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Design of a 3-D Printed Rectenna on Engineered Polylactic Acid for quasi-UWB Localization and SWIPT Applications

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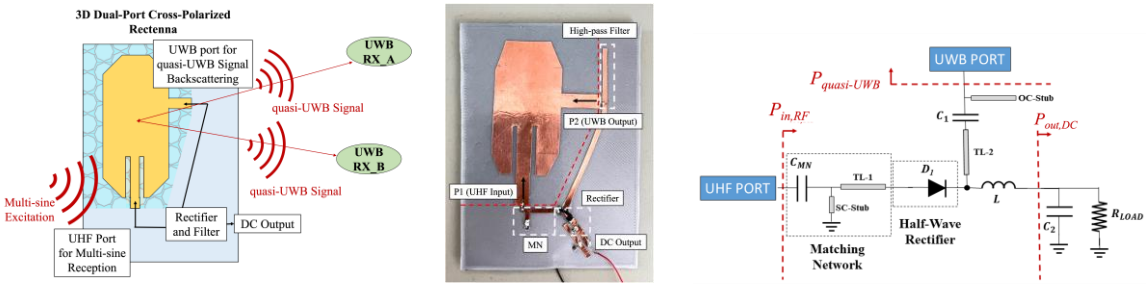
This work presents a dual-mode rectenna system entirely manufactured using 3-D printing techniques on an engineered polylactic acid (PLA) substrate. By leveraging the almost unlimited degrees of freedom offered by 3-D printing techniques, the proposed system demonstrates that it is possible to use widely available, low-cost materials and a fast fabrication process to realize efficient radio-frequency (RF) prototypes. As a proof of concept, the one here described combines ultra-high frequency (UHF) and quasi-ultra-wideband (q-UWB) functionalities, allowing for energy harvesting (EH) and passive backscattering for localization, as well as supporting simultaneous wireless information and power transfer (SWIPT) applications [1].

The antenna features a dual-port design with excitation ports having orthogonal polarization. One port (P1 in Fig. 1(b)) receives a multi-tone signal composed of eight equally spaced, non-synchronized tones in the 2.4 GHz UHF band. Due to the nonlinear behavior of the rectifier's Schottky diode, intermodulation (IM) products are generated, leading to the passive generation of a q-UWB pulse, which is backscattered via the other port (P2 in Fig. 1(b)). This innovative approach takes advantage of energy-efficient wireless power transfer (WPT) while enabling high-accuracy localization without requiring an active UWB signal excitation [2].

The rectenna is based on a customized dual-port planar radiative element and a nonlinear rectifier circuit optimized for SWIPT (Fig. 1). The antenna substrate is designed using a multi-layer PLA structure incorporating an engineered octagonal honeycomb core, enhancing mechanical robustness while optimizing electromagnetic properties such as radiation efficiency and propagation performance within the lossy dielectric. The rectifier circuit is specifically designed to maximize the RF-to-DC conversion efficiency while minimizing the near-carrier spectral lines and increasing the power at higher-order intermodulation harmonics. With an input RF power of –15 dBm, evenly distributed across the eight tones, the system achieves a DC power output of 1.58 µW and generates a backscattered q-UWB pulse with a peak power of approximately 80 nW. The system has been experimentally validated in an indoor environment, demonstrating its effectiveness for both EH and localization. This project highlights the potential of additive manufacturing for the development of low-cost, fully customizable rectenna systems with advanced multifunctional capabilities. By integrating EH and passive UWB backscattering into a single, compact device, the proposed approach opens new possibilities for innovative applications in WPT, smart sensing, and localization systems.



(a) (b) (c)

Figure 1. (a) Schematic layout of the proposed system; (b) photograph of the fabricated rectenna; (c) circuit schematic of the SWIPT tag. © 2023 IEEE

1. G. Battistini, G. Paolini, A. Costanzo, and D. Masotti, "A Novel 3-D Printed Dual-Port Rectenna for Simultaneous Energy Harvesting and Backscattering of a Passively Generated UWB Pulse," *IEEE Transactions on Microwave Theory and Techniques*, **72**, 1, January 2024, pp. 812-821.
2. N. Decarli, M. Del Prete, D. Masotti, D. Dardari, and A. Costanzo, "High-Accuracy Localization of Passive Tags With Multisine Excitations," *IEEE Transactions on Microwave Theory and Techniques*, **66**, 12, December 2018, pp. 5894-5908.