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3D-Printed Tunable UHF RFID PIFA Realized with $BaTiO_3$ Enhanced PLA for Multipurpose Applications

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Abstract

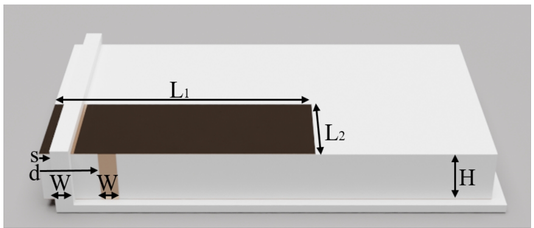
In this work, a new and unconventional design for a UHF RFID PIFA antenna has been studied and realized. 3D-printing by Fused Deposition Modelling (FDM), combined with the use of lab-made PLA filament doped with $BaTiO_3$, enabled the realization of the proposed design. This last consists in two elements sliding one on the other, so enabling the tuning of the resonance frequency as well as the impedance of the antenna.

1 Introduction

In the last few years, the use of FDM 3D-printing has been strongly investigated in many field of applications. In electromagnetism, 3D-printing has been studied as a cost-effective and easy to use method to produce devices with an unconventional form factor. In this regard, studies dealing with the electromagnetic characterization of 3D-printable materials [1, 3], as well as research activities dealing with the realization of novel 3D-printed antennas and radiofrequency circuits have been launched [4, 6]. At this regard, in [3] a dielectric characterization of a commercial PLA filament has been performed by some of the authors. On the other hand, a wider-range overview on the use of 3D-printing in EM applications has been proposed in [7], . Generally, the electrical permittivity of common 3D-printed materials is lower than 2.5. This features can be a drawback in application where either "platform-tolerability" or device compactness is required. To overcome this limit a particular built-in-lab filament, realized by adding $BaTiO_3$ powder to a PLA matrix with aim to improve the low PLA dielectric constant is used to realize the structure of the proposed device. This last, is a compact and platform-tolerant "tunale" UHF RFID PIFA tag antenna characterized by a particular design that enables the antenna to be manually configured. In particular, a portion on the antenna can be moved in order to change either the tag working frequency (ETSI or FCC) or the tag response, depending on the material on which the tag is attached to. The paper is organized as follows. In Section 2 the design of the antenna is described as well as the realization procedure. In Section 3 the results are shown and briefly commented. Finally, in Section 4, conclusions have been pointed out.

2 Design description and prototype realization

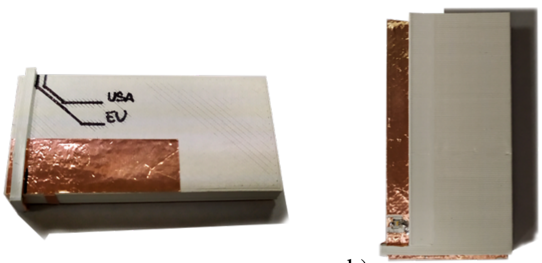
In this work, a particular type of PIFA layout is proposed, as can be seen in Figure 1, where the main dimensions of the antenna are also listed. The device is composed of 2 elements: the body, where the radiating element as well as the feeding line and the background plane are placed, and the ring, which wraps around the body and has copper attached on its inner side. The body can float inside the ring, while the copper on the ring acts as shorting wall for the PIFA. This movement allows to vary the distance between the shorting wall and the feeding line of the antenna, thus enabling a tuning procedure that can adapt the antenna parameters to the ones that better suits the needs of the specific application. It is worth highlighting that a similar layout is enabled by the 3D printing technology. As previously stated, a particular built-in-lab filament composed by PLA doped with 17,5% volume fraction of $BaTiO_3$ has been used for the prototype realization. The filament has been produced mixing and extruding at the same time the Ingeo 4043D PLA pellet with a $BaTiO_3$ -325 mesh powder pure at 99%, through a twin-screw extruder. The doping percentage has been selected to have a good compromise between dielectric constant increment and ease of printing. Indeed, as the amount of $BaTiO_3$ increases, the brittleness increases, and the ease of flow of the material is reduced. This mix guarantees a dielectric constant of 4,8 at



Design Parameters [mm]			
L_1	30.5	s	1.2/3.2
L_2	10.5	d	6.5
W	2	H	6

Figure 1. Rendered model of the realized antenna with the main parameters dimensions listed below.

around 900 MHz and a loss tangent of 0.015 for the substrate of the antenna, helping to reduce antenna size if compared with a standard PLA substrate, as well as making the device more platform-tolerant. A proper simulation campaign performed into CST Microwave Studio Suite, aimed at optimizing the parameters of the antenna to match the impedance of the Impinj Monza R6 chip, has been carried out. The prototype has then been printed with a commercial Creality CR-20 Pro printer. Eventually, the metallic parts have been realized with adhesive copper tape properly shaped through the use of a cutting plotter. In Figure 2 some images of the realized prototype are shown.



a) b)

Figure 2. Top (a) and bottom (b) view of the realized prototype.

3 Results

The realized prototype has been tested and characterized using the system described in [8]. This system allows to determine radiation patterns, maximum reading distance and sensitivity of a tag, which is one of the most important metric to evaluate its performance as described in [9, 10]. In order to validate the capability of the realized antenna to be tuned to different operative conditions, the sensitivity and the maximum reading distance have been measured for two different antenna configurations characterized by the *s* parameter respectively equal to 1.2 and 3.2 *mm*. The former is optimized to make the antenna work in the EU band (865-867 MHz) while the latter is optimized to make it work in the USA band (902-927 MHz) for UHF RFID applications. In Figure 3 the simulation results of the S_{11} curves of both the configurations are shown, while Figure 4, represents the measured sensitivity and related maximum reading distance. Finally, in Figures 5 and 6 the radiation patterns both for E-Plane and H-Plane are reported. The good agreement between simulated and measured results, prove the effectiveness of the proposed design.

4 Conclusions

In this paper, a simple design to realize a tunable UHF RFID antenna has been presented. The use of 3D-printing technology to enable the realization of the substrate for the antenna, characterized by an unconventional shape, has been exploited. Moreover, the use of a built-in-lab printable

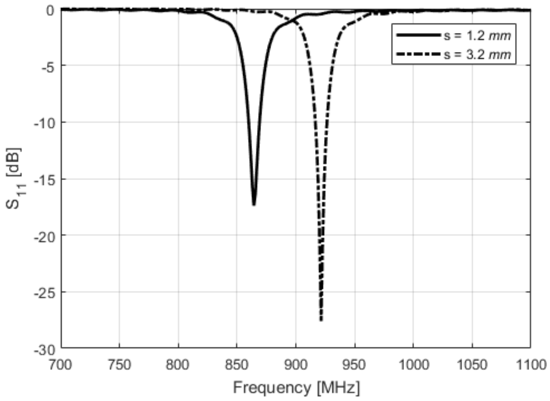
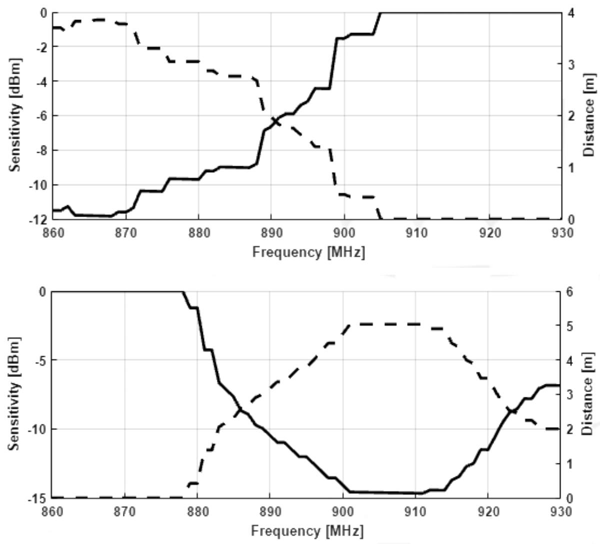


Figure 3. S_{11} curves for two working configurations.



a)

b)

Figure 4. Sensitivity (continuous) and maximum reading distance (dotted) measured for the EU Band (a) and for the USA Band (b).

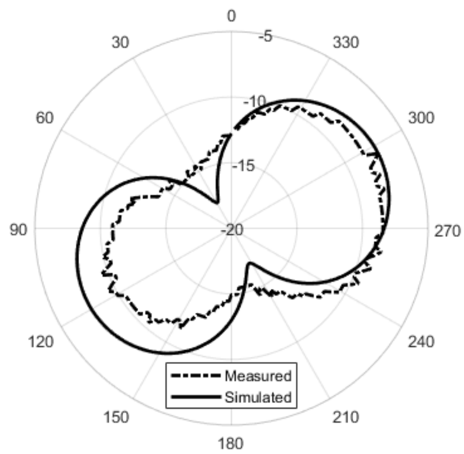


Figure 5. Gain radiation patterns both for simulated and measured E-Plane.

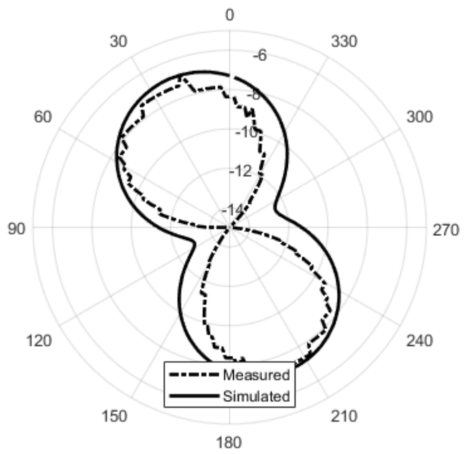


Figure 6. Gain radiation patterns both for simulated and measured H-Plane.

filament, doped with ceramic powders to enhance its dielectric properties, allowed to realize a small and platform-tolerant antenna, for multipurpose application. The tuning capability of the proposed design, allowed to easily modify the working bandwidth of the antenna, moving it from the EU Band to the USA Band of the EPC Global Gen 2 Class 1 Standard. Nevertheless, the same principle could be used to easily adapt the realized antenna to find the better working conditions when, for example, the device needs to be mounted onto different types of material. The interested reader will find more cases of study in further publications on the matter.

References

[1] Castles, Flynn, et al. "Microwave dielectric characterisation of 3D-printed BaTiO 3/ABS polymer composites." *Scientific reports*, vol. 6 2016.

[2] Huber, E., Mirzaee, M., Bjorgaard, J., et al.: 'Dielectric property measurement of PLA'.*2016 IEEE Int. Conf. Electro Information Technology (EIT)*, Grand Forks, ND, 2016, pp. 0788–0792

[3] L. Catarinucci, R. Colella, P. Coppola and L. Tarricone, "Microwave characterisation of polylactic acid for 3D-printed dielectrically controlled substrates," in *IET Microwaves, Antennas Propagation*, vol. 11, no. 14, pp. 1970-1976, 19 11 2017

[4] S. S. Patel, I. J. G. Zuazola, and W. G. Whittow, "Antenna with three dimensional 3D printed substrates,"*Microw. Opt. Technol. Lett.*, vol. 58, no. 4, pp. 741–744, 2016.

[5] M. Mirzaee and S. Noghanian, "Additive manufacturing of a compact 3D dipole antenna using ABS thermoplastic and high temperature carbon paste,"*2016 IEEE International Symposium on Antennas and Propagation (APSURSI)*, Fajardo, 2016, pp. 475-476.

[6] S. Moscato, R. Bahr, T.R. Le, M. Pasian, M. Bozzi, L. Perregrini, and M.M. Tentzeris, "Infill-Dependent 3-D-Printed Material Based on Ninjaflex Filament for Antenna Applications",*IEEE Antennas Wirel. Propag. Lett.*, 2016, 15, pp. 1506-1509.

[7] R. Colella, F. P. Chietera, F. Montagna, A. Greco and L. Catarinucci, "On the Use of Additive Manufacturing 3D-Printing Technology in RFID Antenna Design," *2019 IEEE International Conference on RFID Technology and Applications (RFID-TA)*, Pisa, Italy, 2019, pp. 433-438.

[8] R. Colella, F. P. Chietera and L. Catarinucci, "Electromagnetic Performance Evaluation of UHF RFID Tags With Power Discretization Error Cancellation," in *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 5, pp. 3545-3549, May 2019.

[9] L. Sydanheimo, J. Nummela, L. Ukkonen, J. McVay, A. Hoorfar, M. Kivikoski, "Characterization of passive UHF RFID tag performance", *IEEE Antennas Propag. Mag.*, vol. 50, no. 3, pp. 207-212, Jun. 2008.

[10] P. Nikitin, K. V. S. Rao, S. Lam, "UHF RFID tag characterization: Overview and state-of-the-art", *Proc. Antenna Meas. Techn. Assoc. Symp.*, pp. 1-6, Oct. 2012.