

# A Low-Profile Dual-Band Dual-Polarized Dipole Antenna for 5G Communication Applications

Shiqiang Fu\*, Xuehao Zhao, Chanjuan Li, and Zhongbao Wang

**Abstract**—A dual-band dual-polarized dipole antenna with an artificial magnetic conductor (AMC) reflector is proposed, which can be applied in 5G base stations. The antenna consists of a pair of  $\pm 45^\circ$  crossed dipoles and a wideband AMC reflector. By adopting arrow-shaped dipoles and introducing slots, dual-band characteristic is achieved. The AMC is designed to operate with  $90^\circ$  reflection-phase bandwidth of 2.1–3.9 GHz (30%). Compared with using traditional reflector, the profile height can be reduced from  $0.25\lambda_0$  to  $0.11\lambda_0$  (where  $\lambda_0$  is the free-space wavelength at 2.6 GHz). The measurement results show that the impedance bandwidth with  $|S_{11}| < -14$  dB is about 15.5% (2.44–2.85 GHz) and 18.6% (3.17–3.82 GHz), covering the Sub-6 GHz bands. The average gain is 8.5 dBi in the lower band and 8.2 dBi in the upper band. At 2.6 GHz and 3.45 GHz, the half-power beamwidth of the antenna is  $77^\circ$  and  $80^\circ$ , respectively. In the two bands, the port isolation of the antenna is more than 28 dB, and the cross-polarization level is less than  $-20$  dB.

## 1. INTRODUCTION

With the rapid development of 5G technology, the demand for base station antennas suitable for new bands is increasing. The 5G network band is mainly divided into two major ranges: Sub-6 GHz and millimeter wave. In China, China Telecom and China Unicom have obtained bands of 3400–3500 MHz and 3500–3600 MHz, respectively. China Mobile has obtained 2515–2675 MHz and 4800–4900 MHz bands, and chose to focus on the development of lower bands. In addition, the three companies jointly use the 3300–3400 MHz band across the country for 5G indoor coverage. Therefore, antennas covering the above bands have become a new direction for base station antenna design.

Extensive researches on base station antennas have been conducted, and many different antenna designs have been presented. For example, the dual-polarized suspended patch antennas proposed in references [1, 2] achieve capacitive coupling and broadband matching by modified feeding structures. However, the patch also greatly increases the profile height of the antenna. Antennas in [3, 4] are cavity-backed antennas based on circular slot arrays and stepped-impedance slot, respectively, with low profile and high gain, but their reflective cavities are not easy to fabricate. Therefore, in order to obtain the advantages such as wide bandwidth and stable pattern, dipole antenna has become the most commonly used form. The antennas in [5–7] adopt the unit structure of differential feeding dipole, folded dipole, and internal embedded coupled dipole, respectively. The impedance bandwidths of the three antennas all achieve the coverage of the 2G/3G/LTE (1710–2690 MHz) bands. In [8, 9], the impedance bandwidth is broadened by introducing slots. The dual-band base station antennas proposed in [10–12] both have filtering functions to achieve harmonic suppression, but the feed structure becomes complicated as a result. The whole antenna [13] is fed by using one arm of the dipole to improve impedance matching. The impedance bandwidth of antenna [14] is enhanced by adding eight parasitic strips and two U-shaped slots. Since the antennas [13, 14] are dipole antennas, in order to achieve

---

Received 10 May 2022, Accepted 26 May 2022, Scheduled 13 June 2022

\* Corresponding author: Shiqiang Fu (fushq@dlmu.edu.cn).

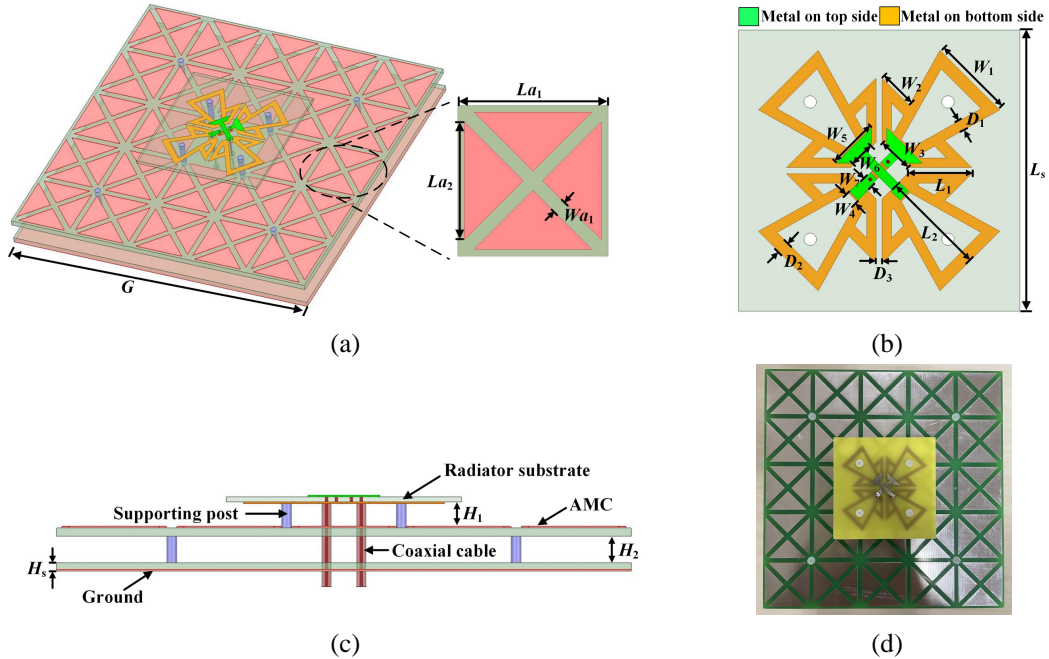
The authors are with the School of Information Science and Technology, Dalian Maritime University, Dalian, Liaoning, China.

unidirectional radiation, the profile height of the antenna is about a quarter of a wavelength. To solve this problem, the traditional PEC reflector is replaced with an AMC reflector. The AMC reflector in [15, 16] has dual-band  $0^\circ$  reflection, but there are problems that the distance between the two bands is too large, and the substrate is expensive. The AMC units of the antennas [17, 18] are both obtained by introducing slots on the square patch, and the profile heights are both reduced by more than 50%.

In this paper, a low-profile dual-band dual-polarized dipole antenna is proposed, which has a stable radiation pattern and high isolation. The antenna adopts a printed dipole structure, which is easy to fabricate. By adopting  $\pm 45^\circ$  crossed slotted arrow-shaped dipoles, the characteristics of dual-bands and dual-polarizations are realized. In addition, the AMC reflector is used instead of the PEC reflector to reduce the antenna profile height. The proposed antenna can be applied to base stations for 5G communication.

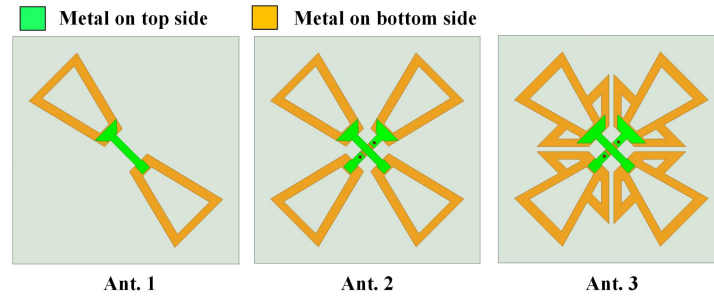
## 2. ANTENNA DESIGN

As shown in Fig. 1, the proposed dual-band antenna is composed of a pair of crossed arrow-shaped dipoles and an AMC reflector. The substrates are supported by eight teflon posts. The antenna radiator is printed on an FR4 substrate with a thickness of 1 mm. As shown in Fig. 1(b), two arrow-shaped dipoles are placed orthogonally and are coupled fed by two T-shaped lines. The feed lines on the two sides are connected through two metal vias with a radius of 0.3 mm. As shown in Fig. 1(c), the outer conductor of the coaxial cables is soldered to one arm of the dipole, and the inner conductor is soldered to the feed lines.

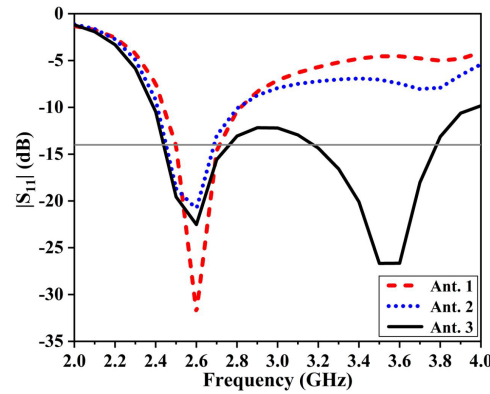


**Figure 1.** Geometry of the proposed antenna. (a) 3-D view. (b) Top view. (c) Side view. (d) Prototype.

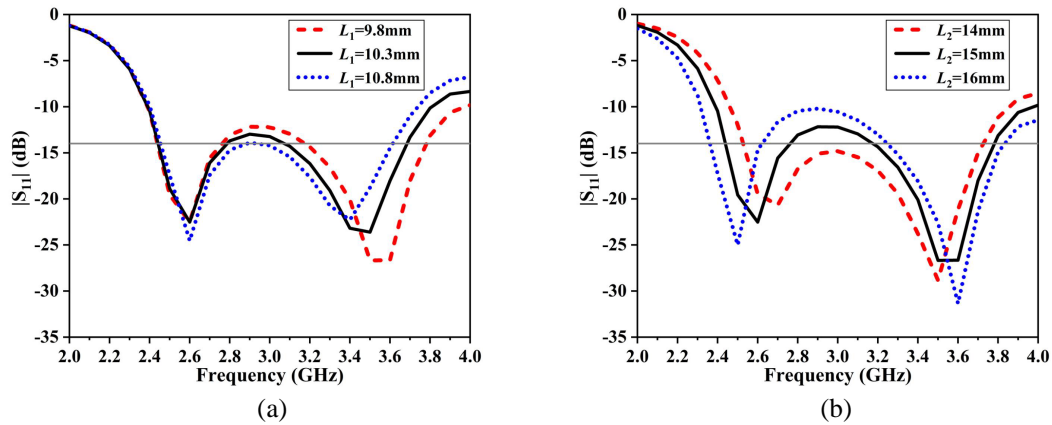
In order to achieve the dual-band dual-polarized radiation, the design process of the proposed dipole radiator is shown in Fig. 2. Ant. 1 is an ordinary bowtie loop dipole. Compared with rectangle, the bowtie shape can improve impedance matching and achieve a wider impedance bandwidth. However, Ant. 1 is a single dipole and cannot achieve dual-polarized radiation. Ant. 2 is obtained by placing two identical Ant. 1 orthogonally, so as to meet  $\pm 45^\circ$  dual-polarized radiation and ensure good diversity reception. The impedance bandwidths of Ant. 1 and Ant. 2 are shown in Fig. 3, and they are both single-band antennas. Therefore, in order to meet the dual-band coverage, the dipole shape is replaced by a slotted arrow-shape in Ant. 3. When one dipole is working, the other dipole acts as a parasitic



**Figure 2.** Evolution of the proposed antenna structure.



**Figure 3.** Reflection coefficients of Ants. 1–3.



**Figure 4.** Simulated reflection coefficients with different. (a)  $L_1$ . and (b)  $L_2$ .

element to add a resonance point to achieve dual-band radiation. The two resonance frequencies of Ant. 3 are mainly affected by parameters  $L_1$  and  $L_2$ . As shown in Fig. 4, when  $L_1$  increases, the upper band moves to the low frequency, while the lower band is basically unchanged. When  $L_2$  increases, the upper band continues to move to high frequency, and the lower band continues to move to low frequency. It shows that the proposed antenna is easy to tune.

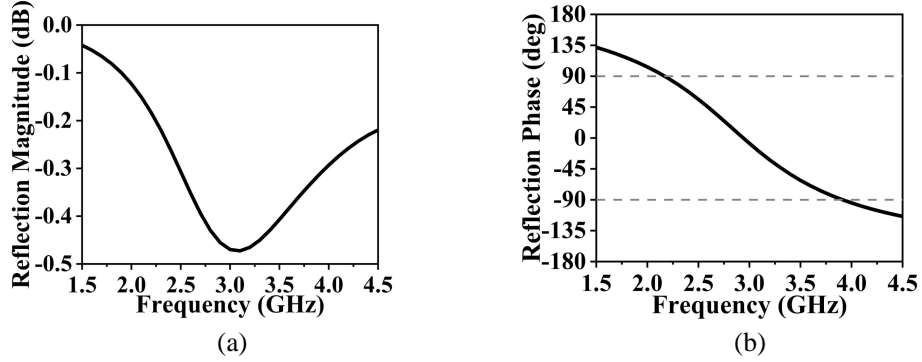
As shown in Fig. 1(a), the AMC reflector is composed of an AMC surface and a metal ground. The AMC surface unit is composed of a square patch and a pair of slotted diagonals, and the reflection amplitude and phase of it are shown in Fig. 5. As shown in Fig. 5(a), reflection amplitudes are more than  $-0.5$  dB over the whole band. Fig. 5(b) shows that the resonance frequency for  $0^\circ$  reflection phase is

3 GHz, and the bandwidth with phase between  $\pm 90^\circ$  is 2.1–3.9 GHz. Through simulation optimization, the other parameters of the antenna are finally obtained as follows:  $G = 110$  mm,  $L_S = 45$  mm,  $L_1 = 10.3$  mm,  $L_2 = 15$  mm,  $W_1 = 13.5$  mm,  $W_2 = 6.1$  mm,  $W_3 = 5.6$  mm,  $W_4 = 2$  mm,  $W_5 = 8$  mm,  $W_6 = 4$  mm,  $W_7 = 1.5$  mm,  $D_1 = 1.5$  mm,  $D_2 = 2$  mm,  $D_3 = 1$  mm,  $H_1 = 5$  mm,  $H_2 = 5$  mm,  $H_S = 1.5$  mm,  $La_1 = 22$  mm,  $La_2 = 17.2$  mm,  $Wa_1 = 2$  mm.

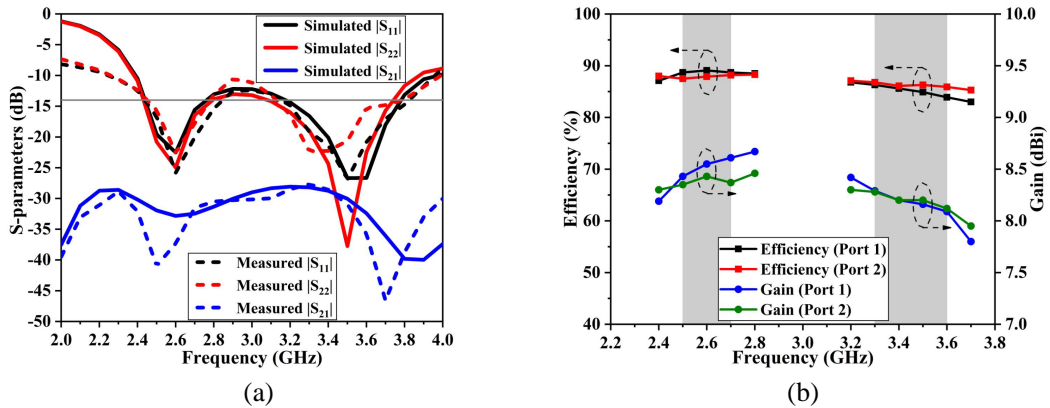
### 3. EXPERIMENTAL RESULTS

The prototype of the proposed antenna is shown in Fig. 1(d). The simulated and measured results of the  $S$ -parameters are compared in Fig. 6(a). The simulated impedance bandwidths for  $|S_{11}| \leq -14$  dB are 2.44–2.76 and 3.18–3.78 GHz, while the measured impedance bandwidths are 2.44–2.85 and 3.17–3.82 GHz. The simulated impedance bandwidths for  $|S_{22}| \leq -14$  dB are 2.43–2.79 and 3.08–3.74 GHz, while the measured results are 2.45–2.77 and 3.13–3.79 GHz. In addition, the simulated and measured  $|S_{21}|$  are less than  $-28$  dB in both bands.

The measured results of the efficiency and gain of the proposed antenna are shown in Fig. 6(b). The measured efficiencies are 88.7%–89.1% and 83.9%–86.3% in the lower band and upper band for Port 1, respectively. The measured average gains for Port 1 in the two bands are 8.5 dBi and 8.2 dBi, respectively, with a change of less than 0.2 dB. For Port 2, the average gain is 8.3 dBi and 8.2 dBi in the two bands, respectively. The normalized radiation patterns when Port 1 is excited at 2.6 GHz and 3.45 GHz are shown in Fig. 7. At 2.6 GHz, the measured half power beamwidths (HPBW) are  $77^\circ$  and  $60^\circ$  in the  $H$ -plane and  $E$ -plane. At 3.45 GHz, the measured HPBW is  $80^\circ$  and  $60^\circ$  in the two planes, respectively. In addition, the measured cross-polarization level is basically less than  $-20$  dB, and the front-to-back ratio is larger than 20 dB over both operating bands.



**Figure 5.** Reflection magnitude and phase of the proposed AMC. (a) Magnitude. (b) Phase.

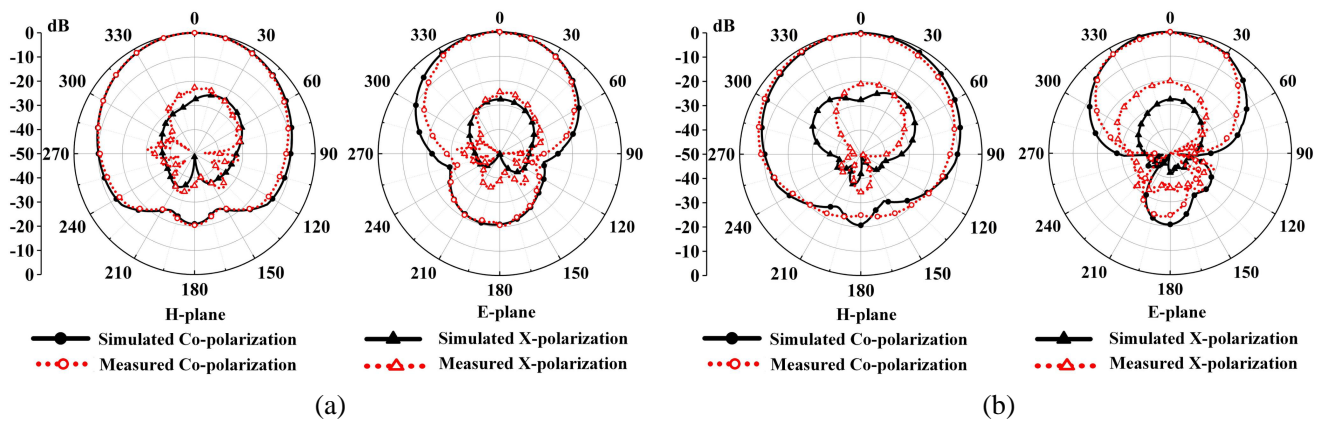


**Figure 6.** Simulated and measured results of the proposed antenna. (a) Simulated and measured  $S$ -parameters. (b) Measured radiation efficiency and gain.



**Table 1.** Comparison of the proposed antenna and reference antennas ( $\lambda_c$  represents the free-space wavelength at the center frequency of the lower band).

Ref.	Frequency Band (GHz)	Profile ( $\lambda_c$ )	Port Isolation (dB)	Gain (dBi)	HPBW ( $^\circ$ )
[2]	2.78–4.4 (45%) ( $ S_{11}  < -10$ dB)	0.14	$> 30$	$8.95 \pm 0.25$	60
[9]	2.14–3.66 (52.4%) 4.48–5.04 (7.4%) ( $ S_{11}  < -10$ dB)	0.28	$> 25$	9.5 5.5	63.5
[10]	2.5–2.7 (0.08%) 3.3–3.6 (0.09%)	0.23	$> 30$	$8.45 \pm 0.15$ $7.65 \pm 0.15$	61 66
[12]	3.12–3.9 (22.2%)	0.14	$> 35$	$8.1 \pm 0.3$	64
[13]	3.3–3.8 (14.1%) 4.8–5.0 (0.04%) ( $ S_{11}  < -10$ dB)	0.21	$> 20$	7.56 7.42	65
[14]	3.2–3.9 (19.7%)	0.17	$> 40$	$6.8 \pm 0.3$	80
Prop.	2.44–2.85 (15.5%) 3.17–3.82 (18.6%)	0.11	$> 28$	$8.5 \pm 0.3$ $8.2 \pm 0.2$	77 80

**Figure 7.** Simulated and measured radiation patterns for Port 1. (a) 2.6 GHz. (b) 3.45 GHz.

A comparison between the proposed antenna and reference antennas is shown in Table 1. It can be seen that the impedance bandwidth for  $|S_{11}| < -14$  dB of the proposed antenna is broader and can cover more 5G bands. Compared with other antennas, the profile height is lower, and the HPBW is wider. Meanwhile, the gains of other antennas are lower than the proposed antenna except for [2] and [9]. Different from die-casting technology and expensive substrate, the proposed antenna is printed on an FR4 substrate, which is easy to fabricate and low in cost.

#### 4. CONCLUSION

A dual-band dual-polarization low-profile dipole antenna for 5G communications is proposed. A pair of slotted arrow-shaped crossed dipoles are used as the radiator of the antenna and are fed by a pair of crossed T-shaped coupling lines. The two dipoles are parasitic elements for each other, thus realizing dual-band radiation. In addition, by replacing the traditional reflector with an AMC reflector, the profile height is reduced to  $0.11\lambda_0$ . The measured results show that the impedance bandwidths of the antenna are 2.44–2.85 GHz and 3.17–3.82 GHz, and the isolation is relatively high. At 2.6 GHz, the peak gain and HPBW are 8.5 dBi and  $77^\circ$ . At 3.45 GHz, the peak gain and HPBW are 8.2 dBi and  $80^\circ$ , respectively.

#### ACKNOWLEDGMENT

National Natural Science Foundation of China, Grant/Award Number: 61871417.

#### REFERENCES

1. Ciydem, M. and S. Koc, "High isolation dual-polarized broadband antenna for base stations," *Microw. Opt. Technol. Lett.*, Vol. 57, 603–607, 2015.
2. Ciydem, M. and E. A. Miran, "Dual-polarization wideband sub-6 GHz suspended patch antenna for 5G base station," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 19, No. 7, 1142–1146, 2020.
3. Wen, S., Y. Xu, and Y. Dong, "A low-profile dual-polarized omnidirectional antenna for LTE base station applications," *IEEE Transac. Antennas Propag.*, Vol. 69, No. 9, 5974–5979, 2021.
4. Lian, R., Z. Wang, Y. Z. Yin, et al., "Design of a low-profile dual-polarized stepped slot antenna array for base station," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 15, 362–365, 2016.
5. Liu, Y.-Y. and Z.-H. Tu, "Differential enhanced broadband dual-polarized printed dipole antenna for base stations," *Microw. Opt. Technol. Lett.*, Vol. 58, 2864–2868, 2016.
6. Ye, L. H., X. Y. Zhang, Y. Gao, et al., "Wideband dual-polarized four-folded-dipole antenna array with stable radiation pattern for base-station applications," *IEEE Transac. Antennas Propag.*, Vol. 68, No. 6, 4428–4436, 2020.
7. Martin-Anton, S. and D. Segovia-Vargas, "Fully planar dual-polarized broadband antenna for 3G, 4G and sub 6-GHz 5G base stations," *IEEE Access*, Vol. 8, 91940–91947, 2020.
8. Cui, G. F., S. G. Zhou, S. X. Gong, et al., "Design of a dual-polarized wideband antenna for 2G/3G/4G mobile communication base station application," *Microw. Opt. Technol. Lett.*, Vol. 58, No. 6, 1329–1332, 2016.
9. Zhu, C., B. Wang, W. Luo, et al., "Dual-wideband dual-polarised magnetoelectric dipole antenna for 4G/5G microcell base station," *Electron Lett.*, Vol. 56, No. 6, 269–271, 2020.
10. Liu, Y., S. Wang, et al., "A compact dual-band dual-polarized antenna with filtering structures for sub-6 GHz base station applications," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 17, No. 10, 1764–1768, 2018.
11. Chu, Q. X., Y. L. Chang, and J. P. Li, "Crisscross-shaped  $\pm 45^\circ$  dual-polarized antenna with enhanced bandwidth for base stations," *IEEE Transac. Antennas Propag.*, Vol. 69, No. 4, 2341–2346, 2021.
12. Li, Y., Z. Zhao, Z. Tang, et al., "Differentially-fed, wideband dual-polarized filtering antenna with novel feeding structure for 5G sub-6 GHz base station applications," *IEEE Access*, Vol. 7, 184718–184725, 2019.
13. Li, Z., J. Han, Y. Mu, et al., "Dual-band dual-polarized base station antenna with a notch band for 2/3/4/5G communication systems," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 19, No. 12, 2462–2466, 2020.
14. Li, M., X. Chen, A. Zhang, et al., "Dual-polarized broadband base station antenna backed with dielectric cavity for 5G communications," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 18, No. 10, 2051–2055, 2019.

15. Zhai, H., K. Zhang, S. Yang, et al., "A low-profile dual-band dual-polarized antenna with an AMC surface for WLAN applications," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 16, 2692–2695, 2017.
16. Lin, J., Z. Qian, W. Cao, et al., "A low-profile dual-band dual-mode and dual-polarized antenna based on AMC," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 16, 2473–2476, 2017.
17. Liu, Q., H. Liu, W. He, et al., "A low-profile dual-band dual-polarized antenna with an AMC reflector for 5G communications," *IEEE Access*, Vol. 8, 24072–24080, 2020.
18. Li, M., Q. L. Lia, B. Wang, et al., "A low-profile dual-polarized dipole antenna using wideband AMC reflector," *IEEE Transac. Antennas Propag.*, Vol. 66, No. 5, 2610–2615, 2018.