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Design, Fabrication and Analysis of Stacked Microstrip Yagi Antenna for Wi-Fi Applications

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Abstract— This paper presents design and performance analysis of the stacked microstrip Yagi antenna.The proposed antenna design employs four substrates of FR4 material, each having a thickness of 1.62 mm and dielectric constant (ϵ_r) of 4.4. In proposed antenna design, aperture coupled feeding has been used to feed power to the antenna. In the proposed antenna design, the ground, feedline, parasitic and driven elements have been stacked together to form a stacked microstrip Yagi antenna. The design and simulation of antenna has been carried out using CST microwave studio (2014) software. The proposed Yagi antenna design has been analyzed in terms of resonant frequency. Return loss (S_{11}), VSWR, gain and percentage bandwidth. It has been observed that the stacked Yagi antenna is resonant at 5.2 GHz with an impedance bandwidth of 836 MHz covering the frequency range of 5 GHz- 5.84 GHz. The return loss (S_{11}) magnitude of -41 dB at resonant frequency of 5.2 GHz has been observed and the antenna has a gain of 10.04 dB. The antenna has directivity of 9.95 dBi and percentage bandwidth of 8.4 percent. The fabrication process of simulated antenna has been carried out. Finally, the fabricated antenna has been successfully tested for return loss (S_{11}) using network analyzer ES5071C-ENA. Both the simulation and experimental results are compared and examined. It has been observed that the proposed antenna can be used for Wi-Fi applications.

Index Terms— Aperture feeding, directivity, gain, microstrip antenna, parasitic element, return loss, Yagi antenna

1 INTRODUCTION

OVER the last 15 years, the printed microstrip Yagi antenna has been proposed in many applications [1], [2], [3], [4], [5], [6], [7]. The microstrip array antenna should have attractive features such as low profile, light weight and easy fabrication [8]. The microstrip antenna is made up of a substrate that has a conducting patch on the top and the ground plane at bottom side. The patch can be of any shape like rectangular, elliptical, circular etc. [9]. However, narrow bandwidth and low radiation efficiency are the major drawbacks of microstrip antennas [10].

In 1989, Huang proposed the first microstrip Yagi array antenna for mobile satellite (MSAT) applications that achieved a high gain and low backside radiations for various applications [1]. Yagi antenna is a directional antenna elements: driven (active) and parasitic (passive). The driven elements are directly connected to the transmission line and receive power from the source, whereas the parasitic elements are not connected to the transmission line and they receive energy only through mutual induction. The purpose of the parasitic elements is to modify the radiation pattern of the radio waves emitted by the driven element and direct them in a narrow beam in one direction. The directors and reflectors are the parasitic elements because they operate on electromagnetic energy radiated by driven elements. The parasitic elements are arranged parallel to the driven elements. The parasitic element longer than the driven element by 5% is known as a reflector and it acts as a concave mirror because it reflects the electromagnetic energy incident on it from the driven elements. The parasitic element shorter than the driven element by 5% is known as a director and it acts as a convex mirror as it beams up the incident energy from driven element [11], [12].

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2 ANTENNA GEOMETRY

Fig. 1 represents the side view of the proposed stacked microstrip Yagi antenna. As shown in fig. 1, the proposed microstrip Yagi antenna has four stacked substrates of FR4 material, each substrate has thickness, h of 1.62 mm and dielectric constant ϵ_r of 4.7. The size of each substrate is 65 x 80 mm². Fig. 1 consists of ground plane at the bottom of substrate 1 and PEC patch elements on the top of each substrate. The geometry of substrate 1, substrate 2, substrate 3 and substrate 4 are shown in fig. 2, fig. 3, fig. 4 and fig. 5 respectively.

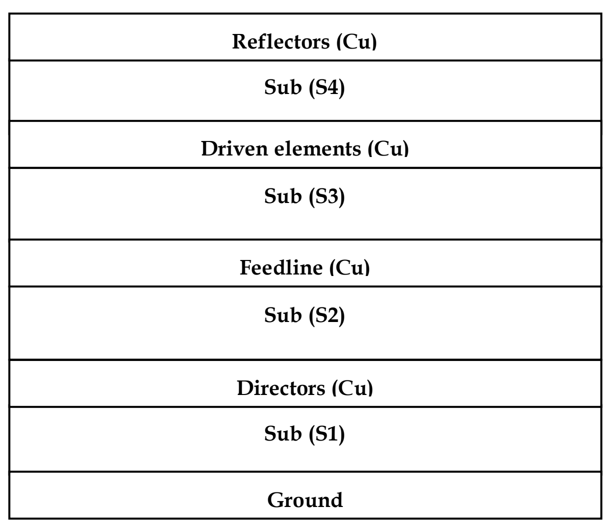

Fig. 1 Side view of stacked microstrip Yagi antenna

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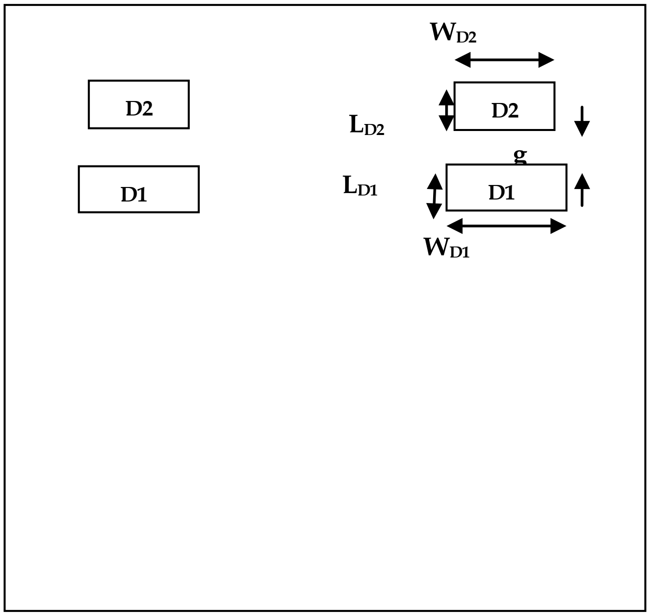

Fig.2 Geometry of Substrate 1

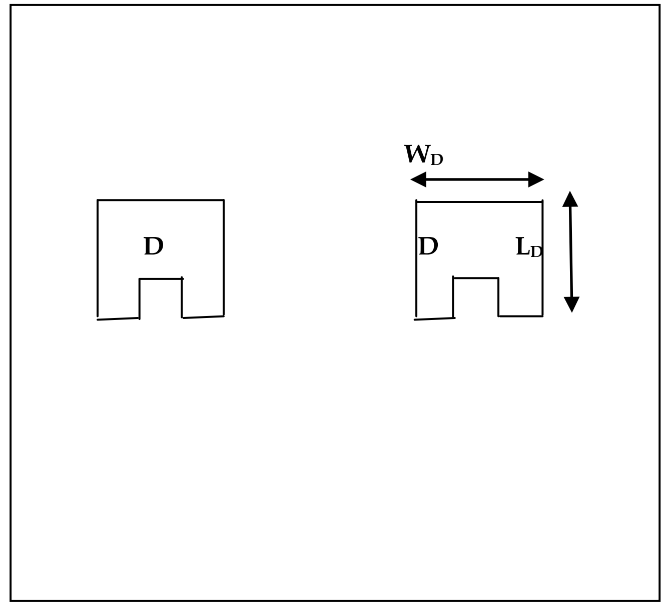

Fig.4 Geometry of Substrate 3

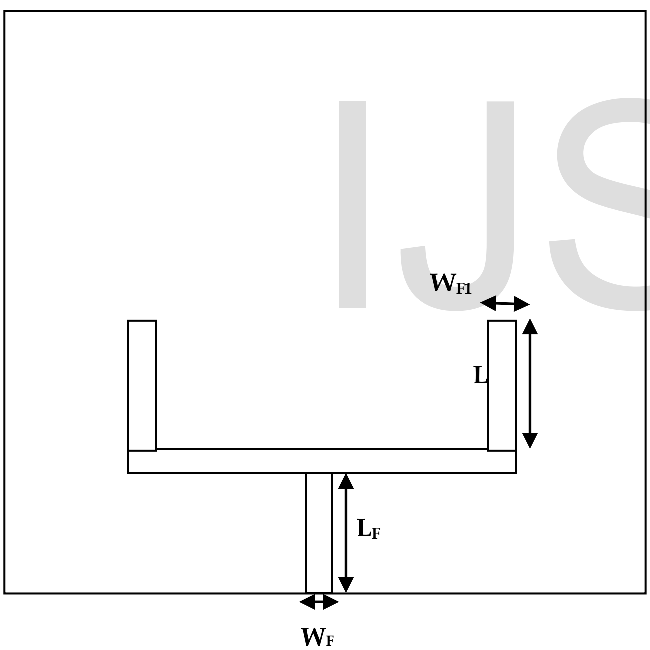

Fig.3 Geometry of substrate 2

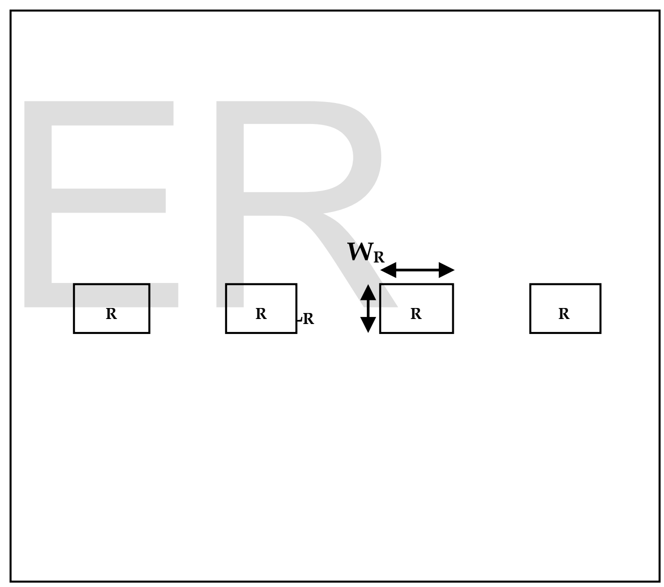

Fig.5 Geometry of substrate 4

Fig. 2 shows the geometry of substrates and illustrates directors D1 and D2 having lengths and widths of L_{D1}, L_{D2} and W_{D1}, W_{D2} respectively with g as the gap between the directors. Fig. 3 consists of feedline having lengths and widths of L_F, L_{F1} and W_F, W_{F1} respectively. The aperture feedline has been used in the Yagi stacked antenna design. The width of the feedline and spacing is adjusted to make sure that the impedance of the antenna is 50Ω so as to perfectly match with connector impedance for maximum power transfer to antenna with minimal back reflections. Fig.4 consists of driven elements having a length of L_D with width W_D. Fig.5 consists of reflectors having a length of L_R and width W_R. All the dimensions of the proposed antenna are listed in table 1.

3 Results And Discussion

The proposed microstrip Yagi antenna has been simulated using CST microwave studio. The designed antenna has been fabricated and then tested using Network Analyzer (E5071C ENA series).

Fig 6, fig 7, fig 8 and fig 9 shows the fabricated microstrip Yagi antenna designs. These antennas have been designed on FR4 substrate with dielectric constant of 4.4 and height of 1.62 mm. The parasitic elements, feedline and driven elements have been physically designed by fabricating on a printed circuit board (PCB) and are tested using E5071C ENA series network analyzer.

TABLE 1

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Dimensions of proposed Yagi Antenna

Parameters	Dimension (mm)
W_D	15.30
W_{D1}	14.54
W_{D2}	13.81
W_R	8.03
W_F	5.6
W_{F1}	3
L_D	11.37
L_{D1}	3.63
L_{D2}	3.45
L_R	4.02
L_F	12.80
L_{F1}	18.10
G	2.56

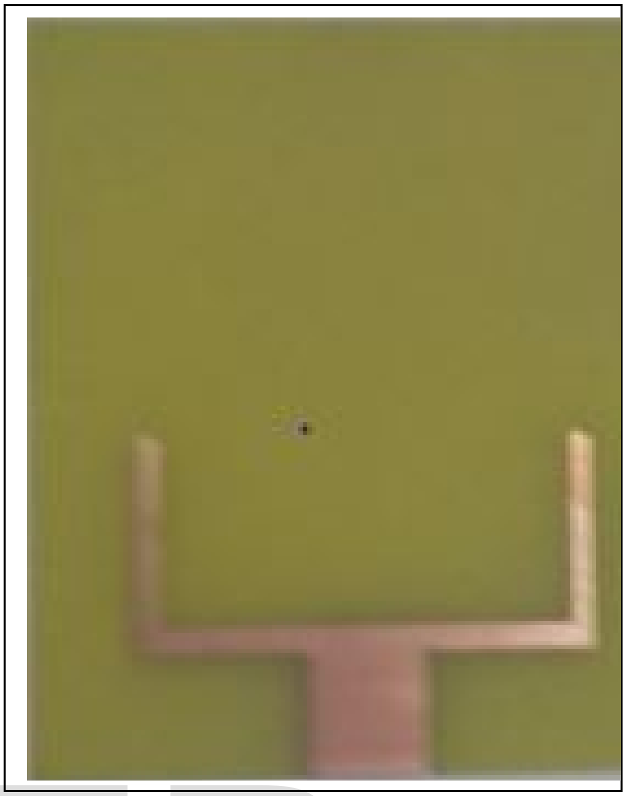

Fig.7 Feedline etched substrate 2

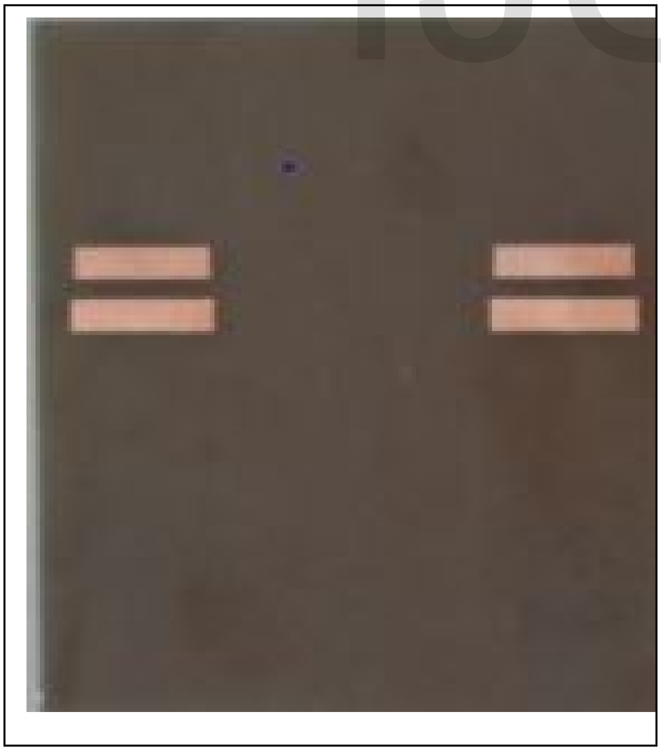

Fig.6 Directors etched substrate 1

Fig.8 Driven elements etched substrate 3

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Fig.9 Reflectors etched substrate

TABLE 2
Tabulated results of simulated return loss, VSWR, gain and bandwidth

PARAMETER	TWO BRANCHES ANTENNA	PROPOSED ANTENNA
RESONANT FREQUENCY	5.52	5.2
RETURN LOSS (S_{11})	-20.38	-40.96
VSWR	1.21	1.01
GAIN (dB)	9.50	10.04
BANDWIDTH (%)	2.00	8.4

TABLE 2 shows the comparison between the two branch microstrip Yagi antenna and the proposed stacked microstrip Yagi antenna. As shown in comparison TABLE 2, it can be calculated that the return loss of 40.96 dB and antenna gain of 10.04 dB of stacked microstrip Yagi antenna is much better compared to the two branch microstrip Yagi antenna, the stacked microstrip Yagi antenna has lead to the gain increased by 0.54 dB and return loss (S_{11}) is improved by -20.58 dB. The simulated results of the proposed clearly illustrates that the percentage bandwidth is 8.4%, which is increased by 6.4% from the two branch microstrip Yagi antenna which has the return loss of -20.38 dB at 5.52 GHz.

Fig. 10 represents the simulated return loss (S_{11}) plot of the stacked microstrip Yagi antenna. The antenna is resonant at a frequency of 5.2 GHz. It has been analyzed that the return loss of the proposed design is 40.96 dB at 5.2 GHz.

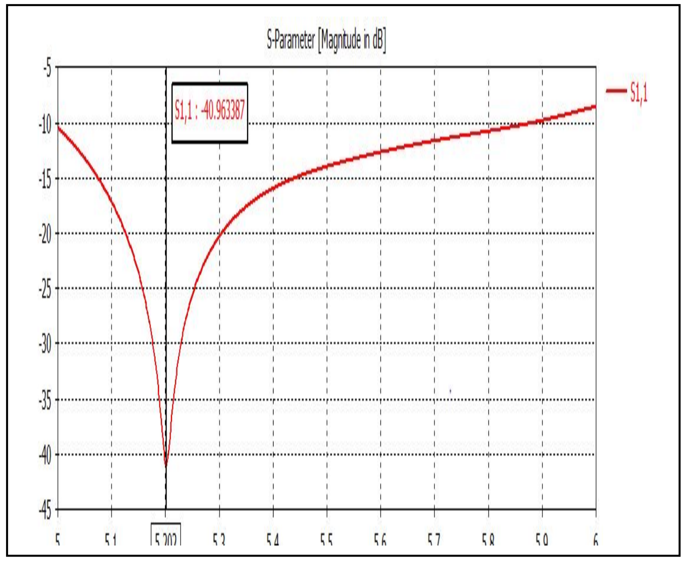

Fig.10 Return loss (S_{11}) plot of proposed antenna

Fig.11 shows the bandwidth results of the stacked microstrip Yagi antenna. The percentage bandwidth of the stacked microstrip Yagi antenna is 8.4%.

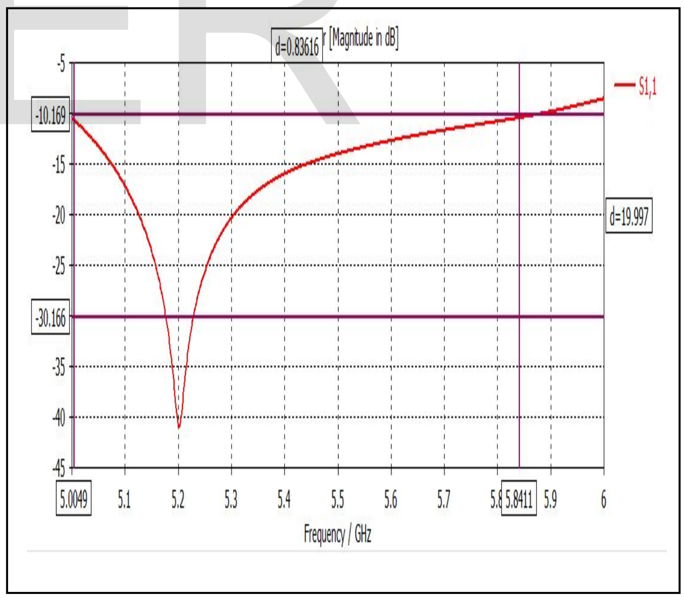

Fig.11 Simulated Return loss plot showing antenna Bandwidth

The simulated far field radiation pattern in Fig.12 and Fig.13 indicate the gain of proposed stacked mirostrip Yagi antenna in 3-D pattern and 2-D space. The half power beamwidth (HPBW) of proposed stacked microstrip Yagi antenna is 35.5 degrees.

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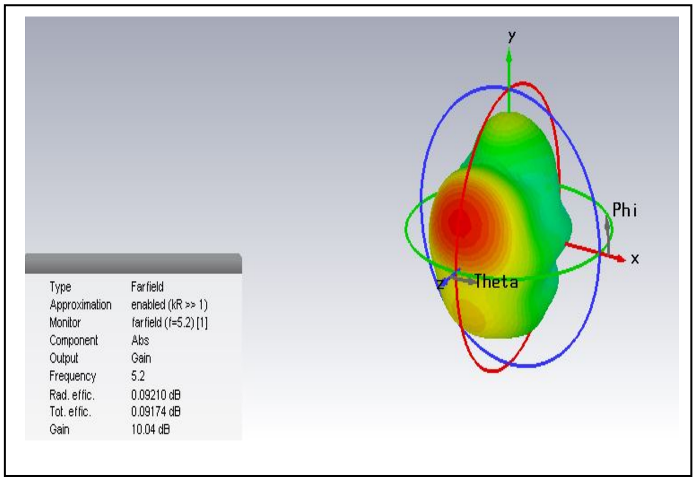

Fig.12 Simulated 3-D plot of radiation Pattern of proposed antenna at 5.2 GHz

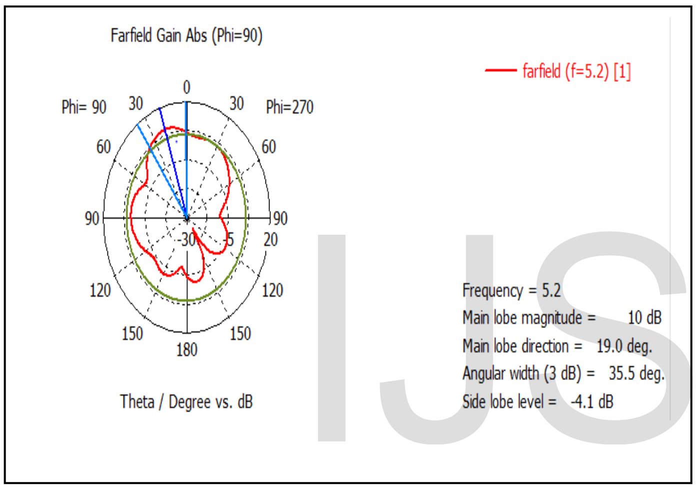

Fig.13 Simulated 2-D plot of radiation pattern of proposed antenna at 5.2 GHz

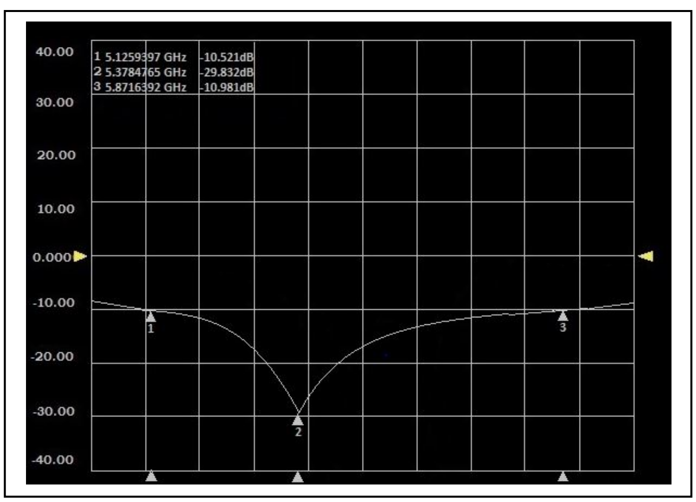

Fig.13 Practical measured return loss (S_{11}) plot of proposed antenna

As shown in fig-13 it can be observed that the practical return loss plot of the stacked microstrip Yagi antenna approximately matches the simulated results It can be observed that the antenna has return loss of -29.83 dB at 5.3 GHz due to reflection losses and spurious feed point radiations and inaccuracies in an antenna fabrication process and during soldering. However, it can be concluded that the antenna covers the 5 GHz frequency band suitable for a Wi-Fi frequency range of 5.15-5.875 GHz.

TABLE 3
Tabular comparison of Simulated Return loss with Practical Return loss results

Antenna	Simulated Results		Practical Results	
Stacked Microstrip Yagi Antenna	Frequency	Return Loss	Frequency	Return Loss
	5.2	-40.96	5.3	-29.83

4 Conclusion

The stacked microstrip Yagi antenna design has been proposed and the antenna performance has been analyzed in terms of return loss, bandwidth, resonant frequency, VSWR, gain. It has been observed that the better resonant frequency, return loss, gain, VSWR and bandwidth can be achieved by fabricating all the driven and parasitic elements on FR4 substrates by using simple fabrication technique and the problem of the low bandwidth of the microstrip Yagi antenna can be overcome by using stacking technique and parasitic elements. The return loss has been improved by employing aperture coupling as feeding technique in the proposed Yagi antenna design. The proposed aperture coupled stacked microstrip Yagi antenna design can be suitably employed for Wi-Fi applications.

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