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An elliptical patch antenna design for real time location systems

Keyur K. Mistry [(1)], Pavlos I. Lazaridis* [(2)], Zaharias D. Zaharis [(3)], Vladimir Poulkov [(4)], Qasim Ahmed [(2)], Faheem Khan [(2)], Maryam Hafeez [(2)] and Ioannis P. Chochliouros[(5)]
(1) Oxford Space Systems, Harwell, OX11 0RL, UK, keyur.mistry@oxford.space
(2) University of Huddersfield, Huddersfield, HD1 3DH, UK.
(3) Aristotle University of Thessaloniki, Thessaloniki, 54124, Greece.
(4) Technical University of Sofia, 1756 Sofia, Bulgaria.
(5) Hellenic Telecommunications Organization S.A., Maroussi, 15122, Greece.

Abstract

Ultra-wideband (UWB) technology is being extensively used for indoor localization problems because of its ability to provide high accuracy, high data rate and low transceiver power for short range communications. There are several integrated circuits developed to apply this technology. However, the range for localization provided by these modules has always been a concern. Therefore, utilizing an efficient antenna design for such modules is significant, as it can increase the range of the localization supported by the modules. This paper presents a cost-efficient antenna design that can be used by UWB systems for localization problems. The antenna is designed to operate in the frequency range 3.7-4.2 GHz to support the communication link used by the TREK100 UWB localization module. The proposed antenna achieves reasonably high realized gain of 5-7 dBi in the desired frequency band, thereby extending the range of the localization system from 75 meters to 250 meters.

1 Introduction

Over the last decade, researchers have shown great interest in Real-Time Location Systems (RTLS). This is because RTLS is a promising candidate to provide tracking and monitoring services for indoor areas, while Global Navigation Satellite Systems (GNSS) including Galileo [1], Global Positioning System (GPS) [2] and Global Orbiting Navigation Satellite System (GLONASS) [3] are not considered to be a feasible solution. Several research organizations present a wide range of solutions for localization, using different technologies like infrared, bluetooth, radio-frequency identification (RFID), ultra-wideband (UWB), wireless local area network (WLAN) and magnetic positioning. However, UWB technology is now extensively used and serves as a promising candidate for localization problems, because of its advantages over other technologies. UWB utilizes a very low energy level for short-range communications and provides high-bandwidth communication over a large portion of the radio spectrum, thereby providing higher data rates. Due to the increased bandwidth, UWB systems have the ability to achieve higher data rates even for low signal-to-noise ratios (SNRs), in noisy environments. Since the transmitted power in UWB systems is low, the battery life of UWB systems is also longer compared to other existing systems. Another advantage of utilizing UWB systems for localization problems is their ability to provide high localization precision of centimeter-level. Consequently, UWB systems, being resistant to multipath signal propagation and not interfering with other radio communication systems, are a viable candidate and an efficient solution to several localization problems [4].

Several companies provide solutions for the indoor localization problem using UWB RTLS. One of these systems is the TREK1000 module developed by Decawave [5]. This module uses a DW1000 integrated circuit (IC), which can be configured as an anchor or tag. The configuration of this IC as anchor/tag depends upon the topologies that are used, according to the application. In this paper, a topology for tracking is selected, where three of the DW1000 ICs are configured as anchors and one of the DW1000 ICs is configured as a tag. Using this topology, the user is able to track the tag within the area covered by the three anchors. The 2D or 3D location of the tag relative to each fixed anchor is determined by using this UWB module. However, the module using the antenna, initially provided by the company, covers a maximum range of 75 meters for indoor localization. The localization range can be increased either by replacing the DW1000 IC or by replacing the existing antenna with another that provides a higher forward gain. Since, the use of a new antenna constitutes an easier and more cost-efficient way to increase the localization range, this paper proposes an elliptical microstrip patch antenna that can extend the localization range of the module from 75 meters to 250 meters. .

2 Proposed antenna design

The TREK1000 module communicates in a 500 MHz bandwidth frequency range, i.e., from 3.7 GHz to 4.2 GHz, in its lower frequency band. While the stock antenna is an omnidirectional antenna with a low gain of around 1-2 dBi, the proposed antenna is designed as a directional antenna so that better forward gain can be achieved to increase the localization range. The microstrip patch antenna presented in this paper, consists of an elliptical patch [6] embedded on the top layer of a dielectric substrate. The schematic diagram of the antenna is shown in Fig. 1. The bottom layer of the substrate consists of a ground plane. The patch is located at the center of the top layer and is fed at the edge of the substrate using a matching line. Overall, the antenna consists of four parts: the elliptical conducting patch, the matching line, the dielectric substrate, and the conducting ground plane. The operating frequency of the antenna is controlled by properly adjusting the lengths of the major axis and the minor axis of the elliptical patch. These lengths are inversely proportional to the resonant frequency of the antenna. The ratio of major-to-minor axis lengths determines the axial ratio of the antenna. The bandwidth of the antenna is directly proportional to the substrate height and inversely proportional to the relative permittivity of the substrate. The matching line can be tuned to achieve good antenna matching.

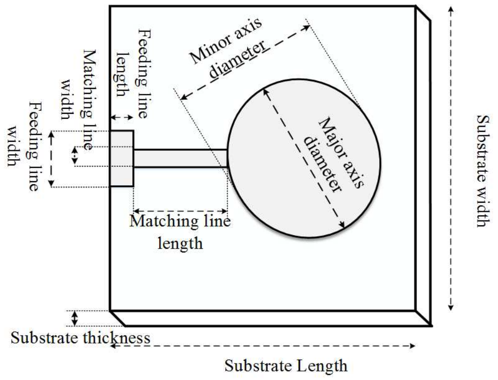
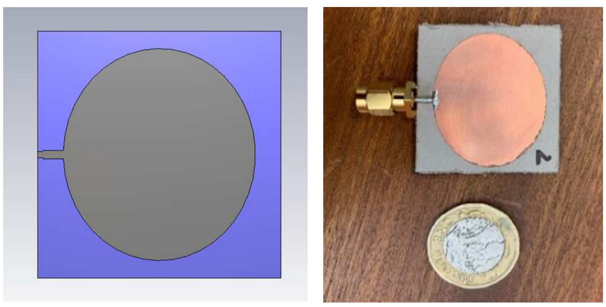


Figure 1. Schematic layout of the proposed antenna.

The dielectric substrate is 2.6mm in thickness with a relative permittivity of around 2. The thickness and relative permittivity of the substrate help the antenna to achieve the required bandwidth. The proposed antenna was designed in electromagnetic simulation software CST Studio Suite. The antenna fabrication used Rogers 5880 LZ laminate substrate provided by Rogers Corporation. The overall dimensions of the antenna are: 38.7mm × 35.2 mm × 2.6 mm. The feeding of the antenna is performed by an SMA connector [8]. Fig. 2(a) displays the antenna model designed in CST, and Fig. 2(b) shows the fabricated antenna.



(a) (b)

Figure 2. (a) Antenna model in CST and (b) the fabricated antenna.

3 Results

The simulation of the antenna design was performed in CST using the frequency domain finite element method with 52948 second order tetrahedral elements. Fig. 3 presents the S11 of the proposed antenna. The antenna presents relatively good but narrowband matching. There is a shift of 150 MHz of the resonant frequency in the simulation towards the lower frequencies.

The realized gain of the antenna is shown in Fig. 4. The antenna achieves reasonably high gain, which is above 6 dBi in the major part of the required frequency range and has a peak value of around 7 dBi at 4.15 GHz. It is noted that higher gain values allow the localization module to increase its range for collecting data.

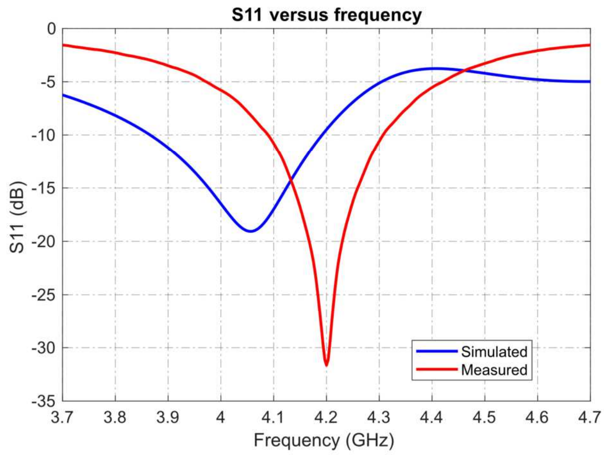


Figure 3. Simulated and measured S11 of the proposed antenna.

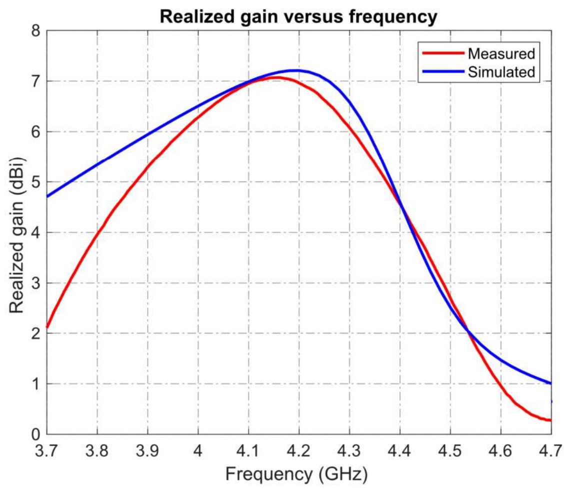


Figure 4. Simulated and measured realized gain of the proposed antenna.

4 Conclusion

A cost-efficient antenna design is proposed in this paper to increase the localization range of a UWB system. The antenna presents relatively good matching in the frequency band of 3.7 GHz to 4.2 GHz, allowing thus to establish a good communication link between the nodes of the UWB system. Additionally, the antenna achieves reasonable high gain of 6-7 dBi, thereby increasing the localization range of the UWB system from 75 meters with the stock omnidirectional antenna to 250 meters with the proposed directional antenna.

7 Acknowledgements

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8 References

1. GALILEO Programme, The Galileo Project—GALILEO Design Consolidation, European Commission, UK, 2003.

2. Department of Defense United States of America and GPS Navstar, Global Positioning System Standard Positioning Service Performance Standards, 4th edition, 2008.

3. Russian Institute of Space Device Engineering, Global Navigation Satellite System GLONASS-Interface Control Document, Version 5.1, Moscow, Russia, 2008.

4. R. S. Kshetrimayum, "An introduction to UWB communication systems," *IEEE Potentials*, vol. 28, no. 2, pp. 9-13, Mar.-Apr. 2009.

5. "TREK1000 Evaluation Kit - Decawave", *Decawave*, 2019. [Online]. Available: https://www.decawave.com/product/trek1000-evaluation-kit/. [Accessed: 09- Jan- 2019].

6. K. K. Mistry *et al*., "A Design of Elliptical Edge-Fed Circularly Polarized Patch Antenna for GPS and Iridium Applications," *2018 2nd URSI Atlantic Radio Science Meeting (AT-RASC)*, Meloneras, 2018, pp. 1-4.

7. K. K. Mistry, P. I. Lazaridis, Z. D. Zaharis, et. al., "Time and Frequency Domain Simulation, Measurement and Optimization of Log-Periodic Antennas," *Wireless Personal Communications*, vol. 107, no. 2, pp. 771–783, Apr. 2019.

8. E. N. Tziris, P. I. Lazaridis, Z. D. Zaharis, J. P. Cosmas, K. K. Mistry, and I. A. Glover, "Optimized Planar Elliptical Dipole Antenna for UWB EMC Applications," *IEEE Transactions on Electromagnetic Compatibility*, vol. 61, no. 4, pp. 1377–1384, Aug. 2019.