DESIGN OF GPS MICROSTRIP SQUARE PATCH ANTENNA

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Abstract: In this paper, a new design of microstrip antenna with a square patch for Global Positioning System (GPS) operating at a frequency of 1.227 GHz (L2-band) is presented. The design is printed on the FR4 substrate has a relative permittivity equals to 4.3 and a thickness of 1.6 mm and loss tangent equals 0.0025. The antenna having return loss $S_{11} = -69.782$ dB, gain = 4.9952 dBi, and voltage standing wave ratio $VSWR = 1.0006$ at $f = 1.265$ GHz for all previously results. The antenna is designed using CST microwave studio version 2019.

Keywords: GPS, return loss, VSWR, Microstrip antenna.

1. Introduction

The Global Positioning System (GPS) is a satellite-based navigation technology developed by the United States Department of Defense (DoD) at the turn of the 1970s. GPS was originally developed as a military system to meet the military needs of the U.S. It was, however, made open later to civilians, and is now a system with a dual-use that both military and civilian users can access. [1]. The system offers users with accurate, ongoing, global, information about three-dimensional position and velocity. [2].

The advancement of lightweight, antennas contributes significantly to the rapid proliferation of civilian and military telecommunications applications, for example, GPS [3]. With the development of navigational technologies, mapping, and satellite communication, there is a persistent need for antenna coverage to reach quickly the weak satellite signals. [4]. The majority of GPS receiver antennas necessitate a circular polarization, thus, microstrip patch antennas (MPAs) are best suited for this purpose. [3,5].

Too many of the advantages of the MPA like low profile, lightweight, compact size, uncostly, easy to mass-produce utilizing printed device technologies. the sense that the antenna is suited for flat and non-planer surfaces, and is suited for Microwave Integrated Circuit Designs (MICs). [4, 6-12]. Even so, there are some of the weaknesses such as reduced bandwidth, poor polarization, and low efficiency [6,7].

The theory and design of antennas have been among the most important subjects over the last

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few years. [6,12]. The Microstrip Antenna (MSA) definition goes back to the start of the 1950s. When Deschamps proposed it in the U.S.A and got a patent by Guttan and Baissinot in France. The development of the MSA antenna over the next 15 years has shown little interest. Due to the lack of microwave substrates and due considerable attention to waveguide plates. the interest in the microstrip antenna began in 1973. [6,7,12-15].

Several types of MSAs exist, and they can be designed to have various shapes and sizes due to their physical characteristics. MPA is the most common and simple antennas. A rectangular form MPA consists of very thin of patch thickness (t) is usually ($t \ll \lambda_0$). The patch width is in the range of $0.3333 \lambda_0 < W < 0.5 \lambda_0$. The height of the substrate is usually $0.003 \lambda_0 \leq h \leq 0.05 \lambda_0$. The dielectric constant of the substrate is typically $2.2 \leq \epsilon_r \leq 16$. The patch can be in a variety of shapes like an elliptical, triangular, circular ring, and square or other various forms [16,17].

Some L2-Band GPS researchers published in [18,19]. A new configuration of the GPS square patch antenna with a coaxial feeding method and operating at 1.265 GHz (L2-Band) frequency is suggested in this study. The parameters used to design the MPA can be stated as follows [7].

$$W = \frac{c}{2 f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + 12 \frac{h}{w}\right)^{-1/2} \quad (2)$$

$$\frac{\Delta L}{h} = 0.412 \left(\frac{\epsilon_{eff} + 0.3}{\epsilon_{eff} - 0.258} \right) \left(\frac{w/h + 0.264}{w/h + 0.8} \right) \quad (3)$$

$$L_{eff} = \frac{c}{2 f_r} \times \frac{1}{\sqrt{\epsilon_{eff}}} \quad (4)$$

$$L = L_{eff} - 2\Delta l \quad (5)$$

Where:

W = the patch width.

ϵ_r = the dielectric constant of substrate.

ϵ_{eff} = the effective dielectric constant.

f_r = the operating resonance frequency.

h = the height substrate.

L_{eff} = the effect length of the patch.

L = the length of the patch.

2. Antenna design

The square patch of the model antenna represents the radiating part that is made from a conducting material (copper), and it is etched on the FR4 substrate (Flame Resistant 4) which has a thickness of 1.6 mm, relative permittivity $\epsilon_r = 4.3$, and loss tangent ($\tan \delta = 0.025$). From the bottom side of the substrate, there is another conducting material called the ground layer. Many slots are added to both patch and ground layer to enhance the performance of the designed antenna where the value of return loss became less than -10 dB as shown in Fig. 1. The type of the feeding technique used is a coaxial feeding, which is located on the diagonal axis in the point of (10 mm, 10 mm) in the x-y plane. The parameters of the designed antenna are illustrating in table 1.

(a)

(b)

Fig.1. construction of the modeled antenna (a) top view (b) bottom view.

Table 1. The list of the designed Antenna Parameters.

Parameter	Value (mm)
L	70
Lp	55
X	1
Y	8
Z	10
S	9.5
h	6

n	2
m	3
K	13
T	9
A	38
B	4
r1	1
r2	2
r3	3
r4	5
r5	6

Where:

L = length of the substrate = W

L_p = length of the patch plane = W_p

r_1, r_2, r_3, r_4, r_5 = the radiuses of the circular slots.

$X, Y, Z, S, h, n, m, K, T, A, B$ = the dimensions of the other slots.

Some parametric study such as changing in L_p , W_p , and feeding point position P have been carried out to improve the performance of the antenna as follows:

2.1. Effect of Changing the patch length L_p

Varying the length of the patch can be noticed from Fig. 2 where there is a significantly changing in the reflection coefficient where the best value can get it when L_p equals 55 mm with obtained the value of $S_{11} = -69.782$ dB at the resonant frequency $f = 1.265$ GHz.

Fig.2. Effect of changing the patch length L_p .

2.2. Effect of Changing the patch Width W_p

As shown in Fig. 3, the best value for the reflection coefficient is that when the width of the patch is equal to 55 mm where the value of $S_{11} = -69.782$ dB at the resonant frequency $f = 1.265$ GHz.

Fig.3. Effect of changing the patch width W_p .

2.3. Effect of Changing the feeding point position P .

Also, the position of feeding point has been changed as shown in Fig. 4. It is clear that when the point of feeding is located at (10 mm, 10 mm) in the x-y plane, the best value of return loss is equal to -69.782 dB at the frequency of 1.265 GHz.

Fig.4. Effect of changing the position of feeding point P .

Fig. 5. shows the reflection coefficient of the proposed antenna versus frequency where it is value equals to -69.782 dB at the resonance frequency $f = 1.265$ GHz.

Fig.5. The return loss of the designed antenna

Also, the value of voltage standing wave ratio (VSWR) has been measured as shown in Fig. 6. Where its value equals to 1.0006 at the frequency $f = 1.265$ GHz which is an accepted value where VSWR must be less than 2. The VSWR represents a measure of impedance matching and can be defined as follows:

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1+\gamma}{1-\gamma} \quad (6)$$

Where γ represent the reflection coefficient

$$\gamma = \frac{Z_R - Z_0}{Z_R + Z_0} \quad (7)$$

And also

$$S_{11} = 10 \log \gamma \quad (8)$$

Fig.6. VSWR of the designed antenna.

The antenna has a good gain as illustrated in Fig. 7. Where it equals to 4.9952 dB at the resonant frequency $f = 1.265$ GHz.

Fig.7. The designed antenna gain

Fig. (8-a) shows the simulation result of the real value of the input impedance where it is equal to 49.968Ω at the resonant frequency $f = 1.265$ GHz, while the Fig. (8-b) shows the simulation result of the imaginary value of the input impedance for the designed antenna which equals to $-9.2508 \times 10^{-5} \Omega$ at the same frequency $f = 1.265$ GHz.

(a)

(b)

Fig.8. The simulation results of the input impedance for the designed antenna (a) real part (b) imaginary part.

In Fig. (9-a) the 2-D of the E-field for the designed antenna is illustrated, where the magnitude of the main lobe is 5.82 V/m in the direction 1.0 deg. Where the angular width (3 dB) is 102.5 deg. The H-field of the designed antenna is illustrated in Fig. (9-b) where the main lobe magnitude is equaled to -45.7 A/m in the direction 1.0 deg. and the angular width (3 dB) is 102.5 deg.

(a)

(b)

Fig.9. The radiation pattern of the designed antenna
(a) E-field (b) H-field.

The antenna has a maximum current equals to 102.907 A/m. The most current is distributed at the center of the radiating patch and it drops near the antenna edges as shown in Fig. 10.

Fig.10 . Distribution of the designed antenna current.

Fig.11. 3-D far-field of the designed antenna.

Table 2. A comparison with other published work.

Reference	Antenna Size (mm ²)	Type of the Substrate Used	Resonant frequency (GHz)	Return Loss (dB)
[18]	86 × 74	Taconic Tly (ε _r =2.2)	1.237	-61
[19]	380 × 775	Rogers RT5880 (ε _r =2.2)	1.27	-34.62
This work	70 × 70	FR4 (ε _r =4.3)	1.265	-69.78

3. Conclusions

For GPS applications, new antenna design has been proposed with a square patch shape operating at L2 band (1.265) GHz. The characteristics of the antenna have been studied and the results are measured by using CST microwave studio version 19. It was found that the antenna has a return loss $S_{11} = -69.782$ dB, VSWR = 1.0006, gain = 4.9952 dBi and real input impedance = 49.968Ω as well as the imaginary input impedance = $-9.2508 \times 10^{-5} \Omega$. Noting that all of the above results operating at the frequency 1.265 GHz. From that, one can conclude that the antenna has very good characteristics and can be modified to work at another frequency and tested in a practical prototype as future work.

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Conflict of Interest

This research deals with the field of telecommunications, therefore, the party benefiting from it is mainly the Ministry of Communications.

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