An Embedded Scheme-Based Dual-band Shared Aperture Base Station Antenna Array

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***Abstract*—This paper introduces a dual-band shared aperture base station array based on the embedded scheme, with mitigated cross-band scattering performance. Through inserting innovative helical filters into low-band (LB) radiators, the adverse impact on high-band (HB) antennas caused by close-placed LB antennas is largely restored, across a wideband of 1.36-2.72 GHz (66.7%). Despite matching difficulties brought by the helical filters, the developed LB antenna achieves successful matching in 0.8-0.96 GHz (17%). This is attributed to the specially designed LC series circuits integrated into the LB baluns. Moreover, the incorporation of helical filters extends current paths and enables a compact aperture size of the LB antennas. This leads to enhanced in-band isolation. Consistency between simulations and measurement results in the fabricated array validates the effectiveness of this design.**

Keywords—dual-band base station array, embedded scheme, filtering antenna, scattering mitigation, broadband.

I. INTRODUCTION

In cross-band base station antenna array designs, the scattering from low-band (LB) antennas to adjacent high-band (HB) antennas often causes severely deteriorated HB performance. To address this challenge, various filtering designs are integrated into the LB antennas [1], [2]. However, these filtering structures have relatively narrow de-scattering bandwidths, with the widest range being only 1.7-2.7 GHz. Additionally, they are based on the traditional side-by-side scheme, where HB antennas are placed next to LB antennas.

The embedded scheme, depicted in Fig. 1, is another widely used dual-band base station array arrangement in industry [3]. This scheme usually employs bowl-shaped LB antennas with hollow-cubed configuration. This type of LB antenna has a naturally reduced shielding effect on surrounding HB antennas. However, it cannot completely address the scattering issue and requires extra baffles or raising the height of the HB antennas [3], [4]. This leads to increased costs and reduced stability. Currently, there are no de-scattering designs customed for the embedded scheme, and directly applying existing scattering reduction designs [1], [2] to the embedded scheme also faces challenges.

This paper proposes an innovative dual-band array based on the embedded scheme, featuring an unprecedented wideband de-scattering HB bandwidth from 1.36 to 2.72 GHz (66.7%). This accomplishment is realized by inserting unique helical filters into the bowl-shaped LB antenna. The noteworthy recovery of the HB performance when integrating with the filtered LB antenna verifies the efficacy of the filtering design.

II. FILTERING DESIGN

The insertion of the helical filters into the LB arms effectively suppresses the scattering in the HB while maintaining LB performance. In the HB, the helical filleter is

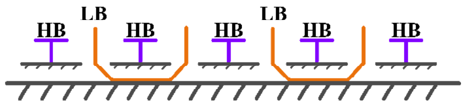

Fig. 1. Side view of a dual-band base station array with embedded scheme.

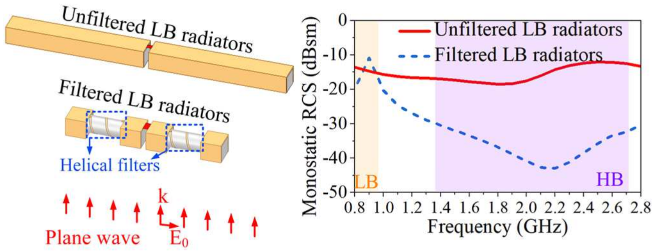

Fig. 2. Scattering results of unfiltered and filtered LB radiators.

equal to a parallel circuit that forms an open circuit performance. Crucially, their insertion divides the LB radiator into small segments with lengths much shorter than the half-wavelength of the highest frequency in the HB. These operations effectively minimize the scattering effect from the LB radiators to the HB antennas. From Fig. 2, in the HB, the filtered LB radiators exhibit significantly reduced scattering performance compared to their unfiltered counterparts, demonstrating the efficacy of the high-stop characteristic. In the LB, the performance of the filtered LB radiators remains comparable to that of the unfiltered ones, indicating the low-pass effectiveness. Notably, the insertion of the helical filters extends the LB current paths, consequently reducing the total length of the LB arms.

III. ARRAY DESIGN AND RESULTS

Fig. 3(a) displays the fabricated embedded share aperture dual-band array. Fig. 3(b) gives more design details of the LB antenna. The LB antenna includes four sub-dipoles to achieve its dual polarization radiation. Each sub-dipole is fed by a balun with specially designed LC series structures. Notably, LB port 1 and LB port 3 are connected to a power divider to realize a common excitation for +45° polarized radiation, with their combined port denoted as port c1. Similarly, LB port 2 and LB port 4 correspond to port c2. To ensure stability and support strength, four 3D-printed T-shaped dielectric supports are custom-shaped to support the LB radiators. Each one comprises four cuboid holders and two cylindrical holders with helical grooves. One LB radiator includes a helical filter and two U-shaped enclosures. The helical filter is realized by winding the copper wire into the helical grooves in the T-shaped support. All the LB components are manufactured independently and then effectively assembled to construct the entire LB antenna.

Fig. 4 compares the S parameters and realized gain results of the HB antennas surrounded by unfiltered and filtered LB radiators in the array. Both HB Ant1 and HB Ant2 show

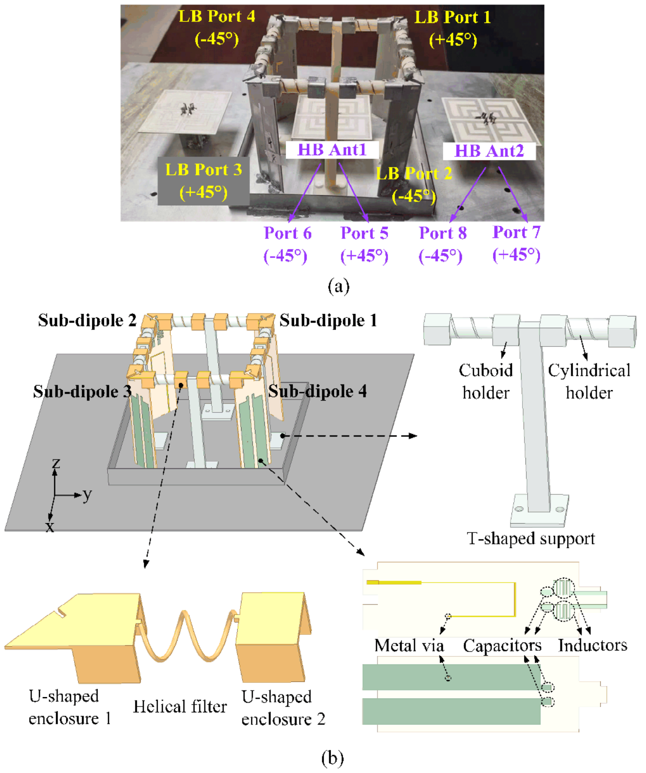

Fig. 3. (a) Fabricated dual-band embedded array. (b) LB antenna design.

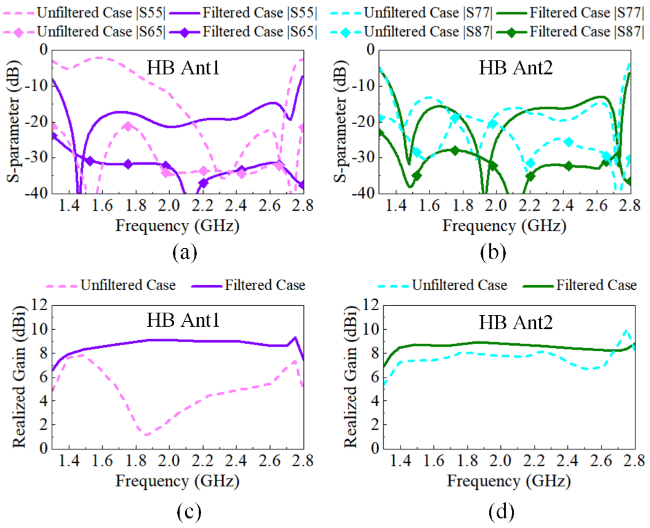

Fig. 4. Performance of HB antennas with the unfiltered and filtered LB radiators. (a) S parameters of HB Ant1. (b) S parameters of HB Ant2. (c) Realized gain of HB Ant1. (d) Realized gain of HB Ant2.

enhanced performance when integrated with the filtered LB radiators, demonstrating the remarkable scattering reduction achieved by the filtered LB antenna. Comparing the unfiltered case results of the two HB antennas shows that HB Ant 2 is less affected than HB Ant1. This is due to HB Ant2 being further from the LB antenna than HB Ant1.

Fig. 5 and Fig. 6 illustrate the results of the LB and HB antennas in the fabricated array. The measured and simulated results display good consistency for both LB and HB antennas. The HB antennas cover a remarkable bandwidth ranging from 1.36-2.72 GHz (66.7%) with stable radiation performance, showcasing superior scattering mitigation accomplished by the filtered LB antenna. The LB antenna operates well in 0.8-0.96 GHz (17.1%). Notably, the LB antenna achieves a

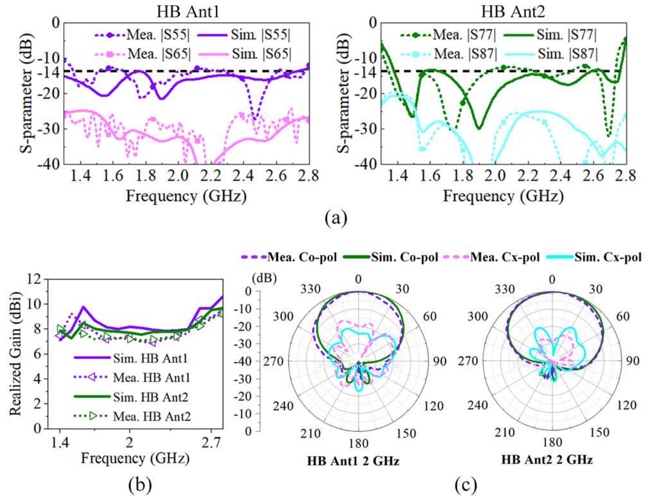

Fig. 5. Measured and simulated results of HB Ant1 and HB Ant2 in the fabricated array. (a) S parameters. (b) Realized gain. (c) Radiation patterns at 2 GHz.

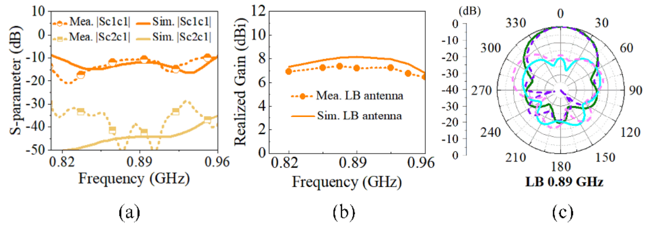

Fig. 6. Measured and simulated results of the LB antenna in the fabricated array. (a) S parameters. (b) Realized gain. (c) Radiation patterns at 0.89 GHz.

miniaturized aperture size of $0.38\lambda_{L0}\times0.38\lambda_{L0}$, leading to improved in-band isolation in the array.

IV. Conclusion

This work presents an embedded dual-band array with wideband cross-band de-scattering ability. By inserting innovative helical filters into the LB radiators, the undesired scattering impact from the LB antenna on the HB antennas is considerably mitigated. This is a successful application of filtering structures in embedded schemes for base station antenna arrays and achieves an impressively wide de-scattering HB bandwidth covering 1.36-2.72 GHz (66.7%). Meanwhile, the LB antenna is well-matched in 0.8-0.96 GHz (17.1%) thanks to specialized LC series structures in its baluns. Its miniaturized aperture size enhances LB in-band isolation, and customized 3D-printed T-shaped supports ensure structural stability. The measured results of the fabricated array prototype are in good agreement with their simulated values, verifying the effectiveness of the embedded array.

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