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DESIGN OF A DUAL-BAND GPS ANTENNA USING A COUPLED FEEDING STRUCTURE FOR HIGH ISOLATION IN A SMALL ARRAY

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ABSTRACT: *This article proposes a novel feeding mechanism to improve the isolation characteristics in the GPS L1 and L2 bands for electromagnetically small arrays (aperture diameter $< \lambda$). In the mechanism, a feeding patch is sandwiched between two radiating patches and excited by two pins with a 90° phase difference. To improve the isolation, ceramic with a high dielectric constant is used as the antenna substrate, and then four identical antennas are mounted on the ground platform. The results prove that the proposed design approach can achieve high isolation in the arrays.* © 2014 Wiley Periodicals, Inc. Microwave Opt Technol Lett 56:359–362, 2014; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.28098

Key words: *GPS antenna; array antenna; coupled feeding antenna*

1. INTRODUCTION

Microstrip patch antennas are commonly adopted as an individual element of GPS arrays because their low profile, multi-band, high-directive, and circular polarization (CP) characteristics are suitable for satellite signal reception. These antennas, however, often exhibit performance degradation, such as low radiation gain and high pattern distortions, when isolation between the elements is not sufficiently ensured [1]. The performance degradation is even more significant when the size of the array aperture becomes much smaller than a quarter of a wavelength. To mitigate this performance degradation, various antenna miniaturization techniques are applied to maximize the isolation by increasing the physical distance between array elements [2, 3].

In this article, we propose a dual-band microstrip patch antenna with a novel feeding mechanism to improve the isolation for small arrays whose aperture diameter is much smaller than a wavelength. The feeding mechanism uses a nonradiating feeding patch between the two radiating patches to increase the isolation by confining the near electromagnetic field between the patches. The feeding patch is excited by two pins with a 90° phase difference for broad CP bandwidth. To improve the isolation, ceramic antenna substrates with a high dielectric constant are adopted, and each antenna element is mounted on a ground platform with an insertion depth of 4 mm. This approach effectively confines fields close to each element, which results in high isolation with minimized mutual coupling. Four identical antenna elements are then built and mounted on a 4-inch circular ground platform, and antenna performances, such as the reflection coefficients, radiation gain, and patterns, of the proposed antenna are measured in a full anechoic chamber. The results demonstrate that the proposed design approach provides a significant isolation improvement in the small GPS antenna arrays.

2. PROPOSED ANTENNA STRUCTURE

Since isolation significantly affects antenna performances, we apply a novel feeding mechanism to improve the isolation characteristics for an array with an aperture diameter of 4 inches. Figure 1 shows the geometry of the proposed antenna structure that consists of a feeding patch and two radiating L1 and L2 patches for dual-band operation. In this structure, near EM fields that decrease the isolation, is caught between two radiating patches. This results in a significant isolation improvement between array elements. The feeding patch is excited by two pins with a 90° phase difference and inserted between two radiating patches [4]. This phase difference is obtained from a 4-port hybrid chip coupler (XC1400P-03S from Anaren) [5], embedded on an RF circuit board (FR4, $\varepsilon_r = 4.5$, tan $\delta = 0.02$), to attain broad CP characteristics. The two radiating patches are

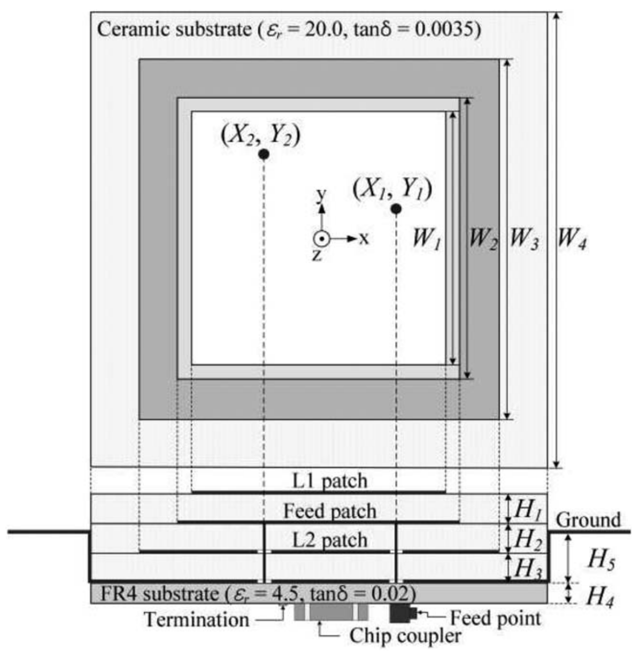

Figure 1 Proposed antenna structure

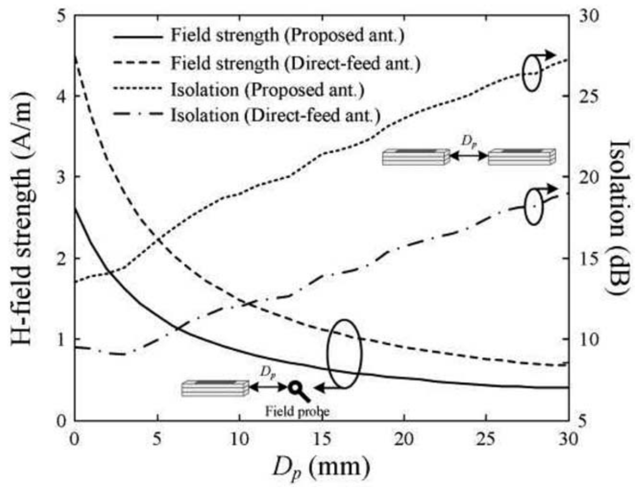

Figure 2 Variations of the isolation and *H*-field distributions according to parameter D_p

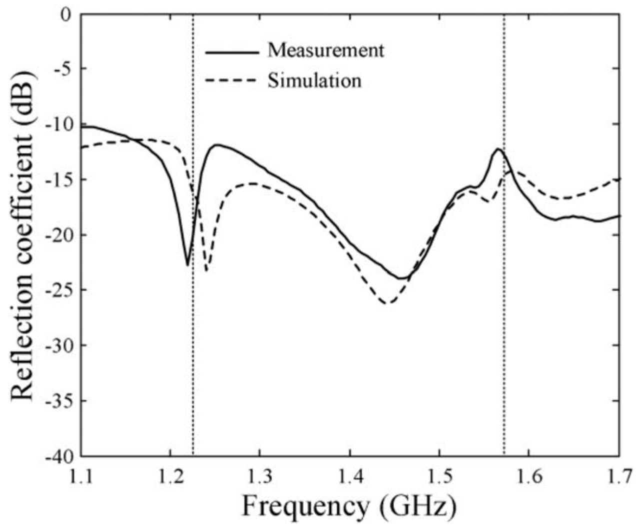

Figure 4 Reflection coefficients of the optimized antenna

electromagnetically coupled with the feeding patch, and the coupling strength is controlled by the width of the feeding patch (W_2) and the substrate heights (H_1, H_2, and H_3). Gains in the GPS L1 and L2 bands are then appropriately determined by the coupling strength and the widths of the radiating patches (W_1 and W_3). The two feeding positions are expressed as (x_1, y_1) and (x_2, y_2). To improve the isolation between array elements, high-dielectric ceramic ($\varepsilon_r = 20.0$, $\tan\ \delta = 0.0035$) is adopted for the antenna substrate, and then, the antennas are mounted on the 4-inch ground platform with an insertion depth of 4 mm.

To verify the advantage of the proposed feeding mechanism, the isolation and the near *H*-field strength of the antenna are compared with those of a conventional direct feeding antenna [6], as shown in Figure 2. The isolation is computed by varying the distance (D_p) between two identical antennas of each feeding mechanism, and the strength of the near *H*-field is observed at various probe positions. The isolation of the proposed feeding mechanism, represented with a dotted line, is significantly increased by 8.29 dB at $D_p = 30$ mm (from 18.97 to 27.26 dB) compared to that of the direct feeding mechanism. As expected, coarser *H*-filed distributions are also observed in the proximity of the radiating patches for the proposed antenna.

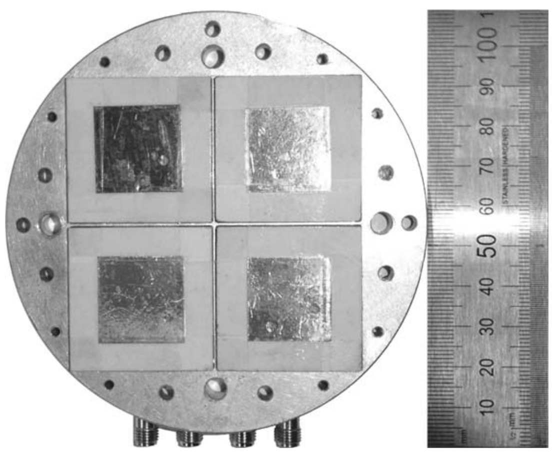

Figure 3 Fabricated GPS antennas with the ground platform

3. OPTIMIZATION AND MEASUREMENT

To further improve the isolation and radiation gain, the detailed design parameters of the proposed antenna are optimized by using a genetic algorithm [7] in conjunction with the FEKO EM simulator [8]. The cost function of the optimization is defined as:

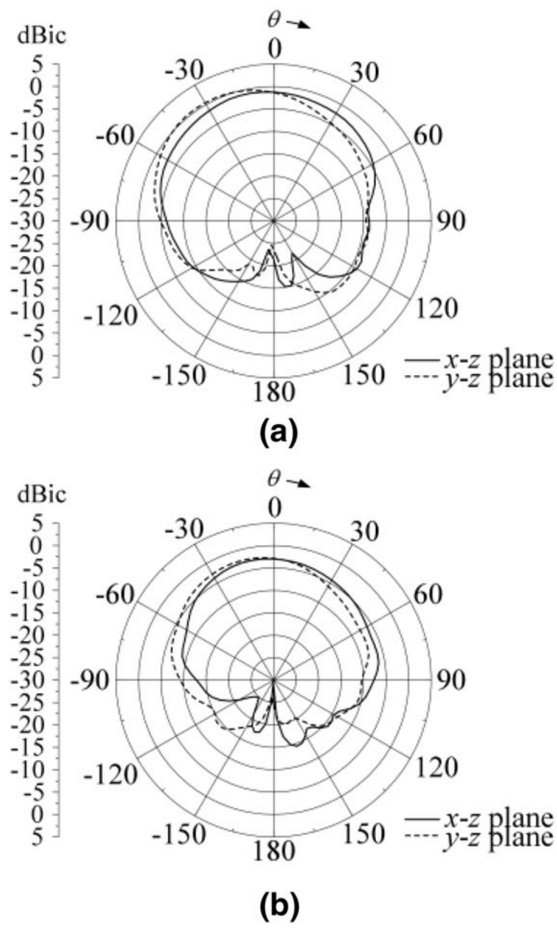

Figure 5 Radiation patterns of the optimized antenna. (a) GPS L1 band (*x-z* and *y-z* planes). (b) GPS L2 band (*x-z* and *y-z* planes)

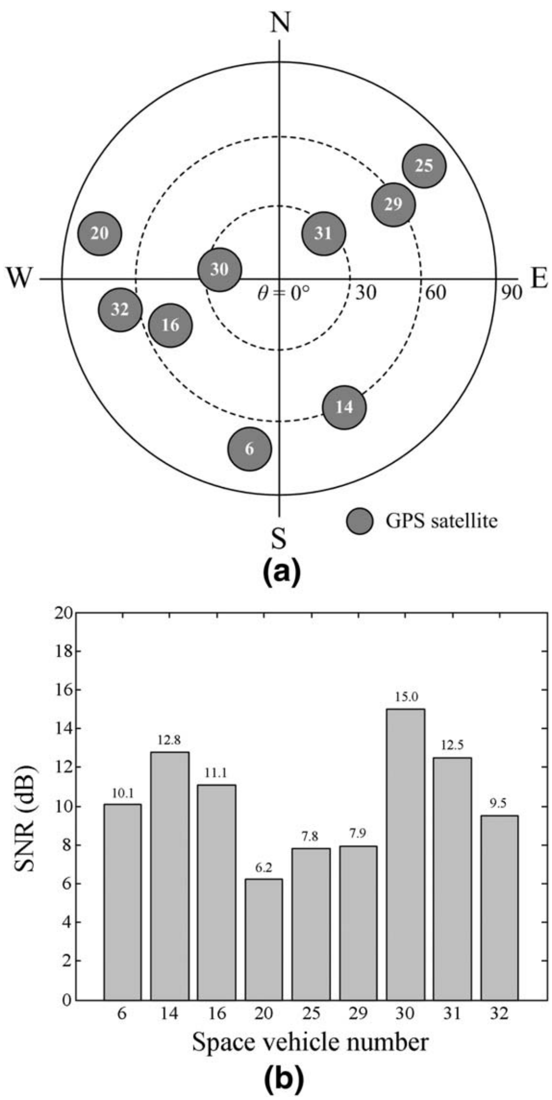

Figure 6 Field test results (a) GPS satellite positions and (b) measured SNR values

$$\text{Cost1} = \frac{|S_{21}|}{\frac{1}{2}\left(\frac{1}{\text{N}\varphi\text{N}\theta}\sum_{\theta=1}^{N_\theta}\sum_{\varphi=1}^{\text{N}\varphi} G_{L1}(\varphi,\theta) + \frac{1}{\text{N}\varphi\text{N}\theta}\sum_{\theta=1}^{N_\theta}\sum_{\varphi=1}^{\text{N}\varphi} G_{L2}(\varphi,\theta)\right)} \quad (1)$$

where $|S_{21}|$ is the ratio of the voltage signal between two array elements, G_{L1} and G_{L2} are the gains of the upper hemisphere ($0° < \theta < 90°$) in the GPS L1 and L2 bands, respectively, and N_φ and N_θ represent the number of evaluated values of φ and θ. The optimized parameters are shown as follows: $W_1 = 20.3$ mm, $W_2 = 21.3$ mm, $W_3 = 27.2$ mm, $W_4 = 34.5$ mm, $H_1 = H_2 = H_3 = 2$ mm, $H_4 = 1$ mm, $X_1 = 5.8$ mm, $X_2 = 2.3$ mm, $Y_1 = -4.2$ mm, and $Y_2 = 6.5$ mm. Figure 3 shows a photo of the fabricated 4-element GPS antenna array with the optimized parameters. Four identical antennas are arranged in a uniform rectangular array with an interval of 35.5 mm (about 0.16 λ at 1.2276 GHz) and mounted in the 4-inch circular ground platform with an insertion depth of 4 mm. Since each antenna width is 34.5 mm, the conducting ground between the antenna elements operates as a shielding wall with dimensions of $34.5 \times 1 \times 4$ mm^3. Because of this conducting ground, near EM fields are efficiently confined near the antenna. Figure 4 shows the measured reflection coefficients of −13.1 dB (GPS L1) and −20.3 dB (GPS L2), which agree well with the simulation. Figures 5(a) and 5(b) show measured radiation patterns of the *x-z* and *y-z* planes at each band. The antenna has average half power beam widths of 92° and 86.5° in L1 and L2 bands. The results demonstrate that the antenna with the proposed feeding mechanism is suitable for use as an individual array element for the small GPS array.

4. FIELD TEST

To measure the SNR values of the L-band GPS signals transmitted from real GPS satellites, a field test was conducted by using the fabricated array on a rooftop of a building (height = 13 m, Pangyo, Korea) in clear weather (temperature: 27.5°C, humidity: 62.6%). Figure 6(a) shows that the antenna recognizes nine GPS satellite positions, specified with space vehicle numbers, that are located from $\theta = 25°$ to $\theta = 76°$. Figure 6(b) shows the measured SNR values for the satellites with the average SNR value of 10.3 dB.

5. CONCLUSION

We have investigated a novel feeding mechanism to improve the isolation characteristics in the GPS L1 and L2 bands for small arrays. In the proposed mechanism, a feeding patch was inserted between the two radiating patches that are printed on the high dielectric ceramic substrate to confine more near EM fields in proximity of the antenna. To verify the suitability of the proposed antenna, antenna's characteristics were measured in a full anechoic chamber, and a field test was conducted at an open site to further verify the SNR values for real GPS satellite signals. The results proved that the proposed mechanism was suitable for use in small GPS arrays.

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