DESIGN OF A MICROSTRIP PATCH ANTENNA IN A SILICON SUBSTRATE USING HFSS

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ABSTRACT

The aim of this paper is to design a compact microstrip patch antenna for use in wireless/cellular devices. A typical cellular phone measures about 14.5 cm by 4.5 cm. Hence the antenna designed must be able to fit in such a cellular phone. A compact microstrip patch antenna has been successfully designed having a center frequency of 1.9 GHz. The ground plane dimensions for the patch antenna have been designed to be 31 mm by 40 mm and the patch dimensions are 22 mm by 31 mm. This is designed and simulated in High Frequency Structure Simulator (HFSS-9.2) of Ansoft Corporation.

Keywords:

1.0 INTRODUCTION OF MICROSTRIP PATCH ANTENNA:

In its most basic form, a Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure-1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

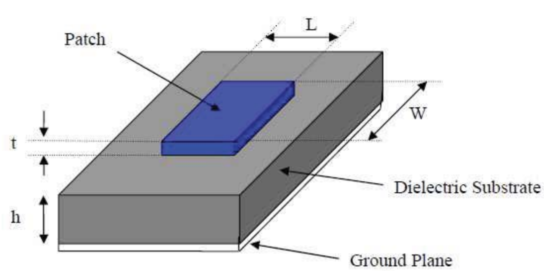

Figure 1: Structure of a Microstrip Patch Antenna [2]

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, elliptical or some other common shape. For a rectangular patch, the length L of the patch is usually $0.3333\lambda_o < L < 0.5\lambda_o$, where λ_o is the free-space wavelength. The patch is selected to be very thin such that $t << \lambda_o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\ \lambda_o \leq h \leq 0.05\lambda_o$. The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$.

2.0 ADVANTAGES AND DISADVANTAGES:

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc. The telemetry and communication antennas on missiles need to be thin and conformal and are often Microstrip patch antennas. Another area where they have been used successfully is in Satellite communication. Some of their principal advantages discussed by [1] and Kumar and Ray [3] are given below:

• Light weight and low volume.

• Low profile planar configuration which can be easily made conformal to host surface.

• Low fabrication cost, hence can be manufactured in large quantities.

• Supports both, linear as well as circular polarization.

• Can be easily integrated with microwave integrated circuits (MICs).

• Capable of dual and triple frequency operations.

• Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas suffer from a number of disadvantages as compared to conventional antennas. Some of their major disadvantages discussed by [3] and Garg et al [4] are given below:

• Narrow bandwidth
• Low efficiency
• Low Gain
• Extraneous radiation from feeds and junctions
• Poor end fire radiator except tapered slot antennas
• Low power handling capacity.
• Surface wave excitation

Microstrip patch antennas have a very high antenna quality factor (Q). Q represents the losses associated with the antenna and a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics. However, surface waves can be minimized by use of photonic bandgap structures as discussed by Qian et al [5]. Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements.

3.0 COAXIAL FEED:

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure 2, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

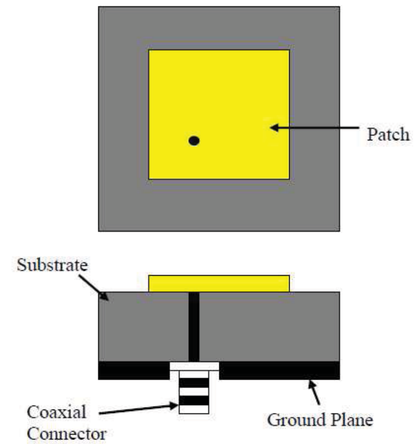

Figure 2: Probe fed Rectangular Microstrip Patch Antenna [2]

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02\lambda o$). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems [3]. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these problems.

4.0 DESIGN SPECIFICATIONS:

The three essential parameters for the design of a rectangular Microstrip Patch Antenna are:

• **Frequency of operation (f*o*):** The resonant frequency of the antenna must be selected appropriately. The Personal Communication System (PCS) uses the frequency range from 1850-1990 MHz. Hence the antenna designed must be able to operate in this frequency range. 1.9 GHz resonant frequency is used in this design.

• **Dielectric constant of the substrate (ε*r*):** The dielectric material is Silicon which has a dielectric constant of 11.9. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.

• **Height of dielectric substrate (*h*):** For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.5 mm. Hence, the essential parameters for the design are:

- fo = 1.9 GHz
- εr = 11.9
- h = 1.5 mm
- Width W=31mm
- Effective dielectric constant (ε_{reff}) =10.7871
- Effective Length(L_{eff})=24mm
- Length Extension(ΔL)= 22.8mm
- The ground plane length(Lg)=31mm
- The ground plane width(Wg)=40mm

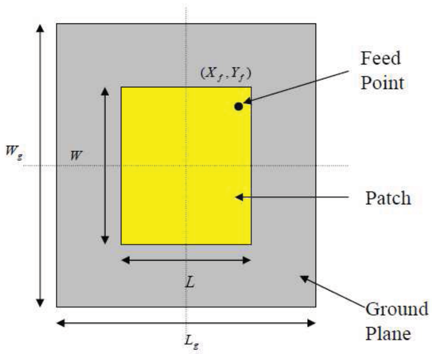

Figure 3: Top view of Microstrip Patch Antenna [2]

5.0 DETERMINATION OF FEED POINT LOCATION (Xf, Yf):

A coaxial probe type feed is to be used in this design. As shown in Figure-3, the centre of the patch is taken as the origin and the feed point location is given by the co-ordinates ($X f$,$Y f$) from the origin. The feed point must be located at that point on the patch, where the input impedance is 50 ohms for the resonant frequency. Hence, a trial and error method is used to locate the feed point. For different locations of the feed point, the return loss (R.L) is compared and that feed point is selected where the R.L is most negative. According to [1] there exists a point along the length of the patch where the Return Loss is minimum. Hence in this design, Yf will be zero and only Xf will be varied to locate the optimum feed point.

6.0 SIMULATION SETUP AND RESULTS:

The software used to model and simulate the microstrip patch antenna is HFSS-9.2 of Ansoft Corporation. HFSS is a high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modelling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modelling, and automation in an easy-to-learn environment where solutions to your 3D EM problems are quickly and accurately obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of the 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields.

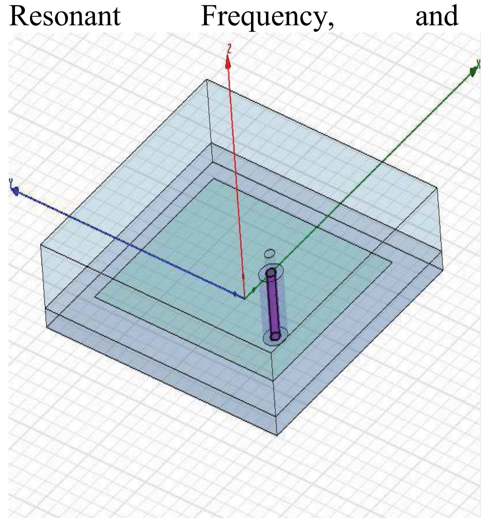
Figure 4: Microstrip patch antenna designed using HFSS-9.2

7.0 RETURN LOSS CALCULATIONS:

The results tabulated below are obtained after varying the feed location along the length of the patch from the origin (centre of patch) to its right most edge. The coaxial probe feed used is designed to have a radius of 0.5mm. A frequency range of 1.7-2.1 GHz is selected and 401 frequency points are selected over this range to obtain accurate results. Table 1 shows the calculated results for different feed locations.

No.	Feed location (Xf ,Yf) (mm)	Centre Frequency (GHz)	Return Loss (RL) (dB)
1	(5,0)	1.75	-16.11
2	(3,0)	1.87	-5.92
3	(4,0)	1.83	-10.48

Table 1: Effect of feed location on centre frequency and return loss

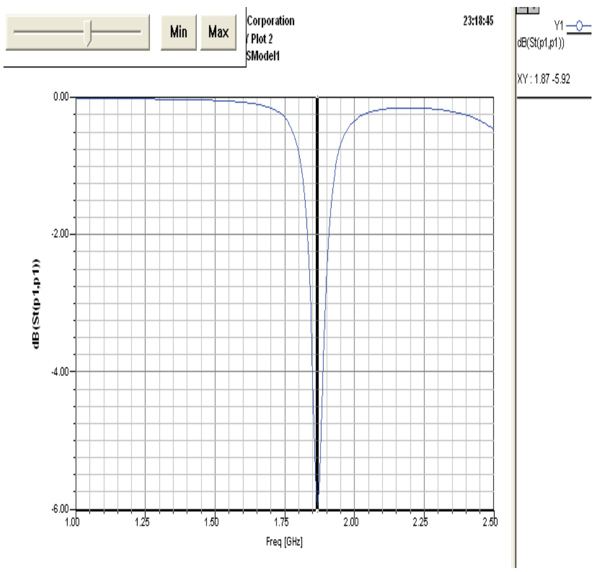

Figure-5: s11 plot for feed position (3,0)

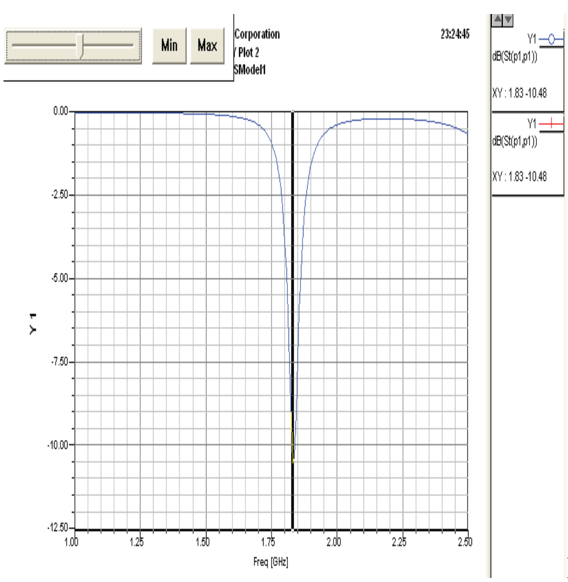

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Figure-6: s11 plot for feedpoint (4,0)

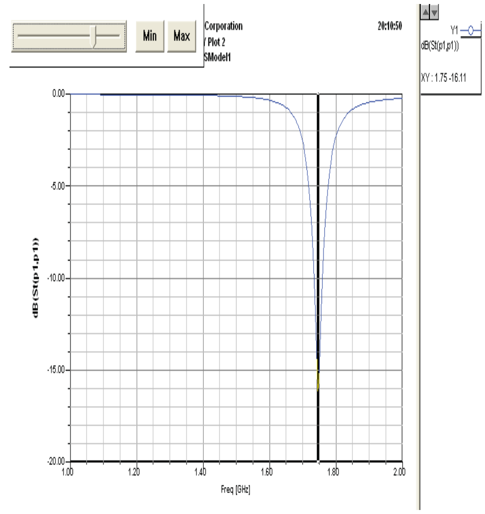

Figure-7: s11 plot for feed position (5,0)

8.0 CONCLUSION:

The designed antenna is compact enough to be placed in a typical cellular phone. Another area for future work is to extend this concept to a multiband design. It is envisioned in the future, that a single handset would serve a number of applications. When the user would be at home, the handset would operate in the same frequency range as used by cordless phones and thus would be connected to the local telephone exchange. When the user would be outside his house, the handset would connect to the cellular network. On a business trip away from home, the handset would then connect though the satellite network to provide service to the user. These different networks would require that the antenna in the handset is able to operate at separate frequencies. The antenna designed in this paper is a uniband antenna centered at 1.9 GHz. Work must be done to design a dichroic or trichroic microstrip parch antenna which can operate at two or three frequencies to serve multiple applications.

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