

# Hexagonal Loop Microstrip Patch Antenna for Wireless Communications

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## ABSTRACT

This work presents a compact broad bandwidth hexagonal loop microstrip patch antenna. The proposed antenna consists of a coplanar waveguide, a hexagonal loop microstrip patch and uses the feeding way of coplanar waveguide. The proposed hexagonal radiator is cut a circular patch out the center of a hexagonal patch. That is, it called hexagon loop. The antenna is designed a very simple structure and compact size for a board bandwidth of a satellite communication. The proposed antenna obtains dual frequency bandwidths of 3.22 GHz (3.34 - 6.56 GHz) and 5.3 GHz (8.6 - 13.73 GHz). Also, the antenna obtains a realized peak gain of 9 dBi at low frequency band and 4.5 dBi - 8.6 dBi at high frequency band and generates circular polarization at high frequency band. The dimensions are  $22 \times 29 \times 1.52 \text{ mm}^3$ . The proposed antenna covers the frequency bands of WLAN, WiMax, and other wireless applications which come under the frequency ranges of S-band, C-band, and X-band.

**Key Words** : CPW to CPS transmission line, hexagonal loop, microstrip patch, WLAN

## I. Introduction

Frequency bands of wireless communication systems of C, X, Ku, and K bands have been used for the various purposes of satellite wireless communication systems. One of the most important things in wireless communication systems is an antenna as its integral component. The scientists need to analyze and fabricate an antenna that will operate in the high frequency bands with characteristics such as broad bandwidth, high gain, and high efficiency for the application of the patch antenna in satellite communication. The bandwidth is an important parameter of antennas which is the antenna operating frequency band. Wide bandwidth antennas are mainly becoming very attractive in future and modern wireless communication systems because of two sig-

nificant factors. Firstly, the wireless portable devices currently need to operate antennas in different frequencies for different wireless transmission applications, and operation bands and functions are increasing more and more, which may affect antenna design, such as multi antennas interference, antenna space limitation, etc. As a result, Ultra-wideband antennas may effectively decrease the number of antennas because one Ultra-wideband antenna can be applied to substitute multi band antennas. Secondly, there are more and more required the wireless transmission devices such as wide bandwidth systems due to having high data rate. Microstrip patch antenna is one of the most used antennas for wireless communication. Its key features include a limited bandwidth, low cost, and ease of manufacture, and easily fabricate using electronic printed circuits<sup>[1,2]</sup>. A lot of advantages of

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patch antennas have been discussed in the relevant literature. However, many researchers have been working to surmount its narrow bandwidth and miniaturized a hexagonal microstrip patch antenna design has been presented application techniques in [3-5]. In [6-8] were presented to highlight the mechanisms for the expansion of the bandwidth of patch antennas. In satellite communication applications, patch antenna design faces the challenge of lower bandwidth and small gain. Many researchers are proposed in the literature to overcome this limitation. Furthermore, future developing trend in the field of satellite communication also focus on the design of more efficient patch antennas. Various techniques are proposed and analyzed to improve such design several requirements. This work is focused to enhance bandwidth, miniaturization, and gain of a antenna. The proposed antenna is a structure of a loop hexagon for increasing the symmetrical electrical circuit paths. The currently popular designs suitable for WLAN operation in the 2.4 GHz (2.4 – 2.484 GHz) and 5.2/5.8 GHz (5.15 – 5.35 GHz/5.725 – 5.825GHz) bands and WiMAX operation in the 2.5/3.5/5.5 GHz bands have been reported in [9, 10]. The Universal Mobile Telecommunications System (UMTS) is a third-generation mobile cellular system for networks based on the GSM standard. UMTS uses wideband code-division multiple access (W-CDMA) radio access technology to offer greater spectral efficiency and bandwidth to mobile network operators. In [11] was researched CPW-fed metamaterial inspired compact multiband antenna for LTE/5G/WLAN communication. The CPW-fed antenna was ensuing 10 dB impedance bandwidth varies from 2.28 to 2.38 GHz, 3.07 to 3.78 GHz, and 5.05 to 7.03 GHz, whereas notch band exist from 2.39 to 3.06 GHz frequency. And it was electric length of  $0.14\lambda_0 \times 0.21\lambda_0$ . In [12], the work was published CPW-fed flower-shaped patch antenna for broadband applications. In [13], there was published a hexagonal patch antenna element proposed for mobile wireless network systems. The antenna element was fed with a coaxial probe for causing the antenna to radiate. The proposed antenna is designed to operate at 2.45 GHz and achieved an impedance bandwidth of about 64 MHz at center frequency 2.45 GHz.

Therefore, the frequency bandwidth of this antenna was very narrow and composed of two layers. On the other hand, the proposed antenna obtains ultra-wide frequency bandwidth and sets up whole elements on a single layer.

## II. Literature and Background

### 2.1 Regular polygon microstrip patch

In order to design hexagonal microstrip patch antenna, first a polygon microstrip patch antenna is designed then its geometry shows as shown in Fig. 1.

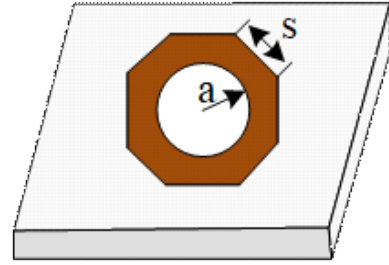


Fig. 1. Structure of circular and hexagonal microstrip patch.

### 2.2 Hexagonal microstrip patch antenna design

A circular microstrip patch antenna is one of the widely used patch configurations. The resonance frequency of the circular microstrip patch is obtained using in Eq. (1),

$$f_r = \frac{\chi_{mn}C}{2a\pi\sqrt{\epsilon_r}} \quad (1)$$

where,  $f_r$  = resonant frequency,  $\chi_{mn} = 1.84$ ,  $C$  = velocity of the light in free space,  $\epsilon_r$  = relative of the substrate.

Whereas the effective radius of circular microstrip patch antenna is given in Eq. (2).

$$a_e = a \left\{ 1 - \frac{2h}{\pi a \epsilon_r} \left( \ln \frac{\pi a}{2h} + 1.7726 \right) \right\}^{1/2} \quad (2)$$

which,  $a$  = actual radius of the circular patch antenna,  $h$  = height of the substrate,  $\epsilon_r$  = relative permittivity of the substrate. The structure of the hexagonal antenn

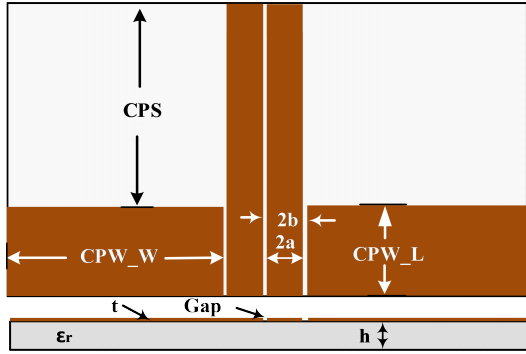


Fig. 2. Structure of CPW to CPS transmission lines

a is shown in the Fig. 1. Practically, the size of the ground plane is about 6 times the substrate thickness, on all sides similarly to the criteria mentioned the in [14, 15]. The geometry of the hexagonal antenna is shown in the Fig. 2.

### 2.3 Hexagonal microstrip patch antenna

Hexagonal and circular structure is one of the various shapes for microstrip patch antennas capable of linear polarization operation that has been reported in the literature<sup>[16]</sup>. The hexagonal microstrip patch antenna size calculation was made considering the invariance of the electrostatic energy below the hexagonal and circular patches, as it was realized for the case of rectangular and circular ones, keeping constant areas. The relationship between the equivalent areas of the circular and hexagonal patches is given in Eqs. (4, 5),

$$\pi a_e^2 = \frac{3\sqrt{3}}{2} S^2 \quad (3)$$

where,  $S$  = sides of a regular hexagonal patch antenna,  $a_e$  = effective radius of the circular patch antenna,  $f_{eff}$  = effective dielectric constant,  $S_e$  = effective value of a side length of hexagonal.

$$S = \frac{2c}{3f_r\sqrt{\epsilon_r}} \quad (4)$$

$$S_e = \frac{2c}{3f_r\sqrt{\epsilon_{eff}}} \quad (5)$$

### 2.4 Coplanar waveguide

A coplanar waveguide (CPW) was proposed by Wen in 1969. A distinct advantage of CPW and CPS lies in the fact that mounting of lumped components in shunt or series configuration is much easier. Drilling of holes or slots through the substrate is not needed. In recent years, the CPW and CPS transmission lines have become more acceptable for many microwave circuit applications. The coplanar transmission lines have become more acceptable for many microwave circuit applications. Coplanar transmission lines have several features which make them attractive for use in MIC and MMIC structures. This feeding mechanism is geometrically complicated and requires long transmission lines. Also, the narrowband delay line used in the design of the wideband antenna is expected to limit the bandwidth and create an unbalanced condition of the antenna operation. This will affect the radiation pattern within the matching bandwidth. Here, we propose an alternative design, which naturally overcomes the bandwidth problem by using a simplified feeding network. The design optimization can also be performed in a way that does not require an expensive and time-consuming numerical analysis.

The CPW consists of a center strip with two ground planes located parallel to and in the plane and on the same surface of the dielectric substrate. They have shown in Fig. 2. The width of a center strip line is  $2a$  and  $2b$  is  $2a$  plus both gap widths of the CPW.

## III. Described Hexagon Patch Antenna

Geometry of the proposed hexagonal loop microstrip patch antenna is shown in Fig. 3. The proposed antenna consists of a radiation part of the hexagonal loop and a feeding part of the CPW to CPS transmission line. It is shown a front-view and a side-view.

The antenna is printed a single plane on substrate with the dielectric constant of  $\epsilon_r = 6.15$  and the height of 1.27 mm. The proposed hexagonal loop microstrip patch is cut a circular patch out a center of a hexagonal patch. The vertical and the horizontal length of the feeding part of CPW are CPW-L and CPW\_W and the width of its center conductor strip line is FW.

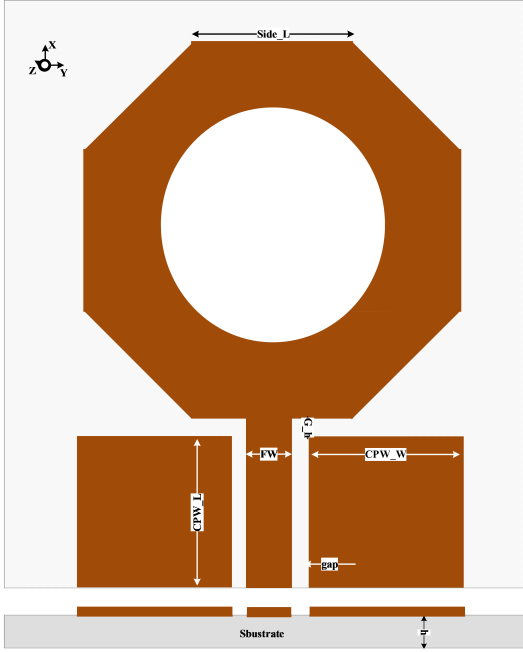


Fig. 3. Geometry of the proposed hexagon loop antenna

Table 1. List of optimized parameters of designed antenna.

| Parameters | Value (mm) |
|------------|------------|
| Side_L     | 8          |
| FW         | 3.6        |
| CPW_L      | 13         |
| CPW_W      | 8          |
| G_h        | 0.8        |
| Gap        | 0.5        |
| h          | 1.52       |

A side length of the hexagon patch is side\_L. It has calculated from in Eq. (5).

Table 1 is optimized designing parameters of the proposed antenna.

#### IV. Simulation and Experimental Measured Results

This work has analyzed the numerical characteristics of the proposed antenna, such as a reflection coefficient, an impedance, a realized peak gain, and circular polarization.

Fig. 4 shows a reflection coefficient. The proposed

antenna obtains dual frequency bands of from 3.34 to 6.56 GHz and from 8.6 to 13.73 GHz. This frequency bandwidths covers the frequency ranges of S-band, C-band, and X-band.

Fig. 5 shows a resistance and a reactance. Resistance of the proposed antenna approaches a characteristic impedance of 50  $\Omega$  and reactance accesses a characteristic impedance of 0  $\Omega$  as well, each operating frequency band. Also, the proposed antenna gen-

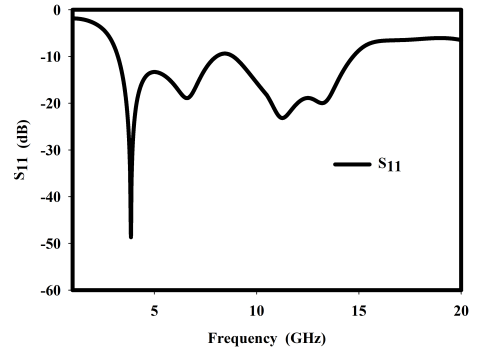


Fig. 4. Reflection coefficient of the proposed antenna

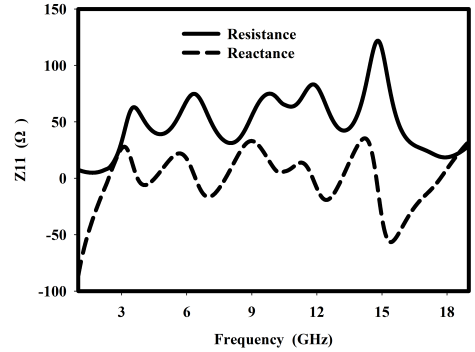


Fig. 5. Impedance of the proposed antenna

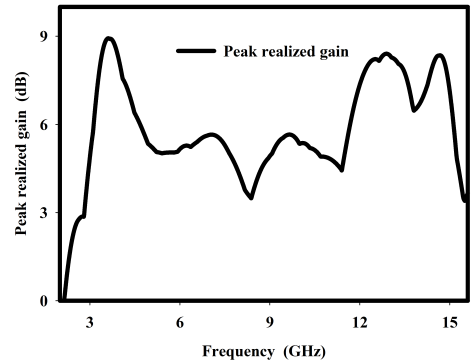


Fig. 6. Peak realized gain of the proposed antenna

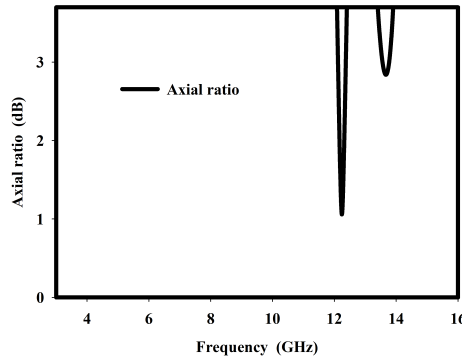
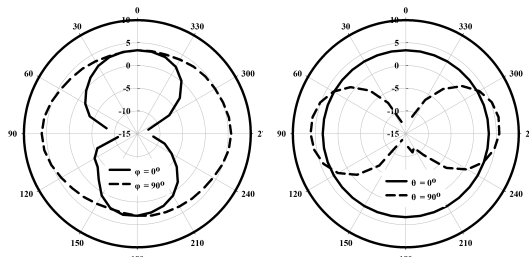
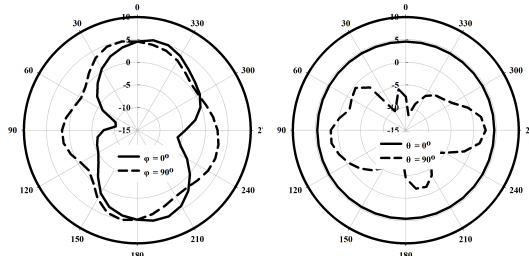


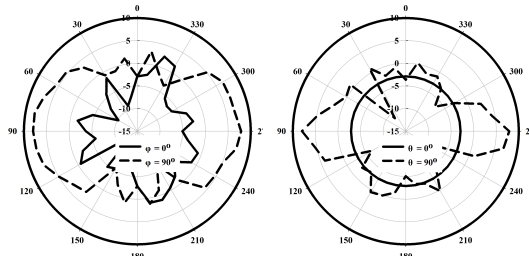
Fig. 7. Circular polarization of the proposed antenna



a) Radiation patterns of an elevation and an azimuth at 3.3 GHz



b) Radiation patterns of an elevation and an azimuth at 5.8 GHz



c) Radiation patterns of an elevation and an azimuth at 12 GHz

Fig. 8. Radiation patterns of the proposed antenna

erates a characteristic impedance at first resonance. It improves characteristics of an antenna, specially ef-

fects a gain of the antenna.

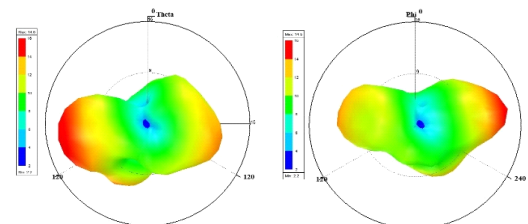
A realized peak gain of the antenna is shown in Fig. 6. There show 9 dBi at low frequency band and 4.5 dBi – 8.6 dBi at high frequency band.

Fig. 7 shows a circular polarization and it generates at X-band of 12 GHz to 13.5 GHz. As we known, the circular polarization is used to useful on wireless communications.

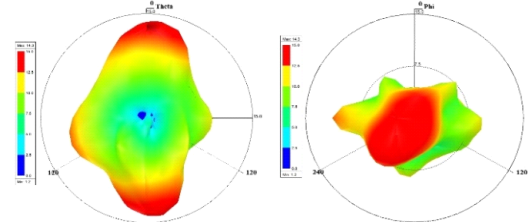
Fig. 8 shows radiation characteristics at an operating frequency of 3.3, 5.8, and 12 GHz. The electric and the magnetic field are demonstrated on the elevation and azimuth plane, respectively. As a results, the radiation patterns are characteristics of the typical small dipole antennas at 3.3 GHz and other frequency bands show the characteristics of a typical planar dipole antenna.

The 3D radiation patterns are shown in Fig. 9. Each 3D pattern appears xz- and xy-plane, this pattern shapes are a similar 2D radiation patterns.

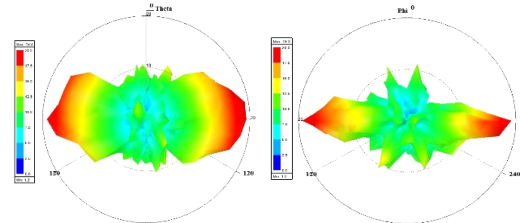
The electrical current paths and their directions are



a) Radiation patterns of an xz- and xy-plane at 3.3 GHz

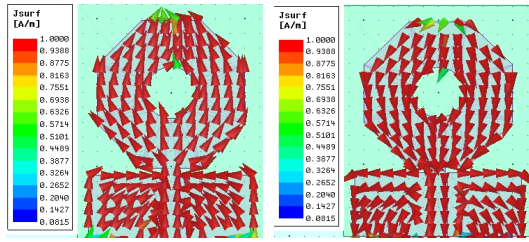


b) Radiation patterns of an xz- and xy-plane at 5.8 GHz

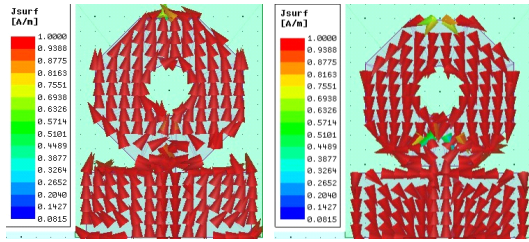


c) Radiation patterns of an xz- and xy-plane at 12 GHz

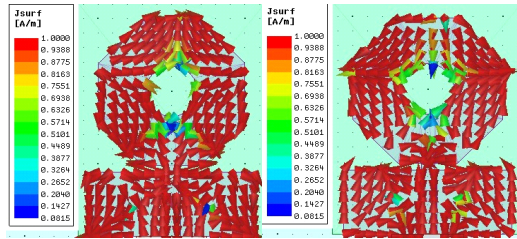
Fig. 9. 3D radiation patterns of the proposed antenna



a) Electrical current path of phases  $60^\circ$  and  $240^\circ$  at 3.3 GHz



b) Electrical current path of phases  $50^\circ$  and  $230^\circ$  at 5.8 GHz



c) Electrical current path of phases  $30^\circ$  and  $210^\circ$  at 12 GHz

Fig. 10. Electrical current paths of the proposed antenna

demonstrated according to each phase. The phases of  $60^\circ$  and  $240^\circ$  at 3.3 GHz, the phases of  $50^\circ$  and  $230^\circ$  at 5.8 GHz and phases of  $30^\circ$  and  $210^\circ$  at 12 GHz are shown in Fig. 10. Also, a direction of each electrical current path flows a reversed phase of  $180^\circ$  and flows a same direction on an equivalent hexagonal patch. But a flowing current path is distorted at 12 GHz because the size of the hexagonal patch is larger than a traveling wave length.

Fig 11 compares a simulated reflection coefficient with a measured reflection coefficient of the proposed antenna. As shown in Fig.11, both reflection coefficient shows a similar frequency band width.

The photograph of the manufactured antenna is shown in Fig. 12. It is connected to an SMA connector. The SMA connector has been used to con-

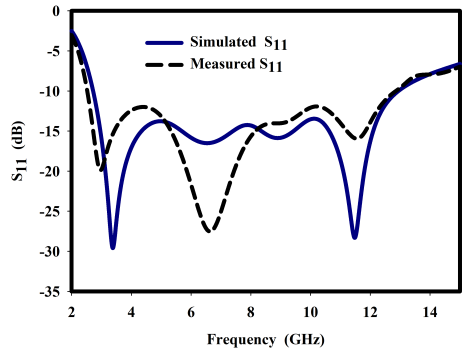


Fig. 11. Simulated and measured reflection coefficients

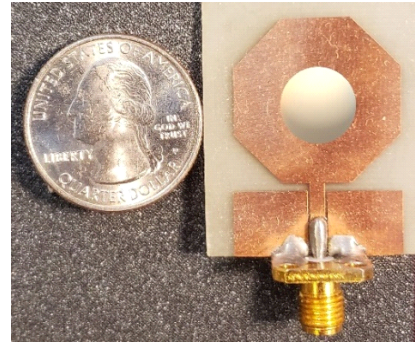


Fig. 12. Manufactured photograph of the proposed antenna

nect to test equipment. The proposed antenna is dimensions of  $22 \times 29 \times 1.524 \text{ mm}^3$ .

## V. Conclusion

This work presented the hexagonal loop microstrip patch antenna and used a feeding way of CPW\_fed. This work considered that most of the typical hexagonal type patch antennas were made completely conductor parts and that it will affect the production and price, therefore, a hexagonal loop-shaped patch antenna was proposed. The proposed antenna was designed a polygon-shape for broad frequency bandwidth and made hollow a center of a patch out for printing easily. This antenna has a very simple structure and compact size. The proposed antenna obtained bandwidths of 3.22 GHz and 5.3 GHz and achieved peak realized peak gain of 4.5 – 9 dBi. The proposed antenna has good characteristics for wireless satellite communications.

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