Design of small CRPA arrays with circular loop antennas for frequency-insensitive properties

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***Abstract*—This paper proposes a small CRPA array with frequency-insensitive properties. The array consists of seven elements, and each element is composed of upper and lower circular loops that are designed to resonate at 1.575 GHz and 1.227 GHz, respectively. The lower loop is fed by the hybrid chip coupler, and the upper loop is electromagnetically coupled for a frequency-insensitive feeding mechanism. Due to the frequency-insensitive behavior, the bore-sight gain of each array element is maintained to be greater than −5 dBic from 1.21 GHz to 1.74 GHz, and this bandwidth can be further extended by adjusting the width of the upper circular loop, which varies the ratio of electric and magnetic coupling strengths in the proposed feeding mechanism.**

Keywords— Microstrip loop antenna, GPS array, broadband.

I. INTRODUCTION

As demands grow for extremely small controlled reception pattern antenna (CRPA) arrays [1], the field of antenna engineering makes a lot of effort to mitigate the mutual coupling effect that degrades the gain of active element patterns. This degradation becomes more significant when an undesired frequency shift occurs in such small arrays. Thus, some previous approaches focus on achieving broadband characteristics by using an external matching circuit [2], via pins [3], and additional parasitic elements [4]; however, these approaches increase the design complexity significantly.

In this paper, we propose the design of small CRPA arrays with frequency-insensitive properties. The array is composed of seven elements, and each element has upper and lower circular loops that are designed to resonate at 1.575 GHz and 1.227 GHz, respectively. The lower loop is fed by two pins connected to two output ports of the hybrid chip coupler, and two loops are electromagnetically coupled with each other for excitation. The frequency-insensitive behavior can be achieved by adjusting the electric and magnetic coupling strengths, which results in the bore-sight gain of each array element to be greater than −5 dBic over a wide frequency range from 1.21 GHz to 1.74 GHz. This bandwidth can be further extended by varying the width of the upper circular loop that affects the coupling ratio of the proposed feeding mechanism. The results demonstrate that the frequency-insensitive behavior of the proposed array is suitable for small CRPA arrays without the increase of the design complexity.

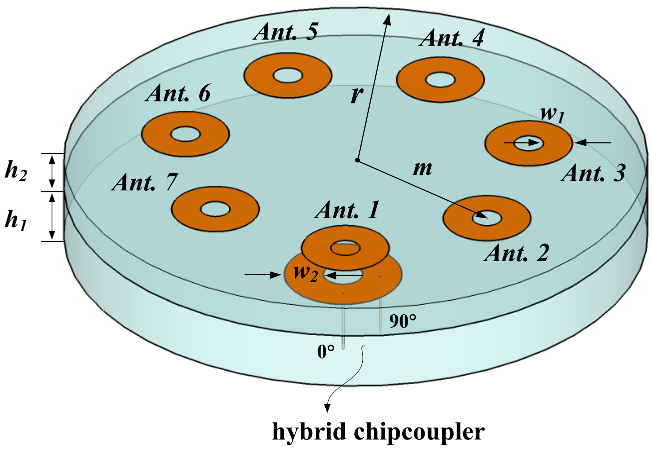

Fig. 1. Geometry of the proposed small CRPA arrays.

TABLE I. DESIGN PARAMETERS AND OPTIMIZED VALUES

Parameters	w_1	w_2	h_1	h_2	r	m
Values (mm)	5.65	7.5	7	5	63.5	45

II. PROPOSED CIRCULAR LOOP ANTENNA ARRAY

Fig. 1 shows the geometry of the proposed seven-element CRPA array, and its array elements are arranged at radius m from the center of a circular ground platform having a radius of *r*. Each array element is composed of upper and lower microstrip circular loops that are printed on a high-dielectric ceramic substrates (ε_r = 20, $tan\delta$ = 0.0035). The upper and lower loops have widths of w_1 and w_2 and located with substrate thicknesses of h_1+h_2 and h_1 from the ground, respectively. To achieve the frequency-insensitive properties with circular polarization, the lower loop is fed by two pins with a phase difference of 90°, and the upper loop is electromagnetically coupled for excitation. Note that the ratio of the electric and magnetic coupling strengths can be adjusted by varying w_1. Detailed design parameters are optimized by a genetic algorithm (GA) in conjunction with the FEKO EM simulator [5], and the optimized values are listed in Table 1.

Fig. 2 shows simulated bore-sight gains of Ant. 1 as a function of frequency, and the results are obtained while terminating ports of other array elements. The solid line indicates the total gain, and the dashed and dotted lines specify co-pol (right-hand circular polarization) and cross-pol (left-hand circular polarization) gains, respectively. The bore-sight gains of the antenna are −2.4 dBic at 1.575 GHz and −4.5 dBic at 1.227 GHz, and the simulated bore-sight gains are greater than −5 dBic from 1.21 GHz to 1.74 GHz, which includes the entire ranges of the GPS L1 and GPS L2 bands.

Fig. 3 shows variations of the bore-sight gain according to w_1. In this comparison, the value of w_1 is increased from 3.25 mm to 5.65 mm at an interval of 0.5 mm. The results present that the resonance frequency of the lower loop is not affected by w_1, and only the resonance in the higher frequency band is adjusted. As a result, the bandwidth for the gain of greater than −5 dBic can be further improved from 427 MHz to 513 MHz, which confirm that the proposed structure is suitable to achieve frequency-insensitive behaviors for small CRPA arrays.

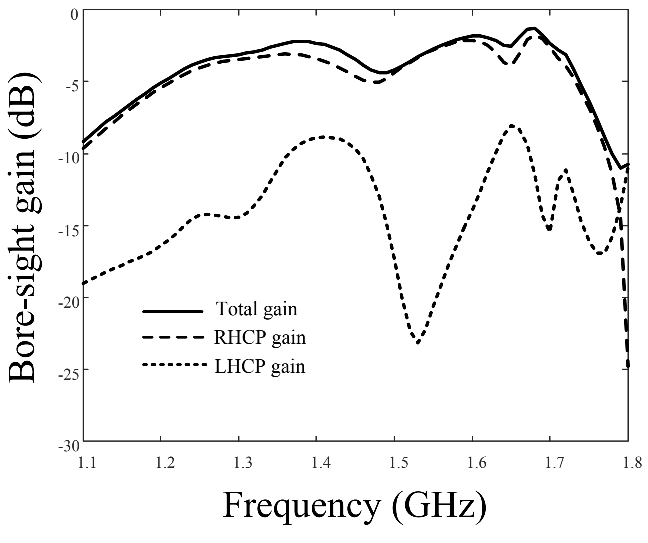

Fig. 2. Bore-sight gain of the proposed antenna.

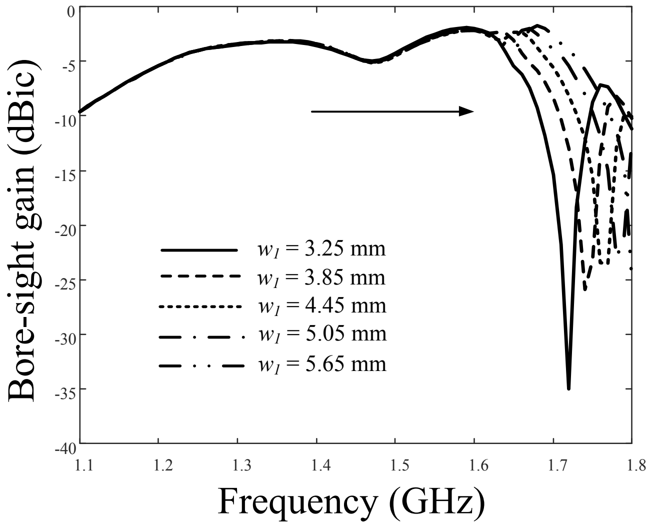

Fig. 3. Variations of bore-sight gains according to ω_1.

III. Conclusion

We investigated the design of frequency-insensitive arrays for small CRPA applications. The frequency-insensitive properties were achieved by the proposed feeding mechanism that allows for the electromagnetic coupling between the two circular loops, and the ratio of the electric and magnetic coupling strengths were adjusted by the width of upper loop. The optimized array showed the bore-sight gains of −2.4 dBic at 1.575 GHz and −4.5 dBic at 1.227 GHz, and the bore-sight gain of each array element is maintained to be greater than −5 dBic from 1.21 GHz to 1.74 GHz.

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