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Tuesday May 17 th 2022: Welcome coffee - Registration and check in

Room: Corridor between Mariners and Tropics A/B

Tuesday May 17: WORKSHOP & TUTORIALS

Room: Mariners

08.30 - 10.00 RFID as Ambient Data

10.30 - 12.00 Workshop on Digital Spectrum Twinning (Session I)

13.00 - 14.30 Workshop on Motion Capture and Localization

15.00 - 16.30 Roundtables, Peer2Peer

17.00 - 18.30 RFID Journal Live Keynote

18.30HRS RFID JOURNAL LIVE EXPO HALL OPENS

Tuesday May 17: WORKSHOP & TUTORIALS

Room: Tropics A

08.30 - 10.00 AI IN RFID

I3.00 - 14.00 Workshop on Digital Spectrum Twinning (Session II)

Wednesday May 18 th 2022: Welcome coffee - Registration and check in

Room: Corridor between Mariners and Tropics A/B

Wednesday May 18 th 2022: PLENARY SESSION

Room: Mariners

08.30 - 08.32 Stewart Thomas: Conference Opening

08.32 - 08.42 Steve Halliday: General Chair's Welcome Message

08.42 - 08.47 Ultan Mc Carthy: TPC rerview & Best Paper Award

08.47 - 08.48 Steve Halliday: Presentation of Best paper award

08.48 - 08.53 Greg Durgin: IEEE Council on RFID Emily Sopensky Award for Meritorious Service

08.53 - 09.08 GS1: Industry Spotlight

09.08 - 09.53 Edwin Kan: The RFID Path to Autonomous Retails and Factories: Challenges and Promises

09.53 - 10.08 OPEN FLOOR Question time

Wednesday May 18 th 2022: INVITED SPEAKERS & POSTER TEASERS

Room: Mariners

10.30 - 10.45 James Rosenthal: Making the Most of IEEE RFID. How to use Whova

10.45 - 11.45 Aline Eid: New Backscatter Horizons: The Emergence of mmID Technology

11.45 - 12.00 Luca Catarinucci: Poster Session Teaser Talks

Wednesday May 18 th 2022: PAPER SESSION: Next-Gen RFID & ID+, Sensors

Room: Mariners

13:00-13:20 HarmonicID: A Tag Identification System for LowPower Analog Backscatter Devices Next Gen

13:20-13:40 Chained, Repeated IQ-Based Data Separation for Streaming from Multiple Tags Next Gen

13:40-14:00 Towards Measurement Range Extension of UHF RFID Temperature Sensors for Industrial Applications Sensors

14:00-14:20 Potentiometric Sensing by means of Self-tuning RFID ICs Sensors

Dilushi Piumwardane (Uppsala University, Sweden); Thiemo Voigt (Swedish Institute of Computer Science & Uppsala University, Sweden); Christian Rohner and Madhushanka Padmal (Uppsala University, Sweden); Vaishnavi Ranganathan (Microsoft Research, USA)

Backscatter tags consume extremely low power and are activated by an external carrier for sensing and communication purposes. Analog backscatter tags achieve further power and cost reductions by moving digitization and computation overhead to a remote receiver. Since analog transmissions have a direct mapping to frequency or amplitude, they do not have a digitized frame structure to convey control information such as addresses. Therefore, when multiple tags are deployed it is challenging to identify the tag that transmits the data. We present a novel fully analog tag identification mechanism that is inspired by musical instruments. Each instrument has a unique harmonic content and therefore the human ear can distinguish different musical instruments even when they are playing at the same frequency. By tuning the tags to reflect a unique harmonic content we enable identification of purely analog tags. Our results show that we can create identities for tags by leveraging signal conditioning to modify harmonics, without the need to add dedicated digital blocks for identification purposes. Experiments on our hardware demonstrate that we can successfully identify the tags even in challenging scenarios such as when they are blocked by walls or in motion

Stewart Thomas (Bucknell University, USA)

This paper describes a simple demodulation technique based on chained, repeating functions for separating and demodulating multiple tags that are simultaneously sending data. When multiple tags

transmit simultaneously, the data streams collide often causing data loss. Most protocols detect such collisions and request devices to re-transmit data. However, it is possible to separate the individual tag data streams from the received samples. In a backscatter communication system, all nodes share a common, phase-coherent communication system. This work uses the unique properties of the backscatter channel to receive data from simultaneously-transmitting tags by demodulating received samples in the complex baseband, removing estimates of the received bits from the incoming data stream and continuing further demodulation through repeated application of the demodulation function until all tag transmissions are removed. While similar to recursion, this is a chained, repeating demodulation process and can demodulate several tags that are simultaneously communicating. This paper presents an overview of the signals in a backscatter communication system and measured results from a bench-top over-the-air test using two tags placed 30 cm apart from each other and 1.67 m away from a +27 dBm, 915 MHz reader. The data streams from the two tags fully overlap, but are correctly recovered through the chained, repeated demodulation process.

Towards Measurement Range Extension of UHF RFID Temperature Sensors for Industrial Applications.....12

Joan Melià-Seguí (Universitat Oberta de Catalunya (FUOC), Spain); Imanol Rojas, Jon Lejarreta Andrés and Xavier Vilajosana (Universitat Oberta de Catalunya, Spain)

Digitization is a priority and a key tool to support the development of the Industry 4.0. Many industries, like the automotive sector, rely on complex and costly processes that are still not completely digitized, suffering from poor traceability and limited optimization options due to the lack of proper knowledge of the process internals. In this article we focus on a highly relevant industrial process as part of the automotive assembly line, the painting process, which requires a fine control of the entire cycle temperature without requiring costly operations or complex human interventions. In this article, we propose a novel cost-efficient method for sensing high temperatures with standard UHF RFID sensors. By using low thermal transmission insulation and polynomial models, we achieve to predict temperatures around 200ºC/400ºF with 1.5% error. We believe our proposal opens novel opportunities in the industry to a more cost-efficient fine-grained and process tailored temperature measurement under high temperature conditions.

Potentiometric Sensing by means of Self-tuning RFID ICs.....17

Francesca Nanni (University of Rome Tor Vergata, Italy); Simone Nappi (University of Rome Tor Vergata & Radio6ense srl, Italy); Gaetano Marrocco (University of Rome Tor Vergata, Italy)

Recently introduced autotuning RFID ICs can provide digital information on the change in the local boundary conditions in the close surrounding of the tag. By exploiting this feature in combination with a varactor diode, a general framework for the controlled sensing of a chemical agent can be achieved. The varactor acts as a transducer converting the potentiometric output of a chemical sensor into a capacitance change that produces in turn a mismatch between the antenna and the IC. Closed-form expressions relate the digital output of the IC to said chemical variation so that it is well mapped within the retuning dynamic range. The method is demonstrated with reference to a pH sensor and looks promising to provide a sensitivity of 18 units per unitary change of the pH and could be read up to 2 m.

Wednesday May 18 th 2022: PAPER SESSION: Protocols & Security

Room: Tropics A

mtOTP against multiple security attacks. We compare privacy, security, computation, and communication properties of TTP-mtOTP against those of other OT protocols for multiple tags that use a TTP.

ML-Aided Collision Recovery for UHF-RFID Systems.....41

Talha Akyildiz, Raymond Ku, Nicholas Harder, Najme Ebrahimi and Hessam Mahdavifar (University of Michigan, USA)

We propose a collision recovery algorithm with the aid of machine learning (ML-aided) for passive Ultra High Frequency (UHF) Radio Frequency Identification (RFID) systems. The proposed method aims at recovering the tags under collision to improve the system performance. We first estimate the number of tags from the collided signal by utilizing machine learning tools and show that the number of colliding tags can be estimated with high accuracy. Second, we employ a simple yet effective deep learning model to find the experienced channel coefficients. The proposed method allows the reader to separate each tag's signal from the received one by applying maximum likelihood decoding. We perform simulations to illustrate that the use of deep learning is highly beneficial and demonstrate that the proposed approach boosts the throughput performance of the standard framed slotted ALOHA (FSA) protocol from 0.368 to 1.837, where the receiver is equipped with a single antenna and capable of decoding up to 4 tags.

Wednesday May 18 th 2022: POSTER SESSIONS

Room: Exhibit Hall

Come check out all out posters

Wednesday May 18 th 2022: EVENING NETWORKING

Room: Luxor Public House

17.30 - 18.00 Young Professionals Networking Dinner

18.00 - 20.00 Networking Dinner

Thursday May 19 th 2022: Welcome coffee - Registration and check in

Room: Corridor between Mariners and Tropics A/B

Thursday May 19 th 2022: PLENARY SESSION

Room: Mariners

08.30 - 08.31 Stewart Thomas: Welcome / open

08.31 - 08.33 Luca Catarinucci: Best Poster Award

08.33 - 08.43 Greg Durgin: CRFID Updates

08.43 - 08.46 Vartan Piroumian: IEEE DTPI 2022 Pitch

08.46 - 08.51 Megan Brewster: Resolving the Internet of *Every* Thing

08.51 - 09.36 Chris Anderson: Building Trust - Using NRDZ's to Shatter Spectrum Silos

09.36 - 09.45 OPEN FLOOR Question time

Thursday May 19 th 2022: PAPER SESSION: AI for RFID, Applications & Software

Room: Tropics A

10:15-10:35 Detection of Malware in UHF RFID User Memory Bank using Random Forest Classifier on Signal Strength Data in the Frequency Domain

10:35-10:55 Artificial Intelligence enhances Smart RFID Portal for retail

10:55-11:15 Experimental Evaluation of Wireless Transport Package Test with Battery-free Backscatter Sensors

11:15-11:35 State estimation scheme for multiple RF tags with an angled single antenna

11:35-11:55 A chamber for stocktaking of courier parcels in a dense environment

13.00-13.30 RFID Journal Live Awards

Detection of Malware in UHF RFID User Memory Bank using Random Forest Classifier on Signal Strength Data in the Frequency Domain.....47

Shah Md Nehal Hasnaeen and Andrew Chrysler (Idaho State University, USA)

A method of detecting UHF RFID tags with SQL injection virus code written in its user memory bank is explored. A spectrum analyzer took signal strength readings in the frequency spectrum while an RFID reader was reading the tag. The strength of the signal transmitted by the RFID tag in the UHF range, more specifically within the 902-908 MHz sub-band, was used as data to train a Random Forest model for Malware detection. Feature reduction is accomplished by dividing the observed spectrum into 15 ranges with a bandwidth of 344 kHz each and detecting the number of maxima in each range. The malware-infested tag could be detected more than 80% of the time. The frequency ranges contributing most in this detection method were the low (903.451- 903.795 MHz, 902.418-902.762 MHz) and high (907.238-907.582 MHz) bands in the observed spectrum.

Artificial Intelligence enhances Smart RFID Portal for retail.....53

Andrea Motroni (University of Pisa, Italy); Marcos R. Pino (Universidad de Oviedo, Spain); Alice Buffi and Paolo Nepa (University of Pisa, Italy)

This paper investigates a low-cost implementation of a UHF-RFID portal enhanced by artificial intelligence to assess whether a tag is crossing the portal or it is static in the surrounding. The reference scenario concerns anti-theft systems in fashion stores, where the use of shielded RFID portals is not feasible and spurious tag readings must be filtered by alternative methods. The portal consists of a commercial RFID reader connected to an array antenna placed at the store entrance to monitor the tag crossing. Data processing involves Received Signal Strength Indicator sequences and a comparison among Support

Thursday May 19 th 2022: PAPER SESSION: Antennas & Propagations, & Digital Spectrum Twinning

Room: Mariners

10:15-10:35 Ray Tracing and Measurement based Evaluation of a UHF RFID Ranging System

10:35-10:55 M-Shaped Folded-patch Antenna for On-Metal UHF RFID Tag Design

10:55-11:15 Radio Frequency Identification Reader Antenna Design With High Gain And Circular Polarization

11:15-11:35 Pseudonymetry: Precise, Private Closed Loop Control for Spectrum Reuse with Passive Receivers

11:35-11:55 Signal Strength Measurements Using Smartphones (Monisha Ghosh). Abstract: Smartphones today contain radios in multiple frequency bands: low (< 1 GHz), mid (1 - 7 GHz) and high (> 24 GHz), covering all the cellular and Wi-Fi bands. The modems constantly measure reference signal power for all cellular and Wi-Fi signals, even if not actively transmitting or receiving data. We describe a methodology for collecting signal strength measurements using APIs on smartphones to read these values directly from the modems on the phones, every few seconds, and uploading the data. We then describe some insights extracted from the signal strength data, combined with speedtests, collected in Chicago over the last 2 years.

13.00-13.30 RFID Journal Live Awards

Ray Tracing and Measurement based Evaluation of a UHF RFID Ranging System.....75

Stefan Hechenberger and Daniel Neunteufel (TU Wien, Austria); Holger Arthaber (Vienna University of Technology, Austria)

This paper presents a ray tracing based channel simulation for the evaluation of ultra-high-frequency (UHF) radio-frequency identification (RFID) ranging methods. In order to account for the diffuse multipath (DM) of an indoor channel, the ray tracer is extended by a statistical model. For the range estimation, a matched filter (MF) and a maximum likelihood (ML) estimator are implemented. The latter exploits the use of multiple-input-multiple-output (MIMO) information. The estimators are evaluated with respect to both the simulated channel model and the data from a measurement campaign. It is shown that the results provided by the simulations and the measurements agree to a large extent. This nominates the presented channel simulation as an efficient method for the evaluation of indoor localization systems.

M-Shaped Folded-patch Antenna for On-Metal UHF RFID Tag Design.....81

Lianfu Zhao (School of Microelectronics, Tianjin University, China); Yongtao Ma (Tianjin University, China); Weijia Meng (TJU, China)

A new M-shaped UHF RFID tag on metal with a compact footprint of 40 mm × 24 mm × 1.1 mm (0.122λ × 0.073λ × 0.003λ at 915 MHz) is proposed. The antenna consists of an M shaped patch and a ground plane. The tag antenna can be easily fabricated on a thin flexible PET sheet substrate. It is fabricated by folding the flexible substrate, and the structure is simple. It has 3 design parameters and can achieve different degrees of conjugate matching. By changing the parameters, the impedance can be easily adjusted and the resonant frequency of the antenna can be changed finely. An equivalent circuit is built to estimate the input impedance of the antenna. The results show that the impedance conjugate matching between the tag antenna and the chip can be easily achieved by using the M shaped feeder. In the simulation, the antenna has a high power transmission coefficient (~1). With an effective isotropic radiated power (EIRP) of 4 W, the tag can achieve a long reading distance of 6.9 m on metal surfaces.

Radio Frequency Identification Reader Antenna Design With High Gain And Circular Polarization.....87

Daniele Inserra (University of Electronic Science and Technology of China, Chengdu, China); Wen Guangjun (University of Electronic Science and Technology of China, China)

In this paper, the design of a high gain circular polarization (CP) radio frequency identification (RFID) reader antenna for the ultra-high frequency (UHF) band is described. The antenna is designed with a 2 × 2 array configuration by applying the sequential rotation technique, which guarantees excellent axial ratio (AR) performance and high gain. Furthermore, in order to maximize the antenna gain, both the height of the CP antenna elements and the antenna element arrangement have been optimized. In addition, the two-level series power divider based feed network central element has been opportunely rotated to minimize the feed network insertion loss. A CP gain larger than 14.6 dBic with a 600 × 600 mm2 antenna array has been measured within the FCC bandwidth 902-928 MHz, with outstanding impedance matching and AR performance.

Pseudonymetry: Precise, Private Closed Loop Control for Spectrum Reuse with Passive Receivers.....91

Meles G Weldegebriel (Washington University in Saint Louis, USA); Neal Patwari (Washington Unoversity in St. Louis, USA); Jie Wang and Ning Zhang (Washington University in St. Louis, USA)

Radio astronomy and other passive radio spectrum users have significant challenges avoiding interference from wire- less communication systems. Even distant transmitters sometimes interfere with passive users. We propose Pseudonymetry, a system that provides (primary) passive users a means to turn off the transmissions of the particular (secondary) wireless transmitter that interferes with it. By controlling the specific transmitter rather than an entire geographical region, Pseudonymetry could increase the spectrum available for wireless systems while en- suring rapid clearing of interferers as necessary for passive use. Pseudonymetry adds a low rate watermark to the secondary (intended) transmitted signal to carry a random, anonymous pseudonym. We show the ability of a passive receiver to decode the watermark, even from a signal received with very low SNR. The passive receiver posts to a centralized database to provide feedback to the secondary transmitters so that they know to vacate the band. We provide analysis that captures the trade-offs in the design of Pseudonymetry, and show initial evidence that a simple amplitude modulation watermarking scheme could enable reliable detection at a distant passive receiver, while resulting in minimal degradation to the error performance of the intended secondary receiver.

Thursday May 19 th 2022: PAPER SESSION: Circuits, Devices & Interrogations

Room: Mariners

13:30-13:50 A Novel LNTA-first Carrier Leakage Suppression Receiver Front-End with Low Noise Figure and High Sensitivity for UHF RFID Reader

13:50-14:10 An All-Digital 1.25 Mbps 5-Subcarrier OFDM Backscatter Uplink with Delta-Sigma Modulation for Improved Spurious-Free Dynamic Range

14:10-14:30 An All-Digital 1 Mbps, 57 pJ/bit Bluetooth Low Energy (BLE) Backscatter ASIC in 65nm CMOS

14:30-14:50 Novel Multi-Resonator Circuits for Chipless RFID Tags Using Asymmetrical Triple-Mode Resonators

(33uW) by the oscillator, and 28% (57uW) by the RF switch used as a backscatter modulator. The ASIC broadcasts up to 1000 packets/sec BLE advertising packets at 1 Mbps, yielding a backscatter modulator efficiency of 57 pJ/bit. The device was validated in both cabled and wireless measurements setups, demonstrating compatibility with unmodified smartphones as well as commercially available BLE chips, such as the Nordic Semiconductor nRF51822. With the wireless test setup used in this work, the ASIC has a theoretical maximum read range of 4.9 m using a smartphone. Building off previous work in BLE backscatter communication using FPGA-based prototypes, this work provides an important quantitative demonstration of the size and power savings that can be achieved in a BLE-compatible backscatter ASIC.

Novel Multi-Resonator Circuits for Chipless RFID Tags Using Asymmetrical Triple-Mode Resonators.....114

Ali Kursad Gorur (Nevsehir Haci Bektas Veli University, Turkey); Engin Dogan (Nigde Ömer Halisdemir University, Turkey); Ceyhun Karpuz (Pamukkale University, Turkey); Adnan Gorur (Nigde Omer Halisdemir University, Turkey)

In this paper, a new asymmetrical triple-mode resonator that can be used in chipless radio frequency identification (RFID) tags is introduced. The proposed resonator is constructed by locating two open-circuited stubs in different electrical length to an open loop resonator. Two resonant frequencies can be controlled by these asymmetrical stubs, while the main resonant frequency is resulted from the nature of the open loop resonator. It is proven that the proposed resonator can allow obtaining 5 frequency codes from a single triple-mode resonator. A multi-resonator circuit is also designed by coupling 6 triple-mode resonators to a bended transmission line which connects input to output port. For the experimental verifications, three circuits having different frequency code combinations have been fabricated and measured in an excellent agreement with the simulated results. Totally 18 resonant frequencies resulted from the 6 triple-mode resonators have been clearly observed in the measurements. The proposed multi-resonator circuit can be utilized for chipless RFID tags and 56 frequency codes can be generated.

Thursday May 19 th 2022: PAPER SESSION: MoCap, ORSS

Room: Tropics A

13:30-13:50 SA-Loc: Scenario-Adaptive Localization in Dynamic Environment using Adversarial Domain Adaptation Regression

13:50-14:10 Radio Frequency Identification and Localization by Wearable LoRa for Search and Rescue in Mountains

14:10-14:30 Device-free Human Tracking Exploiting Phase Disturbances and Particle Filters

14:30-14:50 ORSS Best Paper Winner award

Radio Frequency Identification and Localization by Wearable LoRa for Search and Rescue in Mountains.....120

Giulio M. Bianco (University of Roma Tor Vergata, Italy); Gaetano Marrocco (University of Rome Tor Vergata, Italy)

Long-Range (LoRa) is a low-power wide-area (LPWA) technology which is nowadays the pillar of many IoT (internet of things) systems worldwide. Among the multiple applications that LoRa can enable, the search and rescue (SaR) in the harshest environments wherein standard radiofrequency technologies cannot establish communications is gaining attention. Wearable LoRa radios can significantly foster SaR

an unsupervised domain adaptation regression and an adversarial training module. The first component aims to learn discriminative fingerprinting representations jointly with data collected from seen and unseen scenes. The second one alleviates the distribution divergence of fingerprints collected from seen and unseen scenes, which eventually enables effective knowledge transfer. We evaluate the performance of the proposed method in a challenging setup, the recently released dynamic scenario in the DeepMIMO dataset. The results demonstrate that the proposed method can provide robust and accurate location estimation over variable numbers of the time-varying scenarios, with superior performance over other compared methods.

Thursday May 19 th 2022: PAPER SESSION: MoCap

Room: Mariners

15:15-15:35 UHF-RFID SAR robotic inventory and localization: handling systems vs. multi-antenna solutions

15:35-15:55 Where is the Wall? Radar Imaging-Based Narrowband RFID and Reflector Localization

15:55-16:15 A phase-based relative localization method using a mobile platform with minimal reference tags

UHF-RFID SAR robotic inventory and localization: handling systems vs. multi-antenna solutions.....138

Andrea Motroni, Alice Buffi and Paolo Nepa (University of Pisa, Italy)

UHF-RFID Synthetic Aperture Radar (SAR) Robotic-based localization and inventory systems are now widespread in literature. As known from the SAR theory, the tag localization accuracy along a given spatial direction depends on the antenna motion along the same direction. Indeed, the overall accuracy of the system depends on its capability to also determine the height from the floor of the RFID tag. This paper proposes a comparison between exploiting two antennas at different fixed heights or a single moving antenna hooked to a handling system that describes a vertical motion to localize the tag in the 3D space. The accuracy of the system is investigated with respect to the Signal-to-Noise-Ratio and a discussion on design criteria for the best system is given.

Where is the Wall? Radar Imaging-Based Narrowband RFID and Reflector Localization.....144

Spyridon Peppas, Evangelos Giannelos, Georgios Vougioukas and Aggelos Bletsas (Technical University of Crete, Greece)

Reflections from objects can interfere with RFID localization. This work offers a method for the joint estimation of reflectors' and tags' locations, without any prior knowledge. When block coherence is relatively small and wall reflection relatively strong, the method localizes the tag and the wall/reflector with impressive accuracy, in the order of 5 cm. Narrowband measurements, spread in space can improve the performance of the algorithm, which is important for narrowband UHF RFID. Experimental results also indicate cases where the performance of the method degrades. Hopefully, this work will spark interest on ``classifying'' the environment as line-of-sight or multipath-rich, discovering the order of reflections for the latter case.

A phase-based relative localization method using a mobile platform with minimal reference tags.....150

Zheng Liu (University of Cambridge, United Kingdom (Great Britain)); Zhe Fu (HNUK Consulting Ltd, United Kingdom (Great Britain)); Tongyun Li and Ian White (University of Cambridge, United Kingdom

(Great Britain)); Richard Penty (Cambridge University, United Kingdom (Great Britain)); Michael J Crisp (University of Cambridge, United Kingdom (Great Britain))
A new phase-based localization method for RFID is proposed. The position of a target tag is determined relative to a minimum of 3 reference tags of know locations using phase measurements of the target tag and reference tags along 2 straight trajectories. Experiments show a 2D mean localization error is around 12 cm. Compared to other methods, few reference tags are required, and the only trajectory information required is the distance along the track where phase readings are recorded.