ISSN: 2229-6948(ONLINE)
DOI: 10.21917/ijct.2015.0161

DESIGN OF MULTILAYER APERTURE COUPLED STACKED MICROSTRIP PATCH ANTENNA FOR WLAN APPLICATIONS

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Abstract

One of the major drawbacks of microstrip patch antenna is its narrow bandwidth. The solution of this problem is to use aperture coupled stacked micro strip patch antenna. The antenna uses a combination of aperture coupled feeding technique and multi- layer radiating patch in order for the radiating elements are increase the gain bandwidth. The 'I' and 'H' shaped aperture slots are etched onto the ground plane. It is used to transfer the energy from feed line to stacked patch. A variation of the feed line length controls the selected aperture slots to be active. The waves from the selected activated aperture slots will radiate to particular radiating patch and achieve the desired resonant frequency. The air gap is used to avoid coupling loss between the aperture slots and stacked patches. The observed simulated and measured results show that the proposed antenna structure resonated at 2.51 GHz frequency with reduced return loss and optimum voltage standing wave ratio.

Keywords:

Gain, Radiation Pattern, Return Loss, Microstrip Patch, Air Gap.

1. INTRODUCTION

Microstrip antenna is a low profile and light weight antenna[1-5]. It is characterized by its length, width, input impedance gain and radiation pattern. A micro strip patch antenna (MPA) consists of a conducting patch of any planar or non-planar geometry on one side of a dielectric substrate with a ground plane on other side. The rectangular, circular, triangular and square patches are the basic and most commonly used micro strip antennas. The microstrip antenna consists of conducting patch on the ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970 [5-6]. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations. Various mathematical models were developed for this antenna and its applications were extended to many other fields. Feed line is used to excite to radiate by direct or indirect contact. There are many different techniques of feeding and four most popular techniques as, Microstrip feed is simple to match by controlling the inset position and low fabrication cost. Coaxial feed has high loss and narrow bandwidth of impedance matching. The fabrication of microstrip antenna is easy using etching and photolithography technology. The radiation patterns of such a feed systems are hemispherical with a moderate directivity of about 6dB to 8dB. However, as the substrate thickness increases, surface waves and spurious feed radiation increase [9-10]. In proximity coupled feed different substrates are used. So the fabrication complexity increased.

This paper focuses the aperture coupled multilayer stacked microstrip patch antenna. This proposed structure avoids the connection between the radiating patch and feed line. The two structures are electromagnetically coupled through an electrically narrow slot in the ground plane between them. This slot is also called aperture. This slot will not resonate within the operating frequency band of the antenna because this would produce radiation towards the back of the antenna. The radiator is shielded from the feed structure due to the ground plane. Nevertheless there is small spurious radiation caused by the feed line and coupled through the slot. Another important advantage of this structure is the freedom of selecting two different substrates. In the contradictory requirements on the patch and feeding substrates are stated. Now, the substrate for the feed line and the substrate for the radiating patch can be optimized simultaneously. The selection of a thick low permittivity substrate is strictly necessary to obtain a broadband micro strip antenna. In general all slots radiate in same phase but there is a reversal of polarity of the field inside the guide [15-20].

2. STRUCTURE AND DESIGN

The proposed configuration uses aperture and stacked patch as radiating element. This proposed antenna consists of three substrate layer that use FR4 substrate layer that have a dielectric constant of 4.6, thickness 1.6 mm and tangent loss of 0.0009.In order to increase the gain of antenna, an air gap of 3mm thickness and dielectric constant 1 is added between the feed line substrate (layer3) and substrate (layer2). All the substrates are 104mm*104mm. Fig.1 shows the general structure of aperture coupled microstrip patch antenna. The aperture coupled feed line configuration is shown in Fig.2. Fig.3 shows the design flow of proposed aperture coupled antenna design, which shows that the priority of layer design.

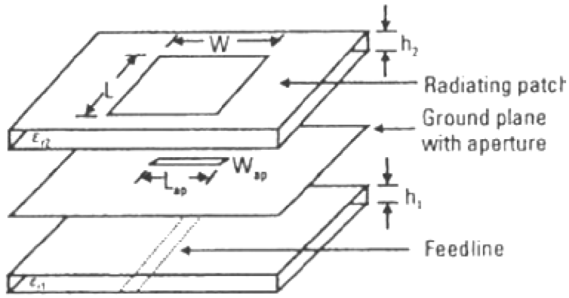


Fig.1. Structure of aperture coupled stacked microstrip patch antenna

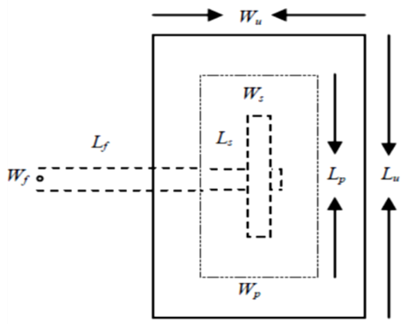


Fig.2. Structure of aperture coupled feed line

The design parameters of microstrip patch antenna can be calculated using the Eq.(1) to Eq.(5). The designed values of proposes aperture coupled microstrip patch antenna can be tabulated in the Table.1, The designed antenna structure has been simulated and optimized using CST microwave studio software which is shown in Fig.4. A rectangle shape with I-shape slot at center is etched on top of substrate 1 while I-shaped patch (bottom patch) is etched on top of substrate 2. The top rectangular dimensions of patch are designed on 2.5 GHz. The feed-line is etched on the bottom of substrate 3. In this design aperture coupler technique is used to separate the feed-line and the radiating lagers on different substrate layer, hence reduces the radiation patterns between them. Two sets of aperture slots with different sizes and shapes (H shape and I shape) are etched onto the ground plane. The H shaped aperture slot on the ground plane is positioned at the aperture with reference to the top patch while the I-shaped aperture slot is positioned at the center with reference to the bottom patch.

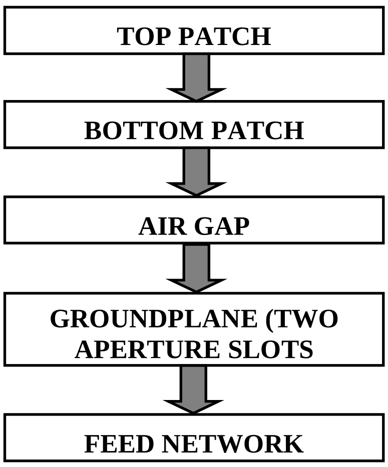


Fig.3. Block diagram of design flow

The function of H shape aperture slot is used to activate the top patch while I shaped aperture slot is to radiate the waves and to activate the top patch. Based on the simplified formulation that has been described, a design procedure is outlined which leads to practical designs of microstrip antennas. The procedure assumes that the specified information includes the dielectric constant of the substrate (ε_r), resonant frequency (f_r), and the height of the substrate, h. The procedure is as follows for an efficient radiator,

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

where,

c is the velocity of light(c=3*10^8 m/s),

ε_r is the dielectric constant of the substrate (ε_r = 4.6 in this case),

f_r is the resonant frequency .

Effective Dielectric constant of the microstrip is determined as,

$$\varepsilon_{reff} = \frac{(\varepsilon_r + 1)}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{2}$$

where,

ε_r is the dielectric constant of the substrate

h is the height of the substrate,

W is the width of the substrate.

Once width is found, the extension of the length (ΔL)is determined as,

$$\Delta L = \frac{0.412 * h\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{3}$$

where,

ε_{reff} is the effective dielectric constant.

Actual Length of the patch can now be determined as,

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} \tag{4}$$

$$L = L_{eff} - 2\Delta L \tag{5}$$

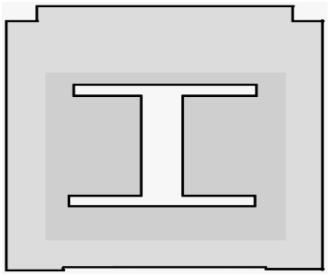
where,

L_{eff} is the effective length

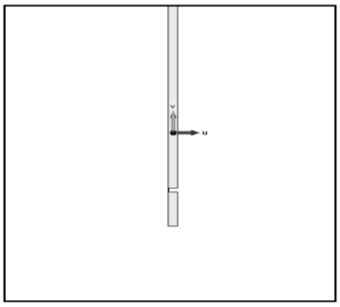
ΔL is the extension of length.

Table.1 Dimensions of proposed aperture coupled microstrip stacked patch antenna.

Parameter description	Values	
	Length (mm)	Width (mm)
Top patch_substrate	104	104
Bottom patch_substrate	104	104
Ground plane_substrate	104	104
I patch	58	43
Feed line	89	3.2
H slot	63	5.4
I slot	34	2



(a)



(b)

Fig.4. Structure of proposed (a) top and (b) bottom patch of proposed antenna

3. SIMULATION RESULTS AND DISCUSSION

The Fig.5 to Fig.7 show the simulated return loss, voltage standing wave ratio and directivity plot of proposed aperture coupled microstrip patch antenna during simulation. The simulated results show that the return loss value is greater than ten in the below zero dB scale (negative),directivity above five and voltage standing wave ratio within two judge the performance of proposed design is excellent. Fig.8 to Fig.17 show the power flow, electric and magnetic energy distribution of the proposed antenna structure during simulation. The Fig.18 to Fig.20 show the three dimensional and polar radiation plot of proposed aperture coupled stacked patch, which shows that the radiation is broadside with good gain and directivity. The observed parameters are tabulated in Table.1.

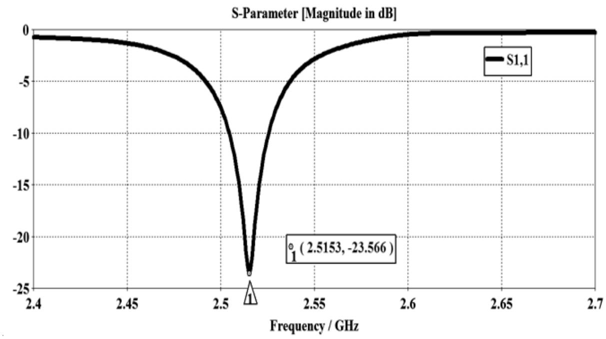


Fig.5. Return loss (S_{11}) plot of proposed aperture coupled microstrip patch antenna during simulation

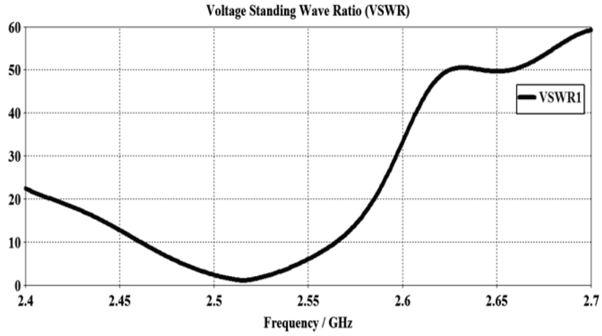


Fig.6. Voltage standing wave ratio (VSWR) plot of proposed aperture coupled microstrip patch antenna during simulation

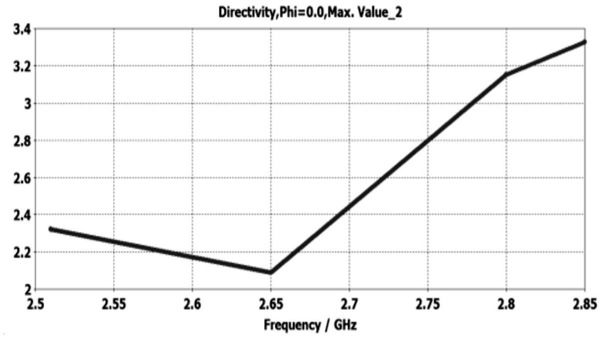


Fig.7. Directivity plot of proposed aperture coupled microstrip patch antenna during simulation

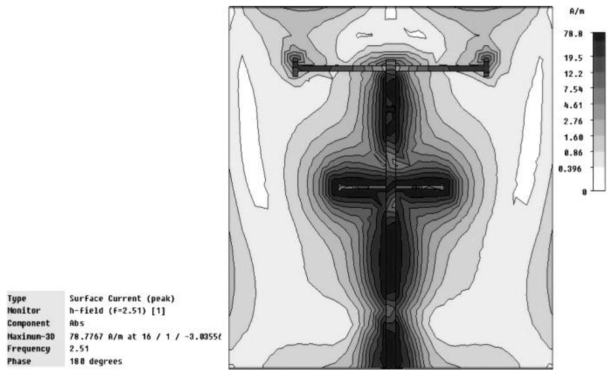


Fig.8. Surface current distribution in the proposed aperture coupled microstrip patch antenna during simulation

Fig.9. Power flow plot of proposed aperture coupled microstrip patch antenna during simulation

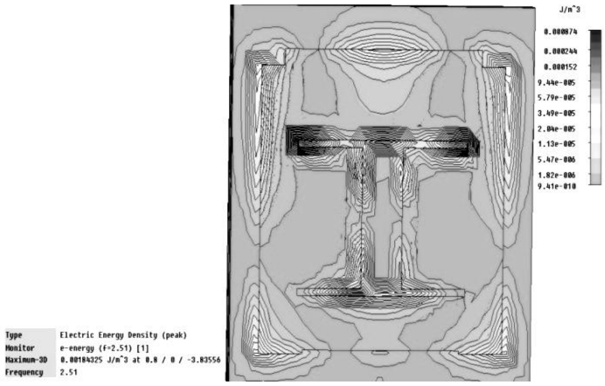


Fig.10. Electric energy distribution plot of proposed aperture coupled microstrip patch antenna during simulation

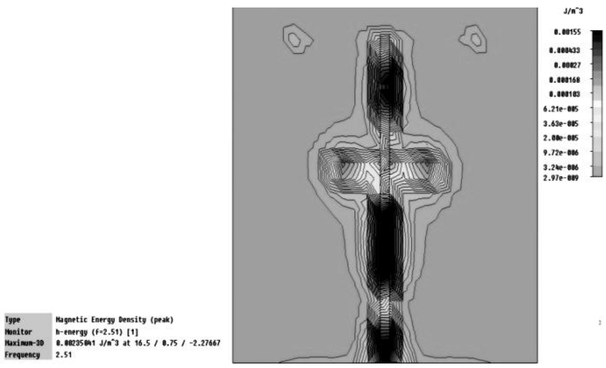


Fig.11. Magnetic energy distribution plot of proposed aperture coupled microstrip patch antenna during simulation

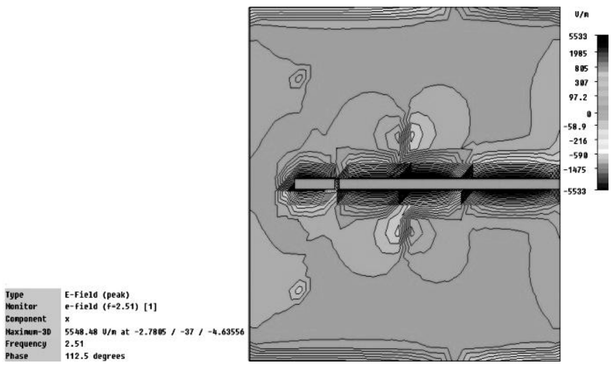


Fig.12. Electric field distribution plot of proposed aperture coupled microstrip patch antenna during simulation in x direction

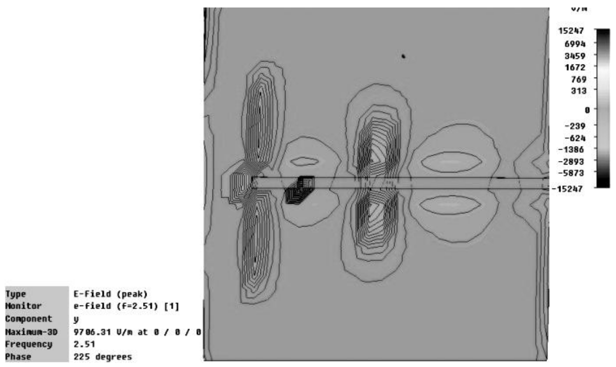


Fig.13. Electric field distribution plot of proposed aperture coupled microstrip patch antenna during simulation in y direction

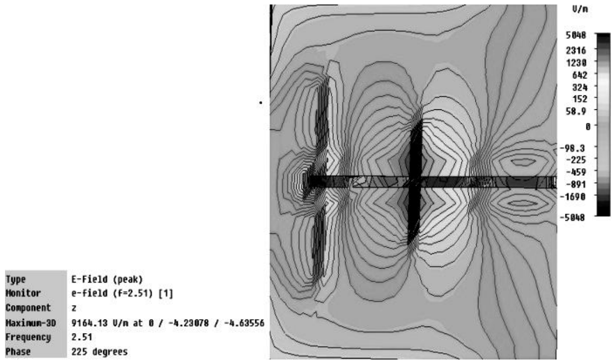


Fig.14. Electric field distribution plot of proposed aperture coupled microstrip patch antenna during simulation in z direction

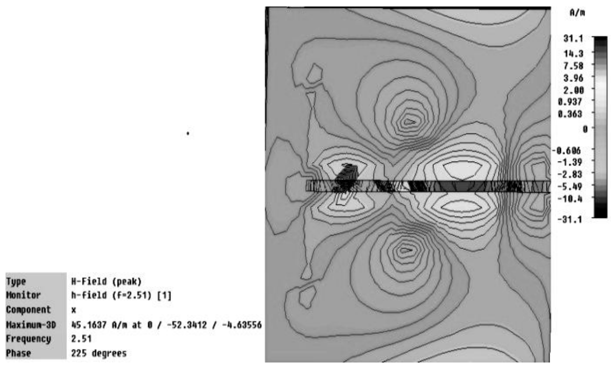


Fig.15. Magnetic field distribution plot of proposed aperture coupled microstrip patch antenna during simulation in x direction

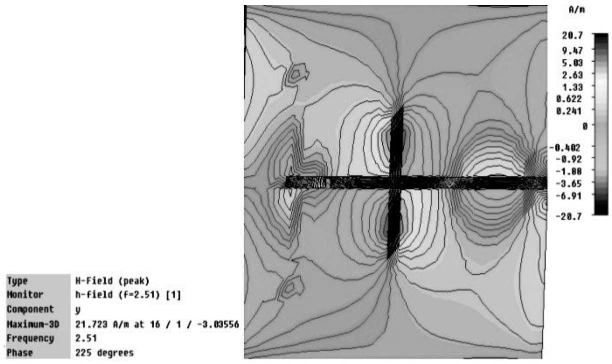


Fig.16. Magnetic field distribution plot of proposed aperture coupled microstrip patch antenna during simulation in y direction

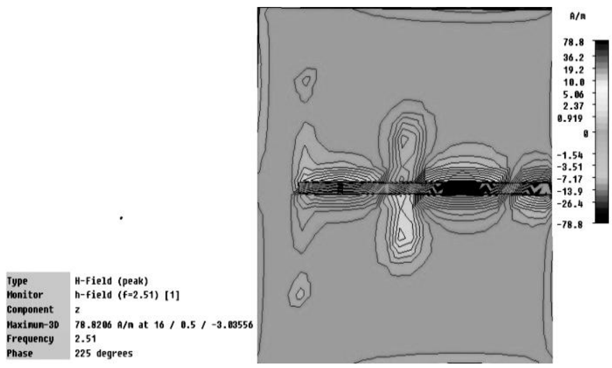


Fig.17. Magnetic field distribution plot of proposed aperture coupled microstrip patch antenna during simulation in z direction

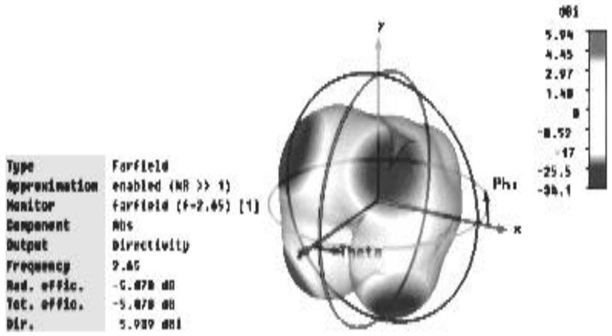


Fig.18. Three dimensional radiation (Directivity) plot of proposed aperture coupled microstrip patch antenna during simulation

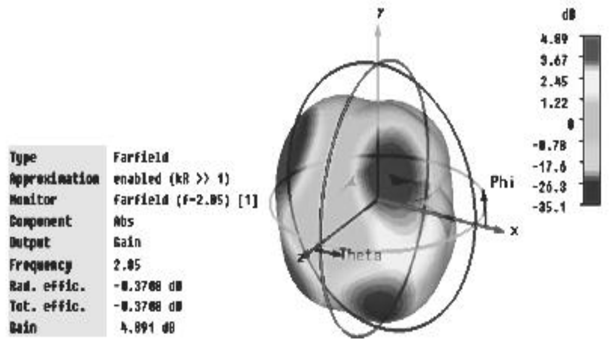


Fig.19. Three dimensional radiation (Gain) plot of proposed aperture coupled microstrip patch antenna during simulation

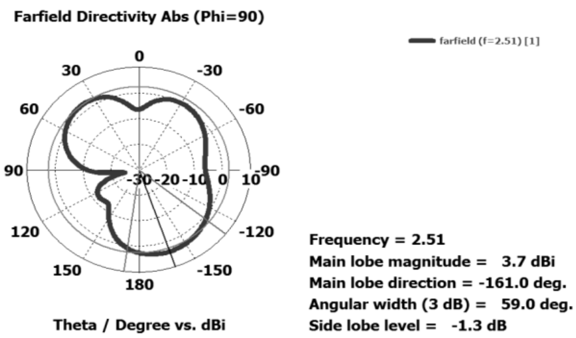


Fig.20. Polar radiation plot of proposed aperture coupled microstrip patch antenna during simulation

Table.2. Extracted parameters of proposed aperture coupled microstrip stacked patch antenna

Parameters	Frequency at 2.51 GHz
	Values
Electric energy density	0.00184325 J/m^3
Magnetic energy density	0.0023504 J/m^3
H field peak in x direction	45.1637 A/m
H field peak in y direction	21.723 A/m
H field peak in z direction	78.8206 A/m
E field peak in x direction	5548.48 V/m
E field peak in y direction	9706.31 V/m
E field peak in z direction	9164.13 V/m
Gain	4.091dB
Directivity	5.939dBi
Return loss	-23.112
Voltage standing wave ratio (VSWR)	1.1542

4. PROTOTYPE OF PROPOSED ANTENNA

The Fig.21 to Fig.26 show the prototype of the proposed aperture coupled stacked patch antenna in different views. The different layers are combined together to form an array. Fig.27 to Fig.29 show the measured return loss and voltage standing wave ratio VBA file and screen shot of the proposed aperture coupled antenna which shows the return loss result at the operating frequency is 26.8 dB (below zero dB scale) and voltage standing wave ratio is within 2. The obtained results are good. Fig.30 and Fig.31 show the simulated and measured return loss and voltage standing wave ratio plot of proposed stacked patch aperture coupled antenna for WLAN applications. The results can be compared with previous results [1-15], which show that the proposed antenna structure radiates excellent with minimum loss.

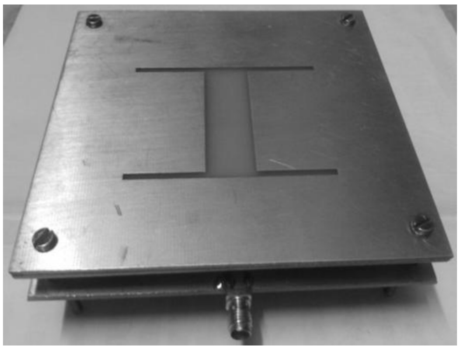


Fig.21. Prototype of proposed aperture couple stacked patch antenna (top view)

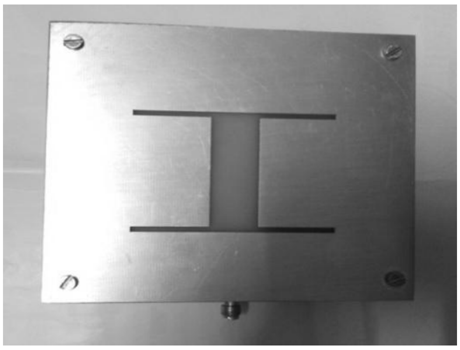


Fig.22. Prototype of proposed aperture couple stacked patch antenna (Front view)

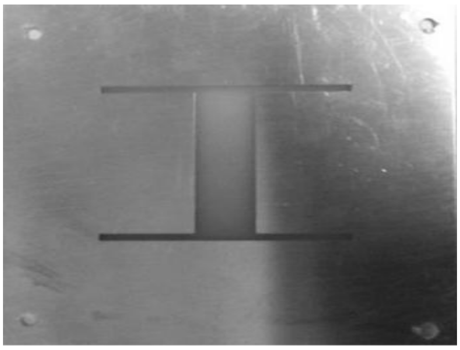


Fig.23. Prototype of proposed aperture couple stacked patch antenna (Top patch-slot)

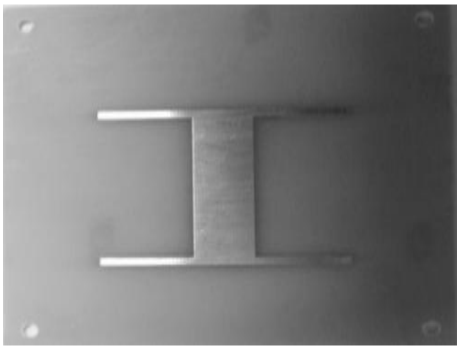


Fig.24. Prototype of proposed aperture couple stacked patch antenna (Top patch)

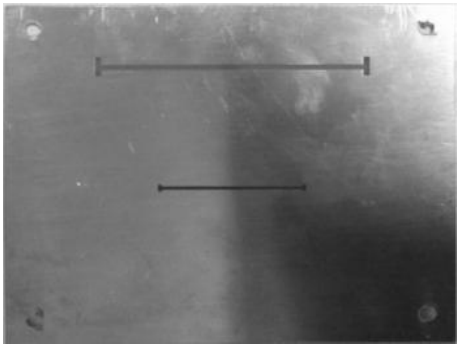


Fig.25. Prototype of proposed aperture couple stacked patch antenna (slot)

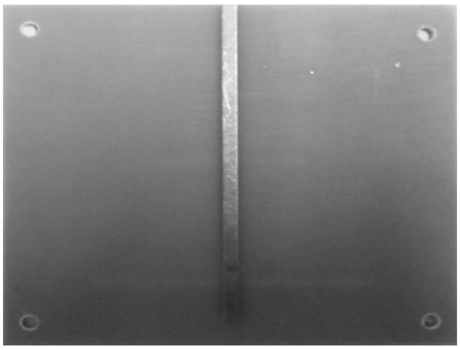


Fig.26. Prototype of proposed aperture couple stacked patch antenna (Bottom patch)

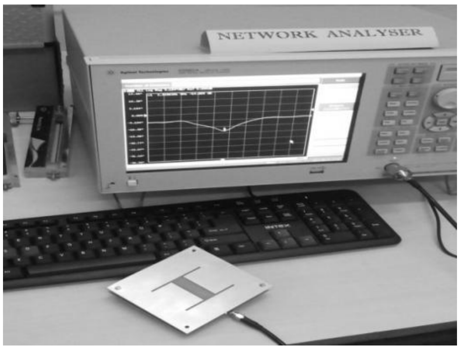


Fig.27. Measurement of return loss of proposed aperture couple stacked patch antenna using network analyser

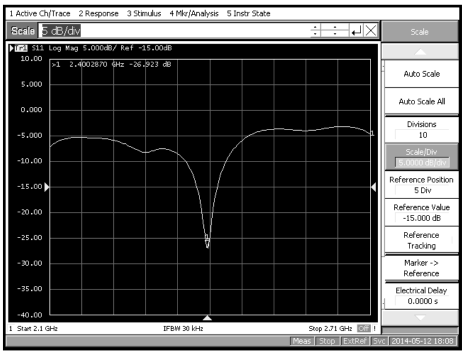


Fig.28. Return loss VBA of proposed aperture couple stacked patch antenna using network analyser

Fig.29. Voltage standing wave ratio (VSWR) VBA of proposed aperture couple stacked patch antenna using network analyser

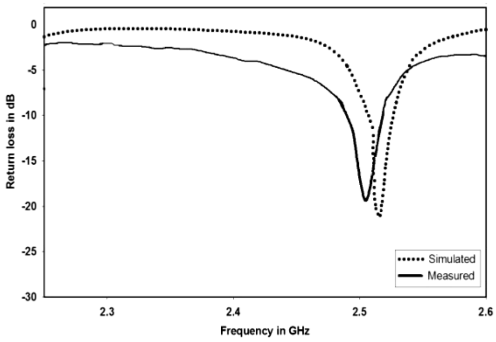


Fig.30. Comparison between simulated and measured return loss (S_{11}) plot of proposed aperture couple stacked patch antenna using network analyser

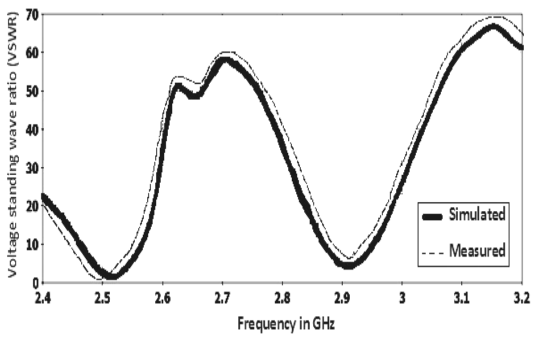


Fig.31. Comparison between simulated and measured voltage standing wave ratio (VSWR) plot of proposed aperture couple stacked patch antenna

5. CONCLUSION

This design focused the modified multi-layer aperture coupled stacked patch antenna for wireless applications such as WLAN. In future the same structure can be stacked and use active devices to make the antenna structure to support multiple frequency bands called reconfigurable antenna. The single aperture coupled stacked patch combined together to form and array to further improve the gain and bandwidth. This can be implemented in future.

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