A Compact and High Isolation Dual Polarization Antenna for Micro-base Station

Bo Yin, Xingxing Feng, Shenwei Mao, and Lijun Sun

***Abstract*—**A compact, low-profile and high isolation dual-polarized patch antenna with good radiation pattern is proposed for micro-base station (operating in 2.5-2.7GHz). This antenna consists of two horizontal substrates and two vertical substrates, both placed orthographically. Low-profile is achieved by employing electromagnetic feed and *Γ* shape feed line. Hybrid feed structure is used to obtain the high port isolation. The differential feed network in port 2 enhances the port isolation and suppresses the cross polarization level. A metal wall is loaded to improve the radiation pattern. For demonstration, the proposed antenna is fabricated and measured. The operation frequency of port 1 and port 2 which can be observed in the measured results are both around 2.6GHz. The desired isolation and radiation characteristics are achieved.

***Keywords*—**Dual-polarized antenna, Micro-base station, Isolation, Low-profile.

I. INTRODUCTION

Although the scale and type of mobile communication service is increasing, mobile traffic service still accounts for a large proportion of the total services. However, there are some practical problems in this industry. For example, insufficient traffic capacity emerging in some crowded public places or office buildings is one issue that plagues us. Additionally, communication interference in remote areas is caused by coverage blind. In order to deal with these problems, a micro-base station should be adopted to provide irreplaceable advantages, except the lower financial and labor cost, compared with the conventional base station.

As base station antennas, microstrip antennas are widely applied because of their characteristics, such as low-profile, lightweight and easy fabrication. What's more, microstrip antennas are conveniently integrated with active circuit [1]. Nowadays, micro base station antenna element with smaller size, compact arrangement, lower height, better integration with circuit is widely used, which makes the coupling between antenna, surface wave interference, internal environment energy reflection of antenna drawing much attention increasingly. The enhancement of mutual coupling will cause the distortion of antenna radiation pattern and SWR. Besides, it is not facile to obtain high port isolation with the limit of the restricted space. Therefore, low-profile, high isolation and compact micro-strip antennas are promising.

Many studies about impedance match bandwidth and isolation of micro-strip base station antenna have been published. Multilayered structure is used to acquire wide bandwidth in restricted space, but the impedance bandwidth is not wide enough for VSWR<1.5, besides, the front-to-back ratio is unacceptable [2-5]. In [6-7], aperture-coupled microstrip feed is adopted to generate dual polarization characteristic for base station antenna, but the port isolation is not good. A dual-polarized micro-base station antenna consists of a pair of PIFAs in [8], but its gain of the PIFA is 4dBi which needs to improve, and the port isolation is also less than 30dB. A microstrip antenna with parasitic elements has a center frequency around 2.6 GHz is proposed in [9], by using two line-polarized radiation patches, the antenna obtains polarization diversity characteristic, but its size is quite large.

A hybrid-feeding dual-polarized microstrip antenna with an aluminum wall for micro-base station is proposed in this paper. The height of the antenna is 22.2mm. The +45° polarization is generated by electromagnetic feed, and the -45° polarization is excited by a pair of *Γ* shape micro-strips with a phase difference of 180°. The 33dB port isolation is achieved by using the hybrid-feeding structure and the differential feed network in port 2. Besides, the aluminum walls improve the radiation pattern. The HPBM of each E and H plane are both more than 60° in the whole frequency band, and the cross-polarized level is below 20dB. Furthermore, the front-to-back ratio is 15dB and the gain is more than 7dBi. The proposed antenna satisfies the needs of micro-base station antenna.

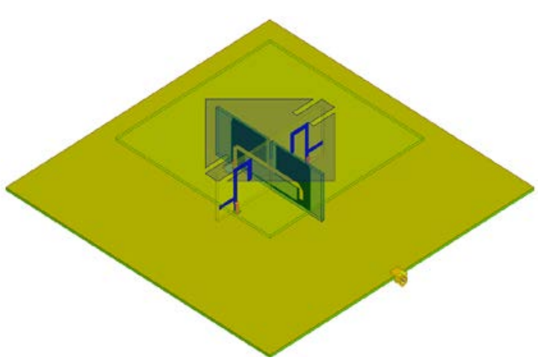
II. ANTENNA DESIGN

In order to improve the communication efficiency, ±45 degree dual polarization antenna is used in this design. Dual polarized antenna is one of the main types of base station antenna. It combines two antennas with orthogonal polarization direction, which can realize the function of receiving or transmitting signals simultaneously. Now the

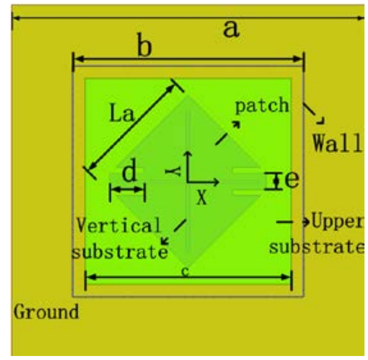
This work was supported by Chongqing Collaborative Innovation Center for Information Communication Technology, and the Foundation of Chongqing Educational Committee (KJ130512 and KJ1600438).
Bo Yin is a master tutor of Chongqing University of Posts and Telecommunications.
Xingxing Feng is a graduate student of Chongqing University of Posts and Telecommunications. (Corresponding author e-mail : 997809279@qq.com)
ShenWei Mao is a graduate of Chongqing University of Posts and Telecommunications.
Lijun Sun is a graduate of Chongqing University of Posts and Telecommunications.

use of dual polarized antenna is mainly ±45 degree polarized antenna. In the past, single polarized antenna is often used in mobile communication, mainly vertical polarized antenna. The polarization current is generated on the earth surface when the horizontal polarization antenna propagates on the ground, and it turns into thermal energy due to the impedance of the earth, which makes the electric field attenuate. However, the vertical polarized antenna is not easy to generate polarization current, which can avoid serious energy attenuation. This is the reason why the vertical polarized antenna used in mobile communication is used. However, because of vertical polarized antenna widely used, the polarization mode of the antenna is single. The only to improve the communication efficiency is to adopt the space diversity. The polarization diversity technique, used in the dual polarized antenna, is more advantageous than the spatial diversity by comparison. In a dual polarization antenna system, the two polarization systems consist of ± 45 degrees have the same propagation efficiency. Therefore, the two systems can be used well as the receiving and transmitting system.

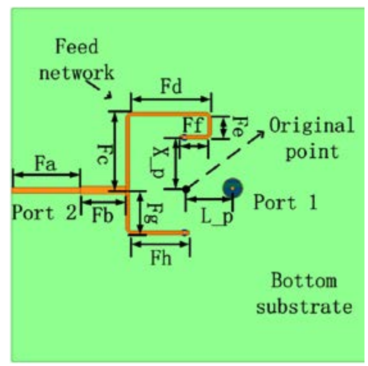
Fig. 1 shows the geometry of the dual-polarized patch antenna. The antenna consists of a horizontal substrate, a horizontal ground plane, and two vertical substrates. And these four substrates are all 1 mm-thick FR4 substrates ($\varepsilon_r = 4.4$). A square copper plate loaded with slots is on the bottom surface of the upper horizontal substrate. For the square patch, the edge length is determined by its resonant frequency. The initial value of La can be estimated as $\lambda_e/2$, where λ_e is the equivalent wavelength for the guided wave in the substrate. And the ground and the differential feed network are on the other horizontal substrate as showed in Fig. 1. Between the upper and lower horizontal substrates, two vertical substrates are placed orthogonally. And two feed structures are designed on two vertical substrates respectively. The feed network is on one of the vertical substrate which solders both Γ shape strips (width of Γ shape strips is 1.5mm). Besides, four aluminum walls are loaded around the antenna. A prototype has been fabricated, and its photograph is showed in Fig. 2.



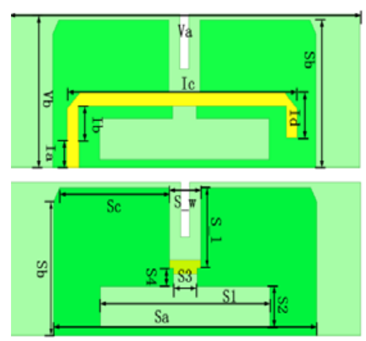
(a) 3D view of proposed antenna



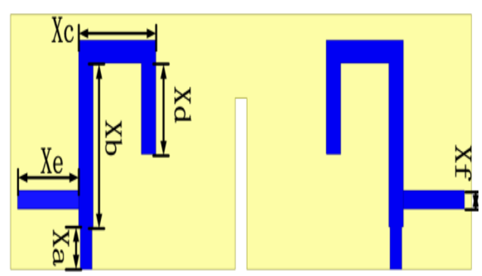
(b) Vertical view



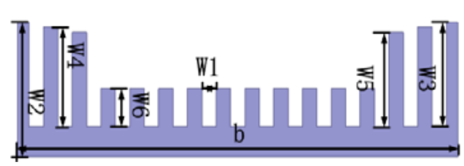
(c) Differential feeding network



(d) Magnetically coupled feeding structure

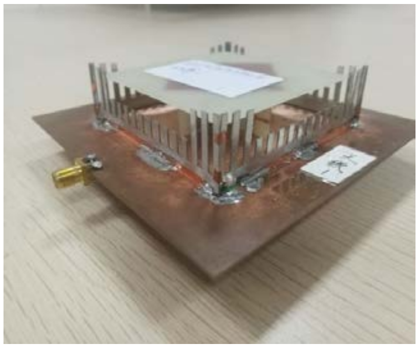


(e) Γ shape feeding line



(f) Aluminum walls

Fig. 1. Geometry of the proposed antenna



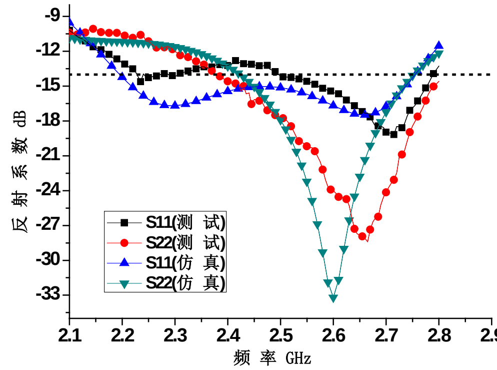
(a) Fabrications of antenna element

(b) Test antenna installed at test gauge in anechoic chamber room

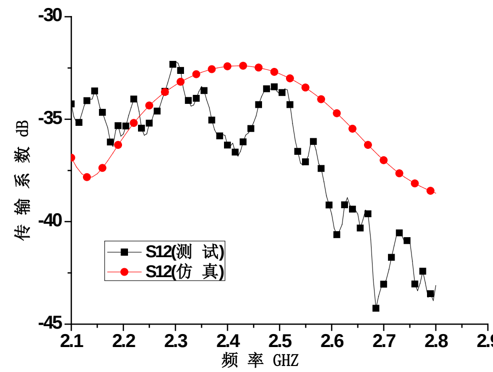
Fig. 2. Photograph of the proposed antenna

III. RESULTS AND DISCUSSION

The S parameter of the proposed antenna can be seen in Fig. 3. The operation frequency of port 1 and port 2 are 2.50GHz-2.78GHz and 2.38GHz-2.90 GHz respectively. 32dB isolation is achieved because the feed structure of port 2 is under the position of null-current locus when port 1 is excited. Port 1 uses magnetically couple to generate +45° polarization [10]. An open-end transmission line and a metal loop with a *T* shape slot are printed on one of the vertical substrates. The *T* shape slot has different widths, so a good impedance matching is achieved. The open-end transmission line divides the *T* shape slot into an open-end slot and a shorted-end slot [12].



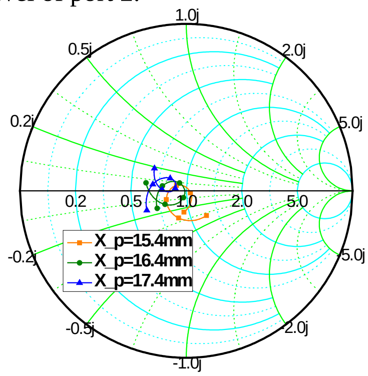
(a) Reflection coefficient of proposed antenna



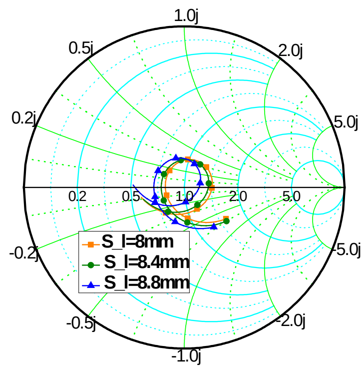
(b) Transmission coefficient of proposed antenna

Fig. 3. Simulated S-parameter for proposed antenna

In Fig. 4, length and width of the two slots impact the impedance bandwidth significantly. The input impedance plot moves to the left due to the increase in *s_l* and *x_p*. By optimizing the parameters, the input impedance is matched with characteristic impedance from 2.5GHz to 2.7GHz, and the high frequency part of the antenna will be more matched. In Fig. 5, it is obvious that more current flows along the *T* shape slot, which brings the changed current path and stronger coupling in slot. These conditions may cause more resonant modes to be excited. In other words, the two slots, which are optimized to achieve wide impedance bandwidth, could be interpreted as two *LC* resonant circuits. Because the metal loop is capacitive coupling to the radiator, the height of it needs to adjust to match antenna input impedance. Besides, at the top of the metal loop, two corners are modified. Different values of *S1* (the width of upper part of *T* shape slot), which influence the high frequency bandwidth, are illustrated in Fig.4. The *Γ* shape strips are on the other vertical substrate and soldered to feed network [11]. The *Γ* shape strips are comprised of two different widths of micro-strips. And an open-end strip (length and width of it are 6.4mm and 1.2mm respectively) is added on both two *Γ* shape strips to tune the impedance matching. The open-end strip cannot close to the patch, because it will bring remarkable capacitive coupling. The height of shape strip is 15.1mm. By properly optimizing the shape and the position of *Γ* shape strips, the input impedance matching of port 2 is acquired. Fig. 4 presents the effect of changing the position on S_{22}. Anti-phase feeding network decreases the cross polarization level of port 2.

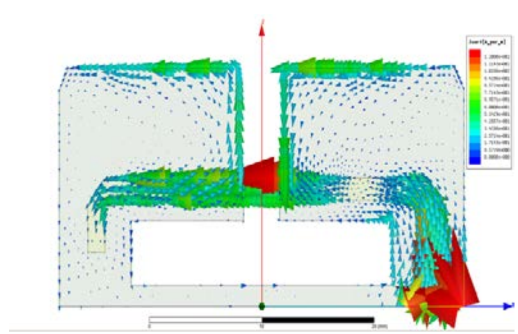


(a) Simulated impedance curve of proposed antenna versus different length of upper slot

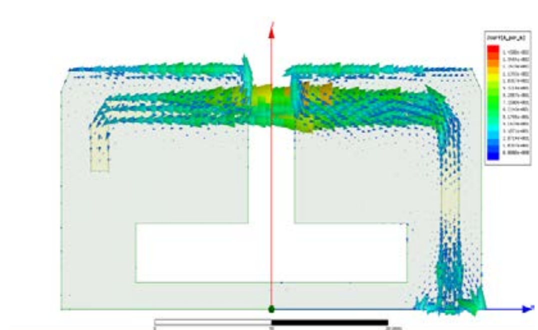


(b) Simulated impedance curve of proposed antenna versus different position of *Γ* shape strip

Fig. 4. Simulated impedance curve of proposed antenna



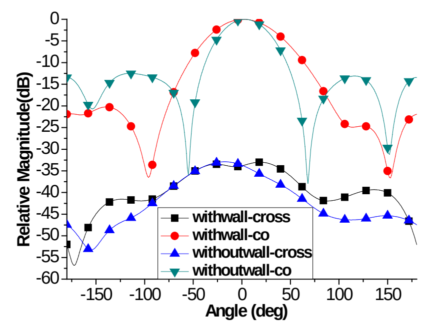
(a) Simulated current vector on proposed fed structure of port 1



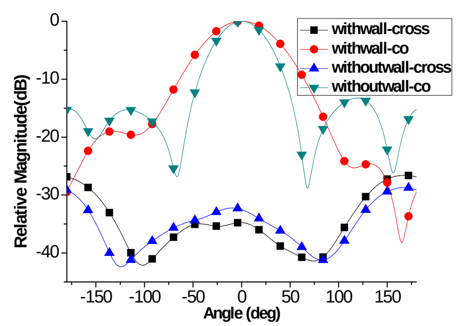
(b) Simulated current vector on conventional feed structure of port 1

Fig. 5. Simulated current vector of port 1

Four zigzag aluminum walls (thickness of the wall is 0.5mm) are located around the dual-polarized antenna. Fig. 1 shows the construction of the zigzag aluminum wall. From edge to middle, the height of the wall gradually decreases. As indicated in Fig. 6, when antenna element is not loaded the aluminum walls, and the gain is high, but beam width is not enough wide to meet the requirements for HPBW about 60°. Obeying the principle of mirror image, loading metal aluminum wall is a good way to solve these problems. In Fig. 6, it shows that when the walls are loaded, both HPBW of +45° and -45° polarization are concentrated effectively in H-plane. Besides, when the beam width becomes wider, the radiation intensity will be more uniform, which leads to the main radiation direction of the gain decreases. The measure and simulation of radiation pattern are presented in Fig. 7. Stable radiation patterns at 2.7GHz are provided, the cross-polarization levels are under -20 dB, and the front-to-back ratio is around 20dB. Because of welding and measuring error, in Fig. 7(d), the cross-polarization level is not completely consistent with the simulation date. The measure result also shows the walls deteriorate the gain from 9dBi to 7dBi. Some of optimized parameters are mentioned in TABLE 1.

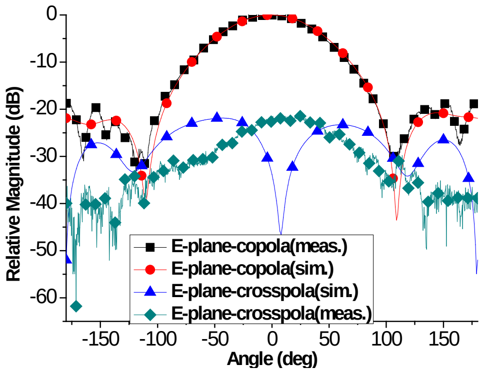


(a) H-plane radiation pattern of port 1

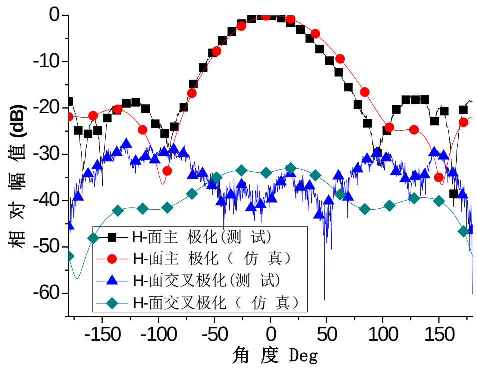


(b) H-plane radiation pattern of port 2

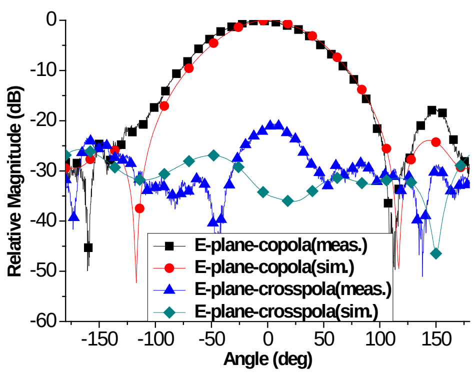
Fig. 6. With/without of Aluminum walls for H-plane radiation pattern



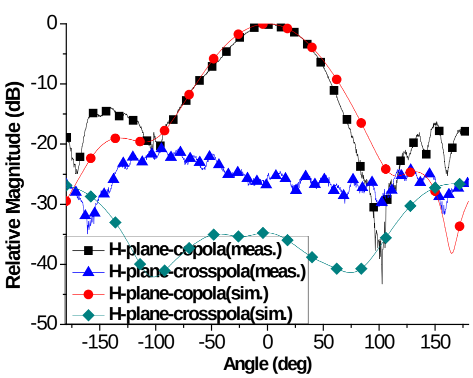
(a) E-plane of port 1



(b) H-plane of port 1



(c) E-plane of port 2



(d) H-plane of port 2

Fig. 7. Radiation pattern of two ports at 2.7GHz

TABLE 1

Design Parameter Value

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
a	120	*Sb*	16.2	*Sa*	36
b	78	*S_w*	4.2	*W6*	6
c	70	*S_l*	8.8	*Id*	5
d	11.4	*S3*	3.2	*W5*	14.9
e	5.65	*S4*	2	*Ic*	30
La	41.5	*S1*	23.2	*W4*	15.7
Fa	23.3	*S2*	4.5	*Ib*	3.8
Fb	15.5	*Sc*	15.1	*W3*	16.5
Fc	26.6	*Sd*	16.2	*Ia*	3
Fd	28	*Xa*	2.8	*W2*	21.3
Fe	8	*Xb*	10.8	*Vb*	16.8
Ff	9.6	*Xc*	8	*W1*	2.5
Fg	14.9	*Xd*	6	*Va*	48
Fh	20.3	*Xe*	6.4	*Xf*	4

IV. Conclusion

A dual polarization square patch antenna with two feed structures orthographically placed is designed and fabricated. S11 and S22 are below -14dB from 2.5 GHz to 2.75 GHz. The differential feeding network and hybrid feeding restrain cross-polarization level and improve port isolation. To obtain enough bandwidth, a modified electromagnetic feed structure and Γ shape microstrip feed structure are employed. By using FR4 and aluminum walls, low cost, low profile and stable radiation pattern are easily achieved. Overall, the proposed dual-polarized antenna is suitable for the application of the micro-base station antenna.

Acknowledgment

This work is supported by Chongqing Collaborative Innovation Center for Information Communication Technology, and the Foundation of Chongqing Educational Committee (KJ130512 and KJ1600438).

References

[1] K.L. Wong, “Compact and broadband microstrip antennas,” New York, NY:John Wiley&Sons, 2002,ch.5.

[2] B. Li, S.W. Yang, M. Huang, and Z.P. Nie, “A Compact and Dual-Polarized Microstrip Array Antenna for Mini Base Station Applications,” Int. Workshop on Microwave and Millimeter Wave Circuits and System Technology(MMWCST), Chengdu, 2012, pp 1-3.

[3] Q. Zhu, S. Yang, and Z. Chen, “Modified corner-fed dual-polarised stacked patch antenna for micro-base station applications,” Electronics Letters, 2015, 51 (8):604-606.

[4] J. Li, S. Yang, B. Li, and Z. Nie, “A low profile dual-band dual polarized patch antenna array with integrated feeding network for pico-base station application,” Microwave & Optical Technology Letters, 2014, 56 (7) :1594–1600.

[5] A.G. Miquel, S. Curto, N. Vidal, J.M. Lopez-Villegas, F.M. Ramos, and P. Prakash, “Multilayered Broadband Antenna for Compact Embedded Implantable Medical Devices: Design and Characterization,” Progress In Electromagnetics Research, PIER 159, 1-13, 2017.

[6] W.W. Li, C. Wang, Y.Q. Lai, and J.H. Zhou, "A compact dual-polarized cavity-backed annular slot antenna for indoor mimo systems," Microwave & optical Technology Letters, 2015 , 57 (2) :384-388.
[7] H.W. Lai, K.M. Mak, and K.F. Chan, "Novel Aperture-Coupled Microstrip-Line Feed for Circularly Polarized Patch Antenna", Progress In Electromagnetics Research, PIER 144, 1-9, 2014.
[8] J.N. Lee, H.K. Kwon, K.C. Lee, "Design of a dual-polarised small base station antenna with a metallic isolator for micro-cell systems," Microwaves Antennas & Propagation Iet, 2015 , 9 (10) :1080-1086.
[9] O.Soykin, A. Kolobov, V. Ssorin, A. Artemenko, and R. Maslennikov, "Planar MIMO antenna system with polarization diversity for 2.5-2.7GHz LTE indoor femrocells," In:9th European Conference on Antennas and Propagation (EuCAP), Lisbon, 2015, pp 1-5.
[10] J.J. Xie, Y.Z. Yin, J.H. Wang and X.L. Liu, "Wideband dual-polarised electromagnetic fed patch antenna with high isolation and low cross-polarisation," Electronics Letters, 2013 , 49 (3) :171-173.
[11] J. Zhang, X.Q. Lin, L.Y. Nie, J.W. Yu, and Y. Fan, "Wideband dual-polarization patch antenna array with parallel strip line balun feeding," IEEE Antennas & Wireless Propagation Letters, 2016 , 15 :1499-1501.
[12] Y.Y. Liu, Z.H. Tu, Q.X. Chu, "Differentially T-shape slot antenna with high common-mode suppression for 2.4/5.2/5.8 GHz WLAN MIMO system," In:2015 Asia-Pacific Microwave Conference (APMC), Nanjing, 2015, pp 1-3.

Bo Yin, the first author of this paper, is a master tutor of Chongqing University of Posts and Telecommunications. And his main research directions are as follows: MIMO technology in radio communication, radio frequency microwave circuit.

Xingxing Feng, the corresponding author of this paper, is a graduate student of Chongqing University of Posts and Telecommunications. Her research directions are antenna and radio wave propagation

ShenWei Mao completed his degree and master's in Chongqing University of Posts and Telecommunications. And his research directions were the design of MIMO antenna and base station antenna.

Lijun Sun completed his master's in Chongqing University of Posts and Telecommunications. And his research direction was the design of MIMO antenna for mobile terminals.