A Dual-Polarized Compact Patch Antenna for Sub-6 GHz 5G Base Stations

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***Abstract*—In this paper, a novel dual-polarized patch antenna with extremely low-profile and compact structure is proposed for Sub-6 GHz 5G base station applications. The proposed antenna avoids using the conventional high-cost multilayer PCB technology, which makes it a low-cost design with a simple configuration. It consists of a radiation patch, a coupled feeding structure and a reflector. The compact size of the antenna can be achieved by etching T shape slots on the radiating patch. A square-ring shape feeding structure is introduced to couple the energy to the patch, achieving polarization of ± 45° and broadening bandwidth. As a result, the dual-polarized antenna could operate from 3.3 to 3.7 GHz with stable radiation patterns. Moreover, a 1 × 3 antenna array is designed and simulation results show that the antenna array could operate from 3.3-3.8 GHz with S_{11}, S_{22} less than -15 dB, high port isolation and stable radiation patterns. The proposed antenna has high potential in the 5G massive multiple-input multiple-output (MIMO) applications.**

***Index Terms* —Patch antenna, ± 45° polarization, compact structure, low profile, massive multiple-input multiple-output (MIMO) application**

I. INTRODUCTION

Massive MIMO technology with 3.5 GHz band (3.3-3.6 GHZ) can simultaneously guarantee signal coverage and channel capacity. Thus , 3.5 GHz band was chosen to be the first frequency band to deploy 5G for major operators including China Telecom and China Unicom.

In addition, in modern communication, polarization diversity is commonly used in the design of base station antennas to reduce the side effects of multipath fading and increase the channel capacity.

As a crucial component in the modern wireless communication system, the base station antenna that can operate in sub-6 GHz 5G bandwidth with low profile, stable radiation patterns and low cross polarization levels has been urgent demands. In recent years, some works on dual-polarized base station antennas for 5G applications [2]-[6] have been carried out.

In [2], a dual polarization, suspended patch antenna covering a broad band of 3.3-3.8 GHz ($|S21| < -30$ dB) is proposed. The size of this antenna is $0.37\lambda_0 \times 0.37\lambda_0 \times 0.15 \lambda_0$. ($\lambda_0$ is the free-space wavelength at 3.55 GHz.) In this design, the L-shaped probe is used to feed the patch, and vertical metal wall is used to increase the port isolation. An extremely compact 5G patch antenna which is composed of main radiator, an annulus, and a reflector is proposed in [3]. The antenna could operate in 3.3-3.6 GHz and has high port isolation as well as gain with compact size $0.29\lambda_1 \times 0.29\lambda_1 \times 0.06\lambda_1$. ($\lambda_1$ is the free-space wavelength at 3.45 GHz.)

In this paper, a compact ±45◦ dual-polarized base station antenna operating in 3.5 GHz bands is proposed. The designed antenna array has good electrical characteristics, including S_{11}, S_{22} < -15 dB, S_{12} < -30 dB at the whole operating frequency bands and stable radiation patterns at both H-plane and V-plane. In addition, the antenna element has great mechanical properties including compact structure ($0.26\lambda \times 0.26\lambda \times 0.09\lambda$, where λ is the free-space wavelength at 3.5 GHz), low profile, high reliability, good stability, light weight.

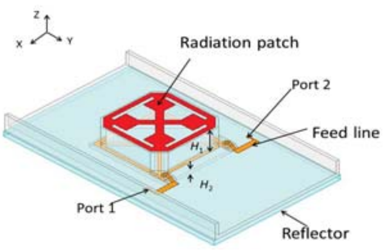
Compared with the other designs, the biggest advantage of the antenna proposed in this work is the small size and simple structure. The performance of the antennas in references is compared with the proposed antenna element in Table I.

TABLE I. COMPARISION OF RELATED WORKS

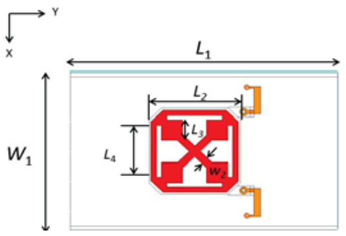
Ref. (Element)	Freq. (GHz)	Size (mm^3)	Port Isolation (dB)
[2]	3.3 - 3.8	32 × 32 × 13.1	< -30
[3]	3.3 - 3.6	25× 25 ×5.3	< -35
[5]	3.3 - 4.27 (S_{11} < -10 dB)	43 × 58 × 11.08 (Include ground plane)	< -20
This work	3.3 - 3.7	22 × 22 × 7.8	< -19

II. ANTENNA ELEMENT DESIGN

To make better description, we define the XOZ-plane as the horizontal plane (H-plane) and YOZ-plane as the vertical plane (V-plane). The geometry of the proposed antenna element is illustrated in Fig. 1. The antenna consists of a main radiation patch, a coupled feeding structure and a reflector. The radiation patch is a square patch of size 22 mm × 22 mm, with four corners cut off and four T-slots etched. By etching the slots, the total size of the radiation patch is reduced compared with conventional square patch antennas. The radiation patch is printed on the top side of the substrate with permittivity of 4.4 and loss tangent of 0.002.



(a)



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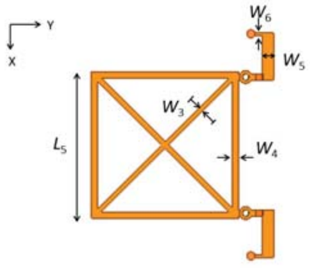


(c)

Fig. 1. (a) 3-D view of the antenna element. (b) Top view of the antenna element. (c) Feeding structure. (Detailed antenna design parameters: L_1 = 63 mm, L_2 = 22 mm, L_3 = 5.4 mm, L_4 = 14 mm, L_5 = 22.6 mm, W_1 = 40 mm, W_2 = 2 mm, W_3 = 0.8 mm, W_4 = 1 mm, W_5 = 1.65 mm, W_6 = 0.5 mm, H_1 = 6.8 mm, H_2 = 1 mm.)

The feeding structure in Fig. 1(c) is composed of a square ring shape microstrip line and a cross microstrip line in the middle of the former. Using this structure, the bandwidth can be extended effectively and the polarization of ± 45° can be achieved. The distance between the microstrip feed line and the reflector (H_2) is 1 mm.

In addition, a substrate with permittivity of 3.3 and loss tangent of 0.0025 is placed above the antenna element to simulate the operating environment in the radome.

The antenna was simulated and optimized in Ansoft HFSS. Fig. 2 shows the comparison of the reflection coefficient between the traditional patch antenna without slots and the proposed antenna element. As can be seen from Fig. 2 that with the same patch size, the resonance frequency

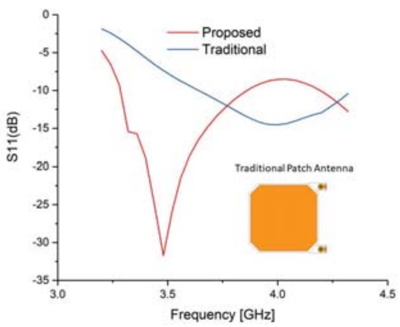


Fig. 2. Simulated S11 between traditional patch antenna and proposed antenna

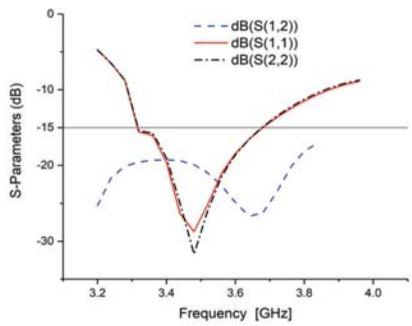


Fig. 3. Simulated S-parameters of the proposed antenna element

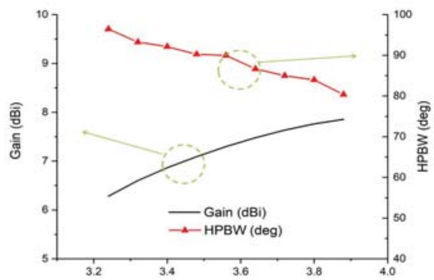


Fig. 4. Simulated gains and HPBW of the proposed antenna element

of the traditional patch antenna is higher than the antenna proposed, which means that the size of the traditional patch needs to be further increased if the resonance frequency of around 3.5 GHz is required. Thus the T-shape slots can effectively reduce the size of the patch antenna.

Fig. 3 shows the S parameters of the antenna element. It operates from 3.3 to 3.7 GHz with S_{11}, S_{22} < -15 dB and the isolation between port 1 and port 2 is less than -19 dB. Stable radiation pattern can also be attained. The gain of the antenna is in the range of 6.6 - 7.7 dBi and the HPBW is in the range of 85 - 93° as shown in Fig. 4.

III. ANTENNA ARRAY

In this section, a 1×3 linear array is designed for base-station applications. As shown in Fig. 5, the size of the antenna array is 40 mm×189 mm, and the spacing between the elements is 63 mm (about 0.73λ).

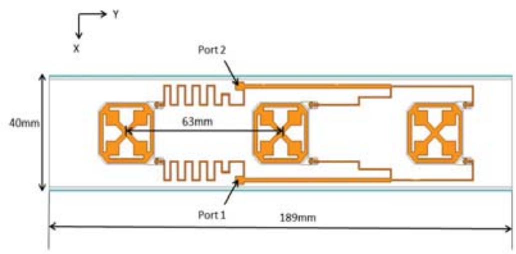


Fig. 5. 1 x 3 antenna array with feeding network

A power distribution network is introduced to feed the antenna, and the power distribution can be realized by changing the width of the microstrip line. By changing the length of the microstrip line, the downdtilt of the antenna array can be adjusted.

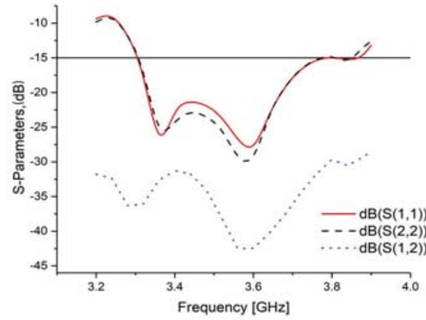


Fig. 6. Simulated S-parameters of the proposed antenna array

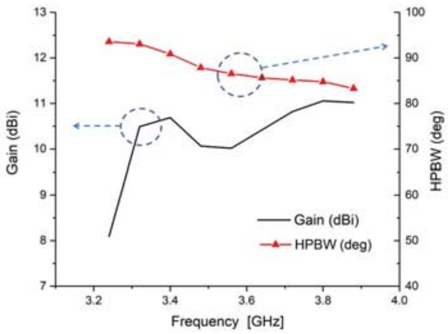
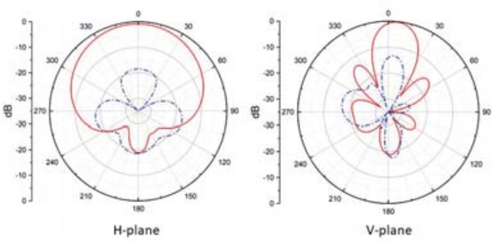
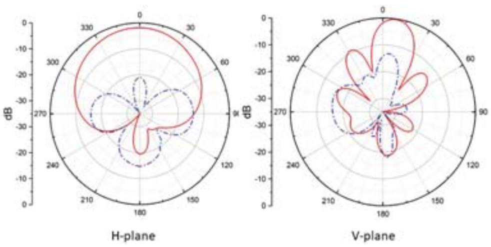


Fig. 7. Simulated gain and HPBW of the proposed antenna array

The S parameters for the antenna array are shown in Fig. 6. It shows that the proposed antenna array could operate from 3.3 GHz to 3.8 GHz band with S11, S22 < -15 dB and the good port isolation < -30 dB could be attained. As shown in Fig. 7, the simulated gain and HPBW over the operating bands are ranging from 10 to 11 dBi and 85° to 93°, respectively. Stable radiation patterns in 3.3-3.8 GHz could also be obtained as shown in Fig. 8.



(a)



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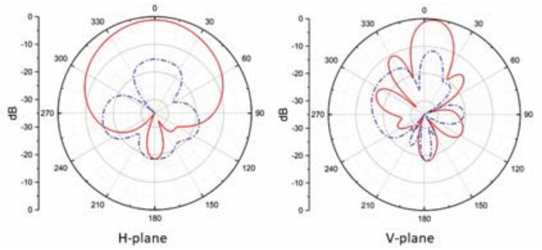

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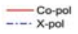

Fig. 8. Simulated H-plane and V-plane radiation patterns of the array when port 1 is excited. (a) 3.3 GHz. (b) 3.6 GHz. (c) 3.8 GHz.

IV. CONCLUSION

In this paper, a broad band, low cost, low profile, dual polarization patch antenna with a simple configuration is proposed for sub-6 GHz 5G base stations. The T-shape slots are etched to reduce the size of the patch. A novel feeding structure is used to extend the bandwidth covering 3.3-3.7 GHz and provide ± 45° slant dual polarization for diversity. The antenna element could meet the index of base station antenna with smaller size (0.26λ × 0.26 λ × 0.09 λ) compared with other designs. A 1×3 array is then proposed to validate the design. The antenna array has a wide operating bandwidth of 3.3-3.8 GHz, high isolation (< -30 dB), stable gain (10 dBi to 11 dBi), and HPBW on the H plane (85° to 93°). Due to these advantages, the proposed antenna is a promising candidate for 5G base station applications.

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