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A SOLUTION FOR INCREASING IMMUNITY AGAINST THE INFLUENCE OF GROUND VARIATIONS ON A BOARD-INTEGRATED GPS ANTENNA

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Abstract—This paper suggests a new solution for enhancing the immunity against the influence of size variation in ground on a board-integrated GPS antenna. The original GPS antenna considered has the advantages of a simple design, low cost, and being directly integrated with the associated circuit board. Nevertheless, its performance depends on the ground of the circuit board. Without any special solution, the original antenna can withstand a ground size enlarged up to 122%, with respect to the minimal size required, for meeting the GPS specification. By using the suggested solution, the antenna can allow a ground size enlarged up to 269%. Thus, the improved antenna is more suitable for practical employment. In this investigation, various prototype antennas, with the suggested solution, were created and examined. Both simulated and measured results obtained demonstrate its promising performance stated above.

1. INTRODUCTION

Modern portable electronic devices, such as cellular phones, personal digital assistants, digital cameras, mobile televisions, and laptop computers, have a tendency to have embedded global positioning satellite (GPS) receivers. Accordingly, an internal antenna is necessary to receive the wireless signals from the GPS. Common patch antennas [1–4], fabricated on thick substrates with high dielectric constants, have been employed for these applications. Obviously, such antennas cannot be directly printed on the associated circuit board and require additional expenses. A board-integrated GPS

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antenna was proposed in [5] to solve this difficulty. This antenna uses two orthogonal strip monopoles, printed directly on the associated circuit-board substrate, to generate a circular polarized characteristic. The board-integrated antenna can be simply designed and with little additional costs involved; however, antenna performance may depend on the surrounding metal ground. Only allowing a moderate size variation in ground, its impedance matching and axial ratio bands can be maintained to cover the entire GPS application band (1.559 GHz to 1.610 GHz).

In the current investigation, we propose a new solution to lower the influence of size variation in ground on the board-integrated GPS antenna. As demonstrated in [5], the original antenna achieves an impedance matching band (determined by a -10 dB return loss) and an axial ratio band (determined by a 3 dB axial ratio) to cover the entire GPS band, when the ground size was varied from 100% to 122% of the minimal size required. In [5], the minimal size is required to be 90% of the size 50 mm $\times$ 104 mm. To address this limitation, an effective solution is suggested for the antenna. The improved antenna allows the ground size to vary from 100% to 269% of the minimal size required. Such an improvement will allow this antenna to be applicable in all devices. Many prototype antennas were created and tested and their simulated and measured results obtained indicate the claimed achievement.

2. A NEW SOLUTION FOR A BOARD-INTERGATED GPS ANTENNA

Figure 1 shows the configuration and geometrical parameters of a right-handed circular polarized board-integrated GPS antenna with a new solution for lowering the influence of size variation in ground. The solution is especially illustrated apart in this figure. The improved GPS antenna, with the solution, will recover the original one when the lengths l_1 and l_2 of the solution are set at zero.

The antenna consists of two orthogonal monopoles, printed on the top surface of a circuit-board substrate. These monopoles are responsible for generating two orthogonal linear polarized waves of equal amplitudes with a 90-degree phase shift between. A metal ground with a square clearance directly under the monopoles is printed on the bottom surface of the substrate (see Fig. 1). The GPS antenna operates in the GPS band (1.559 GHz to 1.610 GHz) and is fed with a 50-ohm microstrip line. To quickly achieve the initial design, the lengths w_1 and w_2 were set at a quarter wavelength at the central frequency of the application band.

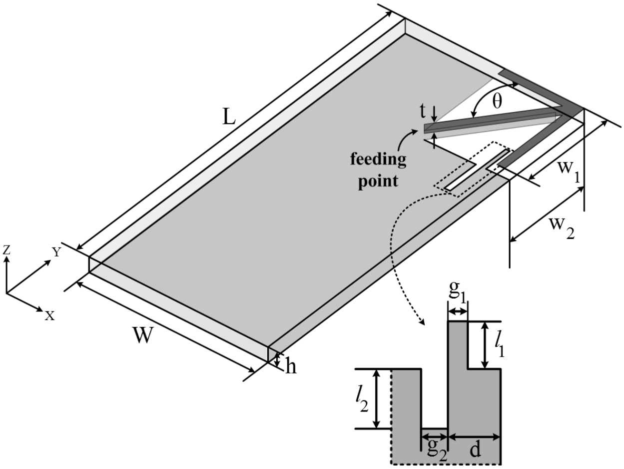


Figure 1. Configuration and geometrical parameters of the solution for lowering the ground-variation influence on the board-integrated GPS antenna.

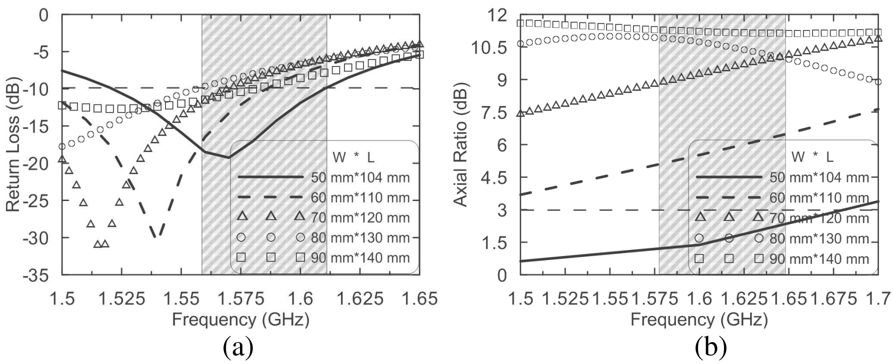


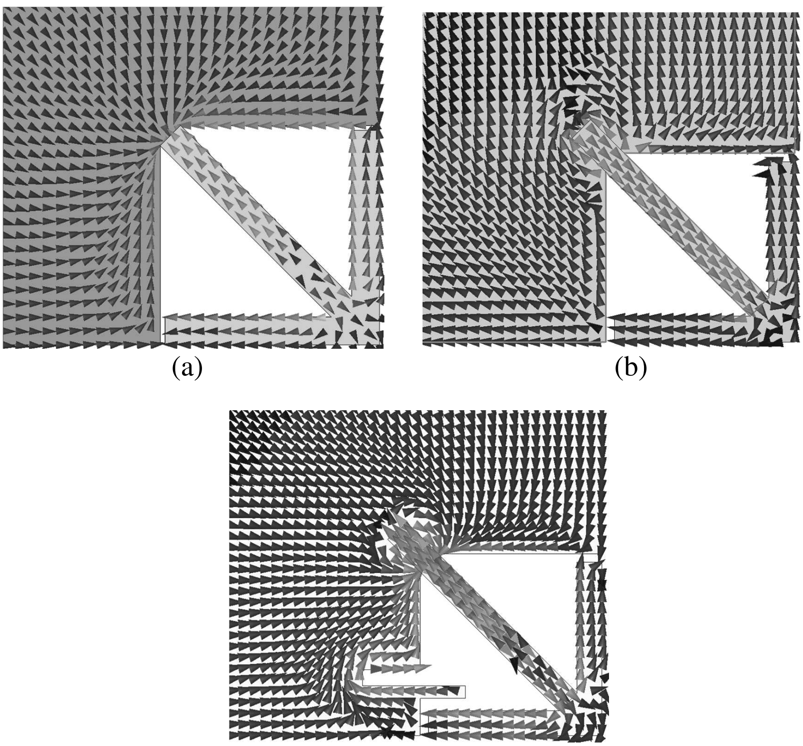
Figure 2. Ground-variation influence on the (a) return loss and (b) axial ratio of the original GPS antenna. $w_1 = 23$ mm, $w_2 = 23.5$ mm, $t = 3$ mm, $h = 1.6$ mm, $\theta = 45°$, $l_1 = 0$ mm, $l_2 = 0$ mm.

The solution, illustrated separately in Fig. 1, increases the immunity of the original antenna against the influence of the size variation in ground. Adding this solution to the original antenna may slightly lower the impedance-matching band, resulting in slightly shorter final lengths of w_1 and w_2. The cause of creating this solution is subtle and will be discussed in the following. Specifically, the circuit board was fabricated using a 1.6-mm-thick FR4 substrate with a dielectric constant 4.4 and a loss tangent 0.025.

3. RESULTS AND DISCUSSION

The influence of the size variation in ground on the return loss and axial ratio of the original GPS antenna ($l_1 = l_2 = 0$) are shown in Fig. 2. Results suggest that the impedance matching bands (determined by a -10 dB return loss) and axial ratio bands (determined by a 3 dB axial ratio) did not successfully cover the entire GPS band for all the other cases, except the case of the smallest ground size. These outcomes are explained by the current distributions shown in Fig. 3.

Figures 3(a) and 3(b) show the current distributions at 1.575 GHz on the original GPS antennas with proper and improper ground sizes,



(a) (b) (c)

Figure 3. Current distributions at 1.575 GHz on (a) the original GPS antenna with an acceptable ground size ($W = 50$ mm, $L = 104$ mm), (b) the original GPS antenna with an unacceptable ground size ($W = 70$ mm, $L = 120$ mm), and (c) the improved GPS antenna with the same ground size ($W = 70$ mm, $L = 120$ mm) as (b).

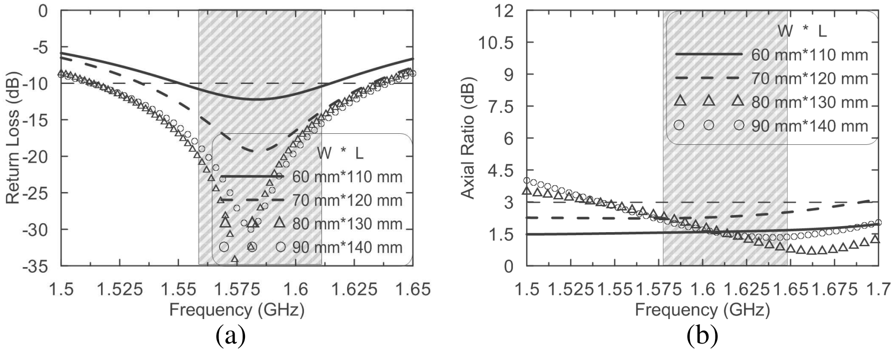


Figure 4. Ground-variation influence on the (a) return loss and (b) axial ratio of the GPS antenna added with the new solution. $w_1 = 21\,\text{mm}$, $w_2 = 22\,\text{mm}$, $t = 3\,\text{mm}$, $h = 1.6\,\text{mm}$, $\theta = 45°$, $l_1 = 5.5\,\text{mm}$, $l_2 = 7\,\text{mm}$, $g_1 = 1.5\,\text{mm}$, $g_2 = 2\,\text{mm}$, $d = 4.5\,\text{mm}$.

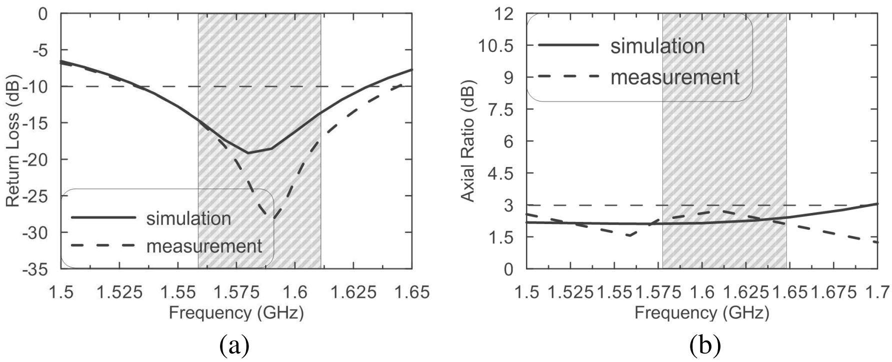


Figure 5. Simulated and measured (a) return loss and (b) axial ratio of the improved GPS antenna. $W = 70\,\text{mm}$, $L = 120\,\text{mm}$, $w_1 = 21\,\text{mm}$, $w_2 = 22\,\text{mm}$, $t = 3\,\text{mm}$, $h = 1.6\,\text{mm}$, $\theta = 45°$, $l_1 = 5.5\,\text{mm}$, $l_2 = 7\,\text{mm}$, $g_1 = 1.5\,\text{mm}$, $g_2 = 2\,\text{mm}$, $d = 4.5\,\text{mm}$.

respectively. Fig. 3(a) demonstrates that the currents on the two monopoles flow in opposite directions. In addition, the current on one of the monopoles flows in the same direction as the current flowing on the square-clearance edge, paralleled to the monopole. Conversely, Fig. 3(b) illustrates that such a condition did not occur in the case with an improper ground size; thus, the impedance matching and axial ratio bands for this case (see Fig. 2) could not cover the GPS band. Physically, the currents on the two clearance edges also played a role in achieving the circular polarized characteristic.

The current distributing condition described above is essential and necessary for generating the circular polarized characteristic of the GPS antenna. Thus, the antenna discussed in Fig. 3(b) requires a solution in order to recover this condition. As shown in Fig. 3(c), the suggested solution works for such an objective. The success of this solution is further demonstrated as follows.

The influence of the size variation in ground on the return loss

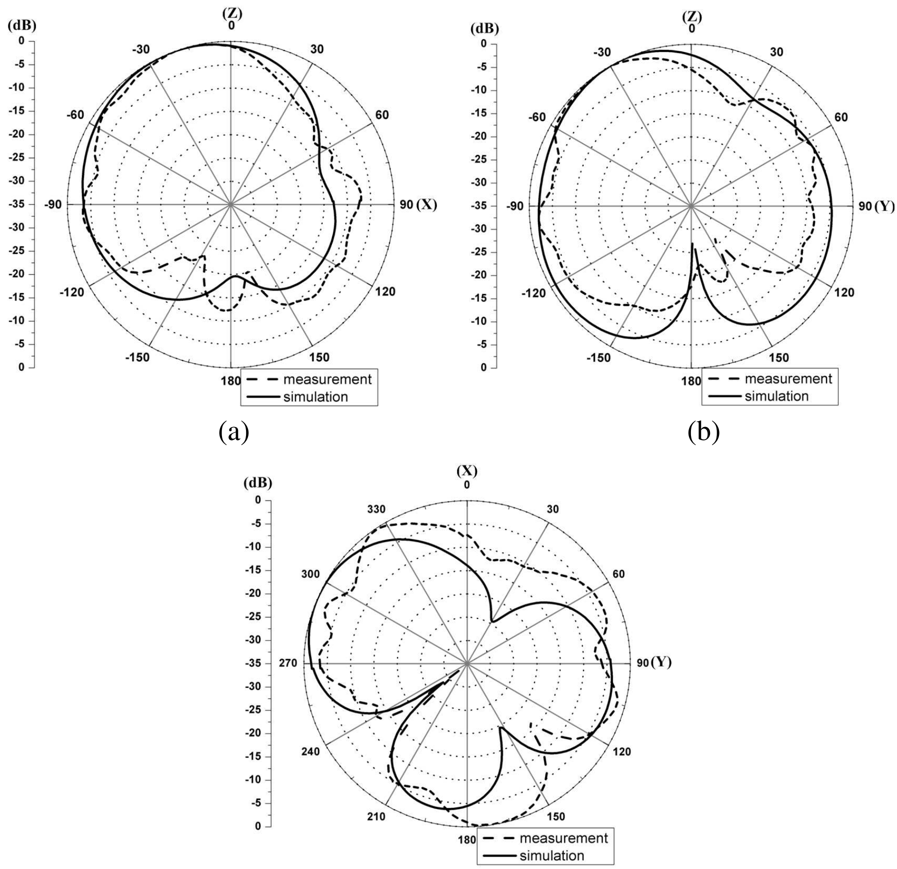


Figure 6. Simulated and measured radiation patterns of the improved GPS antenna at 1.575 GHz: (a) z-x plane, (b) z-y plane, and (c) x-y plane. $W = 70\,\text{mm}$, $L = 120\,\text{mm}$, $w_1 = 21\,\text{mm}$, $w_2 = 22\,\text{mm}$, $t = 3\,\text{mm}$, $h = 1.6\,\text{mm}$, $\theta = 45^\circ$, $l_1 = 5.5\,\text{mm}$, $l_2 = 7\,\text{mm}$, $g_1 = 1.5\,\text{mm}$, $g_2 = 2\,\text{mm}$, $d = 4.5\,\text{mm}$.

and axial ratio of the improved antenna with the solution is shown in Fig. 4. The ground size was highly varied. As this figure indicates, the impedance matching bands of the four cases considered are sufficient for the GPS specification, while the axial ratios of the four cases always remain below 3 dB, all the time, for the entire GPS band.

Figure 5 shows the simulated and measured return loss and axial ratio of the improved antenna with a ground size, $W = 70$ mm, $L = 120$ mm. In addition, Fig. 6 depicts the simulated and measured

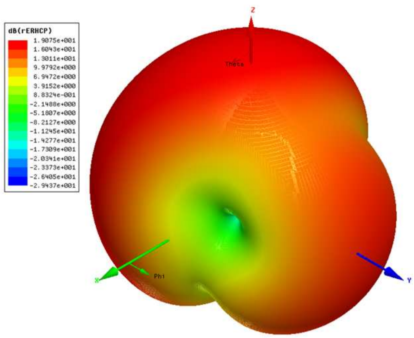


Figure 7. Three-dimensional radiation pattern of the improved GPS antenna at 1.575 GHz. $W = 70$ mm, $L = 120$ mm, $w_1 = 21$ mm, $w_2 = 22$ mm, $t = 3$ mm, $h = 1.6$ mm, $\theta = 45°$, $l_1 = 5.5$ mm, $l_2 = 7$ mm, $g_1 = 1.5$ mm, $g_2 = 2$ mm, $d = 4.5$ mm.

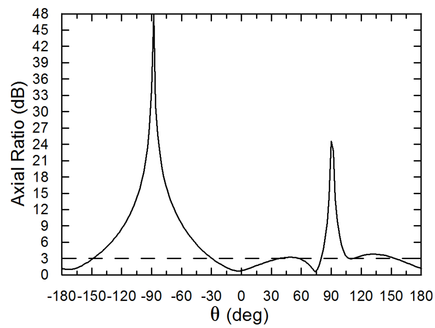


Figure 8. Axial ratio versus angle of the improved GPS antenna at 1.575 GHz. $W = 70$ mm, $L = 120$ mm, $w_1 = 21$ mm, $w_2 = 22$ mm, $t = 3$ mm, $h = 1.6$ mm, $\theta = 45°$, $l_1 = 5.5$ mm, $l_2 = 7$ mm, $g_1 = 1.5$ mm, $g_2 = 2$ mm, $d = 4.5$ mm.

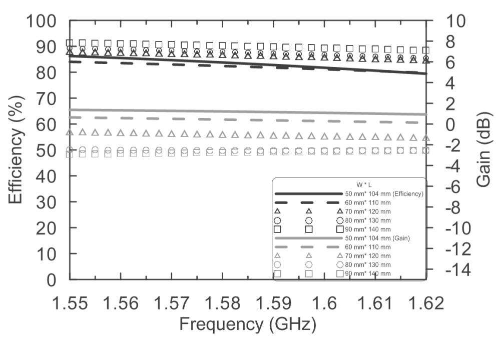


Figure 9. Ground-variation influence on the radiation efficiency and antenna gain of the GPS antenna added with the new solution.

right-handed circular polarized radiation patterns at 1.575 GHz for the same case. Both the simulation and measurement confirm each other, supporting the efficient performance of the proposed antenna. To further illustrate its radiation performance, the three-dimensional antenna pattern is shown in Fig. 7 and the axial ratio versus angle is plotted in Fig. 8. The axial ratio can be maintained below 3 dB in the angle range from $\theta = -30°$ to $\theta = 80°$. Finally, the antenna gain and radiation efficiency are shown in Fig. 9. The improved antennas show high efficiencies and flat gains across the specified frequency range.

4. CONCLUSION

A new solution was proposed for lowering the ground-variation influence on a board-integrated GPS antenna. Also, the cause of developing this solution was explained. The proposed solution can maintain the antenna holding sufficient impedance matching and axial ratio bandwidths over a large range of size variations in the circuit-board ground. The improved antenna can withstand the ground size enlarged up to 269% of the minimum size required. Consequently, the newly proposed solution can increase the practicability and suitability of the board-integrated GPS antenna in modern GPS applications.

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