A Novel Sub-6 GHz and Millimeter Wave Shared-Aperture 5G Base Station Antenna

Wei Huang, Yejun He⋆, and Asif Khan
State Key Laboratory of Radio Frequency Heterogeneous Integration
Guangdong Engineering Research Center of Base Station Antennas and Propagation
Shenzhen Key Laboratory of Antennas and Propagation
College of Electronics and Information Engineering, Shenzhen University, Shenzhen, China
Email: harveymail@yeah.net, heyejun@126.com⋆, asifm20019@gmail.com

***Abstract*—This paper presents a novel embedded dual-band shared-aperture base station antenna, which can work in Sub-6 GHz and millimeter wave band simultaneously. The Sub-6 GHz element is composed of a driving patch and a radiating patch. The millimeter wave element uses the substrate integrated waveguide slot antenna, and the millimeter wave elements are embedded in the radiation patch of the Sub-6 GHz element, sharing the substrate and radiator of the radiation patch. Compared with the traditional embedded shared-aperture structure, this novel scheme is more compact, and the radiation environment of the higher and lower band is relatively independent, so the cross-band coupling has less effect. The simulated results show that the reflection coefficient of the proposed antenna array is less than -14 dB, the cross-band isolation is greater than 38 dB, and the cross-polarization discrimination is greater than 27 dB in the two frequency bands of 3.35-3.75 GHz and 25.8-26.2 GHz.**

***Index Terms*—base station antenna, 5G antenna, shared-aperture, dual-band antenna.**

I. Introduction

The development of the 5G era poses enormous challenges to the communication capacity and transmission rate of mobile communication systems. The Sub-6 GHz band, which is commonly used in 5G base stations, is no longer sufficient to meet the demand. Utilizing millimeter wave spectrum to build 5G base stations is an inevitable trend [1]. However, communication links in the millimeter wave frequency range have serious transmission loss issues, and the transmission distance of millimeter wave signals is very short. In fact, due to the line-of-sight propagation characteristics of millimeter waves, millimeter wave signals not only cannot penetrate obstacles such as buildings, but also significantly attenuate when passing through leaves and rainwater, making millimeter wave communication links very unstable [2]. Therefore, how to ensure reliable millimeter wave mobile communication is a challenge. To address this issue, integrating antennas in the millimeter wave and Sub-6 GHz frequency bands is the future development trend of 5G base station antennas [3].

In this paper, a novel embedded dual band shared-aperture base station antenna has been proposed, with the lower band covering 3.3-3.7 GHz and the higher band operating at 26 GHz. The Sub-6 GHz element consists of a driving patch and a radiation patch. The radiation patch is suspended above the driving patch, and the driving patch excite the radiation patch through coupling. The millimeter wave element uses the substrate integrated waveguide (SIW) slot antenna, the SIW cavity is integrated in the substrate of the radiation patch. Compared with traditional embedded shared-aperture structure, the proposed novel structure shares the radiator of the lower-band element with higher-band elements, achieving structural reuse, reducing material costs. In addition, the higher and lower band antenna radiators of the proposed novel embedded shared-aperture structure are on the same plane and do not share the ground, so the radiation environment between

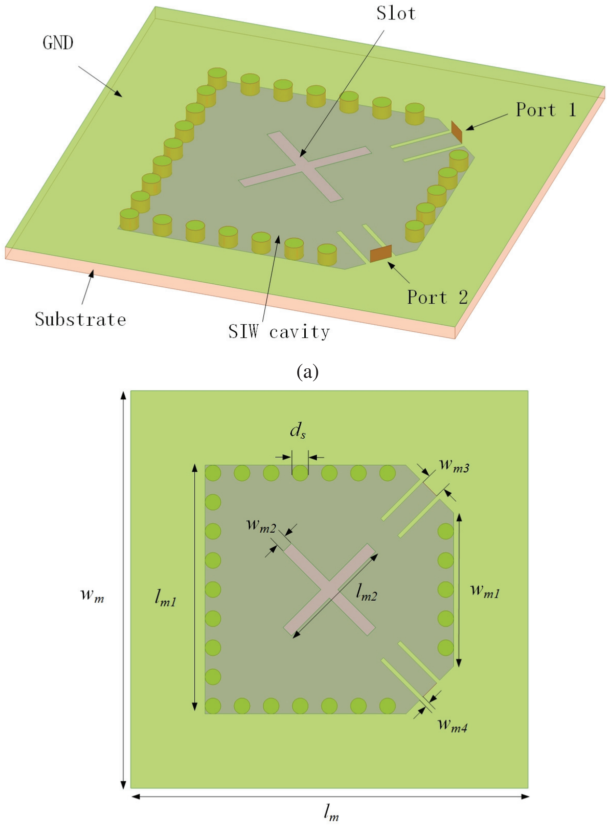

Fig. 1. (a) 3D view and (b) top view of the mmWave antenna element.

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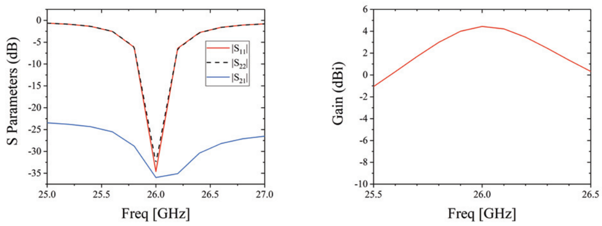
TABLE I
GEOMETRIC PARAMETERS (UNIT: mm)

PRM	l_m	l_{m1}	l_{m2}	w_m	w_{m1}
Value	10	6.25	3	10	3.85
PRM	w_{m2}	w_{m3}	w_{m4}	d_s	
Value	0.3	0.5	0.1	0.4	



(a) (b)

Fig. 2. (a) S-parameters and (b) gain of the mmWave antenna element.

them is relatively independent, which suppress the cross-band coupling.

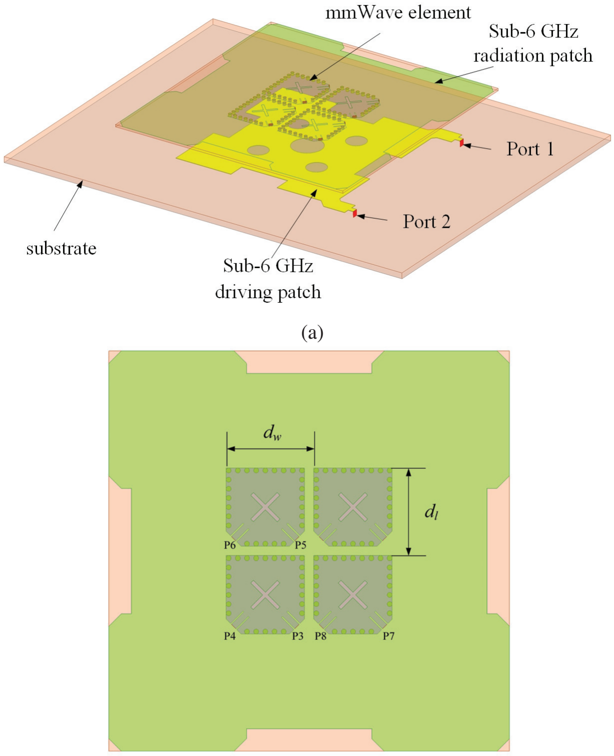
II. Antenna Element

The design of sub-6 GHz antenna elements has been described in detail in our previously published article [4], so this chapter focuses on the design of millimeter wave elements.The millimeter-wave antenna array element uses a SIW slot antenna, and the structure is shown in Fig. 1. The substrate is made of Rogers RO4003 material with thickness of 0.3 mm, dielectric constant of 3.55, and loss tangent of 0.0027. The SIW cavity is integrated in the substrate, and the feed port is set at two adjacent corners to excite +45 and -45 polarization, respectively. The top surface of the substrate is the ground, in which 45 crossed slots are etched with length of 3 mm and width of 0.3 mm. The detailed geometric parameters of this mmWave antenna element are shown in Table I.

After electromagnetic software simulation and optimization, the simulated S-parameters of the mmWave antenna element are shown in Fig. 2(a), and its operating bandwidth range is 25.8-26.2 GHz, and the reflection coefficient $|S_{11}|$ and $|S_{22}|$ less than -14 dB, the port isolation $|S_{21}|$ less than -30 dB. Fig. 2(b) shows the simulated gain, the gain in operating band of this mmWave element is 4.2-4.5 dBi. Fig. 3 shows the horizontal and vertical radiation patterns at 26 GHz, which exhibit good symmetry and stability with XPD above 34 dB.

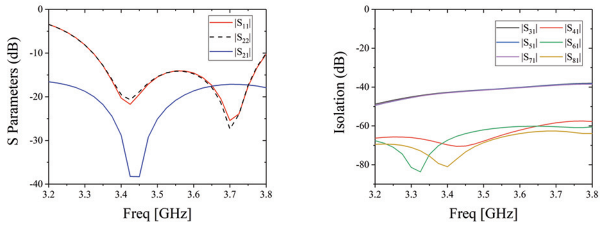
III. Antenna Array

The mmWave antenna element can share the substrate with the sub-6 GHz antenna element, and the radiation patch of the sub-6 GHz element is used as the ground of the mmWave element. Based on this scheme, a novel embedded dual band shared-aperture base station antenna array is constructed, as shown in Fig. 3, which consists of one sub-6 GHz element and four mmWave elements. The distance between mmWave elements is dl = dw = 7 mm. Compared with the traditional



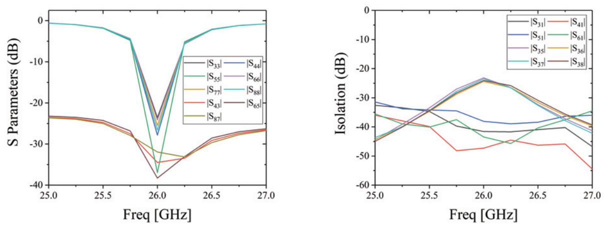
(b)

Fig. 3. (a) The novel shared-aperture antenna array and (b) top view of mmWave antenna array.



(a) (b)

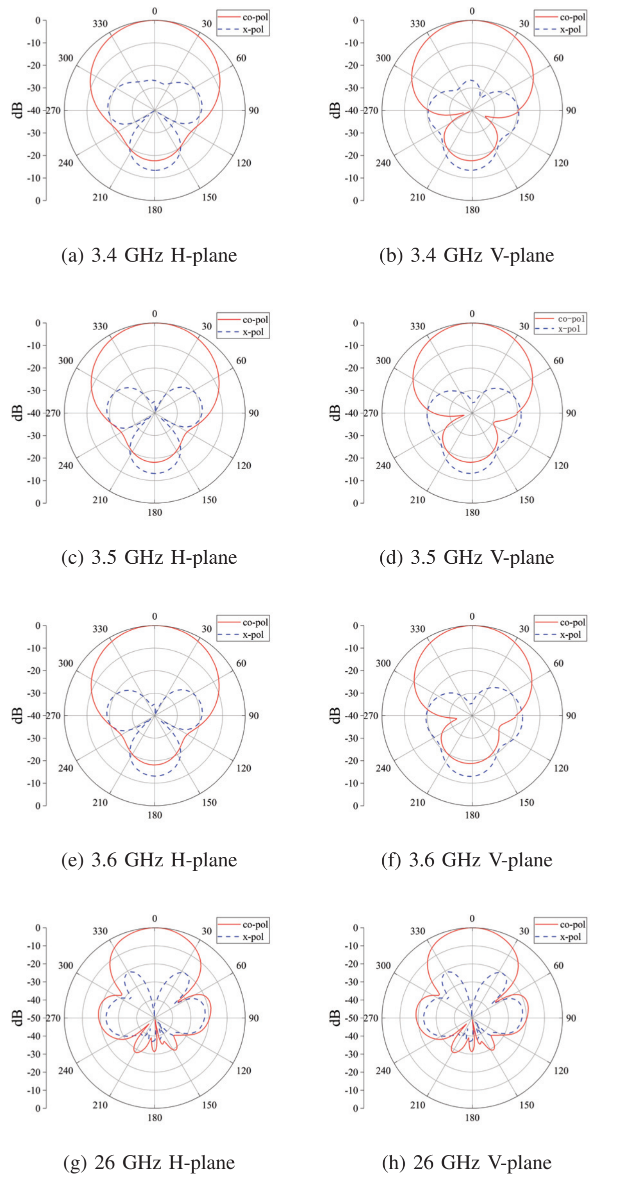
Fig. 4. The S-parameters of the Sub-6 GHz band.



(a) (b)

Fig. 5. The S-parameters of the mmWave band.

embedded structure, the proposed scheme has two advantages. On the one hand, the sharing of radiation patch makes the



(a) 3.4 GHz H-plane (b) 3.4 GHz V-plane

(c) 3.5 GHz H-plane (d) 3.5 GHz V-plane

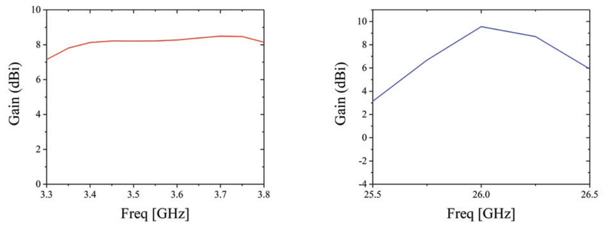
(e) 3.6 GHz H-plane (f) 3.6 GHz V-plane

(g) 26 GHz H-plane (h) 26 GHz V-plane

Fig. 6. The radiation patterns at 3.4 GHz, 3.5 GHz, 3.6 GHz and 26 GHz.

antenna array structure more compact, which can reduce the weight of the antenna and save costs. On the other hand, the radiation plane of sub-6 GHz and mmWave antenna elements are on the same horizontal plane, and they have their own grounds. So the influence of cross-band coupling will be greatly reduced.

The electromagnetic characteristics of this proposed novel shared-aperture antenna array are analyzed and verified by simulation software.The S-parameter results of the antenna array in the sub-6 GHz band are shown in Fig. 4, the operating frequency band range is 3.35-3.75 GHz. In this frequency range, the reflection coefficient of the antenna array elements is less than -14 dB, and the port isolation is greater than 18 dB. The S-parameters of the mmWave band are shown in Fig.



(a) (b)

Fig. 7. The gain of the Sub-6 GHz band and mmWave band.

5, the mmWave elements achieve impedance matching at 26 GHz with the port isolation reaches more than 24 dB. Fig.6 shows the radiation patterns at 3.4 GHz, 3.5 GHz, 3.6 GHz, and 26 GHz. The patterns of both bands are stable with the XPD is greater than 27 dB in the sub-6 GHz band and is as high as 42 dB in the mmWave band. Fig.7 shows the gain of both bands. The proposed novel shared-aperture antenna array reaches the gain of 8.10.3 dBi in the sub-6 GHz band and 9.55 dBi in the mmWave band.

IV. Conclusion

A novel embedded dual band shared-aperture base station antenna array consisting of one sub-6 GHz element and four mmWave elements is proposed. The sub-6 GHz element uses the double-layer patch structure, and the mmWave element uses the SIW slot antenna. The four mmWave elements are integrated in the radiation patch of the sub-6 GHz element. Compared with the traditional embedded shared-aperture antenna array, the proposed novel scheme is more compact, and the radiation environment of different frequency elements is relatively independent so that the influence of cross-band coupling between them is minimal.

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