DESIGN AND SIMULATION OF A FOUR-ARM SPIRAL ANTENNA FOR GPS

Li zheng, NSHU Victor, M. R. Anjum and M. A. Shaheen.
Beijing Institute of Technology, Beijing, P.R. China. 100081.

ABSTRACT*: *This paper presents the design of a four-arm spiral antenna for GPS operating at 1.52~1.6GHz. The advantage of this antenna is that it can achieve a high gain greater than 3dBi with VSWR less than 1.5. Also it can achieve Axial Ratio (AR) less than 5dB. The Computer Simulation Tool (CST) Microwave Studio was used for modeling and simulating the designed antenna. For the implementation of the physical designed antenna SMA Connector terminal is interfaced with recommend polarization Right Handed Circular Polarization (RHCP) for better performance.

Keywords*:* Spiral antenna, CST, EM, GPS, RHCP.

I. INTRODUCTION

The fast growth and increasing demand of smart phones made essential mobile phones for adaptive communication system e.g. Global Positioning System (GPS), Bluetooth and Wi-Fi etc. GPS is known to be satellite based technology. GPS receivers based on several components, where antenna is known to be one an important component. Antenna is an important component which carries many kind of applications such as radio, television, microwave link and satellite. Also it is based on many kind of shapes such that like geometries, sizes and shapes which rely on many factors. The electrical current converts into electromagnetic wave propagation or by reciprocal. It also collects electrical power form electromagnetic waves. Because of the difference in polarization and frequencies used in communication. Therefore the number of antennas are required which is installed in mobile device for increasing of communication [1,2,5]. GPS receivers must be capable enough for efficient performance in against or to combat the undesirable multipath effects caused by reflection or by reflected propagation of electromagnetic wave signal also it minimize the optimum performance of the GPS system. For better discriminate between the reflected and direct signals the transmission of GPS satellite realized by the RHCP also it carries the property to become the LHCP after reflection furthermore, it is the main cause for RHCP required and the ratio of high cross polarized rejection on receiving antenna. The receiving antenna radiation pattern shape is essential for specification of antenna design and for reception of satellite signal required hemispherical coverage [3-4].

For wide band application spiral antennas are known to provide this ability. Which is known for almost its perfect circularly polarized emission of radiation in coverage region. Due to polarization generality and its inherent frequency coverage and wide spatial obtained the wide range of application [4]. It is also known to be that frequency independent antenna where it follows very large bandwidth and also circularly polarized. The radiation pattern typically utilized by spiral antennas carries peak radiation direction which is perpendicular to its plane of spiral radiation broadside. Wideband antennas usually carries much of it space which is needed in the application of sensing application especially in defense industry typically required spiral antenna. Also it is widely used in other application of GPS. Where its benefit of RHCP, circularly polarized signals needed ultra high bandwidth i-e. Cavity back spiral antenna is highly suitable for such kind of requirement. Also both LHCP and RHCP available since its frequency independent antenna designed from weather protected also it is suitable for outdoors application which required circularly polarized radio frequency radiations. Also cavity back antenna is known to be very highly suitable for transmission, reception, scanning, surveillance, monitoring, signal intelligence, telemetry, direction finding and airborne application cause of its feature based on ultra wide band. It is also highly immune to noise if LHCP or RHCP spiral antenna sealed by aluminum cavity. Spiral antenna design performs very high efficiency and this paper objective is to simulate the design antenna and then analyze its effects for four-arm spiral antenna for GPS [5-13].

This research work is organized as follows. Section II briefly describes the antenna design and antenna model structure. The design antenna analysis and simulation result are presented in section III. The conclusions are drawn in section IV.

II. SYSTEM MODEL

Four-arm spiral antenna generally consists of four lines of bent metal inlay on the cylindrical substrate without any grounding. This structure is designed for the antenna has a 3dB gain in all directions and can present radiation pattern with good characteristics. Four-arm spiral antenna has a full 360 degrees reception capacity, once it is integrated in the navigation systems, Therefore it can mainly be used in GPS antenna. Figure.1 shows a four-arm spiral antenna proposed by Kilgus, it is the resonant antenna.

This antenna is composed by four spiral arms, each spiral arms length is $M\lambda/4$ (M is an integer). The terminal feeding are equal for the four spiral arms, the phase difference is 90°one from another i-e. (0°, 90°, 180°, 270°respectively). Four spiral arms generally wound into N/4. And (N=1,2…), Non-feeding side open circuit (when M is an odd number) or short circuit (when M is an even number).

Four-arm spiral antenna can be viewed as composed of two spiral arms, these two spiral arms need to be fed from 90 ° of phase. Resonant four-arm spiral antenna structure parameters can be determined using the following equation (1).

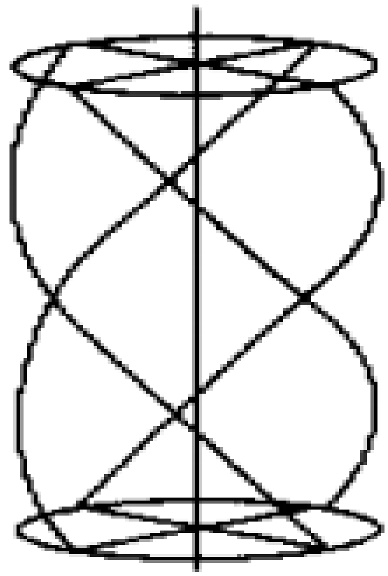

Figure 1. Resonant four-arm spiral antenna

$$L_{ax} = N\sqrt{(1/N^2)(L_{ele} - Ar_0)^2 - 4\pi^2 r_0^2}$$ - ----eq. (1)

where : L_{ax} is the spiral axial length (mm) , L_{ele} is the length of the spiral arms (mm) , r0 is the radius of the spiral (mm) , N is the number of turns of the spiral.

$$A = \begin{cases} 1 & \text{M is an odd number} \\ 2 & \text{M is an even number} \end{cases}$$

the antenna design and model structure with three dimensional is shown in below Figure 2.

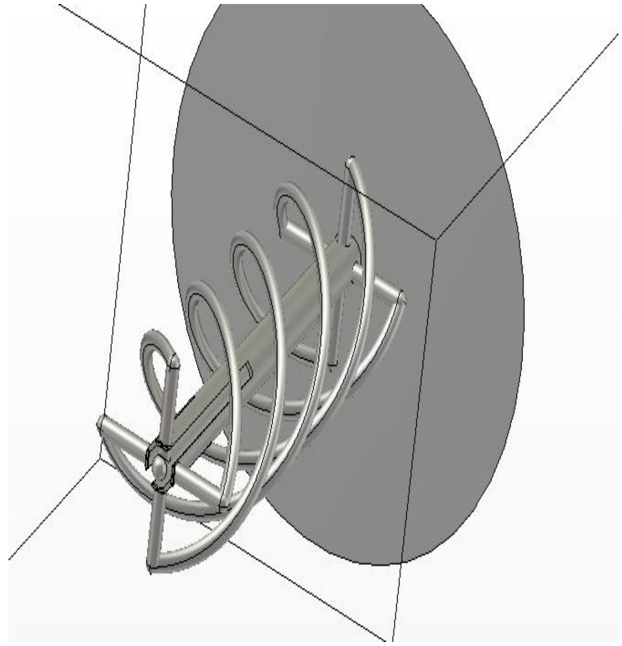

Figure 2. 3D of the final antenna model

III.SIMULATION AND RESULTS

Four-arm spiral antenna simulation results illustrated for standing wave, farfield gain , axial ratio determine its design specification characteristics as shown below in Figure 3, for Standing wave (VSWR), Figure 4, for farfield realized gain, Figure 5, for farfield axial ratio, Figure 6, for its farfield realized gain, Figure 7, for its right hand polarized antenna pattern, and Figure 8, for its L-polarized antenna pattern is discussed also antenna design specification is determine in table. I for VSWR table. II for its gain table(E plan)in dB, table.III explain the Axial Ratio (AR) (E plan) in dB below.

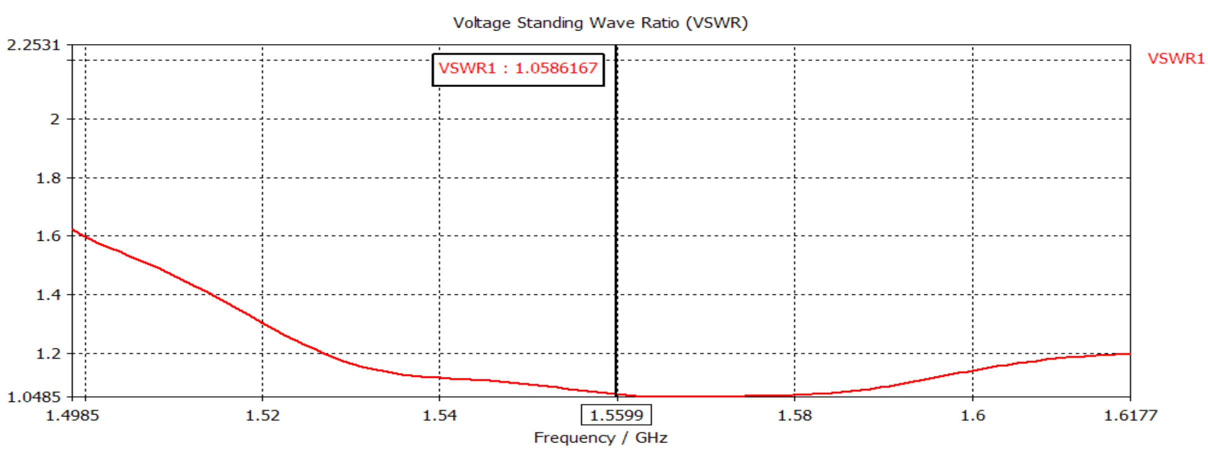

Figure 3. Standing wave (VSWR)

Table.I VSWR

frequency	Min	Center frequency	Max
VSWR	1.30	1.06	1.14

The following is the gain in the frequency band of 1.52-1.60 GHz, the specific gain value is given in the table II below, because the characteristics of the antenna pattern, the results of E plane, H plane pattern are almost the same, so only the result of E-plane is given.

The axial ratio in the frequency band of 1.52-1.60GHz is given below; the specific gain value is given in the table III. Similarly to the gain results, only the result of E-plane is also given

Table. II Gain table（E plan）(dB)

Degree / frequency	-60°	0°	60°
1.52GHz	3.281	4.23	3.028
1.54GHz	3.094	3.892	3.012
1.56GHz	3.424	3.927	3.131
1.58GHz	3.37	3.601	3.236
1.60GHz	3.687	3.6	3.531

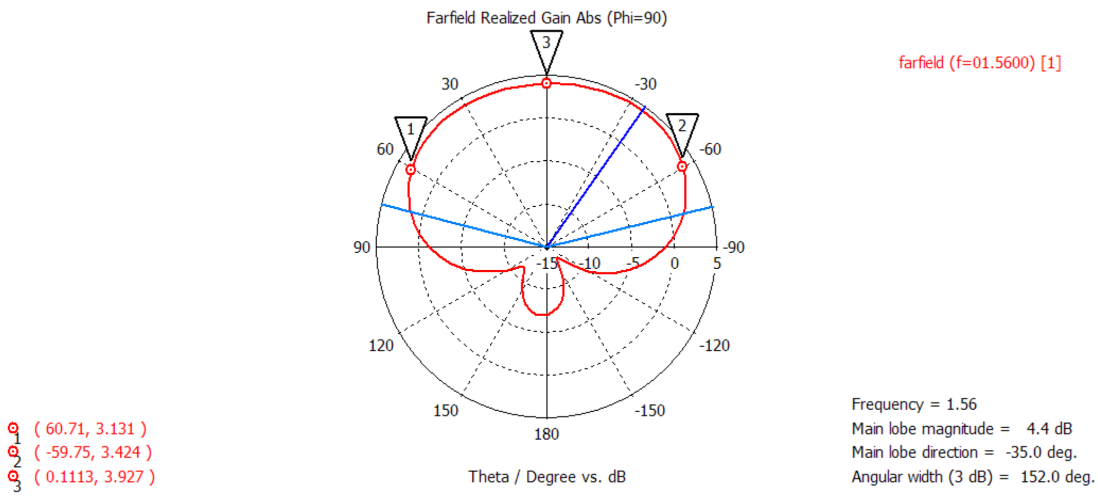

Figure 4. Farfield realized gain

Table.III Axial Ratio (AR)（E plan）dB

degree / frequency	-60°	0°	60°
1.52GHz	3.593	1.992	3.473
1.54GHz	3.243	1.987	3.065
1.56GHz	3.304	2.756	3.367
1.58GHz	3.539	3.684	3.533
1.60GHz	3.918	4.765	3.953

.

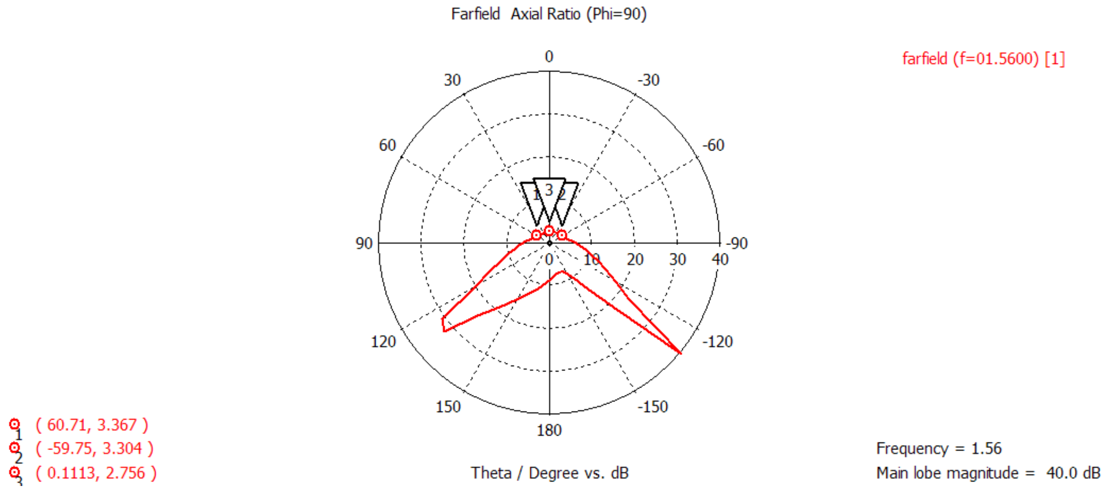

Figure 5. Farfield axial ratio

.

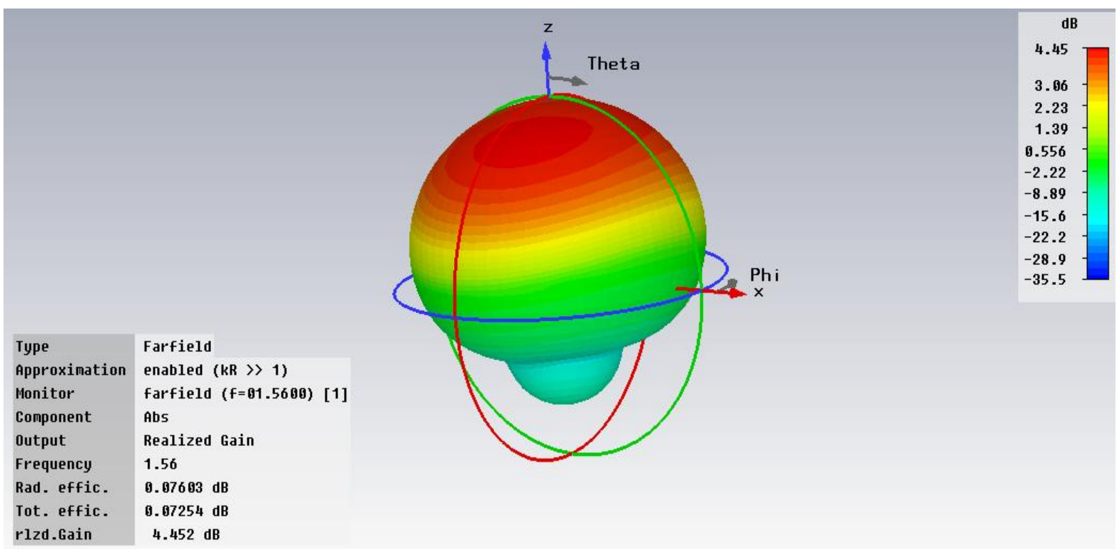

Figure 6. Farfield realized gain

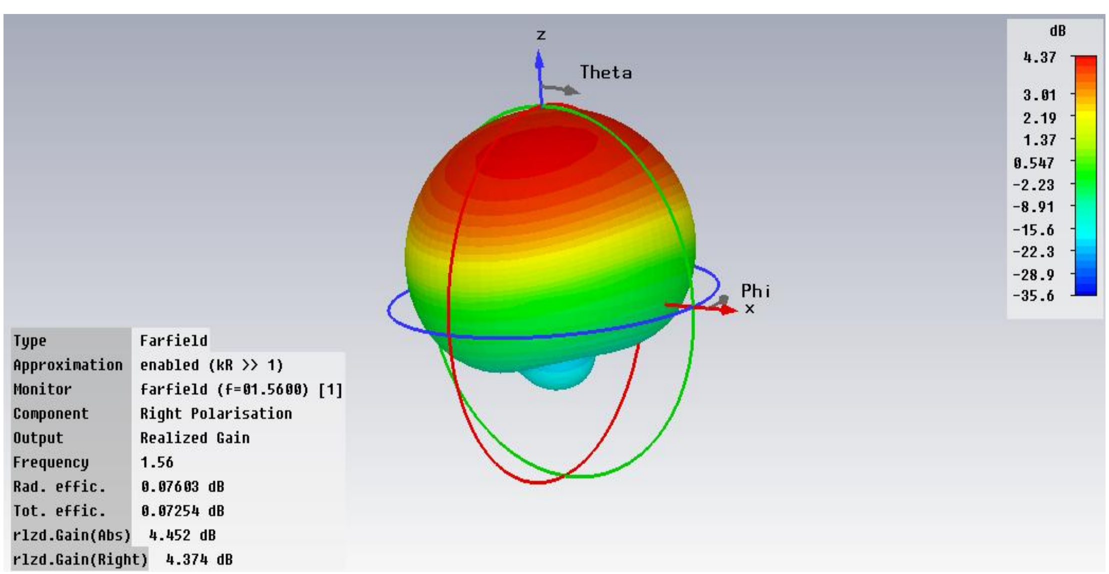

Figure 7. Right-hand polarized antenna pattern

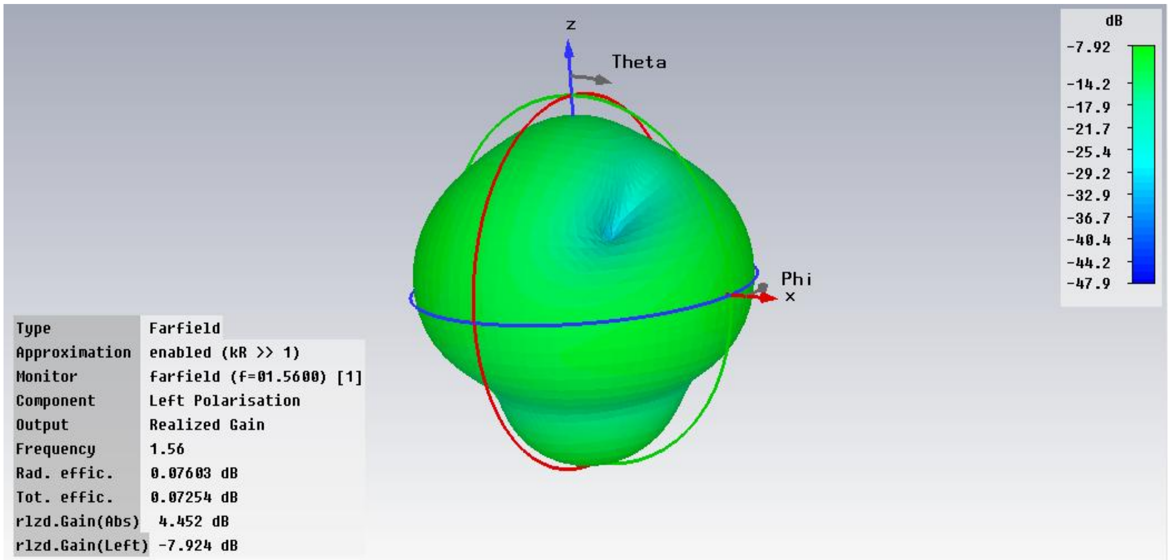

Figure 8. L-polarized antenna pattern

At the final point we validated the antenna polarization. The antenna's 3D pattern at center frequency is as shown in the Figure 6.

We find that the right hand polarized antenna pattern is almost identical to the general direction of the antenna pattern. The radiation of the left polarized antenna is almost impossible. Therefore our designed antenna works in the right hand polarized mode.

IV. CONCLUSION

The simulation of the designed antenna has been achieved the design requirements. The design corner case is mainly due to the fact that the gain and axial ratio within ± 60 ° both must present the excellent directional achievement in a certain range of antenna. The antenna axial ratio in the most cases is less than 3dB, but precisely because of the higher requirements of Omni-directional, in the high-frequency pattern the axial ratio appears between 4-5 dB additionally, this antenna’s back coaxial impedance matching SMA connectors take a longer length, increasing the size of the antenna. Simulation of a four-arm spiral antenna for GPS result shows that considering the coaxial impedance matching connected coaxially to the helical antenna can reduce the antenna geometries complexity. Simulation results have been carried out to verify the effectiveness of the design spiral antenna. This research work on spiral antenna would be helpful to the engineering application of antenna design using CST.

REFERENCES

1. Mohd Yusop, M. F., *et al*. "Coaxial feed Archimedean spiral antenna for GPS application." Applied Electromagnetics (APACE), *IEEE Asia-Pacific Conference* (2010).
2. M.F. Abdul Khalid, M. A. Haron, A. Baharuddin and A. A Sulaiman, "Design of a spiral antenna for Wi-Fi application, " *IEEE International RF and Micowave Conference Proceedings*, K. Lumpur, pp. 428-432, 2-4, (2008).
3. Padros, Neus, *et al. "Comparative study of high-performance GPS receiving antenna designs."* Antennas and Propagation, *IEEE Transactions on* **45**. 4 698-706. (1997).
4. Nurnberger, M. W., T. Ozdemir, and J. L. Volakis. *"A planar slot spiral for multi-function communications apertures."* Antennas and Propagation Society International Symposium, IEEE. **Vol. 2**, IEEE,(1998).
5. Matsunaga, Mayumi, and Toshiaki Matsunaga. *"A dual-polarization single-layered antenna for GPS and ISM bands."* Antennas and Propagation Society International Symposium (APSURSI), IEEE, (2012).
6. Nakano, H., Miyake, J, Oyama, M., Yamauchi, J. “*Metamaterial spiral antenna*” *IEEE Antennas and Wireless Propagation Letters*, **Vol. 10**, p 1555-8, 25 July (2011).
7. Tanabe, M., Matsumoto, M., Masuda, Y. *“A two-arm Archimedean spiral antenna with bent ends”*, *IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications* (APWC), p 535-8, (2012).
8. Liu, Q. Ruan, C.-L. Peng, L. Wu, W.-X. *“A novel compact Archimedean spiral antenna with gap-loading*, Progress In Electromagnetics *Research Letters*, **vol. 3**, p 169-77, (2008).
9. Teng Kai Chen, Huff, G.H.“Strip line-Fed Archimedean Spiral Antenna*” IEEE Antennas and Wireless Propagation Letters*, **Vol. 10,** p 346-9, (2011).

10. L. Barlatey, J. R. Mosig, and T. Sphicopoulos, *"Analysis of stacked microstrip patches with a mixed potential integral equation"*, *IEEE Trans. Antennas Propagat*., **vol. 38**, pp.608 -615, (1990).
11. C. Sun, G. Wan, Z. Han and X. Ma, "Design and simulation of a planar Archimedean spiral antenna, " Progress in Electromagnetic *Research Symposium Proceedings, Xi'an, China,* March, 22-26, (2010).
12. C. A. Balanis, *Antenna Theory: Analysis and Design* 3rd edition John Wiley & Sons, pp. 947-954, 2005.
13. Deal, W.R., Kaneda, N., Sor, J., Yongxi Qian;Itoh, T., "*A new quasi-Yagi antenna for planar active antenna arrays* " Microwave Theory and Techniques, IEEE Transactions on , **vol.48**, no.6, pp.910,918, Jun 2000.