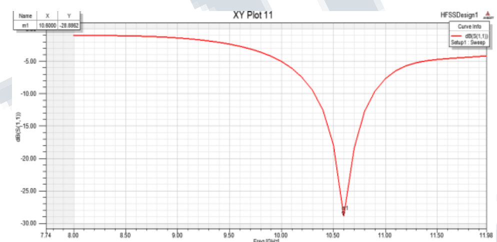

Fig.8: Return loss plot of the microstrip patch antenna.

The VSWR of approximately 1.0 is obtained due to simulation as shown in Fig.9.

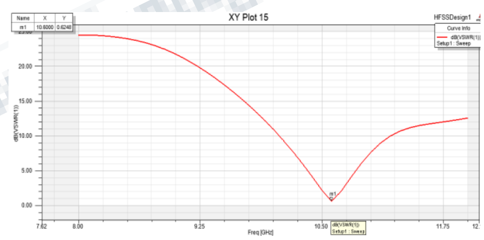

Fig.9: VSWR characteristics of the microstrip patch antenna.

The antenna directivity and gain parameters are plotted as shown in Fig.10 and Fig.11 respectively.

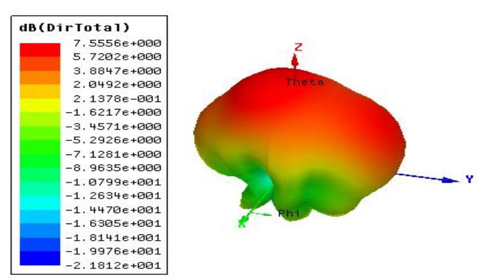

Fig.10: 3D plot of directivity of microstrip antenna.

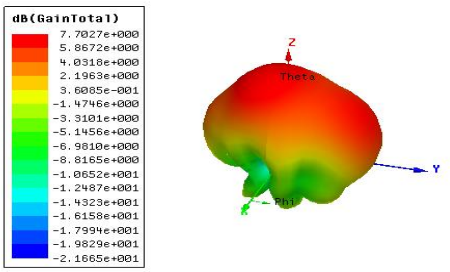

Fig.11: 3D plot of gain of microstrip antenna.

Table 2 gives the parameter values obtained after simulation of the antenna from HFSS.

Table.2: Parameter values of the microstrip antenna.

Antenna Parameters	Values
Return Loss	-29dB
VSWR	≈ 1.0
Max U	0.3222W/Sr
Peak Directivity	7.5556
Peak Gain	7.7027
Radiated Power	0.71085W
Incident Power	1W
Radiation Efficiency	1.0344

VI. CONCLUSION

In this paper, the microstrip antenna parameters are calculated at 10GHz with inset feed mechanism. The simulation tool used is HFSS. The antenna parameters such as return loss, VSWR, gain, directivity, bandwidth are determined from the simulation. The return loss of -29dB at 10.6GHz & VSWR of approximately 1.0 and gain of 7.7dB obtained from the simulation.

REFERENCES

[1] Merbin John, Ayyappan.M, Manoj.B, Stephen Rodrigues, “Bandwidth Enhancement of Microstrip Antenna for 5.8GHz by Optimised Feed Offset”, IEEE International Conference on Communication and Signal Processing, pp. 5090-0396, April 2016.

[2] Sajina Pradhan, Dong You Choi, “Inset Fed Microstrip Patch Antenna for Wireless Communication at 2.45GHz”, Journal of the Korea Institute of Information and Communication Engineering, 18(8): pp.1785-1790, August 2014.

[3] Nazish Irfan, Mustapha C. E. Yagoub, and Khelifa Hettak, “Design of a Microstrip-Line-Fed Inset Patch Antenna for RFID Applications”, IACSIT International Journal of Engineering and Technology, Vol. 4, No. 5, October 2012.

[4] Vinayak Samarthay, Swarna Pundir, Bansi Lal, “Designing and Optimization of Inset Fed Rectangular Microstrip Patch Antenna (RMPA) for Varying Inset Gap and Inset Length”, International Journal of Electronic and Electrical Engineering, pp. 1007-1013, 2014.

[5]M. Ramesh and K. Yip, “Design formula for inset fed microstrip patch antenna”, Journal of Microwaves and Optoelectronics, Vol. 3, No. 3, pp. 5–10, 2003.

[6]A. Kumar, J. Kaur, and R. Singh, “Performance analysis of different feeding techniques”, International Journal of Emerging technology and Advanced Engineering, Vol. 3, No. 3,pp. 884–890, 2013.

[7] Hu Ying , Jackson David R. , Williams Jeffery T. , Long Stuart A, “A Design Approach for Inset Fed Rectangular Microstrip Antennas”, IEEE Antennas and Propagation Society International Symposium, pp. 1491 - 1494 , 2006.

[8] Balanis Constantine A. "Antenna Theory Analysis and Design" , 2nd edition.