

# Design of a High Gain Circularly Polarized Microstrip Antenna for GPS Receiver

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**Abstract.** Advances in communication technology using radio wave continue to increase including in Global Positioning System (GPS). This triggered the emergence of various kinds of research and development in the field of radio wave communication. One of the most widely developed devices today is the antenna. Various innovations and antenna technologies are emerging. In this paper, we will design a high gain microstrip patch antenna with circular polarization characteristics that can be used for GPS applications operating in the L1 1.575 GHz frequency region. The microstrip antenna design consists of a patch radiator with a dual-feed line in order to produce a circular polarization. The design process of this antenna starts with the determination of the antenna specification, calculate the antenna dimension, designs and simulation the antenna using CST Studio Suite software, realizes the antenna, and analyzes the simulation results and the measurement of the antenna. The simulation results show gain of our propose antenna design simulation on the L1 frequency ,that is: gain is 6.254 dB, the bandwidth of antenna is 290 Mhz from 1.366 GHz to 1.655 GHz for return loss less than -10 dB with return loss -20.77 dB and axial ratio is 2.38.

## 1. Introduction

Circular polarization is widely used in Satellite Communications Systems [1], and Global Positioning System (GPS) [2], because circularly polarized characteristics can reduce multipath effects and provide flexibility in the orientation angle between a transmitter and a receiver. There are a number of types of circularly polarized printed antennas. Most of them are reported as various patch antennas, which operate by using small perturbations providing the degenerate modes and 90 degree phase difference. Various techniques for broadband circular polarization has been reported using a radiating element, a parasitic element and a stacked structure [3]. Recently, various printed dipole antennas [4] have been realized due to several attractive features, such as broad bandwidth, lower profile, and lighter weight. In some references, a printed dipole antenna with integrated microstrip balun is used, and broadband characteristics are obtained. The dual-band printed dipole antenna is also reported, which is provided by two pairs of combined parallel arms. With a transverse dipole using rotated configuration then circularly polarized characteristics are met.

In this paper, a circularly-polarized printed dipole antenna is employed to provide circular polarization characteristics. The method used in this simulation is antenna cross-dipole. The effects of the parameters are discussed in the next sections.



## 2. Antenna Design

In the design of an antenna microstrip dipole, it must first be calculated the dimensions of the antenna to be made, especially the length of the dipole arm. To obtain the dimension of dipole microstrip antenna, we must know the parameters of the material to be used, that is dielectric thickness ( $h$ ), and dielectric constant ( $\epsilon_r$ ). To calculate the length of the dipole microstrip arm, we must first calculate the effective Dielectric constant ( $\epsilon_{eff}$ ) of the microstrip using Eq. (1) [5]:

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[ \frac{1}{\sqrt{1 + 12 \frac{d}{w}}} \right] \quad (1)$$

$$W = \left( \frac{c}{2f \sqrt{\frac{\epsilon_r + 1}{2}}} \right) \times 0.1 \quad (2)$$

Where,

$\epsilon_r$  = dielectric Constant

$W$  = width of dipole arm (mm)

$f$  = center frequency

$c$  =  $3 \times 10^8$  (m/s)

$d$  = substrate thickness (mm)

Then the obtain the total length of the dipole arm using Eq. (3) [5]:

$$L = \frac{c}{2f \sqrt{\epsilon_{eff}}} \quad (3)$$

Where,

$L$  = length of dipole arm

$\epsilon_{eff}$  = effective dielectric Constant

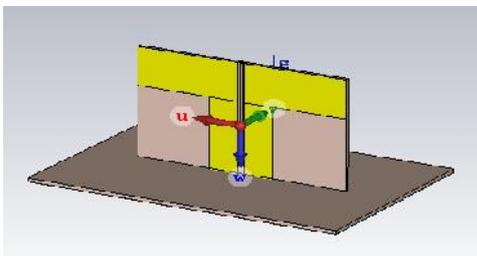
First, we design a single dipole antenna, secondly after the results of a good single antenna simulation has met with the specification, we design the cross-dipole antenna. Figure 1 shows the geometry of the single dipole antenna. Figure 2 shows the geometry of the dipole-cross antenna. It can be seen from Figure 2(a) that the antenna element is simple and easy to manufacture, and also has good characteristics of circular polarization [6].

The antenna substrate is using FR-4 with permittivity 4.5 and thickness 1.6 mm. It is found, in the design process, that the permittivity has no significant effect on the antenna dipole cross performance. The location and size of the patch shown in Figure 1 and 2 will affect the resonant frequency of the antenna.

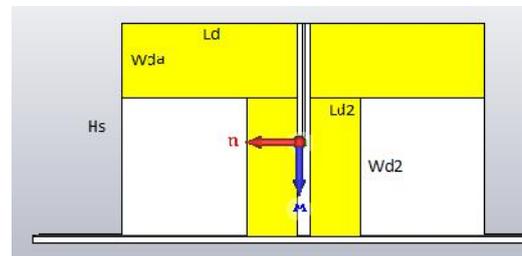
The dimension of the proposed single dipole antenna can be seen in Figure 1. The dimension of the patch single antenna dipole shown in table 1. And the proposed crossed-dipole antenna can be seen in Figure 2. The feeding network of the crossed-dipole antenna can be seen in Figure 2(d). The feeding network consists of microstrip structure, and the radius of the diameter is 90 mm. This feeding network that we used can create circular polarization, for which a  $90^\circ$  phase shift is used. A coax port with 50  $\Omega$  is used to feed the cross dipole antenna dipole with the ports of the feeding network just as shown in figure 2 (d).

**Table 1.** Dimension of the proposed single dipole antenna

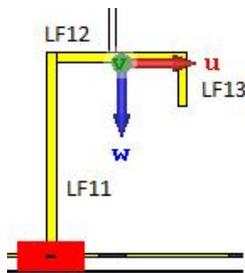
Symbol	Value	Description
Hs	49.51 mm	Width of the substrate antenna
Wd	17.5 mm	Width of single antenna dipole
Ld	40.5 mm	Length of single antenna dipole
Wd2	33.6 mm	Length of antenna
Ld2	11.5 mm	Width of antenna
LF11	22.3 mm	Length of feedline network
LF12	14.5 mm	Length of feedline network
LF13	5.00 mm	Length of feedline network



(a)

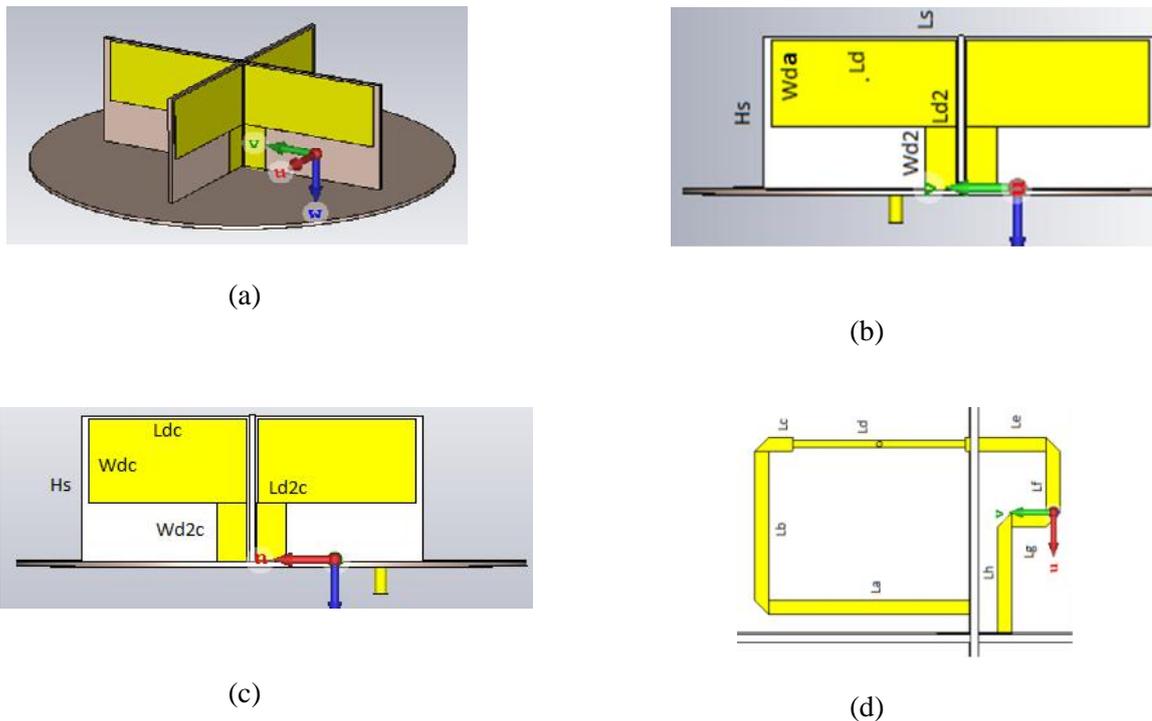


(b)



(c)

**Figure 1.** (a) Layout of the proposed single dipole antenna. (b) proposed printed single dipole antenna. (c) feedline network.



**Figure 2.** (a) Layout of the proposed crossed-dipole antenna. (b) Proposed printed dipole antenna 1. (c) Proposed printed dipole antenna 2. (d) Feedline network.

In order to create circular polarization in the axial direction of the antenna, it should have the same feed current amplitude with 90 degree phase of different and in the other direction could be elliptical polarization. The antenna height and tilt angle dipole were adjusted during the design process. During the design, simulation was performed on the proposed structure in order to optimize some important parameters.

### 3. Results and discussion

According to the optimized results using CST Studio Suite, the parameters of the proposed antenna can be seen in table 2.

**Table 2.** Dimension of the proposes crossed-dipole antenna

Symbol	Value	Description
Hs	47 mm	Width of the substrate antenna
Ls	122 mm	Length of the substrate antenna
Wda	27.1 mm	Width of antenna dipole 1
Ld	56.7 mm	Length of antenna dipole 1
Wd2	20.6 mm	Width of antenna dipole 1
Ld2	9.5 mm	Length of antenna dipole 1
Lsc	109 mm	Length of the substrate antenna
Wdc	27.1 mm	Width of antenna dipole 2
Ldc	50.7 mm	Length of antenna dipole 2
Wd2c	20.6 mm	Width of antenna dipole 2
Ld2c	9.5 mm	Length of antenna dipole 2
La	42.96 mm	Length of feedline network
Lb	35.2 mm	Length of feedline network

Table 2. Cont.

Lc	8.1 mm	Length of feedline network
Ld	37 mm	Length of feedline network
Le	17.2 mm	Length of feedline network
Lf	16.2 mm	Length of feedline network
Lg	10.4 mm	Length of feedline network
Lg	25.76 mm	Length of feedline network

Figure 3 shows the simulated return loss of the proposed antenna. The results show that the impedance bandwidth for return loss below -10 dB is from 1.366 GHz – 1.655 GHz. The VSWR of the antenna design in this simulation averaged less than 2 in the frequency range 1.366 GHz – 1.655 GHz, with the lowest value at the working frequency of 1.575 GHz is 1.2, as shown in Figure 4. The radiation pattern of proposed antenna is directional that can be observed as in Figure 5.

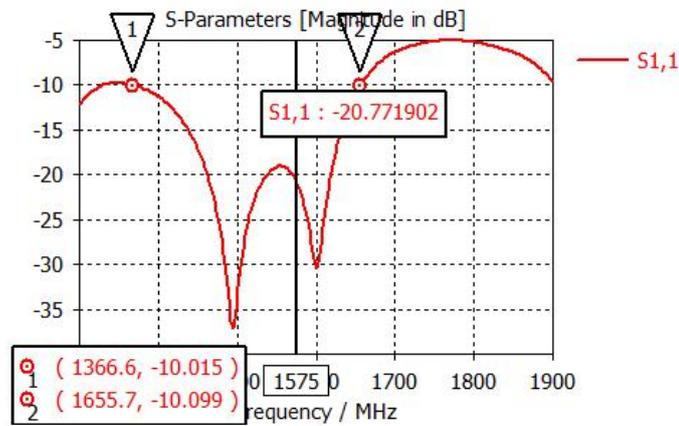


Figure 3. The simulation result of return loss for the proposed printed dipole antenna.

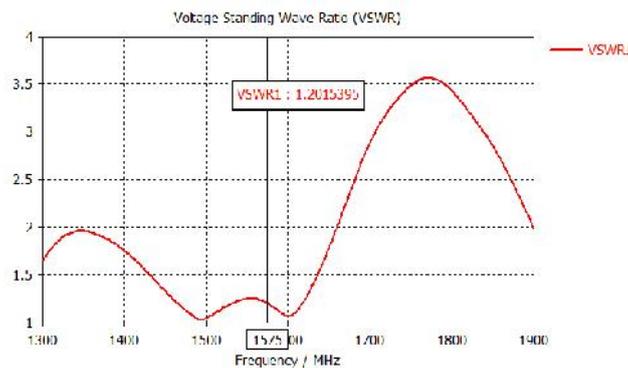
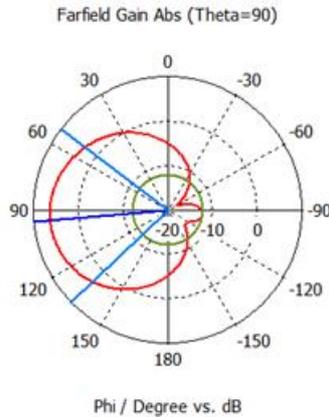
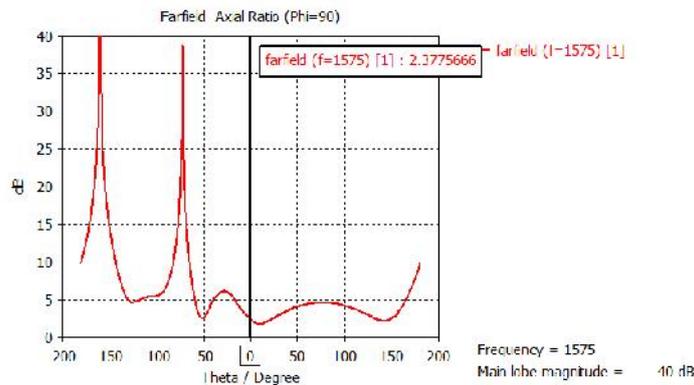


Figure 4. The simulation result of VSWR.

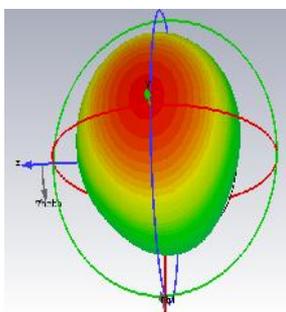


**Figure 5.** The Simulation result of radiation patterns for the proposed antenna at 1.575 GHz

In satellite communications, the receiving antenna generally uses circular polarization to be able to receive signals from satellites at each position, so that the design of the receiving antenna needs to be observed as well as the axial ratio bandwidth value, as in Figure. 6. To ensure circular polarization, the axial ratio is less than 3, if seen of the main beam, and in the range between 0 degree until 60 degree and the range 0 degree until -60 degree is less than 6 dB [7]. Figure 7 shows the radiation pattern and gain of dipole antenna. It can be seen from Figure 7 that this antenna has directional radiation pattern and 6.254 of gain at 1.575 GHz.



**Figure 6.** The simulation result of axial ratio for the proposed printed dipole antenna at 1.575 GHz



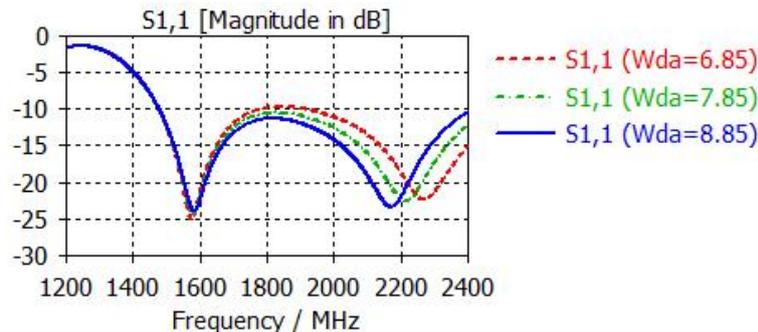
Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=1575) [1]
Component	Abs
Output	Gain
Frequency	1575
Rad. effic.	-1.634 dB
Tot. effic.	-1.671 dB
Gain	6.254 dB

**Figure 7.** The simulation result of gain for the proposed printed dipole

The effects of some important antenna parameters are studied and discussed using CST Studio Suite. Several key parameters which affect the return loss of the printed dipole antenna have been studied as follows.

### 3.1. The width of the printed arms between frequency

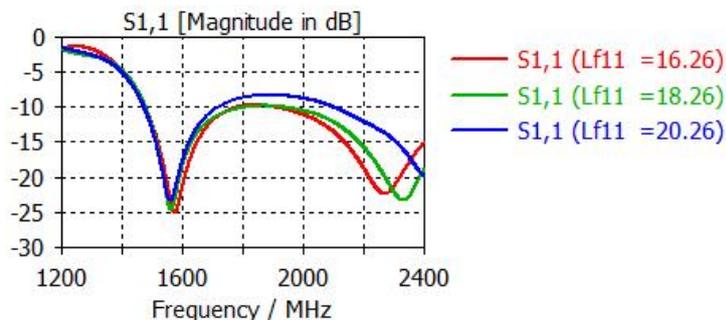
The variation of the width of the dipole antenna arm effects the bandwidth impedance and the frequency range. When the width of the arm becomes wide, the changes in frequency and return loss is not very significant and bandwidth becomes wider as shown in Figure 8.



**Figure 8.** The simulation results of return loss with different arm width.

### 3.2. Length of feedline network before in cross

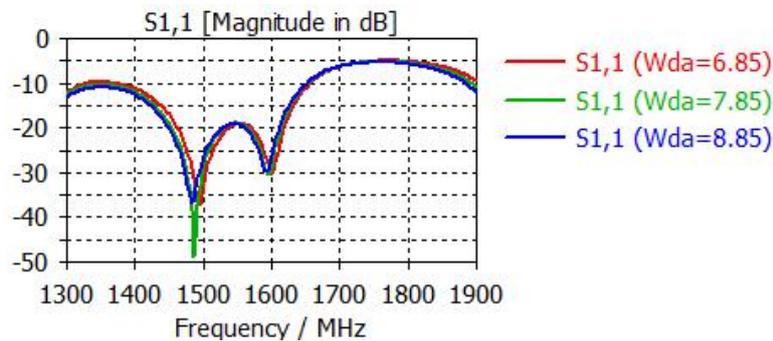
The Variations of the length of the network feedline affect the frequency range and bandwidth. When the network feedline becomes wide, the frequency will decrease slightly, and the bandwidth becomes narrower, as shown in Figure 9.



**Figure 9.** The simulation results of return loss with different length of feedline network

### 3.3. The width of the dipole antenna arm after the cross

The Variations of dipole antenna width affect bandwidth impedance and work frequency. When the width of the arm becomes wide, the frequency decreases and the bandwidth becomes narrower, as shown in Figure 10



**Figure 10.** The Simulation results of return loss with different arm width after cross.

#### 4. Conclusion

In this paper, we designed a cross-dipole antenna microstrip antenna that works at a frequency of 1.575 GHz for GPS receiver applications. Simulation results at 1.575 GHz has a return loss of -20.77 dB and VSWR 1.2. In addition, the bandwidth is 290 MHz with frequency range 1.366 GHz – 1.655 GHz for return loss less than -10 dB. The antenna gain is 6.254 dBi with Axial ratio less than 3 dB. The Axial ratio from -60 degree to 60 degree from main beam is less than 6 dB.

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