Design of small CRPA arrays with high-dielectric ceramic superstrates for gain enhancement

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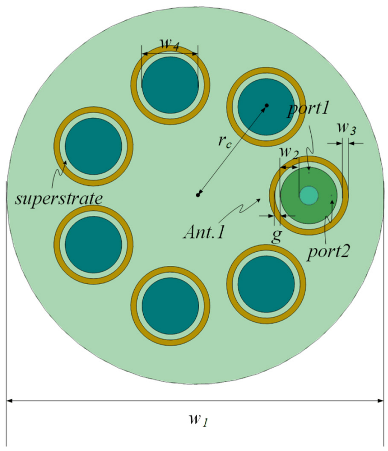
***Abstract*—This paper proposes small CRPA arrays with high-dielectric ceramic superstrates for dual-band operation. Each array element consists of inner and outer microstrip rings printed on a high-dielectric substrate, and a hybrid chip coupler is used for quadrature excitation to achieve circular polarization. The superstrates with high relative permittivity are designed to have a cylindrical shape and are placed above the inner ring area to enhance the bore-sight gain. The results show that the bore-sight gain of the active element pattern is –1.54 dBic at 1.5754 GHz and –3.35 dBic at 1.2276 GHz.**

***Keywords*— high-dielectric superstrate, dielectric loading, small CRPA array.**

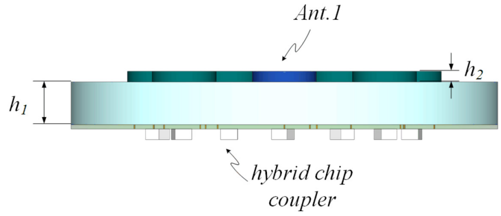
I. INTRODUCTION

Dual-band patch antennas have been widely adopted in controlled reception pattern antenna (CRPA) arrays to mitigate the effect of undesired interferences while achieving accurate position information from the global positioning system (GPS) satellites [1]. In recent years, single-layer patch antennas have gained popularity due to the ease of fabrication, lower fabrication costs, and higher durability compared to multi-layer structures [2]. However, unexpected frequency shifts may occur in extremely small arrays due to the mutual coupling effect [3]. Thus, such frequency shifts should be tuned to enhance the gain by compensating for the effective dielectric constant [4].

In this paper, we propose small CRPA arrays with high-dielectric superstrates for the dual-band operation in the GPS L1 and GPS L2 bands. Each array element is composed of the inner and outer microstrip rings printed on the top of a high-dielectric substrate, and hybrid chip couplers are used to feed the antenna with broadband circular polarization (CP) properties. To enhance the gain degraded by the frequency shift, the effective dielectric constant of the inner ring is adjusted by loading high-dielectric ceramic superstrates. For more efficient adjustment, we design the shape of the superstrates to have a cylindrical shape with the same diameter as the inner ring, and the height and the relative permittivity of the superstrate are determined to maximize the gain in the bore-sight direction. The proposed antenna has a bore-sight gain of −1.54 dBic and −3.35 dBic at 1.5754 GHz and 1.2276 GHz, respectively, and we can confirm that the high-dielectric ceramic superstrates are suitable for enhanced gain in small arrays.



(a) Top view



(b) Side view

Fig. 1. Geometry of the proposed dual-band array with the superstrate.

II. PROPOSED ARRAY WITH SUPERSTRATES

Fig.1 (a) shows the top view of the proposed seven-element circular array that is printed on a high-dielectric ceramic substrate ($\varepsilon_r = 20$, $\tan\delta = 0.0035$) with a diameter of w_1 and a height of h_1. Each array element is located at the distance of r_c from the center of the substrate and consists of the inner and outer microstrip rings printed on the top of the substrate. For broadband CP properties, hybrid chip couplers are used to feed the inner ring with a quadrature phase excitation through thin wires, and the outer ring is electromagnetically coupled to the inner ring. The inner and outer rings have microstrip widths of w_2 and w_3 and are separated by g. The high-dielectric superstrates have a diameter of w_4 and a height of h_2 and are designed to be placed above the inner ring. Note that the outer circumference of the superstrates is designed to be identical with that of inner rings to cover its entire conducting area.

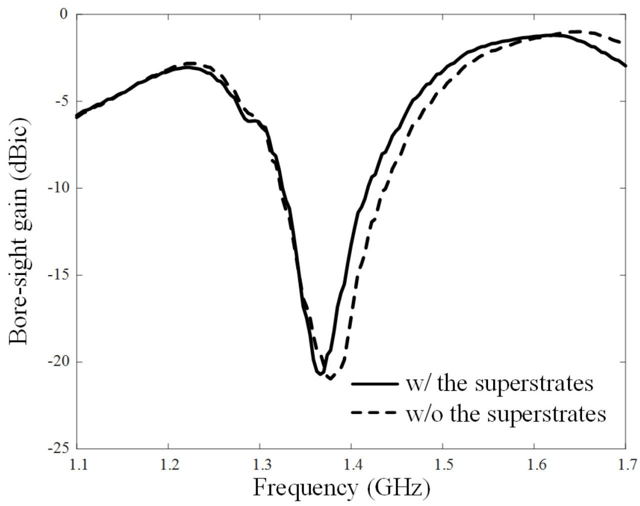


Fig. 2. Comparison of bore-sight gains obtained from active element patterns.

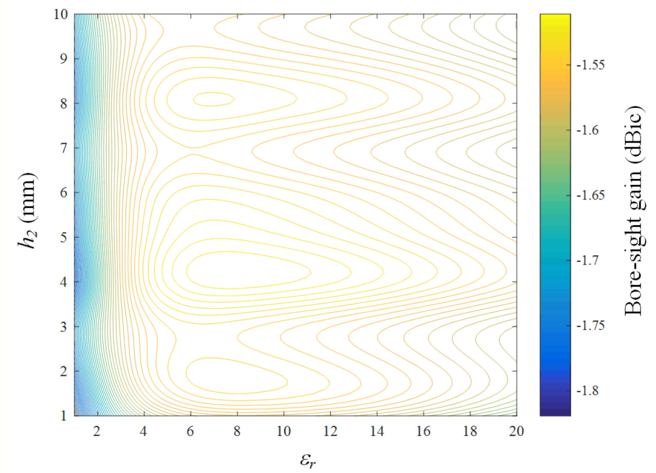


Fig. 3. Variations of bore-sight gains according to ε_r and h_2.

Fig. 2 exhibits the simulated bore-sight gains of the proposed array with the high-dielectric ceramic superstrates, and the results are compared to data obtained without the superstrates. Detailed design parameters are as follows: w_1 = 127 mm, w_2 = 7.3 mm, w_3 = 0.3 mm, w_4 = 22.6 mm, h_1 = 10 mm, h_2 = 4 mm, r_c = 40 mm, g = 0.3 mm. The simulated results are obtained from active element patterns of Ant. 1 while the ports of other array elements are terminated by 50-Ω loads. The solid and dashed lines present the results with and without the superstrates, respectively, and the data confirm that the existence of the superstrate only affects the gain at 1.5754 GHz, which is improved from −1.76 dBic to −1.54 dBic. Fig. 3 presents variations of the bore-sight gain at 1.5754 GHz according to the dielectric constant (ε_r) and the height of the superstrates (h_2). The maximum gain is observed at ε_r = 8 and h_2 = 4.2 mm, and the results demonstrate that the proposed structure is suitable to improve the bore-sight gain in small arrays.

III. CONCLUSION

We investigated the design of small CRPA arrays with high-dielectric superstrates for gain enhancement. The antenna showed the bore sight gain of −1.54 dBic and −3.35 dBic at 1.5754 GHz and 1.2276 GHz. This gain enhancement of about 0.3 dB was achieved by adjusting the resonant frequency in the GPS L1 band. The results demonstrated that the high-dielectric superstrates are feasible to compensate for the gain degradation in small arrays.

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