RFID Paperclip Tags	In this paper, we present RFID tags which double as paperclips. These tags use standard metal paperclip bodies as antennas. This way, the paper holding function of each paperclip is augmented by its RFID functionality. Paperclip tags can be designed so that as they slide on or off the stack of papers, their sensitivities change, and hence the tags can be activated or deactivated. We provide a survey of the prior work, describe the concept of a paperclip tag, demonstrate several prototypes accompanied by experimental results, and discuss possible applications and future work.
A Frequency Signature Based Method for the RF Identification of Letters	A method to identify, thanks to RF signals, the letters of the alphabet is presented in this paper. Every letter, when printed, or realized with metallic strips, on dielectric substrate and excited with an electromagnetic wave exhibits unique electromagnetic signature. This signature is unique and characterizes its RCS; consequently, it could be used for its identification/recognition. A frequency domain approach has been applied to a set of letters corresponding to the standard alphabet. Simulation results obtained with CST are presented and discussed in this paper. The experimental results corresponding to Arial font 24mm are carried out and compared to theoretical predictions. Very good agreement between measurement and simulation is observed. Considering the signature of each letter it is possible to establish an algorithm for letter recognition and identification without error
Dual-Band Channel Gain Statistics for Dual-Antenna Tyre Pressure Monitoring RFID Tags	In this contribution we analyse the read probability enhancement using two simple dual-antenna techniques for passive RFID tags for Tyre Pressure Monitoring applications. Our analysis is based on real-world channel measurements carried out with a full vehicle body for different antenna and steering angle configurations. Two frequency ranges were analysed: European UHF band at about 866MHz and 2.45GHz ISM band. Two antenna combining methods were investigated: Antenna selection and power combining. With the latter a read probability enhancement from 49% to 75% is achievable.
Linearly-Tapered RFID Tag Antenna with 40% Material Reduction for Ultra-Low-Cost Applications	The development of RFID technology are requiring high performance and low cost tag antennas than ever before. To meet these demands, linear tapering technique is firstly proposed in the design of planar tag antennas. With this strategy, the current distribution along antenna arms is effectively assigned by varying the antenna line width. Compared with conventional ones, the tapered antennas can reduce the material cost by over 40% not only for PCB (Printed Circuit Board) processed, but also for ink-jet printing produced dipole and meander line antennas, while they still maintain comparable performance. With an identical volume of conducting material, the tapered antennas can achieve better radiation performance than uniform ones on antenna gains and radiation efficiencies. The method has been successfully verified by applying it onto 869 MHz and 2.45 GHz antennas. The influence of the tapering technique on antenna bandwidth is also investigated.

Reference Modulation for Calibrated Measurements of Tag Backscatter	This paper presents an approach for calibrating backscattering measurements from 860-960\,MHz Ultra-High Frequency Radio Frequency Identification (UHF RFID) tags. An S-parameter model is formulated to relate diode switch and antenna input circuit parameters with the scattering performance of the calibration device. Measurements of modulated backscattered power agree with the model to within +/-0.1 dB. Tag backscatter measurements can then be calibrated by comparing them to the reference signal. In an example testbed, the expanded uncertainty of these measurements is estimated to be +/-0.4 dB, compared with uncertainties worse than -0.9 dB, +1.2 dB for methods that calibrate against radar cross section (RCS) standards in the same testbed.
Optimum Wireless Power Transmission through Reinforced Concrete Structure	Wireless embedded sensors are ideally suitable for monitoring concrete structures because of their small size and ability to measure various quantities inside concrete. Wireless power transmission for such sensors embedded in plain/reinforced concrete slab is studied here. The return loss and transmission loss of dipole and patch antennas are studied at typical RFID frequencies. Also, the antennas' performance is investigated for free-space, dry concrete, saturated concrete and reinforced concrete. Our results lead to the determination of the optimum operating frequency as well as the suitable antenna type for wireless powering. Finally, a matched rectification circuit is designed, and typical battery charging times are calculated.
Photovoltaic Enhanced UHF RFID Tag Antennas for Dual Purpose Energy Harvesting	The most significant barrier to improving passive RFID tag performance for both fixed function ID tags and enhanced RFID tags is the limitation on the amount of power that can be harvested for operation. This paper presents a novel approach for incorporating solar harvesting capability into existing passive RFID tags without increasing the parts count or changing the tag assembly process. Our approach employs the tag's antenna as a dual function element in which the antenna simultaneously harvests RF energy, communicates with the RFID reader, and harvests solar energy for auxiliary power. This is accomplished by using low cost, printable photovoltaics deposited on flexible substrate to form part of the antenna's radiating structure. A prototype of a UHF RFID antenna is demonstrated using commercially available thin film, amorphous solar cells. To quantify the improvement in tag performance, Intel's WISP was used as an initial test vehicle. The effective read range of the tag was increased by six times and exceeded the reader's sensitivity limitations. Additionally, the new antenna allowed for sensing and computing operations to take place independent of the RFID reader under typical office lighting conditions.
Exploration of Printing-friendly RFID Antenna Designs on Paper Substrates	Printed RFID antenna is a promising solution for item-level tagging applications. In order to integrate the antenna printing with the package printing process, it is highly preferred that antenna geometries are printed on paper substrates. However, the electromagnetic property and thickness of paper substrates are subject to change. Thus wideband and material-insensitive printed RFID antennas are desired. This paper presents an analytical model for wideband tag antenna designs. Two matching scenarios, i.e. single-tuned match and double-tuned match, are particularly discussed in detail. Two slim-line antennas printed on paper with screen printing technique are proposed. They benefit from the single-tuned/double-tuned bandwidth optimization and demonstrate a great potential in conductive ink saving. Influences of dielectrics on the bandwidth performance are also studied. Both the electromagnetic property and the thickness of the paper substrates have been taken into account. It is demonstrated that the proposed double-tuned antenna can cover the whole UHF RFID band, and can tolerate a considerable variation in the permittivity like 1~9.

Concealable, Low-Cost Paper-Printed Antennas for WISP-based RFIDs	Paper-based, inkjet-printed antennas are proposed in this paper as replacement for the typical antennas used on the WISP RFID tag. These antennas are designed to be as concealable as possible. The designs presented exploit meandered techniques in order to achieve significantly reduced dimensions. In particularly, text-based meandered line techniques are applied to obtain both decreased size and concealment. The inkjet printing has been chosen to provide a substrate, which suits the aim of concealment for the final device. Moreover, this paper shows how the inkjet printing techniques perfectly match the text-based design proposed in terms of high applicability. A comparison with the normal antennas mounted on the WISP is performed.
Optimum Performance for RFID Tag Immersed in Dielectric Media	While RFID tags near metal have been extensively evaluated in the literature, tags on and in dielectric media have received less scrutiny and rigorous evaluation. In this paper, we develop a rigorous theoretical model for the behavior of RFID tags immersed in a dielectric medium using the Uda model and embedded T-match antenna. From this, we are able to investigate a number of criteria for optimality. We find that the simplest optimality condition is not physically realizable, and more realizable models yield several results that are of practical interest. We make two specific recommendations for future work to increase the accuracy and usefulness of this work
A Systematic RFID Application Platform with Integration Capability for Tour and Exhibition	Firstly, due to the characteristics of the tourist attractions, galleries and museums in China, a systematic RFID Application Platform for the tour and exhibition area is presented in this paper. This systematic RFID Application Platform can successfully support the implementation of four typical RFID application subsystems at the same time. These four typical RFID application subsystems can provide intelligent services respectively for four typical application fields which are ticket management, self-help navigation, visit route recording and tracing, as well as intensity monitor and guidance. Secondly, to make use of the existing resources as much as possible, say, make use of the existing animal information management system in the Beijing Zoo as much as possible, we present a mechanism for the systematic RFID Application Platform to integrate the existing systems to the systematic RFID Application Platform. This mechanism integrates the existing system to the systematic RFID Application Platform by using the Distributed Application Integration Framework. The data between the Platform and the existing system is exchanged by using data share and exchange platforms (DXSâ€DXA). Lastly, we present a discussion of the implementation of the systematic RFID Application Platform, by taking the implementation of the platform in the Beijing Botanical Garden and the Beijing Zoo as two application instances. The open architecture of the systematic RFID Application Platform allows deployment of several applications and integration of existing sources of information.

RFID-CoA: The RFID tags as Certificates of Authenticity	The inadequacy of the traditional, digitally encoded RFID tags in combating counterfeiting prompts us to investigate new hardware-enabled technologies that can complement the remote identification functionality of typical RFIDs in an effective and very low cost way. In this paper, we present RFID-CoA; a system that aims to render typical RFID tags physically unique and hard to near-exactly replicate by complementing them with random 3D scattering structures, which serve as certificates of authenticity (CoA). The unique near-field response, or "fingerprint", of the CoAs is extracted as a set of S21 curves by our reader prototype, the design and development details of which are discussed. The results of our performance analysis show that the intersection probability of the false positive and false negative error probability curves is inconceivably small (10^(-200)). The RFID-CoA tag's lifecycle from fabrication site to store is presented, and a strategy to block potential attacks is discussed. Our system bridges the world of RFID with a large array of anti-counterfeiting applications by exploiting "hardware-enabled", modified-material scattering characteristics in the near-field. Based on our multifaceted analysis, we firmly believe that the demonstrated RFID-CoA technology can prove a valuable tool for the low-cost ubiquitous applicability of RFID technology against counterfeiting.
An Analog Front-End Circuit With Dual-Directional SCR ESD Protection for UHF-Band Passive RFID Tag	In this study, we demonstrate an analog front-end (AFE) circuit with electrostatic discharge (ESD) protection for RFID tag at UHF (860~960 MHz) in a 0.18-mm CMOS technology. A dual-directional silicon-controlled-rectifier (dual-SCR) structure is proposed for the ESD protection under the large-signal operation in RFID input. With the well-designed dual-SCR, a large trigger voltage (VT) of ~ 16.9 V is obtained. The parasitic capacitance of the ESD block is only ~ 34 fF, which has virtually no impact on the core circuits at the frequency of interest. The measured ESD levels achieve 3.0 kV human-body-mode (HBM) and 200 V machine-mode (MM), respectively. The RF-DC rectifier in the RFID circuit can generate a stable power supply output about 1.2 V when the RF input power exceeds -7.5 dBm.
Implementation of an Adaptive Leakage Cancellation Control for passive UHF RFID Readers	In this paper the implementation of an automatic leakage cancellation for UHF (Ultra High Frequency) RFID (Radio Frequency Identification) readers is presented. The system architecture and the control algorithms are described in detail. The proposed architecture has been completely implemented and measurements have been carried out for evaluation. The system is demonstrated to adaptively change the control signals to achieve an optimal leakage cancellation for every situation. It is shown that the Control Module keeps the leakage cancellation level between 41 dB and 46 dB, despite the leakage properties being changed by means of a phase shifter. It is also demonstrated that without such a module, the leakage power increases exponentially as the leakage properties change; e.g. from -41 dBm to -3 dBm with 30â—¦ phase shift. Finally, the system time response has been measured and the system operation has been evaluated in a reflective environment.
A Polar Transmitter Architecture with Digital Switching Amplifier for UHF RFID Applications	With amplitude shift keying (ASK) modulation and signal envelope rising falling edge slope requirements, the efficiency of UHF RFID system can be improved by using polar transmitter architecture than using linear power amplifiers. In this work, to ensure maximum integration and meet EPC Class-1 Generation-2 standards, an all digital polar transmitter is proposed and verified by transient signal analysis and random pattern simulation. The timing and signal quality constraints of the digital polar transmitter circuits are extracted. Due to the use of RF frequency low pass sigma delta modulation, the system can be designed in pure digital process without on-chip inductive components. Compared to the 31% theoretical efficiency by using class-A linear power amplifier, a minimum 77% theoretical efficiency can be achieved in this proposed digital RFID system.

A Software Radio-based UHF RFID Reader for PHY/MAC Experimentation	We present the design and evaluation of a flexible UHF RFID reader that enables new PHY/MAC designs to be prototyped and evaluated. Our reader is built using the USRP software radio platform in conjunction with software we developed in the open-source GNU Radio framework. We believe it is the first inexpensive tool that readily enables changes to the physical and MAC layer of RFID systems. We evaluate our reader and show that it can inventory commercial tags out to 6 meters, which approximates the range of a commercial reader with comparable transmit power. We then show two applications of our reader. The first evaluates the real-world performance of the EPC frame selection algorithm and finds that it performs better than expected. Second, using the Intel WISP programmable RFID tag, we implement and evaluate an extension to the Gen 2 standard that results in up to a five-fold increase in sample rate for streamed sensor data.
A Reconfigurable Chipless RFID Tag Based on Sympathetic Oscillation for Liquid-Bearing Applications	This paper reports on the development of a 10-bit flexible chipless RFID tag, which is based on sympathetic oscillations of LC circuits with different resonant frequencies. The optimization of various component combinations is examined for the trade-off of signals and tag sizes. The near field antennas for detecting proposed tags are presented. The measurement results show that the tag possesses remarkable readability for a read range up to 21 cm and more importantly, it is suited for tagging liquid-bearing containers that are widely used in food industry and medical industry. This tag is, furthermore, reconfigurable and compatible with high throughput ink-jet printing process, enabling a potential pathway towards the realization of low cost RFID tags for HF/VHF band applications.
SmartHat: A Battery-Free Worker Safety Device Employing Passive UHF RFID Technology	In many safety-critical applications, battery performance is a significant limiting factor that affects the feasibility of electronic safety devices intended to alert workers to hazardous situations. In particular, battery capacity and lifetime are difficult to predict when safety devices are exposed to extremes of temperature, humidity, shock, and vibration that are common in construction, excavation, drill rigs, and mining work sites. Because battery failure is unacceptable in safety devices, periodic preventative maintenance is required, adding to device cost and labor cost and reducing acceptance of electronic safety devices. Energy harvesting and communications techniques based on passive UHF RFID technology may offer an alternative to battery power for some types of safety alert devices, particularly where hazardous conditions are created by powered heavy equipment. We present a worker safety device designed around a passive UHF RFID platform that derives its operating power from specialized interrogators mounted on heavy equipment. This device is designed to be integrated with plastic hard hats that are commonly used in the construction industry to yield an intelligent hard hat, called a "SmartHat", that delivers an audible alert directly to workers in proximity to a particular piece of equipment. It is addressible using an ASK interrogator-to-tag link, and backscatters confirmation that an alert has been delivered to the worker. We present the design of the SmartHat tag, including a compact printed-circuit vee style antenna, an RF-to-DC power harvesting circuit, and a microprocessor-driven alert speaker. The tag's average operating power while delivering a pulsed alert is 1.8V at 70uA, or 126uW (-9dBm). Its power-up threshold when not delivering an alert is 1.8V at ~10uA. We also present a specialized interrogator device operating under FCC Part 18 rules in the 902-928MHz band that is mounted to a piece of construction equipment to power and communicate with nearby SmartHats. In outdoor testing of the SmartHat tag and its companion interrogator device, +34.6 dBm transmitter output power feeding a 9dBi Yagi antenna (+43.6dBm EIRP) allows for safety alerts to be delivered at distances of up to 19.5 m.

Group Coding of RF Tags to Verify the Integrity of Group of Objects	RFID is an essential technology to uniquely identify physical objects. In many practical business processes using RF tagged objects, we check not only individual objects but also check if there is no missing objects and no extra objects in a group of objects. While individual objects identifications are done by using RFID, group verifications are usually done by looking up a shipping list or corresponding EDI data which usually require a network connection. In this paper, we propose "group coding of RF tags" by which we can verify the integrity of a group of objects just by writing additional data in RF tags' memory. The additional data is computed from unique IDs of objects that belong to the group. We propose fundamental and general group coding. With the fundamental group coding, we can check if the integrity of a group of objects is preserved or not. It is a parity check of hashes of unique IDs in a group. We also propose general group coding by extending the fundamental group coding. With the general group coding, we can estimate the number of missing objects if the integrity of a group is not verified. The strength of the missing number estimation can be controlled by the size of data written to RF tags. It can be considered as an Low Density Parity Check (LDPC) in physical objects. The theory of group coding is confirmed by a numerical simulation and an experiment. It is shown by the simulation and experiment that we can detect 10 missing RF tags out of 20 RF tags with 99.5% reliability by writing 96-bit data into each RF tags besides its 96-bit unique ID.
High Fairness Reader Anti-Collision Protocol in Passive RFID Systems	With the spread of passive Radio Frequency Identification (RFID) systems, new applications will see the coexistence of more and more RFID readers in the same area. As for wireless devices, also RFID readers experience collisions whenever sharing the same communication channel. In this paper, an anti-collision protocol has been proposed in order to solve the reader collision problem. The aims of the proposed solution are: (1) to prevent and avoid collisions among readers; and (2) to limit the access delay of the readers on the channel, while guaranteeing them fairness with respect to the channel contention. The reader anti-collision here proposed, referred as to High Fairness Reader Anti-Collision Protocol (HF-RACP), has been designed taking into account passive tags and their limitations in terms of computational and frequency selectivity capabilities. In this paper, after presenting the reader collision problem and discussing the simulation models and the evaluation methodology used herein, the simulation results for several anti-collision algorithms are shown in terms of collision avoidance and access delay. The comparison with contention-based schemes, like Listen Before Talk (LBT), demonstrates that HF-RACP is more effective against collisions, improves the fairness among readers and considerably reduces the maximum access delay.
Bandwidth Dependence of CW Ranging to UHF RFID Tags in Severe Multipath Environments	In this paper the impact of the signal bandwidth on the performance of frequency modulated continuous wave (FMCW) radar based ranging to ultra high frequency (UHF) radio frequency identification (RFID) tags is investigated. The analyses are based on ultra-wideband (UWB) channel measurements performed in a warehouse portal, which is a severe multipath environment. It is illustrated that the available bandwidth of the usual ISM bands at 900 MHz, 2.5 GHz and 5.8 GHz is only sufficient for a precise RFID tag localization if moderate or low multipath conditions are given. However, in severe multipath channels the ISM bands are unsuited and UWB signals are needed. The results can be considered a lower bound for signal time of flight (TOF) based localization approaches that utilize Fourier or correlation methods for the signal travel time estimation.

Two-Step Locating System for Harsh Marine Port Environments	With the increasing amount of traffic volume on containers, not only identification but also location estimation of assets has become an important issue in logistics automation in a port environment. The locating system is generally composed of tags, readers, and a location engine. Tags are attached to the object and obtain information via communication with readers that are installed around the tags. The engine continuously attempts to estimate the location of tags by using the obtained information. However, if we attempt to apply this common locating system to a port environment for logistics automation, the system performance is degraded because there are many steel obstacles that cause interference in the RF communication and measurement. In this paper, we propose a two-step approach for location estimation in harsh port environments. We divided readers into two types (fixed and mobile readers); hence, the location method operates in two steps for efficient wireless communication and precise measurement. We implemented all the system components and installed these at a real port for evaluation. The communication and estimation success rate is more than 50% better than that of the existing general locating system, and the location precision is substantially increased.
Holographic Localization of Passive UHF RFID Transponders	In this paper a method for holographic localization of passive UHF-RFID transponders is presented. It is shown how persons or devices that are equipped with a RFID reader and that are moving along a trajectory can be enabled to locate tagged objects reliably. The localization method is based on phase values sampled from a synthetic aperture by a RFID reader. The calculated holographic image is a spatial probability density function that reveals the actual RFID tag position. Experimental results are presented which show that the holographically measured positions are in good agreement with the real position of the tag. Additional simulations have been carried out to investigate the positioning accuracy of the proposed method depending on different distortion parameters and measuring conditions. The effect of antenna phase center displacement is briefly discussed and measurements are shown that quantify the influence on the phase measurement.
Experimental Evaluation of RFID Gate Concepts	The extended reader ranges in the UHF band enable many new applications of RFID systems in the logistic sector. However, this also introduces false positive reads which an cause severe performance issues in the backend system. The performance of RFID gates as basic building blocks of RFID systems directly determines the overall behavior of the RFID application. Approaches to improve the robustness of gates with respect to false positive reads include the heuristic incorporation of proximity sensors and the use of multiple antennae. In this paper we present a comparison of three gate concepts which differ in complexity of the underlying algorithms and hardware requirements. We experimentally evaluate the performance of these gates in a standard conveyor belt application under real-world conditions.

Phase Difference Based RFID Navigation for Medical Applications	RFID localization is a promising new field of work that is eagerly awaited for many different types of applications. For use in a medical context, special requirements and limitations must be taken into account, especially regarding accuracy, reliability and operating range. In this paper we present an experimental setup for a medical navigation system based on RFID. For this we applied a machine learning algorithm, namely support vector regression, to phase difference data gathered from multiple RFID receivers. The performance was tested on six datasets of different shape and placement within the volume spanned by the receivers. In addition, two grid based training sets of different size were considered for the regression. Our results show that it is possible to reach an accuracy of tag localization that is sufficient for some medical applications. Although we could not reach an overall accuracy of less than one millimeter in our experiments so far, the deviation was limited to two millimeters in most cases and the general results indicate that application of RFID localization even to highly critical applications, e. g., for brain surgery, will be possible soon.
New Measurement Results for the Localization of UHF RFID Transponders Using an Angle of Arrival (AoA) Approach	In this paper we present new measurement results for an Angle of Arrival (AoA) approach to localize RFID tags at 868 MHz. Self-designed three element antenna arrays, off-the-shelf IDS R901G RFID reader ICs, and UPM Raflatec DogBone RFID tags are used to generate and detect ISO 18000-6C compliant signals. The experimental setup comprises three antenna arrays and a test environment of size 3 times 3 square meters with 25 test points. The AoA is estimated using the phase differences in the complex baseband signals of adjacent antenna elements within one array. A mean positioning error of 0.21 m was achieved for the considered test grid.
Where's The Beep? A Case Study of User Misunderstandings of RFID	Radio frequency identification (RFID) technology is increasingly being incorporated into everyday objects. This case study examines three examplesâ€"credit cards, transit cards, and the U.S. e-Passportâ€"given ubiquitous computing power through the addition of RFID. We explored user comprehension of RFID technology generally and these implementations specifically to understand if and how the addition of this technology transformed subjects' experiences with these objects. By exploring whether or not the new implementations preserved prior expectations of use, we sought to understand what experiences subjects drew upon to create new mental models for engaging with them. As all three of the objects we examine stored personal or financial information, we were specifically interested to understand how individuals dealt with the novel privacy risks introduced by RFID. We distill our findings into general recommendations for designers contemplating embedding ubiquitous computing into everyday objects, particularly those that manage personal or financial information.
A2U2: A Stream Cipher for Printed Electronics RFID Tags	The design of hardware-oriented ciphers has an increasingly important role to play with emerging ubiquitous and pervasive computing devices such as low cost passive Radio Frequency Identification (RFID) tags. The importance of such ciphers are further highlighted by novel manufacturing technologies such as printed ink to develop extremely low cost RFID tags. Such developments bring with it new challenges, especially in terms of providing security both to protect privacy as well as to enable applications dependent on security, such as e-tickets. In this paper, we present a new stream cipher, A2U2, which uses the principles of stream cipher design and approaches from block cipher design. Our lightweight cryptographic primitive design has taken into consideration the extremely resource limited environment of the printed ink tags to develop a cipher that can be implemented with less than 300 gates with the added benefit of high throughput provided by stream ciphers.

Toward Practical Public Key Anti-Counterfeiting for Low-Cost EPC Tags	In this work we report on a practical design, and a working prototype implementation, of a public-key anti-counterfeiting system based on the Electronic Product Code (EPC) standard for supply chain RFID tags. The use of public-key cryptography simplifies deployment, reduces trust issues between the tag integrator and tag manufacturer, eliminates the need for on-line checks by a central authority, and protects user privacy. Contrary to earlier claims of impracticality, we demonstrate that EPC tags are capable of performing full-strength public-key encryption. The crucial element in our system is WIPR, a recently-proposed variant of the well known Rabin encryption scheme, that enjoys a remarkably low resource footprint (less than 4700 gate equivalents for a complete ASIC implementation) -- for a full-strength 1024-bit encryption. Our prototype system consists of an ultra-high frequency (UHF) tag running custom firmware, which communicates with a standard off-the-shelf reader. No modifications were made to the reader or the air interface, proving that high-security anti-counterfeiting tags and standard EPC tags can coexist and share the same infrastructure. Surprisingly, we identify that the time bottleneck is not the tag's computation time: the delay is dominated by inefficiencies in the way the reader implements the EPC standard. The insights from our performance measurements let us identify how a few simple changes to the reader can drastically improve the system throughput.
Reflected Electro-Material Signatures for Self-Sensing Passive RFID Sensors	In this paper, we evaluate realizations for implementing an RFID reflected electro-material signature (REMS) sensor. REMS sensors allow passive measurement, recording, and reading of environmental data such as temperature in a small, low cost device. This paper presents results from two configurations: a three-section lossless microstrip transmission line and a monopole probe inserted into a lossy medium. A neural network is used to recover the permittivity profile in either case, based on the reflection coefficient of the wave backscattered from an RF tag. The neural network incorporating the Levenberg Marquardt back-propagation algorithm is evaluated in terms of average error, regression analysis and computational efficiency in the presence of realistic noise. A unique contribution of this paper is the exploration of REMS using a dissipative electro-material medium. In the lossy case, two real-valued neural networks are integrated together to reconstruct the complex permittivity from the measured reflection coefficient. The approach is verified over the frequency range 4.0 - 5.0 GHz and less than 4% error was observed in presence of white Gaussian noise with 10dB SNR.
RFID Tag Antenna Based Temperature Sensing in the Frequency Domain	The efficiency of cold supply chain operations can be improved with pervasive temperature sensing. In this paper, we investigate the design of a low-cost RFID based temperature threshold sensor that is capable of relating the violation of a temperature threshold to a shift in the optimal operating frequency at which the tag antenna is well matched to the tag IC. This shift is detectable by commercial UHF RFID readers operating in the 902-928 MHz frequency band. We will illustrate how state change information is preserved using a non-electric memory mechanism that works even in the absence of reader transmitted power. We demonstrate that the sensor works reliably for a read distance of over 3 m and in noisy environments.

Temperature-independent passive RFID pressure sensors for single-use bioprocess components	Single-use biopharmaceutical manufacturing requires monitoring of critical manufacturing parameters. However, the lack of reliable single-use sensors prevents the biopharmaceutical industry from fully embracing single-use biomanufacturing processes. We report an approach for temperature-independent pressure sensing in single-use bioprocess components using passive radio-frequency identification (RFID) sensors. An RFID pressure sensor is fabricated by applying a pressure sensitive flexible membrane to an RFID-tag-based transducer and a layer that modulates the electromagnetic field (EMF) generated in the RFID sensor antenna. The sensor signal is modulated upon pressure-induced flexing of the membrane, providing a desired quantitative response of pressure of the fluid during the operation of the single-use component. We demonstrate a temperature-independent RFID pressure sensor that was tested to measure pressures from -5 to 33 psi with the Â± 0.25 psi accuracy after gamma irradiation. Temperature-independent pressure response is provided from the multivariate analysis of the measured impedance of the sensor.
Cooperative CEP-based RFID Framework: a Notification Approach for Sharing Complex Business Events Among Organizations	Through an organizational perspective, an RFID system must provide services for intelligent data management and business events integration among organizations. The widely adopted EPC Network fails to adequately support application services for event stream capture and lacks event communication methods to provide indirect exchange of events in distributed activities of complex event detection. This work presents an RFID software framework whose purpose is to raise the inter-organizational integration of an RFID middleware through cooperative complex event processing (CEP) mechanisms based on event notification services. Experimental results show that the framework improves activities of design and development of RFID applications and adds new features for integrating, managing and sharing RFID event data.