Design of Dual Band Circular Polarization Stacked Microstrip Antenna for GPS Applications

Dr. Yessar E. Mohammed Ali   **Ahmed J. Abdul Qader**

Dept. Electrical Engineering
College of Engineering/University of Mosul /Iraq 2013
a.yessar@yahoo.com   ah_8611@yahoo.com

Abstract

In this paper dual-band microstrip antenna for Global Positioning System (GPS) application is designed. This design contents on two circular patch (upper circular patch, lower circular patch) printed on a two-layer substrate of an FR4 dielectric layer, and cutting a crossed-slot in the upper patch and four I slots in the lower patch. The antenna can work at GPS Ll band (1.575GHz) and L2 band (1.227GHz) . The design achieved an approximately impedance bandwidth of 15.8 MHz for L1 for two ports, while L2 band is 11.8 MHz for two ports with maximum gain of 2.54dBi and 1.177dBi in the L1 and L2 band respectively for two ports . The resulting circular polarization (with axial ratio ≤ 3 dB) has been found to meet that required for this application. The VSWR is approximately 1.1 (VSWR ≤ 2) for L1 and 1.2 for L2. Results were obtained above using the software CST, which shows that this antenna can meet the demands of the signals of satellite navigation system. The antenna dimensions are $(70*70 \text{ mm}^2)$. The structure is compact and has a good application prospect. The results with low-profile characteristics make the antenna suitable for GPS applications.

Keywords: microstrip antenna, GPS antenna, Circular polarization, dual-band antenna, Global Positioning System.

تصميم هوائي شريحة رقيقة متكدس ثنائي الحزمة ذو استقطاب دائري لاستخدامه في النظام العالمي لتحديد المواقع

د. يسار عزالدين محمد علي   **احمد جميل عبدالقادر**

قسم الهندسة الكهربائية / كلية الهندسة / جامعة الموصل / العراق

الخلاصة

: في هذا البحث تم تصميم هوائي الشريحة الرقيقة ثنائية الحزمة لاستخدامه في النظام العالمي لتحديد المواقع. يحتوي هذا التصميم على طبقتين من الرقعة الدائرية (رقعة دائرية علوية، رقعة دائرية سفلية) مطبوعتين على طبقتين من المادة العازلة نوع FR-4 وفيها قطع على شكل اشارة (+) في مركز الرقعة العلوية من الهوائي ، وأربعة قطوع على شكل حرف I في الرقعة السفلية من الهوائي. الهوائي يعمل عند الترددين GHz 1.227 & 1.575GHz في هذا التصميم تم الحصول على عرض حزمة في كل حزمة متساوية تقريبا ولكلتا نقطتا التغذية حيث ان عرض الحزمة للحزمة الاولى هي 15.8 MHz وللحزمة الثانية هي 11.8 MHz، كما تم تحقيق خاصية الاستقطاب الدائري لهذا التصميم حيث حصلنا على (Axial Ratio ≤ 3dB) وايضا تم الحصول على نسبة الفولتية الواقفة كالاتي (1.1 للحزمة الاولى و 1.2 للحزمة الثانية) . تم الحصول على النتائج اعلاه باستخدام برنامج CST والذي يبين ان هذا الهوائي جيد الاستخدام لاستقبال اشارات الاقمار الصناعية الملاحية . تم تصغير ابعاد الهوائي، والنتائج المبينة يقود الى ان هذا الهوائي مناسب لتطبيقات النظام العالمي لتحديد المواقع.

1- Introduction

Because of their low-profile advantage, circularly polarized (CP) microstrip antennas are very attractive for global positioning system (GPS) applications. However, many of the related designs available in the open literature, operate at the GPS band at 1575 MHz only. Some designs can cover the two GPS bands at 1227 and 1575 MHz, which is necessary in more demanding operations, such as those requiring differential GPS operation [1]. Recently, in order to satisfy the demand for precise and reliable GPS receivers, a high-performance CP antenna covering both L1 and L2 bands is required. Dual-band stacked microstrip antennas, such as antenna structures with an air layer [2] or two different dielectric substrate layers [3], have also been reported for GPS. Both the air layer and the two dielectric substrate layers enable the antennas to carry out the dual-band CP operation, thereby achieving good impedance matching at the two CP operating frequencies. However, the stacked antenna leads to an increase in fabrication complexity. The CP antenna can be used to reduce the multipath effect around a GPS receiver [4].The CP antennas are classified as a single feed type or dual feeds type depending on the number of feed point necessary to generate the CP waves. The dual feeds method has a complex result in larger geometry [5]. Thus, a single feed CP structure, which has a small occupied volume; less complexity, is desired in situation, where it is difficult to place the dual orthogonal feed. In addition, the single feed also does not require an external polarizer [6]. Antennas fed by two probes on the microstrip antenna feed rate equal to 90° phase difference of the two signals, the two feed points, can be formed at right angles to the distribution of circular polarization of radiation. In this paper a dual band CP stacked microstrip antenna is presented using availably common dielectric laminates, which operates at both L1 and L2 frequency bands for GPS applications. Two circular patches are used for obtaining CP characteristics in the dual-band. The antenna is designed and optimized by CST.

2- Theory :

Patch style GPS antennas are very popular due to their small size and low profile. Low cost low profile single frequency, single-feed GPS patch antenna designs are commonly used in cell phone or vehicle applications where size and cost are key considerations. There are also low cost patch designs using dual orthogonal feeds .In our study we are going to build a microstrip antenna that it's going to work with circular polarization, this kind of antennas is widely used as efficient radiators in satellite communications because of the advantages that can provide. The most important of these advantages is that the orientation of the transmitting antenna and receiving antenna orientation need not necessarily be the same, so this allows the designer to have more freedom to design the transmission and reception system. With the use of circular polarized antennas, the system can tolerate changes in the polarization of the signal, these changes may be caused by the reflectivity, absorption, multipath, inclement weather and line of sight problems; conditions that (most of the time) can affect the polarization of a transmitted wave. Hence, circular polarized antennas give us a higher probability of a successful link because they can transmit and receive signals on all planes [7]. In an antenna, circular polarization can be achieved through a single feed or using two feeds in the same patch. In an antenna array, we can generate circular polarization by the sequential rotation of the feeders. The most common and direct way to generate a circular polarization is through the use of a dual-feed technique. The two orthogonal modes required for the generation of circular polarization can be simultaneously

excited using two feeds at orthogonal positions that are fed by $1\llcorner 0°$ and $1\llcorner 90°$ as shown in Figure 1.

During the design of GPS microstrip antenna, the axial ratio of antenna is a vital parameter Usually a pure circular polarization (CP) antenna cannot be made in practice, and the axial ratio (AR) is used to describe the polarization performance of a CP antenna. It is defined as the ratio of the major axis to the minor axis of the elliptic polarization. It is a ratio of electric field amplitudes (not powers), usually expressed in dB that is [8]:
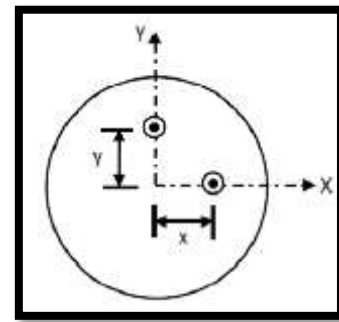
Figure (1) : Dual feed in a circular microstrip antenna.

$$AR(dB) = 20\log\left(\left|\vec{E}_{max}\right|\right) - 20\log\left(\left|\vec{E}_{min}\right|\right) \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(1)$$

If the axial ratio is 0dB, the antenna is pure circular polarization; if it is infinity, the antenna is linear polarization; If the axial ratio is somewhere in between, the polarization is elliptical. As the microstrip GPS antenna pick up the circular polarization signal efficiently, the axial ratio should be less than 3dB in practice.

3- Antenna Structure and Design

The geometry of the proposed dual-band GPS antenna is shown in Figure 2. The antenna consists of crossed-slot in the upper patch and four I slots in the lower patch without an air-gap layer resonating at the L1 and L2. The structure incorporate a round shape ground plane, two substrate layers and two radiating elements and two vertical probe connected to the patch. The upper patch with dimension of $0.1388 \lambda_o$ and Lower patch with dimension of $0.135 \lambda_o$ (where λ_o corresponding to center frequency). The antenna comprises two radiating patch which both is fabricated on FR-4 substrate with relative permittivity $\varepsilon_r = 4.3$, tangent loss $\delta = 0.025$ and thickness $h_u = 0.8$mm, radius 26.375mm for upper substrate and $h_l = 1.6$mm, 70*70mm^2 for lower substrate with two hole radius of 2mm.Fed from the center of 9.2mm, the dual-fed with 50 ohm coax. The upper element is responsible for L1 band and the low element for L2 band.

Probe feed directly through the lower microstrip patch antenna through-hole to connect to the upper microstrip patch antenna. The relationship between the resonant frequency and the radius of the circular patch can be presented by the equation (2) [9].

$$f_{mn} \frac{15 x_{mn}}{2\pi a \sqrt{\varepsilon_r}} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(2)$$

Among them, x_{mn} is the m-zero of $J_n(x)$, obtained by look-up table; (a) is included in the equivalent radius of the edge effects, ε_r is microstrip antenna medium plate relative dielectric constant [10].
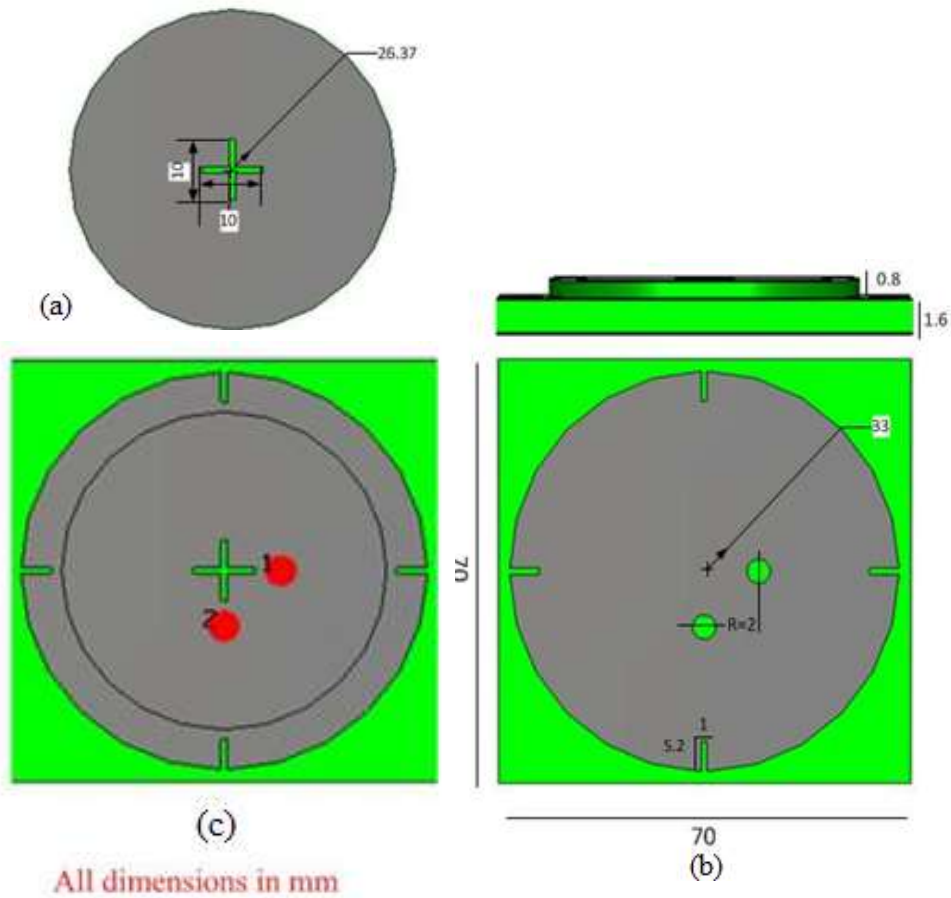
Figure (2) :The proposed antenna structure.
(a): Upper patch.   (b): Lower patch.
(c): Final structure for proposed antenna

4- RESULTS AND DISCUSSION :

The characteristics of the proposed CP antenna are simulated by software CST version 2010. The simulated return loss is shown in Fig.3. Plot shows resonant frequencies at 1.575 GHz with minimum -27.865 dB return loss and 1.227 GHz with -49.302dB return loss for feed one and at 1.575GHz with minimum-26.894 dB return loss and 1.227 GHz with -33.404 dB return loss for feed two.
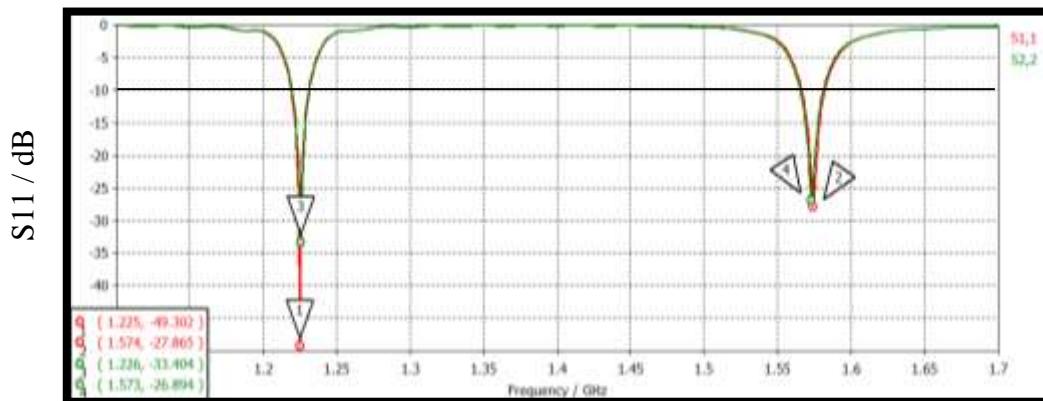

Figure (3) : The Return Loss of the proposed antenna.

The simulated impedance bandwidths (-10dB return loss) for feed one are 11.8 MHz from 1.2192 GHz to 1.231 GHz for lower band, while upper band covers 15.8 MHz from 1.5667 GHz to 1.5825 GHz, The simulated impedance bandwidths (-10dB return loss) for feed two are 11.8 MHz from 1.2198 GHz to 1.2316 GHz for lower band while upper band covers 15.7 MHz from 1.5656 GHz to 1.5813 GHz. Figure (4) represents the impedance (Real & Imag.) for the proposed antenna.
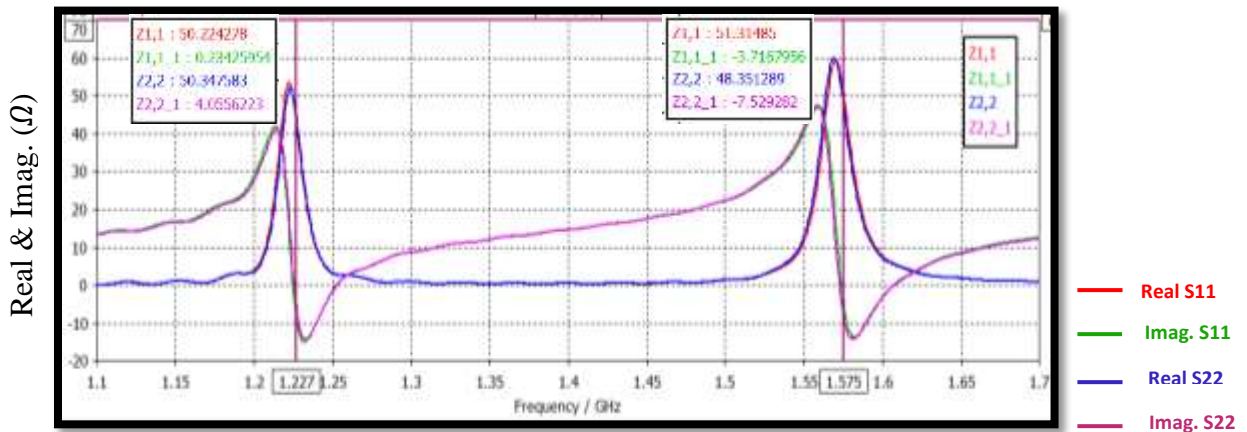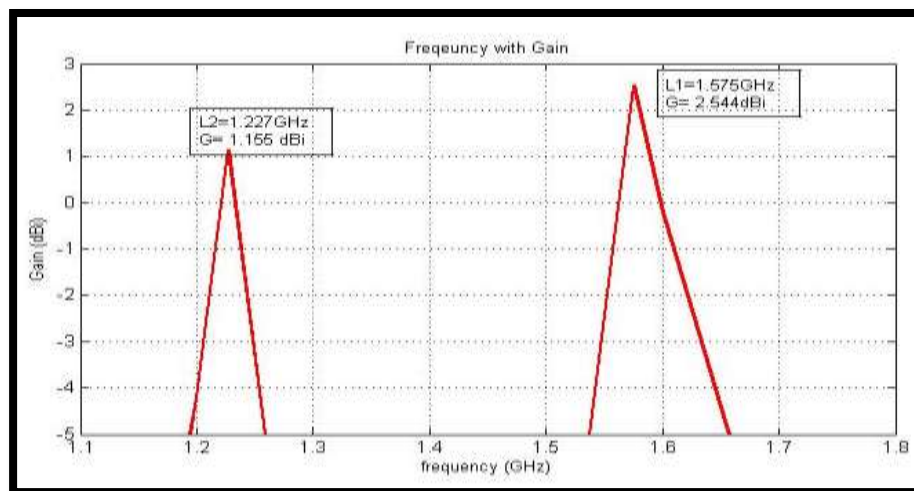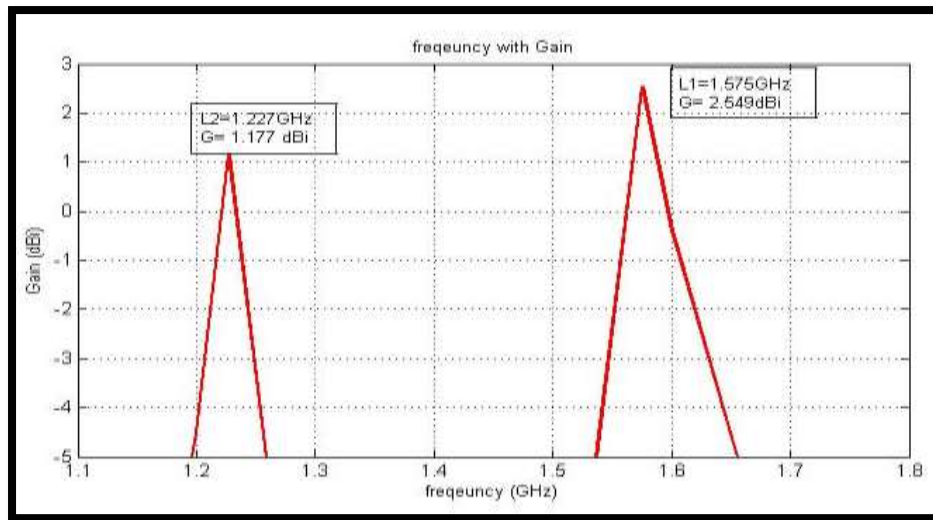

Figure (4) : The impedance of the proposed antenna.

Figure 5 illustrates the maximum antenna gain for frequencies across both of the operating bands. For the feed one, the antenna exhibits gain of 1.155dBi for the lower frequency band (L2) and a peak gain of 2.544dBi for the upper frequency band (L1), while for the feed two, the antenna exhibits gain of 1.177dBi for the lower frequency band (L2) and a peak gain of 2.549dBi for the upper frequency band (L1).
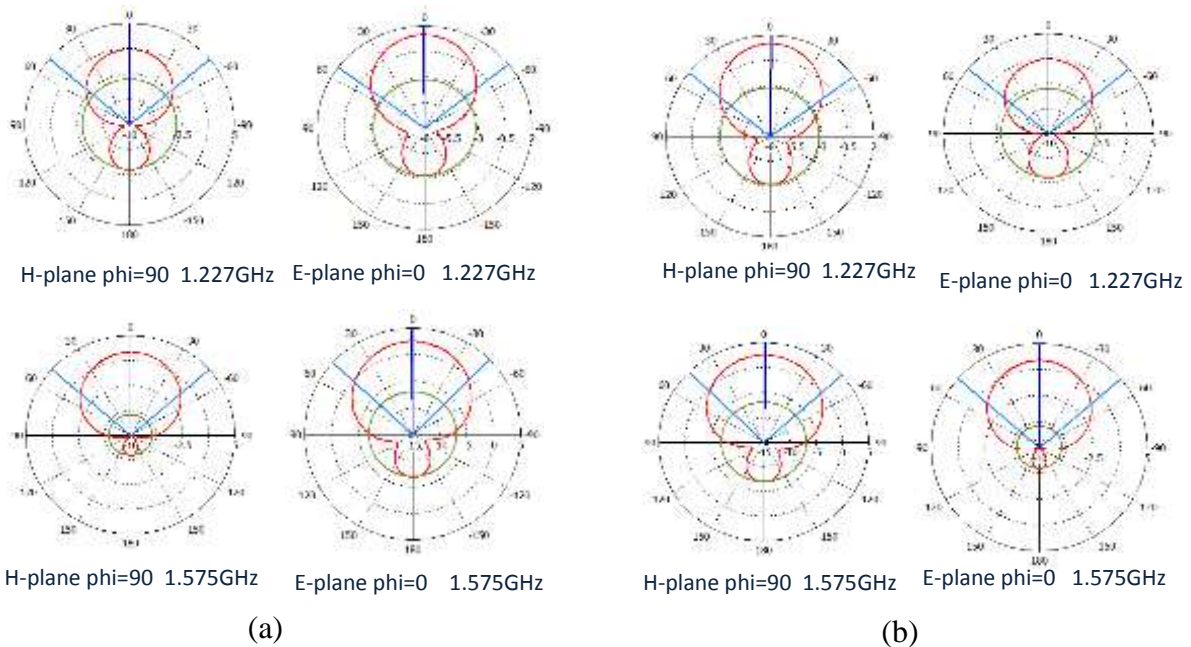

(a)

(b)

Figure (5) : The gain response of the proposed antenna.
(a) Gain for feed one.   (b) Gain for feed two.

The radiation patterns for E-plane and H-plane of the proposed antenna at frequencies 1.227GHz for L2 and 1.575GHz for L1 are shown at Figure (6). Figure (6 a) represent E-plane and H-plane for feed one and Figure (6 b) represent E-plane and H-plane for feed two. The radiation patterns of the antenna are broadside unidirectional which is approximately the same with the radiation pattern of ideal GPS antenna .

H-plane phi=90 1.227GHz   E-plane phi=0   1.227GHz   H-plane phi=90 1.227GHz   E-plane phi=0   1.227GHz

H-plane phi=90 1.575GHz   E-plane phi=0   1.575GHz   H-plane phi=90 1.575GHz   E-plane phi=0   1.575GHz

(a)   (b)

Figure (6): (a) The radiation pattern of the proposed antenna for feed one.
(b) The radiation pattern of the proposed antenna for feed two.

The corresponding performance of the proposed antenna is depicted in Figure 7 and Figure 8. Where Figure 7 represents the VSWR and figure 8 represents Axial Ratio (AR) .For the CP microstrip antenna, the most attractive characteristic is axial ratio. For investigation the polarization characteristics of the GPS antenna, the axial-ratio was simulated over the whole L1 and L2 bands.
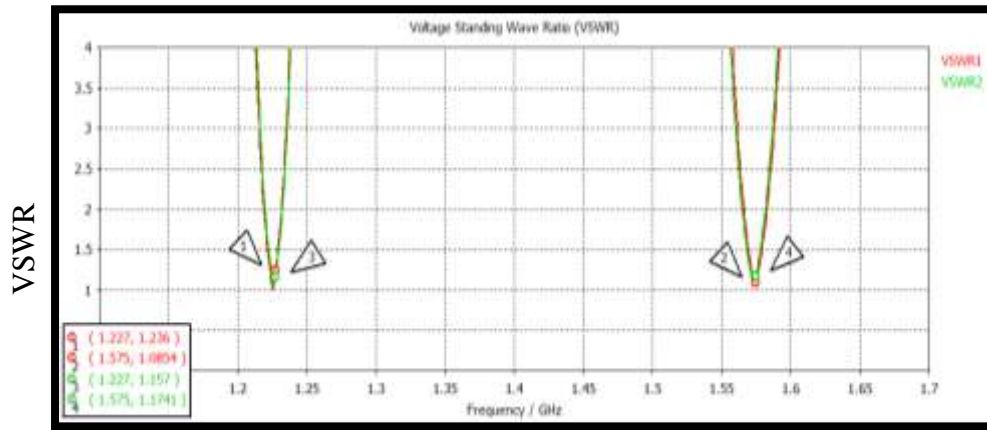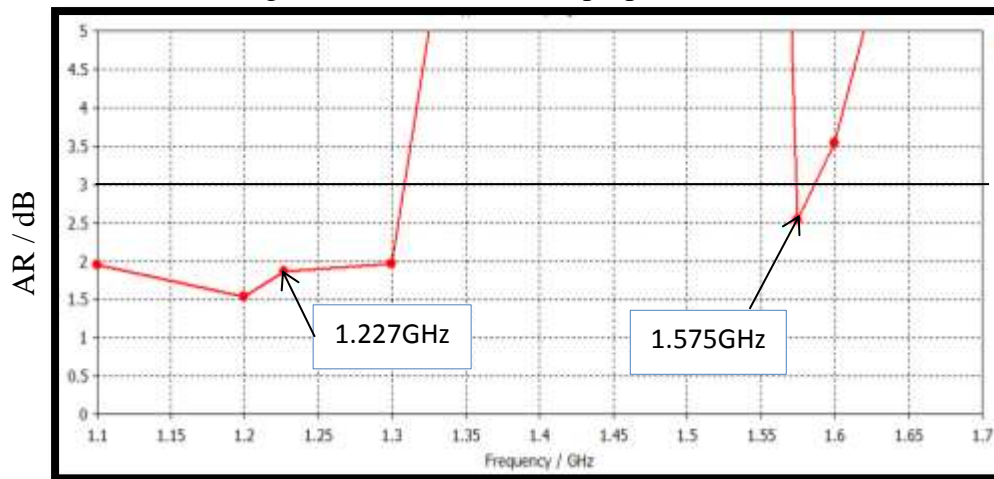

Figure (7) : VSWR of the proposed antenna.

Figure (8) : AR of the proposed antenna.

Table (1) shows a comparison between our results with results obtained from papers [9], [11],[12].

Table (1) shows a comparison between the results

papers		Over all dimensions (m*m^2)	Return loss / S11 (dB)		Axial Ratio / AR(dB)		Gain (dBi)	
			1.575 GHz	1.227 GHz	1.575GHz	1.227GHz	1.575GHz	1.227GHz
My paper	Feed one	70*70	-27.865	-49.302	2.53	1.86	2.544	1.155
	Feed two		-26.894	-33.404	2.53	1.86	2.549	1.177
Paper [9]		130*130	26.4	-35.9	2.858	2.283	6.87	7.27
Paper [11]		140*140	-12.3	-19.2	1.1	0.5	7.5	5.1
Paper [12]		100*100	-18.07	-15.59	----------	----------	4.29	3.34

5- Conclusion

In this paper, a new double feed compact dual-band microstrip patch antenna covering GPS operating frequencies at L1 (1.575 GHz) and L2 (1.227 GHz) has been demonstrated. The two layers of the proposed antenna use the same substrate material. The antenna shows good CP radiation characteristics at the two GPS operating frequencies. Two slots shaped (+) are added in the upper patch, and four (I) shaped in the lower patch. An enhancement in return loss and gain are obtain due to adding slots.

At the same time this design method can be applied to other dual-band and multi-frequency antenna design. Furthermore, the antenna has a hemispherical radiation pattern with a good average gain throughout the operating bandwidth. This makes the proposed antenna design suitable for use in the GPS L1, L2 applications.

6-   References :

[1]. D.M. Pozar and S.M. Duffy, "A dual-band circularly polarized aperture-coupled stacked microstrip antenna for global positioning satellite, " IEEE Trans Antennas Propagat. Vol. 45, pp. 1618–1625, 1997.

[2]. C. M. Su and K. L. Wong, "Adual-band GPS microstrip antenna, " Microwave Opt. Tech. Lett., vol. 33, pp. 238–240, 2002.

[3]. X.F. Peng, S.S. Zhong, S.Q. Xu, and Q. Wu, "Compact dual-band GPS microstrip antenna, " Microwave Opt. Tech. Lett., vol. 44, pp. 58–61, 2005.

[4]. N. Padros, J.I. Ortigosa, J. Baker, M.F. Iskander, and B. Thornberg, "Comparative study of high-performance GPS receiving antenna designs, " IEEE Trans Antennas Propagat. Vol. 45, pp. 698–706, 1997.

[5] OH, J. OH, HONG, and Y. P, YOOK , "Dual circularly polarized stacked patch antenna for GPS/SDMB, " In IEEE International Symposium on Antennas and Propagation Society. San Diego (USA), p. 1-4, July 2008.

[6] KIM, SON, and J. M. YANG, "Design and implementation of dual band circular polarization square patch antenna, " In Proc. Asia-Pacific Microwave Conf. (APMC 2005), Suzhou (China), p. 1-4, Dec. 2005.

[7] L. Changlu , "Antenna Measurement Techniques, " University of Electronics Science Technology of China Press. 1987.

[8] L. Xueguan, and G. Huiping , "Microwave Technology and Antennas, " Xidian University Press. 2006.

[9] U. U. Hussine, M. T. Islam, and N. Misran, "A New I Slotted Compact Microstrip Antenna for L1 & L2 Bands," IEEE International Conference on Space Science and Communication (IconSpace), vol. 2, pp. 286-290, 12-13 July 2011.

[10] L. Boccia, G. Amendola, and G. D. Massa , "A high-performance dual frequency microstrip antenna for global position system, " IEEE Antennas and Propagation Society International Symposium, vol. 4, pp. 66- 69, 2001.

[11] X. Sun, Z. Zhang, and Z. Feng, "Dual-Band Circularly Polarized Stacked Annular-Ring Patch Antenna for GPS Application," IEEE ANTENNAS AND WIRELESS PROPAG AT ION LETTERS, VOL. 10, pp. 49-52, September 2011.

[12] U. U. Hussine, M. T. Islam, and N. Misran, "A Compact Dual-Band Gps Microstrip Antenna," Advances in Natural and Applied Sciences journal, vol. 6, pp. 1214-1218, 2012.