Design and Implementation of Pentagon Patch Antennas with slit for Multiband Wireless Applications

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Abstract:- *This paper describes the design of printed slot antenna and prototyping on available low-cost FR-4 material fed by a microstrip line with a pentagon slot for bandwidth enhancement. In WIFI frequency band which are using now a days, there are two WIFI frequency bands: Lower frequency WIFI band at 2.4 GHz and Higher frequency WIFI band at 5.8 GHz. In this paper, a pentagon microstrip antenna with pentagon slot is designed and analyzed its properties for WIFI connectivity application at 2.45 and 5.8 GHz. The dielectric material FR-4 with relative permittivity (ε_r) of 4.4 and loss tangent (δ) 0.02 has been used as a substrate material for designing of the proposed antenna. The thickness of substrate material used in suggested antenna is 1.6mm. The microstrip line feeding technique with patch insertion has been used to feed the power to the antenna with proper impedance matching of 50Ω so maximum power can transfer. The pentagon microstrip antenna with pentagon slot parameters has been analyzed in terms of return loss (dB), gain (dB) and VSWR, etc. The Ansoft High frequency structure simulator (HFSS) Simulation software has been used for the analysis and simulation. The proto type is fabricated and measured on Vector network analyzer of pentagon microstrip antenna with pentagon slot antenna.*

Key words: Lower and Higher Frequency WIFI Band; Pentagon Microstrip Antenna with pentagon Slot; FR4; HFSS.

1. INTRODUCTION

Now days, there is a very large demand by the end user for integrated wireless digital at low volume and broad bandwidth. To meet these requirements, pentagon microstrip patch antennas are preferred. In this project, Pentagon patch antennas are designed for multiband applications.

There is an ever growing demand in both military and commercial applications for antennas having the attributes of multiband behavior. Fractal geometrics with their complex iterative nature demonstrate these required attributes. A Koch pentagonal fractal antenna is reported in [1] which provides reduction in the overall size of the antenna.

The microstrip patch antenna is a single-layer design which consists generally of four parts (patch, ground plane, substrate, and the feeding part). Patch antenna can be classified as single element resonant antenna. Once the frequency is given, everything (such as radiation pattern input impedance, etc.) is fixed. The patch is a very thin (t< where λo is the free space wavelength) radiating metal strip located on one side of a thin no conducting substrate, the ground plane is the same metal located on the other side of the substrate [2]. The advantages of the microstrip antennas are small size, low profile, and lightweight, conformable to planar and non planar surfaces. It demands a very little volume of the structure when mounting. They are simple and cheap to manufacture using modern printed circuit technology. However, patch antennas have disadvantages. The main disadvantages of the microstrip antennas are: low efficiency, narrow bandwidth of less than 5%, low RF power due to the small separation between the radiation patch and the ground plane(not suitable for high-power applications) [2].

A novel V shaped wire structured pentagonal HF antenna is reported in [3]. The use of fractal antennas for multiband antennas is discussed in 4,5,6]. An overview of different shapes used for fractal antennas were discussed in the above papers. There are many other fractal geometrics that have been found to be useful in developing antenna structures [7,8,9].

In the work durer pentagon [10] fractal concept is introduced in to a pentagon shaped microstrip antenna to obtain multiband behavior and miniaturization

2. DESIGN PARAMETERS OF PENTAGON PATCH ANTENNA

The designing of micro-strip antenna requires resonant frequency(f0), dielectric material and height of substrate(h). The proposed antenna is designed for frequency band 5.2 GHz. The substrate used is FR-4 having dielectric constant ($\in_r$) 4.34 and height (h) 1.6 mm. High dielectric constant is used for size reduction. The antenna is fed by 50 Ω micro-strip line feed. It has a width W and length L_f. The design formulas as given in [11] are as follows

Step 1: Calculation of the Effective dielectric constant(€r):

Equation (1) gives the effective dielectric constant as:

$$\in_{eff} = \frac{\in_r + 1}{2}(1 + 0.3 * h) \quad (1)$$

Step2: Calculation of the Length of Strip (Ls):

The length of the Microstrip Antenna given by the equation (2)

$$Ls = \frac{0.42 * c}{f_r * \sqrt{\in_{eff}}} \quad (2)$$

Step 3: Calculation of the Width of Ground plane(Wg):

The width of the ground plane can be calculated by the equation (3)

$$W_g = \frac{1.38 * c}{f_r * \sqrt{\in_{eff}}} \quad (3)$$

Step 4: Calculation of the Length of Ground plane (Lg):

Here the length of the ground plane is obtained by equation (4)

$$Lg = \frac{0.36 * c}{f_r * \sqrt{\in_{eff}}} \quad (4)$$

Step 5: Calculation of the Resonant Frequency (fr):

Resonant frequency (fr) is given by the equation (5),

$$f_r = 3 + \frac{2}{\sqrt{\in_{ref}}}\left[\frac{21}{Ls} + \frac{65}{Wg} + \frac{18}{Lg} - 3\right] \quad (5)$$

By using the Design Equations the dimensions of the patch were calculated.

3. SIMULATION

A) Pentagon patch antenna

A pentagon patch antenna is simulated. A plane geometry of conventional patch of radius Rp (patch radius) = 13 mm is printed on the substrate of the dielectric material FR-4 having l×w (length × width) = 52 mm×46 mm and thickness (h) = 1.6 mm. The dielectric constant for substrate is εr = 4.4 and has loss tangent 0.002. The antenna is excited through microstrip feed line having dimension L (length) =25 mm and w (width) = 2.8mm. Figure.4.1 shows the structure of pentagon patch antenna.

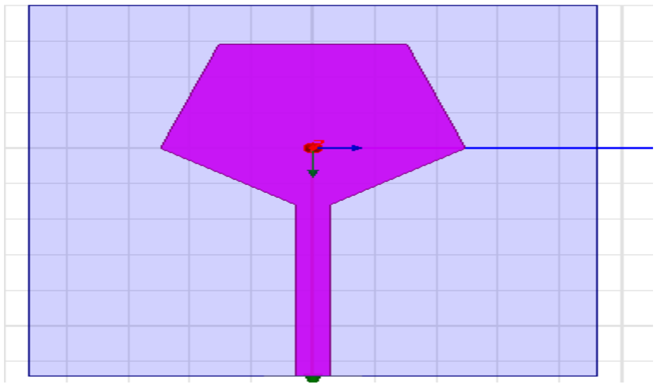

Fig-1: Structure of Basic Pentagon Patch Antenna

The pentagon patch antenna is simulated in HFSS and shown in Figure 1. The Return loss, VSWR and Gain results are observed.

B) Pentagon Antenna structure with Slits

The structure of this antenna is shown in Figure4.1. This antenna is designed by using HFSS software and the substrate used for this antenna is FR4 material of size 46*52mm.The thickness of the substrate is 1.6mm and feed for this antenna is centre feed. This antenna is simulated at 5.8GHz frequency which is useful for WI-MAX applications. The pentagon antenna with slot is designed by using HFSS. The Return loss, Gain and VSWR are observed at 5.8GHz. The slit of pentagon patch has width 0.9mm, length 6.23mm and feed length 25mm and width 2.8mm. A partial ground is used with dimensions of 24 mm*40mm. The simulated antenna structure is shown in Figure2.

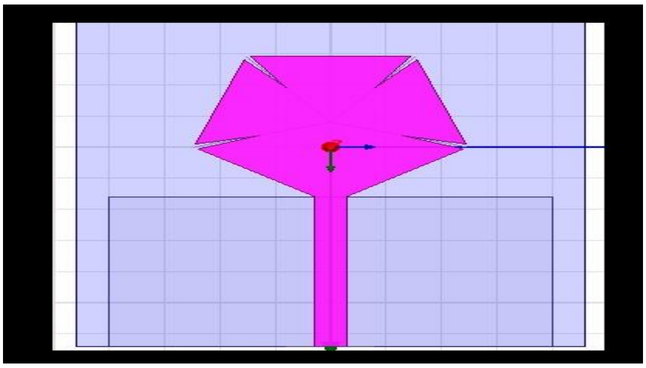

Fig-2: Structure of Pentagon Patch Antenna with slits

4. RESULTS

i) Simulation Results

A) Pentagon patch antenna

The return loss is another way of expressing mismatch. It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line. The simulated results of the return loss for the frequency range from 2 to 14GHz are shown in figure.3. From return loss curve, the operating frequencies are obtained between a bandwidth of 2 to 5.7GHz,7.14 to 10GHz and 11 to 13.2 GHz. Resonant frequencies obtained are 2.4GHz,3.6GHz,5.6GHz and 12.8 GHz.

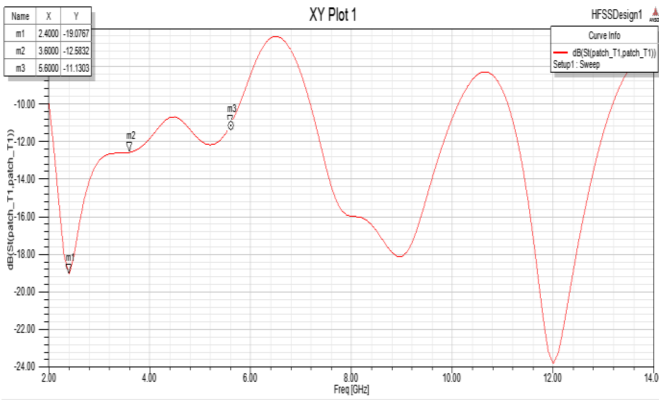

Fig-3: Return loss for basic pentagon patch antenna

The VSWR is basically a measure of the impedance mismatch between the transmitters and antenna. The higher the VSWR, the greater is the mismatch. The minimum VSWR which corresponds to a perfect match is unity. The simulation results of VSWR for the frequency range from 2 to 14 GHz is shown in figure4. The obtained VSWR is below 2 between a bandwidth of 2 to 5.7GHz, 7.14 to 10GHz and 11 to 13.2 GHz.

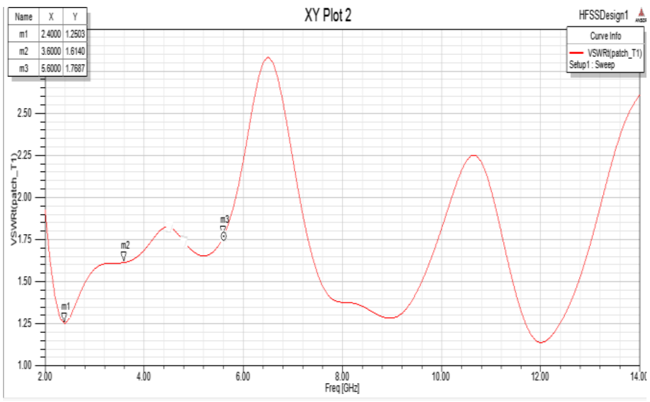

Fig-4 : VSWR for Basic pentagon patch antenna

Gain is nothing but the power transmitted per unit solid angle. The 3-D gain of the pentagon patch antenna is shown in Figure.5. Gain of any antenna should be more than 3dB for any applications. The Gain observed for this antenna is 4.32 dB at resonating frequency 5.6 GHz.

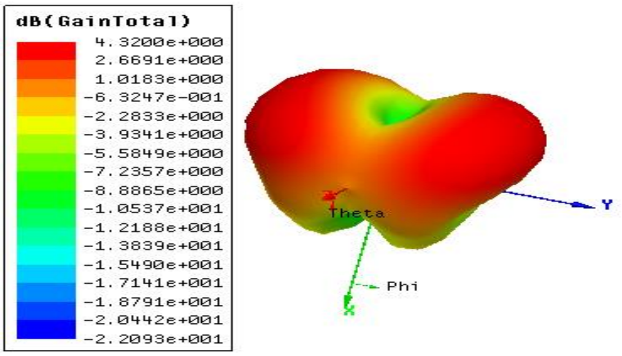

Fig-5: Gain of pentagon patch antenna at operating frequency 5.6GHz

Pentagon patch antennas are simulated with different patch side dimensions and the results are tabulated below

Table-1: Parametric Analysis of Basic Pentagon Patch Antenna in terms of Resonating frequencies and operating frequencies

Antenna Patch side	Operating frequencies (GHz)	Resonating frequencies	Bandwidth of VSWR below2
13mm	2 to 5.7GHz 7.14to 10GHz 11 to13.2GHz	2.4GHz, 3.6GHz, 5.6GHz 9GHz 12GHz	2 to 5.7GHz 7.14 to10GHz 11 to13.2GHz

Table-2: Parametric Analysis of Basic Pentagon Patch Antenna in terms of gain

Antenna Patch side	12mm	13mm	14mm
Gain in dB (at 5.6GHz)	4.02	4.32	4.64

B) Pentagon Antenna structure with Slits

The return loss for pentagon antenna with angular slits is shown in Figure6.

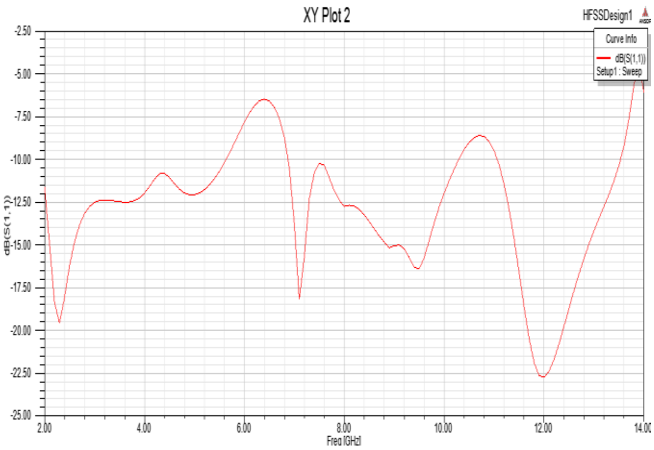

Fig-6 : Return loss plot for Pentagon Antenna with slit

The simulated results of the return loss for the frequency range from 2 to 14GHz are shown in figure 6.From return loss curve, the operating frequencies are obtained between a bandwidth of 2 to 5.7GHz,6.8 to 10.2GHz and 11 to 13.6 GHz. Resonant frequencies obtained are 2.4GHz,6.8GHz,9.2GHz and 12GHz.

The simulation results of VSWR for the frequency range from 2 to 14 GHz is shown in figure 7. The obtained VSWR is below 2 between a bandwidth of 2 to 5.7GHz, 6.8 to 10GHz and 11 to 13.6 GHz.

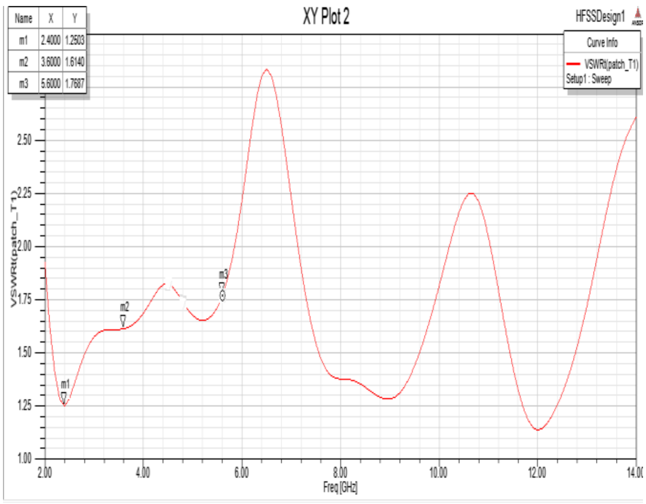

Fig-7: VSWR plot for Pentagon Antenna with angular slits

The Gain of this antenna is 4.45dB at 5.8GHz is shown in Figure 8.

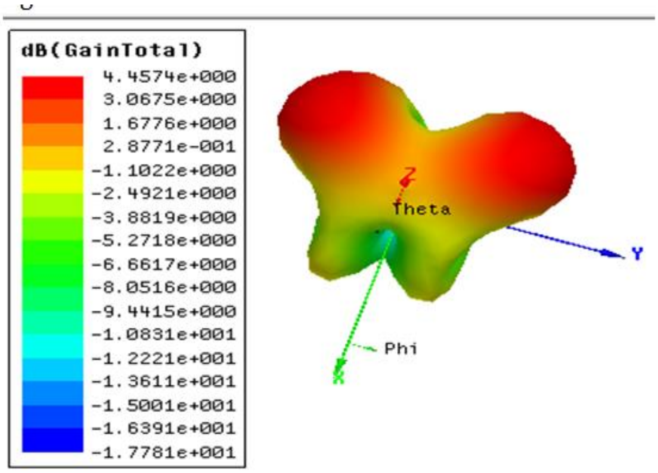

Fig_8: Gain of pentagon patch Antenna with slits at 5.8GHz

Pentagon patch antennas with patch side 13mm is simulated with different slits dimensions (width and height) and the results are tabulated below

Table-3: Parametric analysis of pentagon patch antenna with patch side 13mm with slits in terms of operating and resonating frequencies

Slit dimensions (in mm)	Operating frequencies	Resonating frequencies	Bandwidth of VSWR below2
Width=0.9 Height=6.23	2-6GHz 7.2-3.8GHz	2.4GHz,3.6GHZ,5.8GHz,10.7 GHz	2-6GHz 7.2-13.8GHz
Width=1, Height=6.22	2-6GHz 9.5-14GHz	5.4GHz 11.2GHz	2-6GHz 9.5-14GHz
Width=0.8 Height=6.2	2-5.9GHz 7.2-13.5GHz	5.12GHz 9.8GHz	2-5.9GHz 7.2-13.5GHz
Width=0.9 Height=6	2-5.9GHz 8.5-14GHz	5.34GHz 12.1GHz	2-5.9GHz 8.5-14GHz
Width=0.9 Height=6.4	2-5.9GHz 10.4-13.5GHz	5.6GHz 8.9GHz	2-5.9GHz 10.4-13.5GHz

ii) Fabricated antenna results

A) Fabricated Structure of Basic Pentagon antenna

Fig-9: Fabricated antenna structure

Fabricated Pentagon patch antenna is shown in Figure.9. It has been tested by using vector network analyser (E5071C) and observed fabricated results of return loss, VSWR of the antenna.

Experimental setup for connecting fabricated antenna to Vector Network Analyzer with help of SMA connector is shown in fig 10

Fig-10: Experimental setup of Vector Network Analyzer

Fig 11 shows return loss curve of the fabricated antenna. For this antenna, the resonating frequencies are 2.38GHz, 5.72GHz and 8.468GHz. Return loss observed is -32.70dB at 8.64GHz,-24.3dB at 5.72GHz and -25.48dB at 2.38GHz.Operating frequencies obtained are 2.381GHz, 5.72GHz, and 8.648GHz. Fig 12shows VSWR curve of the fabricated antenna. The VSWR at resonating frequencies 2.38GHz, 5.72 GHz, 8.64 GHz are 1.12, 1.11 and 1.05 respectively. The bandwidth of VSWR below 2 is 2-6GHz, 7.6-10GHz, and 12.4-14GHz.

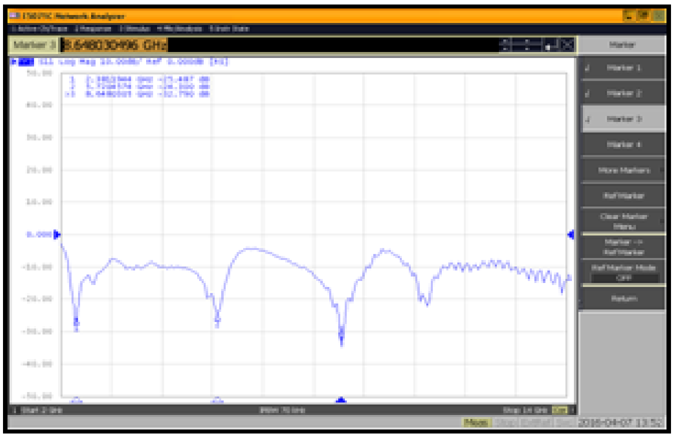

Fig-11: Return loss curve of fabricated pentagon antenna

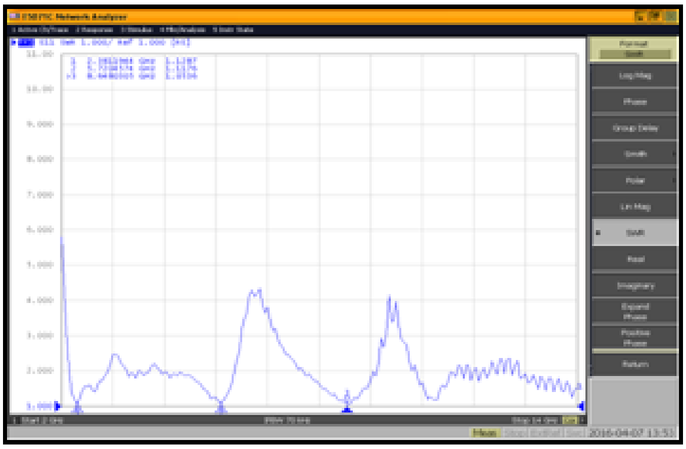

Fig-12: VSWR curve of fabricated pentagon antenna

5. CONCLUSIONS

Simulated and Practical results of pentagon patch antenna and pentagon patch antenna with slits are compared. In order to improve the performance of antenna, slits are introduced at edges of patch antenna

In this work, one normal pentagon shaped antennas resonating at Resonant frequencies obtained are 2.4GHz, 5.6GHz and 12.8 GHz.were obtained by simulation. The antenna produces four bands of frequency where as the fabricated antenna resonating at frequencies of 2.38GHz, 5.72GHz and 8.468GHz. Return loss observed is -32.70dB at 8.64GHz,-24.3dB at 5.72GHz and -25.48dB at 2.38GHz. The pentagon shaped antennas with slits resonating at frequencies obtained are 2.4GHz, 6.8GHz, 9.2GHz and 12GHz. The simulated results of the return loss for the frequency range from 2 to 14GHz are shown in figure 5.2.From return loss curve, the operating frequencies are obtained between a bandwidth of 2 to 5.7GHz,6.8 to 10.2GHz and 11 to 13.6 GHz. Resonant frequencies obtained are 2.4GHz,6.8GHz,9.2GHz and 12GHz.These antennas can be used for WLAN / Bluetooth Wi-MAX application in ISM band. It is also observed that size reduction up to 25 % in terms of overall size.

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