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A Novel Base Station Antenna Array With Electromagnetic Transparent Radiator

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***Abstract*—This paper introduces a novel antenna element with electromagnetic transparency designed for a shared-aperture base station antenna. Drawing inspiration from the wide-angle bandpass frequency selective surface element, triangular patches are incorporated onto a square ring to modify the passband. Utilizing the proposed element as the dipole for the low-frequency band (LB) antenna and adjusting the size of the triangular patches can achieve electromagnetic transparency in the band of 3.2-3.8 GHz. The proposed dual-band dual-polarized shared-aperture antenna array operates in the LB of 1.6-2.1 GHz and the high-frequency band (HB) of 3.2-3.8 GHz. Simulation findings indicate a significant decrease in cross-band scattering within the dual-band array, and the array consistently exhibits a stable radiation pattern across both frequency bands.**

***Index Terms*—Base station antenna, cavity-backed antenna, filtering antenna, shared-aperture antenna.**

I. Introduction

Currently, 5G technology is advancing rapidly. However, 4G systems will still coexist with 5G systems for a considerable period. In order to save space, it is necessary to place antennas at different bands in the base station antenna. However, when antennas at different bands are placed close to each other, cross-band coupling problems may occur, impacting the performance of the antennas [1].

Numerous shared-aperture antenna arrays have been suggested to address cross-band coupling issues, accompanied by various decoupling concepts. To establish a shared-aperture configuration, the HB antenna can be positioned either above, below, or through a co-planar design with the LB antenna. In the case that the HB antenna is located above, the frequency selective surface layer is introduced to reduce the influence between the two band antennas [2], [3]. However, challenges arise when the HB is in close proximity to the LB, making it difficult for the FSS to ensure optimal radiation performance for both LB and HB antennas. In scenarios where high and low frequencies are co-planarly aligned, the HB antenna is embedded into the gap between the dipole elements of the LB antenna [4], [5]. This results in stronger cross-band scattering, requiring an extended period for impedance adjustment.

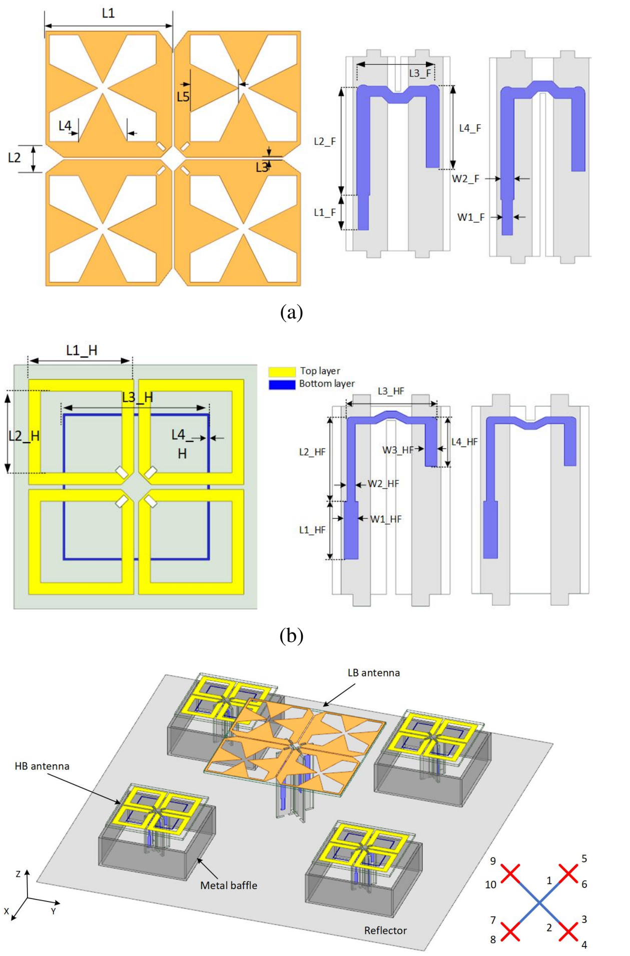
If the HB antennas are positioned below, the LB antenna can incorporate both low-bandpass and high-bandstop chokes [6], [7]. Nevertheless, this configuration leads to an elevated height of the antenna array.

This paper introduces a novel electromagnetic transparent antenna aimed at addressing cross-band coupling issues. The antenna is designed as a band-pass structure, enabling unrestricted passage of high-frequency waves and thereby restoring the radiation pattern of the LB antenna. To mitigate the adverse effects of the LB antenna on HB antennas, a filtering antenna is chosen as the HB antenna element, ensuring high isolation between HB and LB ports. The antenna array is assembled using these LB and HB elements. Simulation results affirm that the array notably diminishes cross-band coupling, successfully reinstates the antenna pattern within the band, and achieves commendable radiation performance.

II. Configuration Of The Antenna Array

Figure 1 illustrates the configurations of the proposed LB and HB antenna elements along with the dual-band array. In Fig. 1(a), the LB element comprises a main radiator and two baluns. The main radiator exhibits electromagnetic transparency effects at HB, while the baluns are positioned between the main radiator and reflector in perpendicular orientations. In the HB element, as illustrated in Fig. 1(b), the radiator consists of two squared loop dipoles printed on the top surface of the substrate. In addition, a square ring is printed on the other side of the substrate to filter out low-frequency interference waves. The introduction of the square ring can effectively isolate the LB coupling wave generated on the HB antenna, which restore the radiation pattern of the HB antenna. The coupling coefficient between the LB and HB antennas dropping below -20 dB. As depicted in Fig. 1(c), the LB element is centrally positioned, surrounded by four HB elements to form an antenna array. Baffles are added around the HB antenna elements, effectively reducing coupling and restoring the antenna radiation pattern.

To elucidate the LB antenna radiator design process, we consider the simulation models of two loops showcased in Fig. 2(a). Loop 1 represents a squared loop structure.In the case of Loop 2, triangular patches are introduced into the center of the squared loop. As depicted in Fig. 2(b), the squared



(a)

(b)

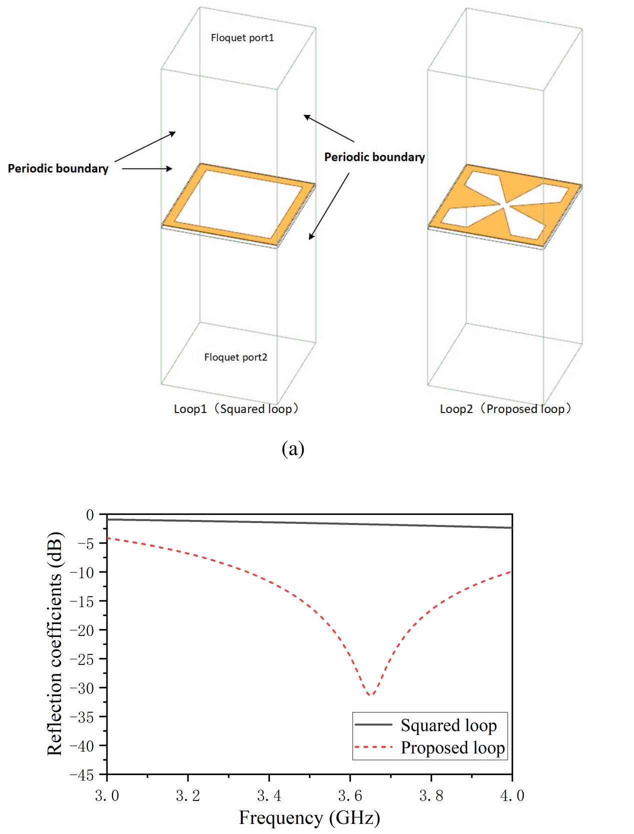
(c)

Fig. 1. Configurations of (a) LB element, (b) HB element, and (c) the dual-band base station antenna array.

TABLE I
GEOMETRIC PARAMETERS (UNIT:MM)

Parameter	L1	L2	L3	L4	L5	L1_F
Value	26	6	0.5	10	10	5
Parameter	L2_F	L3_F	L4_F	L1_H	L2_H	L3_H
Value	15	10	11	12.9	10	18
Parameter	L4_H	L1_HF	L2_HF	L3_HF	L4_HF	W1_F
Value	0.25	4.9	6.9	6.8	3.9	1.5
Parameter	W2_F	W1_HF	W2_HF	W3_HF		
Value	1.9	1.2	0.7	1		

loop exhibits strong reflection in the HB. Consequently, using such a loop as an LB antenna would lead to distortion in the radiation pattern of HB antennas. However, in the case of loop2, it is possible to generate a radiation null at HB. Just as expected, loading the triangular patches, a reflection null is generated at the center of the HB. The transmission coefficient of the LB element exceeds -0.5 dB in the HB, providing evidence that the LB antenna element possesses transmission characteristics at the HB.



(a)

(b)

Fig. 2. Simulation of two loops. (a) Simulation models of Loop 1 and Loop 2. (b) Reflection coefficients of Loop 1 and Loop 2.

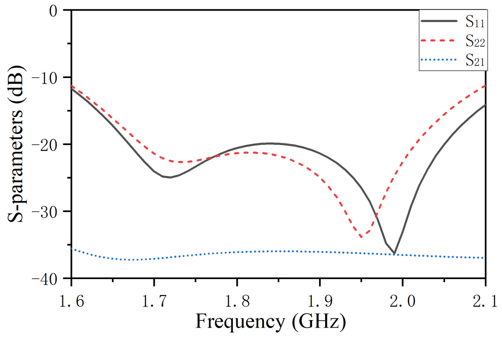
III. Simulation Results And Discussion

In Fig. 3, the simulated S-parameters of the proposed antenna array are displayed. Given the symmetrical nature of the antenna array, we focus on discussing a single HB antenna port.The LB antenna has reflection coefficients $<$-10 dB from 1.6 GHz to 2.1 GHz, and HB antennas have reflection coefficients $<$-10 dB from 3.2 GHz to 3.8 GHz. The isolation of both LB and HB antennas is greater than 25 dB in the whole operating frequency band. As shown in Fig. 4, the realized gain of the LB antenna is 7 ± 1 dBi, and the realized gain of the HB antenna is 7 ± 0.5 dBi. As shown in Fig. 5, the radiation patterns are smooth. It proves that the coupling between the LB and HB antennas is improved.

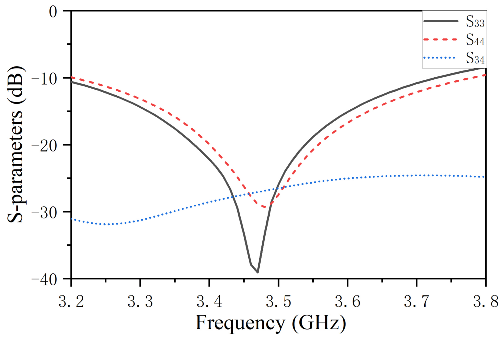
Simulation results reveal that the cross-polarization of the proposed antenna array exceeds 20 dB within the operating band. This signifies the antenna array's commendable directivity and stability. The proposed antenna array effectively combines the characteristics of electromagnetic transparent antenna and filter antenna to meet the needs of base station antenna.

IV. Conclusion

In this paper, an antenna array consisting of an electromagnetic transparent antenna element (LB element) and four



(a)



(b)

Fig. 3. The result of S-parameters of the antenna. (a) LB. (b) HB.

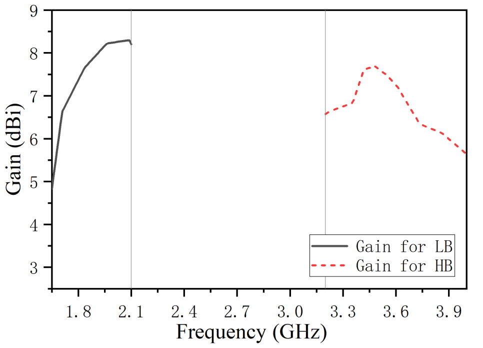
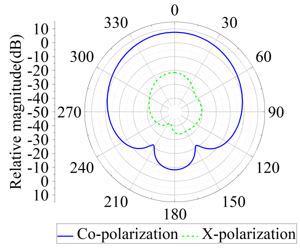
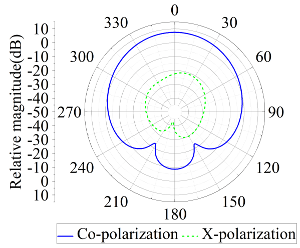


Fig. 4. Simulated peak gain of the antenna.

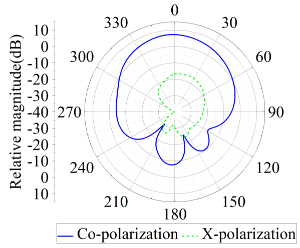
filtering antenna elements (HB elements) is proposed. The electromagnetic transparent antenna is obtained by adding triangle patches to the square loop to change the radiation zero point. To mitigate the scattering effects induced by the HB element in the low band, squared parasitic rings have been incorporated into the HB radiators. The resulting antenna array, comprising the suggested LB and HB elements, exhibits consistent radiation performance across both low and high frequency bands. Therefore, the proposed antenna array is a competitive candidate to the current multi-band base station antennas.



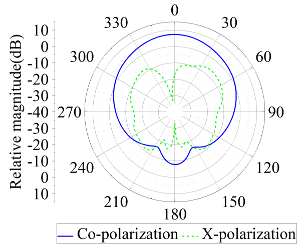
(a) 1.8 GHz Phi = +45°



(b) 1.8 GHz Phi = −45°



(c) 3.6 GHz Phi = +45°



(d) 3.6 GHz Phi = −45°

Fig. 5. The element radiation patterns at 1.8 GHz and 3.6 GHz .

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