A Broadband CPW-Fed Printed Single-Patch Antenna for Galileo Applications

Constantinos T. Angelis and Spyridon K. Chronopoulos

Department of Informatics and Telecommunications
Technological Educational Institute of Epirus, Arta, Greece
kangelis@teiep.gr, schrono@cc.uoi.gr

Abstract. In this research work a novel and compact broadband U-shaped CPW-Fed single-patch antenna is proposed for Galileo applications. The enhanced performance of the single patch antenna relevant to Galileo signal reception and coverage is presented through simulation and analysis using Microwave Office for the purpose of establishing in depth the benefits of antennas in modern navigation apparatus and applications. The proposed antenna has a center frequency in 1.351 GHz and offers a return loss of better than -10dB from 1.1 to 1.6 GHz. Moreover, satisfactory radiation pattern is obtained through simulation. The proposed patch antenna is suitable for implementing low cost, high stable and well circular polarized Galileo antenna, as demonstrated by numerical simulations.

Keywords: Galileo, Printed antenna, CPW-feeding.

1 Introduction

In recent years, there has been tremendous growth in wireless communication technology, especially for the upcoming Galileo Satellite system. When Galileo will be finally operational, four carrier frequencies in the L band named Galileo E5a (1176.45 MHz), E5b (1207.14 MHz), E6 (1278.75 MHz) and E1 (1575.42 MHz) will be broadcasted. The E1 and E5a are designed with the same center frequency, and similar bandwidths compared to the GPS L1 C/A and L5 signals respectively [1], [2].

The upcoming Galileo system in order to provide more accurate navigation services will require modifications or even improvements on the navigation receiving systems. The previous receiving systems begin with the antenna or its terminal. For obtaining the best possible accuracy in navigation terms, along with the utilization of the fully offered capabilities of this new system, state-of-the-art antenna systems must be designed. Low profile antennas have therefore been a very hot research topic in antenna engineering. Many researchers work in designing antennas for Galileo and/or GPS [3-12] applications. In [3,4], dual-band and in [5] multiband printed antennas are designed for Galileo applications. Wideband antennas are designed in [6-8]. Smart Antennas are designed in [9,10]. Finally printed antennas for Safety-Critical Applications and Search and rescue applications are designed in [11,12].

G. Giambene and C. Sacchi (Eds.): PSATS 2011, LNICST 71, pp. 342–350, 2011.

A Galileo antenna is not selected in general, by choosing an antenna which satisfies all previous performance characteristics. This depends on the aimed application. So, the most suitable Galileo antenna is determined by considering the performance characteristics of the specified application, including its type, the frequency domain, the antenna cost, size and profile and whether single elements or an array of multiple elements are needed for satisfying the previous standards. Also, a passive or active antenna may be selected depending on different application types.

In this paper, a novel and compact broadband U-shaped coplanar waveguide CPW-Fed single-patch antenna is proposed for Galileo applications. The proposed antenna operates in the frequency band from 1176.45 to 1575.42 MHz and if broadband approach is considered, then the total bandwidth becomes 427 MHz centered at 1377.5 MHz, i.e. ≈ 31%. The CPW-fed antenna is intended for various applications due to its low-cost and the radiation losses. It is also light weighted and compatible with integrated circuits. The proposed antenna has the advantage of compact size, which makes it attractive for mobile devices. The broadband antenna design was chosen against the multiband design due to the fact that broadband antennas usually present better radiation pattern symmetry and higher polarization purity [10, 13].

2 Antenna Design

According to the Galileo Joint Undertaking, the Galileo Navigation Signals are located in the four frequency bands (in blue) in Figure 1. The frequency bands are the E5a, E5b, E6 and the L1 band, exhibiting a wide transmission bandwidth of the Galileo Signals.

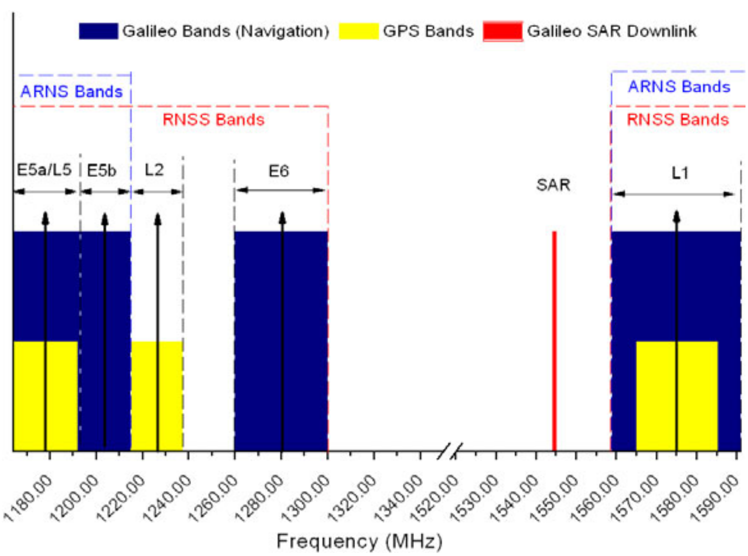


Fig. 1. Galileo frequency spectrum

RNSS (Radio Navigation Satellite Services) affect the selection of frequency bands in the relevant specified spectrum. Moreover, ARNS (Aeronautical Radio Navigation Services) include in their specified spectrum, E5a, E5b and L1 bands, as the previous services are employed by Civil-Aviation users, and allow dedicated safety-critical applications. The lower and upper frequency limits of each band are reported in Figure 1. Galileo carrier frequencies are shown in Table 1, while the Rx reference bandwidths and polarizations are specified in Table 2.

As it has been mentioned by many researchers, the development of an antenna which can operate in all Galileo frequency bands, shown by Fig. 1, and in the same time to fulfill all the design specifications given in Table 3 can prove to be a very difficult task, especially if other constrains like size, weight and cost are also to be taken into account. Another issue that has been faced by many researchers is whether the antenna should be broadband, covering the whole frequency range or multiband covering only the bands of interest separately from each other. Although the second approach seems to be more attractive for the first view due to a potentially better noise and interferer's suppression, it's known from the literature that multiband antennas usually present stronger radiation pattern asymmetry and lower polarization purity [10, 13]. Taking all the above into consideration, in this work we decided to design a broadband antenna to get the most of the performance.

Table 1. Carrier Frequency per Signal

Signal	Carrier Frequency
E5a	1176.450 MHz
E5b	1207.140 MHz
E5 (E5a+E5b)	1191.795 MHz
E6	1278.750 MHz
E1	1575.420 MHz

Table 2. Galileo signals Rx reference bandwidths

Signal	Rx Reference Bandwidth	Polarization
E5	51.150 MHz	RHCP
E6	40.920 MHz	RHCP
E1	24.552 MHz	RHCP

Table 3. Antenna specifications

Parameter	Specifications
Bandwidth	1164 MHz to 1591 MHz (31%)
Return loss	-10 dB min
Polarization	RHCP
Azimuth scanning	360°
Elevation scanning	from 30° to 90° (from 0° to 30° desired)
Gain	10 dBi min. over all scan angles (30° to 90° elevation)
Axial ratio	3 dB min. over all scan angles (30° to 90° elevation)
Cross-polarization	15 dB minimum, 25 dB or better is desirable

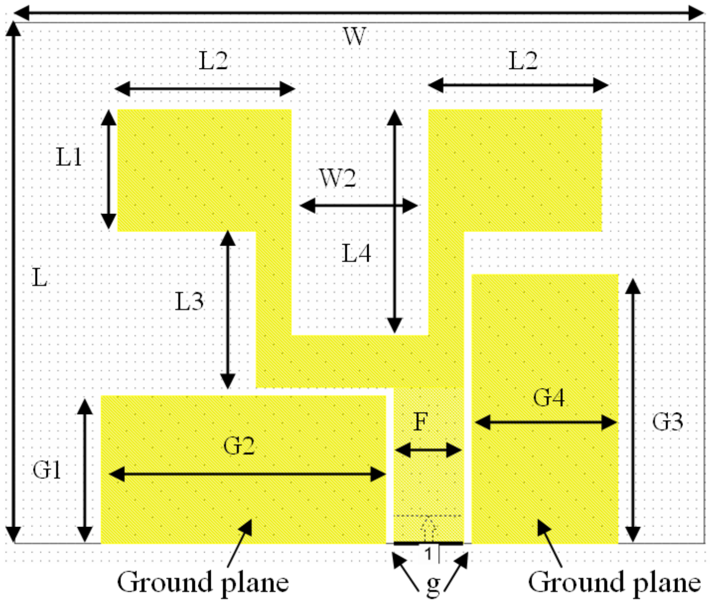


Fig. 2. Two dimensional structure of the proposed antenna

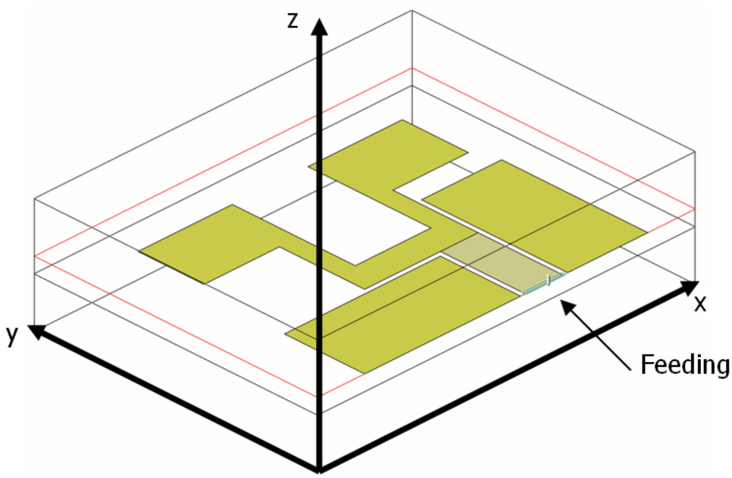


Fig. 3. Three dimensional structure of the proposed antenna

The proposed antenna is etched on a substrate of thickness 1.52 mm and dielectric constant of 3.38. The substrate has a compact dimension of 30 x 40mm^2. Fig. 2 shows the structure of the proposed antenna. The antenna consists of a single layer, which is the radiating layer as the ground plane of the antenna is located on the same side of the CPW-feed and radiating portion. The antenna is simulated using the parameters given in Table 4. The complete structure is presented in Fig. 3 where it is possible to observe the patch of the antenna and its feeding plate.

Table 4. Parameters of the proposed antenna

Parameter	Value	Parameter	Value
W	40mm	L4	14mm
L	30mm	W1	8mm
F	4mm	W2	2.5mm
g	0.5mm	G1	8.5mm
L1	7mm	G2	16.5mm
L2	10mm	G3	15.5mm
L3	9mm	G4	8.5mm

3 Results and Discussion

The reflection coefficient of the antenna was simulated using the AWR Microwave Office software. Using a VSWR≤2 (return loss ≤-9.5 dB) as benchmark, the measured result shows that the antenna covers from 1.160 GHz to 1.595 GHz frequency range; thus the impedance bandwidth is more than 30%. The frequency band that is covered by this antenna is suitable for Galileo as well as GPS bands. Full wave simulations for the antenna including its feeding system were performed showing good results. The reflection coefficient remains under 10 dB for the complete specified frequency range, as shown by Fig. 4.

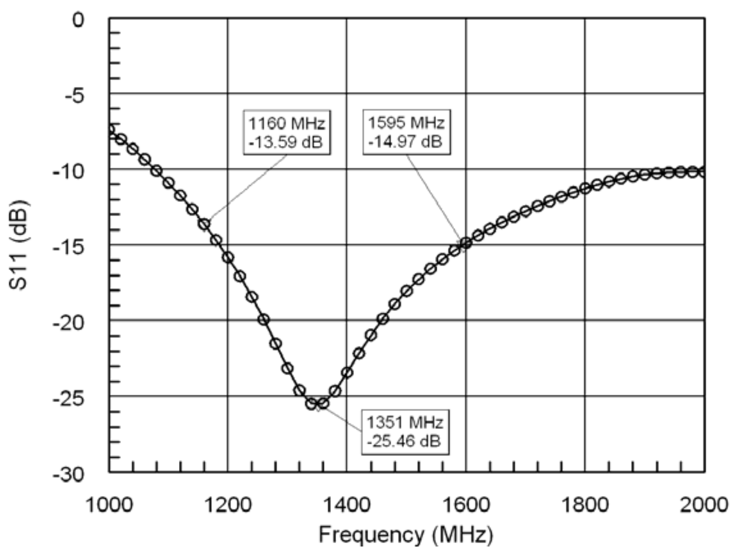


Fig. 4. Simulated reflection coefficient versus frequency

Figure 5 shows full 360 degree conic cuts at an elevation angle of 45 degrees. Both right-hand (RHCP) and left-hand (LHCP) circular polarizations are shown (a) for the E5a/b band, (b) for the E6 band and (c) for the L1 band.

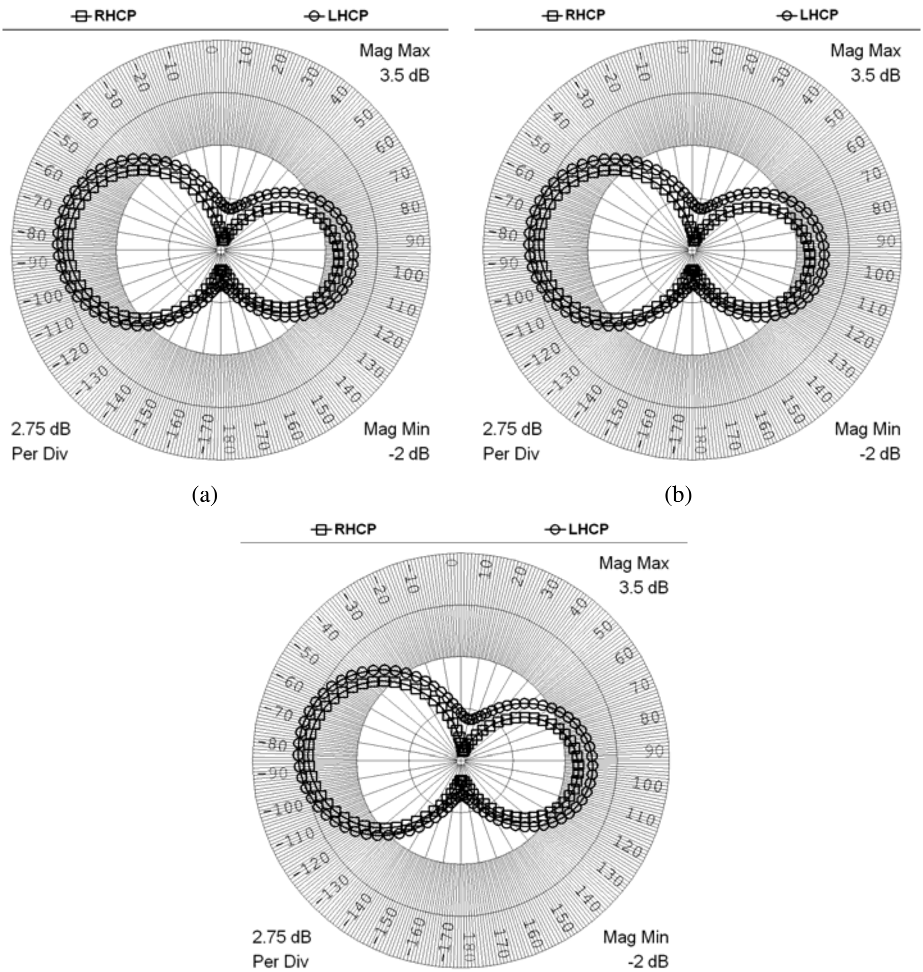
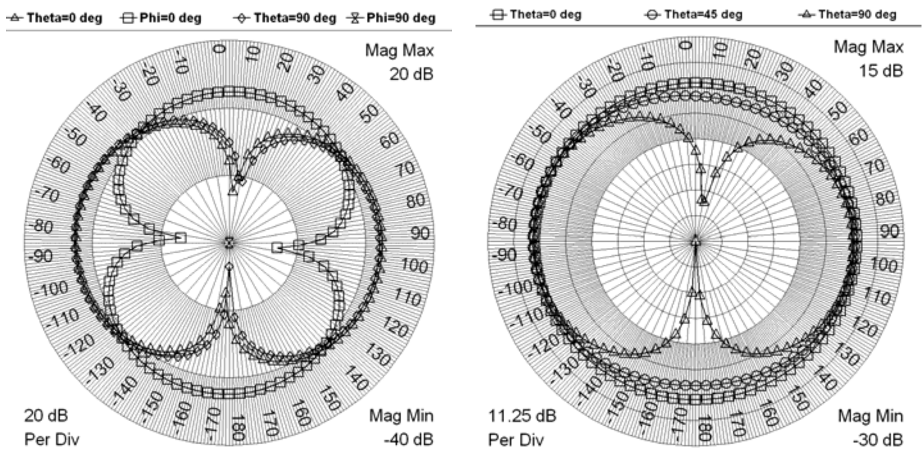


Fig. 5. RHCP and LHCP polarizations at an elevation angle of 45 degrees **(a)** for the E5a/b band, **(b)** for the E6 band and **(c)** for the L1 band

Figure 6 (a) shows Conic Cuts polarized along E_θ and E_φ at the center frequency of the complete Galileo band, $f_c = 1.380\,\text{GHz}$. The Theta (θ) and Phi (φ) components of the E-field are plotted.

Figure 6(b) shows Conic Cuts which capture the total power in all directions for fixed values of Frequency and Theta (θ) at the center frequency of the complete Galileo band, $f_c = 1.380\,\text{GHz}$. The total power is defined as the sum of the power contained in E_θ and E_φ.



(a) (b)

Fig. 6. (a) Conic Cuts polarized along E_θ and E_φ for the complete Galileo band. **(b)** Conic Cuts of the total power in all directions for the complete Galileo band.

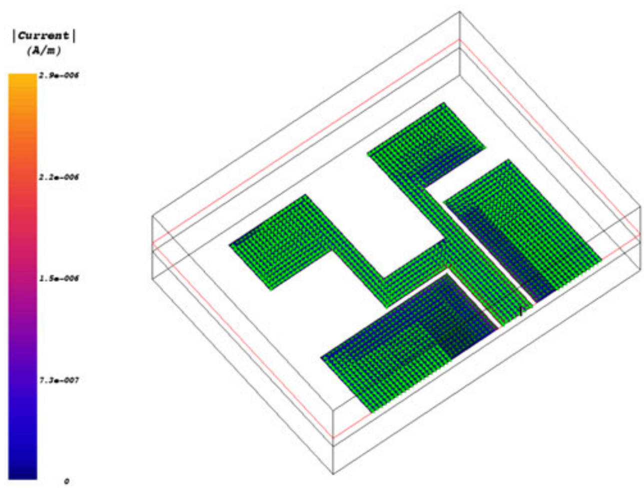


Fig. 7. Animation snapshot of the electric current in all directions for the complete Galileo band

Figures 7 and 8 display representations of the electric current and of the electric field respectively occurring on the specified 3D view of the proposed antenna. The current and the electric field are overlaid with the structure drawn in wire frame mode.

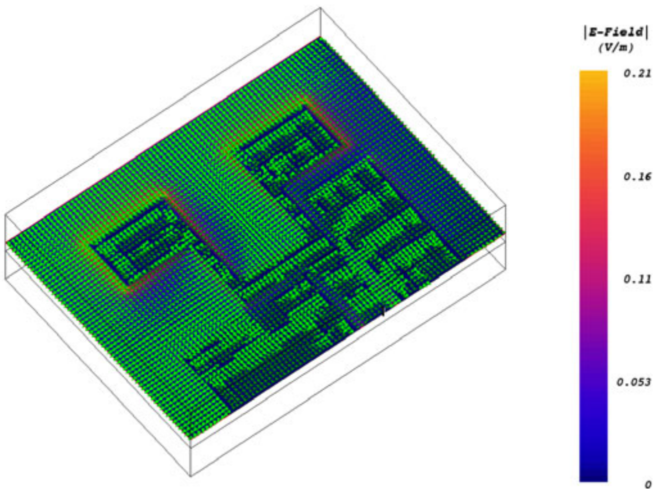


Fig. 8. Animation snapshot of the electric field in all directions for the complete Galileo band

4 Conclusion

In this paper, a compact U-shaped CPW-fed printed antenna is proposed for the Galileo bands. The proposed antenna has been successfully simulated in a small area of 30 x 40 mm^2. Acceptable return loss and satisfactory radiation patterns are obtained through simulation. Further investigations are undergoing. The next step is to finish the antenna construction and to measure it and afterwards to design an antenna array with the proposed antenna as the basic element.

References

1. European Space Agency/Galileo Joint Undertaking, Galileo Open Service Signal in Space Interface Control Document (OS SIS ICD) (1) (May 23, 2006)
2. GPS Joint Program Office, Navstar GPS Space Segment / Navigation User Interfaces, IS-GPS-200D, Revision D (December 7, 2004)
3. Ramírez, M., Parrón, J.: Design, Fabrication and measurement of a dual-band circularly-polarized stacked microstrip antenna for Galileo and GPS. In: Proceedings of the Fourth European Conference on Antennas and Propagation (EuCAP) (April 12-16, 2010)
4. Hebib, S., Aubert, H., Pascal, O., Fonseca, N., Ries, L., Lopez, J.M.: Pyramidal multi-band antennas for GPS/Galileo/MicroSat application. In: 2007 IEEE Antennas and Propagation International Symposium. United States, Honolulu (2007)
5. Ur Rehman, M., Gao, Y., Chen, X., Parini, C.: Dual-element Diversity Antenna for Galileo/GPS Receivers. In: 13th IAIN World Congress and Exhibition, Stockholm (October 27-30, 2009).
6. Robin, G., Peter, R., Steve, S.: The Development of a Professional Antenna for Galileo, Roke Manor Research Limited (2009-2010)

7. Sohyeun, Y., Dongpil, C., Inbok, Y.: Wideband Receive Antennas of Sensor Stations for GPS/Galileo Satellite. In: 4th Advanced Satellite Mobile Systems, ASMS 2008 (August 26-28, 2008)
8. Rens, B., Marta, M.-V., Jens, L., Sybille, H., Luca, S.D., de Peter, M.: Low Profile GALILEO Antenna Using EBG Technology. IEEE Transactions on Antennas and Propagation 56(3), 667 (2008)
9. Neves, E.S., Vita, P.D., Dreher, A.: Smart Antenna Array for GPS and Galileo Applications. In: 2nd ESA Workshop on Satellite Navigation User Equipment Technologies, Noordwijk, The Netherlands (December 2004)
10. Neves, E.S., Dreher, A.: An antenna array for the Galileo system with beamforming capabilities. Deutscher Luft- und Raumfahrtkongress (DLR), Germany (2006)
11. Cuntz, M., Konovaltsev, A., Hornbostel, A., Schittler Neves, E., Dreher, A.: GALANT – Galileo Antenna and Receiver Demonstrator for Safety-Critical Applications. In: Proceedings of the 10th European Conference on Wireless Technology, Munich Germany, p. 59 (October 2007)
12. Montero Jose, M., Esteban, C., Ana, T.: Search and rescue antenna for Galileo constellation. In: Antennas and Propagation Society International Symposium (APSURSI), Torondo, pp. 1–4 (2010)
13. Wong, K., Chiou, T.: Broad-band single-patch circularly polarized microstrip. IEEE Trans. Antennas Propagat 49, 41–44 (2001)