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REGULAR ARTICLE

Analysis of A Low-Profile Hexagonal Patch Antenna for Next Generation Wireless Communications

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Hexagonal patch antenna is therefore very different from conventional antennas. For next-generation cellular networks, a novel wideband hexagonal patch antenna concept is being presented. The structure is made up of microstrip rectangles and hexagonal structures, with a total area of 40 × 40 ×1.5 mm^3. Hexagonal patch antenna is designed utilizing RT duroid substrate. An improved S_{11} of more than 15 dB at the resonating frequency is observed at 2.5 GHz (2.26-2.84 GHz). 3.6 dB gain has been observed at the resonant frequency of 2.5 GHz. Effective impedance matching has been achieved by using the microstrip transmission line edge feeding technology and DGS in the ground plane. Hexagonal patch antenna produces high-quality double-polarized radiation and wide bandwidth, designed and simulated in far-field radiating settings. A novel, lightweight, high gain and wide-bandwidth hexagonal patch antenna is also needed for the 5G smartphone antenna system. The hexagonal patch antenna is a better choice for future 5G cellular applications due to its performance and small architectures. The 5G wireless communication antenna is therefore very different from conventional antennas.

Keywords: Hexagonal patch antenna, HFSS, gain, 5G systems, Next gen applications.

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1. INTRODUCTION

Recent years have seen a rapid advancement in the field of mobile wireless networking. Broadband 3G mobile phones and other wireless applications like WLAN, Bluetooth, RF have been introduced as a result of the popularity of 2G applications. An essential part to transceive the signal is the antenna. HPAs with low-profile, multifunctional and wide band RF applications are increasingly chosen for mobility and safety. The development of low-profile, extremely efficient, compact, HPAs that can be included into wireless devices is required to meet all of these requirements. The commercial expansion of 5G is expected to occur in the early 2020s [1-3].

The use of mm Wave frequencies, which aim for more bandwidth and improved spectral efficiency, is one significant distinction between 4G and 5G communication enabling technologies [4]. Moving closer to the RF bands and away from the present frequency ranges (< 4 GHz) introduces new features that need careful study [5-7]. A compact open-slot antenna that maintains ultra-wideband performance while increasing bandwidth [8]. Using fractal shapes is one way to reduce antenna size and increase bandwidth. To achieve a large bandwidth, fractal self-similarity and space-filling characteristics are crucial [9-10]. One way to conceptualize the self-similarity attribute is as a partition of a full shape into smaller sections, each of which is a scaled-down version of the whole. This leads to broadband and multiband behaviour in antennas. They occupy less space that leads them to get smaller since they have a long electrical length yet aggregate into a small area and make efficient use of space.

A frequency-notched UWB fractal-printed slot antenna is analysed for RF applications [11]. A circular monopole antenna has been integrated with metamaterials for modern telecom systems is introduced [12]. A tortoise shaped quad band MPA is analysed for C-band and Ku band applications [13]. A rectangular open slot in the middle is considered as ground plane. The patch is composed of triangular pieces and hexagonal rings that work together with the antenna to create a fractal design. An UWB printed monopole antenna is analysed for UWB applications [14]. Additionally, a variety of feed architectures, stacked patches and different patch and slot geometries can be used to achieve wideband characteristics. Fractals have numerous applications in various scientific and architectural domains, according to [15].

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2. DESIGN & ANALYSIS OF HEXAGONAL PATCH ANTENNA (HPA)

The monopole hexagon form is utilised to design the HPA in this research. Nevertheless, the impedance bandwidth is constrained when using a monopole configuration. As a result, HPA with separate dimensions were designed to improve the bandwidth and radiation properties. The proposed radiating patch structure consists of a hexagon attached to the hexagonal ring to attain high gain. The HPA receives microwave power via the microstrip transmission line. In order to match the input impedance of HPA and the output impedance of the power-feed is connected to 50 Ω microstrip transmission line. This will produce good radiation characteristics by distributing the current uniformly throughout the patch and along its boundaries. The hexagonal patch antenna structure was simulated using the Ansys HFSS software tool. Hexagonal patch antennas geometry and design are shown in Figure 1. The dimensions for HPA are shown in Table 1. HPA is made with a Rogers Ultralam 1250 substrate that has ε_r of 2.5 and obtained loss tangent tanδ of 0.0015 and had a thickness of 1.5 mm. A monopole is connected to a 40 × 40 × 1.6 mm^3 hexagonal patch antenna via a 50 Ω microstrip transmission line. The hexagonal patch antenna was designed using the following mathematical calculations.

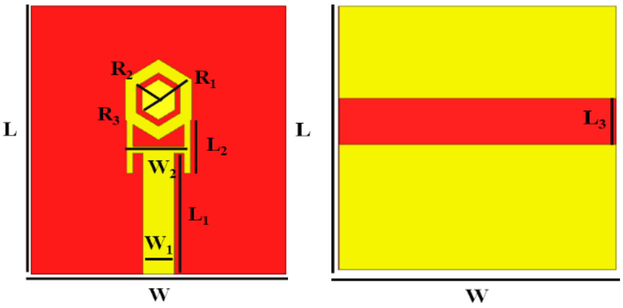
$$L = \frac{C}{2F_r\sqrt{\varepsilon_{reff}}} - 2\Delta l \quad (1)$$

$$a = \frac{F}{\sqrt{1+\frac{2h}{\Pi\varepsilon_r}[\ln\left(\frac{\Pi f_r}{2h}\right)+1.7726]}} \quad (2)$$

$$F = \frac{8.791*10^9}{f_r\sqrt{\varepsilon_r}} \quad (3)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\left[\frac{12h}{w}\right]\right]^{-1/2} \quad (4)$$

In the hexagonal patch, 'a' stands for the radius, which is found using equation (2), and 'L' for the length, which is found using (1). In this case, the variable 'h' stands for the material's thickness. Equation (2) is used to generate F. The center frequency of the substrate is represented by f_r.



(a) (b)

Fig. 1 – Prposed HPA (a) Top surface (b) Bottom surface6

Table 1 – Dimensions of the proposed HPA

Parameter	Values (mm)
L	40
W	40
L_1	18
W_1	4.8
L_2	8
W_2	9
L_3	7
W_3	12
R_1	8
R_2	6
R_3	4

3. RESULTS AND DISCUSSIONS

Radiation parameters of the HPA, including gain, S_{11}, VSWR and radiation pattern, performance are discussed in this section. In the hexagonal patch antenna, the resonating element radiates around the corners as well as along the feed line by increasing the bandwidth. Reflection co-efficient and VSWR of HPA is shown in figure 2. Hexagonal patch antenna operates at 2.5 GHz and offers S_{11} of – 18 dB. HPAs VSWR at the resonating frequency is 1.2 and is shown in Figure 2. Because of its compact size, this antenna is a good option for next generation wireless communication applications. This suggests that there aren't many reflected signals, guaranteeing effective signal transmission and reception. The overall gain is represented in three dimensions in Figure 3. Different colours indicate different gain levels, while the color bar on the left shows the antenna's total gain in dB. A maximum gain of 3.6 dB has been observed at 2.5 GHz and is shown in figure 3. The simulated radiation pattern of the HPA at 2.5 GHz is displayed in Figure 4. The H-plane and E-plane are fashioned like dumbbells in the pattern. The pattern is the same as the radiation pattern of a dipole/monopole antenna. Figure 7 displays the hexagonal patch antennas current distribution. The color red represents the largest field distribution. It has been observed that the maximum value is 40 Am^{-1}. The radiation zones are determined by the distribution of surface current in the hexagonal patch; the areas with the maximum radiation intensity are indicated in red. Figure 5 shows that the antenna's edges and center have the highest radiation intensity. Figure 6 represents E-field distribution of the HPA. The maximum amount of distribution is represented by using red color and is observed at the feed line and corners of the patch. Maximum value of 150 vm^{-1} has been observed at 2.5 GHz.

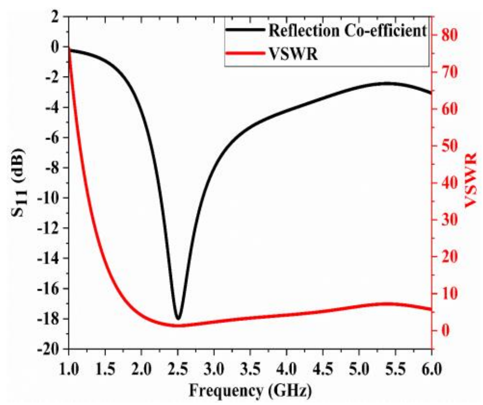


Fig. 2 – VSWR and reflection co-efficient of the HPA

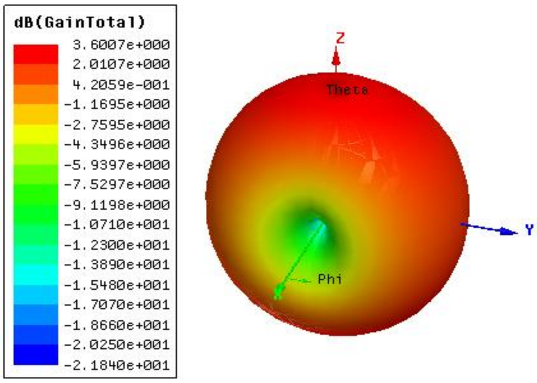
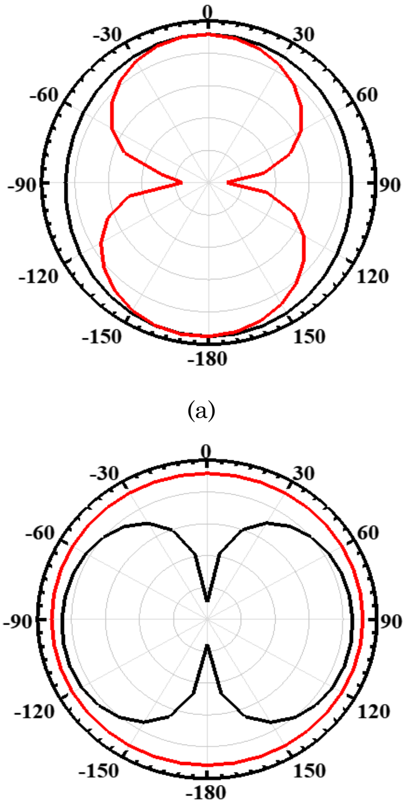


Fig. 3 – Obtained gain of the proposed HPA



(a)

(b)

Fig. 4 – Radiation pattern for HPA at 2.5 GHz (a) *E*-plane (b) *H*-plane

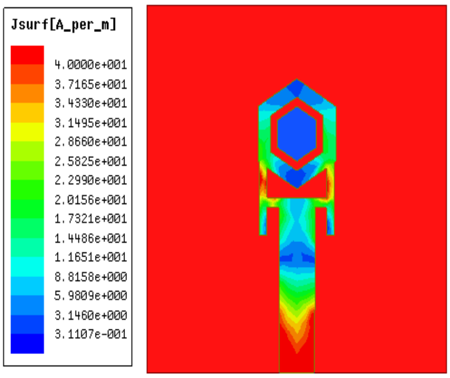


Fig. 5 – Obtained surface current distribution of the HPA

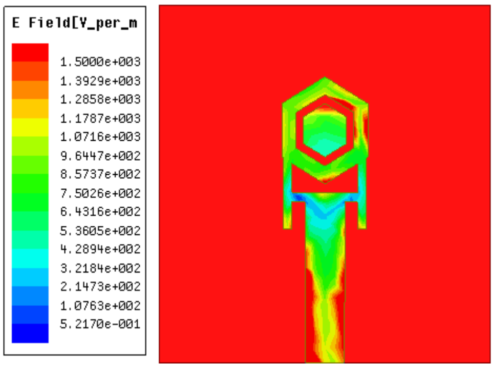


Fig. 6 – *E*-Field distribution of the proposed HPA

Table 2 compares the performance of HPA with other traditional antennas. One benefit of this design is that the antenna with a strip has a broadside radiation pattern over the whole matching bandwidth. The measured gain and impedance bandwidth of the HPA at the specified frequencies are compiled in Table 2. It is easy to see the expected improvement in radiation characteristics, at 2.5 GHz. In the frequency range where the feed structure is present, the increased return loss characteristics are less than − 10 dB.

Table 2 – Comparison table of HPA with the existing literature

Ref	Bandwidth (dB)	Gain (dB)	Dimensions (mm^2)
[15]	4.4 %	2.02	60 × 60
[16]	2.3 %	4.33	22 × 33.54
[17]	3.2 %	3.4	40 × 40
This work	24 %	3.6	40 × 40

4. CONCLUSION

Hexagonal patch antenna is designed utilizing RT duroid substrate and occupies an area of 40 × 40 × 1.5 mm^3. S_{11} of – 18 dB and 3 dBi gain of 3.6 dB gain has been observed at 2.5 GHz. An impedance bandwidth of 24 % has been observed for HPA at 2.5 GHz. VSWR of 1.2 has been observed at 2.5 GHz. Hexagonal patch antenna produces high-quality double-polarized radiation and wide bandwidth, designed and simulated in far-field radiating settings. A novel, lightweight, high gain and wide-bandwidth hexagonal patch antenna is also needed for the 5G smartphone antenna system. The hexagonal patch antenna is a better choice for future 5G cellular applications due to its performance and small architectures. The 5G wireless communication antenna is therefore very different from conventional antennas.

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Аналіз низькопрофільної шестикутної патч-антени для бездротового зв'язку наступного покоління

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Для стільникових мереж наступного покоління представлена нова концепція широкосмугової гексагональної патч-антени. Структура складається з мікросмужкових прямокутників та гексагональних структур загальною площею 40 × 40 × 1,5 мм³. Гексагональна патч-антена розроблена з використанням RT duroid підкладки. Покращений *S*11 понад 15 дБ на резонансній частоті спостерігається на частоті 2,5 ГГц (2,26-2,84 ГГц). Коефіцієнт посилення 3,6 дБ спостерігається на резонансній частоті 2,5 ГГц. Ефективне узгодження імпедансу було досягнуто завдяки використанню технології мікросмужкового живлення лінії передачі та розподіленого розподілу смуг (DGS) у площині землі. Гексагональна патч-антена виробляє високоякісне двополяризоване випромінювання та широку смугу пропускання, розроблене та змодельоване в умовах випромінювання далекого поля. Для антенної системи смартфонів 5G також потрібна нова, легка гексагональна патч-антена з високим коефіцієнтом посилення та широкою смугою пропускання. Шестигранна патч-антена є кращим вибором для майбутніх стільникових застосувань 5G завдяки своїй продуктивності та малій архітектурі.

Ключові слова: Шестигранна патч-антена, Високочастотний набір RFSS, Коефіцієнт підсилення, Системи 5G.