2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

A design of elliptical edge-fed circularly polarized patch antenna for GPS and Iridium applications

Keyur K. Mistry * (1), Pavlos I. Lazaridis (1), Emmanouil N. Tziris (2), Zaharias D. Zaharis (3), Bo Liu (4), Thomas D. Xenos (3) and Ian A. Glover (1)

(1) Department of Engineering and Technology, University of Huddersfield, Huddersfield HD1 3DH, UK, keyur.mistry@hud.ac.uk

(2) Brunel University, Uxbridge, UK

(3) Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Thessaloniki, 54124, Greece

(4) Wrexham Glyndwr University, Wrexham, UK

Abstract

This study presents a design of an elliptical edge-fed circularly polarized patch antenna to facilitate GPS and Iridium dual-band satellite applications like Search and Rescue (SAR) operations. The simulation of the antenna was performed in CST simulation software in the frequency range of 1.3 GHz – 2 GHz. The proposed antenna provides good matching with low S_{11} in the dual-band: GPS (1.563 GHz – 1.587 GHz) and Iridium (1.616 GHz – 1.6265 GHz). Additionally, the simulated realized gain and axial ratio are in compliance with the required specifications. This design provides a cost-efficient and compact solution for the required dual-band application.

1. Introduction

In recent years, there have been significant advancements in the field of wireless communications, thereby increasing the use of wireless devices with reduced size. However, miniaturizing wireless devices is a complex problem because reducing the size of antenna may degrade the antenna performance. Furthermore, the complexity of this problem is to find an optimal design because of the tradeoff between antenna performance, antenna size and battery life. In order to design an antenna with reduced size along with good antenna performance, better matching of the antenna needs to be achieved using special feeding networks [1].

As stated in [1], there are cases of space and satellite communication systems, where the antenna is not only responsible for reception, but also for transmission. In such cases, an antenna with low antenna performance may lead to excessive power consumption, thereby degrading the battery life of the system. Furthermore, there can be power losses due to polarization mismatch of the transmitting and receiving antenna, and due to this reason circularly polarized antennas are preferred over linearly polarized antennas. The circularly polarized antenna can achieve 3dB better power level in comparison to the linearly polarized antenna [1-2]. Additionally, circular polarization terminates the requirement of transmitting and receiving antenna to be in exact line of sight, as the beam-width of circularly polarized antenna covers a wider-angle range. Circularly polarized antennas have been used for various wearable antenna applications like fire-fighting [3], health monitoring systems for medical applications [4], and space and military applications [5]. Therefore, circularly polarized antennas are considered as the best candidates for mobile satellite communication for Global Positioning System (GPS) and Iridium applications.

In order to design an antenna for GPS and Iridium applications, it is mandatory to note that the designed antenna should have the capability to cover GPS L1 band (1.563 GHz – 1.587 GHz) and Iridium frequency spectrum (ranging from 1.616 GHz - 1.6265 GHz) [6]. Several circularly polarized antennas have been proposed for GPS [7-8], and for GPS and/or Iridium combined [1-2], [9-10]. A good candidate for this application is the elliptical patch antenna. Initial studies on elliptical patch antennas exhibiting circular polarization are presented in [11-12] . Circularly polarized microstrip antennas can use a single feed type or a dual feed type, depending on the number of feed points required to generate circularly polarized waves. Furthermore, slot coupled methods can also be used in order to match the impedance of the antenna and reduce the antenna size [13]. A detailed study on the position of the feed and the position of the slot to match the impedance is shown in [13-14]. Another feeding technique for circular polarization is the proximity-coupled method, based on electromagnetic coupling, which has been studied in detail in [15-16].

This paper proposes a design of elliptical patch antenna which provides circular polarization and can cover GPS and/or Iridium frequency spectrum. In order to improve the matching of the antenna, the edge-fed technique is used by introducing a feeding line segment and a matching line segment connected to the elliptical patch. However, different feeding networks could be used depending on the application of the design. The proposed design provides good matching with low S_{11} values at GPS L1 band and Iridium band. The antenna is also circularly polarized and provides good realized gain and axial ratio.

2. Antenna design

The proposed antenna design uses an elliptical patch embedded on the top of a square planar substrate with relative permittivity (ε_r) equal to 2. The bottom part of the substrate consists of a ground plane. The proposed antenna can be schematically shown as below:

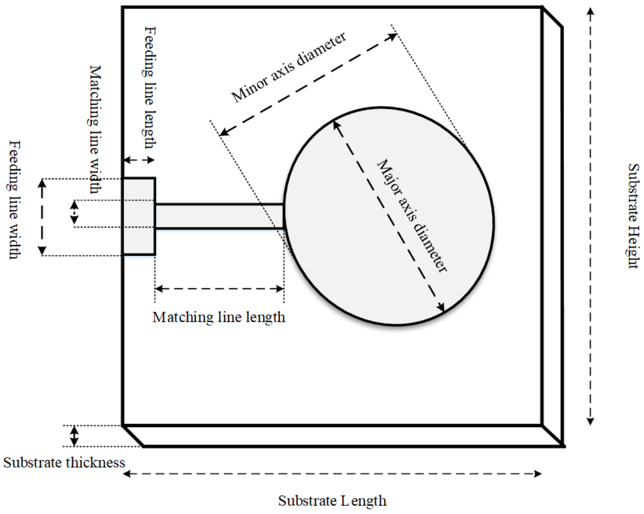

Figure 1. Schematic design of proposed antenna.

As shown in Figure 1, the antenna consists of 5 fundamental parts: dielectric substrate, ground plane, elliptical patch, feeding line and matching line. The diameter of the major axis and minor axis of the ellipse play an important role in determining the operating frequencies of the antenna. Since the antenna is intended to operate at a closely spaced dual band, the diameter of the major axis and minor axis should be approximately same. The patch diameters are inversely proportional to the resonance frequencies of the antennas. However, the axial ratio is dependent on the ratio of major axis to the minor axis of the ellipse. Therefore, if the axial ratio needs to be improved, the ratio of the axis of the ellipse will play a deciding role. The bandwidth of the antenna is directly proportional to the substrate height and inversely proportional to the relative permittivity of the substrate. The matching of the antenna can be improved by varying the dimensions of matching line and feeding line. The excitation to these antennas can be done through SMA connectors and coaxial cables, connected at the edge of the feeding line.

The overall dimensions of the proposed antenna is 152.53 mm x 152.53 mm x 2.6 mm. The height of dielectric substrate should be 2.6 mm in order to achieve the desired antenna performance. Any substrate material could be used with a relative permittivity of 2. Table 1 shows the dimensions of the antenna.

Table 1. Dimensions of the proposed antenna design.

Parameters	*Values*
Substrate length	152.53 mm
Substrate height	152.53 mm
Substrate thickness	2.6 mm
Major axis diameter	74.57 mm
Minor axis diameter	72.63 mm
Matching line length	34.46 mm
Matching line width	2.52 mm
Feeding line length	5 mm
Feeding line width	8.5 mm
Relative permittivity of substrate	2
Copper clad thickness	35 μm

3. Antenna simulation

The proposed circularly polarized antenna design is capable of operating at dual-band frequency: GPS and Iridium. A computer-aided design (CAD) model of the proposed antenna design, with desired dimensions was built and simulated in CST electromagnetic simulation software. The simulation was performed with an accuracy of -50 dB using hexahedral meshing consisting of 72,960 mesh cells. The estimated reflection coefficient level of 0.0001 was set with open boundary conditions for the simulation of the proposed design. The excitation to the antenna was provided using a waveguide port attached to the feeding line of the antenna. The farfield monitors were setup from 1.5485 GHz – 1.7115 GHz in order to examine the performance of the antenna in the required frequency range. Figure 2 shows the model of the proposed antenna design in CST simulation software.

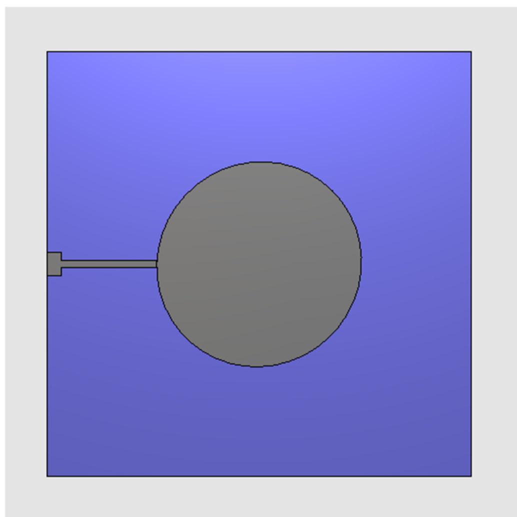

Figure 2. CAD model of the proposed antenna design in CST.

In Figure 3, the S-parameter (S_{11}) versus frequency curve for the proposed antenna design is presented. It is evident that the antenna has good matching, with low S_{11} values below -10 dB in the GPS L1 and Iridium frequency bands. The higher S_{11} values in the frequency band other than GPS L1 and Iridium frequency band in the curve, also suggests that the antenna rejects other bands except the dual -band frequencies.

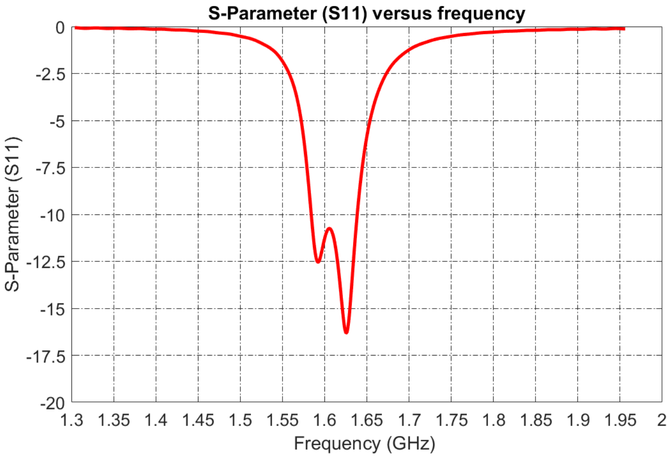

Figure 3. S-Parameter (S_{11}) versus frequency.

Figure 4 presents realized gain (dBi) of the antenna and it is evident that the proposed antenna provides gain above 7.6 dBi in the GPS L1 as well as Iridium frequency band. The simulated gain is the boresight realized gain, which shows compliance with the gain required in the desired dual-band for search and rescue operations in remote areas.

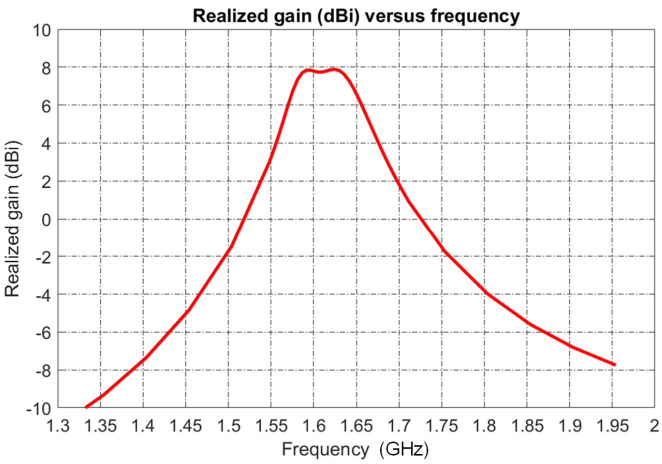

Figure 4. Realized gain (dBi) versus frequency.

The axial ratio of an antenna is defined as the relation between right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP) electric fields. It is the measure of absolute value gain of the antenna. Figure 5 presents the axial ratio (theta=0, phi=0) of the proposed antenna at GPS L1 and Iridium frequency bands. The axial ratio of the proposed antenna suggests that the antenna provides circular polarization in the GPS L1 and Iridium frequency bands. However, the axial ratio for the proposed antenna needs further improvements.

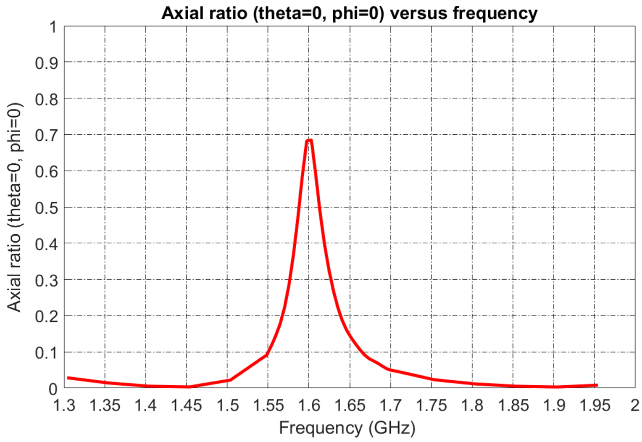

Figure 5. Axial ratio (dB) versus frequency.

4. Conclusion

A cost-efficient and compact antenna design for GPS L1 and Iridium frequency dual-band satellite applications like search and rescue operations is proposed in this paper. The antenna design is circularly polarized with boresight realized gain above 7.6 dBi in the desired dual-band. The proposed antenna design consists of an elliptical patch with feeding line segments and matching line segments to achieve good matching.

7. References

1. E. Kaivanto, E. Salonen, and H. Khaleel. "Circularly Polarized Wearable Antennas", *WIT Transactions on State-of-the-art in Science and Engineering*, 82, 2014, pp.145-161.

2. E. Kaivanto, M. Berg, E. Salonen and P. de Maagt, "Wearable Circularly Polarized Antenna for Personal Satellite Communication and Navigation", *IEEE Transactions on Antennas and Propagation*, vol. 59, no. 12, pp. 4490-4496, 2011.

3. L. Vallozzi, P. Van Torre, C. Hertleer, H. Rogier, M. Moeneclaey, and J. Verhaevert, "Wireless communication for firefighters using dual-polarized textile antennas integrated in their garment," *IEEE Trans. Antennas Propag.*, vol. 58, no. 4, pp. 1357–1368, Apr. 2010.

4. A. Alomainy, Y. Hao, and F. Pasveer, "Numerical and experimental evaluation of a compact sensor antenna for healthcare devices," *IEEE Trans. Biomed. Circuits Syst.*, vol. 1, no. 4, pp. 242–249, Dec. 2007.

5. P. Salonen and Y. Rahmat-Samii, “Textile antennas: Effects of antenna bending on input matching and impedance bandwidth,” *IEEE Aerosp. Electron. Syst. Mag.*, vol. 22, no. 12, pp. 18–22, Dec. 2007.

6. S. Pratt, R. Raines, C. Fossa, and M. Temple, “An operational and performance overview of the Iridium low earth orbit satellite system,” IEEE Commun. Surveys & Tutorials, vol. 2, no. 2, pp. 2–10, 1999.

7. P. Salonen, Y. Rahmat-Samii, M. Schaffrath, and M. Kivikoski, “Effect of textile materials on wearable antenna performance: A case study of GPS antennas,” in *Proc. IEEE Antennas and Propagation Society Int. Symp.* 2004, Jun. 2004, Monterey, CA, USA, pp. 459–462.

8. L. Vallozzi, W. Vandendriessche, H. Rogier, C. Hertleer, and M. Scarpello, “Design of a protective garment GPS antenna,” *Microw. Opt. Technol. Lett.*, vol. 51, no. 6, pp. 1504–1508, 2009.

9. A. Dierck, H. Rogier and F. Declercq, "A Wearable Active Antenna for Global Positioning System and Satellite Phone", *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 2, pp. 532-538, 2013.

10. J. Lilja, P. Salonen, T. Kaija and P. de Maagt, "Design and Manufacturing of Robust Textile Antennas for Harsh Environments", *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 9, pp. 4130-4140, 2012.

11. L. C. Shen, “The elliptical microstrip antenna with circular polarization,” *IEEE Transactions Antennas and Propagation*., vol. AP-29, pp. 90-94, Jan. 1981.

12. S. Long, L. C. Shen, D. Schaubert and F. Farrar, "An experimental study of the circular-polarized elliptical printed-circuit antenna", *IEEE Transactions on Antennas and Propagation*, vol. 29, no. 1, pp. 95-99, 1981.

13. H. Iwasaki, "A circularly polarized small-size microstrip antenna with a cross slot", *IEEE Transactions on Antennas and Propagation*, vol. 44, no. 10, pp. 1399-1401, 1996.

14. W. H. Aksun, Z. H. Wang, S. L. Chung, and Y. T. Lo, “On slot-coupled microstrip antennas and their applications CP operation theory and experiment,” *IEEE Trans. Antennas Propagat.,* vol. 38, pp. 1224-1230, Aug. 1990.

15. M. Davidovitz and Y. T. Lo, “Rigorous analysis of a circular patch antenna excited by a microstrip transmission line,” *IEEE Trans. Antennas Propagat.,* vol. 37, pp. 949-958, Aug 1989.

16. H. Iwasaki, H. Sawada, and K. Kawabata, “A circular polarized microstrip antenna using singly-fed proximity coupled feed,” in *Proc. Int. Symp. Antennas Propagat.,* Sapporo, Japan, Sept. 1992, pp. 797-800.