2022 IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications (IMWS-AMP) | 978-1-6654-7834-2/22/$31.00 ©2022 IEEE | DOI: 10.1109/IMWS-AMP54652.2022.10106962

A Broadband Low-Profile Antenna Array Using Shorting Pins for 5G Millimeter Wave Applications

Li Zhang[1], Yihao Xu[1], Yejun He[1,*], Qingfeng Zhou[2], Long Zhang[1], Zongyi Zhou[3]
1. Guangdong Engineering Research Center of Base Station Antennas and Propagation
Shenzhen Key Lab of Antennas and Propagation
College of Electronics and Information Engineering, Shenzhen University, Shenzhen, China
2. Dongguan University of Technology, Dongguan, China
3. KZ Broadband Technologies Ltd., Shenzhen, China
Email: wzhangli@szu.edu.cn, 2787490958@qq.com, heyejun@126.com, enqfzhou@ieee.org
longzhang717@163.com, szhou@kztech.cn

***Abstract*—A broadband and low-profile antenna operating at 5G millimeter wave band with ring structure and shorting pins is presented. The antenna has impedance bandwidth of 23.35-28.92 GHz (21.4% for 26 GHz) and it can cover the 5G millimeter wave band (24.25-27.5 GHz). The antenna also can achieve a gain of better than 6.75 dBi, and the maximum gain reaches 9.4 dBi. The height of the antenna is only 0.09λ. The 1$\times$4 antenna array with the isolation below -20 dB is designed based on the antenna element. In the working band of 24.25-27.5 GHz, the realized gain of the array is greater than 10.8 dBi, with a maximum gain of 14.5 dBi.**

***Index Terms*—5G, millimeter wave antenna, shorting pins, broadband, low profile, array.**

I. Introduction

Mobile communication technology has evolved rapidly in the past several decades. Increasing of wireless communication transmission rates, from 1G to 5G, has also generated greater challenges for wireless service providers [1]. Recently, 5G bands are divided into sub-6 GHz and millimeter wave bands. Millimeter wave band has gotton much more attention because of its ample wave band resources. At present, patch antenna is the mainstream technology in millimeter wave antenna [2] [3]. A dual-polarization patch antenna operating at millimeter wave band (24-29 GHz) is proposed in [3]. Loading the shorting pin which is equivalent to adding a capacitor can not only adjust the impedance of the antenna but also decrease the size of the antenna [4] - [7]. In [5], the size of the antenna can be decreased by using the technique of loading a shorting pin. Compared with the E antenna which not use the shorting pin loading, the proposed patch antenna can reduce the size by 60%. In [6], loading the shorting pins on the symmetrical dual-loop antenna is used to strengthen the peak gain and adjust the impedance of the antenna. By loading two magneto-electric feeding structures and shorting pins, the impedance bandwidth of the proposed antenna can be increased from 14.0% (VSWR $\leqslant$ 2.5) to 46.8% (VSWR $\leqslant$ 1.5).

In this paper, a broadband and low-profile antenna loading ring structure and shorting pins is presented. The antenna achieves -10 dB impedance matching bandwidth of 23.35-28.92 GHz (21.4% for 26 GHz). The antenna element also has a gain of better than 6.75 dBi, while the highest gain of proposed antenna is 9.4 dBi. Then on the basic of antenna element, a 1$\times$4 antenna array with the isolation below -20 dB is proposed. In the working band of the array (23.5-28.5 GHz), the gain is greater than 10.8 dBi, with a highest gain of 14.5 dBi.

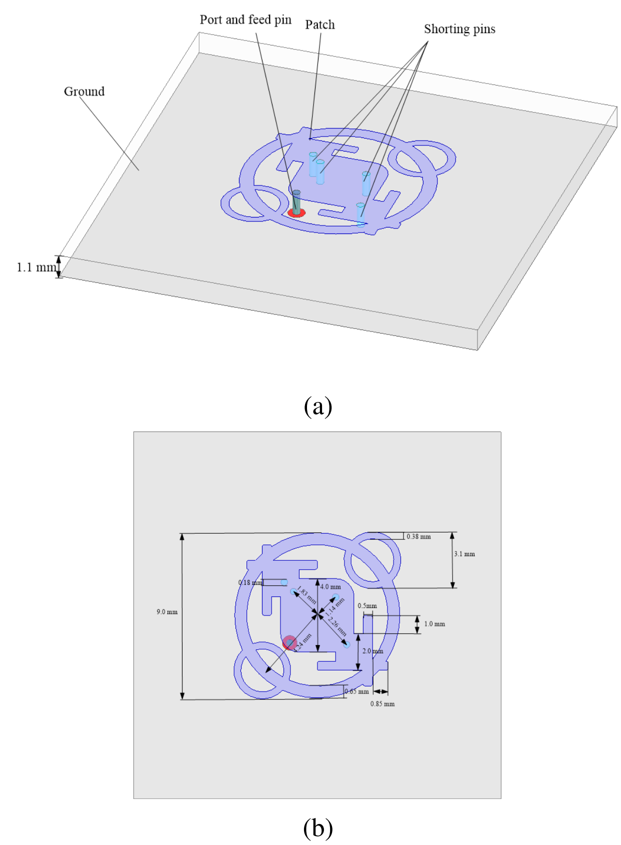
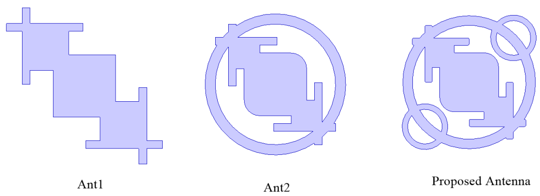


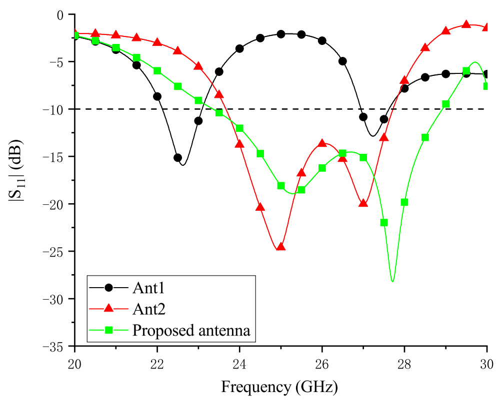
Fig. 1. The structure of antenna element: (a) 3D view, (b) Top view.

II. Antenna Element Design

Figure 1 displays the overall structure and design parameters of the antenna. Rogers 5880 is used as a substrate material of the antenna. A ring structure and shorting pins are added in this antenna design, which can increase the impedance bandwidth of the antenna.



(a)



(b)

Fig. 2. (a) Antennas with different patch structures, (b) $|S_{11}|$ of the antennas with diverse structures.

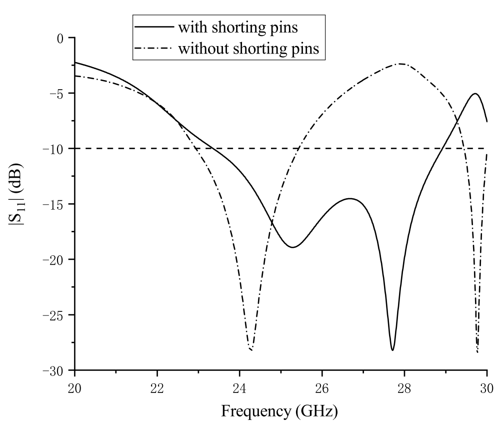


Fig. 3. $|S_{11}|$ of the antennas with and without shorting pins.

The ring structure can bring the two resonant points of the antenna close together. A strong coupling will be formed between the shorting pins and the feed pin, which is equivalent to adding a capacitor. The antenna can obtain better impedance bandwidth because of the addition of shorting pins. The radiation element of the antenna is processed by fillet cutting which can also enhance the impedance bandwidth of proposed antenna.

Figure 2 displays the design changes of proposed antenna, and shows the S parameters of antenna with different structures. We can see that Ant2 adds a ring structure on the basis of Ant1, which can make the distance between the two resonant points closer. Compared with Ant2, two small ring structures are added to the proposed antenna, which also enhances the impedance bandwidth of proposed antenna. Different S parameters with and without shorting pins are given in Fig. 3. The matching bandwidth of proposed antenna can be increased by adding shorting pins from 10.3% to 21.4%.

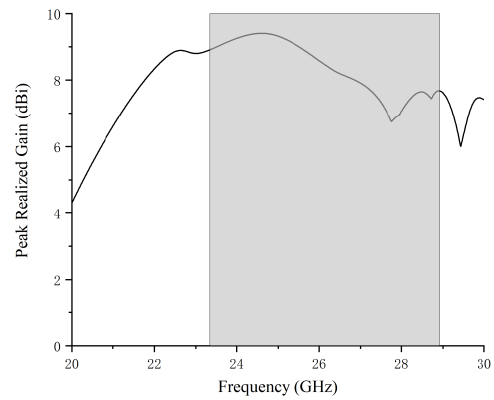
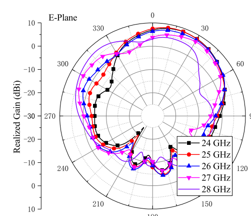
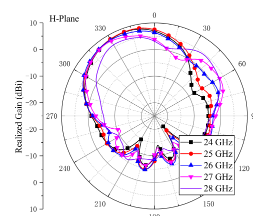


Fig. 4. Realized gain of the antenna element.



(a)



(b)

Fig. 5. Radiation patterns of the antenna element: (a) E-plane, (b) H-plane.

The realized gain of proposed antenna in the operating band is displayed in Fig. 4. We can see that the antenna can maintain a realized gain of greater than 6.75 dBi with a maximum gain of 9.4 dBi at 24.5 GHz. The simulated radiation patterns at different frequency points of proposed antenna are shown in Fig. 5.

III. Antenna Array Design

On the basic of antenna element, a 1×4 antenna array is proposed. The structure of antenna array is dispalyed in Fig. 6, and the spacing of the antenna elements is 12 mm. According to the S parameters shown in Fig. 7, the antenna array can keep its isolation of below -20 dB while keeping its return loss below -10 dB from 23.5 to 28.5 GHz.

The simulated radiation patterns of array at different frequency points are displayed in Fig. 8. In Fig. 9, it can be seen that the realized gain is better than 10.8 dBi while the maximum gain exceeds 14.5 dBi in the operating band of the array (23.5-28.5 GHz).

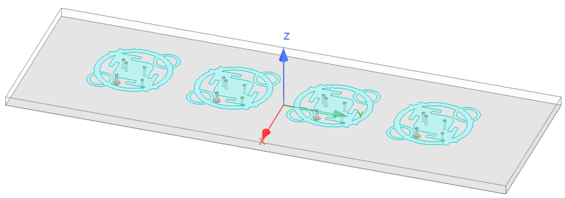
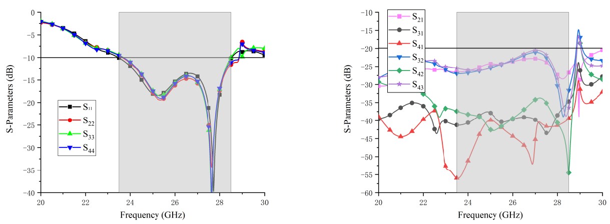
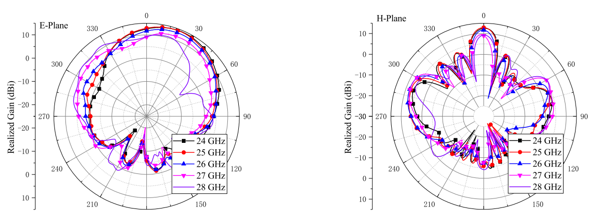


Fig. 6. The structure of the antenna array.



(a) (b)

Fig. 7. S Parameters of proposed antenna array: (a) $|S_{ii}|$, (b) $|S_{ij}|$.



(a) (b)

Fig. 8. Radiation patterns of proposed antenna array: (a) E-plane, (b) H-plane.

IV. Conclusion

In this paper, a broadband low-profile patch antenna array operating at millimeter wave band is proposed. The ring structure and four shorting pins are added to increase the impedance matching bandwidth of the proposed antenna element. By adjusting various parameters, the proposed antenna element finally achieves -10 dB impedance matching bandwidth of 23.35-28.92 GHz (21.4% for 26 GHz). The antenna element can achieve a gain of more than 6.75 dBi, and the maximum gain of the antenna element is 9.4 dBi. Then the 1×4 antenna array is designed based on the antenna element. The proposed antenna array can maintain the return loss under -10 dB from 23.5 to 28.5 GHz, while keeping the isolation below -20 dB. In the working band of the array (23.5-28.5 GHz), the gain is better than 10.8 dBi, while the highest gain is 14.5 dBi.

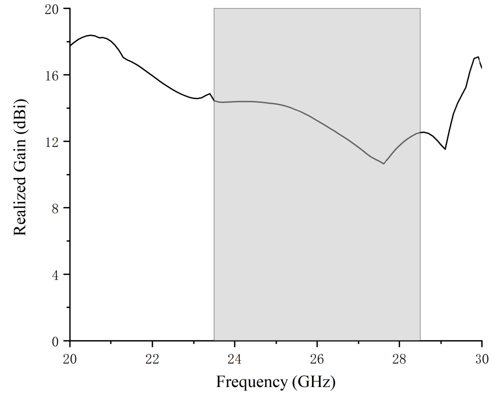


Fig. 9. Realized gain of the antenna array.

The proposed array can be suitable for 5G millimeter wave applications.

Acknowledgment

This work is supported in part by the National Natural Science Foundation of China (NSFC) under Grants 62071306 and 61801299, and in part by Shenzhen Science and Technology Program under Grants JSGG20210802154203011, JCYJ20200109113601723 and JSGG20210420091805014.

References

[1] T. S. Rappaport *et al.*, "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!," *IEEE Access*, vol. 1, pp. 335-349, 2013.

[2] C. Han, G. Huang, T. Yuan and C. Sim, "A Dual-Band Millimeter-Wave Antenna for 5G Mobile Applications," in *Proc. 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting*, 2019, pp. 1083-1084.

[3] C. Zhao, Y. Liu, Y. Zhang, A. Ren and Y. Jia, "Broadband Dual Polarization Antenna Array for 5G Millimeter Wave Applications," in *Proc. 2019 International Symposium on Antennas and Propagation (ISAP)*, 2019, pp. 1-3.

[4] X. Zhang and L. Zhu, "Patch Antennas With Loading of a Pair of Shorting Pins Toward Flexible Impedance Matching and Low Cross Polarization," *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 4, pp. 1226-1233, April 2016.

[5] A. C. O. Pedra, G. Bulla, P. Serafini and A. A. A. de Salles, "Shorting pins application in wide-band E-shaped patch antenna," in *Proc. 2009 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC)*, 2009, pp. 229-234.

[6] J. Liu, Z. Tang, Z. Wang, H. Li and Y. Yin, "Gain Enhancement of a Broadband Symmetrical Dual-Loop Antenna Using Shorting Pins," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 8, pp. 1369-1372, Aug. 2018.

[7] M. K. Ray and K. Mandal, "Shorting Pin and Slot Loaded Dual Band Microstrip Antenna for MICS and GPS Applications," in *Proc. 2018 IEEE Indian Conference on Antennas and Propogation (InCAP)*, 2018, pp. 1-4.