Design of Inset Feed Patch Antenna for S Band Applications

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Abstract - In this paper, an inset feed patch antenna is designed for S band frequency range with operating frequency of 3GHz. The simulation is done in CST microwave studio. The gain of the designed patch antenna is significantly improved along with several other parameters like bandwidth and VSWR. The antenna purposed is suitable for several remote sensing applications.

Key Words: Inset fed patch antenna, S band, CST microwave studio

1. INTRODUCTION

The antennas form essential part of any communication system. Since the advent of radio, there have been tremendous research on designing and improving the parameters of antennas so as to cater the growing requirements of communication equipments. Antennas basically are used along with a transmitter and receiver pair, the transmitter provides the electric current at the antenna terminals which the antenna radiates at the receiver side, the radiation is received by another antenna and it converts a fraction of the radiation as the current at its terminals. The receiver includes an amplifier section which amplifies the current and performs several other functions like filtering, decoding. In recent years, as components have reduced in size the need to develop small antennas that can be incorporated with the integrated circuits is increased. Bandwidth, power, radiation pattern are some of the other important parameters observed along with reduced size when designing such antennas .Several advancements in microstrip antenna have been observed and now the focus has shifted in designing antennas for remote sensing and wireless applications. In order to design such antennas, their corresponding parameters must be obtained through a combination of simulations and theoretical calculations.

There are several feeding mechanisms for patch antenna like the coaxial probe feeding mechanism, microstrip line feed, proximity coupled [1] but inset fed patch antennas have a better advantage because of their ability to provide impedance control [2] modelled closely to $\cos^2$ relation

In this paper, the parameters required for an inset fed patch antenna with center frequency 3 GHz are discussed.

2. CHARACTERISTICS OF MICROSTRIP PATCH ANTENNA

The basic geometries of several microstrip patch antennas like circular, elliptical, rectangular, triangular antennas have several common features. For instance, each antenna type has infinite resonant modes and the resonant frequency of each is depended on the relative permittivity of the substrate ϵ_r and the size and shape of the antenna [3]. The antennas also have larger dimensions than the physical one because of fringing fields at the edge of the patch several empirical factors have to added in order to account these change in dimensions.

The resonant modes have their own characteristic radiation patterns and usually the modes are selected in a manner that the pattern maximum of the microstrip antenna is broadside and the polarization of such antennas is linear however with design modifications circular polarization can also be obtained.

Microstrip patch antennas also have a feature of bandwidth enhancement by varying the impedance with the most common method using thick low dielectric constant substrate this however leads to spurious radiation to avoid this, planar impedance matching which have a considerable improvement on the bandwidth of the antennas up to 15% [4].

3. GEOMETRY OF INSET FEED PATCH ANTENNA

The inset fed patch antenna has a substrate of FR4 with ϵr =4.4, the thickness of the substrate is 0.035mm and the height (h) is 1.6mm. The patch is made of copper annealed, the notch width is selectively chosen in order to achieve high gain and a low return loss at the operating frequency 3GHz.

The patch is made rectangular initially then it is cut in order to form inset feed antenna with the chosen notch width being the distance between the inset feed line and the antenna in the horizontal axis. The position of inset feed point is depth or vertical distance of the feed line from the base line of the patch antenna to its termination.

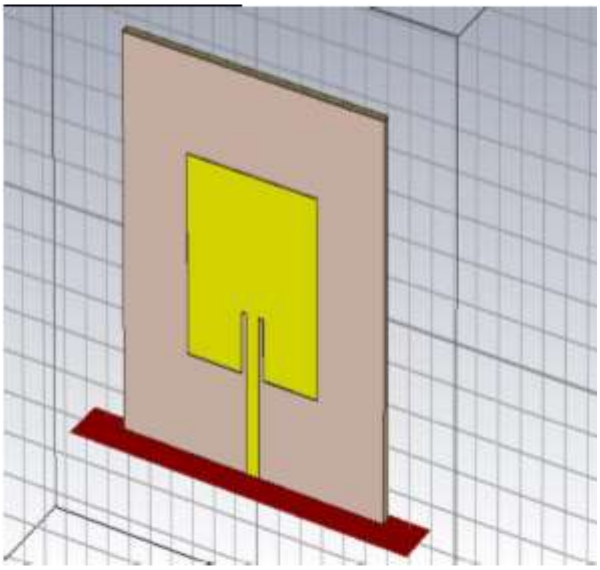

Fig 1: Inset fed patch antenna

Table 1: The values of the parameters

Operating Frequency GHz	3
Resonant Frequency GHz (f_r)	2.97
Width mm W	30.07
Length mm Lp	23.63
Position of inset feed point mm (y)	7.2
Notch width mm (g)	0.2967
Width of the microstrip feed line mm	2.967
Dielectric constant	3.938

4. DESIGN PROCEDURE

It is necessary to understand the important parameters of the antenna, the most fundamental are the operating frequency, the effective dielectric constant and the height of the substrate. Along with these parameters it is important to understand the goals the proposed antenna should attain. Some antennas focus on bandwidth enhancement others on return loss or gain. In this paper a focus is made on improving the gain of conventional inset fed patch antenna by selecting appropriate notch width. The notch width is set to be W/10. Where W is the width of the microstrip feed line in mm.

The design equations are used are described in [5,6,7]. A detailed explanation of them are also provided in aforementioned references.

$$W_p = \frac{v_o}{2f_r} * \sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

The width of the patch W_p is calculated using the above formula where f_r is the resonant frequency and ϵ_r is dielectric constant, v_o is speed of light in vacuum.

The resonant frequency is calculated by[4] and The effective dielectric constant ϵ_{reff} is then obtained using

$$f_r = \frac{v_o}{\sqrt{2\times\varepsilon_{reff}}}\frac{4.6\times10^{-14}}{g} + \frac{f}{1.01}$$

$$\varepsilon_{reff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left[1+12\frac{h}{W_p}\right]^{-1/2} \quad (2)\ \&\ (3)$$

(W/h>1)

The effective length of the patch is (4)

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

The extended length due to fringing is calculated (5)

$$\frac{\Delta L}{h} = \frac{[\varepsilon_{reff}+0.3]\left[\frac{W_p}{h}+0.264\right]}{[\varepsilon_{reff}-0.258]\left[\frac{W_p}{h}+0.8\right]}$$

The real length of the patch is (6)

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

The position of the inset feed point is calculated by [6] note that the input impedance is 50Ω (7)

$$y = \frac{10^{-4}\left\{\begin{matrix}0.001699\varepsilon_r^{\,7}+0.13761\varepsilon_r^{\,6}-6.1783\varepsilon_r^{\,5}+\\93.187\varepsilon_r^{\,4}-682.69\varepsilon_r^{\,3}+2561.9\varepsilon_r^{\,2}-4043\varepsilon_r^{\,1}+6697\end{matrix}\right\}L_p}{2}$$

$$2 \le \varepsilon_r \le 10$$

The above formula is obtained using curve fit and it is in close agreement with simulation results[6]. Substituting the values of $\varepsilon_r = 4.4$, f =$3\times10^9 Hz$, $v_o = 3\times10^{11}\ mm/s$ with g=W/10 the above equations can be solved and their values are listed in table 1.

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5. SIMULATION RESULTS

The antenna designed was simulated in CST microwave suite. CST studio provides wide array of tools to design and improvise antenna structure. Simulation is a key step in development of antennas it provides insights on the working of the antenna and helps us identify areas that need improvements also it makes development of antennas faster and economical.

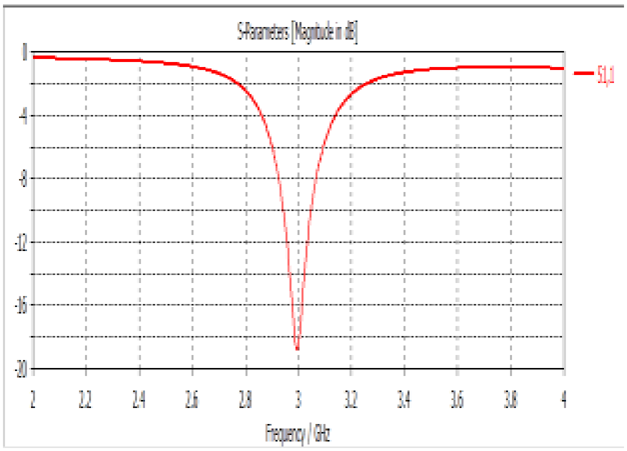

Fig 2: Return loss of the inset feed patch antenna with g=W/10

The return loss of the inset fed patch antenna doesn't show significant improvement compared to conventional antennas. It is at -19.2 db at 3 GHz. However, when the notch width was increased to 1mm there was a significant improvement in the return loss but as it can be observed the bandwidth is reduced about 10%-11%. The bandwidth obtained with g=W/10 is 101MHz. It is calculated from the graph of the return loss with the difference between f_2 and f_1 at -10db. Therefore, a tradeoff is observed notch width should be selected in a manner that provides a better bandwidth thus compromising the return loss. Change in the design of the conventional inset feed patch antenna can help in providing good return loss with significant bandwidth enhancement [8].

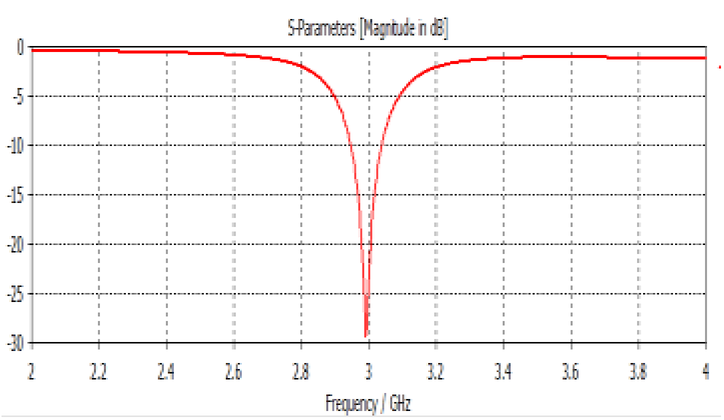

Fig 3: Return loss of the inset feed patch antenna with g=1mm

Since the parameter in consideration for designing of the antenna was the gain hence notch width with g=W/10 was chosen, also it is observed that when the notch width is decreased further to W/20 the return loss further degrades to -14.1 db.

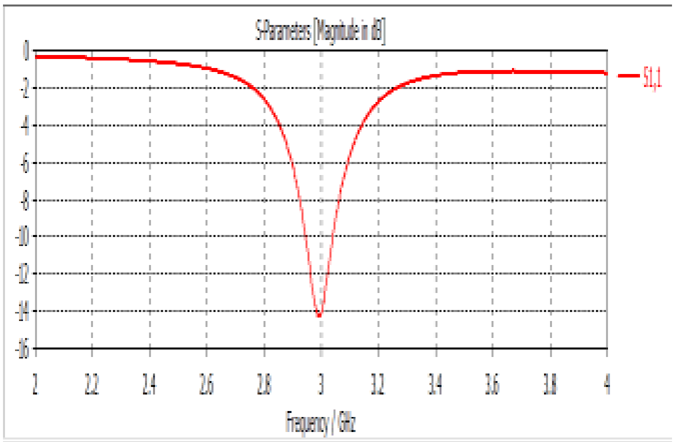

Fig 4: Return loss of the inset feed patch antenna with g=W/20

The VSWR obtained is good as it should be in range of 1-2. If VSWR is closer to 1 then it suggests that there is better impedance matching hence efforts must be undertaken to keep VSWR closer to 1. This prevents loss of energy as the antenna consumes less power which is critical in remote conditions for instance, weather radar. Since the antenna proposed is specifically designed for s band applications which include air traffic monitoring, providing RF sources for particle accelerators care was taken to maintain VSWR closer to 1 and in the simulations the VSWR obtained is 1.12 at the operating frequency.

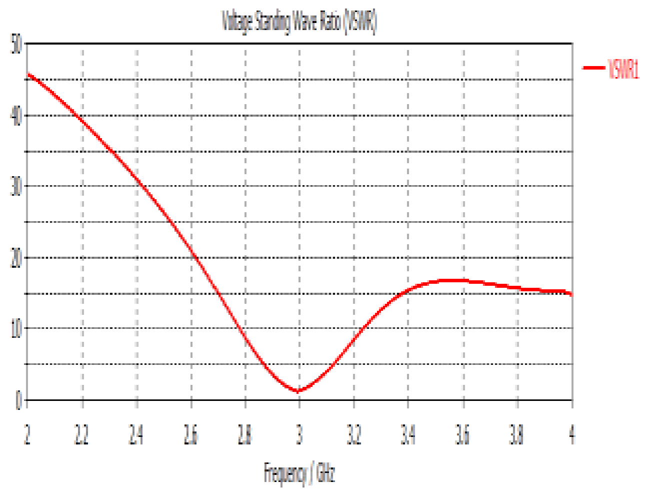

Fig 5: VSWR obtained for the antenna(g=W/10)

Antenna gain is one of the most important characteristics of antenna it is defined as ratio of the power transmitted by the antenna in the direction of peak radiation (obtained from radiation pattern) to that of an isotropic source. In application like radar imaging a high gain antenna is highly beneficial but not so in case of a cellular antenna. The conventional antennas like dish antennas are very large in size but with miniaturization new antennas are being designed aimed at providing high gain with smaller areas.

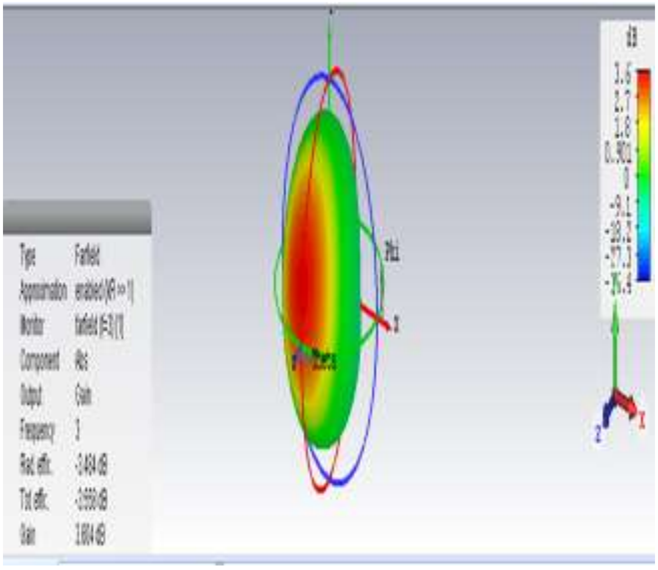

Fig 6: 3D plot of designed antenna with g=W/10

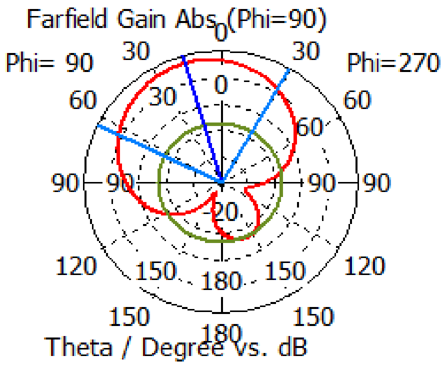

Fig 7: Polar plot of the antenna gain (g=W/10), gain=3.61 db

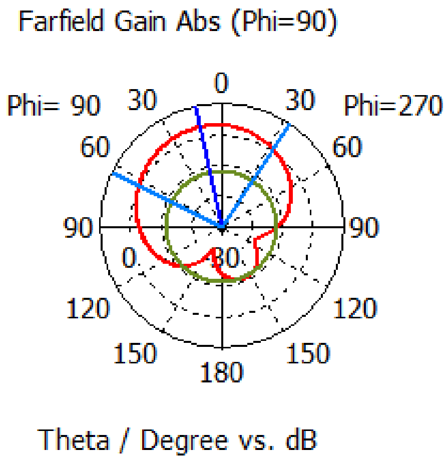

Fig 8: Polar plot of the antenna gain (g=1mm),gain=3.19 db

As we can see the gain is reduced for g= 1mm but as discussed earlier bandwidth obtained is higher for g=W/10. When considering g=W/20 the bandwidth is further improved as seen from Fig 4 but return loss is further degraded.

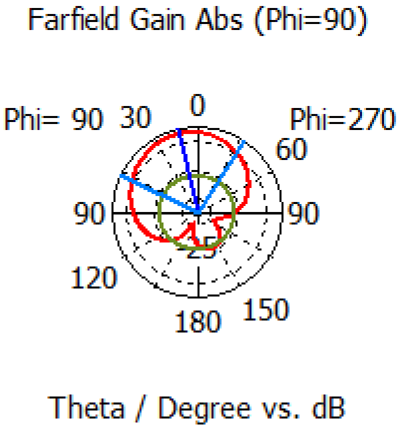

Fig 9: Polar plot of the antenna gain (g=W/20 mm), gain=3.17 db

Table 2 : Comparison of return loss and antenna gain for different notch width values for the operating frequency of 3 GHz

Notch Width	1mm	W/10	W/20
Antenna gain (db)	3.19	3.61	3.17
Return Loss(db)	-28.9	-19.2	-14.1

With the details shown in the table the highest gain is obtained with g=W/10 for the operating frequency of 3GHz. Hence g=W/10 is chosen as the desired notch width for the designed antenna.

6. CONCLUSION

The paper focusses on designing and analysis of inset feed patch antenna for s band applications. CST microwave studio was used to simulate the antenna designed using above equations. Several parameters were analyzed from the plots obtained. The effect of notch width on the return loss and the bandwidth was discussed. The antenna was designed to be compact and be cost-effective. To cater the requirements of remote sensing applications an inset feed microstrip patch antenna was designed with high gain and efficient bandwidth. The next step further would to introduce of slots that could further improve the bandwidth and the gain of the antenna and study the effects of slots antenna parameters at various bands in the spectrum.

7. REFERENCES

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