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Design and Implementation of a Single Feed Dual Band Microstrip Patch Antenna For GPS Applications

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Abstract: The purpose of this paper was to design and implementation a single feed, dual frequency (L1, L2) patch antenna for the Global Positioning System (GPS). The results from the simulation and measurement for this antenna is presented, compared, and used as part of the validation process for the dual frequency, right hand circularly polarized patch antenna designed for GPS L1, L2 operation. This prototype antenna design was targeted at dual frequency, high accuracy civil applications for future GPS applications. The antenna was designed based on the simulations from Computer Simulation Technology (CST), through which the radiation patterns and other antenna parameters were generated such as return loss (S11), gain, VSWR, and axial ratio (AR). The proposed antenna has overall dimensions 81.5*81.5 mm^2. The predicted performance of this prototype antenna from CST simulation generally matches the performance specification for a GPS dual frequency patch style antenna. The simulation and measured results showed good agreement.

Keywords: Dual-frequency, Microstrip antenna, Global Positioning System Antenna (GPSA), Circular polarization.

Introduction

Most modern global positioning system (GPS) receivers only operate frequency of 1575MHz with right hand circular polarization (CP). Needing more accurate information, some applications occupation differential GPS whose antenna covers both L1 and L2 (1227MHz) bands[1]. Patch style GPS antennas are very popular due to their small size and low profile. A circularly polarized microstrip antenna is widely used for global positioning system (GPS) applications owing to its advantages of low cost, low profile, and broad receiving pattern [2]. The antenna for circular polarization (CP) can be used to reduce the multi-path effect around a GPS receiver. Circular polarization is used on the GPS signal to avoid faraday rotation problems associated with L-band propagation through the earth's ionosphere. It also has the additional benefit of not requiring rotational alignment of the antenna at the user terminal. The signal transmitted from the satellites is right-hand circular polarized and, therefore, the terminal antenna must also use Right Hand Circular Polarization (RHCP) in order to have the maximum received signal strength. The purity of the circular polarization has a direct impact on the receive gain of the antenna. The higher the axial ratio of the antenna, the less efficient the antenna will be at receiving the circularly polarized signal. The axial ratio of the antenna is specified to be at most 3 dB over the entire bandwidth of the transmitted signal[3]. The ideal radiation pattern of a terminal user GPS antenna is shown in figure 1. The pattern is a broadside unidirectional beam. Constant coverage should be maintained in azimuth. To reduce the reception of multipath signals, it is necessary that the antenna pattern have deep nulls along the horizontal. Therefore, the elevation pattern should be nearly constant down to an angle of 10^o – 15^o from horizontal.

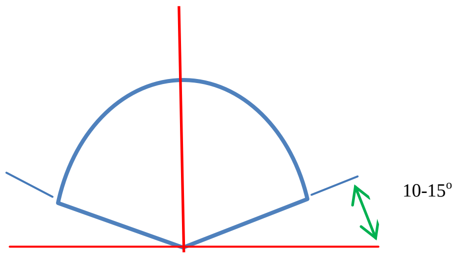

Figure 1: The ideal radiation pattern of a terminal user GPS antenna.

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Several patch antenna structures have been described for dual band operation with circular polarization and specially for GPS applications [1,4,5,6]. High relative permittivity substrate (e.g. ceramic substrate) [7] or low relative permittivity substrates with slits [8] are used in these designs.

Several characteristics from a general antenna design perspective, such as center frequency, bandwidth, VSWR, gain, input impedance and polarization, are first defined with GPS application in mind. The selection of a GPS antenna is not simply picking up an antenna satisfying, all performance requirements listed above. Based upon the particular application, the most suitable GPS antenna is determined by considering the performance requirements for that particular application, including[9]:

- Type of application: aircraft, ground reference station, spacecraft, vehicle, or cell phone, etc. Different performance levels are needed for these different types of applications.
- Frequency consideration: depending upon the type of application and the performance requirements, single frequency or a multi-frequency antenna will be determined.
- Whether a single element or an array of multiple elements is necessary to satisfy the system requirements.
- Antenna size and profile: Mounting surface for the particular application will limit the size and profile of the antenna which could be used. For applications such as aircraft, aerodynamics of antenna is also important.
- Cost of the antenna is also a factor which should be considered when selecting a GPS antenna; this is especially true for the mass commercial market.
- Depending on different applications, either a passive or active antenna may be selected.

In this paper, a single feed dual band microstrip antenna for GPS applications is presented. It consists of a square-shaped antenna with two slots, one circle in the patch and three circle in the ground plane. Details of the proposed antenna and simulated, measured results are presented and discussed.

ANTENNA GEOMETRY AND DESIGN

The geometry of the suggested dual-band antenna is explained in figure 2. The thickness of the substrate used is 1.6 mm, FR-4 substrate (εr =4.3 , tangent loss = 0.025). A 50 Ω coaxial probe feed is located along the direction 45° to the centerlines of the square patch, location feed (10 , 10) .The ground plane and the substrate have the square area size of 81.5*81.5 mm2 . In order to obtain a circular polarization characteristics, a square shape antenna has been chosen. The best design parameters are selected after parametric study to select the best parameters the antennas work at the resonance frequency of the L1 and L2 for GPS application.

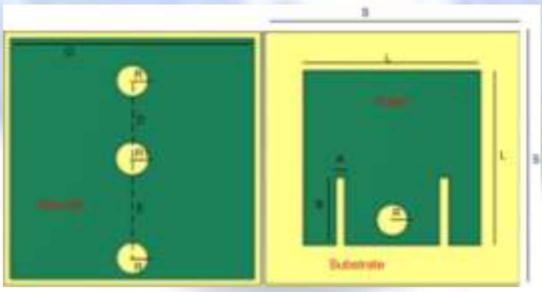

Table 1 indicates the optimum design parameters of the suggested antenna.

Table 1. The parameters of the suggested antenna.

parameter	*Value in mm*
S	81.5
L	56.32
A	3
B	22
R	5
R1	5.3
D	25
E	32
G	77.4

Table 2 indicates the design goals of the suggested antenna.

Table 2. Performance Goals of Prototype GPS L1, L2 Antenna.

parameter	***specifications***
Frequency (GHz)	1.575 & 1.227
Gain (dBi)	> 0
Axial Ratio (dB)	≤ 3
Polarization	RHCP
Input Impedance (Ω)	50
VSWR	< 2

SIMULATION RESULTS AND DISCUSSION

The return loss for the suggested antenna is presented in figure 3. At resonant frequencies of 1.575 GHz and 1.227 GHz the antenna had return loss at -32.3 dB and -23.5 dB respectively. The simulated impedance bandwidths (-10dB return loss) are 20 MHz from1.56GHz to 1.58GHz for L1, while for L2 is 13 MHz from 1.22GHz to 1.233 GHz. On this curve it can be clearly seen that we have reached and obtained a narrowband antenna which agree with the standards of GPS.

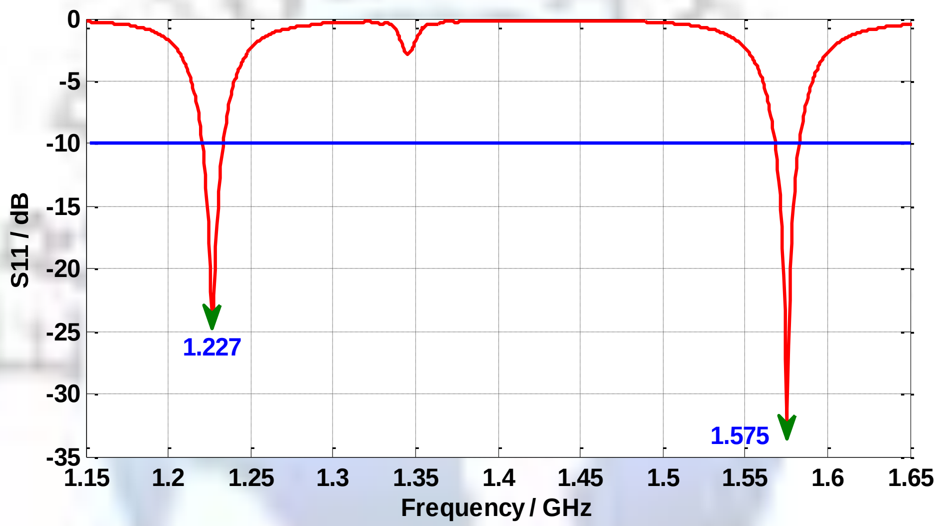

Figure 3. Return loss for the suggested antenna.

The typically desired value of VSWR to specify a good impedance match is 2.0 or less. Figure 4 indicates the VSWR of the suggested antenna. The VSWR of the 1.575GHz is 1.06 and 1.14 for 1.227GHz.

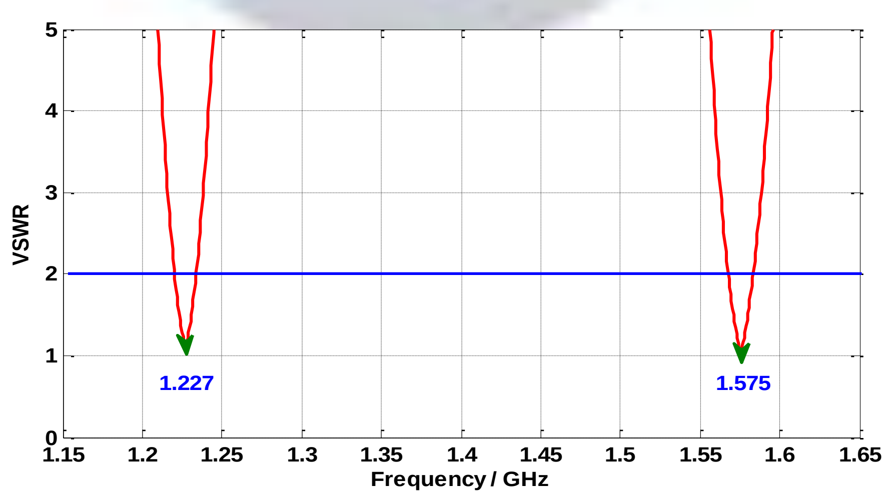

Figure 4. Plot of the VSWR for the suggested antenna.

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The CP (Circular Polarization) antenna could have many different kinds and constructions where the basic operation principle is to radiate two orthogonal filed components with equal amplitude but in phase quadrature.

Figure 5 illustrates the antenna axial ratio versus frequencies (1.575GHz & 1.227 GHz) with 3 dB.

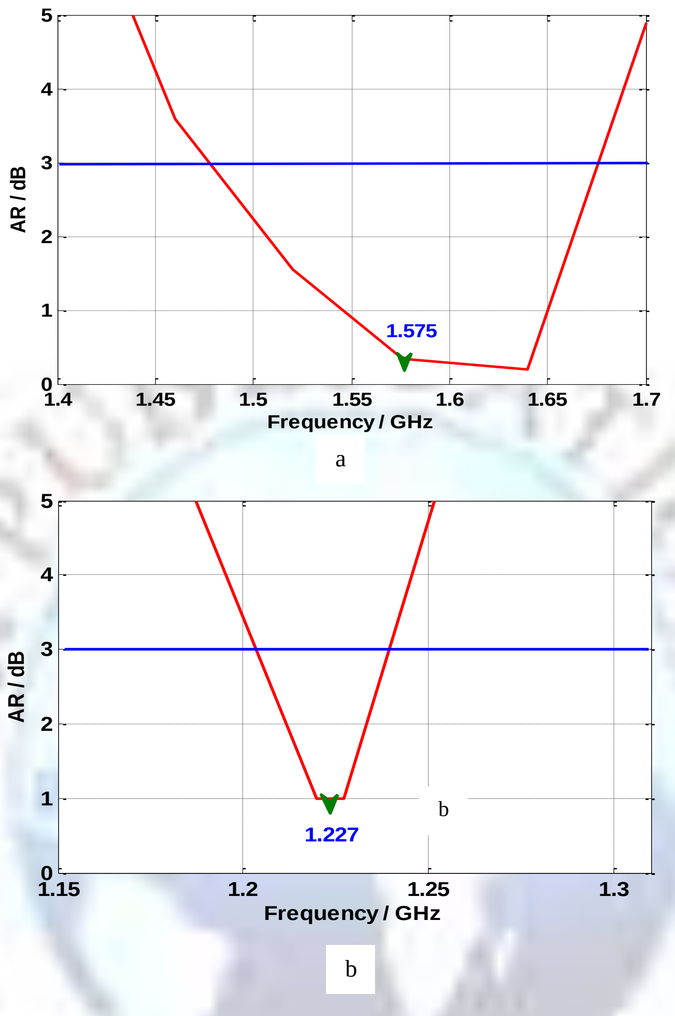

Figure 5. Plot of the Axial Ratio versus frequency for the suggested antenna.
a 1.575 GHz
b 1.227 GHz

PRACTICAL RESULTS

Figure 6 shows the fabricated suggested antenna and figure 7 shows the transmitter and receiver positions in the anechoic chamber. The used spectrum analyzer (GSP-830, GWINSTEK 9KHz – 3 GHz) was placed outside the chamber and connected to the receiver through SMA cable. The antenna in the receiver side was placed on a turn table with remote control to scan the antenna by 360o from outside the chamber. Wires, turn table and other parts were protected by absorbing material to reduce reflections. The signal generators used to supply the transmitter antennas was (Anritsu/ MG3670B/ 2.25 GHz). The far field patterns of the proposed antenna was measured in anechoic chamber in the department of Electrical Engineering / University of Mosul.

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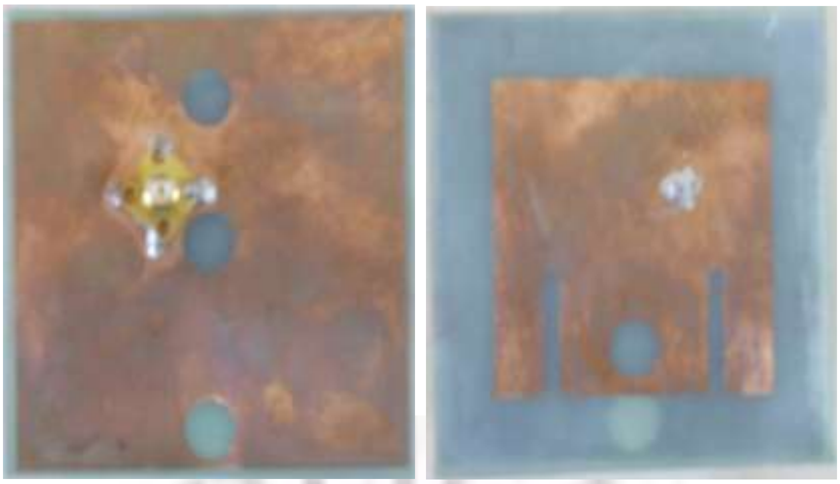


Back view

Front view

Figure 6. The fabricate of suggested antenna.

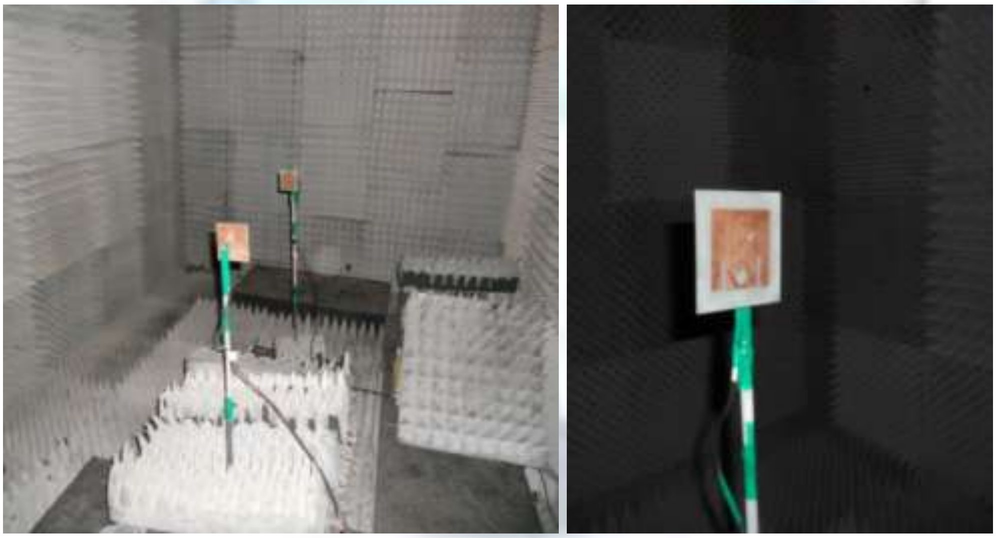


Figure. 7. The transmitter and receiver positions in the anechoic chamber.

The radiation pattern for E-plane (x-y plane) and H-plane (x-z) of the suggested antenna at frequencies 1.575GHz for L1 and 1.227GHz for L2 are shown at figure 8. The simulated and measured results indicate that the radiation patterns at two center frequencies have similar to a conventional antenna radiation patterns of GPS. The radiation pattern is almost a broadside unidirectional beam. Good agreement is noticed between simulation and experimental results.

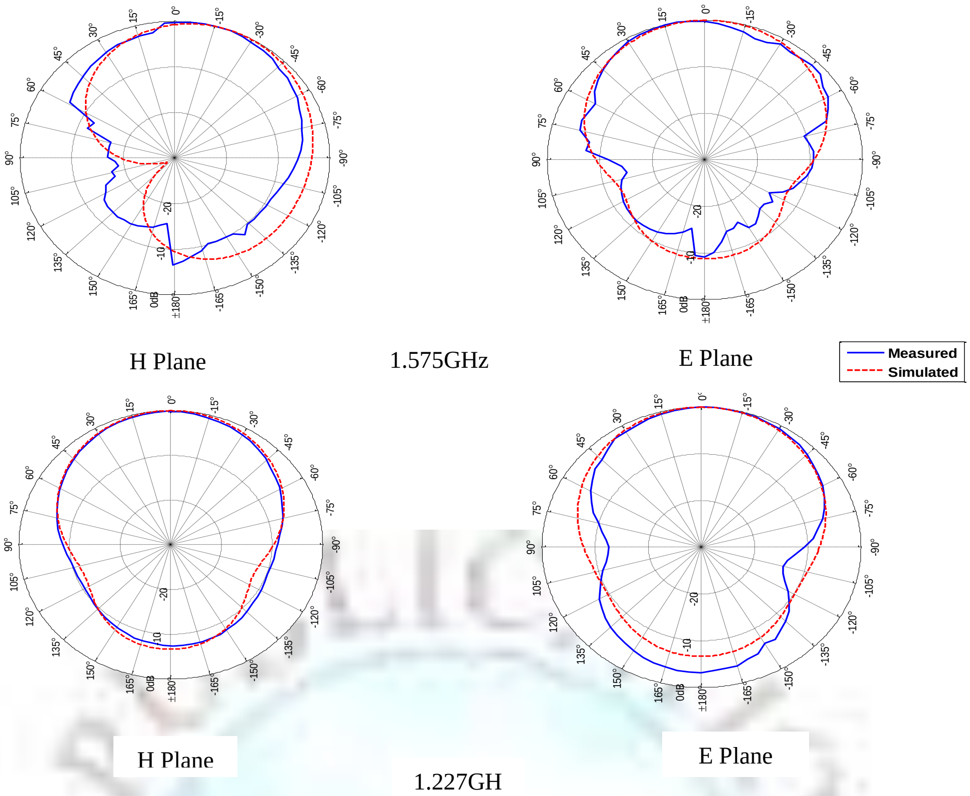
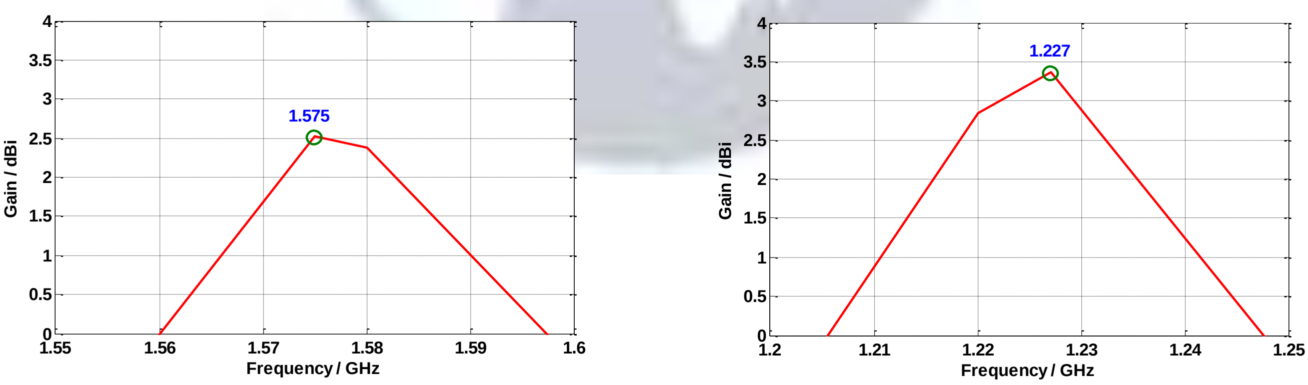


Figure 8. Radiation Pattern of the suggested antenna

The gain is an advantageous measure describing the performance of the suggested antennas. It is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. The gain of the suggested antenna was calculated from the far field patterns using the CST package, and the obtained gains versus frequency are shown in figure 9.



a

b

Figure 9. Plot of the gain versus frequency for the suggested antenna.
a 1.575 GHz
b 1.227 GHz

Table 3 shows comparison between the measured and simulated gain for the suggested antennas.

Table 3. Comparison between the measured and simulated gain

Antenna \ Frequency GHz	1.575	1.227
Simulated gain	2.528	3.373
Measured gain	3.1	2.915

Figure 10, demonstrates the efficiency of the suggested antenna. The suggested antenna succeeded efficiency of (50.1%) for the 1.575 GHz band while the efficiency of (60.3%) at frequency of 1.227 GHz.

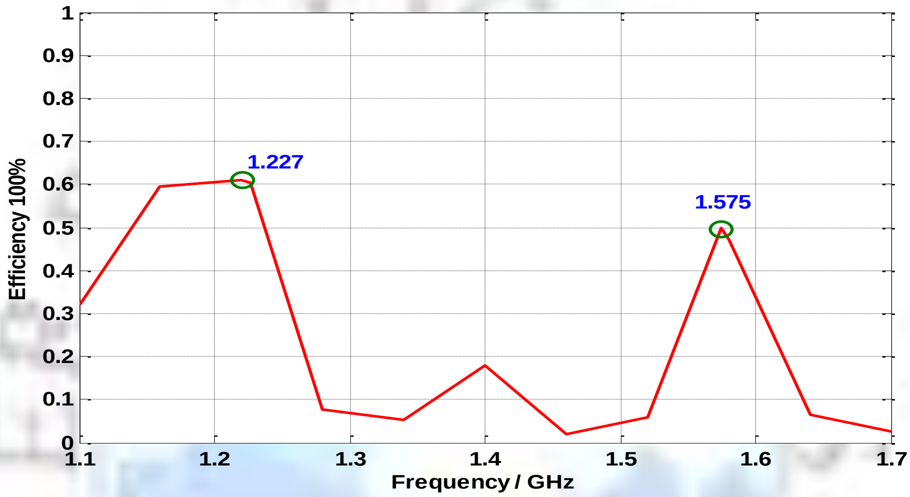


Figure 10. Plot of the efficiency for the suggested antenna

CONCLUSION

A single feed dual-band microstrip patch antenna is suggested in this paper and fabricated on a FR4 substrate of overall dimensions 81.5*81.5 mm2. The thickness of the substrate is 1.6 mm with a relative permittivity of 4.3. The suggested antenna can be used in GPS system, since its bands of operation are: 1.575 GHz, 1.227 GHz. the suggested antenna exhibits impedance bandwidth of 20 MHz at 1.575GHz and 13 MHz at 1.227GHz. The antenna also shows good CP (circular polarization) radiation characteristics at the two GPS operating frequencies. The simulation and measured results showed good agreement. From the results, it is seen that the suggested antenna achieves good dual band performance and the antenna has a hemispherical radiation pattern with a good circular polarized, this makes the suggested antenna design suitable for use in the GPS applications.

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