# Re: A Circularly-Polarized Octagon-Star-Shaped Microstrip Patch Antenna with Conical Radiation Pattern


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***Abstract*— A new circularly-polarized (CP) microstrip patch antenna with omnidirectional radiation is proposed and investigated. The proposed CP antenna has a single feed, a low profile and a very simple structure. The patch has an octagon-star shape, and can be considered as a superimposition of two square patches. By generating two orthogonal degenerated TM 11 modes from the two superimposed square patches, omnidirectional CP radiation is achieved for the proposed antenna at fr=1.575GHz.**

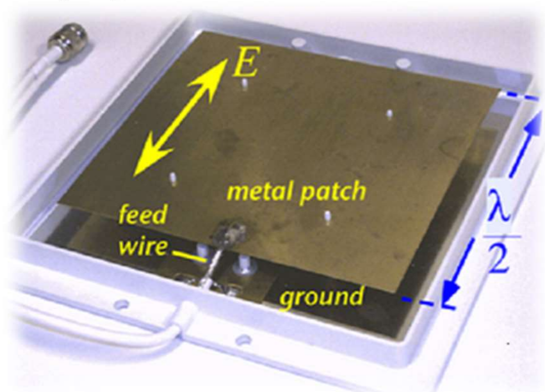


***Keywords—component, formatting, style, styling, insert** (key words)*


## I. Introduction

Recently, the field of wireless communication is the most widely researched area and the study of communication system is incomplete without knowing the operation and the use of different types of antenna. The study of microstrip patch antennas has made great progress in recent years. Compared with conventional antennas, microstrip patch antennas have more advantages and better prospects. They are lighter in weight, low volume, low cost, low profile, smaller in dimension and ease of fabrication and conformity. Moreover, the microstrip patch antennas can provide dual and circular polarizations, dual-frequency operation, frequency agility, broad band-width, feed line flexibility, beam scanning omnidirectional patterning. Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated.

Micro strip antenna consists of a very thin metallic strip placed on a ground plane with a di-electric material in-between. The radiating element and feed lines are placed by the process of photo-etching on the di-electric material. Usually, the patch or micro-strip is chosen to be square, circular or rectangular in shape for the ease of analysis and fabrication. The following image shows a micro-strip or patch antenna.




The length of the metal patch is λ/2. When the antenna is excited, the waves generated within the di-electric undergo reflections and the energy is radiated from the edges of the metal patch, which is very low.
The radiation pattern of microstrip or patch antenna is broad. It has low radiation power and narrow frequency bandwidth.

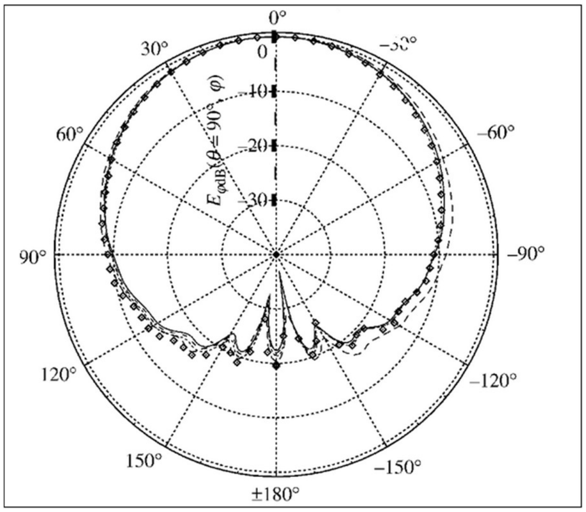


Figure: Radiation pattern (polar form)

The radiation pattern of a microstrip or patch antenna is shown above. It has lesser directivity. To have a greater directivity, an array can be formed by using these patch antennas. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible.

## II. Background

The geometry of a microstrip antenna consists of a dielectric substrate of certain thickness $d$, having a complete metallization on one of its surfaces and of a metal "patch" on the other side. The substrate is usually thin ($d \ll \lambda$). The metal patch on the front surface can have various shapes, although a rectangular shape, as shown below, is commonly used. The antenna may be excited using various methods. One common approach is to feed from a microstrip line, connecting the microstrip antenna at the center of one of its edges. The microstrip line may be connected to a feeding circuitry or directly fed by connecting a signal source across the microstrip line and the ground plane.

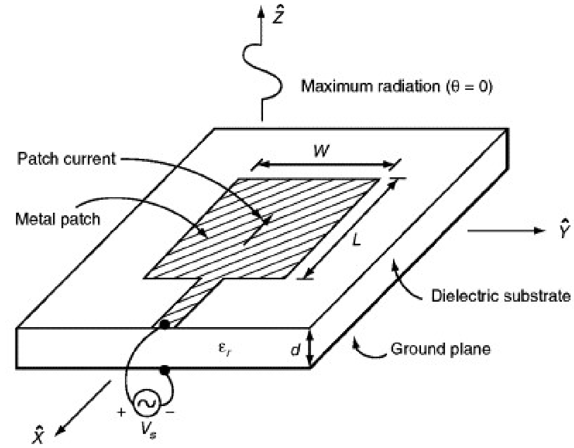


Figure: Rectangular patch antennae

The microstrip antenna produces maximum radiation in the broadside (perpendicular to the substrate) direction and ideally no radiation in the end-fire (along the surface of the substrate) direction. The size of the antenna is usually designed such that the antenna resonates at the operating frequency, producing a real input impedance. For a rectangular microstrip antenna, this requires the length of the antenna, $L$, to be about half a wavelength in the dielectric medium. The width of the antenna, $W$, on the other hand, determines the level of the input impedance. The microstrip antenna can be thought of as a rectangular cavity with open sidewalls. The fringing fields through the open sidewalls are responsible for the radiation. However, the structure is principally a resonant cavity, with only limited fringing radiation. Therefore, the bandwidth of the radiation is poor compared to the bandwidth of antennas discussed earlier. The small bandwidth, however, is adequate in a large class of communication applications

## III. Motivation

Microstrip antennas are relatively inexpensive to manufacture and design because of the simple 2-dimensional physical geometry. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency. Patch arrays can provide much higher gains than a single patch at little additional cost; matching and phase adjustment can be performed with printed microstrip feed structures, again in the same operations that form the radiating patches. The ability to create high gain arrays in a low-profile antenna is one reason that patch arrays are common on airplanes and in other military applications.

An advantage inherent to patch antennas is the ability to have polarization diversity. Patch antennas can easily be designed to have vertical, horizontal, right hand circular (RHCP) or left hand circular (LHCP) polarizations, using multiple feed points, or a single feed point with asymmetric patch structures. This unique property allows patch antennas to be used in many types of communications links that may have varied requirement

## IV. SIMULATION METHODOLOGY

A configuration of the proposed octagonal-star-shaped patch antenna to be reproduced is shown below;

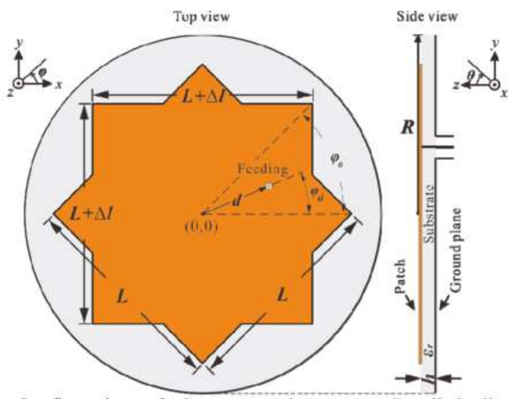



Fig. 1. Configuration of the proposed antenna. Detailed dimensional parameters are given in Table I.

The antenna is constructed on a single-layer circular substrate that has a radius of $R$, a height of $h$ and a relative permittivity of $\varepsilon_r$. The patch on the top of the substrate has an octagon-star shape. This star-shaped patch can be considered as a superimposition of two square patches, in which one square has a length of $L$ and the other square has a length of $L + \Delta l$. The two squares have an angular displacement of φ 0 = 45° while sharing the same center. The feeding point is located on the bisector of the two diagonals of the square patches (φ d = φ 0 /2), at a distance of d from the center of the patch. Detailed dimensional parameters are given in Table I.

Table I – Properties used for simulation

| Patch | | | | | | |
|---|---|---|---|---|---|---|
| *L (mm)* | *Δl (mm)* | *d (mm)* | *R (mm)* | $\emptyset_0$ (°) | $\emptyset_d$ (°) | *Material* |
| *94.4* | *1* | *32.2* | *80* | *45* | *22.5* | Copper (annealed) |
| *Substrate* | | | | | | |
| *h (mm)* | *R (mm)* | | | | $\varepsilon_r$ | *Material* |
| *3* | *80* | | | | *2.164* | User-defined |
| *Ground* | | | | | | |
| *h (mm)* | *R (mm)* | | | | | *Material* |
| *0.035* | *80* | | | | | Copper (annealed) |
| *Coaxial Feed* | | | | | | |
| *Inner diameter (d) (mm)* | | *Outer diameter (D) (mm)* | | *Impedance (Z_0) (Ω)* | $\varepsilon_r$ | |
| *1.5* | | *5.2* | | *50* | *2.16* | |

The ground was design using a circular cylinder model the properties as shown below;

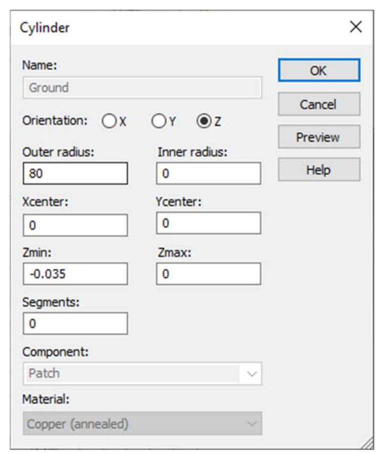



*Figure: Ground properties*

The substrate was defined as a new material with $\varepsilon_r$ as 2.164 as specified in Table I.

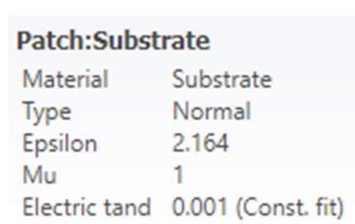



*Figure: Substrate material definition*

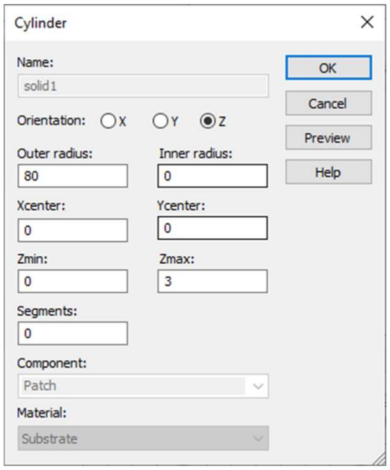



*Figure: Substrate properties*

The patch was designed using the properties as shown.

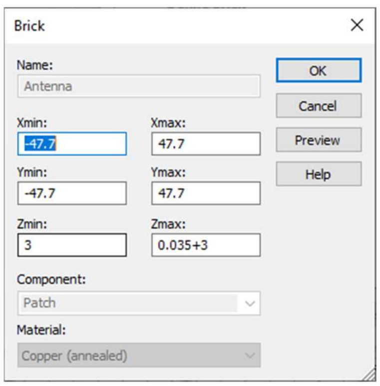



*Figure: Patch properties*

Both ground and patch used the same copper (annealed) material as specified below;

| Patch:Antenna | |
|---|---|
| Material | Copper (annealed) |
| Type | Lossy metal |
| Mu | 1 |
| Electric cond. | 5.8e+07 [S/m] |
| Rho | 8930 [kg/m^3] |
| Thermal cond. | 401 [W/K/m] |
| Specifc heat | 390 [J/K/kg] |
| Diffusivity | 0.000115141 [m^2/s] |
| Young's modulus | 120 [kN/mm^2] |
| Poisson's ratio | 0.33 |
| Thermal expan. | 17 [1e-6/K] |

*Figure: Copper material definition*

A coaxial feed was used to provide power to the antenna as shown below;

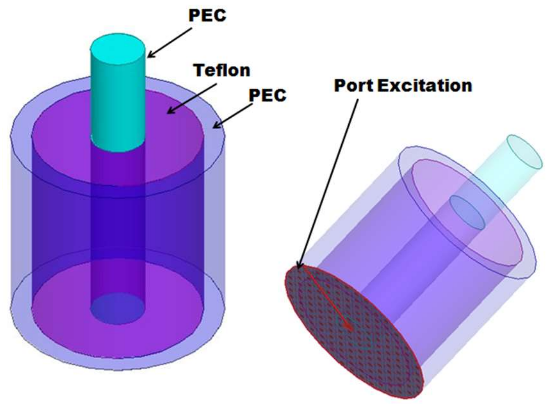



*Figure: Coaxial material layers*

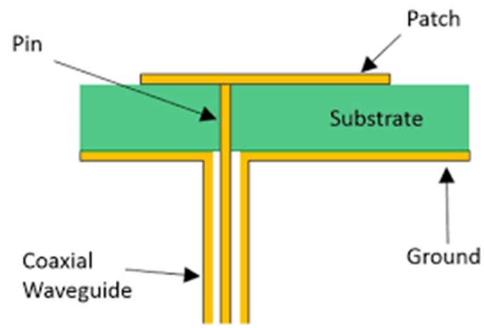



*Figure: Coaxial feed connections*

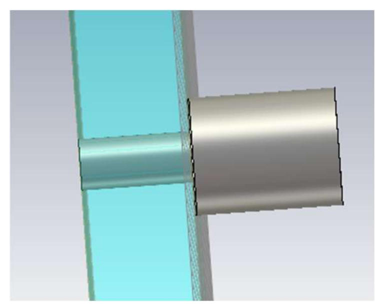


*Figure: Coaxial feed-point waveguide*

The complete octagonal-star-shaped patch antenna model used for simulation is shown below;

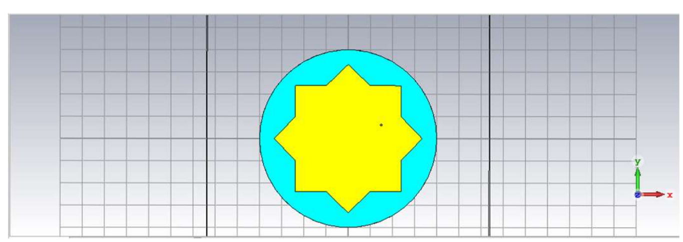


*Figure: Complete antenna model for simulation*

## V. Simulation Result

The following results were obtained;

*a) Far-field directivity*

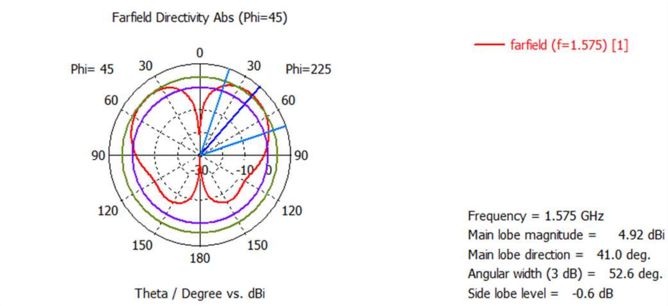



*Figure: Far-field radiation*
*Phi=45 (1D-polar diagram)*

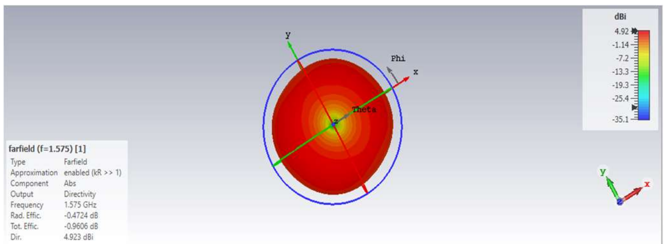



*Figure: Far-field radiation (directional)*
*[Top VIew]*

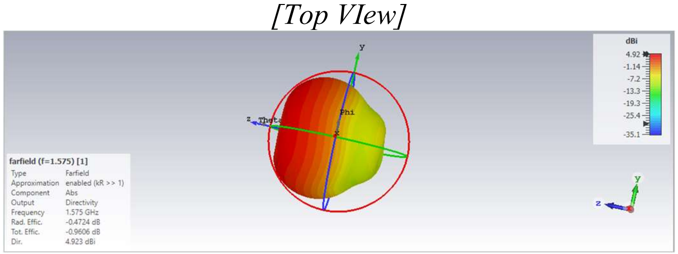



*Figure: Far-field radiation*
*[Side View]*

*b) Electric field variations*

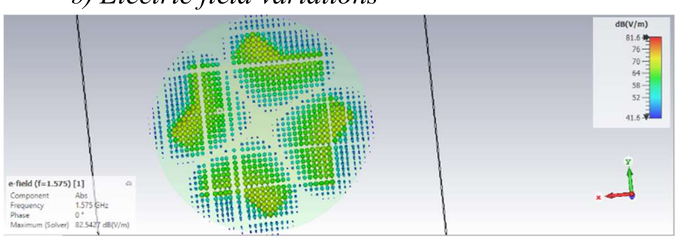



*Figure: E-Field* ***(at fr=1.545GHZ)***
***[Top Face of Antenna]***

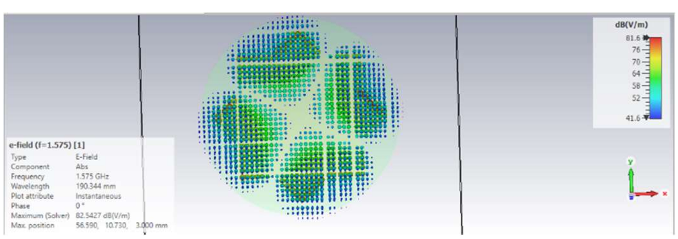



*Figure: E-Field* ***(at fr=1.545GHZ)***
***[Top Face of Antenna]***

*c) Magnetic Field variations*

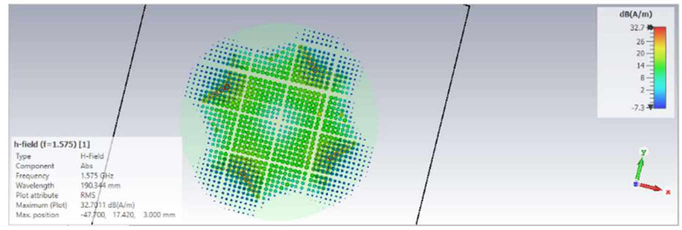



*Figure: h-field RMS* ***(at fr=1.545GHZ)***
***[Top Face of Antenna]***

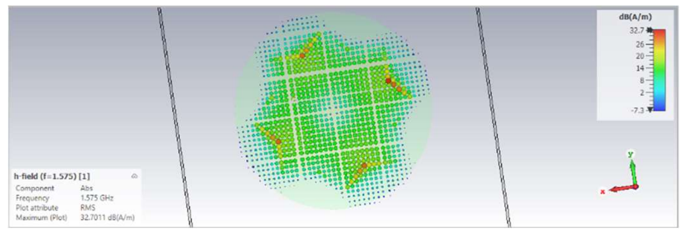



*Figure: h-field RMS* ***(at fr=1.545GHZ)***
***[Top Face of Antenna]***

*d) s-parameter*

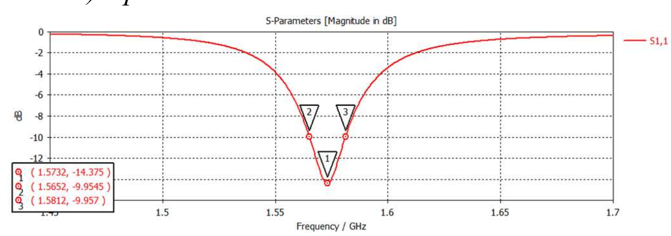



*Figure: s-parameter showing resonant frequency of 1.57 GHz*
*Bandwidth at -10 dB = 16MHz*

*e) Voltage Standing Wave Ratio*

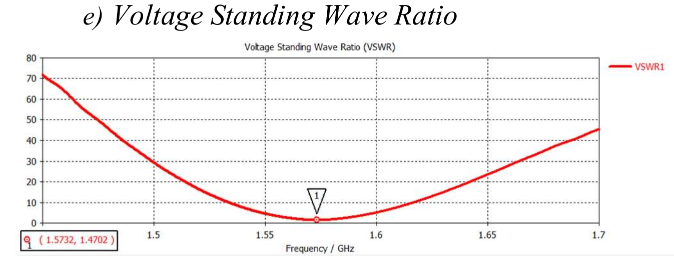
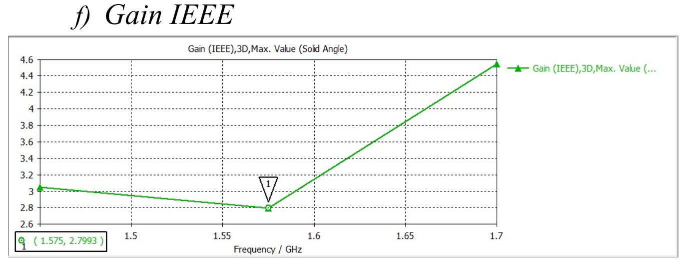
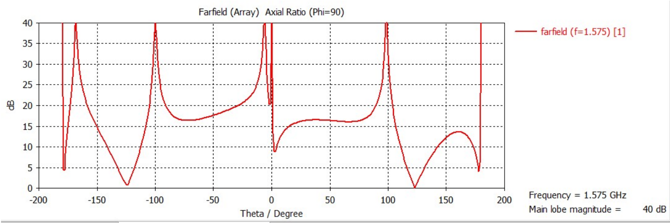



*Figure: VSWR showing resonant frequency of 1.57 GHz*

*f) Gain IEEE*




*g) Axial Ratio*




*h) Efficiency*

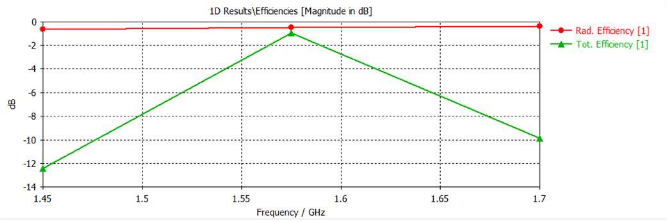



*Figure: Efficiency plot*

## VI. Discussion

Compared with the multi-layered designs, the presented antenna has higher gain, lower profile, and simpler structure without additional feeding network or additional substrate layer. Our work is free of additional feeding network for orthogonal modes excitation, and thus shows advantages of single feed, smaller size and lower design complexity.

However, it has poor radiation pattern symmetry and requires a higher profile. The AR bandwidth of the presented antenna is narrow when compared with other designs. Nonetheless,
the AR bandwidth is sufficient for the GPS L1 band application

## VII. Conclusions

A microstrip patch antenna, CP octagon-star-shaped, has been proposed. Without any additional feeder network, the proposed antenna has a single feed, a low profile, and a very simple structure. By generating two orthogonal degenerated TM11 modes using an octagon-star-shaped patch radiator, omnidirectional CP radiation is obtained. Circular polarized antennas are very effective in combating multipath interference, Faraday's rotation effect and orientation constraints between the transmitter and the receiver antennas

## References

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