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

D.G. Bhalke, Sunita Thorat, Rahul Mapari, Rutuja Kothe

Abstract*: *A parallel combination of pair of λ/4 Resonator and the rectangular patch has enhanced the bandwidth and suppressed the unwanted harmonic radiations of the proposed antenna. Due to electromagnetic coupling effect, the pair of λ/4 resonator excites the radiating patch. Both λ/4 resonator and resonating patch excites at two different frequencies which are close to each other and this helps to increase the bandwidth of a proposed antenna. Also a shorting pin is used between the two λ/4 resonators which suppress the unwanted harmonic radiations. Design of a proposed antenna is done using the HFSS (High Frequency Simulation software). The Hardware results are observed on VNA (Virtual Network Analyzer).The operating frequency 3.6GHz.The proposed antenna is used in WLAN applicatio

Keywords : λ/4 resonator, Bandwidth Enhancement, Electromagnetic coupling, Harmonic Suppression.

I. INTRODUCTION

Microstrip Patch antenna is being widely used in different fields of communication due to its various advantages like it is small in size, has low profile, light in weight, ease to install. Nowadays, in many applications, a very small size antenna is demanded. Microstrip antenna is best suitable for all those applications. So these antennas are mainly used in many wireless applications, mobile communications, WLAN, Wimax, Radar systems, Satellite communication, military applications [1][2]. Even though having many advantages, antenna suffers from disadvantages like narrow bandwidth, surface wave radiations. Also there has been a greater need for miniaturized antenna, but the performance of antenna degrades in terms of antenna gain, bandwidth and efficiency while reducing the size of antenna. So it has been a difficult task for the researchers to increase the performance of antenna while reducing its size. So they have been making continues efforts in the area of enhancing the bandwidth, increasing the gain and radiation efficiency while miniaturizing the size of an antenna [3] [4]. The main purpose of our proposed antenna is to enhance the antenna bandwidth not affecting the gain and the efficiency of the antenna.

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Different feeding techniques are used to enhance the bandwidth such as aperture coupling, stacked patch configuration, proximity coupling [5] [6]. In most of the techniques due to the multilayer, the size of the antenna increases as the substrate becomes thicker. In [6], the non-contacting fed network technique is used, but again the substrate thickness increases. Also it is challenging task to employ the feeding network and the patch on a single layer with a thin substrate.

Researchers have also found that by making the different slots in the radiating patch, bandwidth can be increased. So slots with shapes like 'U', 'E', 'Ψ' [7] [8], were made on the radiating patch. But again in this case, the air or the foam material has to be used as the substrate which again increases the size on an antenna. So it was then observed that a non-resonating resonator which forms impedance matching network also helps to increase the bandwidth. The λ/2 resonator was first employed [9] [10] [11].

Along with the bandwidth enhancement, we have also tried suppressing the unwanted harmonic radiations. Mainly filters are used to suppress the unwanted radiations [12]. But again the filters increased the antenna size. So different techniques came into existence like electronic band gap structure, DGS (Defective ground structure), compact resonant cell. But it degrades the front to back ratio.

In our proposed antenna, we have reduced the length of the resonator to λ/4.The radiating patch is placed in parallel with the pair of λ/4 resonator on a single layer with a very thin substrate. The two λ/4 resonators are combined together with the help of the shorting pin. Combining effect of both increases the bandwidth and also suppresses the harmonic radiations.

II. METHODOLOGY

Fig. 1 shows the physical layout of the proposed antenna. 'L_p' and 'W_p' are the length and the width of the radiating patch respectively and 'L_r' and 'W_r' are the length and the width of the λ/4 resonators respectively. Shorting pin denoted as 'Pin', between two λ/4 resonators, joins both the λ/4 resonators which has the radius r = 0.5 mm. The shorting pin also connects the ground and the patch. The distance between the pair of

resonators and the radiating patch is denoted by distance'd'. The bandwidth can be varied by adjusting the distance'd' and the radius 'r'. The simulation of the physical structure of antenna design is done using the HFSS (High frequency simulation software).

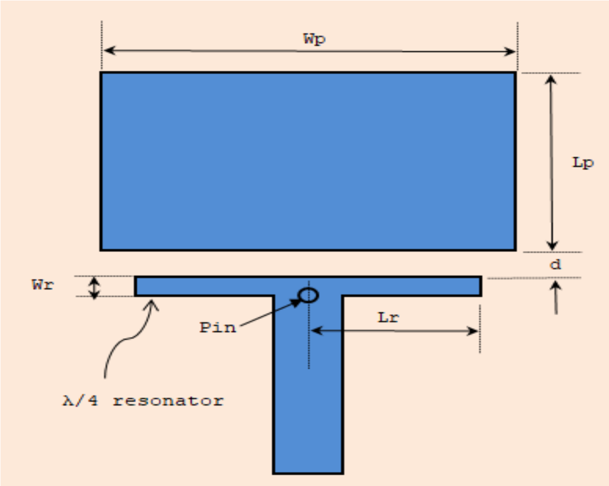

Fig.1: Geometry of the proposed wideband patch antenna.

The material used for the substrate is FR4 Epoxy with relative permittivity 'ϵ_r'=4.4. The height of the substrate 'h' is 1.6mm. Basic formula to calculate the width of the traditional patch antenna is,

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

Where c= (3 x 10^8 m/sec)

Relative permittivity ϵ_r= 4.4

f = resonating frequency

The patch length is given by,

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

Where,

'L_{eff}' is effective length and 'ΔL' is effective extended length,

L_{eff} is calculated by using,

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

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

Where, 'ϵ_{eff}' Effective permitivity and, ΔL is calculated using,

$$\Delta L = 0.4124\,\frac{\epsilon_{e+0.3}}{\epsilon_{e-0.258}}\,\frac{\left(\frac{w}{h}\right)+0.264}{\left(\frac{w}{h}\right)+0.8} \quad (5)$$

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

$$L_p = \frac{1}{f_0\sqrt{(\epsilon_{rp}\,\mu_0\,\epsilon_0)}} \quad (6)$$

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

Where

f_o = *Operating frequency*,

μ_0=Free space permeability,

ϵ_0 = Free space permittivity,

ϵ_{rr} = The effective permittivity of the patch

ϵ_{rp} = are the effective permittivity of the λ/4 resonators

The antenna is designed at the operating frequency of 3.6 GHz and the simulation is done on HFSS (High Frequency simulation software). For comparison, the results of traditional and the proposed antenna are shown on HFSS.

The proposed antenna configuration size is 18 mm x 27 mm and the λ/4 resonator size is 11.08 mm x 0.5mm. The distance 'd' between the λ/4 resonator and the resonating patch is 0.5 mm. Radius of shorting pin is r=0.5mm. Fig: 2(a) and Fig. 2 (b) shows the traditional antenna and proposed antenna designed using HFSS software.

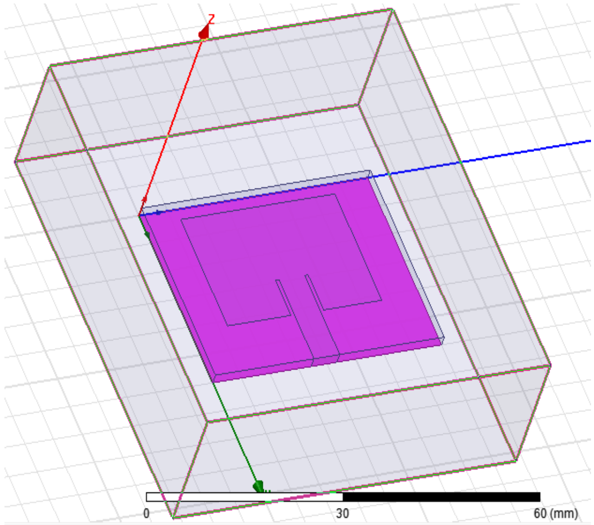

Fig 2(a): Traditional insert fed antenna designed on HFSS software

III. EXPERIMENTALVERIFICATION

Bandwidth Enhancement

As seen from the Fig. 3(a), the traditional antenna bandwidth is very small. While from Fig.3 (b), we observe that the proposed antenna resonates at two different frequencies 3.3 GHz and 3.8 GHz and the measured frequency range with |S11| lower than −10dB is 3.252GHz - 3.920 GHz. Hence the bandwidth of the proposed antenna is larger than traditional antenna. The below table shows that when radius of the shorting pin R=0.4mm, then the maximum frequency the band range is obtained.

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	38GHZ – 3.3GHZ

A. HARMONIC SUPPRESSION

Fig. 3(a) shows that the traditional antenna resonates at many unwanted frequencies other than the resonating frequency. While Fig. 3(b), shows that the 2^{nd} , 3^{rd} and further unwanted harmonis are completely suppressed in the proposed antenna.

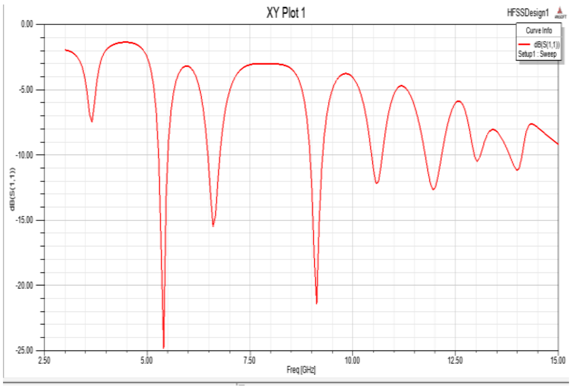

Fig. 3(a):- Simulated result of reflection coefficient (S11) vs. frequency for traditional fed antenna

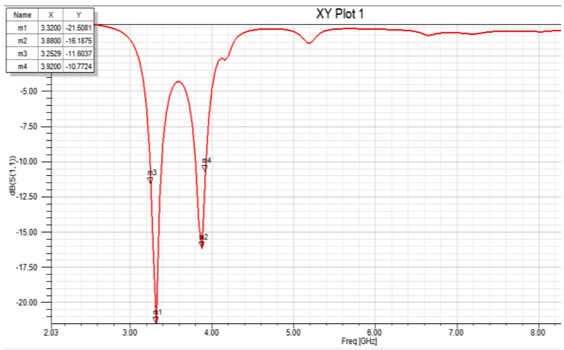

Fig 3(b):- Simulated result of reflection coefficient (S11) vs. frequency for proposed antenna.

Gain: The gain of the proposed antenna obtained in 2 dB is shown in fig. 4.

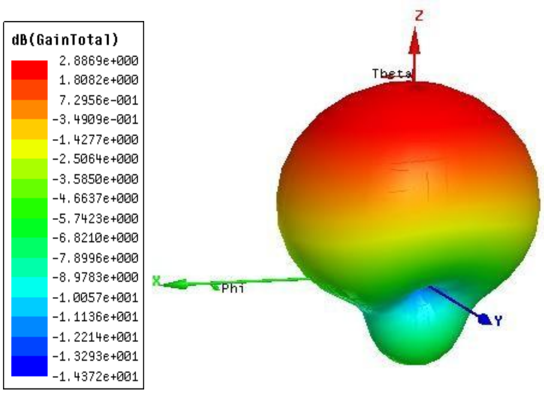

Fig. 4: 3-D gain in dB

RADIATION PATTERN

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

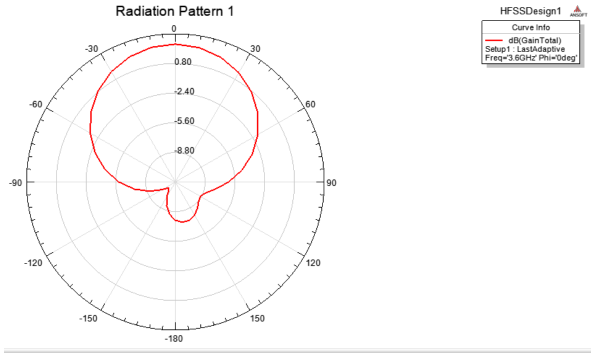

Fig 5(a):- Radiation Pattern of traditional antenna at φ= 0°

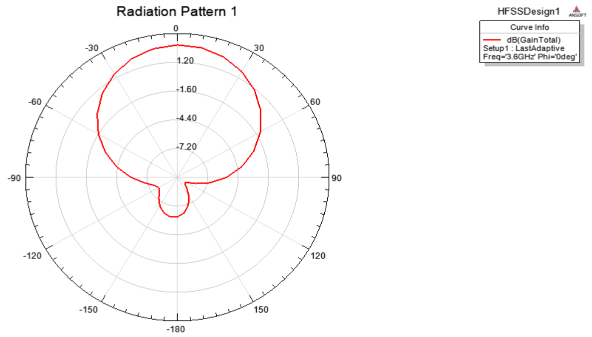

Fig 5(b):- Radiation Pattern of proposed antenna at φ= 0°

IV. MEASURED RESULT

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

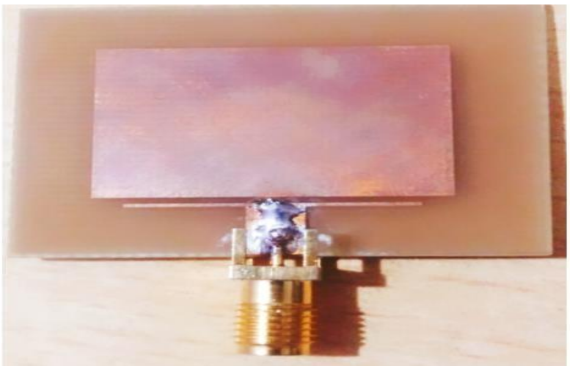

Fig. 6: Fabricated Antenna

It is observed that the result on VNA and HFSS are almost similar. In Fig. 7 shows the output on VNA. It is observed that the radiating patch resonates at M1= 3.46 GHz and the resonator resonates at M2=3.88GHz. Hence the bandwidth observed is ‘M4-M3’ i.e. 3.94GHz – 3.41GHz.

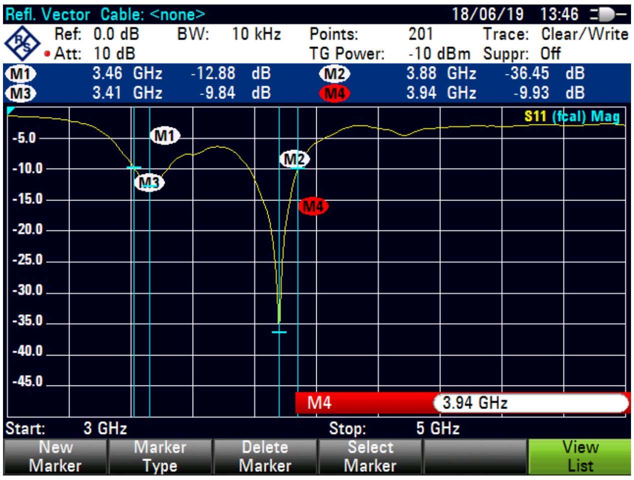

Fig 7:- S11 results on VNA of the proposed antenna

V. CONCLUSION

A single layer compact electromagnetically fed patch antenna has been proposed, designed and fabricated. The bandwidth of the antenna is enhanced by using a pair of λ/4 resonator. Also we have observed that the bandwidth is widened by adjusting the distance between the patch and the λ/4 resonator. The maximum bandwidth obtained is 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.

REFERENCES

1. Rappaport Theodore S.,Murdock James N., & Gutierrez Felix. (2011). “State of the Art in 60-GHz Integrated Circuits and System for Wireless Communications” Proc. IEEE, vol. 99, no. 8, pp. 1390–1436, Aug.2011.
2. Balanis C. A., “Antenna Theory,” in Analysis and Design, J. Wiley & Sons, New York,1997.
3. G. Kumar and K. P. Ray, “Broadband Microstrip Antennas,” MA USA: Artech House, Boston,2003.
4. S. A. RazaviParizi, “Bandwidth enhacement techniques”, Nov 15th2017.
5. B. Kaufman and D.M. Pozar “Increasing the bandwidth of Microstrip Antenna by proximity coupling”, Electron. Lett., vol. 23, no. 8,pp. 368–369, Apr.1987.
6. C. Chen, A. Tulintseff, and R. Sorbello, “Broadband two-layer microstrip antenna,” in Proc. IEEE Antennas Propag. Soc. Int. Symp., Boston, MA, USA, Jun. 1984, pp.251–252.
7. Waterhouse R. B. and W. S. T. Rowe, “Investigation into the performance of proximity coupled stacked patches,” IEEE Trans
8. .on Antennas Propag. vol. 54, no. 6, Jun. 2006.
9. K. P. Ray and A. A. Deshmukh , “Analysis of broadband Psi (ψ)-shaped microstrip antennas”, IEEE Antennas Propag. Mag., vol. 55, no. 2,pp. 107–123, Apr.2013.
10. Lee K. F and T. Huynh, “Single-Layer Single-Patch Wideband Microstrip Antenna,” Electronics Letters, 16, August 1995, pp. 1310-1312.
11. Huang X. B, Fang D. G, and Wang H., “A single layer wideband U-slot microstrip patch antenna array,” IEEE Antennas Wireless Propag. Lett., vol. 7, pp. 9–12, Feb.2008.
12. Veeresh G. Kasabegoudar ., and Vinoy K. J., “Coplanar capacitively coupled probe fed microstrip antennas for wideband applications”, IEEE Trans. on Antennas Propag., vol. 58, no. 10, pp. 3131–3138, Oct.2010.
13. G. Yang ,M. Ali, and R. Dougal, “Miniature circularly polarized rectenna with reduced out-of-band harmonics,” IEEE Antennas andWirelessPropag.Lett.,vol.5,no.1,pp.107–110,Dec.2006.
14. M. Tsutsumi and Y. Horii , Harmonic control by photonic bandgap on microstrip patch antenna,” IEEE Microw.ave Guided Wave Lett., vol. 9, no. 1, pp. 13–15, Jan.1999.
15. Sujoy Biswas, DebatoshGuha, C. Sudarshana Kumar, “Control of higher harmonics and their radiations in microstrip antennas using compact defected ground structures,” IEEE Trans. and Antennas Propag., vol. 61, no. 6, pp. 3349–3353, Jun.2013.
16. Y. J. Sung and Y. S. Kim, “An improved design of microstrip patch antennas using photonic bandgap structure,” IEEE Trans. Antennas Propag., vol. 53, no. 5, pp. 1799–1804, May2005.

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