Waveform optimization for enhancing wireless power transfer efficiency

Ragnar Thobaben ragnart@kth.se , Boules Atef Mouris Nessim boules@kth.se .

Introduction:

Wireless power transfer (WPT) has been attracting much attention recently. It is considered to be the only way to have true wireless devices by eliminating the need for wires [1]. A typical WPT system consists of a wireless power transmitter and rectifying antenna (rectenna). The major challenge that WPT faces is the output DC power from the rectenna which depends on the RF-to-DC conversion of the rectifier circuit. It has been discovered that high peak-to-average power ratio (PAPR) can exploit the non-linear nature of the rectifier circuit and boost the RF-to-DC conversion efficiency of the rectenna [2].

The goal of this project is to model and optimize the performance of the rectifier under two different types of high PAPR signal excitations: square power-optimized waveforms (POW) and Gaussian POWs [3], and compare them to multisine excitation. In addition, it is required to model and evaluate the impact of these signal excitations on co-existing communication systems. Performance evaluations are done through mathematical modeling, circuit simulations, and experimental measurements in real scenarios.

Thesis Project outline:

This project gives the student the opportunity to develop a solid understanding of wireless systems starting from mathematical modeling, going through circuit analysis, antenna design and experimental measurements. In order to do measurement studies, the student will acquire the required knowledge to work with software defined radios such as NI-USRPs and/or Ettus radios. After the completion of the project, the student will have the chance to publish a research paper.
The expected outcomes of this project in summary are:

1) Mathematical modeling and optimization of the WPT system under different signal excitations listed above.
2) Designing an efficient rectenna and validating the mathematical model through circuit simulations.
3) Implementing the WPT system using software defined radios and the designed rectenna (an existing rectenna at ETK could be an alternative to fabricating a new one).
4) Evaluating the impact of square and Gaussians POWs on co-existing communication systems through mathematical modeling and measurements.

Requirements

The candidate is expected to have a good theoretic knowledge in the fields of signal processing, wireless communications, antenna theory, circuit theory, and optimization theory (e.g. linear and/or convex optimization).
Knowledge or previous experience with software defined radios and antenna measurements is a plus but not necessary.

References:

[1] C. R. Valenta and G. D. Durgin, "Harvesting Wireless Power: Survey of Energy-Harvester Conversion Efficiency in Far-Field, Wireless Power Transfer Systems," in *IEEE Microwave Magazine*, vol. 15, no. 4, pp. 108-120, June 2014.
[2] A. Boaventura, A. Collado, N. B. Carvalho and A. Georgiadis, "Optimum behavior: Wireless power transmission system design through behavioral models and efficient synthesis techniques," in *IEEE Microwave Magazine*, vol. 14, no. 2, pp. 26-35, March-April 2013.
[3] M. S. Trotter and G. D. Durgin, "Survey of range improvement of commercial RFID tags with Power Optimized Waveforms," 2010 IEEE International Conference on RFID (IEEE RFID 2010), Orlando, FL, 2010, pp. 195-202.