# Guest Editorial: Special Issue on IEEE RFID 2017 Conference

RADIO frequency identification (RFID) is a wireless technology based on tag antenna load modulation where in the majority of cases the tag itself is not a source of RF energy. The term "RFID" is generic and covers many frequency bands and standards.

Low frequency (LF) and high frequency (HF) RFID systems are based on inductive coupling between the reader and the tag and can be traced back to 1920s (U.S. patent 1744036 "Process for radiotelegraphic or radiotelephonic communication"). Ultra-high frequency (UHF) and microwave RFID systems use electromagnetic waves propagating between the reader and the tag and can be traced back to 1930s (early radar work by Britain on IFF transponders to distinguish enemy aircraft) and to 1940s (the Great Seal Bug by Russian/Soviet inventor Leon Theremin and the seminal work "Communications by Means of Reflected Power" published by American researcher Harry Stockman in Proceedings of the IRE).

Since then, RFID technology has significantly progressed. Current UHF RFID ICs are more complex than Intel 80386 processor (which had 275,000 transistor count) while consuming less power during operation than honeybee's brain (which consumes about 10 microwatts). RFID technology now extends beyond pure identification and encompasses low power wireless devices and systems with sensing, networking, security, and localization capabilities, with applications ranging from inventory management and asset tracking to patient safety, item authentication, and automatic vehicle identification.

Two RFID technologies, NFC (short range, in HF band) and RAIN (long range, in UHF band) are currently supported by two industry alliances, NFC Forum and RAIN RFID Alliance which promote the worldwide adoption of these technologies that already connect billions of items to the Internet. Commercial system solutions based on these technologies are currently available for many applications, and wide consumer adoption is happening now, allowing users (individuals and businesses) to identify, locate, and authenticate RFID-tagged items in real time, enabling the true vision of Internet of Things.

RFID technology has an evolving nature and is developing very rapidly. Just in the last 10 years, there were about 3,000 issued U.S. patents and about 8,000 IEEE journal and conference publications (all with "RFID" in their titles). In 2017, IEEE launched a new IEEE Journal of Radio Frequency Identification (JRFID). This special issue is the first issue of JRFID. It presents a collection of extended papers from IEEE RFID 2017 conference, a highly competitive premier international technical conference on RFID that took place in Phoenix, AZ on May 9-11, 2017. The twelve papers presented in this issue are written by researchers from five countries: USA, Russia, U.K., Austria, and Australia. The topics of the papers range from automatic vehicle identification, antenna design, propagation channel analysis, and tag localization methods to channel coding, data encryption, system security, power management, and implantable biomedical devices.

Larionov *et al.* provide a comprehensive study of a UHF RFID automatic vehicle identification system performance under different protocol settings, antennas and propagation environment parameters. The propagation analysis assumes time-variant environment caused by Doppler effect of moving tags. The estimations of an inventory round duration, the number of rounds the tag participates in and the tag identification probability are provided. The system simulation is performed, and the vehicle identification probability is shown to vary significantly over the reader settings and environment conditions.

Yang *et al.* describe a new approach to UHF RFID where a large metal structure provides the communication channel between the RFID reader and passive tags placed on the structure, which in effect is operating as a near field antenna. Results suggest that a standard passive tag utilizing a dipole antenna and oriented normal to the metal surface can efficiently harvest the electric field to be read at distance over 50 m along a metal bar with this method.

Qi *et al.* describe an antenna in application to signal strength-based radio tomographic imaging (RTI) that allows tagless identification and tracking without entering a building by deploying an ad-hoc sensor network on the exterior wall of the building. To strengthen the RF power on each radio link within the network, they design an E-shape patch antenna to avoid impedance mismatch when brought into proximity of dielectric materials. They demonstrate that such an antenna improves the accuracy of the RTI system by 43% when compared to microstrip patch and dipole antennas that are commonly used in state-of-art RTI systems.

Galler *et al.* present measurement results of a recently introduced time-of-flight ranging method, which can be used with off-the-shelf EPC Class1 Gen2 tags. A ranging signal with a bandwidth of approximately 25 MHz is used. The ranging principle is successfully verified, and its practical performance limitations, resulting from multipath propagation, are discussed. In addition, the multiple-input multiple-output RFID reader testbed based on modified software defined radios is shown and some implementation aspects are discussed.

Grebien *et al.* examine time-of-flight based ranging over the UHF RFID backscatter channel. The paper analyzes the

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ranging performance bound for a line-of-sight plus dense multipath channel and proposes an algorithm to estimate both the line-of-sight and dense multipath parameters utilizing a multiple-input multiple-output setup. The proposed algorithm, which could be applied to the system presented by Galler *et al.*, shows a ranging precision in the range of 0.5 m for a bandwidth of 50 MHz.

Hui *et al.* propose the code division multiple access (CDMA) within the broadband harmonic backscatter RFID system to enable the simultaneous real-time tag localization with centimeter accuracy and millimeter deviation. They investigate the impacts of the number of tags with respect to the sampling rate, tag power consumption and locating errors originated from the inter-tag collision, and present an experimental prototype for verification.

Varner *et al.* explore a novel signaling approach to facilitate wireless communications using ambient signals as RF carriers. The paper describes the mathematical behaviors of the perfect pulse, a waveform which has unique DC-nulling properties, gives design criteria for their implementation in current real-world scenarios, and offers a preliminary measurement campaign serving as a proof of concept for their use and suggesting the expected baseline performance of such a system. This paper is a pioneering attempt to tackle ambient communications in RFID from a telecom and physical layer perspective.

Durgin *et al.* present two example implementations of balance block codes (BBCs) for encoding backscatter RFID signals with up to 50 percent increased real data rate. Using specifications based on today's RFID reader hardware, the range and reliability of these BBCs are shown to be comparable to the current UHF Gen2 standard's FM0 protocol, while adding insignificantly more circuit complexity, cost, and power consumption. Using this encoding scheme, next-generation backscatter systems or retrofit enhanced RFID tags would be able to transmit more data or singulate faster with virtually no observable performance penalty.

Ulz *et al.* propose a novel NFC-based device configuration approach. This approach not only provides a secured communication protocol but also considers security at the device level and therefore is applicable for industrial as well as for personal use. They also present three update mechanisms to account for the different requirements regarding security and usability that result from these two usage scenarios. The applicability of this approach is shown by a demonstrator and an evaluation that highlights the minimum protocol overhead imposed by the implemented security measures.

Degnan *et al.* explore using the Simon Cipher key schedule as a hash that is targeted toward RFID and IoT applications with the practical benefit of reusing the existing hardware where space and power are at a premium. By a single component change, the key schedule becomes a one-way compression function that can be used for stream verification.

Sun *et al.* present a fully-integrable power management unit for fully passive UHF RFID tags. The excess harvested energy, which is typically wasted in the convention system, is exploited and utilized to improve the overall performance of the tag. Through smart power routing, this stored energy is used to sustain the supply voltage of tag circuitry. This approach can reduce cold start-up time, mitigate consequences of brownouts and extend the operational range and the responsiveness of tags, especially those with passively powered sensors.

Kampianakis *et al.* present a dual-band approach for HF wireless power delivery and UHF backscatter communication in implanted biomedical devices. They implement a custom implant device that backscatters data at 5 Mbps at 915 MHz and receives powers through an HF wireless power transfer (WPT) link with an efficiency of 17%. This is the first demonstration of a complete backscatter-based implantable system operating at a data rate of 5 Mbps or greater, including a real-time off-the shelf receiver system, HF WPT, and offering multi-channel neural and electromyography (EMG) recording.

This collection of papers represents only a small sampling of various active research topics in the field of RFID. Undoubtedly, RFID technology will continue to develop and will continue to pose many interesting challenges for researchers and engineers in both academia and industry.

PAVEL NIKITIN
Guest Editor for the Special Issue
Impinj, Inc.
Seattle, WA, USA

**Pavel Nikitin** (S'98–M'02–SM'07) received the Ph.D. degree in electrical engineering from Carnegie Mellon University, Pittsburgh, PA, USA, in 2002. He is currently a Senior Staff Antenna Designer with Impinj, Inc., Seattle, WA, USA, where he is involved into research and development of RFID products. He is also an Affiliate Associate Professor with the Electrical Engineering Department, University of Washington. He previously worked at Honeywell, Intermec, the University of Washington, IBM, and Ansys. He has authored over 50 IEEE technical publications, has over 30 issued U.S. and European patents. He was the recipient of the 2017 and 2010 IEEE RFID Conference Best Paper Awards and the 2005 Antenna Measurement Techniques Association (AMTA) Symposium Best Paper Award.