Design of 4x1 Circular Microstrip Patch Array Antenna for WLAN Applications

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Abstract— Microstrip patch antennas consists of a thin,flat rectangular or circular metallic patch, which is printed on a dielectric substrate, with a ground plane attached to the opposite side of patch upon substrate. The patch is connected to a coaxial cable or a microstrip transmission line and it emits electromagnetic waves into free space. This type of antenna is used in a variety of fields, including wireless communication, radar sensing, medical applications, and military applications. The antennas needed for these applications are lightweight, conveniently mountable, and have a wide bandwidth. The antenna with the microstrip array and with the edge feeding method has been designed. We had improved the antenna characteristics such as return loss,gain and directivity. It has a return loss of 27.9 dB at a resonance frequency of 2.45 GHz and is intended for a gain of 8.60db. The substrate consists of adielectric material with a permittivity (Ɛr) of 4.4, a thickness of 1.6mm (about 0.06 in) and fed via an edge feed line method with a resistance of about 50 Ohm. This antenna can be applied to S-band applications like radartracking, Weather updates. The tool we have used to design and evaluate the antenna's characteristics is HFFS.
Keywords: Antenna, Microstrip Patch, Circular Patch array, Quarter wave transformer, WLAN, HFFS

1. INTRODUCTION

The improvement of communication technology has been significant and shows no indications of slowing down, not least of which is the wireless communication system. An antenna collects radiation from a charge. Antenna end of a transmission line permits the current to flow out, but the associated electric field does not stop.
An antenna is a tool that establishes a connection between a transmitter and a receiver by utilizing radio waves that are traveling through the air.

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When supplied with an electric current from a radio transmitter, the antenna's terminals radiate the energy as electromagnetic waves. Conversely, during reception, the antenna intercepts the power of radio waves and generates an electric current at the receiver's terminals, which is then amplified. The antenna transmits a circular wave front and the wave reached at receiving antenna which is far away from transmitting antenna is a plane wave which is operating as a transition in between guided wave and an empty space.

The patch of antenna pattern is supposed to be as typical to it as practicable. End- fire radiators can also be utilized with the appropriate mode. The microstrip patch is comprised of a ground plane just under the dielectric material and a metallic overlay placed over the base. High conductivity material is utilized to construct patch, tiny strip transmission line and ground plane. Microstrip patch antennas are distinct from traditional non- printed antennas in a variety of ways. Their primary drawbacks are surface wave excitation, low gain, and limited bandwidth, all of which reduce radiation efficiency. One of their more major disadvantages, like low bandwidth, may be solved with a variety of methods.

Antennas with significantly greater directivity can be employed to enhance network performance with a greater range for communication, which is particularly useful in WLAN applications. Together with antenna directivity, microstrip antennas' small size—far better to that of other enclosed or manufactured forms of antennas—also makes these useful for use in Wireless sensor networks.

2. ANTENNA DESIGN

Monopole design & array design are really the 2 methods of the design process.

2.1 Monopole Design

A micro strip antenna is formed by sandwiching a metallic strip between a ground plane and a dielectric substance. These antennas are tiny and emit less radiation. The patch is calculated by using the below formula:

$$r = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon F\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]}\right\}^{\frac{1}{2}}} \qquad (1)$$

Where,

$$F = 8.791 * \frac{10^9}{fr\sqrt{\varepsilon}} \qquad (2)$$

Hence radius=17mm.

2.2 Microstrip Patch Array Design

2.2.1 *Geometry*:

The inter-element spacing and feedline widths are computed by Transmission-line formulas, and then a 1x4 geometrical layout is chosen.

2.2.2 *Spacing between elements:*

An evenly symmetric radiation pattern in both directions is created by the inter-element spacing of $\lambda/2$.

Interelement spacing = 62.5 mm

2.2.3 *Feed Line widths:*

The feed line width are found by using the below expression:

$$Z = \frac{60}{\sqrt{\varepsilon reff}} \ln \left[\frac{8h}{w} + \frac{w}{4h}\right] \quad \text{where } \frac{w}{h} \leq 1 \quad (3)$$

$$Z = \frac{120\pi}{\sqrt{\varepsilon reff}\left[\frac{w}{h}+1.393+0.667\ln\left(\frac{w}{h}+1.444\right)\right]} \quad \text{where } \frac{w}{h} > 1 \quad (4)$$

$$\varepsilon_0 = 8.854 \times 10\text{-}12 \text{ F/m} \quad (5)$$

$$\text{Where } \varepsilon = \varepsilon_r * \varepsilon_o \quad (6)$$

For a circular shape patch, the best feeding point is often one-third of the way from the patch's central. The location of feed is determined as follows:

$$X = \frac{L}{2\sqrt{\varepsilon_{reff}}} \quad (7)$$

$$Y = \frac{W}{2} \quad (8)$$

The typical substrate dimensions are L and W:

L = 2xDiameter of the patch = 2×(2r) (9)

W = 2xDiameter of the patch = 2x(2r) (10)

The dimensions can be follows as:

The radius of the patch is 17mm and the location of feed is taken as (5,5,0).

Each patch is connected to a 100Ωfeedline. At the junction of the two 100Ωlines, the equivalent is 50Ω. A quarter wave transformer is linked between a 50 equivalent point and a 100Ω line, obtaining an impedance = 70.7Ω. In the end the 100Ω lines are connected to quarter wave transformer so that the equivalent impedance becomes 50Ω at the feed location.

Table 1. Dimensions of Patch Antenna

PARAMETER	DIMENSION
Height of the Substrate, h	1.6mm
Dielectric Constant of substrate (FR4Epoxy),ε	4.4
Radius of the patch, r	17mm
Inter-Element Spacing	62.5mm
100Ω feedline width	0.7mm
50Ω feedline width	3mm
70.7Ω feedline width	1.6mm

3. PARAMETERS ANALYSIS

3.1 Directivity (D):

The ratio of the radiation intensity in a given direction from the antenna to the average radiation intensity in all directions.

$$D = \frac{MAXIMUM\ RADIATION\ INTESITY\ OF\ ANTENNA}{RADIATION\ INTESITY\ OF\ ISOTROPIC\ ANTENNA} \quad (11)$$

3.2 GAIN:

When comparing to an isotropic antenna, the ratio of radiation intensity in a given direction to radiation intensity obtained if the antenna's power accepted is radiated iso-tropically. The description is normally made in terms of the gain of a perfect, isotropic, lossless antenna.

$$G = \eta * D \quad (12)$$

3.3 ANTENNA EFFICIENCY:

An antenna's efficiency explains how well an antenna will broadcast its output with reducing transmission line losses.

$$\eta = \frac{Poutput}{Pinput} \quad (13)$$

3.4 POLARIZATION

Antenna polarization describes thealignment of the E(electric) and H(magnetic) fields of the electromagnetic wave it can receive or transmit. Depending on the intended use, antennas can be designed to exhibit horizontal, vertical, circular, or elliptical polarization.

3.5 RADIATOIN PATTERN

Radiation pattern defines as the distribution of electromagnetic energy produced by antenna in a graphical way. The pattern can be directional or omnidirectional, depending on the antenna's design.

4. SIMULATION IN HFFS

Firstly, we designed single element microstrip patch antenna. Further we designed 4X1 MICROSTRIP PATCH ARRAY ANTENNA.
The following are images captured in HFFS.

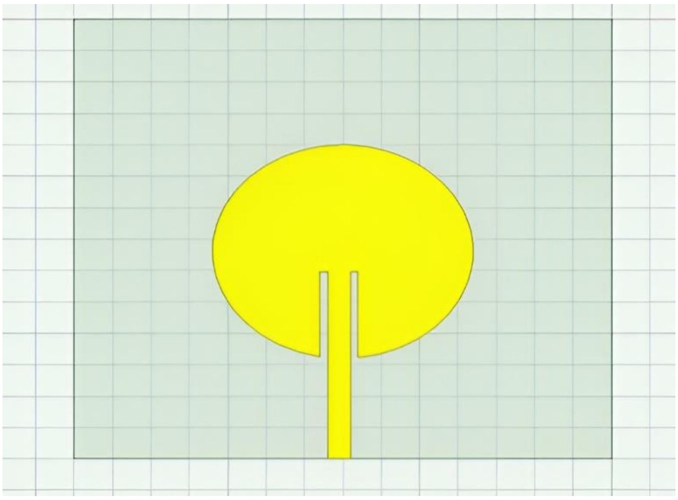

Fig. 1.TOP VIEW OF SINGLE PATCH ANTENNA

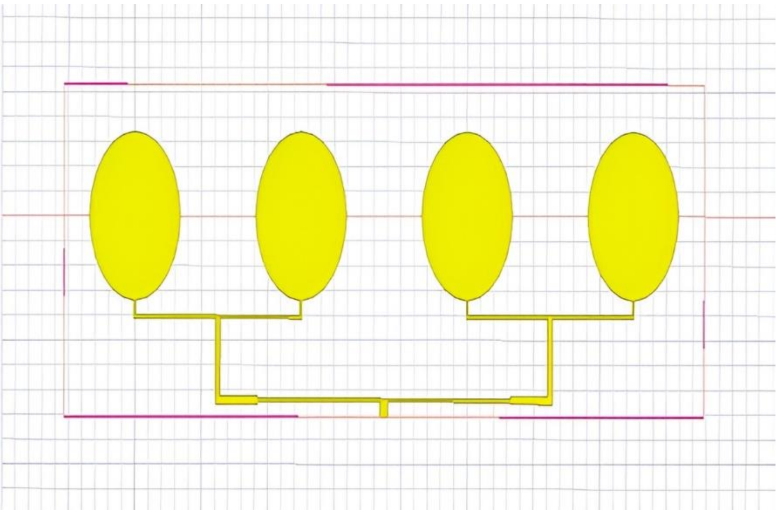

Fig. 2.TOP VIEW

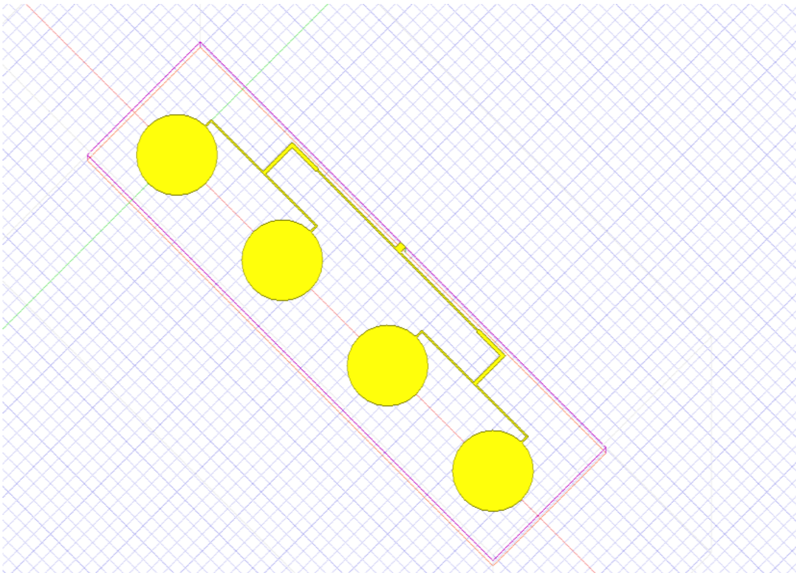

Fig.3.ISOMETRIC VIEW

5. SIMULATION RESULTS

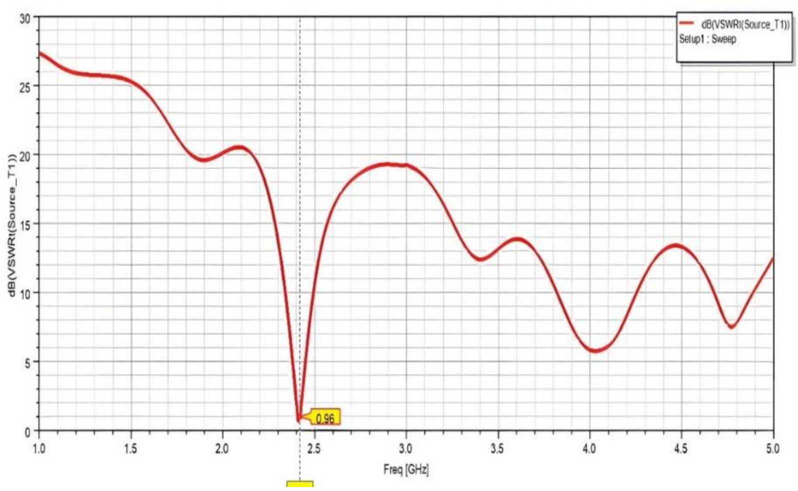

Fig. 4. VSWR

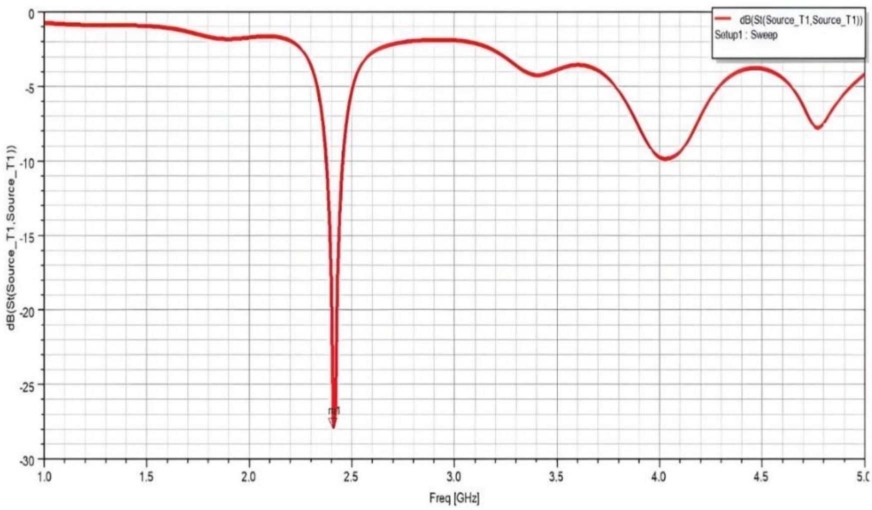

Fig. 5. RETURN LOSS

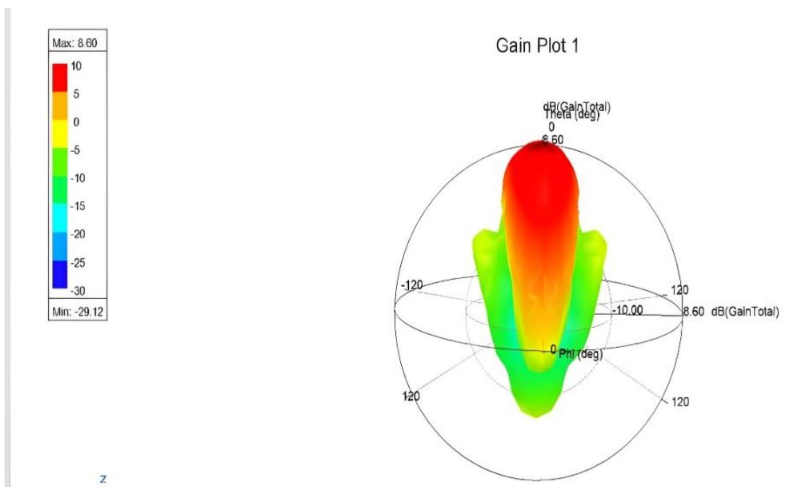

Fig. 6. GAIN

Fig. 7. DIRECTIVITY

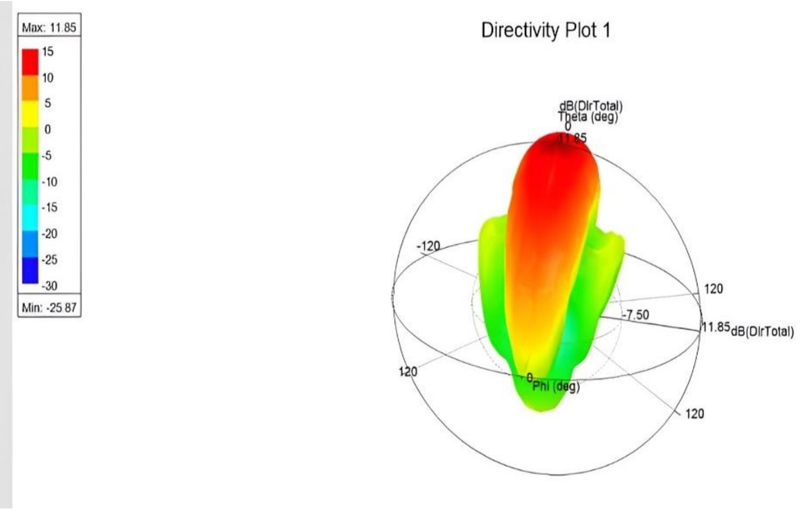

Table 2. Results of Patch Antenna

PARAMETER	OBTAIND VALUE
GAIN	8.60
DIRECTIVITY	11.85
RETURN LOSS	-27.9309
VSWR	0.95

This 1x4 patch antenna beats a single circular patch antenna because circular patches are multiplied and a quarter-wave transformer is utilized. The obtained gain is 8.6 and the calculated directivity is 11.85. The simulated outcomes additionally show that its return loss is -27.93 and its voltage standing wave ratio is 0.95, which is remarkably close to the ideal antenna.

6. CONCLUSION

A 1x4 circular patch array antenna is designed using Ansys HFFS tool and it is simulated to obtain the antenna parameters. In this design edge feed is used and quarter wave transformer results enhanced yields in Gain, Directivity, VSWR, Reflection coefficient and Return Loss.In this paper, we have the operating frequency at 2.4GHz and obtained the gain as 8.60 and the directivity is enhanced upto 11.85.The values of return loss is 27.93db and the VSWR is 0.95 which is closer to the ideal ratio.

The linear data flow from nodes towards the control node in WLAN applications, which is directional with other networks antennas, these applications require extremely directional antennas. Wideband antennas are in high demand. Microstrip antennas have a limited bandwidth and poor efficiency, and the state of the substrate has a big impact on how well they work. Due to its smaller area, the circular patch has an advantage over the rectangular one. They do have high input impedance around the circle, though, which is a drawback. Many antennas have been the subject of constant study to improve them and develop them more portable to be utilized in all fields.

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