Design And Analysis of Compact Asymmetric Fractal Patch antenna with Enhanced Bandwidth and Harmonic Suppression for Wireless Applications

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Abstract— **A micro strip patch antenna with capability of both bandwidth improvement and harmonic reduction is proposed. For this purpose, a pair of $\lambda/4$ patch resonators is specified and coupled in proximity to a rectangular patch. An asymmetric fractal antenna with slots along radiating edges is designed. The wideband patch is obtained by making partial gnd and coupled radiating $\lambda/4$ resonators to this antenna. As compare with the other antennas, the electrically thick substrate is not needed for the proposed antenna, so it has less low-profile property. With the use of $\lambda/4$ resonators and capacitive coupling, harmonic radiating modes can be reduced. The proposed antenna for 2.4 GHz is fabricated using FR4 substrate with dimension of 56mm * 56mm * 1.6mm. The substrate has dielectric constant of 4.4 and thickness 1.6 mm. The antenna achieves impedance matching over the frequency band of 1.60 to 2.87 GHz (52.91%). Therefore it covers Wi-Fi 2.40 to 2.50GHz band, WLAN 2.40 to 2.48GHz band and LTE 2.50 to 2.69 GHz band. The Simulated and testing results shows good enhancement in the bandwidth than the traditional patch, and the unwanted radiation from other higher requested radiating modes has been effectively reduced.**

Keywords— Bandwidth improvement, patch antenna, coupled feed, harmonic reduction, wideband and quarter-wave resonator.

I. INTRODUCTION

In advance communication systems the antenna and the front-end are situated closely or integrated together [1]. In these systems, the patch antenna is effectively integrated with many active and passive circuits like filters, oscillators, amplifiers, and mixers. Usually the micro strip antenna usually suffers from fundamental drawbacks. One is the small bandwidth because of high *Q* and the other is the high level of harmonic radiation, which will reduced the ability of the system and even cause negative interferences with other systems. To improve the bandwidth of patch antennas many attempts have been made by using the aperture coupling feed [2], accessibility integrate feed [3], or stacked patch configurations [4]–[6].

When compared with the probe-fed method, the micro strip fed approach is much useful in the application of an array antenna with radiating elements. In this context, the strip feeding network and patch radiating elements can be fully merge on a single-layer substrate and by using the printing technology, the entire array can be fabricated simultaneously. However, the dielectric substrate's thickness must be electrically little, so that it turned into the structure of a wide-band micro-strip patch antenna on a single-layer substrate. So far, some techniques have been noted to solve this problem. as in[6], extra non-radiating resonators are used in the development of impedance-matching network. In [7] and [8], a composite right-/left-handed resonator and a half wavelength ($\lambda/2$) resonator and are added, respectively, to gain the wideband operation. Since the sizes of the feeding networks are enlarged by these features, these approaches can hardly be used in the structure of an array. A size-minimization method is noted in [9], but the extra T-shaped resonator changed the patch configuration. Moreover, the harmonic radiation can't be reduced because this T-shaped resonator worked as a $\lambda/2$ resonator.

In this paper, a micro-strip patch antenna with improved bandwidth and well harmonic suppression performance is suggested. As noted in [10], a patch may be fed capacitively by the coupling gap. In this experimentation, two $\lambda/4$ resonators are employed and situated in proximity to the radiating patch for wideband radiation under double resonances. The advantages of this method are as follows.

1) Operating bandwidth of antenna is improved for an electrically thin substrate, and it may be additionally controlled to some extent by accommodating the gap width into the λ/4 resonators and the patch.
2) At high frequency the harmonic radiation is effectively reduced thanks to the attributes of λ/4 resonators and capacitive feeding structure.
3) The feeding line area's size is little so as not to enlarge the size of the antenna if used in array applications.

II. GEOMETRY AND WORKING PRINCIPLE

The dielectric used FR4-epoxy substrate which is having 4.4 mm relative permittivity and the 1.6 mm thickness. The rectangular patch antenna's resonant frequency having length L and width W is determined using following formula.

A. *Geometry*

Step 1: Calculation of Lambda (λ0)-
Lambda (λ0)=c/f=3x10^8/2.4x10^9
(λ0)=125mm at 2.4 GHz
The center frequency will be approximately given by:

$$fc \approx \frac{c}{2L\sqrt{\varepsilon_r}}$$

$$L = \frac{c}{2fc\sqrt{\varepsilon_r}} \quad ----(1)$$

Where fc=is centre freq=2.4GHz
εr=4.4 and c=3x10^8
L=28.4mm

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad \text{-------------} \; \mathbf{(2)}$$

For c=3*10^8 m/s2, *fr*=2.4GHz, ε *r*=4.4
We get **W=38.0 mm.**
Feed width calculate by using

$$Z_0 = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(8\left(\frac{H}{W_f}\right) + 0.25\left(\frac{W_f}{H}\right)\right) \text{ ---------- } (3)$$

We get **Wf=2.8mm**
Step 5: Calculation of Feed length (L50)-
Feed length (L50)=lam/4*sqrt (4.4)
Ls0=49mm
Step 6: Calculation of Resonator length (Lr)-
Feed length (Lr)=lam/4
Lr=14.5mm
Step 7: Calculation of Substrate dimension-
Ls=L+2*6h=28.4+2*6*1.6=49mm
Ws=W+2*6h=38+2*6*1.6=59mm

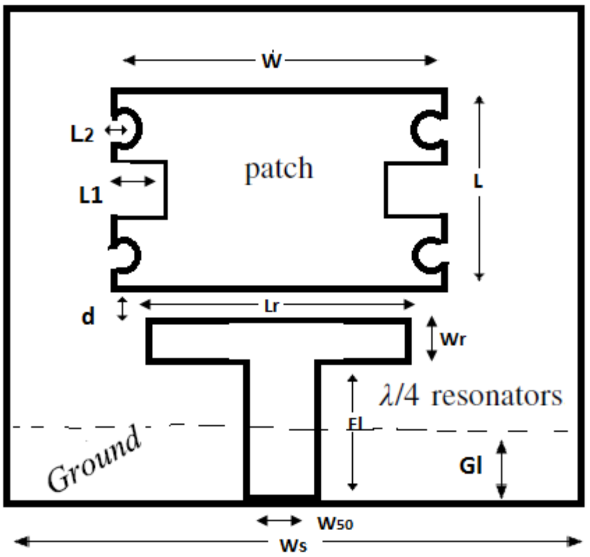


Fig.1 Geometry of the proposed wideband I Shape patch antenna

The proposed antenna is simulated by utilizing the HFSS simulation software and the finalized dimensions are:
L = 28mm, W = 36mm, L1 = 8mm, d=2mm, Wr = 1mm, Fl = 14mm, Lr = 30mm, Ls = 56mm, Gl=12mm and Ws = 56mm

Figure 1 shows the patch antenna with the dimension. As shown in the Figure, the patch is fed with a microstripline resonator.

B. Working Principle

A resonator type patch antenna generally requires an electrically thin substrate, but it suffers from narrow bandwidth. An effective method for bandwidth enlargement is to build a dual-resonance structure. For this purpose, an extra non radiating resonator is generally introduced behind the radiating patch. Rather than lumped resonator in a thick substrate, two $\lambda/4$ resonators is used here as a coplanar distributed resonator, which is situated in proximity to the main patch as shown in Fig. 1. The coupling gap helps in achieving a wideband performance. Its width influence the dual resonant frequencies. Therefore, the gap width can be optimized to make the dual resonant frequencies near one another, in this manner combination of two smaller bands into a single wide band.

In addition to bandwidth improvement, the proposed feeding technique can effectively reduce the spurious radiation made by harmonic resonant methods of the patch radiator; this is explained in following explanation. The patch antenna is capacitively fed through $\lambda/4$ resonators. Here the energy is transmitted to the patch in discrete frequencies where both the patch and $\lambda/4$ resonators are resonating, which is totally unique from the traditional insert-fed patch antenna.

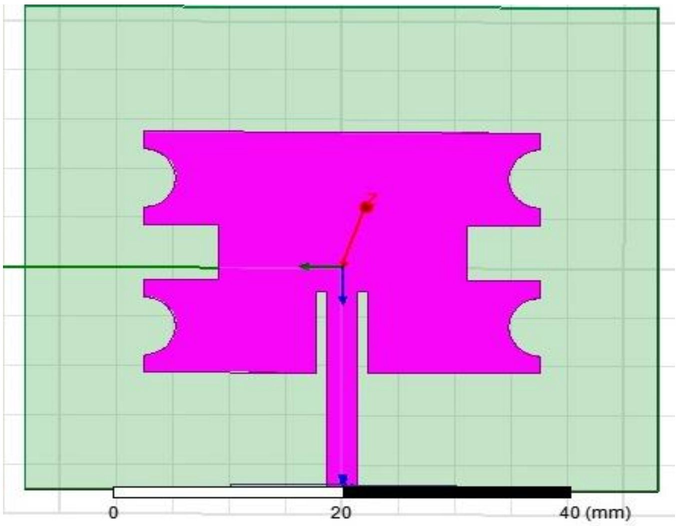


Fig 2. Traditional Asymmetric fractal Patch Antenna

Simulation of this antenna has been completed in HFSS. From figure 5 the value of Return loss is -31.85dB at 2.4GHz. The proposed antenna exhibits a wide impedance bandwidth about 1270MHz and there is harmonic reduction through entire band from 1 to 10GHz.

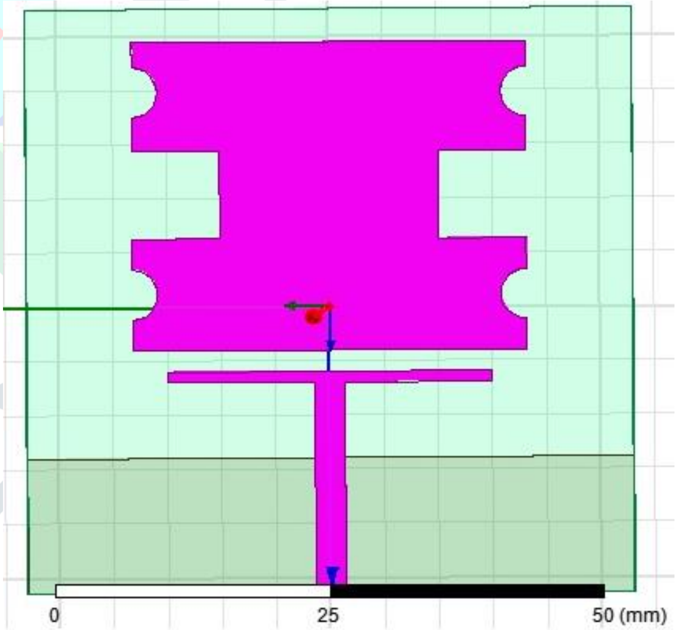


Fig 3. Proposed Asymmetric fractal Patch antenna

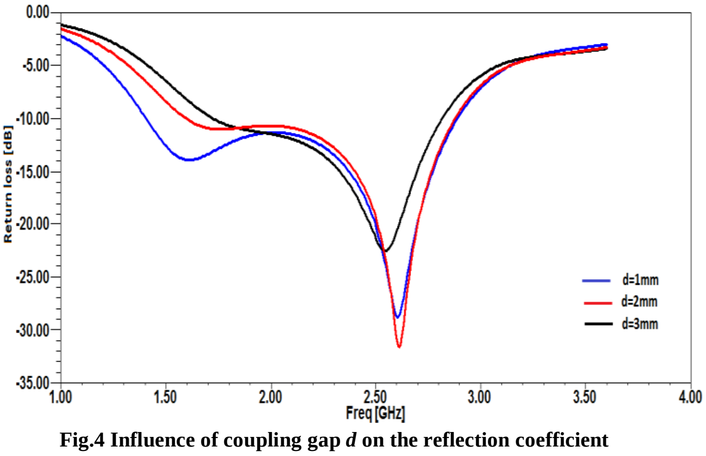


Fig.4 Influence of coupling gap *d* on the reflection coefficient

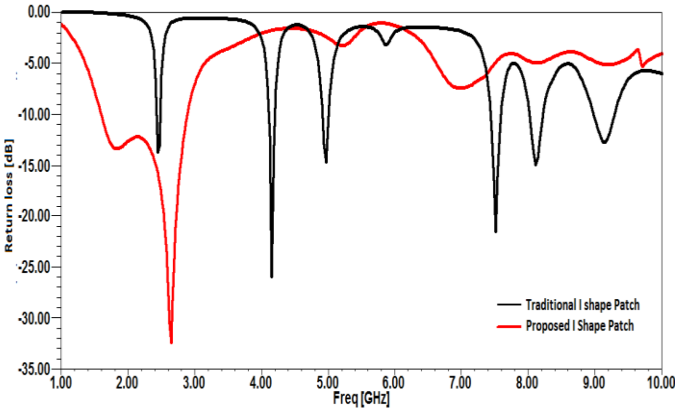


Fig 5: Simulated reflection coefficients of the proposed and traditional patch antennas in a wide frequency range

In addition to bandwidth improvement as described above, the undesired harmonic radiation at high frequencies can be effectively reduced by the proposed strategy. Fig. 5 shows the simulated reflection coefficients in a wide frequency range under three different *d* values. For comparison, the result of a traditional I shape patch operating at 2.4 GHz is also plotted in the same figure. There are many higher request radiating methods beyond the dominant TM10 mode for the insert-fed I shape patch. However, the greater part of them will vanish in the proposed I shape patch antenna, confirming effective reduction of harmonic radiations. Looking at the results of d = 1.0 and 3.0 mm, we can further say that the harmonic reduction is dependent on the gap width and the operation bandwidth. Use of d=2.0mm gives the largest operating bandwidth.

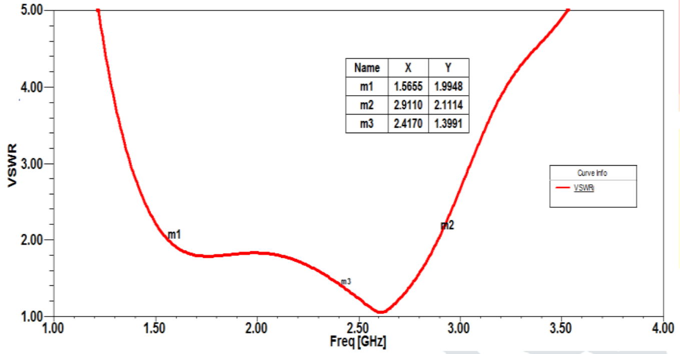


Fig.6 VSWR of proposed antenna

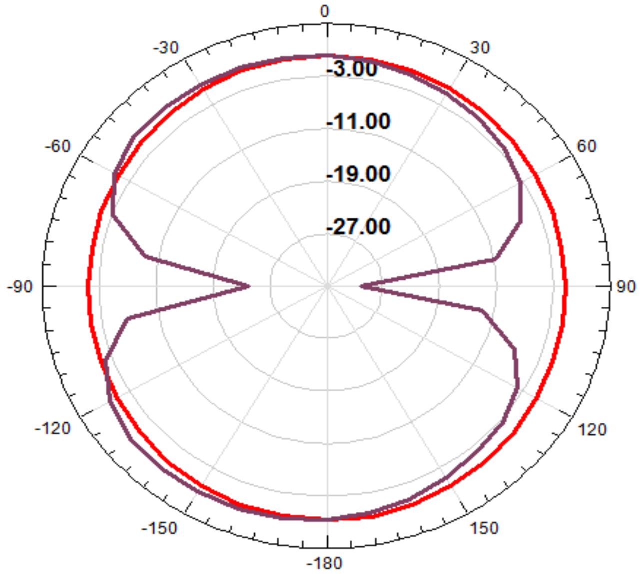


Fig.7 Radiation pattern

Fig.7 shows that the radiation patterns of antenna are Omnidirectional in both E-plane & H plane at freq 2.4GHZ.

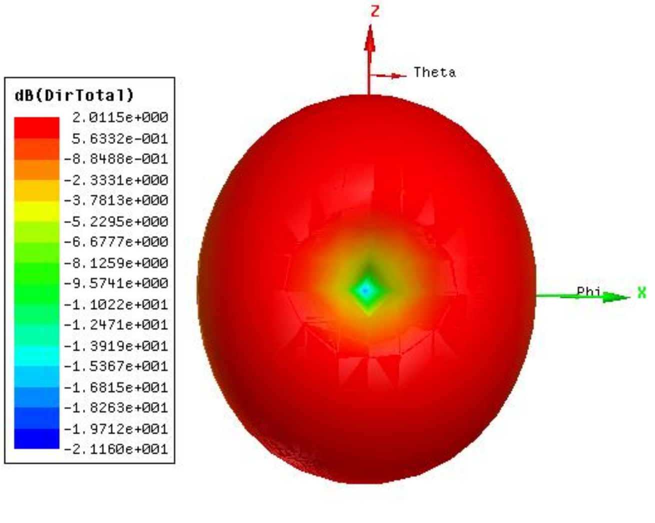


Fig 8: 3D Gain

The simulated gain of the antenna at 2.4 GHz is 2 dBi as shown in figure 8.

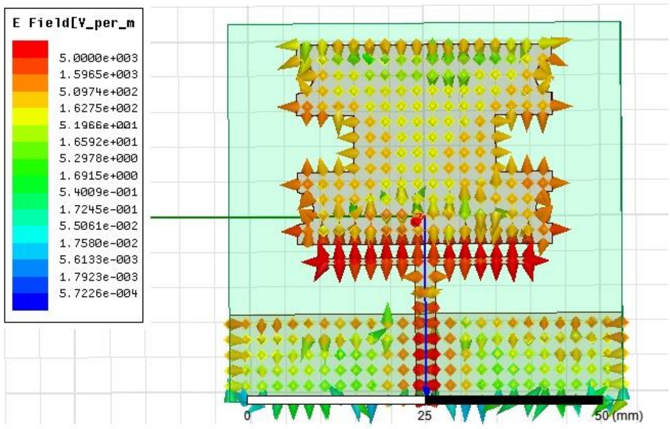


Fig.9 Surface current distributions

The current distribution of the antenna at 2.4 GHz is displayed in figure 9. Red colour shows maximum current along the radiating edges of patch.

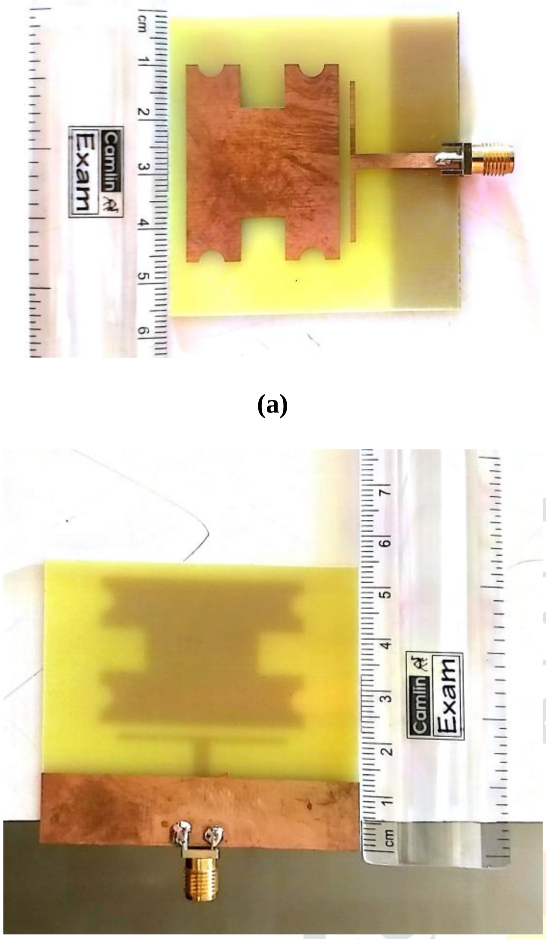
III.COMPARISON TABLE

To increase the presentation of the antenna, a couple of λ/4 micro-strip line resonators is presented. As shown from the table, proposed and traditional patch antenna are described. It conclude that proposed asymmetric fractal patch antenna technique's both bandwidth & harmonic's of antenna are improved.

Sr. No.	Results	Freq (GHz)	Return loss (dB)	VSWR	BW (MHz)	Gain (dB)
1.	Traditional-shape fractal asymmetric Patch Antenna	2.4	-23.33	1.17	60	4.2
2.	**Proposed Asymmetric fractal Patch Antenna**	**2.4**	**-26..10**	**1.07**	**1580**	**2.0**

Table 1 Comparison table

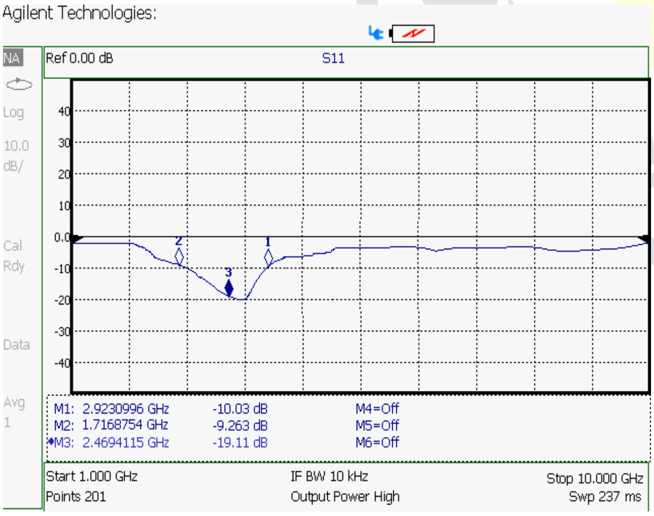
V. TESTING RESULTS



(a)

(b)

Fig. 10 Fabricated antenna (a) Patch view (b) Ground structure



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M1: 2.9230996 GHz   -10.03 dB   M4=Off
M2: 1.7168754 GHz   -9.263 dB   M5=Off
M3: 2.4694115 GHz   -19.11 dB   M6=Off
Start 1.000 GHz     IF BW 10 kHz        Stop 10.000 GHz
Points 201          Output Power High   Swp 237 ms
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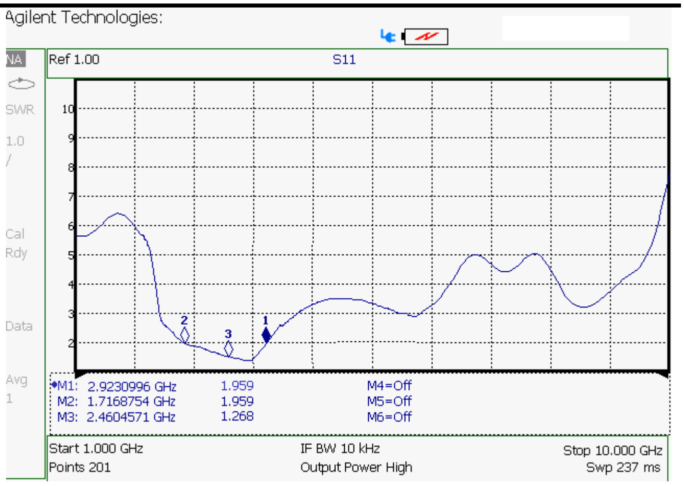
Fig 11. Return loss antenna



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M1: 2.9230996 GHz   1.959   M4=Off
M2: 1.7168754 GHz   1.959   M5=Off
M3: 2.4604571 GHz   1.268   M6=Off
Start 1.000 GHz     IF BW 10 kHz        Stop 10.000 GHz
Points 201          Output Power High   Swp 237 ms
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Fig 12.VSWR of antenna

Figure 10 shows the actual photo of fabricated antenna. The fabricated antenna is tested using Agilent Technologies N9923A vector network analyzer. The testing results are as shown in figure 11 & 12, which shows a better matching with th simulation results.

IV. CONCLUSION

New compact coupled-fed asymmetric fractal patch antenna in with enhanced bandwidth and reduced harmonics is designed using single-layer substrate. By using a couple of λ/4 resonators, the bandwidth of the patch antenna is essentially enlarged and the harmonic radiations are successfully reduced, while another advantages of the patch antenna, like low profit, easy integration and low cost, still remain. Our investigation indicates that the bandwidth of the patch can be enlarged by adjusting the gap into the patch and the λ/4 resonator. To approve the design technique, a prototype antenna working at band Wi-fi 2.4 GHz is designed. Its performance is compared with a traditional insert-fed patch antenna. The measured and simulated results show that the bandwidth has been enlarged by 20 times and the higher mode radiations have been successfully suppressed. In addition, more symmetric radiation patterns and good gain is obtained. These properties of proposed antenna show that it can be used for Wi-Fi, WLAN and LTE applications.

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