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Research Article

A Compact Wideband Stacked Antenna for the Tri-Band GPS Applications

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Abstract

A compact wideband stacked patch antenna is presented for the applications of GPS systems. This antenna covers the L1, L2, and L5 GPS bands of operating frequencies 1.575, 1.227, and 1.176 GHz, respectively. High permittivity dielectric materials are used to minimize the antenna dimensions. The obtained antenna is of dimensions $32\times18\times2.117$ mm. To verify the design, the time dependence field distribution, the scattering parameters, and the radiation pattern are presented. The scattering parameters show that the antenna operates at the GPS frequencies with lower than −10 dB. The finite difference time domain (FDTM) with the perfect matched layer (PML) is used in the present analysis.

1. Introduction

In the last few years, the microstrip antennas are the most rapidly developing antennas. These antennas have a wide application in the fields of mobile communications, integrated systems, satellites, and so forth. The microstrip antennas have many advantages compared with the conventional microwave antennas which are light weight, small size, low cost, and ease of installation. One of the most important disadvantages of the microstrip antennas is their limited bandwidth, especially to cover a certain band of a specific application. The present work focuses on a design of a wideband microstrip antenna for the GPS applications [1–4]. GPS systems have three bands, namely, L1 (1.575 GHz), L2 (1.227 GHz), and L5 (1.176 GHz) [2]. Recently, several low-profile antennas have been published for covering the last bands. In [1], antenna for a dual band L1 and L2 is presented while in [2, 3], the antenna is designed for the three bands L1, L2, and L3. In [3], a tunable technique is used to adapt the antenna for operating at the required bands while in [4], a modified F-shaped antenna with high permittivity is used.

In the present work, a compact stacked patch antenna is obtained for covering the three GPS bands without any tuning techniques. The antenna is fed by a microstrip feeder which is suitable to be integrated with the planar circuits. High permittivity dielectric materials are used to minimize the antenna dimensions. Two different dielectric substrates of 22 and 25 dielectric constants are used. The finite difference time domain [5, 6] and the perfect matched layer (PML) [7] are used in the present analysis.

2. Antenna Structure

The proposed stacked antenna is shown in Figure 1. The rectangular patch antenna has length equal to $L = 16$ mm, and width equal to $W = 12.45$ mm. The lower substrate is of height equal to 0.794 mm. The lower patch is fed by a microstrip line of width 2.490 mm. The upper patch has the same dimensions of the lower one, and it is allocated upper the lower one.

Figure 1: Geometry of the proposed stacked antenna (all the dimensions are in mm).

3. Antenna Design

To reduce the size of the antenna, high dielectric constant materials are used as dielectric substrates. Two different cases are considered.

Case 1. The two substrates are of a ceramic dielectric material of a relative permittivity equal to 22, and the upper substrate has a height equal to 1.820 mm.

Case 2. The two substrates are of a dielectric material of a relative permittivity equal to 25, and the upper substrate has a height equal to 1.323 mm. This structure is more compacted than the first one.

4. Simulation and Discussions

The proposed stacked antenna is designed by using the finite difference time domain (FDTD) [5, 6]. The perfect matched layer (PML) is applied to terminate the computational domain [7].

For the antenna of Case 1, the field distribution for different time steps at the plane of the lower patch is given in Figure 2. However, Figure 3 shows this distribution for the same time steps at the plane of the upper patch. From Figures 2(d) and 3(d), one can observe that the field is transferred to the upper patch from the lower one.

Figure 2: The field distribution $Ez(x, y, z)$ at a plane of the lower patch of Case 1 at different time (n the number of time steps).

Figure 3: The field distribution $Ez(x, y, z)$ at a plane of the lower patch of Case 1 at the same time steps of Figure 2.

The scattering parameters for Case 1 antenna are given in Figure 4. This figure shows that the return loss for the proposed antenna is less than 10 dB from 1.15 GHz to 1.75 GHz. This range covers the tri-band of the GPS applications.

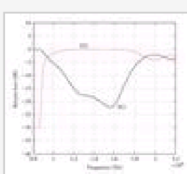

Figure 4: The scattering parameters of Case 1 stacked antenna for the tri-band GPS applications.

Figure 5 shows the input impedance of Case 1 proposed structure. The real part of this impedance is almost equal to 50 Ω while its corresponding imaginary part is almost zero over the GPS bands.

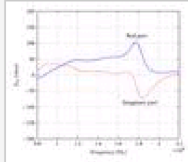

Figure 5: The corresponding input impedance of antenna has scattering parameters shown in Figure 4.

Figure 6 shows that the scattering for the second antenna has the dimensions given in Case 2. The return loss in this figure shows that the GPS bands are covered with less than 10 dB from 1.05 GHz to 1.65 GHz.

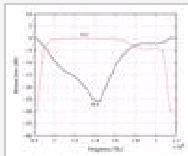

Figure 6: The scattering parameters of Case 2 stacked antenna for the tri-band GPS applications.

The input impedance of the second structure is shown in Figure 7. As in the case of the first structure, the real part of this impedance is almost equal to 50 Ω as its imaginary part tends to zero.

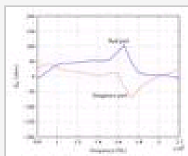

Figure 7: The corresponding input impedance of antenna has scattering parameters shown in Figure 6.

Figure 8 shows the radiation pattern of Case 1 stacked antenna which is almost unchanged over GPS bands. In addition, the figure shows that broad pattern coverage is achieved which is suitable for the portable GPS applications.

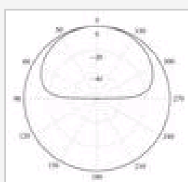

Figure 8: The radiation pattern of Case 1 stacked antenna.

5. Conclusion

A compact wideband stacked antenna is presented to cover the tri-bands of the GPS. High permittivity dielectric materials are used to minimize the antenna dimensions which are $32 \times 18 \times 2.117$ mm. The scattering parameters show that the antenna operates at the GPS frequencies lower than −10 dB. The antenna compact structure and its broad pattern coverage make this antenna suitable to be used in portable GPS applications. The finite difference time domain (FDTM) with the perfect matched layer (PML) is used in the present analysis.

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