Dual-Polarized Filtering Antenna Array for 5G Base Station Applications

(Invited Paper)

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***Abstract*—In this paper, a dual-polarized antenna array with filtering characteristic is designed with simple structure for sub-6GHz frequency band. The antenna array consists of six filtering antenna elements where each element includes a radiation patch, a feeding patch and a reflector. On the feeding patch of each element, an octagonal slot is cut for adjusting the impedance and enhancing impedance matching. A 1 to 6 micro-strip power divider is designed to excite the antenna array. As shown in the measured results, this 5G array exhibits the reflection coefficient $|S_{11}|$ of smaller tan -10 dB, the gain of more than 13.2 dBi, the first sidelobe suppression above 15 dB and out of band gain suppression of 24.3 dBi over the frequency band.**

***Index Terms*—Dual-polarization; filtering antenna; sub-6 GHz; base station antenna array.**

I. Introduction

5G mobile communication systems are being deployed all over the world, while 3G/4G mobile communication systems will also coexist with 5G mobile communication systems. Base station antennas that operate in all spectrum will be the shape of things to come [1], which makes the electromagnetic environments in base station more and more complex. The mutual coupling between antenna elements operating in different bands will result in the deterioration of antenna impedance matching, port isolation and radiation pattern. In recent years, to cope with the problems brought by the increasingly complex electromagnetic environment, filtering antennas have been used in base station. Sub-6GHz 5G band is more suitable for outdoor signal coverage than millimeter wave band because of its smaller loss and wider coverage. Therefore, it is of great significance to study and design a dual-polarized filtering antenna working in sub-6GHz 5G band.

In the past years, many novel filtering antennas have been proposed and studied [2]-[5]. In [2], a 5G filtering antenna composed of multiple layers of patches can achieve high selectivity by adding filtering patch. In [3], a filtering base station antenna with dual polarization and simulated out-of-band gain suppression of 13 dB was designed, which generates radiation null by introducing chokes at the edge of the radiation arms. A wide band $\pm$ 45°dual-polarized filtering base station antenna was designed in [4], which generates radiation null by adding parasitic loops. However the profile of the antennas proposed in [3] and [4] are relatively high. In [5], a compact, low profile filtering patch antenna with high frequency selectivity was proposed, where the antenna achieves filtering characteristics by loading two slot lines on the patch, however it can only achieve one polarization.

In this article, a dual-polarized low profile base station antenna array with good filtering characteristic is proposed. Base on the filtering element, a 1 $\times$ 6 antenna array is simulated, manufactured and verified.

II. Antenna Array Design

The element of the antenna array is based on the antenna proposed in [6] without adding isolation block. The antenna element's geometry is shown in Fig. 1. It is a multi-layer structure consisting of a radiation patch, a feeding patch and a reflector. This element can attain two radiation nulls in 1.7-2.1 GHz and 4.8-5 GHz. According to the explanation of the generation of two radiation nulls in [6], the radiation null in higher frequency band is generated because the opposite currents are excited on the radiation patch, while the radiation null in lower frequency band is generated because there is almost no radiation current distributed on the radiation patch at lower frequency. More details and working mechanism of the element are discussed in [6].

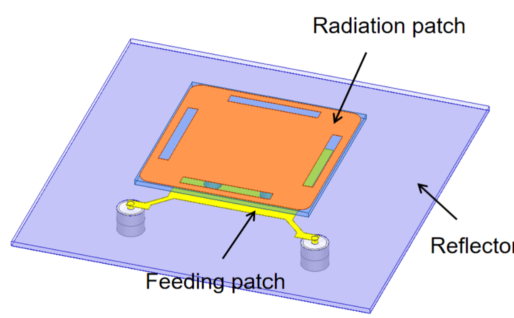

Fig. 1. Geometry of the filtering element.

A six-element array is proposed based on the above antenna element. A 1 to 6 microstrip power divider for exciting the array is simulated and optimized in ADS and HFSS. The configuration of this linear array is shown in Fig. 2. In order to better description, the XOZ-plane is defined as the vertical plane (V-plane) and YOZ-plane is defined as the horizontal plane (H-plane). The size is 64 mm × 384 mm × 5.8 mm, and the spacing between the elements is 64 mm. (about 0.74λ, λ represents the wavelength in free space of 3.45 GHz.)

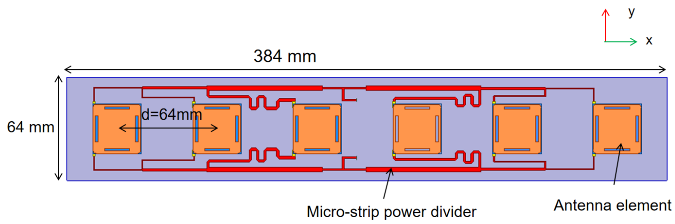

Fig. 2. Configuration of the six-element filtering antenna array.

For base station antenna array, the spacing of the elements can influence the gain, sidelobe level, volume, coupling between elements and other factors. The influence of the spacing d on array's gain and HPBW of V-plane in the case of uniform excitation is shown in Fig. 3. The spacing d increases from 54 mm to 84 mm, the gain of the array increases by about 1.7dBi and the HPBW of the V-plane radiation pattern decreases by about 4.8°. However, with the increase of d, the antenna sidelobe suppression gradually decreases as shown in Fig. 4, and the antenna volume also increases with the increase of spacing.

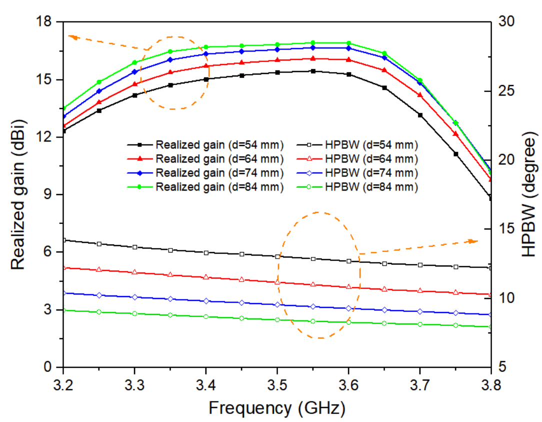

Fig. 3. The effect of the spacing d on gain and HPBW.

The higher gain and narrower beamwidth could be obtained by increasing the spacing of the elements appropriately. However, too large spacing will lead to the first side lobe of V-plane radiation pattern rise, resulting in energy waste and signal interference, and too large volume is not conducive to the integration of the base station. However, if the spacing is too small, the coupling between elements will be enhanced, which will lead to the deterioration of impedance matching, port isolation and radiation pattern. Considering the radiation performance requirements of the base station antenna and the size of the antenna, d = 64mm is selected as the spacing of the elements.

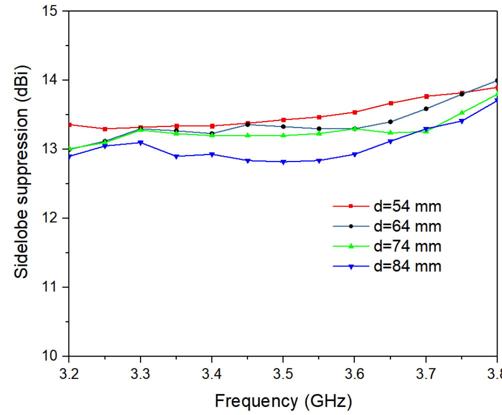

Fig. 4. The effect of the spacing d on sidelobe suppression.

The amplitude and phase of the elements' excitations are important factors affecting the array performance. To reduce the first sidelobe level of the radiation pattern on V-plane, the excitations of the elements are not uniform. Fig. 5 shows the amplitude of S parameter of the power divider after optimization in ADS (Advanced Design System).

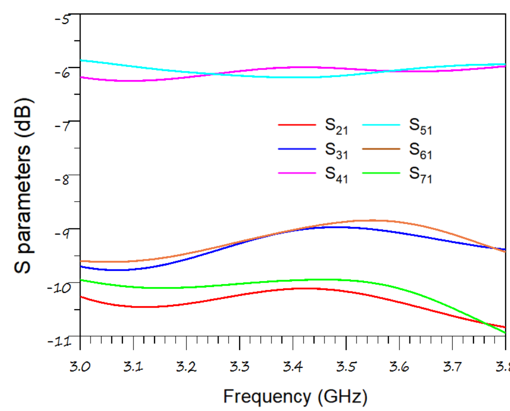

Fig. 5. The amplitude of S parameter of the power divider in ADS.

III. Measurement and Discussion

For validation, the antenna array is fabricated and measured. Fig. 6 exhibits the prototype of this array.

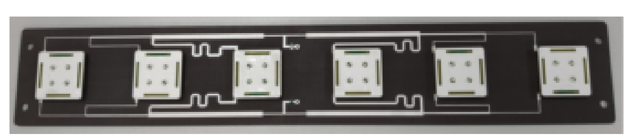

Fig. 6. The prototype of the filtering antenna array.

The simulation and measured S parameters are plotted in Fig. 7. The antenna array works within 3.3-3.6 GHz with reflection coefficient smaller than -10 dB and polarization isolation greater than 20 dB. The measured gain within working bands are above 13.2 dBi, while the out-of-band (1.7-2.1 GHz and 4.8-5 GHz) gain suppression reaches 24.3 dBi as plotted in Fig. 8. The radiation patterns at 3.3 and 3.6 GHz are exhibited in Fig. 9. The measured results agree well with the simulation ones. The sidelobe suppression on V-plane is above 15 dBi. The stable radiation patterns can meet the design requirement of base station antennas.

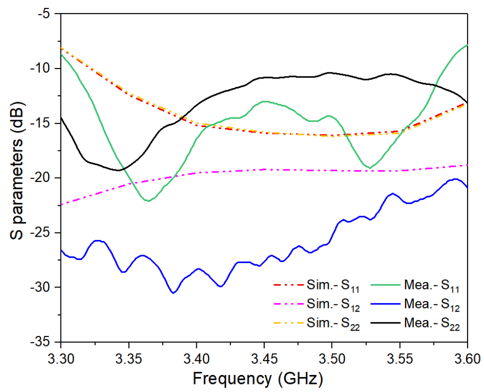

Fig. 7. Simulated and measured S parameters for the proposed array.

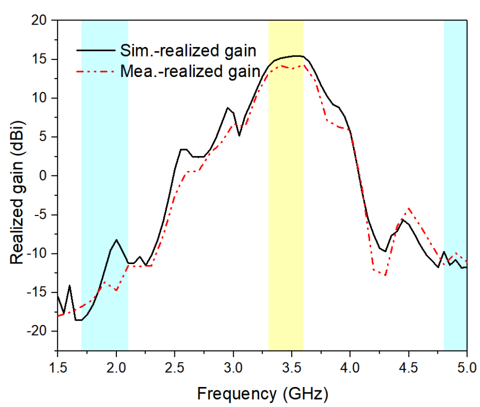

Fig. 8. Simulated and measured realized gain for the proposed array.

IV. Conclusion

A novel 5G base station filtering antenna array with low profile and ± 45 °dual polarization is proposed in this paper. The antenna could achieve good filtering characteristic without adding any filter structure. A 1×6 linear array with sidelobe suppression above 15 dBi is fabricated and measured. As the results exhibit, this antenna array could work in 3.3-3.6 GHz with VSWR of smaller than 2 ($|S_{11}|$ <-10 dB), the polarization isolation of greater than 20dB and realized gain of greater than 13.2 dBi. The antenna has out of band gain suppression of 24.3 dBi with stable radiation patterns within the whole band.

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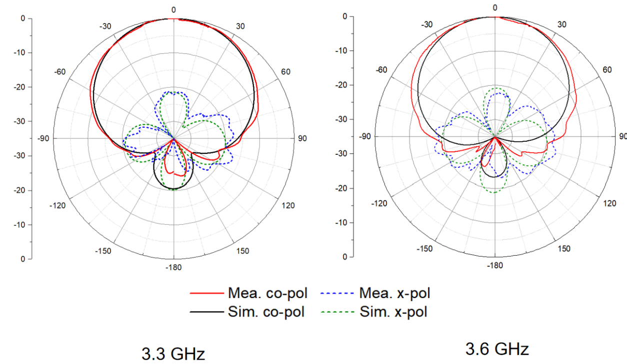
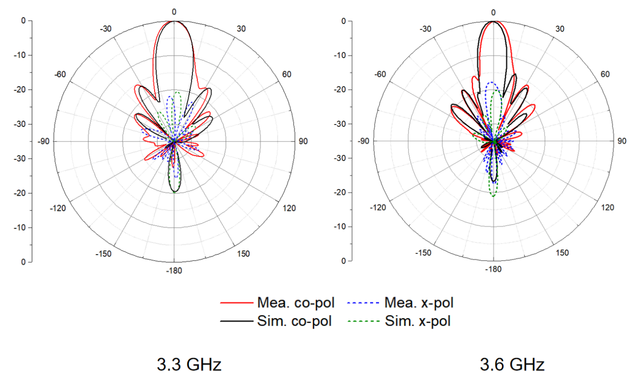


(a)



(b)

Fig. 9. Simulated and measured radiation patterns at 3.3 GHz and 3.6 GHz. (a) H plane. (b) V plane.

References

[1] Y. He, Y. Yue, L. Zhang and Z. N. Chen. "A dual-broadband dual polarized directional antenna for all-spectrum access base station applications,"*IEEE Trans. Antennas and Propag.*, vol. 69, no. 4, pp. 1874-1884, April. 2021.

[2] 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 Wireless Propag. Lett.*, vol. 19, no. 8, pp. 1316-1320, Aug. 2020.

[3] W. Yu, H. Lin, B. Liao and W. Duan, "A compact dual-polarized low-pass filtering antenna with wideband out-of-band rejection," *IEEE Antennas Wireless Propag. Lett.*, vol. 20, no. 12, pp. 2329-2333, Dec. 2021.

[4] C. F. Ding, X.-Y. Zhang, Y. Zhang, Y.-M. Pan and Q. Xue, "Compact broadband dual-polarized filtering dipole antenna with high selectivity for base-station applications," *IEEE Trans. Antennas and Propag.*, vol. 66, no. 11, pp. 5747-5756, Nov. 2018.

[5] J. Y. Jin, S. Liao and Q. Xue, "Design of filtering-radiating patch antennas with tunable radiation nulls for high selectivity," *IEEE Trans. Antennas and Propag.*, vol. 66, no. 4, pp. 2125-2130, April 2018.

[6] X. Gao, Y. He, L. Zhang and Z. Zeng, "A novel dual-polarized 5G base station filtering antenna," 2021 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (APS/URSI), pp. 579-580, 2021.