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-AMP54652.2022.10106844

Design of Slot-Coupled Broadband 5G mmWave Base Station Antenna Based on Double-Layer Patch

Chao You[1], Yejun He[1,*], Wenting Li[1], Long Zhang[1], Sai-Wai Wong[1], Zongyi Zhou[2]
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. KZ Broadband Technologies Ltd., Shenzhen, China
Email: heyejun@126.com

***Abstract*—A broadband mmWave base station antenna with a double-layer symmetrical patch structure is presented in the article. The base station antenna consists of three-layer dielectric substrate, two pairs of patches, a microstrip line and four rectangular parasitic patches. The bandwidth of the antenna is increased by adding rectangular metal through holes on the dielectric substrate and slotting on the double-layer patch. Adding parasitic structures on the feed patch improves the impedance matching performance of the antenna. Simulation results show that the proposed antenna can achieve a -10 dB impedance bandwidth of 46.5% and a stable radiation pattern in the 24.04-38.64 GHz frequency band, and its in-band gain can reach 7.2±0.1 dBi. The proposed antenna has an ultra-wide impedance bandwidth and good gain effect, so it is promising as an alternative antenna for future 5G communication system applications.**

***Index Terms*—Millimeter wave, patch antenna, broadband.**

I. Introduction

With the development of 5G mobile communication technology, the research on mmWave is flaring like fire due to the wider spectrum resources of mmWave. At the same time, different countries and regions have specific divisions for 5G millimeter waves. For example, the millimeter-wave frequency bands planned by China are mainly in the range of 24.25-27.5 GHz and 37-42.5 GHz, while the millimeter-wave frequency bands planned by the EU are mainly in the range of 24.25-27.5 GHz, 31.8-33.4 GHz and 40.5-43.5 GHz. Therefore, it is of great significance and value to make the antenna to operate in multiple frequency bands. In [1], the third-order resonance structure is formed by the hairpin resonator, the U-shaped groove in the middle, and the patch on the top layer, the bandwidth is extended to a certain extent, but the spectral range is limited. Although a wide-bandwidth magnetoelectric dipole structure antenna with a defect ground structure was proposed [2], its structure is complex and the processing cost is high. In [3], a differentially driven aperture antenna was used, where the antenna has high gain and wide bandwidth, however its aperture is large and the overhead is too high. Lou *et al.* [4] illustrates the use of massive MIMO arrays, however the arrays still cannot meet the needs of broadband and low cost.

In this paper, a broadband millimeter-wave antenna is obtained by using slot feeding and two-layer symmetrical patch coupling radiation. The proposed antenna can well cover multiple frequency bands and has stable gain, which can provide options for future 5G mmWave base station applications.

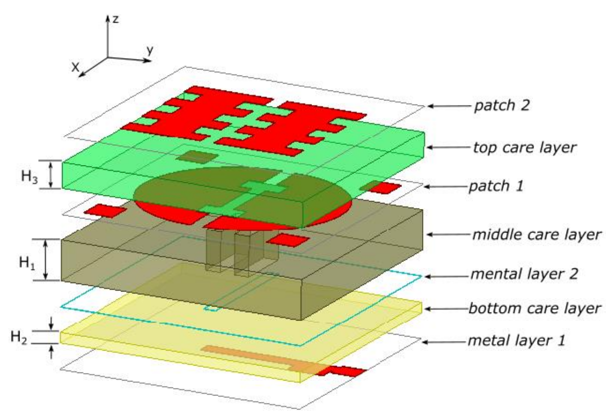

Fig. 1. 3D view of the antenna (Detailed antenna parameters: H_1 = 0.787 mm, H_2 = 0.203 mm, H_3 = 0.5 mm).

II. Antenna Design

The structure of the antenna is shown in Fig. 1. The bottom layer is a Rogers RO4003(tm) substrate with a dielectric constant of 3.55 and an electrical loss tangent of 0.0027. The middle and upper layers are two Rogers RT/duroid 5880(tm) substrates, where the dielectric constant is 2.2 and the electrical loss tangent is 0.0009. A section of microstrip patch with open stubs is printed on the lower surface of the underlying substrate, the upper surface of the antenna serves as the floor of the antenna, and a rectangular slot is etched in the middle of the floor. At the same time, a pair of semicircular rectangular patches are etched on the upper surface of the middle-layer substrate and a pair of rectangular patches are etched on the upper surface of the top-layer substrate. And rectangular grooves are etched on the edges of the two pairs of patches, respectively. In addition, a pair of rectangular metal through holes are dug out in the middle of the middle-layer substrate. Finally, four rectangular parasitic patches are etched on the four corners of the upper surface of the middle-layer substrate. The specific dimensions of the antenna are shown in Fig. 2. The performance of the antenna was simulated and optimized in Ansoft HFSS software.

To understand the design flow of the antenna, Figure 3 compares and discusses the proposed antenna with three other reference antennas. The radiating structure of the Ant1 only

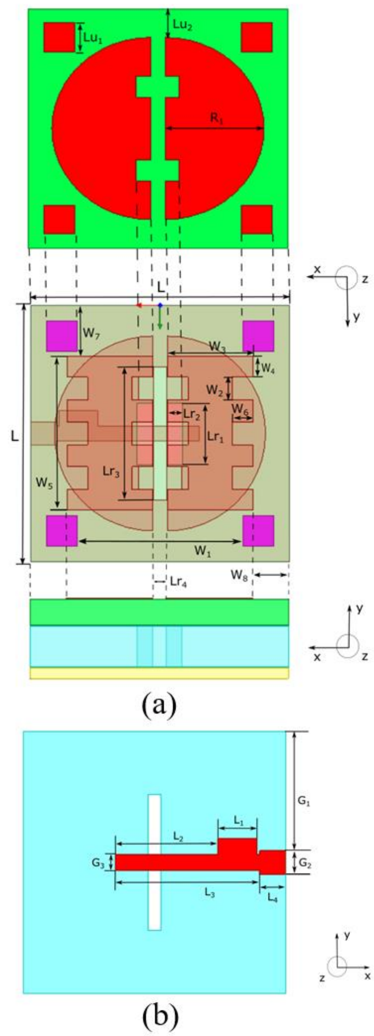

Fig. 2. Configuration of the proposed antenna. (a) Top view and side view of the antenna. (b) Bottom view of the antenna (Detailed antenna parameters: L = 5 mm, W_1 = 3.20 mm, W_2 = 0.45 mm, W_3 = 1.66 mm, W_4 = 0.4 mm, W_5 = 3 mm, W_6 = 0.4 mm, W_7 = 1 mm, W_8 = 0.7 mm, Lr_1 = 1.2 mm, Lr_2 = 0.3 mm, Lr_3 = 2.6 mm, Lr_4 = 0.25 mm, Lu_1 = 0.6 mm, Lu_2 = 0.6 mm, R_1 = 1.9 mm, G_1 = 2.27 mm, G_2 = 0.45 mm, G_3 = 0.3 mm, L_1 = 0.75 mm, L_2 = 1.95 mm, L_3 = 2.75 mm, L_4 = 0.5 mm)

consists of semi-circular patches that have been grooved. Ant2 adds a layer of radiation structure on the basis of Ant1 . For Ant3, six rectangular slots are dug out of the edge of the top-layer patch. In the proposed antenna, an open-circuit stub is added on the bottom microstrip line.

As shown in Fig. 4, the S-parameters of the proposed antenna and three reference antennas are simulated and measured. Ant1 exhibits two resonance points, but they are far apart, and are not matched in the larger frequency band in the middle.

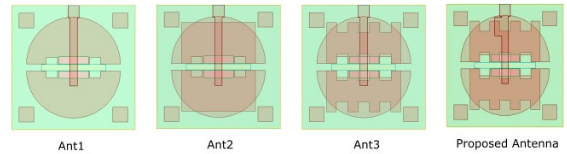

Fig. 3. Top view of the reference antennas and the proposed antenna.

Ant2 shortens the distance between the two resonance points, and at the same time the resonance point moves towards low frequencies. Ant3 makes the extreme value of the low frequency resonance point larger, while the high frequency resonance point is shifted to the right. The high-frequency resonance point of the proposed antenna continues to move to the right, and the frequency bands between the two resonance points are matched, and a wider impedance bandwidth is realized.

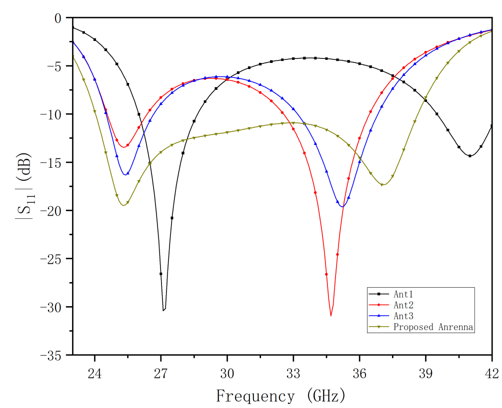

Fig. 4. Simulated S-parameters of the reference antennas and the proposed antenna.

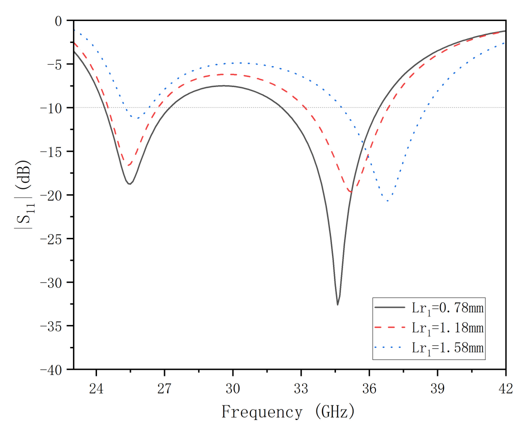

Fig. 5. Simulated S-parameters corresponding to different Lr_1.

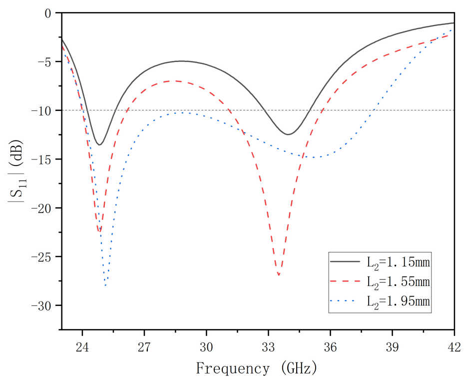

Fig. 6. Simulated S-parameters with different L_2.

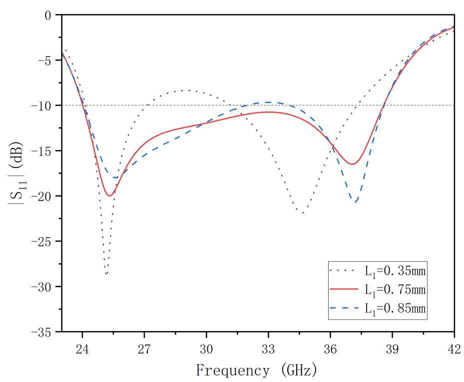

Fig. 7. Simulated S-parameters with different L_1.

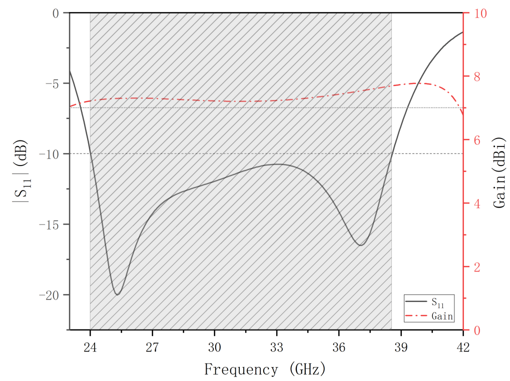

Fig. 8. Antenna impedance and gain simulation curve.

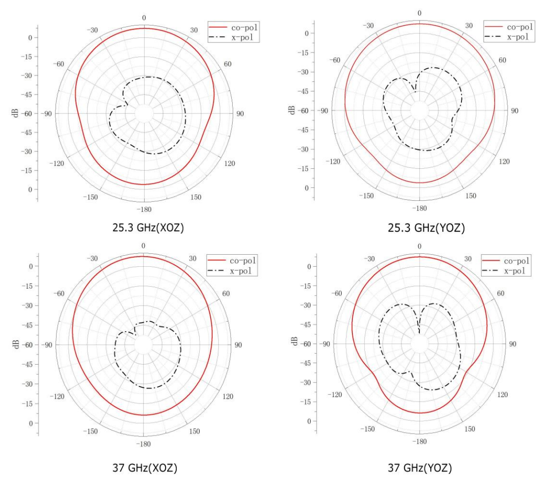

Fig. 9. The radiation patterns at 25.3 GHz and 37 GHz.

On the basis of Ant3, Figure 5 shows the effect of rectangular metal vias on impedance matching. As the length increases, the high frequency resonance point gradually moves to the right, while the matching of the low frequency range becomes worse. For the overall consideration, the length of Lr_1 is selected as 1.18 mm.

In Fig. 6, the antenna's broadband effect is obtained when L_2=1.95 mm. In Fig. 7, the antenna's broadband effect is obtained when L_1=0.75 mm. In Fig. 8, within the impedance bandwidth, the antenna gain is stable and higher than 7 dBi. And Fig. 9 shows the pattern of high and low frequency resonance points, and its main polarization pattern is stable.

III. Conclusion

This paper introduces a dual-patch broadband millimeter-wave base station antenna. The proposed antenna has a wider impedance bandwidth by adding open stubs and using rectangular metal vias and slots. The operating frequency of the proposed antenna is 24.04-38.64 GHz (S_{11} <-10 dB), achieving a relative bandwidth of 46.55%. The gain of the antenna remains stable in the operating frequency band, reaching 7.2±0.1 dBi. The proposed antenna is expected to be a candidate for 5G mmWave base station antennas.

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] C. -X. Mao, S. Gao and Y. Wang, "Broadband High-Gain Beam-Scanning Antenna Array for Millimeter-Wave Applications," *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 9, pp. 4864-4868, Sept. 2017.

[2] J. Yin, Q. Wu, C. Yu, H. Wang and W. Hong, "Broadband Endfire Magnetoelectric Dipole Antenna Array Using SICL Feeding Network for 5G Millimeter-Wave Applications," *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 7, pp. 4895-4900, July 2019.

[3] K. Fan, Z. -C. Hao, Q. Yuan, J. Hu, G. Q. Luo and W. Hong, "Wideband Horizontally Polarized Omnidirectional Antenna With a Conical Beam for Millimeter-Wave Applications," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 9, pp. 4437-4448, Sept. 2018.

[4] M. Lou et al., "Performance analysis of sparse array based massive MIMO via joint convex optimization," *China Communications*, vol. 19, no. 3, pp. 88-100, March 2022.