Design of a GPS Antenna Element Using Circular Dual-loop With an Extended Cavity Structure

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***Abstract* – This paper proposes a circular dual-loop GPS antenna with an extended cavity structure for a small GPS array. The antenna element consists of lower and upper circular loops printed on a high-dielectric ceramic substrate, and the extended cavity structure exists above the ground plane to improve the isolation characteristic. Antenna characteristics depending on cavity height are analyzed and the results show that the proposed structure can improve the isolation characteristic by reducing the leakage field. The isolation is further enhanced by miniaturizing the antenna size with maximized the effective dielectric constant.**

***Index Terms* — GPS antenna, Microstrip loop antenna, Cavity antenna, Antenna array.**

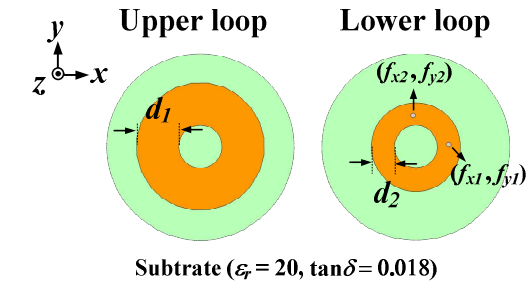
1. Introduction

The antenna array is widely used to minimize the interferences caused by jamming signals or multipath channel environment in global positioning system (GPS). The improvement of the isolation characteristic between array elements is essential because the mutual coupling causes the unwanted resonant frequency shift, bore-sight gain reduction, and pattern distortion in an extremely small GPS array. The mutual coupling can be reduced by inserting an additional structure between antenna elements [1], [2]. This approach has disadvantages that increase the manufacturing cost and design complexity. Thus, some previous researches focus on minimizing the antenna size by using lumped elements [3], metamaterial substrate [4], and slots in antenna radiators [5] to increase the separation distance between array elements for isolation improvement. However, these studies have a limitation to reduce the mutual coupling caused by leakage field from an antenna element.

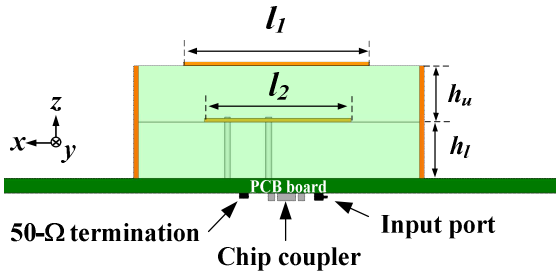
In this paper, we propose the design of a circular dual-loop antenna with an extended cavity that improves the isolation characteristic by substantially reducing the leakage field. The isolation is further enhanced by miniaturizing the antenna size with maximized the effective dielectric constant of the substrate. The proposed antenna is composed of a lower circular feed loop and an upper circular resonating loop printed on a high-dielectric ceramic substrate. Extended cavity structure, which can improve the isolation characteristic, exists above the ground plane and surrounds the side of the ceramic substrate entirely. The lower feed loop is fed by two ports of a hybrid chip coupler (XC1400P-03S from Anaren) for circular polarization characteristic, and the upper loop is then magnetically coupled to the lower loop for preventing gain reduction with low reactance variations [6]. We observe the antenna characteristics according to the height of an extended cavity structure to verify the improvement of the isolation characteristic and antenna miniaturization. The results show that the proposed antenna is suitable for achieving isolation enhancement by reduction of the leakage H-field strength from the extended cavity structure and miniaturization of the antenna size.

2. Proposed antenna element

Fig. 1 shows the geometry of the proposed GPS antenna element. The antenna consists of upper and lower circular loops printed on a high-dielectric ceramic substrate (ε_r = 20, tanδ = 0.004) with thicknesses of h_l and h_u, respectively. The upper and lower circular loops are designed with diameters of l_1 and l_2, and widths of w_1 and w_2. The lower feed loop is directly connected to two ports of a hybrid chip coupler denoted as (f_{x1}, f_{y1}) and (f_{x2}, f_{y2}) for CP properties. The upper loop is electromagnetically coupled to the lower loop for preventing significant gain reduction with low reactance



(a)



(b)

Fig. 1. Geometry of the proposed antenna. (a) Top view. (b) Side view.

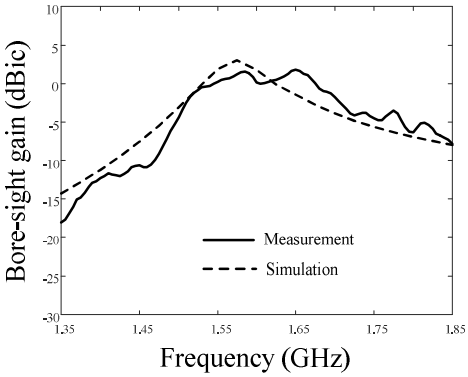


Fig. 2. Bore-sight of the proposed antenna.

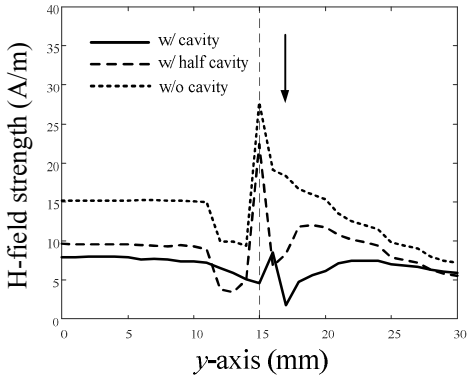


Fig. 4. H-field strength according to the cavity height.

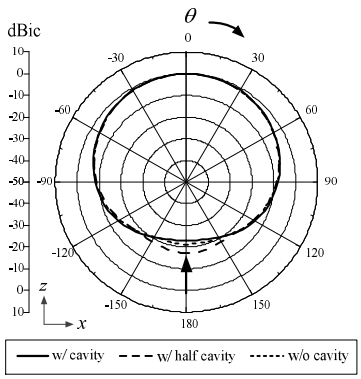


Fig. 3. 2-D patterns of the proposed antenna according to the cavity height.

variations [6]. The extended cavity structure exists above the ground plane and surround the entire side of the ceramic substrate. This extended cavity structure can reduce the leakage field from the antenna substrate and miniaturize the antenna size by increasing the effective permittivity of the substrate. Fig. 2 shows the measured bore-sight gain compared to the simulated data. The dashed line indicates the simulated results, and the measurement is represented by the solid line. The simulated and measured values are 3.0 dBic and 1.1 dBic at 1.575 GHz, and greater than 0 dBic from 1.53 GHz to 1.62 GHz. The resonant frequency increases as the cavity height decreases, and the value without extended cavity is 1.65 GHz. This resonant frequency shift according to the cavity height can verify that the proposed extended cavity structure miniaturizes the antenna size by maximizing the effective permittivity of the substrate. The normalized radiation patterns according to the cavity height are shown in Fig. 3. The back radiation at $\theta = 180°$ is reduced from −22 dB to −18 dB, and this result demonstrates that the extended cavity structure can improve the front-to-back ratio (FBR) at resonant frequency effectively. Fig. 4 presents the H-field strength of the antenna at $z = x = 0$ mm (0 mm ≤ y ≤ 30 mm). The leakage H-field strength is substantially reduced from the location of the extended cavity which is indicated vertical dashed line (y = 15 mm). This leakage field reduction can derive the isolation improvement between adjacent array elements in an extremely small GPS antenna array.

3. Conclusion

The design of an antenna element for an extremely small GPS array by using circular dual-loop with extended cavity structure was proposed to enhance the isolation characteristic. The proposed antenna had measured bore-sight gain of 1.1 dBic at 1.575 GHz, and the gain was greater than 0 dBic from 1.53 GHz to 1.62 GHz. We analyzed the antenna characteristic such as resonant frequency, radiation pattern, and leakage field from the antenna element according to the cavity height. The results demonstrated that the proposed extended cavity structure enhances the isolation characteristic by reduction of the leakage field from the antenna. Moreover, this isolation improvement can be enlarged by miniaturizing the antenna size with maximizing the effective permittivity of the dielectric substrate due to the extended cavity structure.

Acknowledgment

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