

# Design of a Probe-fed Wideband Circular Patch Antenna with Suspended Microstrip Configuration for WLAN Applications

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**Abstract** In this paper, a new probe-fed wideband antenna with a circular patch and a coupled stacked ring is proposed. This antenna can be implemented by using suspended microstrip technique with total thickness of about 0.09 of center frequency wavelength. By using a novel feeding technique, in this antenna about 40 % reduction in area compared to similar works can be achieved. The obtained bandwidth in this antenna according to simulation results satisfying  $VSWR < 2$  is about 27.5 % from 5 to 6.6 GHz using two resonant frequencies. Also a comprehensive theoretical and parametric study is done in order to facilitate its designing in various frequency bands.

**Keywords** antennas, wideband antennas, probe-fed antennas, circular patch.

## Introduction

Microstrip patch antennas offer some well-known advantages such as thin profile, light weight, low cost, and compatibility with integrated circuitry. In the category of patch antennas, circular types of them are widely used in wireless communications because of their omnidirectional radiation pattern. In design of these types of antennas, achieving good mechanical characteristics such as low thickness and area, beside wide bandwidth, are some well-known design goals for designers. In some papers several techniques adopting air substrate in circular patch antennas have been proposed to achieve a very wide bandwidth [1-9]. However the antenna thicknesses in these works are larger than  $0.1\lambda_0$  (where  $\lambda_0$  is the wavelength in free space). There are other antenna designs with low thickness [10, 11], and designed by adopting a center-fed circular patch and a coupled annular ring, and some of them exhibits high bandwidth of about 27.4 % [11]. In the antenna presented in [11], the total area based on the outer radius of its all patches is large and about  $1.2\lambda_0^2$ . In this paper, we present a reduced size circular patch antenna with bandwidth similar to [11], and considerable reduction in total area and acceptable thickness of about  $0.09\lambda_0$ . In the antenna presented in this paper a coupled annular stacked ring is used above a circular patch. The underlying circular patch is fed by a rectangular strip together with a probe that cause in reduction in area of the antenna. In order to facilitate its designing in various frequencies, a comprehensive theoretical and parametric study is also done.

## Antenna Geometry

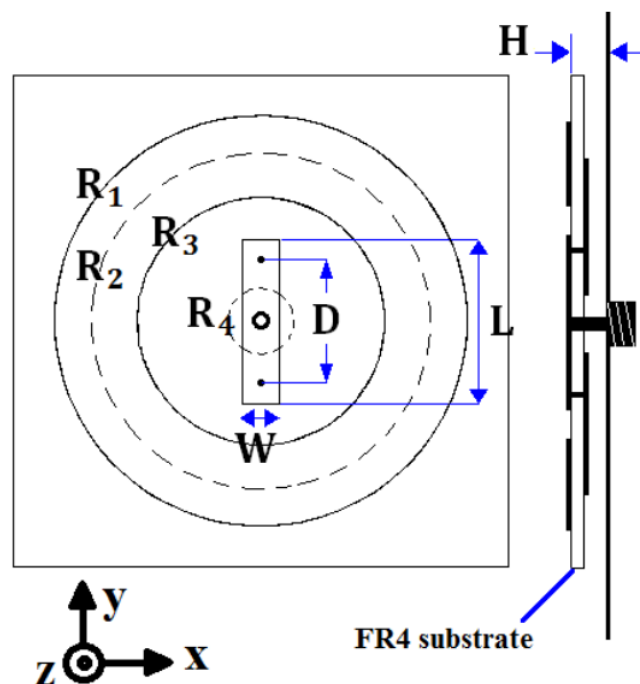
Structure of the proposed antenna has been shown in Fig. 1. A two-layer PCB, with different patches at its top and bottom

sides is fabricated using FR4 substrate. Then, it is placed above a complete ground plane with an appropriate distance and fed using a coaxial probe. The effective permittivity of the total substrate is less than that of a complete FR4 substrate. This configuration that is called “suspended microstrip configuration” makes fabrication process of the antenna easy. A set of possible design parameters of this antenna is given in Table 1.

Also two via holes with diameter of 30 mil in the FR4 board near the feed point are created that should be metalized in fabrication process. Thickness of the FR4 substrate is 1.6mm and its  $\epsilon_r$  is 4.4. Diameter of the feeding probe is 1.27mm. The total thickness is 4.5mm that is less than  $0.09\lambda_0$  (where  $\lambda_0$  is the wavelength at 5.8 GHz in free space).

**Table 1** A set of design values for parameters of the proposed antenna in millimeters.

Parameter	$R_1$	$R_2$	$R_3$	$R_4$	D	W	L	H
Value	25	19.5	14.5	2.5	15	4.45	20	4.5



**Fig. 1** Structure of the proposed antenna and definition of its parameters, values  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  show radiuses of the circles in the geometry of the antenna.

## Simulation Results

This antenna has been simulated by using Ansoft® High Frequency Structure Simulator (HFSS), and VSWR plot of its input port has been shown in Fig. 3 by a solid curve. According to the simulated VSWR plot, this antenna has 27.5 % bandwidth from 5 to 6.6 GHz with  $VSWR < 2$ , which is similar to the antenna in [11].

One of the features of this antenna is its size reduction compared to other similar works. A computation shows that maximum area of the total antenna (based on area of a circle with radius of  $R_1$ ) is about  $0.73\lambda_0^2$  for parameter values of Table 1, which is 40 % less than the antenna presented in [11].

For better study of this antenna, the simulated surface current densities on circular patches are shown in Fig. 2.

As seen in Fig. 2, by increasing the frequency, first the bottom patch and then, the top patch are excited. Also, excitation of the top patch is more severe at higher frequencies. Therefore, it is expected that changes in the parameters of the top patch mostly affect the antenna response at high frequencies. This evaluation is verified in Fig. 3, in which the inner and outer radiuses of the top patch has been changed. According to Fig. 3, change in parameters of the top patch mostly affects VSWR at above 5 GHz and does not change the starting frequency of the operating band. Reduction in area of the top patch by changing its inner or outer radiuses increases the second resonant frequency and the first resonant frequency remains fixed.

According to Fig. 2, distribution of the surface current on the bottom patch at 5 GHz is at its strongest level compared to higher frequencies. Also the surface current is mostly distributed near the inner circle of the bottom patch. Results of a parametric study on the bottom patch have been shown in Fig. 4. This figure shows that VSWR is mostly sensitive to the “inner” radius of the bottom patch and has very low sensitivity

to its outer radius, which can be expectable according to the surface current distribution. Also variation of the inner radius (or  $R_4$ ), affects VSWR at lower frequencies and has less effect at higher frequencies of the operation band. Reduction in  $R_4$  reduces the first resonant frequency because of the increment in area of the bottom patch.

In this antenna, the bottom patch is fed indirectly, by a rectangular strip connected to both the bottom patch and the feeding probe. This strip reduces resonant frequency of the bottom patch by increasing the length of the current paths. Therefore, by this technique the total size and area of the proposed antenna can considerably be reduced.

Simulated radiation pattern of the proposed antenna by using HFSS has been shown in Fig. 5. The main beam is obtained at  $\theta = 30^\circ$ . There is a null at broadside angle because the antenna is fed at its center point, where for even modes (and not for odd modes) strength of electric field has a high value. Therefore, the first mode that is excited is the second order mode. Radiation at H-plane has an Omnidirectional pattern as shown in Fig. 5b.

## Conclusion

In this paper, a new wideband patch antenna structure was presented. In this antenna about 27.5 % bandwidth has been achieved with  $VSWR < 2$  according to simulation results. Comparison with previous works shows that this antenna is reduced size compared to [11], low profile compared to [1-9], and easy to implement because of using suspended microstrip configuration. Its parametric dependencies have been proven by using theoretical approaches that can help in redesigning the antenna in various frequency bands. This design can be proposed for WLAN applications based on IEEE802.11a at frequency ranges of 5.15-5.35 GHz and 5.725-5.875 GHz.

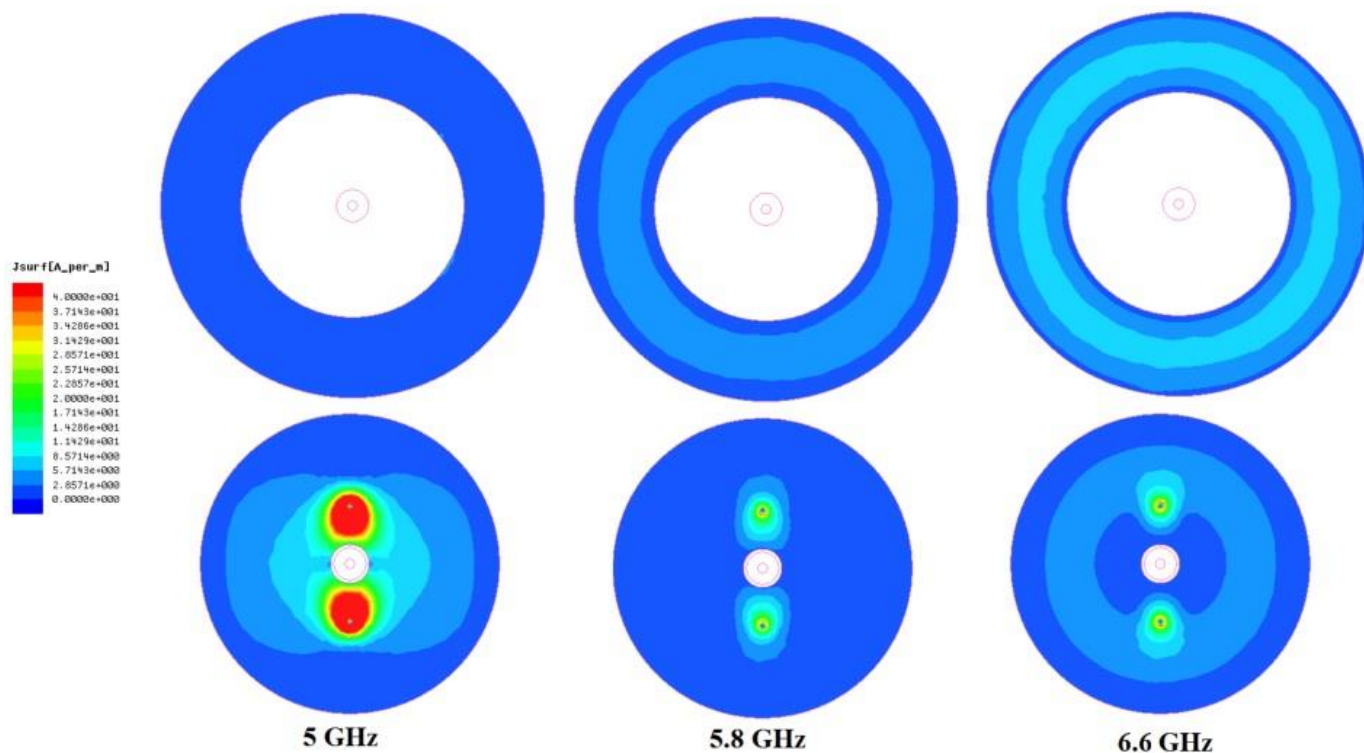
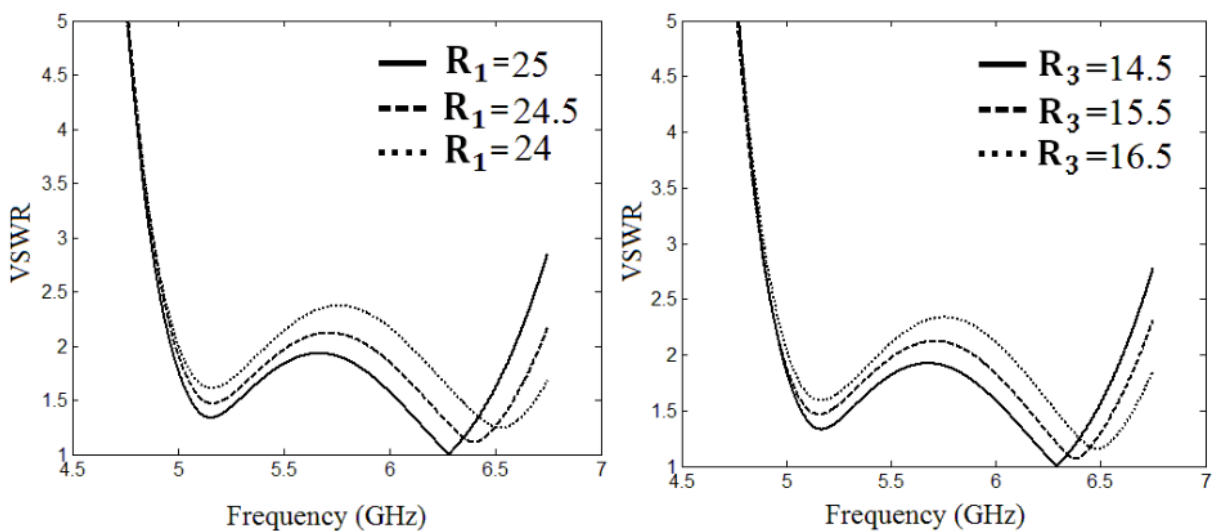
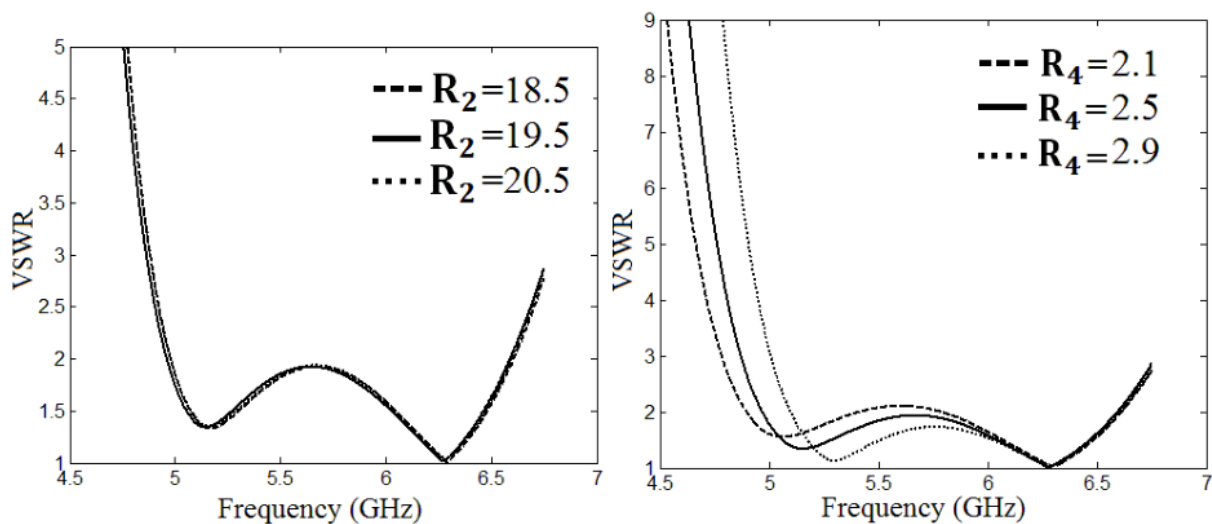


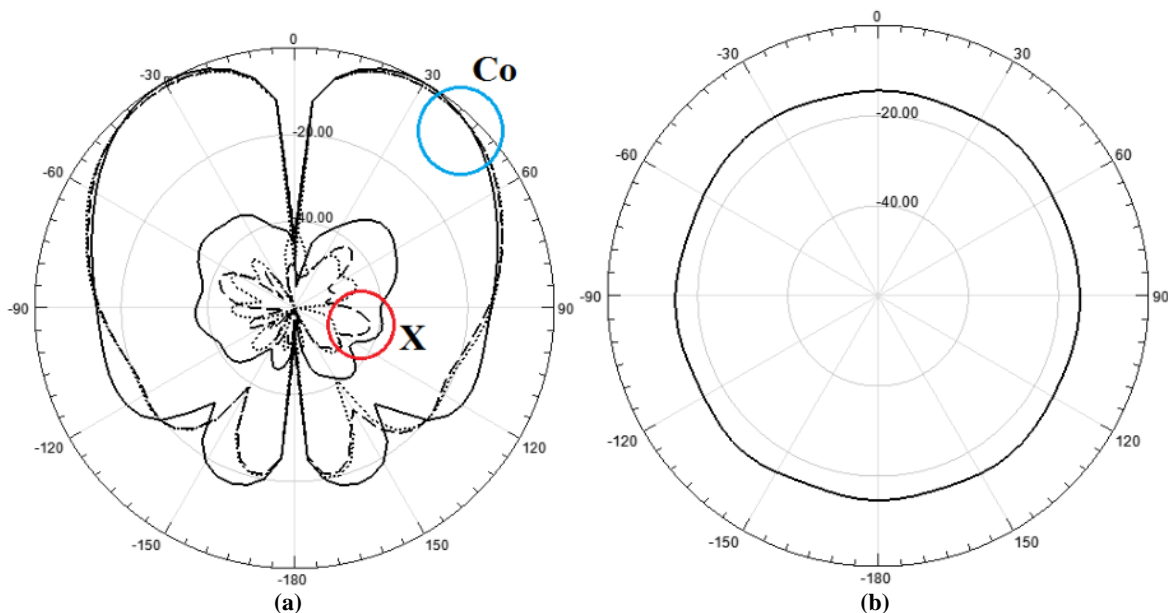
Fig. 2 Surface current densities for various frequencies on the top patch (up) and the bottom patch (down).



**Fig. 3** Effect of variation of inner and outer radiuses of the top parasitic patch on VSWR, values of the parameters are given in millimeters.



**Fig. 4** Effect of variation of inner and outer radiuses of the bottom patch on VSWR, values of the parameters are given in millimeters.



**Fig. 5** E-plane radiation pattern of the proposed antenna for  $\varphi = 0^\circ$  (xz plane - dotted),  $\varphi = 45^\circ$  (solid) and  $\varphi = 90^\circ$  (yz plane - dashed) (a), and H-plane radiation pattern for  $\theta = 90^\circ$  (b), both at 5.8 GHz.

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