Enabling the Co-Existence of Multiband Antenna Arrays

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***Abstract*—This paper identifies a kind of interaction mechanism that has not been well addressed before, the cross-band scattering in multi-band antenna arrays. First the cross-band scattering effect is demonstrated on an interleaved dual-band base station antenna array section as an example. Then an effective de-scattering method is proposed, which is to insert chokes on low band antennas. The working mechanism and principle of the chokes are also presented in this paper. Finally, this method is applied on the base station antenna array section to demonstrate its effectiveness.**

Keywords—Array, base station antenna, scattering suppression, multiband

I. INTRODUCTION

Most modern cellular base station antennas are wideband multiband antennas with multiple columns usually covering the bands 698 – 960 MHz and 1710 – 2170 MHz [1]. The columns are interleaved to the extent possible without serious performance degradation in order to make maximum use of the available space within an antenna package. Common configurations are pairs of high-band dual-polarized antenna columns located on either side of a low-band dual-polarized antenna column. In this case, the pair of high-band columns is used to provide 4-way MIMO capability [2]. Typically the horizontal spacing of the high-band columns is about one wavelength which is optimum for MIMO performance. This arrangement is shown in Fig. 1. Where 4-way MIMO capability is required, two such sets of columns may be placed side-by-side. Such configurations typically have high- and low-band elements in close proximity often with elements overlapping. This leads to significant currents of one band being excited on the elements of the other band which in turn leads to serious distortion of the radiation patterns. This problem has frequently been accepted as the price to be paid for packaging the columns in such close proximity, however, by using the choking technique described in this paper, the problem can be largely eliminated.

The problem of excitation of low-band currents in the high-band elements is usually caused by a single common mode resonance of the high-band element at a frequency in the low band. While its effects can be serious, it can usually be corrected by moving the resonance to a higher frequency outside the low band. A useful technique is introducing capacitance between the high-band radiating elements and the balun.

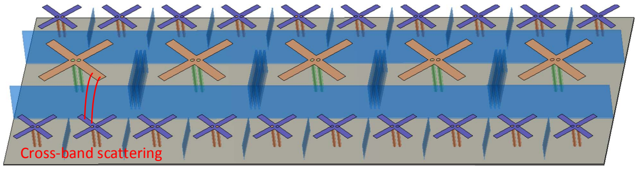


Fig. 1. A schematic diagram of a typical 3G/4G base station antenna array.

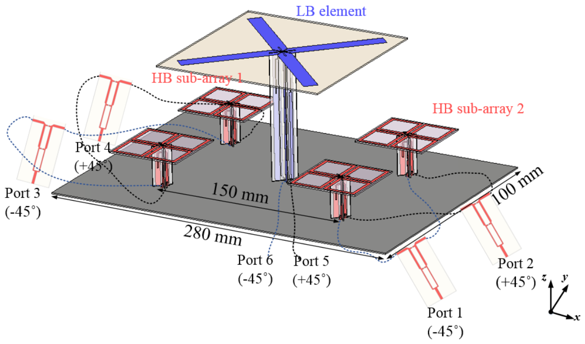


Fig. 2. Configuration of the interleaved BSA array section.

The problem of excitation of high-band currents in the low-band elements and their radiation is less easily solved. The technique of blocking high-band currents in the low-band radiators has been found useful and is the topic of this paper.

In this paper, a new method based on choking techniques is illustrated to suppress the cross-band scattering and enable the co-existence of arrays in different bands. By introducing LB-pass HB-stop chokes into LB antennas, the HB currents induced on the LB antennas when the HB antennas are radiating can be significantly reduced. The intended radiation pattern of the HB elements are largely restored.

II. CROSS-BAND SCATTERING DEMONSTRATION

First, the cross-band scattering problem is demonstrated in a section of a dual-band dual-polarized base station antenna array shown in Fig. 2. In this array section, a single cross-dipole [3] is used as the LB element, and square-shaped cross-dipoles [4]-[6] are used as the HB elements. The LB element is located midway between the four HB elements in two columns. Each column is a sub-array consisting of two

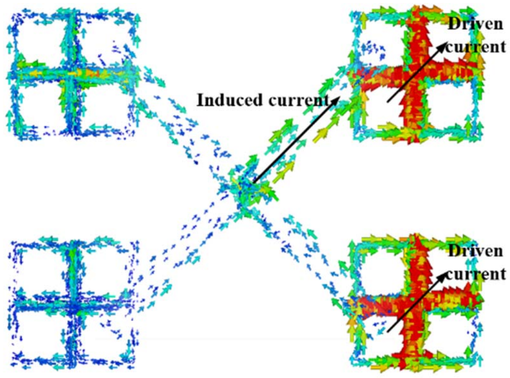
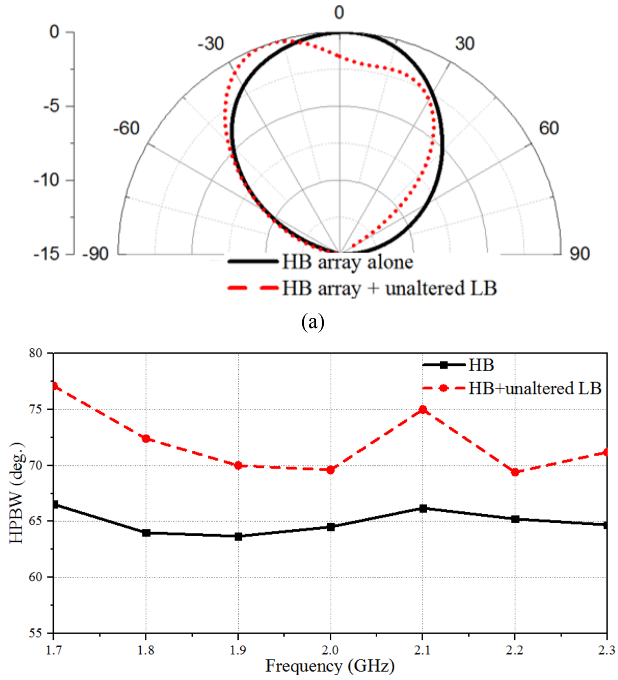


Fig. 3. Current distribution on the array section when HB array on the right column is excited at 1.7 GHz.



(a)

(b)

Fig. 4. (a) Horizontal radiation patterns, and (b) HPBW of the HB array without and with the unaltered LB element.

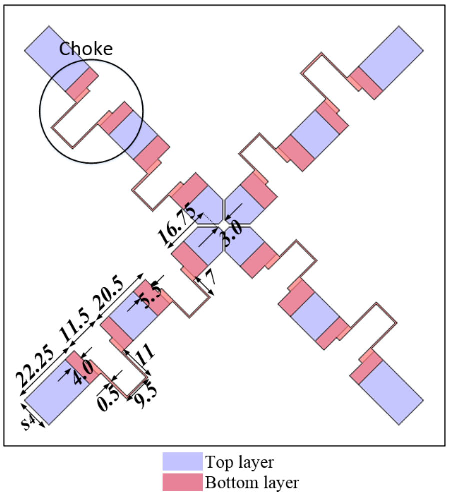


Fig. 5. Configuration of the choked LB radiator.

HB elements. The two HB columns are fed independently. The HB elements of one column with the same polarization are excited simultaneously. The LB element is fed separately at the inputs to the two baluns. The element spacings were chosen for good MIMO performance while keeping the array compact. The LB element operates from 0.82 GHz to 0.98 GHz, and the HB element operates from 1.70 GHz to 2.30 GHz.

Fig. 3 shows the simulated current distribution on the elements when one column of HB antenna sub-array is excited as an example. It is observed from the figure that significant currents are induced on the LB antenna, which will re-radiate and deteriorate the radiation patterns of the HB antennas. To better demonstrate the scattering effect, the radiation patterns in the horizontal plane (*xoz*-plane) with and without the LB element are shown in Fig. 4(a). Before adding the LB element, the HB array has a symmetrical pattern with the main beam pointing at the boresight. After adding the LB antenna element, significant distortion of the pattern is observed. In Fig. 4(b), the half-power-beamwidth (HPBW) of the two cases are plotted since stable HPBW around $65^{\circ}\pm5^{\circ}$ is a critical requirement for base station antennas [7]. According to the figure, with the presence of LB antenna, the HPBW of the HB antenna does not meet the requirement for cellular coverage any more as a result of the scattering.

III. DESIGN OF CHOKED LB ELEMENT FOR SCATTERING SUPPRESSION

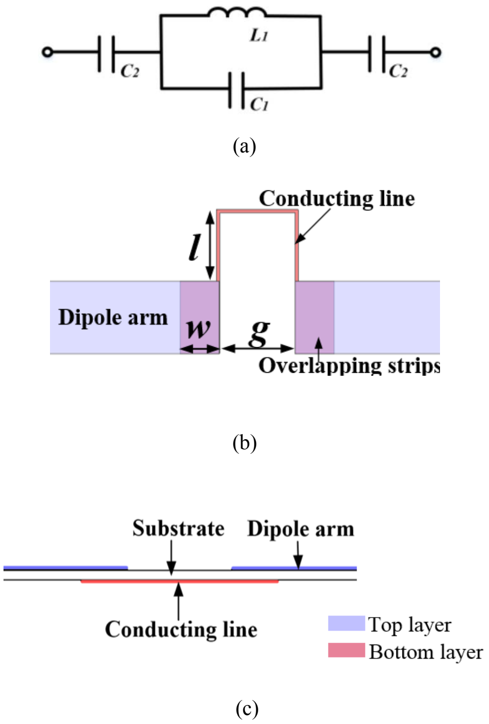
An effective way to mitigate the cross-band scattering is to suppress the induced HB current on the LB antennas. In our work, this is achieved by inserting chokes periodically along LB arms, as shown in Fig. 5. Chokes are designed to present an open circuit at the high band and a short circuit at the low band, so that they block the HB current but affect the LB current as little as possible.

The circuit model of the proposed choke is presented in Fig. 6(a). Each choke consists of a parallel resonant at the HB comprising L_1 and C_1, and a series resonance at the LB with two additional capacitances C_2. These requirements give

$$j2\pi f_h C_1 + \frac{1}{j2\pi f_h L_1} = 0 \tag{1}$$

$$\frac{2}{j2\pi f_l C_2} + \frac{1}{j2\pi f_l C_1 + \frac{1}{j2\pi f_l L_1}} = 0 \tag{2}$$

where f_h is the open-circuit frequency point at the HB, and f_l is the short-circuit frequency point at the LB. Once L_1, C_1, and C_2 are suitably chosen, the chokes are then implemented using conducting strip structures, as shown in Figs. 6(b) and 6(c). The thin conducting strip and the capacitance across the gap provide L_1 and C_1, respectively. C_2 is realized by placing strips on the bottom layer of the substrate and overlapping them with dipole arms on the top layer. The dimensions of chokes are further optimized considering three criteria, i.e., to maximize the HB suppression, to minimize the negative effect on the LB current, and to guarantee impedance matching. The optimized dimensions are presented in Fig. 5. The substrate used has a dielectric constant of 4.4, a loss tangent of 0.0025, and a thickness of 1.0 mm. After optimizing the choked LB radiator, it is fed by baluns and impedance matching elements described in [7]-[9], and is well-matched from 0.82 GHz to 0.96 GHz.



(a)

(b)

(c)

Fig. 6 (a) Circuit model of the choke. (b) Top, and (c) side views of the realized choke.

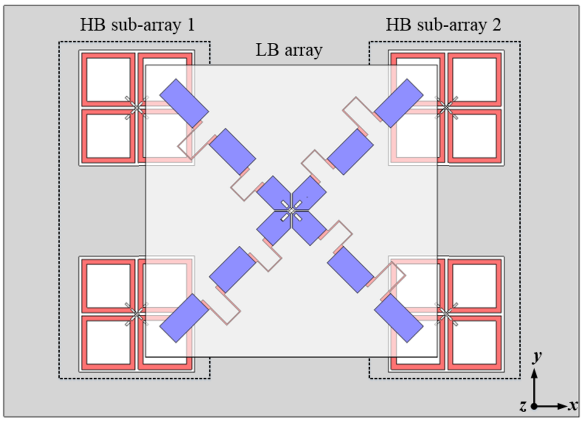
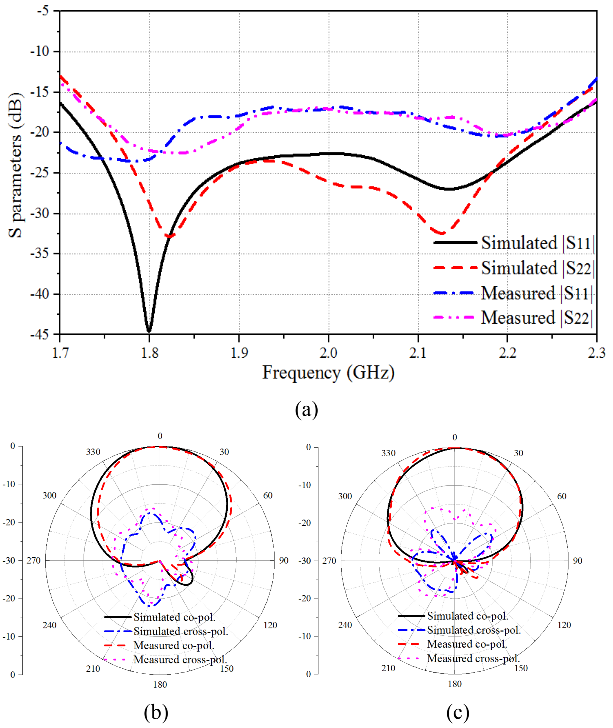


Fig. 7. Arrangement of the interleaved dual-band array with choked LB elements.

IV. DUAL-BAND ARRAY WITH CHOKED LB ELEMENT

The optimized choked LB element is implemented in a dual-band antenna array section to examine their effectiveness in suppressing the HB scattering in a realistic environment. The configuration of the array section is shown in Fig. 7. Except for the modification of the LB element, the arrangement of this array is unchanged from that of Fig. 2.

A prototype of the antenna array section was fabricated and tested. Figs. 8 and 9 show the experimental results of the HB array and LB element, respectively. The HB array is well matched from 1.71 GHz to 2.28 GHz with a bandwidth of 28.6%. The LB element is well-matched from 0.82 GHz to 1.0 GHz with a bandwidth of 19.7%. Symmetrical and stable radiation patterns can be observed across the entire high and low bands.

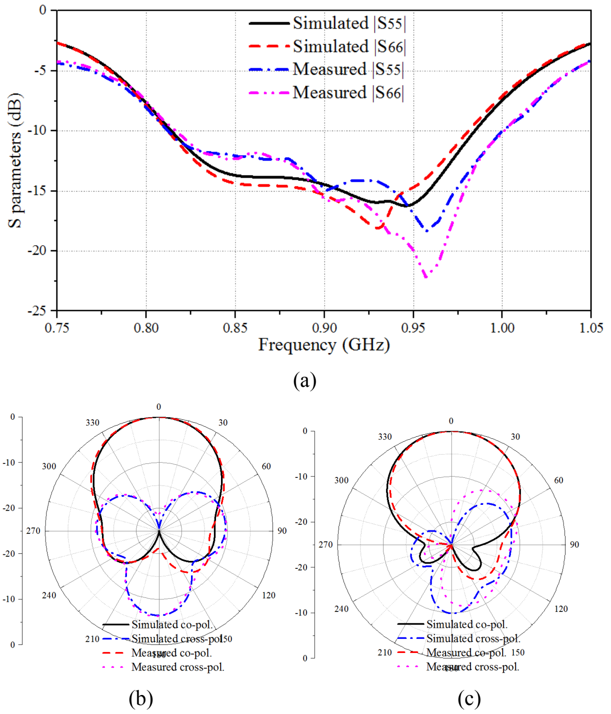


(a)

(b)

(c)

Fig. 8. (a) Simulated and measured reflection coefficients of the HB array. Radiation patterns of the HB array at (b) 1.7 GHz and (c) 2.2 GHz.



(a)

(b)

(c)

Fig. 9. (a) Simulated and measured reflection coefficients of the choked LB element. Radiation patterns of the choked LB element at (b) 0.82 GHz and (c) 0.96 GHz.

The experimental results demonstrate that the presence of the choked LB element does not deteriorate the radiation performance of the HB arrays, and the dual-band array is well-performed across both bands. This dual-band array example verifies that the choking technique is an effective method to mitigate the cross-band scattering in multi-band environment. It guarantees the co-existence of the antennas at different bands without damaging their performance characteristics.

Similar choking methods can be adopted to solve the cross-band scattering issue in future multiband antenna systems.

V. CONCLUSION

With the continued pursuit of antenna size reduction and multifunctionality, multi-band antenna arrays, where antennas working at different bands are interleaved in a compact way, will become ubiquitous. A significant challenge to realize compact high-performance multi-band antenna array is to suppress the cross-band scattering between the antennas working at different bands. Specifically, the HB antennas excite currents on the LB elements that re-radiate, significantly deteriorating the radiation pattern of the HB antennas. This paper introduces an effective way to suppress the cross-band scattering by inserting chokes into LB elements. The chokes effectively block the HB currents with minimum effect on LB operation. In this way, little HB current is induced on the LB antenna and deterioration of the HB pattern is alleviated. The effectiveness of the method is demonstrated on a dual-band base station antenna array section as an example. Comparisons have been made between the two cases, i.e., the LB antenna is a conventional cross-dipole or a choked cross-dipole. It is observed that the choked dipole exhibits a much less scattering effect on the HB antenna radiation.

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