Design and Analysis of Microstrip Patch Antenna with Enhanced Bandwidth and Harmonic Suppression for WLAN Applications

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Abstract:- *In this paper, a pair of λ/4 resonator is used in parallel with the rectangular patch to enhance the bandwidth and suppress the harmonic radiations. A pair of λ/4 resonator excites the radiating patch using an electromagnetically coupled technique. The radiating patch and a pair of λ/4 resonator, resonates at two frequencies which are close to each other and help to increase the bandwidth. Also a shorting pin is used which combines the two λ/4 resonators which helps is suppressing the Harmonic radiations. The Proposed antenna is resonating at 3.6GHz. FR4- Epoxy material is used for substrate with relative permittivity of 4.4. The antenna is fed with the Line fed. The Simulation is done using the HFSS (High frequency simulation software).The Hardware Results are checked on the VNA (Vector Network Analyser). The return loss obtained is above -20dB.*

Key Words: Bandwidth Enhancement, Electromagnetic coupling, Harmonic Suppression, λ/4 resonator

1. INTRODUCTION

In Modern communication system, Microstrip antennas are much popular due to its features like low cost, light weight, easy to install, low profile and also easy to integrate with the other devices such as filters, oscillators, amplifiers etc. These characteristics of microstrip antenna make them suitable for many applications like in radar systems, satellite communications, military applications, mobile communications, WLAN; Wimax etc [1-3].In spite of having such advantages, traditional Microstrip antenna suffers from narrow bandwidth and the spurious radiations that decrease the system efficiency. And so the antenna becomes unsuitable for the wide band applications. Many researchers have been investigating in this area to increase the bandwidth [4] and reduce the harmonic suppression [12].

To enhance the bandwidth many different feeding techniques have been used such as proximity coupling feed, aperture coupling feed, stacked patch configuration [5-6]. In these techniques, the structure of antenna is multilayer and a patch is fed through a non-contacting fed network. But due to this, the size of the antenna becomes larger. The substrate becomes thicker. It is challenging to employ the patch and the feeding network on a single layer using a thin substrate.

So another method was then employed by cutting the different shapes slots in the radiating patch such as 'U', 'E', 'Ψ' shaped [7,8]. But again in this type of antenna, the air or the foam material has to be used and again the size of the antenna increases. So to overcome with this problem, an impedance matching network is formed using non- resonating resonators. In this, a composite resonator and a half wavelength λ/2 resonator are employed as a non-resonating element to increase the bandwidth [9-11].

In this paper, along with the bandwidth enhancement we have also employed an antenna structure such that it eliminates the harmonic radiation. Many researchers have employed the techniques to reduce the harmonic radiations. Basically, harmonic radiations are reduced by using the filters [12]. But then the size of the antenna increases. So the researchers employed the different techniques like using the electromagnetic band gap structure, compact resonant cell and defected ground structure [13-15].But due to these, the front to back ratio degrades.

In the proposed antenna, a patch is capacitively fed using a coupling gap. A pair of a λ/4 resonator is placed in parallel with the radiating patch. This increases the bandwidth of the antenna with a single layer using a thin substrate. Use of the shorting pin is done to combine the two λ/4 resonators. Also the high frequency harmonic radiations are suppressed.

2. METHODOLOGY

In the proposed antenna design, the radiating patch is placed in parallel with the pair of a λ/4 resonator. The length and the width of the radiating patch is denoted as 'L_p' and 'W_p' respectively as shown in the fig: 1 and the length and width of λ/4 resonator are denoted as 'L_r' and 'W_r' respectively.

A shorting pin is used to combine the two λ/4 resonators. The shorting pin connects the patch and the ground. The radius of the shorting pin is denoted by 'r'. Also the distance between the radiating patch and pair of the resonators is denoted by distance'd'. By adjusting the radius 'r' and the distance'd', we have achieved maximum wide band.

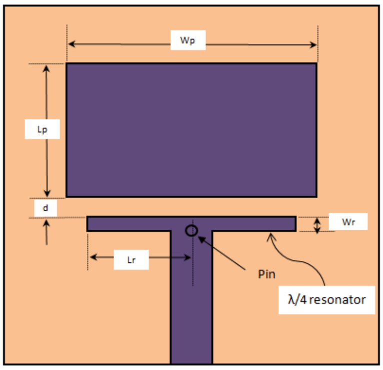

Fig1: - Geometry of the proposed wideband patch antenna.

The FR4 Epoxy substrate with relative permittivity of 'ϵ_r'=4.4 is used. The substrate height is h=1.6mm.Formulae to calculate the length and the width of the traditional patch antenna are,

The patch width is given by,

$$w = \frac{c}{2f\sqrt{\frac{\epsilon_r+1}{2}}} \quad (1)$$

Where,

C= (3 x 10^8 m/sec)

Relative permittivity ϵ_r= 4.4

f = resonating frequency

The patch length is given by,

$$L = L_{eff}\text{-}2\Delta L \quad (2)$$

Where,

$$L_{eff} = \frac{c}{2f\sqrt{\epsilon_{eff}}} \quad (3)$$

And

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\frac{1}{\sqrt{(1+\frac{12h}{w})}} \quad (4)$$

Also,

$$\Delta L = 0.412h\frac{\epsilon_e+0.3}{\epsilon_e-0.258}\frac{(W/h)+0.264}{(W/h)+0.8} \quad (5)$$

In our design, the length of the radiating patch and the resonator are denoted by 'L_p' and 'L_r' which are given as below,

$$L_p = \frac{1}{2f_0\sqrt{\epsilon_{rp}}\sqrt{\mu_0\epsilon_0}} - 2\Delta L \quad (6)$$

$$L_r = \frac{1}{f_0\sqrt{\epsilon_{rr}}\sqrt{\mu_0\epsilon_0}} \quad (7)$$

Where,

ΔL is effective extended length, μ_0 and ϵ_0 are the free space permeability and permittivity and ϵ_{rr} and ϵ_{rp} are the effective permittivity of the patch and the λ/4 resonators respectively. The operating frequency is 3.6 GHz. Substrate thickness is h=1.6mm.

Simulation is done using HFSS (High Frequency simulation software).Here we have compared the results of two antenna on HFSS. One is trational antenna and the other is the proposed antenna.

The patch size in proposed antenna is 18mm x 27mm and the size of λ/4 resonator is 11.08mm x 0.5mm. Shorting pin radius is r=0.5mm.The distance between the resonating patch and the λ/4 resonator is denoted by'd' and is 0.5mm.

The traditional and proposed antenna is designed using Ansoft Software HFSS as shown in fig: 2(a) and fig: 2(b) respectively.

3. EXPERIMENTAL VERIFICATION

A] Bandwidth Enhancement:-

The bandwidth of the traditional antenna is very small as shown in fig: 3(a).While the proposed antenna resonates at 3.3GHz and 3.8 GHz. The measured frequency range of the proposed patch antenna with |S11| lower than −10dB is 3.252GHz - 3.920 GHz as shown in fig: 3(b).

The table shows that the maximum frequency band is obtained when the radius of the shorting pin is r=0.4. The result are observed on HFSS software

***Table I**:- Effect of change in radius of shorting pin on the bandwidth.*

Radius of the shorting pin(mm)	Bandwidth range in dB
r = 0.4	3.9GHz - 3.2GHZ
r = 0.5	3.8GHZ – 3.2GHZ
r = 0.6	3.8GHz – 3.3GHZ

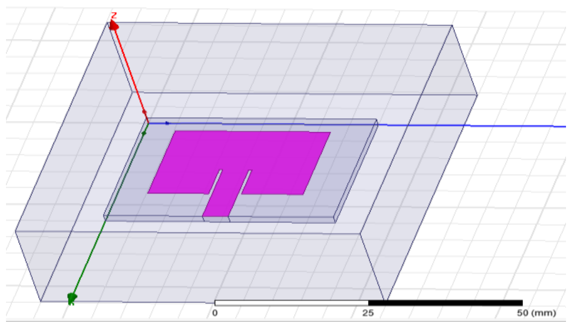

Fig 2(a):- Traditional insert fed Antenna design on the HFSS Software

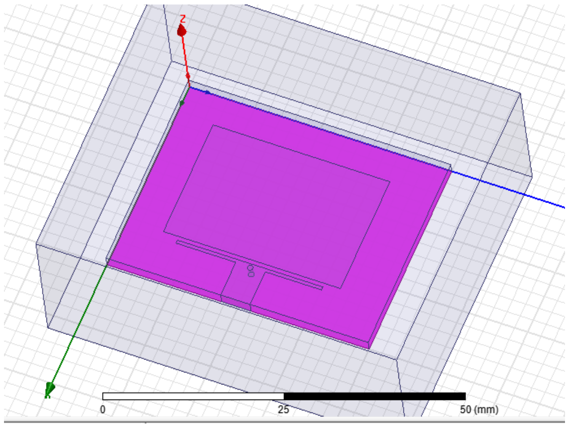

Fig 2(b):- Proposed Antenna design on the HFSS Software

B] Harmonic Suppression:-

In the graph of figure 3(a) and 3(b) we observe that harmonic radiations are suppressed in the propsed antenna.

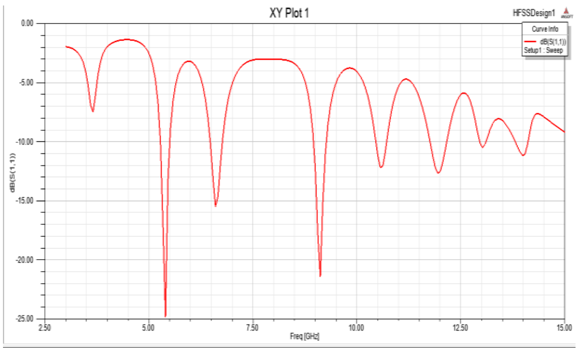

Fig 3(a):- Simulated result of reflection coefficient (S11) vs. frequency for traditional fed antenna

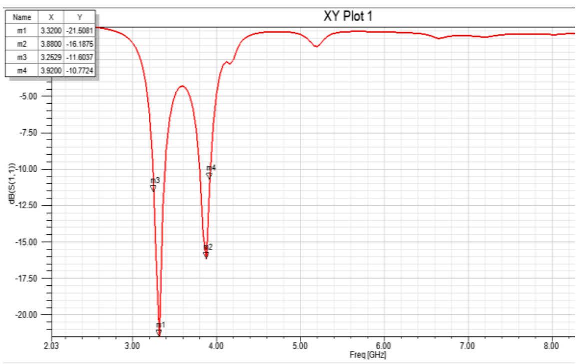

Fig 3(b):- Simulated result of reflection coefficient (S11) vs. frequency for proposed antenna.

C] Gain:-

The proposed antenna gain obtained is 2dBi as shown in figure 4.

D] Radiation Pattern:-

The traditional antenna and proposed antenna radiation pattern measured at φ=0° are as shown in the figure 5(a) and 5(b).

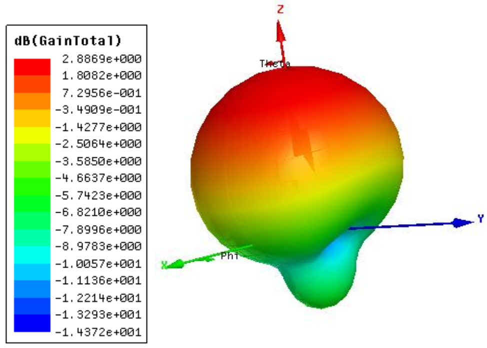

Fig 4:- 3-D Gain in dB

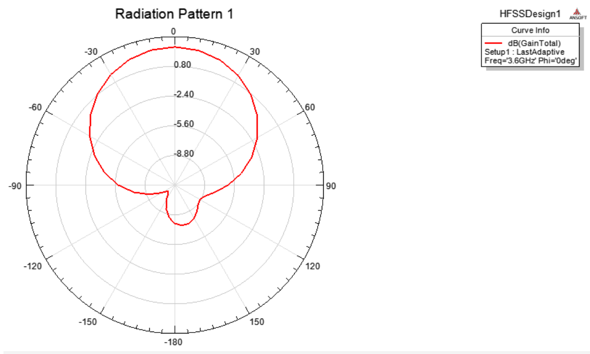

Fig 5(a):- Radiation Pattern of traditional antenna at φ= 0°

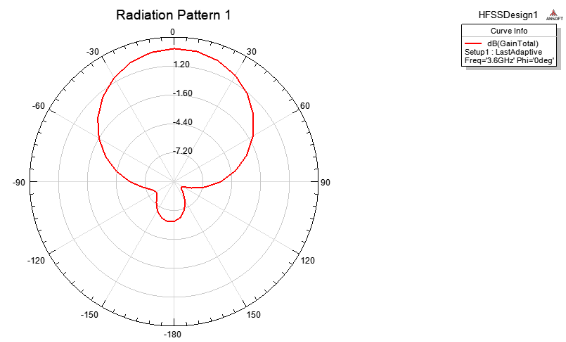

Fig 5(b):- Radiation Pattern of proposed antenna at φ= 0°

4. MEASURED RESULT

The figure 6 shows the fabricated antenna. The result of the fabricated antenna are measured on the VNA(Vector Network Analyser).

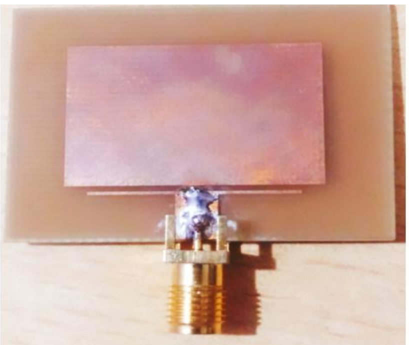

Fig 6:- Fabricated antenna

It is seen from the result on VNA and HFSS that the simulation result and the VNA results are almost similar. In figure 7, it is observed that the radiating patch and the resonator are resonating at two different frequency, i.e. M1 at 3.46GHz and M2 at 3.88GHz. While the bandwidth is observed at M4-M3 i.e. 3.94GHz – 3.41GHz.

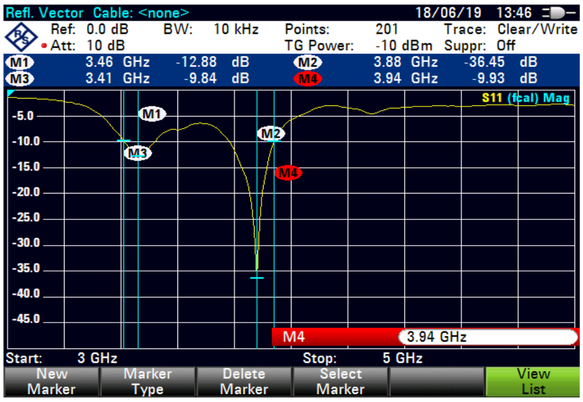

Fig 7:- S11 results on VNA of the proposed antenna

5. CONCLUSION

In this paper, a single layer compact electromagnetically fed patch antenna is designed and fabricated.The bandwidth of the antenna is enhanced by using a pair of λ/4 resonator. Also it is observed that the bandwidth is widened by adjusting the distance between the patch and the λ/4 resonator. The maximum bandwidth is odtained at d=0.5mm.The designed antenna resonates at 3.6GHz. The traditional and proposed antenna are compared and proved that the proposed antenna has good performance. The measured and simulated result shows that the antenna bandwidth has enhanced and the suppression of the harmonics radiation is successfully done.

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