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A Low-Profile Dual-Polarized Wideband Antenna for 5G Massive MIMO Base Station

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***Abstract*—This paper presents a novel low-profile patch antenna with dual-polarization for 5G base station. It consists of a radiation patch and a feed patch. The coupled feed patch excites the radiation patch for dual-polarization. The edges and corners of these two patches are regularly cut to improve impedance matching. There is only a substrate trestle between the two patches, which is a simple structure with low processing cost. The operating frequency range of the patch antenna is 3.3-3.7 GHz, and the size is only 0.37$\lambda\times$0.37$\lambda\times$0.1λ (λ is the wavelength of 3.5 GHz). The simulation results show that the proposed antenna reaches the reflection coefficient $|S_{11}|$, $|S_{22}|$<-15 dB, port isolation $|S_{21}|$<-19 dB, and cross-polarization discrimination (XPD) greater than 27 dB in the operating frequency band. In addition, an 1$\times$3 antenna array is designed based on this antenna element. The antenna array achieves reflection coefficients $|S_{11}|$, $|S_{22}|$<-10 dB, and port isolation $|S_{21}|$<-20 dB in the 3.3-3.7 GHz frequency band. The half-power beam width of H-plane is between 65°-76°, and the radiation pattern is symmetrical and stable. The potential of this antenna in 5G massive multiple-input multiple-output (MIMO) application has been verified.**

***Index Terms*—5G base station, dual-polarization, massive MIMO, low-profile, patch antenna.**

I. Introduction

With the rapid development of the fifth-generation mobile communication technology, the number of 5G communication base stations is rapidly increasing worldwide. Since the N78 frequency band (3.3-3.8 GHz) balances the signal coverage and communication bandwidth rate, it is the most commonly applied frequency band in current 5G communications in many countries and regions.[1] In addition, dual-polarized antennas are widely used in base stations to increase channel capacity and suppress multipath effects.[2] The dual-polarized sub-6 GHz 5G base station antenna has naturally attracted the attention of more and more researchers.

A stacked patch antenna with an extremely low-profile was reported in [3]. The antenna excites the patch to produce dual polarization through aperture coupling, and the operating frequency band is 3.6-3.8 GHz. Due to using the stacked structure with 4 patches, the horizontal size of this antenna is relatively large. In [4], a compact dual-polarized sub-6G base station antenna was proposed and verified. In order to reduce the interference between the devices communicating in different frequency bands, four slots perpendicular to the coupling cross aperture are added to suppress the antenna gain in the high frequency band outside the operating frequency range. [5] demonstrated a suspended dual-polarization patch antenna for 5G base station applications. In this case, the adoption of parasitic patches and vertical metal walls broadened the operating bandwidth and improved the port isolation.

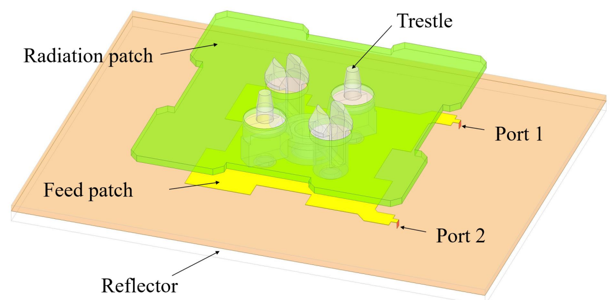


Fig. 1. Perspective view of the proposed antenna.

Based on cited researches, this paper proposes a miniaturized dual-polarized base station antenna with low-profile for 3.3-3.7 GHz frequency band. The size of the proposed antenna is only 0.37$\lambda\times$0.37$\lambda\times$0.1λ, where λ is the wavelength of 3.5 GHz. The detailed parameters comparison of the aforementioned antenna and the one presented in this paper is summarized in Table I. In addition, an 1$\times$3 antenna array is constructed, and differential excitation is achieved through a dedicated feed network. The antenna array reaches the reflection coefficient $|S_{11}|$<-10 dB and the port isolation $|S_{21}|$<-20 dB in the 3.3-3.7 GHz frequency band. The presented antenna not only reveals satisfactory electromagnetic performance, but also has the advantages of simple structure, easy processing and low cost. Therefore, the antenna proposed in this paper is suitable for popularization in 5G base station applications.

II. Antenna Element

The presented dual-polarized 5G base station antenna is shown in Fig. 1. The proposed antenna element consists of a radiation patch and a coupled feed patch. The coupled feed patch drives the radiating patch to achieve dual-polarization. These two patches are only supported by a substrate trestle with dielectric constant of 3.5 and loss tangent of 0.002. Fig.

TABLE I
COMPARISON OF THE REFERENCES AND THIS PAPER

Ref	Freq(GHz)	Size(mm^3)	XPD(dB)	Iso(dB)
[3]	3.6-3.8	81×86×3	34	45
[4]	3.3-4.27	43×58×11.08	22	20
[5]	3.3-3.8	32×32×13.1	26	30
This work	3.3-3.7	32×32×8.7	27	19

TABLE II
GEOMETRIC PARAMETERS (UNIT: mm)

PRM	d_1	d_2	d_3	h_1	h_2	h_3	h_4	l_1	l_2
Value	4	2.6	4.8	0.8	0.762	2	5.9	22	6.5
PRM	l_3	l_4	l_5	l_6	l_7	w_1	w_2	w_3	w_4
Value	2.2	0.7	32	10	1	2.2	2.5	0.7	1.8

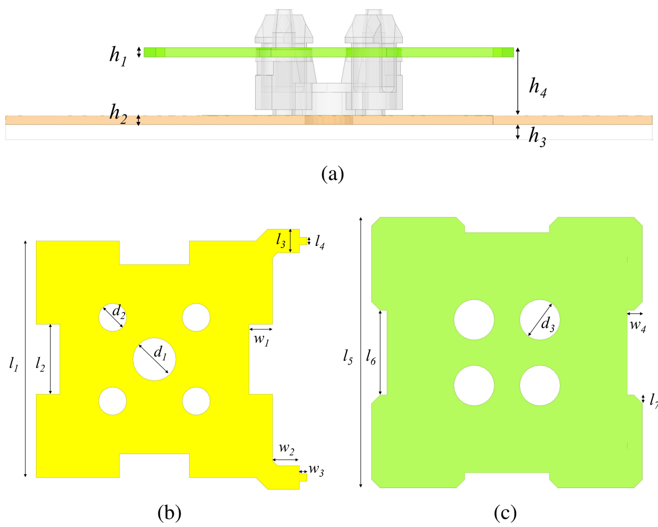


Fig. 2. The (a) side view, (b) feed patch and (c) radiation patch.

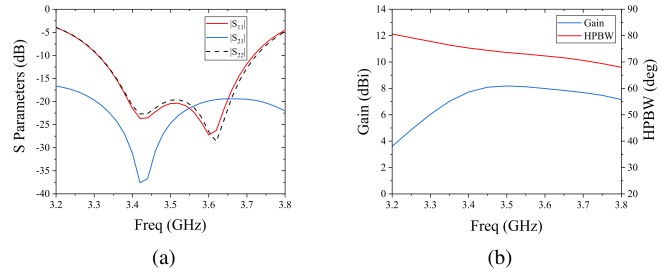


Fig. 3. Simulated (a) S-parameters, (b) HPBW and gain of the element.

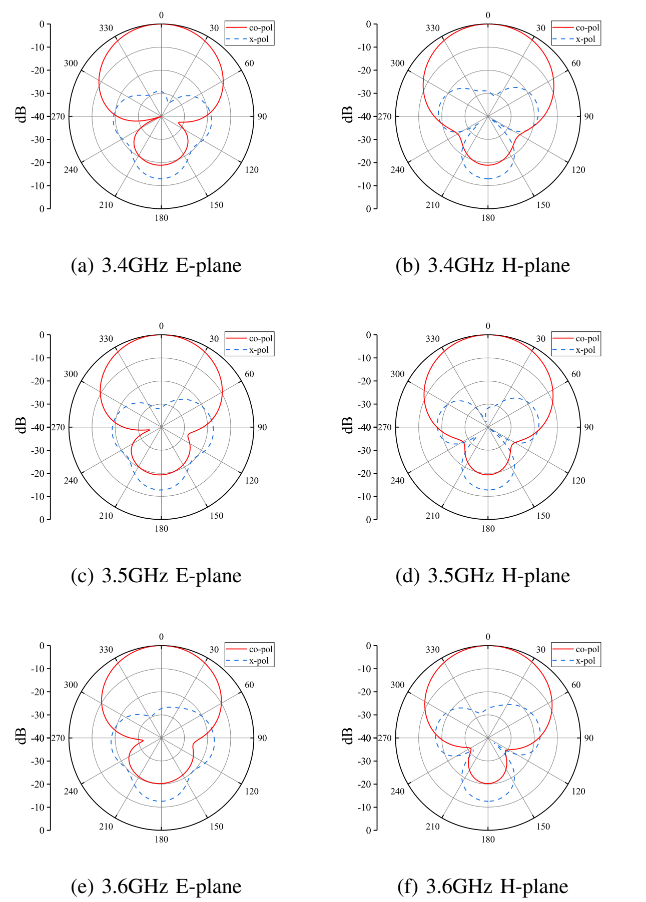


Fig. 4. The element radiation patterns at 3.4 GHz,3.5 GHz and 3.6 GHz.

2(a) gives the side view of the presented antenna. The feed patch of this antenna is laid on a 43 mm×56 mm×0.762 mm Arlon AD300A substrate with dielectric constant of 3 and loss tangent of 0.002. There is a reflector with the thickness of 2 mm at the bottom of the substrate. The radiation patch is fixed 5.1 mm above the feed patch. The structures of the two patches are demonstrated in Fig. 2(b) and Fig. 2(c) respectively. The feed patch is an edge recessed square with five vias in the middle. The radius of the central via is larger than those on the edges. The feed ports are led out from the upper and the lower right corner of the feed patch respectively. The shape of the radiation patch is similar to the feed patch, except that the radiation patch has truncated some corners. The structural design of these two patches improves the impedance matching and broaden the operating bandwidth. Table II summarizes the detailed geometric parameters of the proposed antenna.

Electromagnetic simulation and optimization of the proposed antenna are carried out. Fig. 3(a) describes the variation of the S-parameters of the antenna element with frequency. In the 3.3-3.7 GHz frequency band, the reflection coefficients $|S_{11}|$ and $|S_{22}|$ of the proposed antenna are less than -15 dB, the port isolation $|S_{21}|$<-19 dB. As illustrated in Fig. 3(b), the gain and the half-power beamwidth (HPBW) changes smoothly, the gain is 7.5±0.5 dBi, and the HPBW is 70°-78°. The radiation patterns of this antenna at 3.4 GHz, 3.5 GHz and 3.6 GHz are given by Fig. 4. Symmetry and stability have been achieved in these radiation patterns. The XPD of E-plane and H-plane are both greater than 27 dB.

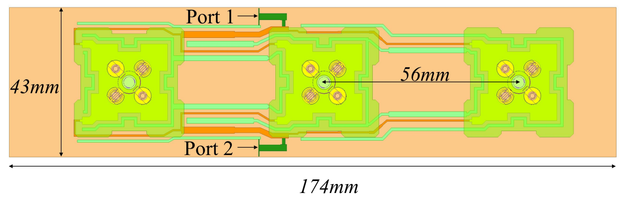
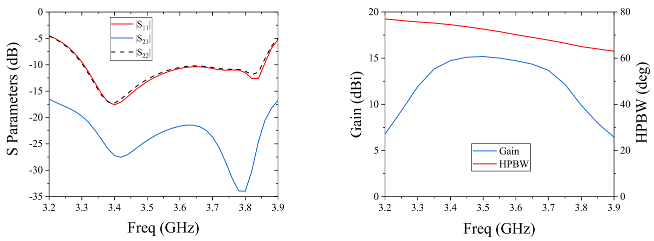


Fig. 5. Top view of the proposed 1×3 antenna array.



(a) (b)

Fig. 6. The (a) S-parameters, (b) HPBW and gain of the antenna array.

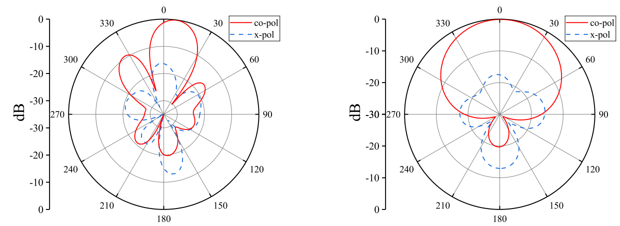
III. Antenna Array

In order to verify the proposed antenna, an one-dimensional linear antenna array based on 3 presented antenna elements is designed, as shown in Fig. 5. The antenna array has the length of 174 mm and the width of 43 mm. The distance between the center of each element is 56 mm. A feed network with power distribution and phase shifting functions is designed to excite the antenna array. A metal envelope structure is placed around the shape of the primary radiation patches and the feed network. This metal wall can improve the isolation between port 1 and port 2 of the antenna array.

The electromagnetic characteristics of this antenna array are analyzed and verified by simulation software. The S-parameters of the proposed antenna array are given by Fig. 6(a). The reflection coefficient $|S_{11}|$, $|S_{22}|$<-10 dB in the frequency band from 3.3-3.7 GHz, the parameter $|S_{21}|$ that reflects the isolation between port 1 and port 2 is less than -20 dB. Compared with a single antenna element, the operating frequency band has widened, but the reflection coefficient of this antenna array is increased. Fig. 6(b) shows the trend curves of the gain and HPBW of the presented antenna array. It can be seen that in the frequency range of 3.3-3.7 GHz, the gain is around 14 dBi, and the half-power beam width is $72° \pm 4°$. The radiation pattern at the center frequency of the operating frequency band (3.5 GHz) is demonstrated in Fig. 7. In the E-plane pattern, the upper sidelobe suppression and the downtilted performance are well achieved. The H-plane radiation pattern maintains symmetry and stability.

IV. Conclusion

A novel patch antenna with dual-polarization is proposed in this paper for 5G base station application. The antenna element consists of a feed patch and a radiation patch, These two patches are only supported by a substrate trestle.



(a) E-plane (b) H-plane

Fig. 7. The radiation patterns of the antenna array at 3.5 GHz.

Therefore, the proposed antenna has miniaturized size of $0.37\lambda \times 0.37\lambda \times 0.1\lambda$, where λ is the wavelength of 3.5GHz. As the simulation results indicate, in the operating frequency band from 3.3-3.7 GHz, the reflection coefficients $|S_{11}|$ and $|S_{22}|$ of the proposed antenna are less than -15 dB, the port isolation $|S_{21}|$<-19 dB, and the gain reaches 7.5±0.5 dBi. The E/H-plane XPD and HPBW of the antenna element are 27 dB and 70°-78° respectively. In addition, a 1×3 antenna array with the size of 43 mm×174 mm×8.7 mm is designed. The simulated reflection coefficients $|S_{11}|$, $|S_{22}|$<-10 dB in the frequency band from 3.3-3.7 GHz, the port isolation $|S_{21}|$ is less than -20 dB as well. In the frequency range from 3.3-3.7 GHz, the array gain is around 14 dBi, and the array HPBW reaches $72° \pm 4°$.

Compared with the cited references, the proposed antenna has obviously advantages in size and structural simplicity. Therefore, it is suitable to popularization in 5G base station applications. The miniaturized volume and satisfactory electromagnetic performance of the presented antenna array verifies the superior potential of this antenna in 5G massive MIMO applications.

Acknowledgment

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References

[1] S. Fu, Z. Cao, X. Quan, and C. Xu, “A broadband dual-polarized notched-band antenna for 2/3/4/5g base station,” *IEEE Antennas and Wireless Propagation Letters*, vol. 19, no. 1, pp. 69–73, 2020.

[2] Y. Li, Z. Zhao, Z. Tang, and Y. Yin, “Differentially fed, dual-band dual-polarized filtering antenna with high selectivity for 5g sub-6 ghz base station applications,” *IEEE Transactions on Antennas and Propagation*, vol. 68, no. 4, pp. 3231–3236, 2020.

[3] Y. Gao, R. Ma, Y. Wang, Q. Zhang, and C. Parini, “Stacked patch antenna with dual-polarization and low mutual coupling for massive mimo,” *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 10, pp. 4544–4549, 2016.

[4] K. Xue, D. Yang, C. Guo, H. Zhai, H. Li, and Y. Zeng, “A dual-polarized filtering base-station antenna with compact size for 5g applications,” *IEEE Antennas and Wireless Propagation Letters*, vol. 19, no. 8, pp. 1316–1320, 2020.

[5] M. Ciydem and E. A. Miran, “Dual-polarization wideband sub-6 ghz suspended patch antenna for 5g base station,” *IEEE Antennas and Wireless Propagation Letters*, vol. 19, no. 7, pp. 1142–1146, 2020.