Latest News on RFID Systems Guest Editorial of the Special Issue on SpliTech 2022 and IEEE RFID-TA 2022 Conferences

THE IEEE JOURNAL OF RADIO FREQUENCY IDENTIFICATION (JRFID) has the pleasure to host a joint Special Issue collecting extended versions of papers coming from two international conferences held in 2022. The first is the *IEEE International Conference on RFID-Technology and Applications (RFID-TA)*, held in Cagliari, Italy, on September 12-14, 2022. The second is the *International Symposium on Advances in RFID Technology and Electromagnetics for IoT* organized within the *International Conference on Smart and Sustainable Technologies* (*SpliTech*), hosted in Split and Bol, Croatia, on July 5-8, 2022. SpliTech was technically co-sponsored by the IEEE Council on RFID (CRFID).

Authors from academia and industry attending above conferences have common interests in sharing the recent advancements in the area of RFID from multidisciplinary points of view. Both conferences were held during the pandemic period, so they had an even more important role to "remotely" connect researchers and scientists coming from all around the world.

The 12^{th} edition of the *IEEE RFID-TA Conference* had a hybrid format, by hosting more than sixty oral speeches organized in twelve technical sessions and two workshops. Advanced antenna solutions, novel backscattered-based systems, chipless tags, RFID systems for healthcare, wireless power transfer, and localization are some of dealt topics. A special industry session "The RFID Industry meets Academia", brought together international leading industrial stakeholders, including tag, IC and reader manufacturers, system integrators, solution developers, early adopters and end-users. The event focused on open challenges and unmatched needs in industrial settings aiming to inspire the research audience and steer future scientific trends towards real-world unsolved issues. Three outstanding keynote speakers were hosted. Camilla Coletti presented a talk titled "Graphene integrated photonics for next-generation datacom and telecoms", discussing challenges of scalable graphene integration, a recent demonstration of photonic building blocks, and opportunities presented by such technological advances. Fabiana Arduini held a talk titled "Design of novel paper-based devices for smart analysis", where she reported new challenges faced by her working team in exploiting the features of paper to design smart biosensors able to treat the sample, to contain any reagent needed for measurements, to on-site synthesize nanomaterials, and to make measurements delivering novel paper-based devices. Finally, Joshua R. Smith exposed a presentation on "Backscatter communication without a carrier" by describing a new method for passive wireless communication that does not rely on an RF source. Competitions for the *Best Paper Award* and the *Best Student Paper Award* were also organized. The work by Ashkan Azarfar et al. titled "Respiration Monitoring using Doppler-Modulated Depolarizing Chipless Tags" received the *Best Paper Award*. While the paper titled "Flexible epidermal device for the RFID-based potentiometric sensing of skin parameters" authored by Francesca Nanni et al. received the *Best Student Paper Award*.

Also, the *International Symposium on Advances in RFID Technology and Electromagnetics for IoT* was held in a hybrid format and comprised six technical sessions, two keynote speakers, and a plenary speaker. The primary topics included small antennas and RF sensors for IoT applications, the fusion of RFID with other technologies, the role of RFID as a key technology for society and industry, RFID and electromagnetic devices that leverage artificial intelligence (AI), new ideas from young researchers in RFID, and RFID sensing. In total, 34 oral presentations were delivered by international authors.

The Symposium featured two keynote speeches, one from Prof. Alice Buffi titled "RFID Vehicles: a Pervasive Solution for Item Tracking and Beyond", and another from Prof. Cecilia Occhiuzzi titled "RFID in the Industrial IoT era: Data-Driven Approaches for Monitoring Plants and Goods". Additionally, the plenary speech delivered by Prof. Manos Tentzeris on "Zero-Power RFID-enabled Wireless Ultrabroadband Modules for IoT", was well-received and formed a key part of the entire *Splitech Conference*.

Ten papers from both conferences have been extended and published in this Special Issue [A1], [A2], [A3], [A4], [A5], [A6], [A7], [A8], [A9], [A10], coming from Finland, France, Germany, Greece, and Italy. Among the main topics emerge antenna design, backscatter communication, sensing, localization systems, and novel implementations.

Summary of Special Issue Works: In the framework of novel antenna design [A1], [A2] and new backscatter communication systems [A3], [A4] several solutions appear.

In [A1], a compact harmonic tag was introduced, consisting of three metal layers, and manufactured on organic substrates to reduce its environmental impact and improve integrability in parcels and packages of interest. The tag reaches a readout distance of 6 m with a transmitter power

Digital Object Identifier 10.1109/JRFID.2023.3290848

of 25 dBm EIRP, which remains unchanged when metal or water objects are placed in proximity with the tag, by proving a satisfying robustness. In [A2], the effect of randomness in the context of a high density of RFID tags was discussed. The tag antenna was replaced by a half-wave dipole having similar behavior, to obtain a low-cost model. Therefore, RFID tags were modelled by a set of half-wave dipoles, with and without T-match, and the reader was replaced by a plane wave. The RFID forward link was investigated statistically, and a non-negligible influence of the coupling on the received power at the chip level was observed in this preliminary study. This technique allows the quantification of the percentage of tags that are not powered up in a given scenario and may help the RFID designer to assess performance of the RFID link, when combined with the reverse link.

In [A3], the authors proposed a system that employed LTE-cell specific reference signals and channel estimator for receiving backscatter modulated signals. The presented backscatter device used two square waves with different nominal frequencies to perform frequency shift modulation. The LTE channel estimator is particularly suitable in Ambient Internet of Things applications for receiving backscattered signals.

The aim of the research discussed in [A4] is to evaluate the performance of the filled corner reflector concept by using 3D-printed ceramics with a high permittivity. By exploiting this concept in conjunction with additive ceramic manufacturing of alumina and zirconia materials, the half power beamwidth (HPBW) of the radar cross-section (RCS) could be improved by more than 80% when compared to a standard metallized corner reflector reference. It has been shown that, for alumina, the general RCS level is comparable to the metal corner reflector, making it an alternative with a significantly wider aperture angle and HPBW.

Novel sensing solutions have been also proposed [A5], [A6], [A7], [A8]. Specifically, in [A5] a new method for estimating the orientation of a tagged object using a simple procedure based on off-the-shelf components was discussed. The proposed system adopted a circularly polarized RFID antenna and an Extended Kalman filter that used only phase measurements as inputs. The filter estimated rotation angle, velocity, and acceleration of the object, as well as tag-reader distance. The method appeared to be suitable for practical applications where the measurement of the rotation speed or the angular variation was required, and it represented a valid alternative to other methods based on different technologies, especially in harsh environments. The article concludes that the proposed system is robust, and it can obtain satisfactory results even when the nominal configuration setup can only approximately be reproduced.

In [A6] an RFID sensor that can be integrated into artificial metal-free tricuspid valves was proposed. The study included numerical simulations and experimental tests that showed the stable communication performance of the sensor and its little sensitivity to reader-sensor misalignment. The paper also mentioned the possibility of adjusting the antenna impedance to valves of different sizes and shapes by using the auto-tuning capability of the IC and T-match techniques. The sensor can measure realistic temperature profiles with high accuracy, making it suitable for capturing physiological variations related to fever and other health abnormalities. The study suggests the possibility of directly transferring the copper trace by laser cutting or inkjet printing on the polymeric stent of the valve for a more realistic application.

Still in the framework of healthcare, a hybrid system architecture for novel Points-of-Care (PoCs) based on RFID and NFC is proposed in [A7]. High-level architecture of the platform, hardware selection and secure transmission of medical data were discussed. Temperature sensing, activity recognition and chemical sensing were implemented. An implementation example regarding the domestic monitoring of an acute myocardial infarction survivor was deployed and tested. Pros and cons were discussed to investigate new needed features of hardware architecture and sensors for PoCs.

In [A8], a study on a gesture control interface system based on passive RFID integrated into clothing and furniture was described. The system used four tags, with one acting as a gesture initiator, and it was tested successfully in both furniture and clothing setups. The study suggested that the use of a gesture initiator tag significantly improves system reliability. The authors proposed further work to optimize timings and integrate a user feedback system.

Further contributions, extended and published in this Special Issue, deal with the macro-topic of RFID-based localization systems for both outdoor [A9] and indoor [A9] applications.

In [A9], recent advances in phase-based RFID monitoring of soil surface displacement were presented. A long-term outdoor RFID localization method was described by analysing the main challenges occurred, based on a 5-years landslide monitoring in different test areas. Then, solutions were proposed to mitigate them, by exploiting various data processing and fusion techniques. Thanks to the adoption of multi-source, e.g., multiple frequencies, antennas and tags, data fusion, and a proper calibration the overall average data availability increased up to 38%, by dealing the main issue of multipath and shadowing in outdoor scenario.

Tag localization by a handheld UHF-RFID reader was proposed in [A10], thanks to the combination with an optical camera. The handheld device recognized optical landmarks at known locations to estimate the reader position. Simultaneously, it collected phase data from the co-located reference RFID tags to calculate the device velocity. By exploiting a data-fusion approach, the 3D antenna trajectory was estimated. Then, it was employed together with unwrapped phase measurements to locate multiple tags, by solving a proper minimization problem in real-time. A localization error lower than 1 m is obtained from the experimental analysis.

In Closing: This special issue collected the extended versions of papers presented at *IEEE RFID-TA 2022 Conference* and the *International Symposium on Advances in RFID Technology and Electromagnetics for IoT* organized within the *2022 International Conference on Smart and Sustainable*

Technologies (*Splitech*). This wants to highlight the hot topics of the RFID community, worldwide. We look forward to the next edition of the IEEE RFID-TA series, which will be held in Aveiro, Portugal, on September 4-6, 2023 (https://2023.ieee-rfid-ta.org/).

We would like to express our appreciation to all the authors contributing to this Special Issue on IEEE JOURNAL OF RADIO FREQUENCY IDENTIFICATION.

APPENDIX: RELATED WORKS

[A1] L. Balocchi, V. Palazzi, S. Bonafoni, F. Alimenti, P. Mezzanotte, and L. Roselli, "Compact green harmonic transponders for parcel tracking," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 247–256, 2023.

[A2] A. Mughal, J. M. Sudersanan, S. Mostarshedi, B. Poussot, and J.-M. Laheurte, "Statistical evaluation of the coupling effects between tags in a UHF RFID forward link," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 257–266, 2023.

[A3] J. Liao, X. Wang, K. Ruttik, R. Jäntti, and D.-T. Phan-Huy, "In-band ambient FSK backscatter communications leveraging LTE cell-specific reference signals," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 267–277, 2023.

[A4] K.-D. Jenkel, B. Sievert, A. Rennings, M. Sakaki, D. Erni, and N. Benson, "Radar cross-section of ceramic corner reflectors in the w-band fabricated with the LCM-method," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 278–283, 2023.

[A5] E. D. Giampaolo, F. Martinelli, and F. Romanelli, "Exploiting polarization mismatch to estimate the orientation of rotating UHF RFID tags," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 284–292, 2023.

[A6] F. Naccarata and G. Marrocco, "Integrated wireless RFID temperature sensor for biological aortic valve prostheses," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 293–300, 2023.

[A7] G. M. Bianco et al., "UHF RFID and NFC point-of-care—Architecture, security, and implementation," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 301–309, 2023.

[A8] A. Shaikh, A. Vianto, S. Jabari, O. Buruk, J. Hamari, and J. Virkki, "Passive RFID based control interface integrated into clothing and furniture," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 310–318, 2023.

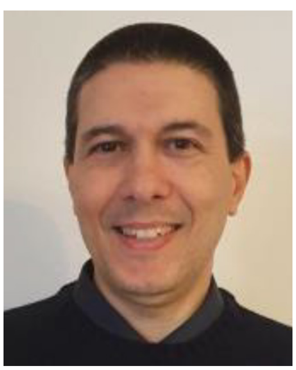
[A9] A. Charléty, M. L. Breton, L. Baillet, and E. Larose, "RFID landslide monitoring: Long-term outdoor signal processing and phase unwrapping," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 319–329, 2023.

[A10] A. R. Chatzistefanou, G. Sergiadis, and A. G. Dimitriou, "Tag localization by handheld UHF RFID reader with optical and RFID landmarks," *IEEE J. Radio Freq. Identif.*, vol. 7, pp. 330–340, 2023.

G. ANDREA CASULA, *Guest Editor*
Department of Electrical and Electronic Engineering
University of Cagliari
09124 Cagliari, Italy

LUCA CATARINUCCI, *Guest Editor*
Department of Innovation Engineering
University of Salento
73100 Lecce, Italy

ALICE BUFFI, *Guest Editor*
Department of Energy, Systems, Territory and Constructions Engineering
University of Pisa
56122 Pisa, Italy



G. Andrea Casula (Senior Member, IEEE) received the M.S. degree (summa cum laude) in electronic engineering and the Ph.D. degree in electronic engineering and computer science from the University di Cagliari, Cagliari, Italy, in 2000 and 2004, respectively. From 2006 to 2017, he was an Assistant Professor of Electromagnetic with the Department of Electrical and Electronic Engineering, University of Cagliari, where he has been an Associate Professor since 2017 and is teaching courses in electromagnetics and antenna engineering. He authored 55 papers on indexed international journals, more than 60 proceedings of international conferences and one chapter of international books. His main research activities are in the field of waveguide slot antennas; RFID antennas and wearable antennas; wearable antennas on SIW technology; epidermal antennas for medical applications; SIW slot antennas; microwave components and antennas for radio astronomy applications; and printed log-periodic dipole antennas. He serves as an Associate Editor for various international journals, including IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, organized several special sessions in IEEE international conferences, such as EuMW, MMS, RFID-TA, and SpliTech, and has been the General Chair of the 2022 IEEE International Conference on RFID Technology and Applications.

Luca Catarinucci (Senior Member, IEEE) is an Associate Professor of Electromagnetic Fields with the Department of Innovation Engineering, Univesity of Salento, Lecce, Italy, where he teaches microwaves and electromagnetic solutions for Hi-Tech. Besides various activities in the classical areas of electromagnetics, in 2005, he begun a new research tread referred to radiofrequency identification systems (RFID), dealing with reader and tag antenna design, realization of microwave circuits for the integration of UHF RFID systems with sensor networks, design of automatic platforms for the over-the-air performance evaluation of RFID tags, prototyping of fully passive RFID tags provided with computational and sensing capabilities, study of new antennas for handheld RFID readers, joint use of 3D-printed electronics and RFID, and introduction of Doppler-based RFID-inspired backscattering modulation. He authored more than 200 scientific works of which 83 on indexed international journals, four chapters of international books, and dozens of proceedings of international conferences. Moreover, he holds two national patents about RFID technology.

Dr. Catarinucci is currently the Vice President of Technical Activities at the IEEE Council of RFID and the Chair of the IEEE Technical Committee on Additively Manufactured Electronic Systems. He serves as an Associate Editor for various international journals, including IEEE JOURNAL OF RADIO FREQUENCY IDENTIFICATION and is/has been on the organization committee of prestigious international conferences, including EuMW 2014, MMS 2015, IEEE RFID-TA, IEEE RFID, and SpliTech, in the framework of which he is the General Chair of the Annual International Symposium on Advances in RFID Technologies and Electromagnetics for IoT.

Alice Buffi (Senior Member, IEEE) received the B.S. and M.S. degrees (summa cum laude) in telecommunications engineering and the Ph.D. degree (Doctor Europaeus) in applied electromagnetism in electrical and biomedical engineering, electronics, smart sensors, and nanotechnologies from the University of Pisa, Pisa, Italy, in 2006, 2008, and 2012, respectively.

Since 2012, she has been with the University of Pisa, where she is currently an Associate Professor with the Department of Energy, Systems, Territory and Construction Engineering. She has coauthored several international journal papers and international conferences contributions, one European patent, and one European patent application. Her current research topics include measurement methods to locate static or moving items/people through radio frequency identification (RFID) systems operating at the ultra-high-frequency (UHF) band in Industry 4.0 scenarios. Besides, she has interests in classification methods for smart gates and smart storage systems and aging process in battery cells. She was a recipient of the Best Poster Award at the IEEE RFID International Conference 2023, the Best Poster Award at the IEEE International Symposium on Measurements and Networking 2022, the Best Paper Award at the IEEE RFID-TA 2019 International Conference, and the Young Scientist Award from the International Union of Radio Science, Commission B, in 2013 and 2016. She serves as an Associate Editor for the IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT and the IEEE JOURNAL OF RADIO FREQUENCY IDENTIFICATION. She also serves as the Steering Committee Chair of the IEEE JOURNAL OF RADIO FREQUENCY IDENTIFICATION and the Chair of the IEEE CRFID's Technical Committee on Motion Capture and Localization (IEEE TC-MoCap). Additionally, she serves as the Distinguished Lecturer for the IEEE Council on RFID for the three-years period 2023–2025. She is a member of the IEEE Instrumentation and Measurement Society, the IEEE Antennas and Propagation Society, and the IEEE Council on RFID.