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Analysis, Design and Development of Patch Antenna for S-Band Applications

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ABSTRACT

Patch Antenna is a low profile antenna very much suitable for low frequency microwave application. This paper deals the Analysis, Design and Development of Patch Antenna for Wireless medical applications in the range of 2–4 GHz. The design parameters together with their relevant equations allow analytical calculations before simulation is performed. Finally a practical design is worked out to highlight the design steps required and CAD simulations are also described. The antenna is designed and analyzed using CST Microwave Studio. Here PTFE (Poly Tetra Fluoro Ethylene) material is used as substrate material, above which the rectangular patch is placed. The ground plane is incorporated with defective ground structure (DGS) to improve antenna performance. This antenna can be utilized for 4G frequency spectrum bandsand also for Industrial, Scientific and Medical (ISM) band applications. The antenna is fed with coaxial feed as waveguide port. The results presented that the antenna has gain of 7.4 dB. The simulation result provides that antenna can provide better gain and directivity. DGS which is realized by is a form of periodic structure has ability to reject certain frequency bands and passes certain frequency bands with less attenuation. Thus it improves gain and directivity. The Return loss, VSWR, radiation pattern and gain are observed.

Keywords: Patch Antenna, Return loss, VSWR, Radiation Pattern, Gain

1. INTRODUCTION

The evolution of wireless technologies is flavored into different generations depending on the maturity level of underlying technology. The patch antenna was proposed in 1953 by Deschamps. The classifications into these generations are not based on any parameters. Efforts have been made for the development of 4G (LTE) wireless technology [2]. The 3G (ITU) is limited to maximum bit rate factor of 10 and user plane traffic (UMTS>30msec). The resource assignment procedure is too big to handle traffic with high bit rate. It provides better spectrum efficiency, high data rates and lower latencies, flatter IP core architecture when it is compared with 3G technology [1]. The patch antenna presented here is a type of microstrip antenna. It consists of dielectric substrate sandwiched between the ground plane and the patch. It is virtually a parallel plate capacitor. When the patch size is proportional to signal frequency, it resonates at some frequencies. The application of Microstrip patch antenna due to its low profile, compactness, low cost, manufacturing repeatability extends widely. The practical drawbacks of micro strip antenna are it offers narrow bandwidth and low gain because of conductor, dielectric and surface wave losses. The losses depend on substrate thickness, permittivity and tanä of the material. To improve gain further, patch antenna is designed with DGS on ground plane which provides compactness and high gain. The DGS is a technique used to etch defected pattern on the back side of the ground plane [3].

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2. ANTENNA DESIGN PROCEDURE

The following sections deal the design of patch antenna. Patch antennas performance depends on certain parameters which are calculated and utilized in this project. The operating frequency (f_0 = 3GHz), substrate permittivity (ε_r = 2), substrate height (h = 1.9 mm) and loss tangent (tan δ = 0.0013) are first selected for the targeted gain. From the known parameters, the unknown parameters such as length L_p and width W_p of the patch, length L_g and width W_g of the ground are calculated using the empirical formulae below.

The width of the patch is

$$W_p = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

The effective permittivity (ε_{eff}) of the substrate is

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

Effective length is

$$L_{eff} = L_p + 2\Delta L = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \tag{3}$$

where ΔL is fringing field length extension written as

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

The length of patch is given by

$$L_p = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} - 2\Delta L \tag{5}$$

The length (L_s) and width (W_s) of the substrate are

$$\begin{aligned} L_s &= L_p + 6h = L_g \\ W_s &= W_p + 6h = W_g \end{aligned} \tag{6}$$

which are also the dimensions of the ground plane

3. ANTENNA CONFIGURATION

The constraints of the antenna design are the size of the device, substratematerial and location of the feed point. The antenna structure is printed on PTFE (Poly Tetra Fluoro Ethylene) substrate. The geometry of the antenna is shown in Figure 1 and Figure 3. The physical dimensions are given in the Table 1. The ground plane should be greater than the patch dimension. The ground plane has 18mm×16mm×5mm and the patch has 12mm × 10mm × 3mm. The substrate material is Poly Tetra Fluoro Ethylene (PTFE) with permittivity of 2 with thickness 1.9mm. The patch shape plays a crucial role in approaching compactness

Table 1
Design Parameters of the Rectangular Patch Antenna

Parameter	*Dimension*
L_p	34.37 mm
W_p	33.33 mm
L_s	45.77 mm
W_s	44.7 mm
Substrate height h	1.9 mm
E_r	2

and improved gain. A 50Ω coaxial probe feed is used to feed the patch since it a low cost feeding technique and can be easily affixed. The feed point position is located in such a way to provide good impedance matching.

3.1. Coaxial probe Feeding Method

The patch antenna can be excited by different methods like in fed line method, microstrip line feed and coaxial probe feed methods. In our case, it is fed with coaxial probe which has characteristic impedance of 50 ohm. The inner conductor of the probe is attached to the patch at a particular feed position from the back of the ground plane without touching the ground plane. The outer conductor is connected to the ground plane. Hence the coupling offers pure inductive reactance in nature. The coaxial cable has central conductor radius of 0.63 mm, outer conductor radius as 2.5 mm and the radius of the inner dielectric is 2.25 mm made of Teflon of $\varepsilon_r = 2.1$

The equivalent circuit of coaxial feed patch is shown in Figure 2, which denotes the inductive part due to inner conductor.

We are using PTFE as the dielectric material of dielectric constant 2. The position of the probe plays an important role in effectively radiating the energy into space. The probe must be connected at a point where the impedance is nearly equal to 50 ohm. This can be calculated theoretically since we know the impedance at the corner of the patch. The values of the impedance for the coaxial probe feed follows direct proportionality

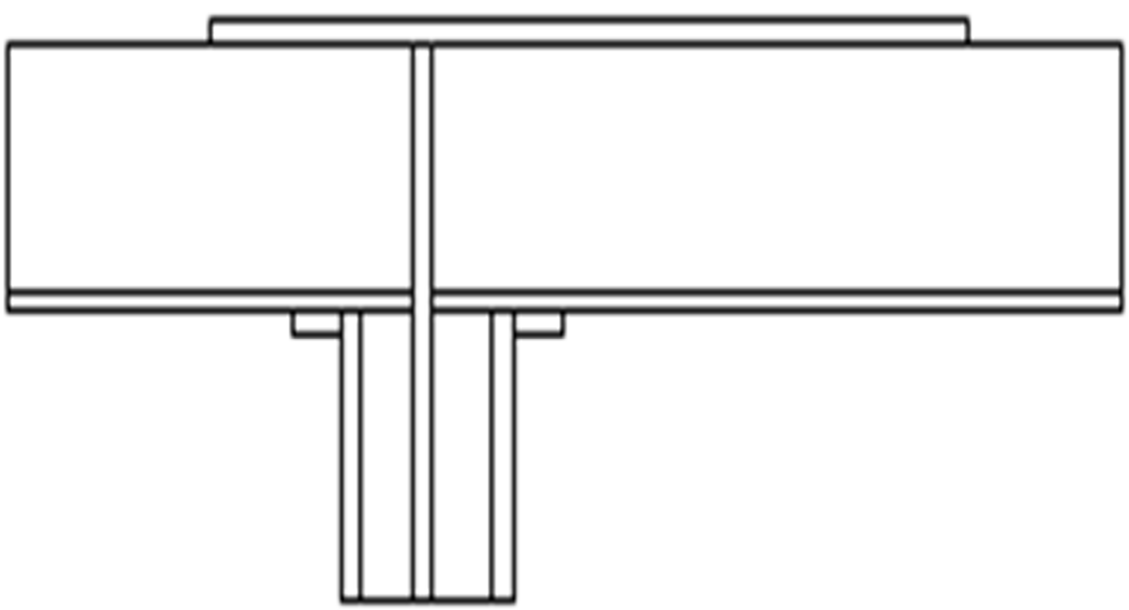

Figure 1: Geometry of Patch Antenna

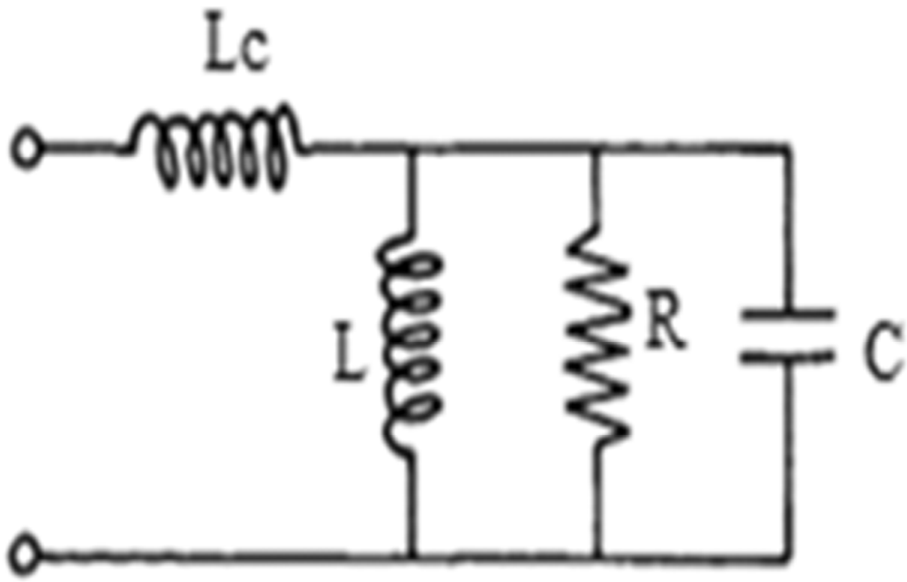

Figure 2: Equivalent circuit of Patch Antenna

with $Cos^2\left(\frac{\pi y_0}{L}\right)$ where y_0 is the distance of the point of impedance observation from the patch edge. The impedance at $y = y_0$ from patch edge is

$$Z_{(y=y_0)} = Z_{(y=0)}Cos^2\left(\frac{\pi y_0}{L}\right) \tag{7}$$

The impedance of the coaxial line is

$$Z = \frac{60}{\sqrt{\varepsilon_r}}\ln\left(\frac{b}{a}\right) \tag{8}$$

where '*b*' is the radius of the outer conductor and '*a*' is the radius of the inner conductor. But practical purpose the empherical formula to determine the feed point location is

$$X_f = \frac{L_p}{\sqrt{\varepsilon_{eff}}} \text{ and } Y_f = \frac{w_p}{2} \tag{9}$$

4. SIMULATION AND RESULTS

With the above parameter values, the patch antenna is designed and simulated. The following figures clearly depict the results offered by the antenna. The gain, radiation pattern, returns loss and energy field pattern are shown in the following Figure 4 to Figure 7.

5. CONCLUSION

Design, Analysis and Performance improvement of Patch Antenna are presented for applications in the frequency range of 2 – 4 GHz. The Gain and radiation pattern of the antenna can be improved with added periodic structures in the ground plane. The proposed ground structure in the patch antenna could achieve higher gain than the normal patch antenna. The S parameter and total efficiency were measured to validate the simulation results.

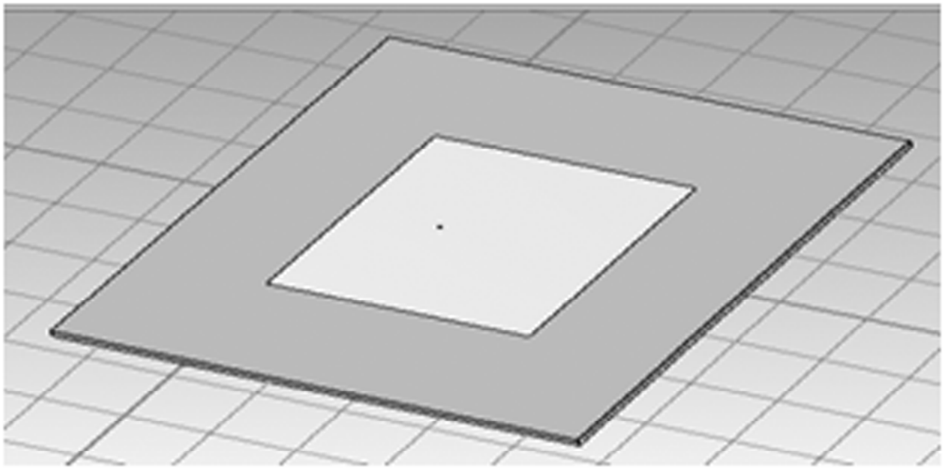

Figure 3: Top view of the half patch antenna with bottom coaxial feed

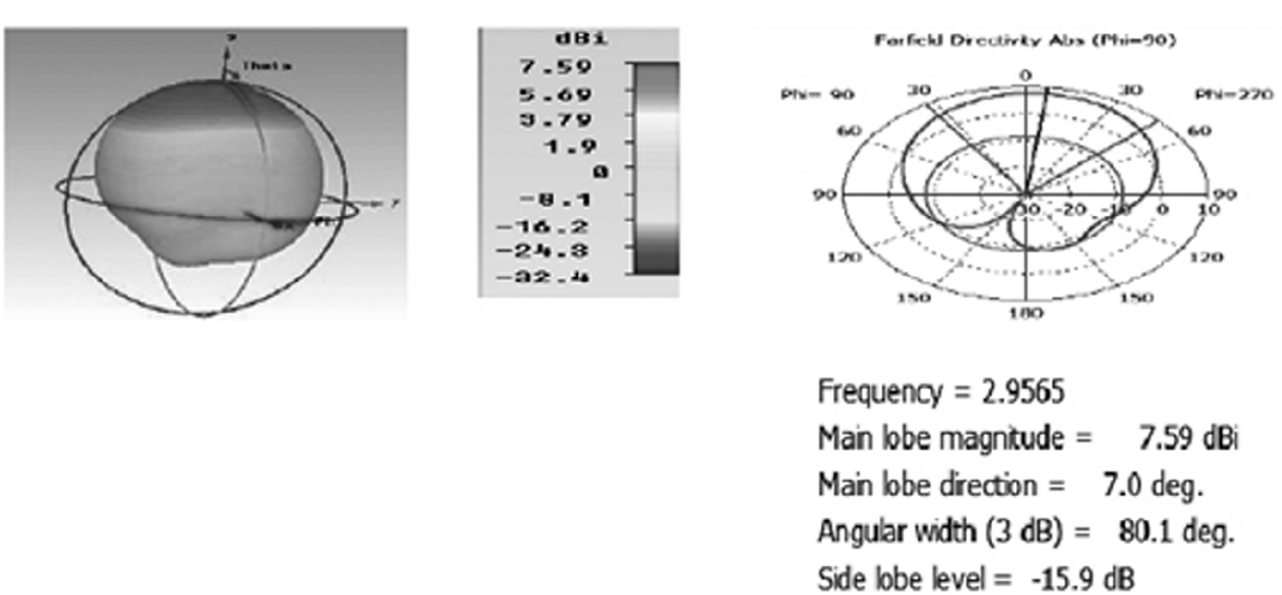

Figure 4: Gain of Antenna

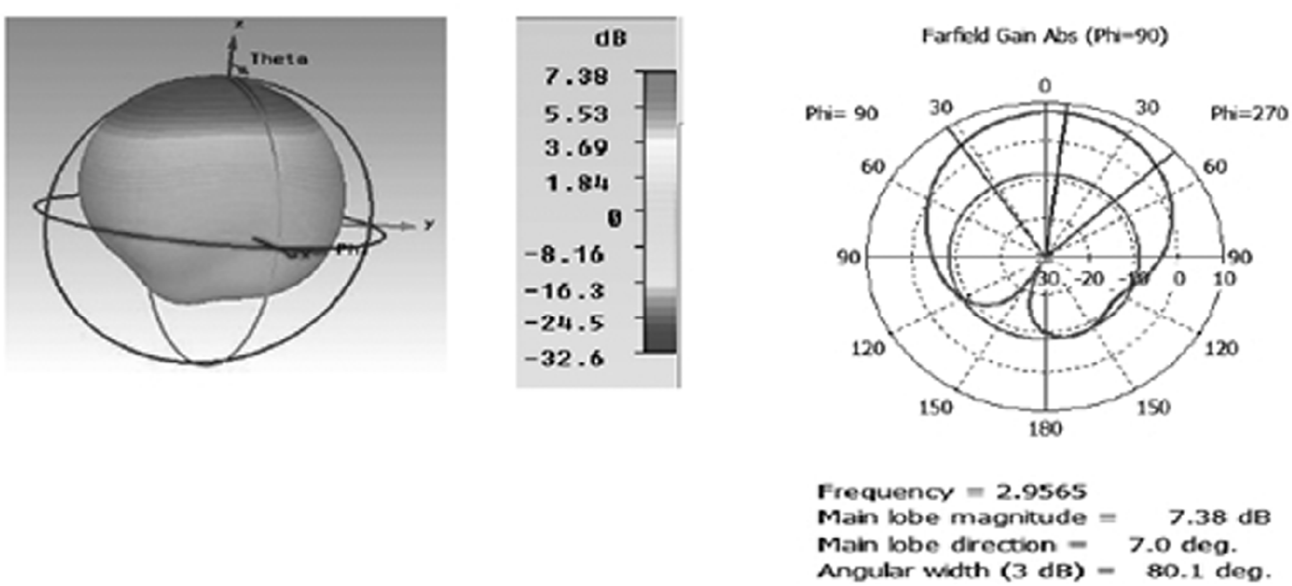

Figure 5: Radiation Pattern and Directivity of Antenna

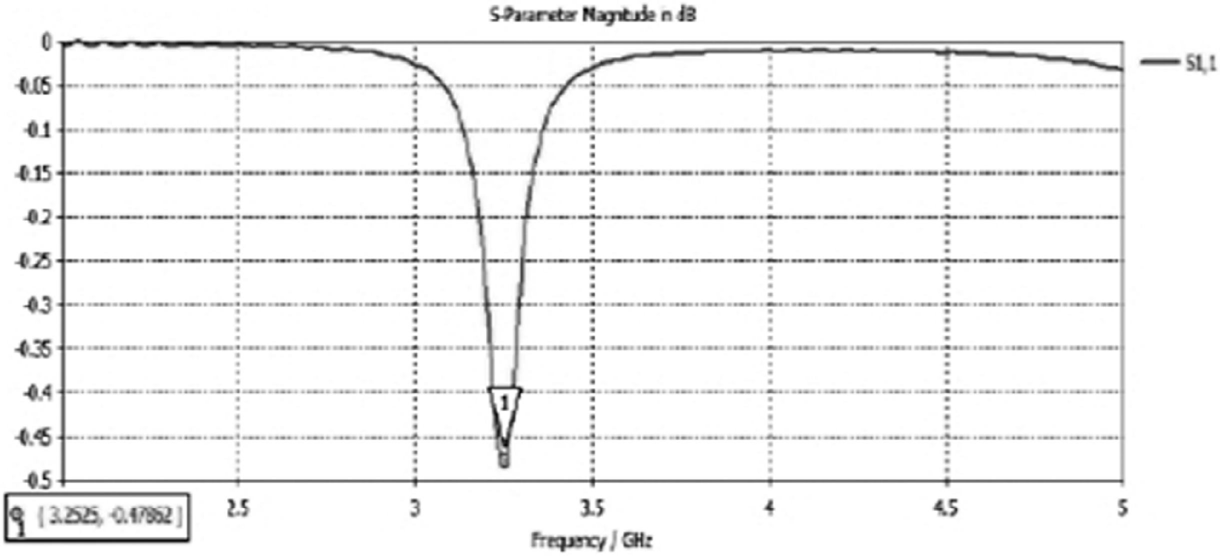

Figure 6: Return Loss (S_{11}) at center frequency

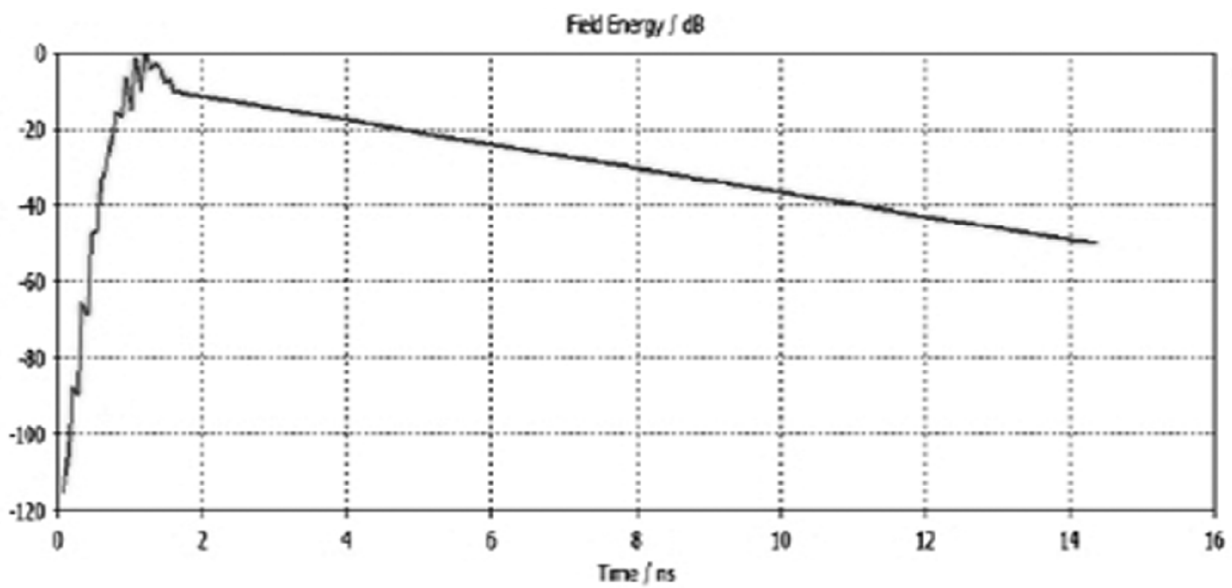

Figure 7: Energy Field Graph

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