PhD thesis details:

Host laboratory: CITI

Contact : guillaume.villemaud@insa-lyon.fr

Titre: Optimized Wireless Power Transfer for IoT devices in Industry 4.0 or Smart Buildings

Context and background

Wireless Power Transfer (WPT) is an old principle to remotely feed a device using radiowave, already proposed by Tesla. But during a long time it was intrinsically restricted to very short ranges or using high power sources. Recent advances in low-power electronics as well as waveform optimization now pave the way to a new generation of long range WPT [1-2].

For long range WPT, the farfield radiated electromagnetic fields must be captured by the receiving device to be fed with a power level larger than its sensitivity. This sensitivity is directly linked to the architecture of the rectifying circuit used in this receiver, and then the amount of harvested energy is depending on the efficiency of this rectifier. But if we enlarge the view of the whole system, the received power is depending on the source, the radio channel, and the position of the receiver. Therefore, most of the recent works on optimizing long range WPT are based on a joint optimization of the source and the receiver [3-5]. The CITI laboratory has also proposed several original ways of performing such an optimization depending on the whole system study [6-8].

Keywords

Wireless Power Transfer, IoT, LoRa, Energy Consumption, Waveform Optimization, Batteryless.

Main objectives

This PhD thesis will focus on the optimization of WPT based on a systemic view of the whole WPT link (source, radio channel and receiver) in two main high potential scenarios: wireless monitoring of industrial machines for industry 4.0 and communications in ventilation ducts for Smart Buildings. In the first case, the main challenge will be to wirelessly feed IoT nodes based on a LoRa specific protocol (developed in a previous European project). The potential of using a modified LoRa Gateway as the source (or a combination of several sources) will be investigated. In the second case, we will reuse our results on ventilation duct propagation properties, to propose an optimized way of feeding smart sensors with a highly increased range. In both cases, the PhD student will perform a complete study combining theory, system-level simulations and experimentations.

Therefore, the goal of this thesis is threefold:

- To realize an extensive state-of-the-art for farfield WPT optimization, considering different frequency bands, waveforms, and one or several sources (dedicated or not);
- To propose, study and optimize specific architectures, at least one dedicated to each target scenario (Industry 4.0 and Smart Buildings);
- To establish some reference scenarios to be tested with a proof of concept, develop such experimental proofs to validate the actual potential and efficiency of the proposed architectures.

Supervisors

Guillaume Villemaud (HDR, 50%), Florin Hutu (50%)

Dissemination

Of course, a large dissemination of the proposed works will be ensured in international conferences, high quality journals and potentially via patents. Our goal is also to collaborate in COST actions, particularly we were strongly involved in the IRACON action and therefore if the new INTERACT proposal is accepted this will offer a good place of interaction with other European partners. Possible collaborations are also envisaged with University of Bologna (Italy), CTTC (Spain) and University of Oulu (Finland). Potential industrial partners: Spie ICS, Atlantic, GreenWake technologies. Moreover, this work could be naturally applied to IoT scenarios, therefore the context of the SPIE IoT Chair hosted at the CITI laboratory could be a rich place of interaction and collaboration.

Expected profile of the candidate

Master of Sciences or Engineering degree in Telecommunications or Electrical Engineering with a strong background in radiocommunications, RF architectures and signal processing.

References

[1] COST Action IC1301 Team, "Europe and the Future WPT", IEEEMicrowaveMagazine,18, 4, June 2017, pp. 56-87.2.

[2] C. R. Valenta and G. D. Durgin, “Harvesting Wireless Power,” IEEE Microwave Magazine, 15, 4, June 2014, pp.108-120.3.

[3] N. Pan, M. Rajabi, D. Schreurs and S. Pollin, “Multi-sineWireless Power Transfer with a Realistic Channel and Rec-tifier Model,” IEEE Wireless Power Transfer Conference, June 2017.4.

[4] B. Clerckx and E. Bayguzina, “Waveform Design for Wireless Power Transfer,” IEEE Transaction on Signal Processing, 64, 23, March 2016, pp. 6313 - 6328.5.

[5] J. Kim, B. Clerckx and P.D. Mitcheson, “Prototyping and Experimentation of a Closed-Loop Wireless Power Transmission with Channel Acquisition and Waveform Optimization,” IEEE Wireless Power Transfer Conference, May 2017.

[6] R. Rousseau, F. Hutu and G. Villemaud," On the Use of Vector Fitting and State-Space Modeling to Maximize the DC Power Collected by a Wireless Power Transfer System," 2nd URSI Atlantic Radio Science Conference, May 2018.

[7] Regis Rousseau, Guillaume Villemaud, and Florin Hutu, "State-Space Model Representation to Characterize an Energy-Harvesting Circuit", URSI Radio Science Letters, vol. 2, 2020

[8] Florin Hutu, Vincent Lechappe, Guillaume Villemaud, and Michael Di Loreto, "Study of Distributed Beamforming for Wireless Power Transfer in the Presence of RF Impairments", URSI Radio Science Letters, vol. 2, 2020