

# DESIGN AND ANALYSIS OF PATCH ANTENNA WITH ENHANCED BANDWIDTH AND HARMONIC SUPPRESSION FOR WLAN 5GHz APPLICATIONS

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## ABSTRACT

A single-layer microstrip-fed patch antenna with capabilities of both bandwidth enhancement and harmonic suppression is proposed. For this purpose, a pair of  $\lambda/4$  microstripline resonators is introduced and coupled in proximity to a rectangular patch. The wideband property can be obtained by making effective use of the two resonances introduced by the radiating patch and nonradiating  $\lambda/4$  resonators. Different from other reported dual-resonance patch antennas, the proposed antenna does not require the electrically thick substrate, so it has attractive low-profile property. Thanks to the good features of  $\lambda/4$  resonators and capacitive feeding scheme, harmonic radiating modes of the patch antenna can be significantly suppressed as highly demanded in modern highly integrated communication systems. The working principle, equivalent circuit, and design procedure are extensively described. Finally, a prototype antenna operating at 5.0 GHz is designed and fabricated. The Simulated results show that its bandwidth 420MHz is 3 times wider than that of the traditional insert-fed patch counterpart, and the harmful spurious radiation from other higher order radiating modes has been effectively suppressed.

**Keywords:** — Bandwidth enhancement, coupled feed, harmonic suppression, patch antenna, quarter-wave resonator

## 1.INTRODUCTION

In Modern communication and radar systems, the antenna and the front-end are placed closely or even integrated together [1]. In these systems, the microstrip patch antenna is much popular since it can be easily integrated with many other active and passive circuits such as filters, amplifiers, oscillators, and mixers. Despite these attractive features, the microstrip antenna usually suffers from several inherent drawbacks. One is the narrow bandwidth because of its resonant property with a high  $Q$ ; the other is the high level of harmonic radiation, which will decrease the efficiency of the system and even cause harmful interferences with other systems. To enhance the bandwidth of patch antennas, many efforts have been made by using the aperture coupling feed [2], proximity coupling feed [3], or stacked patch configurations [4]–[6].

When compared with the probe-fed method, the microstrip fed approach is much useful in the implementation of an array antenna with a number of radiating elements. In this context, the microstrip feeding network and patch radiating elements can be fully integrated on a single-layer substrate and the entire array can be fabricated simultaneously by using the printing technology. However, the thickness of the dielectric substrate must be electrically small, so that it brings a challenging task in the design of a wideband microstrip fed patch antenna on a single-layer substrate. So far, a few techniques have been reported to solve this problem. In [6], additional nonradiating resonators are employed to construction impedance-matching network. In [7] and [8], a half wavelength ( $\lambda/2$ ) resonator and a composite right-/left-handed resonator are employed, respectively, to achieve the wideband performance. Since the sizes of the feeding networks are significantly enlarged, these approaches can hardly be applied in the design of an array. A size-miniaturization method is reported in [9], but the patch configuration is destroyed by an extra T-shaped resonator. Moreover, the harmonic radiation cannot be suppressed because this T-shaped resonator operates as a  $\lambda/2$  resonator.

In this paper, a microstrip-fed patch antenna with enhanced bandwidth and good harmonic suppression performance is presented. As reported in [10], a patch could be capacitively fed by a coupling gap. In our method, a pair of  $\lambda/4$  resonators is

employed and placed in proximity to the radiating patch for wideband radiation under dual resonances. The advantages of this method are as follows.

- 1) Operating bandwidth of a single-layer patch antenna is enhanced even for an electrically thin substrate, and it can be further controlled to some extent by adjusting the gap width between the patch and the  $\lambda/4$  resonators.
- 2) Harmonic radiation at high frequency is effectively suppressed thanks to the characteristics of capacitive feeding structure and  $\lambda/4$  resonators.
- 3) The feeding-line section is small in size so as not to increase the overall size of the patch antenna in array applications.

**2.2 LITERATURE REVIEW**

SR.NO	PUBLISHER'S NAME	PAPER'S DETAILS	STATEMENTS
1	<ul style="list-style-type: none"> <li>• T. S. Rappaport</li> <li>• J. N. Murdock</li> <li>• F. Gutierrez, Jr</li> </ul>	State of the art in 60-GHz integrated circuits and systems for wireless communications, <i>Proc. IEEE</i> , vol. 99, no. 8, pp. 1390–1436, Aug. 2011.	The antenna and the front-end are placed closely or even integrated together
2	D. M. Pozar	Microstrip antennas,” <i>Proc. IEEE</i> , vol. 80, no. 1, pp. 79–91, Jan. 1992.	To enhance the bandwidth of patch antennas, many efforts have been made by using the aperture coupling feed

**2. GEOMETRY AND WORKING PRINCIPLE**

The dielectric chosen is FR4-epoxy substrate having relative permittivity of 4.4 and the thickness of 1.53mm. The resonant frequency of the rectangular patch antenna, of length L and width W can be calculated using the following formula.

**2.1. Geometry**

Step 1: Calculation of Lambda ( $\lambda_0$ )-

$$\text{Lambda } (\lambda_0) = c/f = 3 \times 10^8 / 5.0 \times 10^9$$

$$(\lambda_0) = 60\text{mm at } 5.0 \text{ GHz}$$

The center frequency will be approximately given by:

$$f_c \approx \frac{c}{2L\sqrt{\epsilon_r}}$$

$$L = \frac{c}{2f_c\sqrt{\epsilon_r}} \quad \text{----- (1)}$$

Where  $f_c$  is centre freq=5.0GHz

$\epsilon_r$ =4.4 and  $c=3 \times 10^8$

**L=13.75mm**

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

We get **W=18.25 mm.**

Feed width calculate by using

For  $c=3 \times 10^8 \text{ m/s}^2, f_r=5.0\text{GHz}, \epsilon_r=4.4$

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

We get **Wf=2.84mm**

Step 2: Calculation of Feed length (L50)-

Feed length (L50)=lam/4\*sqrt (4.4)

**L50=7.5mm**

Step 3: Calculation of Resonator length (Lr)-

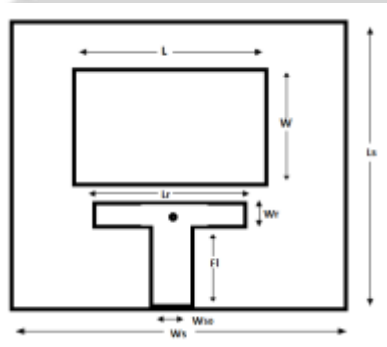
Feed length (Lr)=lam/4

**Lr=15.0mm**

Step 4: Calculation of Substrate dimension-

**Ls=L+2\*6h=13+2\*6\*1.6=31mm**

**Ws=W+2\*6h=19+2\*6\*1.6=37mm**



**Fig-1:** Geometry of the proposed wideband patch antenna

**Table-1:** Calculated Dimension table

Sr.No	Parameters	Dimensions(mm)
1.	L	13.7
2.	W	30.4
3.	Ls	31.0
4.	Ws	37.0
5.	FL	7.5
6.	Lr	15.0
7.	W50	2.85

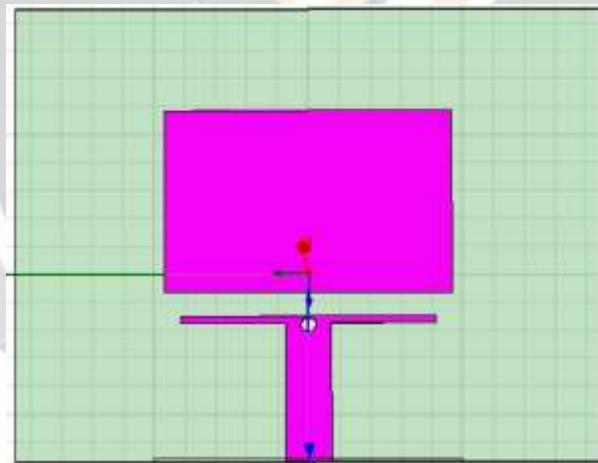
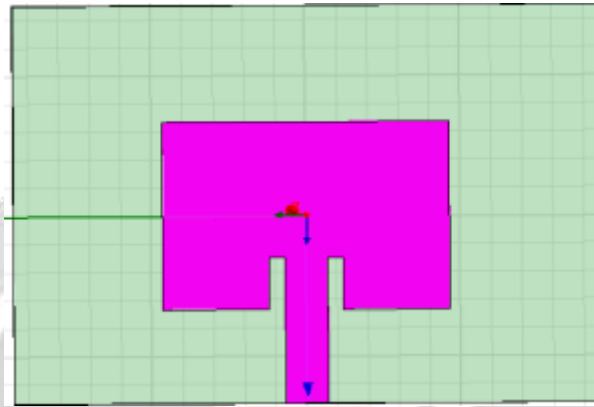
**2.2 Working Principle**

A resonator-type patch antenna usually requires an electrically thin substrate, thus suffering from a narrow bandwidth. An effective method for bandwidth enhancement is to construct a dual-resonance structure. For this purpose, a extra non radiating resonator is usually introduced in proximity to the radiating patch. Instead of the above lumped resonator in a thick substrate, a pair of λ/4 resonators is employed herein to form a coplanar distributed resonator, which is placed in proximity to the main patch as depicted in Fig. 1. The coupling gap plays a key role in achieving a wideband performance. Its width affects the dual resonant

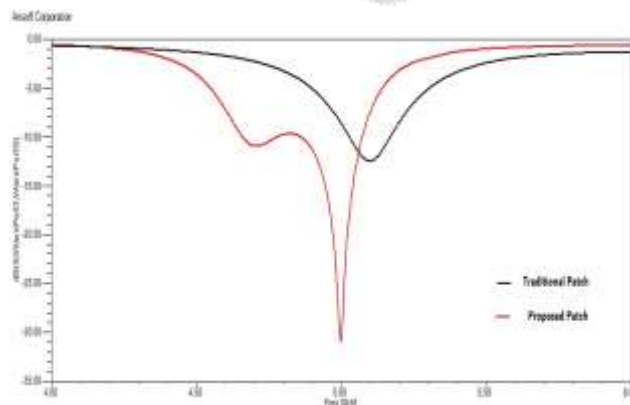
frequencies significantly. Therefore, the gap width can be optimized to make the two resonant frequencies close to each other, thus combining two narrower bands into a single wide band.

In addition to bandwidth enhancement, the proposed feeding method can effectively suppress the spurious radiation caused by harmonic resonant modes of the patch radiator. It can be intuitively explained in the following two aspects. On the one hand, the patch antenna is capacitively fed through a pair of  $\lambda/4$  resonators. In this case, the energy can only be transmitted to the patch in discrete frequencies where both the patch and  $\lambda/4$  resonators are resonating, which is completely different from the traditional insert-fed patch antenna.

**Fig-2.2:** Traditional Patch Antenna



**Fig-2.2.3:** Proposed Patch antenna

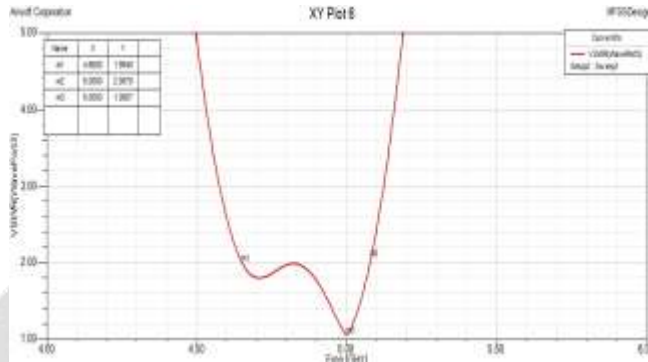


**Fig-2.2.4:** Return loss of Tradition Vs Proposed patch antenna

Fig.2.2.4 we can see that proposed patch antenna show that its bandwidth 420MHz is 3 times wider than that of the traditional insert-fed patch antenna.

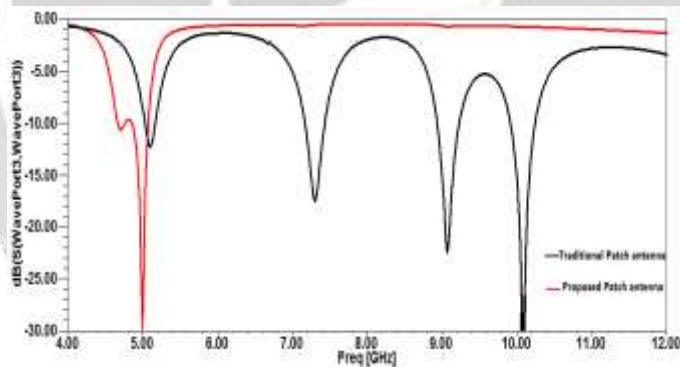
**3. SIMULATION RESULTS**

Simulation of this antenna has been carried out in HFSS. The simulation results are given in the following section:



**Fig-3.1:** VSWR

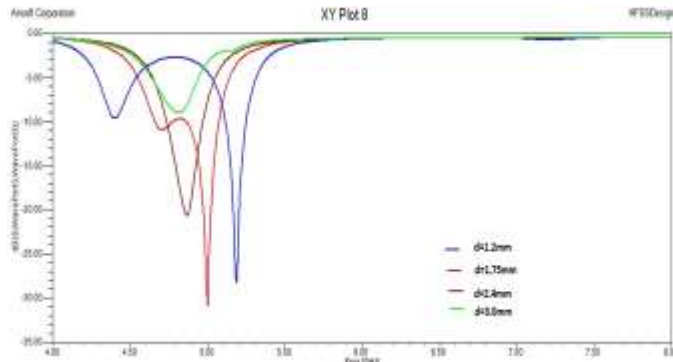
From the Fig.3.1 we can be seen that the VSWR lies below the value 2 from 4.65 GHz to 5.08 GHz frequency band.



**Fig-3.2:** Simulated reflection coefficients of the proposed and traditional patch antennas in a wide frequency range

As shown in figure: 3.2 the value of Return loss is -29.85dB at 5.0GHz. The proposed antenna exhibits a wide impedance bandwidth about 420MHz and there is harmonic reduction through entire band from 4 to 12GHz.

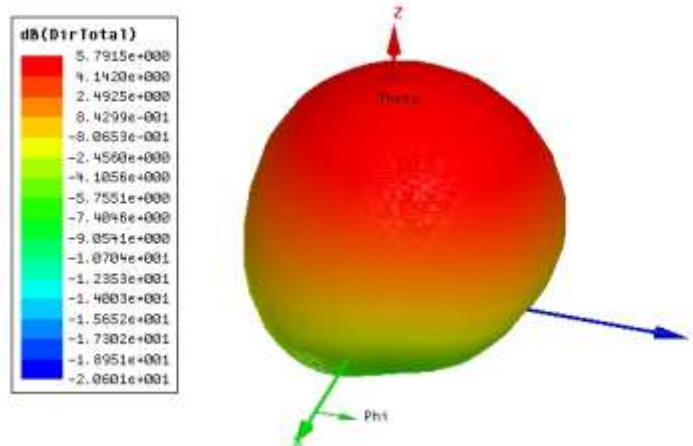
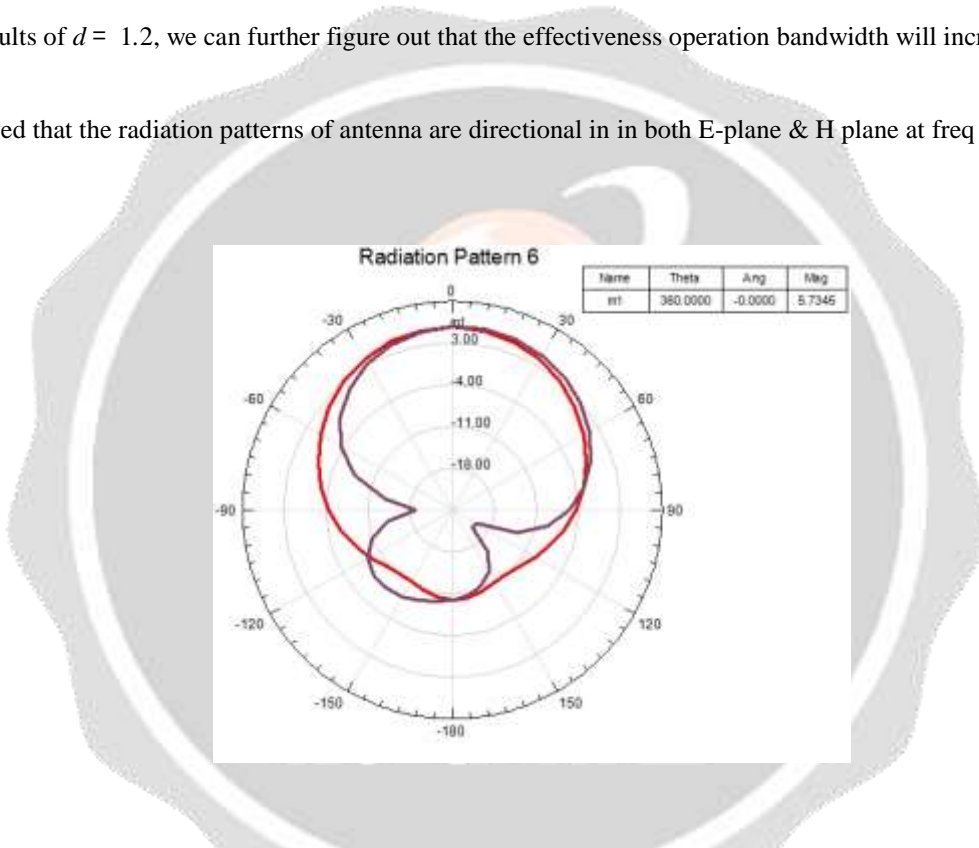
In addition to bandwidth enhancement as described above, the undesired harmonic radiation at high frequencies can be effectively suppressed by the proposed technique. Fig. 3.3 displays the simulated reflection coefficients in a wide frequency range under four different *d* values. For comparison, the result of a traditional insert-fed patch operating at 5.0GHz is also plotted in the figure 3.2.



**Fig-3.3** Influence of coupling gap  $d$  on the reflection coefficient

Comparing the results of  $d = 1.2$ , we can further figure out that the effectiveness operation bandwidth will increased.

Fig.3.2 it is observed that the radiation patterns of antenna are directional in in both E-plane & H plane at freq 5GHZ.



**Fig-3.4:** 3D Gain

The simulated gain of the antenna at 5.0 GHz is presented in Figure 3.4. The maximum gain is 5.8 dBi at 5.0 GHz.

#### 4. COMPARISON TABLE

To improve the performance of this antenna, a pair of  $\lambda/4$  microstripline resonators is introduced. As seen from the table, Traditional patch antenna, and proposed patch antenna are described. It concludes that proposed patch antenna technique's both bandwidth & gain of antenna are improved.

Sr. No.	Results	Freq (GHz)	Return loss (dB)	VSWR	BW (MHz)	Gain (dB)
1.	Traditional Patch Antenna	5.0	-12.39	1.62	140	5.7
2.	<b>Proposed Patch Antenna</b>	<b>5.0</b>	<b>-30.90</b>	<b>1.34</b>	<b>420</b>	<b>5.8</b>

**Table-4:** Comparison table

#### 5. CONCLUSION

This paper presents a new compact coupled-fed patch antenna in a single-layer substrate. By using a pair of  $\lambda/4$  resonators, the bandwidth of the patch antenna is significantly enlarged and the harmonic radiations are effectively suppressed, while other advantages of the patch antenna, such as low cost, low profile, and easy integration, still remain.

In the analysis, an equivalent circuit model is proposed to analyze and design this proposed antenna. Our investigation shows that the bandwidth of this patch can be widened by adjusting the gap between the patch and the  $\lambda/4$  resonator. To validate the design method, a prototype antenna operating at WLAN band 5.0 GHz is designed. Its good performance is demonstrated by comparison with a traditional insert-fed patch antenna. The simulated results show that the bandwidth has been enlarged by 3 times and the higher mode radiations have been successfully suppressed. In addition, more symmetric radiation patterns and gains have been obtained.

#### 5. REFERENCES

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