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Microstrip Patch Antenna for GPS Application

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Abstract

The study and the design of rectangular microstrip patch antenna for multiband applications are presented in this paper. They can be simulated on antenna design software's such as High Frequency Simulation Software (HFSS), Advanced Design System Momentum (ADS) and Agilent Vector Network Analyzer (E8361A) where different feeding techniques have been deployed to get the desired results. Two rectangular microstrip patch antennas of frequencies 1.5 GHz and 2.4 GHz are designed and simulated on HFSS.

Keywords: *Microstrip Patch Antenna, Frequency, GPS, HFSS, Simulation*

INTRODUCTION

Due to the increase demand in the connectivity and high speed of data rates, telecommunication systems require antennas that can radiate more than one pattern at various frequencies. They need to have more functionality and acquire lesser space. The microstrip patch antenna is one such solution. Microstrip patch antennas are widely used from past many years for their advantages. The patch antenna on a chip is easy to design, fabricate, lighter and can be implemented at cheaper costs. The Microstrip Patch Antenna is divided into three sections the first and at the bottom is the ground plane or also called as the ground layer, the next or middle layer is the dielectric substrate layer and the last or the top layer is the microstrip patch and has various applications in different fields such as Wireless application (Wi-Fi, LAN, and Bluetooth), Military applications, Global Positioning System, Satellite communication and cognitive radio systems. The major limitation of microstrip patch antenna is their narrow bandwidth. Although different techniques are proposed to increase the bandwidth, practical implementation of many of these structures involves complex process that makes them uneconomical for mass production. The new generation of the communication, mobile or satellite communication provokes considerable changes in patch antenna, from which the various modern applications require a functioning in wide band and multiple bands.

REVIEW ON EARLIER WORKS

Vinitkumar Dongre et al [l], presents the design of rectangular microstrip patch antenna using coaxial feed to function on single and dual frequency band for GSM, GPS and Bluetooth applications. It also discusses three single and three dual band coaxially feed rectangular microstrip patch antenna. For antennas to operate at multiple frequency band, either a broadband or multiband antenna are used and if the multiple resonating frequencies are far from each other multiband microstrip antennas are preferred over broadband patch antenna. This paper designs three single and three dual band coaxial feed rectangular microstrip patch antenna for GSM, GPS and Bluetooth applications. The designed antenna is simulated using IE3d software. This paper proposes the design of coaxial feed rectangular microstrip antenna to operate well in 900 GSM, 1225 GPS and 2450 Bluetooth frequency band, 1.56 mm thick FR-4 substrate having dielectric constant 4.4. To determine the initial patch dimensions, appropriate formulas are used for length, width and co-ordinates X and Y of the coaxial patch. Resonant frequency of a single band patch antenna can be varied by changing the patch length. Variations of feed point along the width has no effect on antenna impedance whereas variation of the feed point along the length changes the patch impedance causing variations in return loss at resonant frequency. When the feed location is moved towards the origin along the length, the impedance decreases giving higher reflection coefficient and when the feed location is moved away from the origin, impedance increases giving lower reflection. Microstrip patch antenna giving two resonant frequencies with a single patch structure is called as dual band antenna. This paper designs a slot loaded rectangular microstrip antenna coaxially fed at its diagonal for exciting two orthogonal modes TM01 and TM10 which is essential for obtaining a dual band operation. In this paper, a square slot of dimension 4mm*4mm is designed for GSM and GPS, 2.5mm*2.5mm is designed for GPS and Bluetooth and for GSM and Bluetooth which is placed exactly at the center of the main patch. Feed point is optimized by moving the feed point along the diagonal connecting corners of slot and patch. The ratio of patch dimensions L/W is varied for obtaining resonant frequencies. As the ratio increases, both the resonant frequencies will decrease simultaneously. The ratio is varied till the higher resonating frequency matches with the required resonant frequency, once the higher resonation frequency is obtained, corresponding patch width is kept constant and only length is varied and as length increases, lower resonating frequency decreases. The designed antenna shows dual resonating characteristics with acceptable loss. The simulated results of proposed single band antenna and dual band antenna are shown in table 1 and table 2 respectively.

Table 1: *Simulation Results of Single Band Antenna.*

Parameters	**Antenna1**	**Antenna2**	**Antenna 3**
Application	GSM	GPS	Bluetooth
Frequency (GHz)	0.890-0.915	1.563-1.587	2.400-2.483
Length (mm)	80	44.45	28.80
Width (mm)	100	58	35
X (mm)	14.5	7.65	4.75
Y (mm)	45	25	15
Resonant Frequency (GHz)	100	1.575	2.41
Return Loss (dB)	31.60	22.45	27

Table 2: *Simulation Results of Dual Band Antennas.*

Parameters	**Antenna1**	**Antenna2**	**Antenna 3**
Application	GSM	GPS	Bluetooth
Frequency (GHz)	0.890-0.915 1.563-1.587	1.563-1.587 2.400-2.483	1.710-1.785 2.400-2.483
Length (mm)	80	44.5	14.5
Width (mm)	44	28.5	28.5
X (mm)	8.8	4.75	4.6
Y (mm)	45	25	15
Fr1 (GHz)	0.900	1.571	1.755
Fr2 (GHz)	1.575	2.2	2.4
Return Loss 1 (dB)	-16.10	-18.50	-19
Return Loss 2 (dB)	-19.90	-15	-18

Houda Werfelli et al, [2] designs a rectangular microstrip antenna in Advance Design System Momentum (ADS). The designed rectangular patch antenna has been formulated using glass epoxy substrate. Different feeding techniques of microstrip antenna have been discussed. In feeding process, the edge of the microstrip patch is connected to a conducting strip, this feeding method furnishes that the conducting line can have the opportunity of being engraved on same substrate of patch antenna giving the planar shape. In coaxial probe feeding techniques, the outside conductor of a coaxial connector attached at ground plane, while the inside is extended across the dielectric and is welded at the radiating element antenna. The disadvantage of this technique is that it is difficult to model and produces narrow bandwidth. The feeding techniques with proximity coupled, utilizes two dielectric substrates in order that the feed line is between two substrates and the radiating element is on top of the upper substrate. In Aperture coupled feed, a microstrip feed line is separated by the ground plane to the radiating patch. The feed line and the radiating element is coupled through an aperture or a slot in the ground plane, the slot is centered under the radiating element. The rectangular patch antenna is designed for an Ultra-Wideband (UWB) system communication application, operating at 4.1 GHz frequency. Different formulas are used to determine the dimensions of the rectangular patch like width and length. The rectangular patch antenna is designed using electromagnetism simulation software ADS. The antenna is also simulated on Ansoft High Frequency Structure Simulator (HFSS) Software. The antenna shows significant results and operates well in 4.3 GHz with -30 dB return loss.

Rahul Pandey and Sakshee Pandey, [3] focus on designing a reconfigurable triband microstrip patch antenna to radiate different patterns at different frequencies. The antenna is designed for these three frequencies 2.4GHz, 5.2GHz and 7.5GHz where each frequency has a designated antenna design and later they have included all of these three individual antennas on one single chip. For the design dimensions of the microstrip patch they have used the standard formulas. The width of the rectangular patch is given by the formula (1)

$$W = \frac{1}{2f_r\sqrt{(\mu_o \epsilon_o)}}\sqrt{(\frac{2}{\epsilon_r+1})} \quad (1)$$

And the Length of the rectangular patch is given by the formula (2)

$$L = \frac{1}{2f_r\sqrt{\epsilon_{eff}}\sqrt{(\mu_o \epsilon_o)}} - 2\Delta L \quad (2)$$

Where,

$$\Delta L = 0.41h\frac{\epsilon_{eff}+0.3}{\epsilon_{eff-0.258}}\frac{(\frac{w}{h}+0.264)}{(\frac{w}{h}+0.8)} \quad (3)$$

And,

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}(1+10\frac{h}{w})^{-B} \quad (4)$$

Where B is given by the following equation

$$B = 0.5642\{1 + \frac{1}{49}\ln\left(\frac{\left(\frac{w}{h}\right)^4+(\frac{w}{52h})^2}{(\frac{w}{h})^4+0.432}\right) + \frac{1}{18.7}ln1 + (\frac{w}{18.1})^3\}(\frac{\epsilon_{r-0.9}}{\epsilon_r-3})^{0.053} \quad (5)$$

The height of the substrate is h and ΔL comes into picture due to the effect of fringing fields. The fringing fields greatly affect the measurements of bordering field which is an important parameter in the elements of measurements of the patch and height of the substrate. It is due to this impact of bordering that the reception equipment of the antenna looks electrically more intensive and there’s a difference between the physical measurements. And the fringing fields thus increase the effective length of the microstrip patch by ΔL. To reduce the effect of this fringing fields a potent and consistent effective permittivity from a dielectric material and considers the bordering and wave spread in the line. For compensating the effect of fringing, we reduce $2\Delta L$ from the actual length of the patch. The ground plane width and length are calculated by the following equations

$Wg = 6h + W$ (6)

$Lg = 6h + W$ (7)

But for the better performance of the antenna, the width and the length of the ground plane are considered twice of the width and length of the patch. Thus, the equations for the calculation become

$Wg = 2W$ (8)

$Lg = 2L$ (9)

The dimensions for the microstrip patch antenna are calculated using the above formulas and a FR4 epoxy substrate is chosen and for which the dimension of the height is 1.59mm and the substrate's dielectric value is known as 4.3. The parameter f_r is the resonant frequency of the antenna. The length and the width of a microstrip patch antenna is inversely proportional to the resonant frequency of the desired antenna. Thus the lowest frequency antenna will have a greater dimension and vice versa. They have shown the way to integrate all of the three separate antennas on a single chip. Since, their paper consists of the means of reconfiguring an antenna, which operates when some conditions are met during its operations. So to execute these conditions several mechanisms of control switches can be used such as RF MEMS, PIN diodes, Varactor or by using Photoconductive elements. These control switches are included in between each individual antenna. The condition by which each antenna is on is as follows.

1. When all three control switches are on the operation mode switches to 2.4 GHz.
2. When the two control switches from the microstrip feed are on the operation mode shifts to 5.2 GHz.
3. When one switch from the microstrip feed is on the mode of operation shifts to 7.5 GHz.

The RF MEMS (Micro Electro Mechanical Switch) has a good means of isolation than the other switches and can be used commercially.

Qian Li, Yanyu Wei et al, [4] presents an antenna that is printed on an FR4 Substrate. The thickness and the relative permittivity of the FR4 substrate is 1.6mm and 4.4 respectively. The C- shaped monopole and the U- Shaped loop is etched on the top of the substrate and a modified ground slot on the bottom of the substrate. The C- shaped monopole is the main radiating element at 1.6 GHz. For the 2.45 GHz frequency the resonant current is concentrated on the U- Shaped monopole. And lastly for the 5.5 GHz band the modified ground slot operates as a major resonator for its operation. The measurement of S-parameters of the antenna are simulated using Agilent Vector Network Analyzer (E8361A). They have measured consistent results in the practical implementation with the simulated results. The radiation pattern obtained are quasi omni –directional.

Nirmen Mahmoud and Ehab K.I. Hamad, [5] paper talks about a tri-band antenna for multiband applications. The multiband functionality is provided by the four monolith L-shaped slots within the rectangular radiating patch. The antenna proposed is basically a rectangular micro strip patch and a partial ground plane fed by a 50 ohm micro strip line. The simulations are accomplished by using 3D full wave FEM-based EM simulator. The radiation patterns simulated at the desired resonant frequencies are nearly Omni-directional. The proposed antenna can be used for Bluetooth, WLAN and WiMAX wireless applications at 2.4GHz, 5.5GHz and 3.5 GHz respectively. The proposed antenna is printed on a FR4 dielectric substrate with relative permittivity of 4.5 and the entire substrate is of size 20x20x1.6 mm2. The -10dB impedance bandwidth of the designed antenna covers the frequency ranges from 2.122-2.339

GHz, 3.384-3.575GHz, and 5.599-5.776 GHz, which meets the specifications of Bluetooth (2.4 to 2.485 GHz). WiMAX (3.3-3.6GHz) and WLAN (5.15-5.825 GHz) applications. The design of the proposed antenna has a main radiator element and the feeder is on the top face of the substrate while the conducting partial ground plane is on the bottom face of the substrate. The simulation results are obtained using the 3D full-wave Finite Element Method based Ansoft High Frequency Structure Simulator (HFSS). The real design requirements such as the operating frequency, bandwidth, and radiation pattern are met by considering some approximations. The calculations are based on the transmission line model. Etching slots in the radiating patch behaves as a filtering element where slot dimensions are controlling the rejection band of the band-notched filter or the resonance band of the resonant filter. Series LC circuits produces minimum impedance at resonance, whereas parallel LC circuits provide maximum impedance at their resonant frequency. For a Dual Band resonant frequency antenna, another resonant frequency is generated by etching another L-shaped slot within the radiating patch just above the first L-shaped slot. The first resonant at 2.4 GHz, and a second resonance at 3.5 GHz for WiMAX application, is kept as it is at this step. For a Triple Band resonant frequency antenna, the third resonant frequency band is generated by etching a third L-shaped slot within the radiating patch just above the second L-shaped slot. The space between the third and second L-slots is selected equal to the one between the second and first L-slots. It is observed that, for a given frequency, the individual corresponding slots are vigorous whereas the other parts are sluggish, which confirms the independence of the frequency bands. Thus the proposed antenna operating at 2.4 GHz, 3.5 GHz and 5.5 GHz, makes it promising for Bluetooth, WiMAX and WLAN.

Yu-Hang, Huang et al, [6], paper proposes that the entire antenna can be built on a full printed circuit board so that it is easy to process. The circularly polarized antenna is widely used in satellite communication and navigation systems. It has a number of advantages, such as anti-multipath interferences and reduces the effect of “Faraday rotation” caused due to the ionosphere The Global Navigation Satellite Systems (GNSS) nowadays play an important role in daily military, civil, and commercial applications and a circularly polarized antenna with good performance is the key to these applications. The demands of modern Global Positioning System (GPS) applications are met by using a dual-band or broadband PQHA covering both L1 (1.575 GHz) and L2 (1.227 GHz) bands. The quadrifilar helix antenna (QHA) is a good candidate as it has an excellent axial ratio and cardioid-shaped radiation pattern. The printed QHA (PQHA) is more popular due to its light weight and low cost. The antenna proposed in this paper adopts metal slots instead of metal strips of the traditional PQHAs as radiation arms. A traveling wave micro strip feeding network is used so that the structure of the proposed antenna is simpler when compared with the existing dual-band PQHAs. The radiation arms and the feeding network are designed and built on a full printed circuit board (PCB) to minimize the cost and provide easy fabrication. The conventional PQHAs always use the metal strip as the radiation element. The geometry of the proposed antenna is such that the overall structure is built on a full PCB with a relative permittivity of 2.2 [Rogers RT/ duroid 5880 (tm)]. Two sets of slots with different lengths as the radiation elements are employed, which are distributed on the exterior and inner surface of PCB, respectively. On the exterior surface, six longer slots working at 1.227 GHz are evenly distributed and the fan-shaped end is used to improve energy coupling from the feeding micro strip line. Six shorter slots etched on the inner surface working at 1.575 GHz are connected to the longer slots by metallized vias. Thus in this paper, a dual-band slot helix antenna employing a folded traveling wave feeding network is proposed. The circular polarization generating of the proposed antenna is analyzed. The dual-band radiation is realized by using a double-faced slot radiation structure. The experimental results show that the antenna shows a good performance in both GPS L1 and L2 bands [7-10].

INTERMEDIATE RESULTS

Two rectangular microstrip patch antennas of frequencies 1.5 GHz and 2.4GHz have been designed and simulated on HFSS. A 1.5mm FR4 epoxy substrate of dielectric constant 4.4 is used for the design.

Table 3: *Antenna Design and Simulation Parameters.*

Parameters	Antenna 1	Antenna 2
Operation Frequency (GHz)	1.5	2.4
Length (mm)	47.44	29.47
Width (mm)	60.85	38.03
Dielectric Height (mm)	1.5	1.5
Patch height (mm)	0.05	0.05
S parameters (dB)	-1.48	-7.86
VSWR	3.048	2.514
Gain (dB)	1.803	3.432

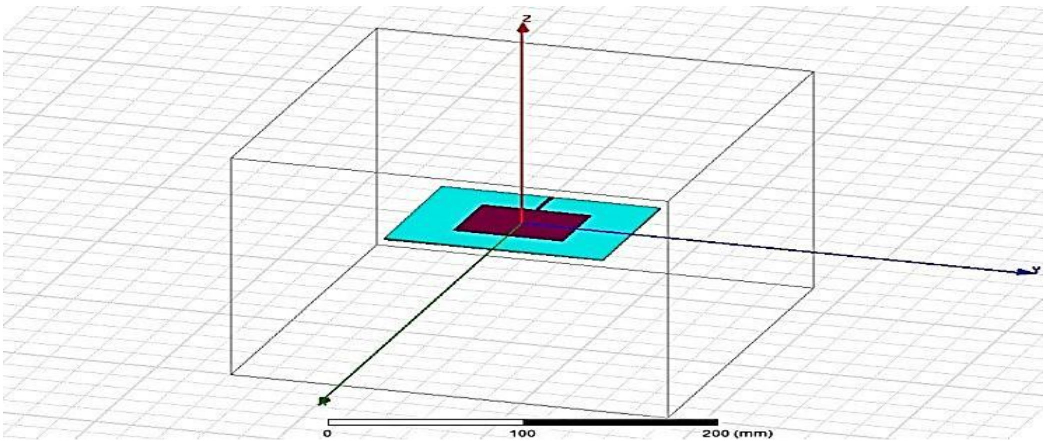

Figure 1: *Microstrip patch design of 1.5 GHz.*

Figure 2: *S-Parameters for 1.5GHz.*

Figure 3: *VSWR plot for 1.5GHz.*

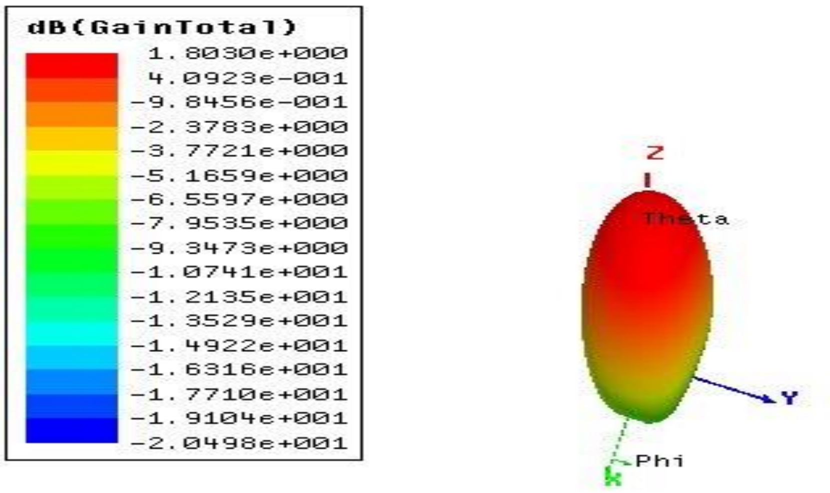

Figure 4: *Gain Plot for 1.5GHz.*

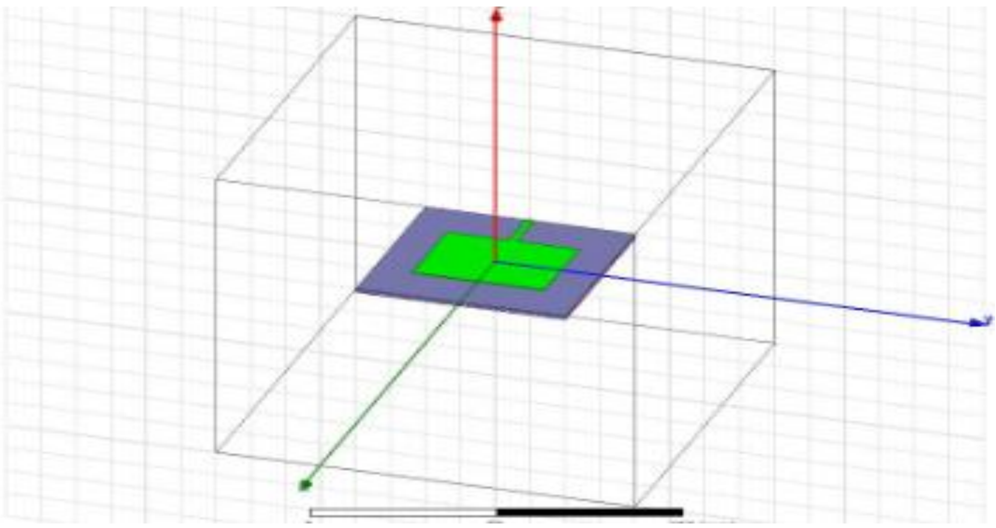

Figure 5: *Microstrip Patch design for 2.4 GHz.*

Figure 6: *S-Parameter plot for 2.4 GHz.*

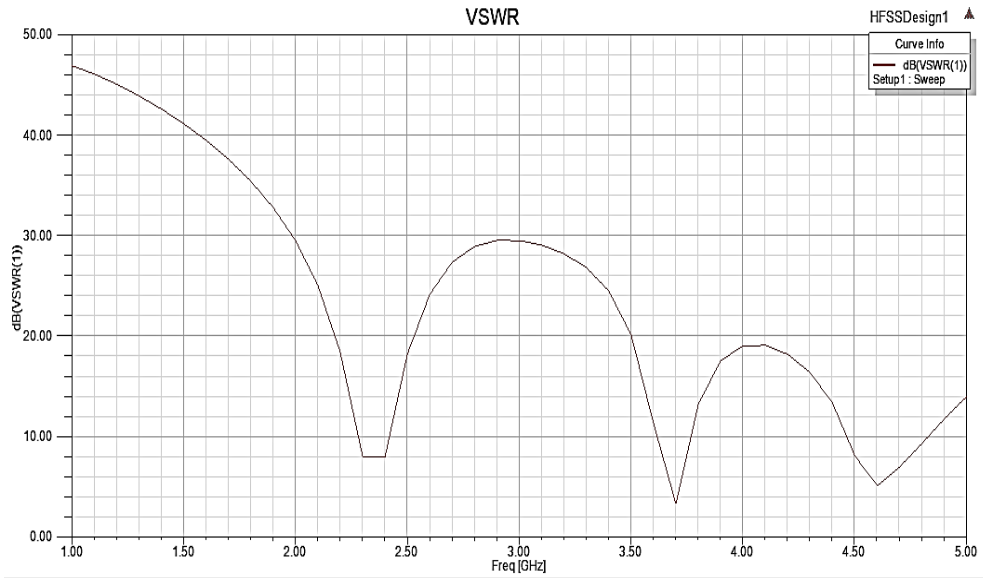

Figure 7: *VSWR plot for 2.4GHz.*

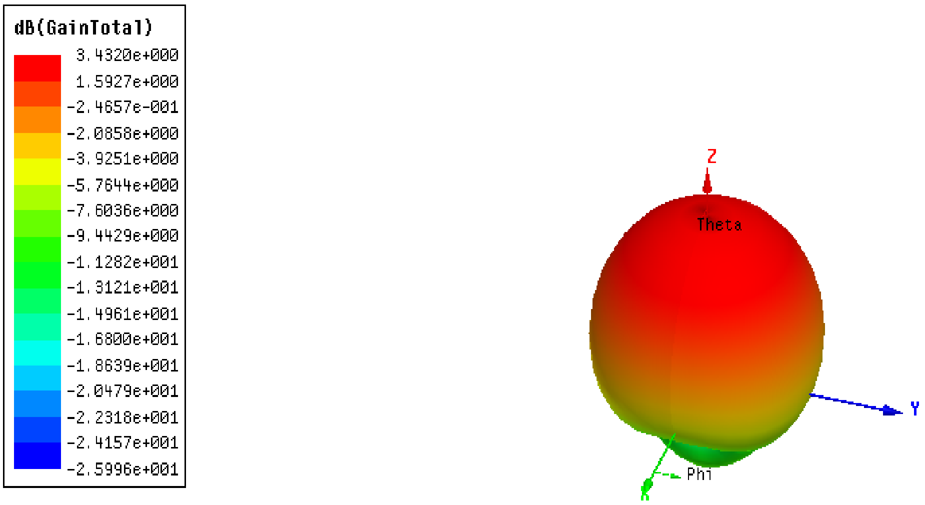

Figure 8: *Gain Plot for 2.4GHz.*

CONCLUSION

The patch antenna for 1.5GHz frequency, design on HFSS is shown in figure 1), the simulated results for S-Parameters, Voltage Standing Wave Ratio (VSWR), and Antenna Gain are shown in figures 2, 3 and 4 respectively. The graphs for S-Parameters and VSWR shows peak at 1.5GHz. The gain measured for the antenna is 1.803dB.The patch antenna for 2.4GHz frequency, design on HFSS is shown in figure 5 and the simulated results for S-Parameters, VSWR, and Antenna Gain are shown in figures 6, 7 and 8 respectively. The graphs for S-Parameters and VSWR shows peak at 2.4GHz. The gain measured for the antenna is 3.4320dB.

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