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Proposed Dual Band Double Layer Stacked Microstrip Patch Antenna for GPS Applications

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Abstract- This paper proposes a double layer high gain, dual-band Microstrip patch antenna to serve the applications of Global Positioning System (GPS) covering the operating frequencies of (1.227 and 1.575) GHz. The design has double layers with two truncated corners in the lower one. The proposed dimensions are as follows: lower and upper substrates as well as the lower ground are 120 mm^2; upper ground is 82.5 mm^2 while lower and upper patches are (55.2x55.2) mm^2 and (94x94) mm^2, respectively. For the lower band, the proposed design has achieved 40.6 MHz impedance bandwidth from 1.2051 GHz to 1.2457 GHz. While, operating in the upper band has achieved 16.7 MHz from 1.5666 to 1.5833 GHz. The maximum gain achieved is 8.04 dB in the lower band and 5.153 dB in the upper one. The simulation results which show low-profile characteristics qualify the proposed antenna design to serve GPS applications.

Keywords: High gain; Microstrip antenna; Dual-band antenna; Antenna for GPS; Global Positioning System.

Introduction

Nowadays, antennas, with dual-band, are attracting lots of research efforts based on the fact that these antennas have many applications in communications. An example of these applications is to handle two different protocols or even two different systems such as GPS and satellite communication (Chen, 2012). Since microstrip patch antennas have low profile, small size, and they can be easily printed, they have been largely deployed in many applications (H. M. Chen, 2009) (X. Sun, 2011). Most of the published literatures offer 1.575 GHz operation frequency in the GPS band only. On the other hand, few designs have covered the two GPS bands of (1.227 and 1.575) GHz. Because most of the modern navigation applications require differential GPS operations, it is necessary to meet these growing demands when designing the microstrip antenna (M. Ramirez, 2011). In general, Microstrip antennas with dual-band have two categories: the first one utilizes a single layer or patch (Z. Tu, 2010) (K. B. Hsieh, 1998) while the second one utilizes two stacked patches (Wong, 2000) (U. U. Hussine, 2011). Dual-band stacked Microstrip antennas, for instance, is one example of antenna structures with an air layer (X. Sun, Dual-Band Circularly Polarized Stacked Annular-Ring Patch Antenna for GPS Application, 2011) or even two different dielectric substrate layers (K. B. Hsieh, 1998), have been also reported for GPS. Every one of these two design examples enables the antennas to handle the dual-band CP operation and consequently seeking for remarkable impedance matching at the two frequencies of the CP operation. According to (Balanis, 2005) a double layer, high gain and stacked microstrip patch antenna is presented without an air layer. In this work, the same Balanis antenna is suggested but with an air layer. In the proposed design, one corner-truncated square lower patch is stacked without an air gap. The features of the proposed antenna design are precisely presented and discussed. The software CST Microwave studio version 2010 is used to simulate the designed antenna.

Antenna structure

Figure 1 demonstrates the geometrical shape of the proposed antenna. The configuration involves a ground plane, two patches and two substrate layers. The final design dimensions after the optimization process in CST Microwave Studio are: (s =120mm, d=7.2mm, hp=0.035mm (thickness of patches), k=94mm, hair=10mm, x =23.3mm, a=55.2mm). The dimensions of the upper patch are denoted by (kxk) mm^2 while for the lower patch are denoted by (axa) mm^2.

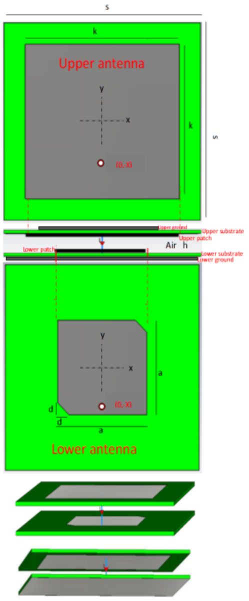


Figure 1. The proposed antenna.

The width of the patch can be calculated from eq(1).

$$w = \frac{v_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Where W is the width of the patch, f_r is the operation frequency, v_o is the free-space velocity of light, ε_r is the relative dielectric constant.

Due to the Fringing phenomenon, the electrical length will be extended by ΔL (Balanis, 2005). Therefore, the effective dielectric constant will be taken into account in the design process and it can be calculated using eq (2).

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{\mathrm{h}}{w}\right)^{-\frac{1}{2}} \qquad (2)$$

Where h represents the substrate height.

The extended incremental length can be found from eq (3)

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)} \tag{3}$$

The actual length L of the patch is found using eq (4)

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_o\epsilon_o}} - \Delta L \tag{4}$$

Results and Discussion

1. Return losses

Figure 2 illustrates the reflection coefficient plot of the suggested design of the antenna. The return losses at the resonant frequencies 1.575 GHz and 1.227 GHz are respectively -15.689 dB and -30.402 dB. According to the same figure, the simulated impedance bandwidth of the antenna is about 40.6 MHz (1.2051 GHz to 1.2457 GHz) for the lower band. Whereas, it is about 16.7 MHz for the upper band (1.5666 GHz to 1.5833 GHz). It can be obviously seen that this antenna is a dual band which matches the principles and requirements of GPS bands.

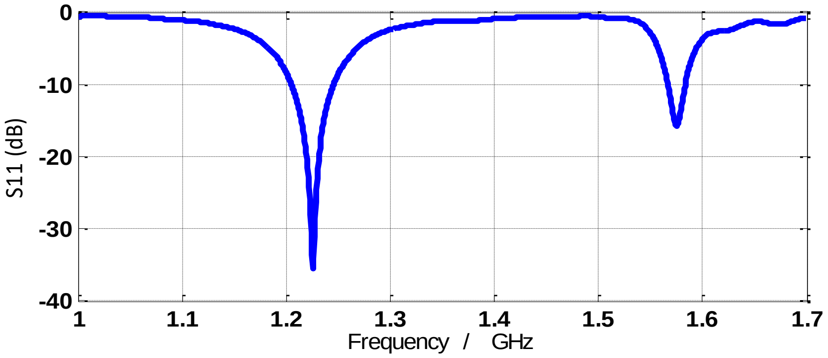


Figure 2. S_{11}-parameter versus frequency.

2. Input impedance

The proposed antenna achieves good matching at both operational frequencies, 1.227 GHz and 1.575 GHz as shown in figure (3).

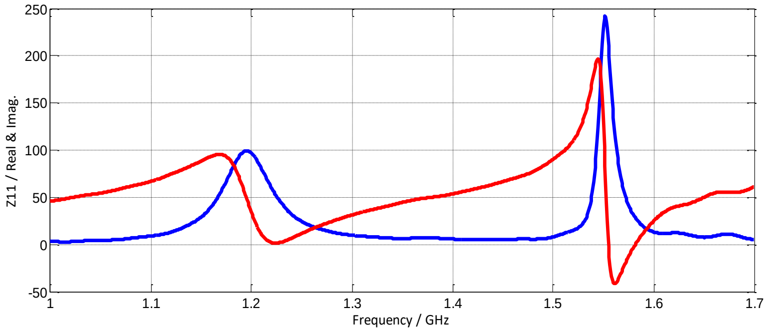
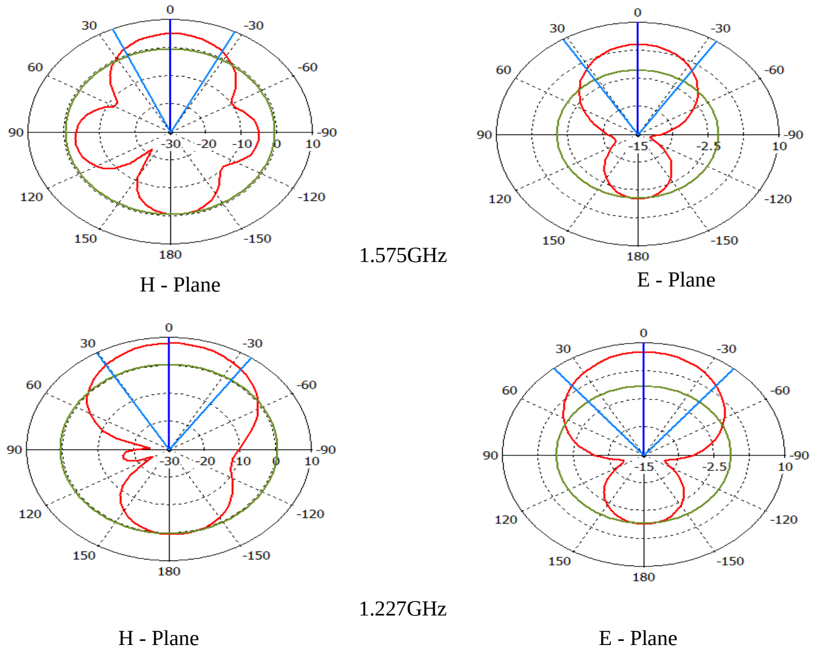


Figure 3. Input impedance of the proposed work

3. Radiation pattern

Figure 4 presents the plots of the E-plane and H-plane at frequencies of (1.227 and 1.575) GHz. The simulation results have shown that the proposed antenna radiation pattern is similar to a traditional antenna radiation pattern of GPS as they are both directive.



1.575GHz

H - Plane

E - Plane

1.227GHz

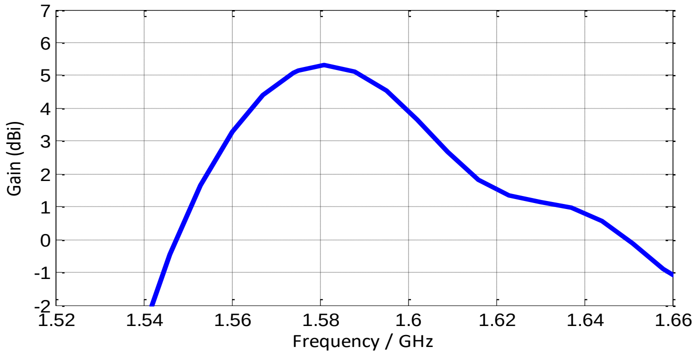
H - Plane

E - Plane

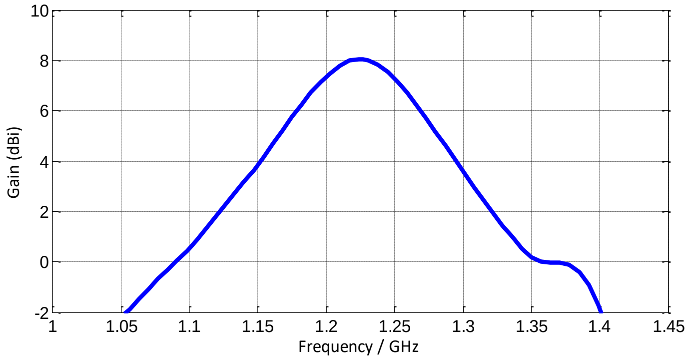
Figure 4. Radiation pattern of suggested design

3. Gain and efficiency

Based on the fact that the gain of an antenna would reflect how much of the electromagnetic energy is collected in one direction compared to other direction, it is vital parameter to be estimated for this design. Figure (5) shows the calculated gain obtained by CST Microwave Studio at (1.227 and 1.575) GHz. The maximum gain value of 5.153 dB appears at 1.575 GHz while the frequency of 1.227 GHz has a maximum gain of 8.04 dB. These achieved values are considered relatively good if compared to conventional antennas.



a. 1.575GHz



b. 1.227GHz

Figure 5. Gain in dBi
(a) 1.227 GHz band (b) 1.575 GHz band

4. VSWR

Another measure to specify whether or not an antenna has an impedance matching at the operation frequency is the VSWR. As it is shown in figure 6, the VSWR at both frequency bands are less than 2.0, which is the largest value of VSWR to indicate good matching.

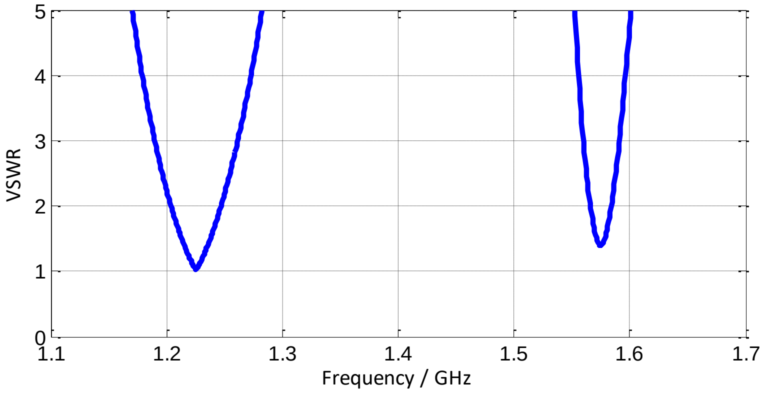


Figure 6. VSWR of the proposed antenna

5. Polarization

Generally, the Axial Ratio (AR) value determines the type of the polarization of an antenna to be linear, circular, or elliptical. The axial ratio of the suggested design of the antenna is presented in figure (7). Since the value of the Axial Ratio is less than 3dB, the polarization is circular indeed.

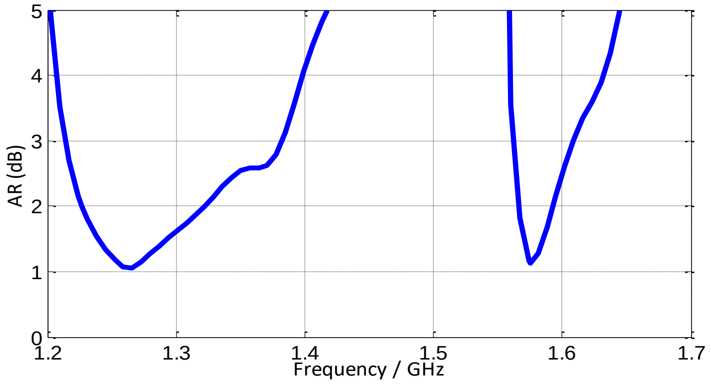


Figure 7. AR of the proposed antenna

6. Radiation efficiency

The radiation efficiency of the designed antenna is demonstrated in figure 8. At 1.227 GHz band, the antenna achieved an efficiency of (97.2%) while the radiation efficiency is (50.2%) at 1.575 GHz band.

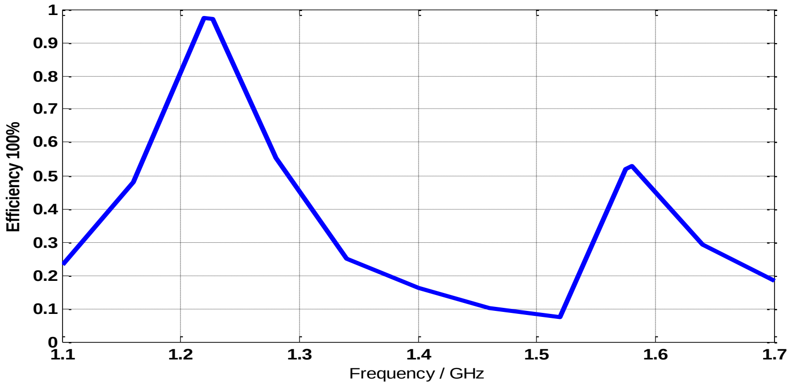


Figure 8. Radiation efficiency

Conclusion

Dual band, high gain, microstrip patch antenna to serve GPS applications is designed and simulated in this article. The achieved impedance bandwidth in this proposed design is, 40.7 MHz at 1.227 GHz and 16.7 MHz at 1.575 GHz. Agreeable radiation characteristics to the conventional GPS antenna are obtained. The proposed antenna provides a gain of 5.153dBi and 8.04dB for (1.227 and 1.575) GHz, respectively.

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