Miss.Prajakta Asabe Journal of Engineering Research and Application www.ijera.com
ISSN : 2248-9622, Vol. 8, Issue 8 (Part -I) Aug 2018, pp 08-12

RESEARCH ARTICLE OPEN ACCESS

Design And Analysis of A Compact Slotted Patch antenna with Enhanced Bandwidth and Harmonic Suppression for WLAN Applications

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ABSTRACT

A single-layer a compact microstrip-fed Slotted patch antenna with capabilities of both bandwidth enhancement and harmonic suppression is proposed. For this purpose, a pair of λ/4 microstripline resonators is introduced and coupled in proximity to a cross slits rectangular patch. The Size reduction is obtained by using plus slits introduced in middle of rectangular patch and the wideband property can be obtained by making effective use of the two resonances introduced by the radiating patch and nonradiating λ/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 λ/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 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 470MHz is 3.5 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. The measurement results are in close agreement with the simulation results.

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

Date of Submission: 28-07-2018 Date of acceptance: 13-08-2018

I. 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 (λ/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 λ/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 λ/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 λ/4 resonators.

2) Harmonic radiation at high frequency is effectively suppressed thanks to the characteristics of capacitive feeding structure and λ/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.

II. GEOMETRY AND WORKING PRINCIPLE

The antenna has been design on FR4 material with height of 1.6mm.dimension of L& W is calculated by below equations.

A.Geometry

Step 1: Calculation of Lambda (λ0)-
Lambda (λ)=c/f=3x10^8/5.0x10^9
(λ)=60mm at 5.0 GHz

The center frequency will be approximately given by:

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

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

Where fc=is centre freq=5.0GHz
εr=4.4 and c=3x10^8
L=13.75mm

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

For c=3*10^8 m/s2, fr=5.0GHz, εr=4.4
We get **W=18.25 mm.**
Feed width calculate by using

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

We get **Wf=2.84mm**
Step 5: Calculation of Feed length (L50)-
Feed length (L50)=lam/4*sqrt (4.4)
L50=7.5mm

Step 6: Calculation of Resonator length (Lr)-
Feed length (Lr)=λ/4
Lr=15.0mm

Step 7: Calculation of Substrate dimension-
Ls=L+2*6h=13+2*6*1.6=31mm
Ws=W+2*6h=19+2*6*1.6=37mm

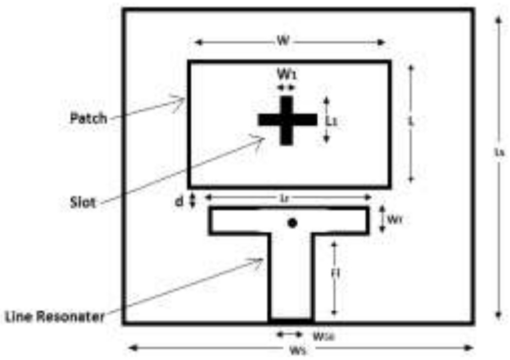


Figure 1: Geometry of the proposed wideband patch antenna

The proposed antenna is optimized by using the HFSS Software and the optimized parameters are: L = 12.0mm, W = 17mm, d=1.7mm, Wr = 1mm, Fl = 9.5mm, Lr = 15.5mm, Ls = 32mm, L1=8mm, W1=2mm, W50=3mm d=1.75mm and Ws = 38mm. Figure 1 shows the design of proposed Slotted patch patch antenna and its dimension. As shown in the Figure, the patches are fed by microstrip line resonater.

B.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.

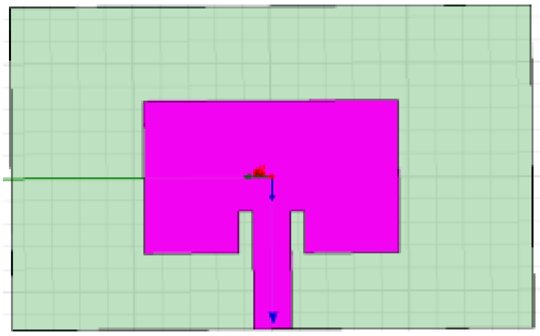


Fig 2: Traditional Patch Antenna

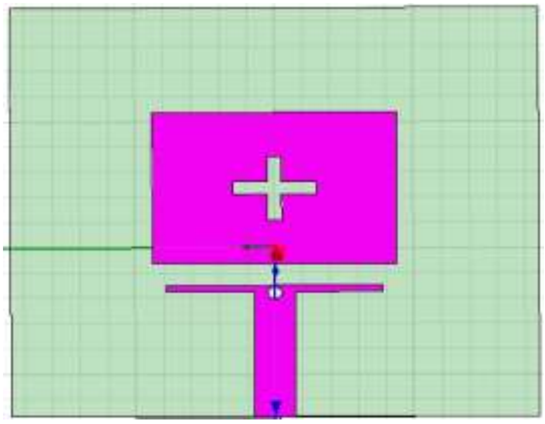


Fig 3: Proposed plus Slotted Patch antenna

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 λ/4 resonators. In this case, the energy can only be transmitted to the patch in discrete frequencies where both the patch and λ/4 resonators are resonating, which is completely different from the traditional insert-fed patch antenna.

III. SIMULATION RESULTS

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

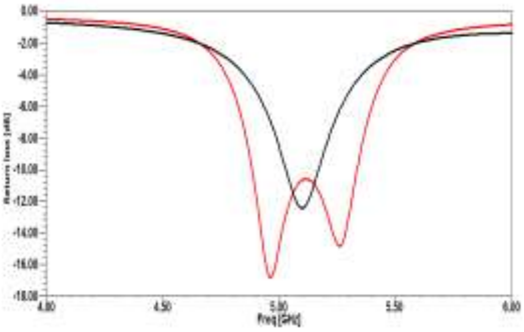
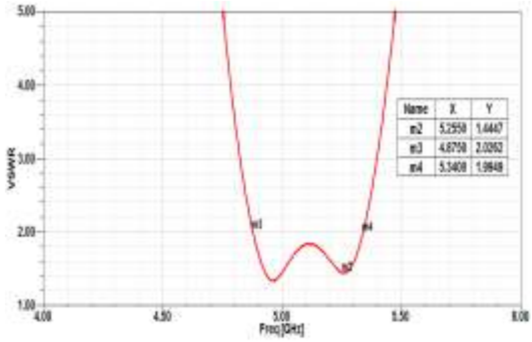


Fig 4: Return loss of Traditional Vs Proposed patch antenna

Fig.4 we can conclude that proposed slotted patch antenna show that its bandwidth 470MHz is 3.5 times wider than that of the traditional insert-fed patch antenna



Name	X	Y
m2	5.2558	1.4447
m3	4.8758	2.0062
m4	5.3408	1.9848

Fig 5: Proposed Patch VSWR

From the Fig.5 we can be seen that the VSWR lies below the value 2 from 4.87 GHz to 5.34 GHz frequency band.

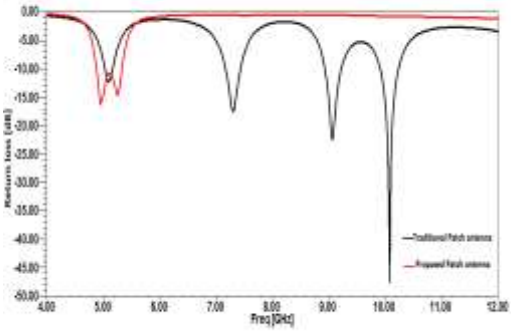


Fig 6: Simulated Return loss of the Proposed and traditional

As shown in figure: 6 the value of Return loss is -16.85dB at 5.0GHz. The proposed antenna exhibits a wide impedance bandwidth about 470MHz 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. 7 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 6.

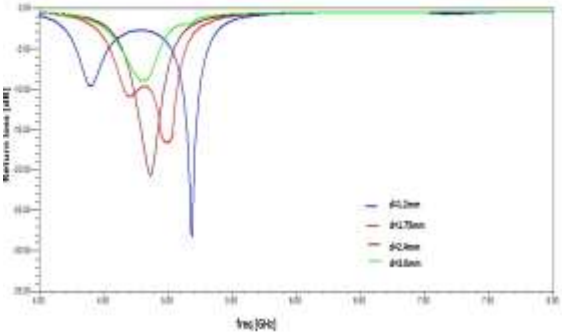


Fig7: Influence of coupling gap d on the reflection coefficient

Comparing the results of d = 1.2, 1.75, 2.4 and 3.0, we can further figure out that the effectiveness operation bandwidth will increased.

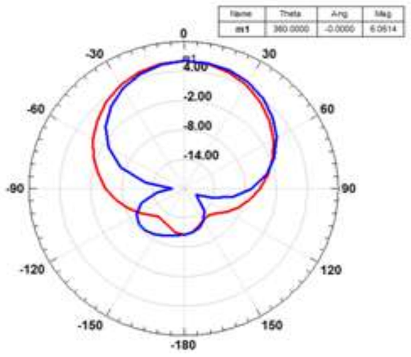


Fig 8: E and H plane radiation pattern

Fig.7 It is observed that the radiation patterns of antenna are directional in in both E-plane & H plane at freq 5GHz.

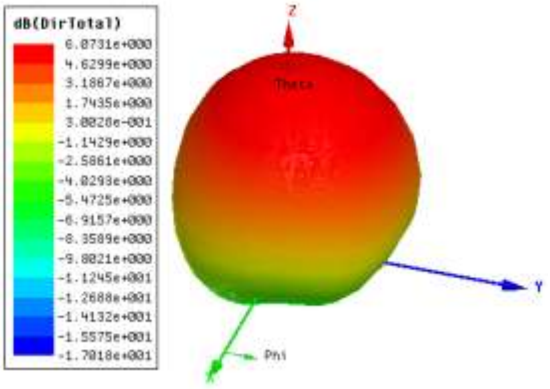


Fig 9: 3D Gain

The simulated gain of the antenna at 5.0 GHz is presented in Figure 7.The maximum gain is 6.0 dBi at 5.0 GHz.

IV. MEASUREMENT RESULTS

The Proposed plus Slotted patch antenna has been fabricated and tested. The antenna have been tested using vector network analyser Agilent technology N9916A series. The Measurement results of proposed patch antenna getting bandwidth of 500MHz (from 4.9GHz to 5.4 GHz) at VSWR 2:1. The measured and simulated return loss of proposed antenna has been shown in fig.11.

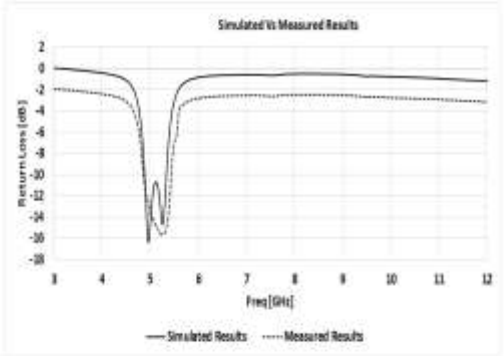


Fig 11 :Simulated Vs Measured Return loss of proposed patch antenna

Fig 12: VNA setup of proposed patch antenna

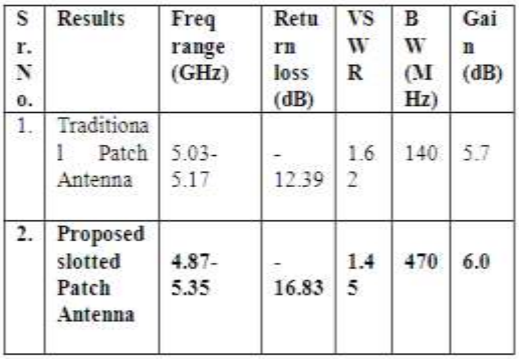
A good agreement between experimental and simulated results is observed except some slight variation. This may be due to the tolerance in manufacturing, uncertainty of the thickness and/or the dielectric constant of the substrate and lower quality of SMA connector (VSWR = 1.3), larger tan delta= 0.02 of the substrate and soldering effects of an SMA connector. Fig.12 shows fabricated proposed patch antenna.

Fig 13: Prototype Fabricated Patch antenna

V. COMPARISON TABLE

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

Table 1 Comparison table



Sr. No.	Results	Freq range (GHz)	Return loss (dB)	VSWR	BW (MHz)	Gain (dB)
1.	Traditional Patch Antenna	5.03-5.17	-12.39	1.62	140	5.7
2.	**Proposed slotted Patch Antenna**	**4.87-5.35**	**-16.83**	**1.45**	**470**	**6.0**

VI. CONCLUSION

This paper presents a new compact coupled-fed slotted patch antenna in a single-layer substrate. By using a pair of λ/4 resonators, the bandwidth of the slotted 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, and compact size.

In the analysis, a traditional vs proposed to analysis patch antenna has been done. Our investigation shows that the bandwidth of this patch can be widened by adjusting the gap between the patch and the λ/4 resonator. To validate the design method, a proposed slotted patch antenna operating at band WLAN 5.2 GHz has been 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 3.5 times and the higher mode radiations have been successfully suppressed. In addition, more symmetric radiation patterns and gains have been obtained. These properties of proposed antenna show that it could be successfully used for WLAN applications. The measurement results are in close agreement with the simulation results.

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Miss.Prajakta Asabe "Design And Analysis of A Compact Slotted Patch antenna with Enhanced Bandwidth and Harmonic Suppression for WLAN Applications "International Journal of Engineering Research and Applications (IJERA) , vol. 8, no.8, 2018, pp. 08-12