Dual-band orthogonal polarised shared aperture array with shared-elements

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In this paper, an orthogonal polarised dielectric resonator antenna (DRA) which can operate at S- and C-band, has been designed as “shared-element” for forming a dual-band shared aperture array. Furthermore, in this shared aperture array, the S-band array contains four shared-elements, and the C-band array contains four shared-elements and twelve C-band DRA elements. Moreover, a phase compensation power divider is employed to help offset the radiation performance differences between the two types of antenna elements when forming the C-band array. A prototype array was fabricated and measured, showing that the antenna can cover the band of 2.4–2.63 GHz and 6.9–7.1 GHz, respectively. The isolation between bands is higher than 30 dB. The cross-polarisation levels are less than -30 dB in both bands.

Introduction: In modern communication and radar systems, the dual-band shared aperture array is considered to be a good candidate for its multifunction and small size [1, 2].

Several shared-aperture arrays have been reported, and the typical configurations are based on perforated technique [2–4], interlaced technique [4–6], and multi-band antenna elements [7–9]. In general, the shared-aperture arrays based on multi-band antenna elements realise the reuse of antenna itself, which leads to higher aperture efficiency. However, in a shared-aperture array based on multi-band antenna, the physical element spacing is the same at the different bands, but the electric length is different. Thus the frequency ratio (FR) of the higher band to the lower band is theoretically limited to smaller than two to avoid grating lobes at the higher band [9].

In this paper, a dual-band shared aperture array with an FR of 1:2.8 based on dual-band shared DRA elements has been designed. We evenly replaced some of the conventional C-band DRA array elements with shared elements to ensure that element spacing of both bands is at the proper electrical length. Moreover, we used phase compensation technology to offset the difference in phase patterns between them for excellent array radiation characteristic.

Design and analysis of the array element: The dual-band shared DRA element is working at the fundamental HEM\(_{11}\) mode with probe fed in S-band and HEM\(_{13}\) mode with slot coupled in C-band. The detail information is shown in Figure 1a, and the electric field distribution of HEM\(_{13}\) mode is shown in Figure 2. Figure 3a shows that the antenna covers the frequency bands of 2.4–2.63 GHz and 6.9–7.1 GHz with reflection coefficient below -10 dB.

The C-band DRA is working at HEM\(_{11}\) mode with slot coupled, and the detailed information is shown in Fig. 1b. The C-band antenna covers the frequency bands of 6.55–7.55 GHz with reflection coefficient below -10 dB as Figure 3b shows, which completely covers the working frequency band of the shared elements at C-band.

Fig. 1 Configuration of two types of DRA elements: (a) Dual-band shared DRA element, (b) C-band DRA element
Fig. 5 Configuration of the dual-band shared aperture array: (a) Top view, (b) side view

Fig. 6 Photo of the prototype antenna array and experimental environment

Fig. 7 Measured and simulated S-parameter

Fig. 8 Measured and simulated radiation patterns at S-band: (a) xoz plane, (b) yoz plane

Fig. 9 Measured and simulated radiation patterns at C-band: (a) xoz plane, (b) yoz plane

The simulated and measured radiation patterns are shown in Figures 8 and 9. In both two bands, the simulated and measured co-polarisation patterns show good agreement, and the measured cross-polarisation is better than $-30$ dB in the main lobe. However, the measured cross-polarisation is worse than simulated data in both two band. The possible causes are analysed as follows. In S-band, the feed probes are cut and welded manually, the length error is unavoidable, and the symmetrical characteristic of the array is affected, and which influence the polarisation performance. Moreover, the elements are pasted on GND by glue manually, and the position errors of DRA array will occur inevitably, which will influence the polarisation performance too. Especially in C-band, the small size elements are more sensitive to position error.

Conclusion: In this paper, an S/C shared aperture array with a FR of 1:2.8 based on dual-band shared DRA elements and phase compensation power divider is presented. Meanwhile, the problem that the FR of a dual-band shared aperture array based on dual-band element is no more than two is solved. The proposed antenna array is fabricated and measured, covering the frequency bands of 2.4–2.63 GHz and 6.9–7.1 GHz with the reflection coefficient below $-10$ dB, the isolations between bands are over 30 dB, the cross-polarisation level for both bands is lower than $-30$ dB in the main lobe. The proposed antenna has many advantages such as high aperture efficiency, high integration, and low cost and this technology has broad prospects in shared aperture array applications.

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