MINISTERO DELL'ISTRUZIONE, DELL'UNIVERSITÀ E DELLA RICERCA

Direzione Generale per il Coordinamento e lo Sviluppo della Ricerca

Relazione Scientifica finale
PRIN 2010-2011 - protocollo: 2010WHY5PR

Coordinatore Scientifico

CHIANI **(cognome)**	Marco **(nome)**	
Professore Ordinario **(qualifica)**	04/04/1964 **(data di nascita)**	CHNMRC64D04H294P **(Codice Fiscale)**

Università degli Studi di BOLOGNA
(Università/Ente)

Dati Progetto

Titolo del progetto:	Etichette e sensori eco-compatibili localizzabili ed identificabili con tecniche wireless a banda ultra larga (GRETA)
Finanziamento MIUR:	Euro 1.156.976
Cofinanziamento:	Euro 495.848
Costo progetto:	Euro 1.652.824

Lista delle Unità di Ricerca (UR)

nº	Responsabile Scientifico	Qualifica	Istituzione	Dip/Ist/Div/Sez
1.	CHIANI Marco	Professore Ordinario	Università degli Studi di BOLOGNA	Ingegneria dell'Energia Elettrica e dell'Informazione "Guglielmo Marconi"
2.	BOZZI Maurizio	Professore Associato (L. 240/10)	Università degli Studi di PAVIA	INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE
3.	ROSELLI Luca	Professore Associato confermato	Università degli Studi di PERUGIA	INGEGNERIA
4.	SANTUCCI Fortunato	Professore Associato confermato	Università degli Studi de L'AQUILA	Ingegneria e scienze dell'informazione e matematica

nº	Responsabile Scientifico	Qualifica	Istituzione	Dip/Ist/Div/Sez
5.	CONTI Andrea	Professore Associato (L. 240/10)	Università degli Studi di FERRARA	Ingegneria

Costo complessivo rendicontato Euro: 1734452.454

Durata effettiva del progetto: 36 mesi

Obiettivo della ricerca eseguita

The evolution of the contemporary society and the developments of information technologies are pushing towards the introduction of systems more and more distributed in the environment. In this context we find the paradigms of the Internet of Things, the Ubiquitous Electronics, and the Autonomous Logistics, which are gaining an increasing popularity. The impact of systems composed of a plurality of low-cost nodes (tags) that are spatially distributed, identifiable, localizable, and capable to sense physical parameters, is potentially enormous in fields such as logistics, security, energy, and health-care.
Nowadays, the identification, localization, and sensing functionalities are offered separately by different wireless technologies such as Radio-Frequency IDentification (RFID), Wireless Sensor Networks (WSN), and Real-Time Locating Systems (RTLS).
It is commonly accepted that the integration of the aforementioned functionalities in a unique low-cost device would extend tremendously the range of applications: however, this is not possible with the existing technologies, considerably different from each other. Hence, such an integration requires to identify new technological solutions and an ex-novo system design. Moreover, it is clear that the employed electronic circuits will have to possess a feature so far considered only marginally and usually ex-post, but key in the future: full compatibility with the environment.
Starting from these considerations, the global objective of GRETA project is the conception of innovative solutions and disruptive technologies aimed at the realization of a distributed system for identification, localization, tracking and monitoring in indoor scenarios, based on environmentally friendly materials, where the tags must be:
1. localizable with sub-meter precision even in indoor scenarios and in the presence of obstacles;
2. small sized (flat, with an area in the order of a few square centimeters) and working without cumbersome batteries;
3. made with recyclable materials, to be integrated in goods, clothes and packaging.

The specific goals followed to attain this main aim have been:

Objective 1: Development of building blocks such as microwave components and antennas on recyclable material substrates. It was tackled the development of microwave components in Substrate Integrated Waveguides (SIW) and System in Package (SiP) technology, their integration (SiP-SIW) and interconnection with communication and energy harvesting systems, built on eco-compatible materials.

Objective 2: Development of RFID autonomous sensors by mean of integration of sensors and energy harvesting circuits within RFID tags. To guarantee the energetic autonomy of the paper-based microsystems, RF energy storage techniques and smart power management systems have been combined. To this purpose innovative antenna topologies on paper substrates have been developed to obtain radiation efficiencies similar to that of traditional substrates without exceeding the layout area.

Objective 3: Models identification and assessment for propagation and backscattering from objects and antennas radiated with UWB signals. An experimental activity has been carried out, using UWB devices, to create a database of re-irradiated waves measurements. Clutter has been modeled in the 3-10 GHz band for typical indoor environments and objects backscattering properties (boxes, pallets, persons) has been characterized.

Objective 4: Development of advanced signal processing techniques for communication, sensing, and clutter and interference effects mitigation. Low-complexity methods to identify and localize tags making use of the cooperative readers network have been designed and analyzed in real environments where interference, clutter, and multipath between transmitter and receiver are present, both taking care of the European regulatory constraints on the radio spectrum usage and the application requirements in terms of high energy efficiency. Particular attention has been given to passive low-complexity solutions based on backscatter modulation.

Objective 5: Localization and tracking algorithms design. Such innovative algorithms rely on the analysis of signals reflected by tags taking into account the complexity/accuracy trade off. Tracking solutions based on perception and mobility models have been investigated. The goal is to ensure a sub-meter localization accuracy in the considered environments with operating range of several meters.

Objective 6: Identification, sensing, and localization/tracking at high accuracy (sub-metric) functionalities integration and final demonstrator. A new concept of integrated wireless network for identification, tracking and monitoring of eco-compatible tags has been developed and finally validated via a demonstrator prototype.

Descrizione della ricerca eseguita

As by Modello A, the following reports have been produced:
- Deliverable D1 (M6) Reference scenarios and applications requirements definition
- Deliverable D2 (M12) Report on the first year of activity
- Deliverable D3 (M24) Report on the second year of activity
- Deliverable D4 (M36) Final project report

These documents are available on the GRETA website www.greentags.eu (PDF with password “gretadeliverables2016”).

Below, a short description of the research, extracted from the deliverables, is reported.

The GRETA project covered both system and technological aspects.
From the system architecture perspective, various potential solutions have been analyzed corresponding to different impacts in terms of energy consumption, complexity and performance. Specifically, both active and passive architectures, the latter based on UWB backscatter modulation, have been considered. For each solution link budget and coverage analysis have been carried out. To overcome the limited coverage obtained when using passive tags, some solutions have been proposed.
A modular tag has been designed, considering the two possibilities of using a stand-alone UWB tag for both localization and communication purposes, and a hybrid UHF-UWB architecture, exploiting a standard Gen.2 RFID tag subsystem, to implement the communications protocol. In this way, the UWB subsystem can be used for accurate localization and ranging algorithms, exploiting the standard off- the-shelf UHF-RFID chip. Furthermore, an enhanced UHF-UWB version has been investigated, where the standard Gen.2 communication protocol is modified to enable a tighter interaction with the UWB part in order to obtain a performance improvement. Three configuration modes have been introduced:
• UWB-Stand-Alone;
• Gen2-UWB;
• Gen2-UWBEnhanced.
The main objective of the final demonstrator is the Gen2-UWB one.
The UWB interrogator structure has been designed, by considering the differences among the three modes, while an important output of this project step has been the final definition of both the UWB-UHF parameters and link budget analysis.
The energy harvesting component design has had to face the simultaneous operations of UHF energy harvesting and UWB communication, by designing a diplexer, which must be able to provide both matching conditions and filtering for the two operating bands.
Both simulations and experimental measurements, considering pro and cons of different circuit implementations, have been carried out to analyze the performance of the UWB backscatter modulator.
The design of the IC backscattering modulator is based on the UMC Low-voltage CMOS 180 nm (or UMC L180) technology. The fundamental advantages of the proposed CMOS technology are its low cost, the low gate delay, lower than 60ps, and the presence of zero and low voltage threshold devices models. The results obtained depend on the trade-off between the parasitics elements of the integrated circuit transistor: its channel resistance R, and drain-source capacitance C.
The adoption of green technologies presents an important improvement in the manufacturing technique of green, eco-compatible and cost effective SIW microwave passive components. The proposed process for the implementation of SIW circuits on paper consists of two steps: the preliminary preparation of the metalized paper substrate and the manufacturing of the circuit, which requires both milling machining and subsequent metallization of the via holes. Beside the fabrication process, the electromagnetic characterization of the involved materials is presented, as well as design and measurements of several prototypes of SIW microwave devices.
The microwave front-end of the proposed tag architecture needs two fundamental blocks: a UWB antenna and a diplexer. The first device is required to collect microwave power in very large frequency band and the diplexer is mandatory to separate the path related to the energy harvesting and the one used by data transmission. Both devices can be implemented on paper substrate, and the two frequency bands adopted are the 868 MHz and the lower part of the UWB channel. This design guarantees 1.7 GHz of bandwidth for data link, in particular from 3.1 to 4.8 GHz.
Considering the selected UWB-UHF hybrid tag, the reader network management protocols may exploit the UWB tag population estimation, in order to make more energy efficient the ISO/IEC 18000-6C standard. It has been

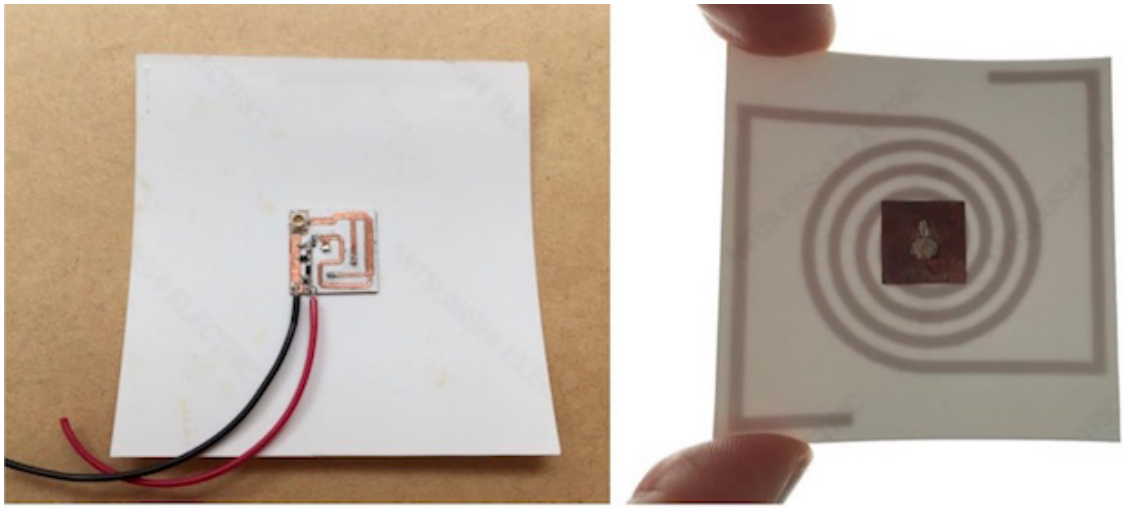
demonstrated that is possible to lower the energy consumption of about 25% by using the hybrid tag with respect to the current standard. Performance analysis shows that the identification time can be efficiently reduced, by exploiting the UWB localization information.
For a wide set of applications, characterized by large-scale tags deployments, single reader systems (one reader-multiple tags) are often unable to cover the entire region of interest, given the limitations of the reader's interrogation range. This motivates the use of multiple readers, geographically distributed and networked in some fashion. Multireader MAC protocols design is challenging given that different kind of collision problems arise. UWB technology can be again conveniently exploited for ranging, localization and tag population estimation and as a support for MAC layer operations.

An ASIC prototype of the tag was designed and implemented in a 0.18 μm CMOS process. The design targeted ultra-low power consumptions and included several interacting sub-systems: a RF part including both UHF and UWB components (UHF rectifier, UHF synchronization extractor, UWB switch), a power conversion/management section, an analog front-end for embedded sensing purposes, and a digital control circuit. The prototypes are available both as unpackaged and packaged devices.
For what concerns the tag implementation, a novel UWB-UHF antenna that integrates in the same structure two radiating elements working in two frequency bands has been designed. The antenna has been fabricated on a paper substrate and tested also in the final demonstrator. The backscatter modulator has been designed in order to operate in the UWB European lower band. The performance has been evaluated in terms of reflection coefficients and power consumption. The UHF front-end has also been implemented and is composed of a power rectifier for Energy Harvesting (EH) and a signal demodulator. The complete front-end is presented and the performance are evaluated with a harmonic balance simulation, by using an input voltage source, and through a transient simulation for the demodulator behavior with a time varying modulated input signal. For what concerns the tag test, the subsystems have been separately tested. In particular, the UWB backscatter modulator performance have been analyzed by measuring the reflection coefficients by means of a vector network analyzer, the power rectifier performance have been analyzed by measuring its output power as a function of the RF input power, and the demodulator has been tested by measuring the comparator output as a function of the RF input power.

In order to prove the performance of the paper tag, several measurements of the prototype parts (antenna, diplexer, and tag) were conducted. Starting from the issues and constraints previously underlined, the main guidelines for the receiver design have been derived, based also on so-far unexplored readers configurations for RFID applications. The signal processing for localization and tracking has also been presented. In particular, a method for the blind selection of representative observations has been introduced to enhance the accuracy of the location information. Furthermore, a range information model for wideband ranging has been proposed and some example of applications for soft-decision ranging presented. Experimental results for the range estimates have been used to validate the effectiveness of the system for sorting objects moving on a conveyor belt. To this aim, localization and tracking of tag positions is performed to determine the order-of-arrival of the stream.

The system integration for multiple reader coexistence and their synchronization has been also investigated. For what concerns the network management protocols, two solutions based on Framed-Slotted ALOHA collision arbitration with dynamic frame adaptation and compressive sensing have been introduced. An alternative approach to the Mode 2 and Mode 3 for the UHF-UWB Tags have been presented based on the integration of the previously described UWB tag with a standard UHF EPC Gen.2 tag.

A final demonstrator of the GRETA test-bed has been developed for assessing the performance of UWB tags based on backscatter modulation. The extensive characterizations of the adopted instrumentation, the configurations, the processing schemes, the setup, and the measurement results, have been described in the project deliverables. For the test-bed, a probe interrogation signal is built in Matlab according to the IEEE 802.15.4a specifications. Then, the signal has been generated by the Tektronix AWG7082C Arbitrary Waveform Generator and transmitted through a UWB antenna. The UWB tag has been emulated with discrete components. At the receiver side, a Vivaldi antenna collects the signal reflected by the environment and the tag. The received waveform is acquired by using a TDS6604 wideband oscilloscope. The samples are then processed to extract the tag antenna mode component from the raw collected data and then estimate the distance between the tag and the reader after de-spreading and code synchronization. The complete collection of experimental results is presented in the deliverables available on the project website.



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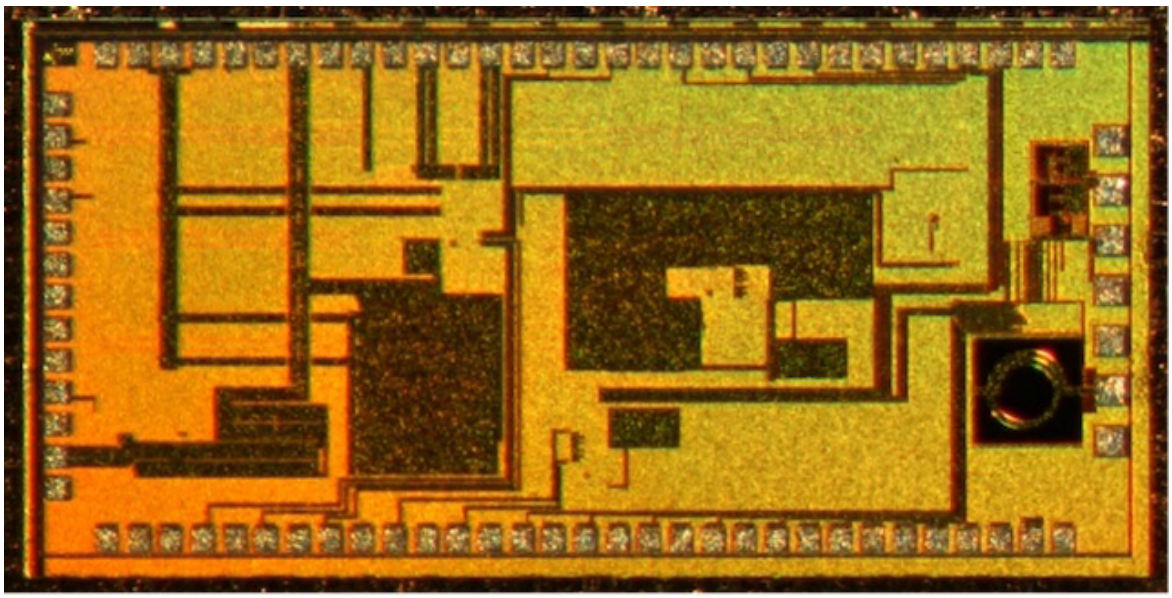

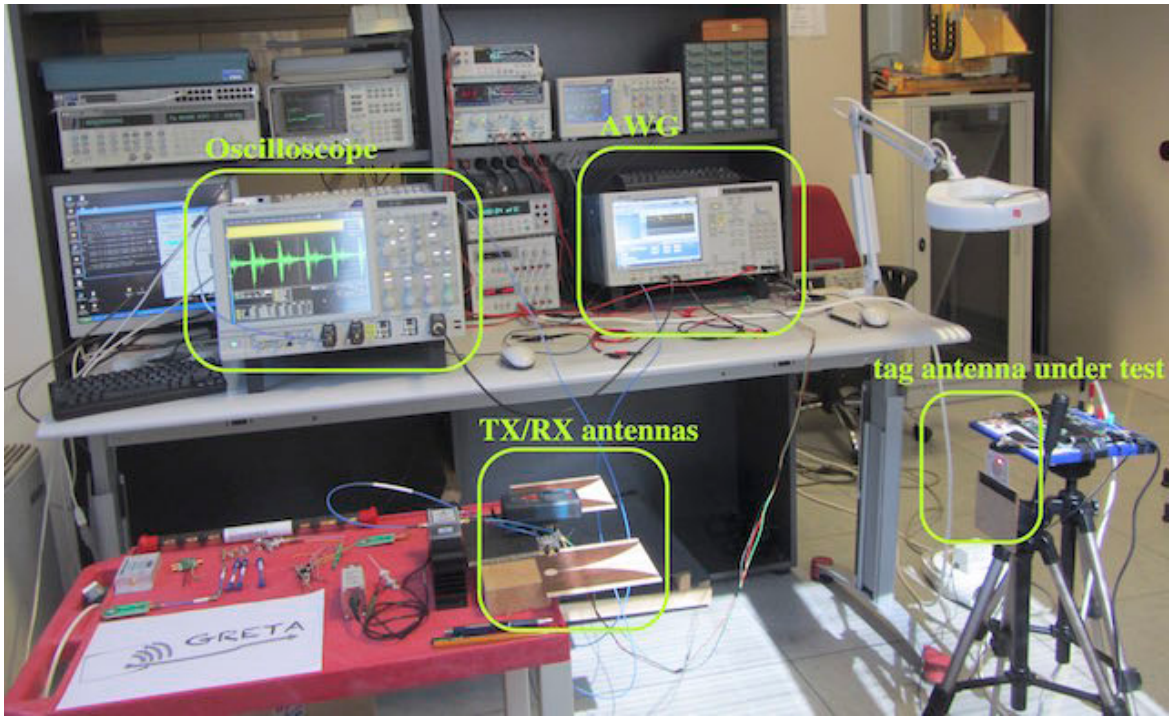
Oscilloscope
AWG
tag antenna under test
TX/RX antennas
GRETA

Problemi riscontrati nel corso della ricerca

Nessun problema riscontrato

Risultati scientifici conseguiti

Tipologia del risultato	Si/No	Descrizione
Realizzazione di nuova strumentazione scientifica e/o di dispositivi avanzati	SI	1. Realization of UWB-UHF antenna working in two frequency bands and fabricated on a paper substrate; 2. Design and implementation of a 0.18 μm CMOS chip including a RF part (UHF rectifier, UHF synchronization extractor, UWB switch), a power conversion section, an analog front-end for embedded sensing purposes, and a digital control circuit; 3. Realization of a final demonstrator to test the feasibility of the Networked-Green RFID system proposed.
Messa in opera di metodologie scientifiche avanzate	SI	1. Indoor localization and tracking algorithms for UWB-UHF RFID systems based on green tags; 2. Development of tags identication and positioning techniques relying on multistatic configuration based on energy showers to further enhance the localization coverage and power up passive tags; 3. Development of sorting algorithms for tags moving on conveyor belts and equipped with green tags. Validation by exploiting measurements data. 4. Development of two network management protocols based on Framed-Slotted ALOHA (FSA) collision arbitration with dynamic frame adaptation and compressive sensing (CS).
Altro	NO	

Prodotti realizzati

Tipologia del risultato	Si/No	Descrizione
Pubblicazioni scientifiche: (indicare pubblicazione con autori, titolo, tipo di pubblicazione -monografia, libro di testo, capitolo di libro, rivista, atti di congressi, corpora, relazioni su invito, - e se soggetta a processo di revisione)	SI	For the complete list of publications including journals and conferences, please refer to the GRETA website www.greentags.eu For space reason, only journals are listed below, while conferences are reported in the "Notes" field. JOURNALS M. Dini, A. Romani, M. Filippi, and M. Tartagni, “A Nanopower Synchronous Charge Extractor IC for Low-Voltage Piezoelectric Energy Harvesting With Residual Charge Inversion,” IEEE Trans. Power

Tipologia del risultato	Si/No	Descrizione
		Electron., Feb. 2016. D. Masotti, A. Costanzo, M. Del Prete, V. Rizzoli, "Time-Modulation of Linear Arrays for Real-Time Reconfigurable Wireless Power Transmission," IEEE Transactions on Microwave Theory and Techniques, Feb. 2016 M. Chiani, “Distribution of the largest root of a matrix for Roy’s test in multivariate analysis of variance,” Jour. of Multiv. Analysis, 2016. B. Sobhani, T. Zwick, and M. Chiani, “Target TOA association with the Hough Transform in UWB Radars,” IEEE Trans. Aerosp. and Electr. Syst., 2016. A. Mariani, A. Giorgetti, and M. Chiani, "Wideband Spectrum Sensing by Model Order Selection," IEEE Trans. on Wireless Comm., Dec. 2015 E. Paolini, G. Liva, and M. Chiani, “Coded slotted ALOHA: A graph-based method for uncoordinated multiple access,” IEEE Trans. Inform. Theory, Dec 2015. M. Del Prete, A. Costanzo, A. Georgiadis, A. Collado, D. Masotti, Z. Popovic, "A 2.45-GHz Energy-Autonomous Wireless Power Relay Node," IEEE Transactions on Microwave Theory and Techniques, Dec. 2015 N. Decarli, F. Guidi, D. Dardari, “Passive UWB RFID for tag localization: Architectures and design,” IEEE Sensors Journal, 2015. A. Mariani, K. Sithamparanathan, and A. Giorgetti, "Periodic Spectrum Sensing with Non-Continuous Primary User Transmissions," IEEE Trans. on Wireless Comm., March 2015. D. Dardari, “Detection and accurate localization of harmonic chipless tags,” EURASIP Journal on Advances in Signal Processing, 2015. F. Guidi, A. Guerra, and D. Dardari, “Personal mobile radars with millimeter-wave massive arrays for indoor mapping,” IEEE Trans. on Mobile Computing, 2015. M. del Prete, A. Costanzo, A.Georgiadis, A. Collado, D. Masotti, and Z. Popovic, “A 2.45 GHz Energy-autonomous Wireless Power Relay Node”, IEEE Transactions on Microwave Theory and Techniques, Dec. 2015 M. Fantuzzi, D. Masotti, A. Costanzo, “A novel integrated UWB-UHF one-port antenna for localization and energy harvesting”, IEEE Transactions on Antennas and Propagation, Sept. 2015 D. Masotti, A. Costanzo, V. Rizzoli, “Smart wireless power transfer operated by time-modulated arrays via a two-step procedure”, International Journal on

Tipologia del risultato	Si/No	Descrizione
		Antennas and Propagation, July 2015 S. Bartoletti, A. Giorgetti, M. Z. Win, and A. Conti, “Blind Selection of Representative Observations for Sensor Radar Networks,” IEEE Trans. Veh. Technol., Apr. 2015. A. Camarda, A. Romani, E. Macrelli, and M. Tartagni, “A 32 mV/69 mV input voltage booster based on a piezoelectric transformer for energy harvesting applications,” Sensors Actuators A Phys., May 2015. M. Dini, A. Romani, M. Filippi, and M. Tartagni, “A Nano-Current Power Management IC for Low Voltage Energy Harvesting,” IEEE Trans. Power Electron., 2015. A. Mariani, A. Giorgetti, and M. Chiani, “Model order selection based on information theoretic criteria: Design of the penalty,” IEEE Trans. Signal Processing, June 2015. D. Dardari, P. Closas, and P. M. Djuric, “Indoor tracking: Theory, methods, and technologies,” IEEE Trans. Veh. Technol., vol. 64, no. 4, pp. 1263–1278, April 2015. Special Section. A. Costanzo, M. Dionigi, D. Masotti, M. Mongiardo, G. Monti, L. Tarricone, R. Sorrentino, "Electromagnetic Energy Harvesting and Wireless Power Transmission: A Unified Approach," Proceedings of the IEEE , vol.102, no.11, pp.1692,1711, Nov. 2014. F. Guidi, N. Decarli, S. Bartoletti, A. Conti, and D. Dardari, “Detection of multiple tags based on impulsive backscattered signals,” IEEE Trans. Commun., 2014. N. Decarli, A. Giorgetti, D. Dardari, M. Chiani, and M. Z. Win, “Stop-and-go receivers for non-coherent impulse communications,” IEEE Trans. Wireless Commun.,vol.13 n.9, pp. 4821–4835, Sep. 2014. M. Chiani, “Distribution of the largest eigenvalue for real Wishart and Gaussian random matrices and a simple approximation for the Tracy-Widom distribution,” Journal of Multivariate Analysis, vol. 129, pp. 69 – 81, 2014. S. Bartoletti, A. Conti, A. Giorgetti, and M. Z. Win, “Sensor radar networks for indoor tracking,” IEEE Wireless Commun. Lett., vol. 3, no. 2, pp. 157–160, Apr. 2014. F. Guidi, C. Roblin, A. Sibille, and D. Dardari, “Analysis of UWB tag backscattering and its impact on the detection coverage,” IEEE Trans. Antennas Propag.,vol. 62, n. 8, , pp. 4292–4303,Aug. 2014. M. Dini, A. Romani, M. Filippi, V. Bottarel, G. Ricotti, and M. Tartagni, “A Nano-current Power Management IC for Multiple Heterogeneous Energy Harvesting Sources,” IEEE Trans. Power Electron., vol. PP, no. 99,

Tipologia del risultato	Si/No	Descrizione
		pp. 1–1, 2014. A. Camarda, A. Romani, and M. Tartagni, “Piezoelectric Transformers for Ultra-low Voltage Energy Harvesting Applications,” Procedia Eng., vol. 87, pp. 1521–1524, 2014. N. Decarli, F. Guidi, and D. Dardari, “A novel joint RFID and radar sensor network forpassive localization: Design and performance bounds,” IEEE J. Sel. Topics Signal Process.,vol. 8, no. 1, pp. 80–95, Feb. 2014, special Issue on Non-cooperative Localization Networks. B. Sobhani, E. Paolini, A. Giorgetti, M. Mazzotti, and M. Chiani, “Target tracking for UWB multistatic radar sensor networks,” IEEE J. Sel. Topics Signal Process.,vol. 8, no. 1, pp. 125–136, Feb. 2014, special Issue on Non-cooperative Localization Networks. N. Decarli, A. Guerra, A. Conti, R. D’Errico, A. Sibille, and D. Dardari, “Non-regenerative relaying for network localization,” IEEE Trans. Wireless Commun., vol. 13, no. 1, pp. 174– 185, Jan. 2014. R. Moro, S. Kim, M. Bozzi, M. Tentzeris, “Inkjet-Printed Paper-Based Substrate Integrated Waveguide (SIW) Components and Antennas,” International Journal of Microwave and Wireless Technologies, Vol. 5, No. 3, pp. 197–204, June 2013. S. Kim, B. Cook, T. Le, J. Cooper, H. Lee, V. Lakafosis, R. Vyas, R. Moro, M. Bozzi, A. Georgiadis, A. Collado, and M. Tentzeris, “Inkjet-printed Antennas, Sensors and Circuits on Paper Substrate,” IET Microwaves, Antennas and Propagation, Vol. 7, No. 10, pp. 858–868, July 16, 2013. R. Moro, S. Agneessens, H. Rogier, A. Dierck, and M. Bozzi, “Textile Microwave Components in Substrate Integrated Waveguide Technology,” IEEE Transactions on Microwave Theory and Techniques, Vol. 63, No. 2, pp. 422-432, Feb. 2015. M. Pasian, M. Bozzi, and L. Perregrini, “Crosstalk in Substrate Integrated Waveguides,” IEEE Transactions on Electromagnetic Compatibility, Vol. 57, No. 1, pp. 80-86, Feb. 2015. R. Moro, S. Moscato, M. Bozzi, and L. Perregrini, “Substrate Integrated Folded Waveguide Filter with Out-of-Band Rejection Controlled by Resonant-Mode Suppression,” IEEE Microwave and Wireless Components Letters, Vol. 25, No. 4, pp. 214-216, April 2015. P. Gamba, E. Goldoni, P. Savazzi, P.G. Arpesi, C. Sopranzi, J-F. Dufour, M. Lavagna. Wireless Passive Sensors for Remote Sensing of Temperature on Aerospace Platforms. IEEE SENSORS JOURNAL, VOL. 14, NO. 11, NOVEMBER 2014.

Tipologia del risultato	Si/No	Descrizione
		S. Kianoush, A. Vizziello, P. Gamba, “Energy-efficient and Mobile-aided Cooperative Localization in Cognitive Radio Networks,” IEEE Transactions on Vehicular Technology, vol. PP, no. 99, June 2015. P. Di Marco, C. Fischione, F. Santucci, and K.H. Johansson, Modeling IEEE 802.15.4 networks over fading channels. IEEE Transactions on Wireless Communications, Volume:13 , Issue: 10, Oct. 2014 K. Witrisal, P. Meissner, E. Leitinger, Y. Shen, C. Gustafson, F. Tufvesson, K. Haneda, D. Dardari, A. F. Molisch, A. Conti, M. Z. Win, "High-Accuracy Localization for Assisted Living: 5G systems will turn multipath channels from foe to friend," IEEE Signal Process. Mag., vol. 33, no. 2, pp. 59 – 70, Mar. 2016. S. Bartoletti, W. Dai, A. Conti, and M. Z. Win, “A Mathematical Model for Wideband Ranging,” IEEE J. Sel. Topics Signal Process., vol. 9, no. 2, pp. 216–228, Mar. 2015, Special Issue on Situational Awareness from Networked Sensors and Social Media. A. Conti, D. Dardari, M. Guerra, L. Mucchi, and M.Z. Win, “Experimental characterization of diversity navigation,” IEEE Syst. J., vol. 8, no. 1, pp. 115–124, Mar. 2014. Alimenti, F.; Mariotti, C.; Palazzi, V.; Virili, M.; Orecchini, G.; Mezzanotte, P. & Roselli, L. "Communication and Sensing Circuits on Cellulose," Journal of Low Power Electronics and Applications, 2015, 5, 151. V. Palazzi, F. Alimenti, P. Mezzanotte, M. Virili, C. Mariotti, G. Orecchini, L. Roselli, "Low-Power Frequency Doubler in Cellulose-Based Materials for Harmonic RFID Applications," Microwave and Wireless Components Letters, IEEE , vol.24, no.12, pp.896,898, Dec. 2014. L. Roselli, N. B. Carvalho, F. Alimenti, P. Mezzanotte, G. Orecchini, M. Virili, C. Mariotti, R. Concalves, and P. Pinho, "Smart surfaces: Large Area Electronics (LAE) systems for IoT enabled by energy harvesting," Proceedings of the IEEE , vol.102, no.11, pp.1723,1746, Nov. 2014. Alimenti, F.; Mezzanotte, P.; Giacomucci, S.; Dionigi, M.; Mariotti, C.; Virili, M.; Roselli, L., "24 GHz Single-Balanced Diode Mixer Exploiting Cellulose-Based Materials," in Microwave and Wireless Components Letters, IEEE , vol.23, no.11, pp.596-598, Nov. 2013 S. Kim, C. Mariotti, F. Alimenti, P. Mezzanotte, A. Georgiadis, A. Collado, L. Roselli, M.M. Tentzeris, "No Battery Required: Perpetual RFID-Enabled Wireless Sensors for Cognitive Intelligence Applications," IEEE Microwave Magazine, vol. 14, n. 5, July-August 2013, pp. 66-77. F. Alimenti, C. Mariotti, P. Mezzanotte, M. Dionigi, M.

Tipologia del risultato	Si/No	Descrizione
		Virili, L. Roselli, "A 1.2 V, 0.9 mW UHF VCO Based on Hairpin Resonator in Paper Substrate and Cu Adhesive Tape," IEEE Microwave and Wireless Component Letters, vol. 23, n. 4, April 2013, pp. 214-216.
Tesi di dottorato collegate	SI	1. "Location and map awareness technologies in next wireless networks", PhD candidate Anna Guerra, supervisor Prof. Davide Dardari (Università di Bologna) 2. "Wireless Localization Systems: Statistical Modeling and Algorithm Design", PhD thesis by Stefania Bartoletti, supervisor Prof. Andrea Conti (Università di Ferrara)
Realizzazione di prototipi	SI	Greta test-bed for experimental system validation. Set-up: - Tektronix AWG7082C Arbitrary Waveform Generator - TDS6604 Oscilloscope - Tx/Rx UWB Antennas (Vivaldi) - Tag antenna realized on paper substrate For a more detailed description, refer to deliverables D3, D4 downloadable from the GRETA website www.greentags.eu (PDF password "gretadeliverables2016")
Brevetti realizzati nell'ambito del progetto	NO	
Sintesi di nuove molecole e/o di materiali artificiali	NO	
Sviluppo di software open source o commerciale (dare titolo del programma, numero di linee di codice, uso previsto, link al website dove il software si trova,…)	NO	
Altro	NO	

Realizzazione di nuovi network e collaborazioni

Tipologia del risultato	Si/No	Descrizione
Accordi di collaborazione con organizzazioni scientifiche nazionali	NO	
Accordi di collaborazione con imprese nazionali	NO	
Accordi di collaborazione con organizzazioni scientifiche internazionali	SI	The research in the framework of the project GRETA has been developed in close collaborations with several major international scientific partners, including: - CEA-LETI (Commissariat à l'Energie Atomique et aux Energies Alternatives, Laboratoire d'électronique des technologies de l'information), Grenoble, FR - MIT-LIDS (Massachusetts Institute of Technology, Laboratory for Information & Decision Systems), Cambridge,

Tipologia del risultato	Si/No	Descrizione
		USA - DLR (German Aerospace Center), Munich, Germany - KTH (Royal Institute of Technology), Sweden
Accordi di collaborazione con imprese internazionali	NO	
Altro	NO	

Note

For the complete list of publications including journals and conferences, please refer to the GRETA website www.greentags.eu

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L. Valentini, M. Cardinali, M. Mladjenovic, P. Uskokovic, F. Alimenti, L. Roselli, J. Kenny, "Flexible Transistors Exploiting P3HT on Paper Substrates and Graphene Oxide Films as Gate Dielectrics: Proof of Concept," Science of Advanced Materials, vol. 5, n. 5, May 2013, pp. 1-4.

L. Aluigi, T.T. Thai, M.M. Tentzeris, L. Roselli, F. Alimenti (2013). "Chip-to-package wireless power transfer and its application to mm-Wave antennas and monolithic radiometric receivers 2013 IEEE Radio and Wireless Symposium." Proceedings of 2013 IEEE Radio and Wireless Symposium 202- 204, In:2013 IEEE Radio and Wireless Symposium. 20-23 January 2013, Austin, TX.

DIFFUSIONE DEI DATI SCIENTIFICI

Informazione

Modalità	Si/No	Descrizione
Pubblicazioni	SI	As by Modello A, the following reports have been produced:

Modalità	Si/No	Descrizione
(escluse quelle con referaggio)		- Deliverable D1 (M6) Reference scenarios and applications requirements definition - Deliverable D2 (M12) Report on the first year of activity - Deliverable D3 (M24) Report on the second year of activity - Deliverable D4 (M36) Final project report These documents are available on the GRETA website www.greentags.eu (PDF with password “gretadeliverables2016”).
Depliant	NO	
CD-Rom	NO	
Altro	SI	• Interview RAI TG3 – Chiani • Interview ClassTV – Dardari • Packology, Rimini 11-14 Giugno – Costanzo • TEF Channel interview, April 4th 2013, Roselli • Dissemination Event at Telecom Italia, Torino, 26/2/2015 "UWB Backscatter Identification and Localization for IoT Energy-Efficient Applications"–(Davide Dardari)

Realizzazione/partecipazione a eventi

Modalità	Si/No	Descrizione
Organizzazione di congressi	SI	• IEEE Workshop on Advances in Network Localization and Navigation (ANLN) at ICC 2013, Budapest, June 9-13 (Dardari, Conti et al.) • IEEE 2nd Workshop on Advances in Network Localization and Navigation (ANLN) at ICC 2014, Sidney, 2014 (Dardari, Conti et al.) • Organization of the Workshop on Localization of energy autonomous devices(Costanzo/Dardari) at EUMW 2014, Rome, Oct. 2014 • IEEE 3rd Workshop on Advances in Network Localization and Navigation (ANLN) at ICC 2015, London, 2015 (Dardari, Conti et al.) • Promoter and co-organizer of the GRETA Special Session at the 5th International EURASIP Workshop on RFID Technology, 22-23 October 2015, Rosenheim, Germany;
Comunicazioni a congressi nazionali	SI	• GTTI/SIEM Ancona 24-26 Giugno – Chiani • Invited talk at the International Conference on Electromagnetics in Advanced Applications (ICEAA 2013), Torino, Italy, September 2013 - Bozzi. • International Summer School on "Emerging Technologies for mm-Wave Passive Components"in Pavia, Sept. 2013 – Lecture on "Substrate Integrated Waveguide (SIW) Technology"– Bozzi
Comunicazioni a congressi internazionali	SI	The list of attended conferences where GRETA project presentations have been given is reported in "Note", previous section. Below a partial list of additional workshops and events. A full list is reported in "Note" of the current section. • IEEE Workshop on Advances in Network Localization and Navigation (ANLN) at ICC 2013, Budapest, June 9-13 (Dardari, Conti et al.) • Seminar at Universitè Catholique Louvain, 3/7/2013 - Dardari • Costanzo, D. Masotti "CAD Tools and Techniques for Co-Design of Multi-Source Energy Autonomous Systems", Digest of IEEE EuMC 2013 Workshop W03: Energy harvesting, circuit and system advances for

Modalità	Si/No	Descrizione
		battery-less Radio Frequency Identification (RFID) systems, Norimberga, October, 2013 • IEEE 2ndWorkshop on Advances in Network Localization and Navigation (ANLN) at ICC 2014, Sidney, 2014 (Dardari, Conti et al.) • Organization of the Workshop on Localization of energy autonomous devices(Costanzo/Dardari) at EUMW 2014, Rome, Oct. 2014 • Best student paper award A. Guerra, N. Decarli, F. Guidi, and D. Dardari, "Energy sprinklers for passive UWB RFID,"in IEEE International Conference on Ultra-Wideband, ICUWB 2014, Paris, France, Sep 2014 • Davide Dardari, Andrea Conti, "Localization of passive tags using UWB backscatter modulation"at Workshop on Localization of energy autonomous devices (EuMW 2014) • Costanzo, D. Masotti, "Object selection and detection by monopulse RADAR", Digest of IEEE EuMC 2014 Workshop WS6: Localization of energy autonomous devices, Roma, October, 2014 • D. Masotti, "Time-modulated arrays for smart WPT", oral presentation at 4th meeting of COST – WIPE (action IC1301), Graz, 30-31 March, 2015 • Costanzo, D. Masotti, M. Del Prete, R. Trevisan, "Potential space applications of two far-field and near-field WPT systems",invited at International Microwave Symposium (IMS) 2015 Workshop WFK: New technology application for Space, Phoenix, May, 2015 • Costanzo, D. Masotti, M. Fantuzzi, "RF-baseband nonlinear co-design of zero-power harvesting systems",invited at International Microwave Symposium (IMS) 2015 Workshop WFC: Nonlinear RFID systems, characterization and exploitation, Phoenix, May, 2015 • Costanzo , Imperial college, London (UK) 14 ottobre 2015 Invited lecture for PhD students • Costanzo, "COMBINING UWB- AND UHF- RFID FOR LOCALIZATION AND SENSING", 2nd European School on RFID Harvesting and sensing, Technosite, Valence (France) 27 ottobre 2015. • Costanzo, "UWB-UHF circuit and system solutions for simultaneous wireless powering, tracking and sensing at ultra-low power", at the European school of Antennas (ESOA): Wireless networks: from Energy harvesting to information processing, CTTC, Barcellona 10 novembre 2015. • Costanzo, D. Masotti, M. Fantuzzi "Combining UWB- and UHF-RFID for localization and sensing", invited in Workshop "European Initiatives to Develop Wireless Power Supply for Sensor Node Evolution"in IEEE Radio and Wireless Week 2016 (RWW), 24-27 Jan. 2016. • R. Trevisan, A. Costanzo, "Circuit Level Design of Systems for Simultaneous Data and Power Transfer",invited at International Microwave Symposium (IMS) 2016 Workshop WFJ: Theory and Application of Wireless Power Transfer, San Francisco, June, 2016 • Florian, F. Mastri, R.P. Paganelli, D. Masotti, A. Costanzo "Power amplifier load variation in high efficiency near-field inductive resonant wireless power transfer links with variable distance between transmitter and receiver",invited at International Microwave Symposium (IMS) 2016 Workshop WFK: Power Amplifiers with Variable Load, San Francisco, May, 2016 • Seminar at the Universidad Miguel Hernández de Elche, Spain (April 2013) – Bozzi • Seminar at the Faculty of Sciences of Tunis, Tunisia (July 2013) - Bozzi • Seminar at the Ghent University, Ghent, Belgium, October 2013 - Bozzi • Invited talk at the 2014 IEEE Topical Meeting on Wireless Sensors and Sensor Networks (WISNET 2014), Newport Beach, California, USA, January 2014 - Bozzi • Seminar at the Tianjin University, Tianjin, China, March 2014 - Bozzi • Seminar at the Universidad de Cantabria, Santander, Spain, April 2014 - Bozzi • Plenary keynote speech at the 15th International Conference on Electronic Packaging Technology (ICEPT 2014), Chengdu, China, August 2014 - Bozzi. • Invited talk at the XXXI General Assembly of the International Union of Radio Science (URSI GA 2014), Beijing, China, August 2014 - Bozzi. • Invited talk at the 35th Progress In Electromagnetics Research Symposium

Modalità	Si/No	Descrizione
		(PIERS 2014), Guangzhou, China, August 2014 - Bozzi. • Seminar at the Chinese University of Hong Kong (CUHK), Hong Kong, August 2014 - Bozzi. • Invited talk at the BioSense Center, University of Novi Sad, Novi Sad, Serbia, February 2015 - Bozzi. • Short Course "Substrate Integrated Waveguides" at EuMC 2013, Nuremberg, Germany, October 6, 2013. - Bozzi • Focused Session "Microwaves in Agriculture, Environment and Earth Observation (MAGEO)" at the EuMC 2013, Nuremberg, Germany, October 6-11, 2013– Bozzi
Altro	NO	

Divulgazione scientifica on-line

Modalità	Si/No	Descrizione
Creazione di siti	SI	The website GRETA: www.greentags.eu contains the project deliverables (PDF, password "gretadeliverables2016"), and the list of publications and dissemination activities (public).
Creazione di pagine web	SI	The website GRETA: www.greentags.eu contains the project deliverables (PDF, password "gretadeliverables2016"), and the list of publications and dissemination activities (public).
Altro	NO	

Note

The website GRETA:

www.greentags.eu

contains the project deliverables (PDF, password "gretadeliverables2016"), and the list of publications and dissemination activities (public).

Below, the list of the dissemination activities.

DISSEMINATION ACTIVITIES

GTTI/SIEM Ancona 24-26 Giugno – Chiani

Interview RAI TG3 – Chiani

Interview ClassTV – Dardari

Packology, Rimini 11-14 Giugno – Costanzo

• IEEE Workshop on Advances in Network Localization and Navigation (ANLN) at ICC 2013, Budapest, June 9-13

(Dardari, Conti et al.)
• Seminar at Universitè Catholique Louvain, 3/7/2013 - Dardari
• Costanzo, D. Masotti "CAD Tools and Techniques for Co-Design of Multi-Source Energy Autonomous Systems", Digest of IEEE EuMC 2013 Workshop W03: Energy harvesting, circuit and system advances for battery-less Radio Frequency Identification (RFID) systems, Norimberga, October, 2013
• IEEE 2ndWorkshop on Advances in Network Localization and Navigation (ANLN) at ICC 2014, Sidney, 2014 (Dardari, Conti et al.)
• Organization of the Workshop on Localization of energy autonomous devices(Costanzo/Dardari) at EUMW 2014, Rome, Oct. 2014
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• Costanzo, D. Masotti, "Object selection and detection by monopulse RADAR", Digest of IEEE EuMC 2014 Workshop WS6: Localization of energy autonomous devices, Roma, October, 2014
• D. Masotti, "Time-modulated arrays for smart WPT", oral presentation at 4th meeting of COST – WIPE (action IC1301), Graz, 30-31 March, 2015
• Costanzo, D. Masotti, M. Del Prete, R. Trevisan, "Potential space applications of two far-field and near-field WPT systems",invited at International Microwave Symposium (IMS) 2015 Workshop WFK: New technology application for Space, Phoenix, May, 2015
• Costanzo, D. Masotti, M. Fantuzzi, "RF-baseband nonlinear co-design of zero-power harvesting systems",invited at International Microwave Symposium (IMS) 2015 Workshop WFC: Nonlinear RFID systems, characterization and exploitation, Phoenix, May, 2015
• Costanzo , Imperial college, London (UK) 14 ottobre 2015 Invited lecture for PhD students
• Costanzo, "COMBINING UWB- AND UHF- RFID FOR LOCALIZATION AND SENSING", 2nd European School on RFID Harvesting and sensing, Technosite, Valence (France) 27 ottobre 2015.
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• Costanzo, D. Masotti, M. Fantuzzi "Combining UWB- and UHF-RFID for localization and sensing", invited in Workshop "European Initiatives to Develop Wireless Power Supply for Sensor Node Evolution"in IEEE Radio and Wireless Week 2016 (RWW), 24-27 Jan. 2016.
• R. Trevisan, A. Costanzo, "Circuit Level Design of Systems for Simultaneous Data and Power Transfer",invited at International Microwave Symposium (IMS) 2016 Workshop WFJ: Theory and Application of Wireless Power Transfer, San Francisco, June, 2016
• Florian, F. Mastri, R.P. Paganelli, D. Masotti, A. Costanzo "Power amplifier load variation in high efficiency near-field inductive resonant wireless power transfer links with variable distance between transmitter and receiver",invited at International Microwave Symposium (IMS) 2016 Workshop WFK: Power Amplifiers with Variable Load, San Francisco, May, 2016
• Seminar at the Universidad Miguel Hernández de Elche, Spain (April 2013) – Bozzi
• Seminar at the Faculty of Sciences of Tunis, Tunisia (July 2013) - Bozzi
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• Focused Session "Microwaves in Agriculture, Environment and Earth Observation (MAGEO)" at the EuMC 2013, Nuremberg, Germany, October 6-11, 2013– Bozzi
• Workshop "Substrate Integrated Waveguide Component and System" at the International Wireless Symposium (IWS 2014), Xi'an, China, March 24-26, 2014 - Bozzi.
• Invited seminary"'Green RFID': an enabling technology towards the Internet of Things (IoT) world" given at the following institutions:
o Tsingua University (Beijing, China)
o Beihang University (Beijing, China)
o Jaotong University (Beijing, China)
o North China University (Taiyuan, China)
o Shanxi University (Taiyuan, China)
o Taiyuan University of Technology (Taiyuan, China)

• Invited speech at the IEICE 2013 "RFID, WPT and Energy Harvesting made "green": concurrent technologies for the future networked society"17-20 settembre 2013, Fukuoka, Giappone
• Focus Session "Novel Materials and Technologies for Microwave Components" at the 35th Progress In Electromagnetics Research Symposium (PIERS 2014), Guangzhou, China, August 25-28, 2014 - Bozzi.
• Workshop "New Trends in Substrate Integrated Circuits (SICs)" at the 44rd European Microwave Conference (EuMC 2014), Rome, Italy, October 5-10, 2014 - Bozzi.
• Special Session "Paper-based Microwave Circuits and Antennas" at PIERS 2013, Stockholm, Sweden, August 12-15, 2013.– Bozzi
• The GRETA project has been mentioned and briefly illustrated within the presentations that Fortunato Santucci has made at Mid-Sweden University in Sundsvall, Sweden (August 20th, 2015) and at ENSEA in Paris (October 14, 2015).
• Roberto Valentini, invited speech at the Donald Bren School of Information and Computer Science, University of California, Irvine. "Presentation of the Doctoral research activity". March 20, 2015.
• M.Faraone, R.Alesii, S.Tennina, F.Graziosi, "Device Free Patients Localization in Controlled Indoor Environments", IEEE CAMAD2014, December 1-3, 2014, Athens, Greece
• March 2015 – A. Conti (UNIFE) together with M. Z. Win (MIT), IEEE Tutorial, "Network Localization and Navigation: from Theory to Practice,"IEEE WCNC'15, New Orleans
• February 2014 – A. Conti (UNIFE), IEEE Distinguished Lecture, "Network Localization of Tagged and Untagged Objects"at Nanyang Technology University, Singapore
• February 2014 – A. Conti (UNIFE), IEEE Distinguished Lecture, "Network Localization of Tagged and Untagged Objects"at Institute for Infocomm Research A*STAR, Singapore
• October 2014 - Davide Dardari (UNIBO), Andrea Conti (UNIFE), "Localization of passive tags using UWB backscatter modulation"at Workshop on Localization of energy autonomous devices (EuMW 2014)
• June 2013 - A. Conti (UNIFE), Invited talk at the 2013 IEEE Communications Theory Workshop, Phuket, Thailand. Talk's title "Network Localization in the Presence of Backscattering Interference,"a joint work with DavideDardari (UNIBO), Nicolò Decarli (UNIBO), Francesco Guidi (UNIBO), and Stefania Bartoletti (UNIFE)
• June 2013 - A. Conti (UNIFE), Invited talk at Chulalongkorn University, Bangkok, Thailand. Talk's title "Network Localization of Tagged and Untagged Objects,"a joint work with colleagues reported above
• September 2013 - A. Conti (UNIFE). Keynote Speech entitled "Network Localization"at IEEE ISPCC'13, JUIT, India

Tabella riassuntiva delle spese sostenute per Unità Operativa

nº	Responsabile Scientifico	Spesa A (A.1-A.2)	Spesa A.4	Spesa B	Spesa C	Spesa D	Spesa E	TOTALE
1.	**CHIANI Marco**	175.912,24	122.501,97	179.048,526	77.535,73	17.499,97	35.586,73	**608.085,166**
2.	**BOZZI Maurizio**	116.353	89.559,47	123.547,482	16.374,62	23.898,39	29.659,84	**399.392,802**
3.	**ROSELLI Luca**	77.894,46	59.492,61	82.432,242	8.892,56	20.323,17	18.789,44	**267.824,482**
4.	**SANTUCCI Fortunato**	63.484,18	63.051,19	75.921,222	4.298,68	629,6	10.509,82	**217.894,692**
5.	**CONTI Andrea**	62.133,43	88.651,14	90.470,742	0	0	0	**241.255,312**
	Totale	**495.777,31**	**423.256,38**	**551.420,214**	**107.101,59**	**62.351,13**	**94.545,83**	**1.734.452,454**

Risorse umane complessivamente ed effettivamente impegnate

	Mesi/persona TOTALE
Personale DIPENDENTE a tempo indeterminato	109,757
Personale DIPENDENTE a tempo determinato	0
Personale non dipendente: solo personale con contratto attivato con l'Ateneo/ente cui afferisce l'unità di ricerca	84
Personale non dipendente a carico esclusivo del progetto	208,293
Totale	**402,05**

	Mesi/persona TOTALE
Altro personale	0
Totale	**402,05**

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