RF Wireless Powering: Enabling Extended Autonomy in Wireless Devices

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Batteries in wireless devices contribute significantly to toxic waste generation and incur maintenance expenses. CSEM, ETHZ and EPFL collaborate on wirelessly transfer energy to small wireless systems (sensors, computer peripherals, wearables, disposable assays, etc.) for achieving battery-free systems. As a first step, future system specifications have been identified both for the transmitter module as well as for the receiver. Concepts for efficient RF rectifiers and Tx/Rx antennas are proposed.

Wireless power transmission consists of transmitting electrical energy from a power source to an electrical load, without interconnecting wires. Wireless Power Transfer (WPT) offers advantages that reach beyond cost savings and convenience. Some situations, settings, and uses are inherently incompatible with traditional wired electrical sources. This encompasses industrial scenarios demanding energy transmission spanning centimeters to meters and the deployment of small sensor networks in environments where wiring is impractical or impossible.

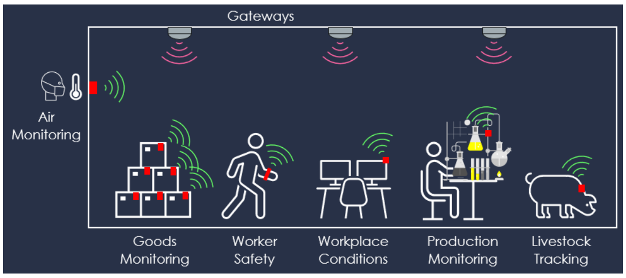

Figure 1: A vision of WPT for IoT system (purple: source of energy, green: receiver of energy).

Although solutions that harness energy from sources like ambient light, vibrations, or thermal gradients have been available for an extended period, their effectiveness is hampered by the sporadic nature of these sources, resulting in reliability issues. Wireless power transfer (WPT) has several unique features such as scalability, flexibility in device placement, adaptability, contactless operation, and ease of integration with potentially important and far-reaching benefits for clean energy and carbon emissions reductions. WPT system integration into a variety of devices, including IoT sensors, wearables, and medical implants, without the need for physical connectors or charging pads makes them potentially battery-free. This further radically reduces e-waste for these trillion-scale devices.

We aim at efficiently transmit RF wireless power transmission to small mobile IoT devices (remote sensing and actuation). The system is expected to meet various specifications, including accepting a wide power supply range, ensuring satisfactory transfer efficiency across a broad spectrum of harvested power and robustness regarding the wireless sensor's location. Millimetre-wave frequencies (e.g., 24 GHz or higher) are a promising band that allow the use of an intelligent transmitter with beamforming capabilities, allowing for smaller receiving antennas and less bulky receivers.

The basic principle of RF-WPT is to convert RF signals from either ambient or added power sources to DC electrical current. An important performance aspect of a dedicated RF-energy transfer is the ability to maintain RF-to-DC conversion efficiency over a wide range of operating conditions, including variations of input power and output load resistance. RF-WPT solutions efficiency are highly dependent on RF input power. Moreover, sustaining reliable operations within the regulatory constraints of possible radiation power limits is challenging.

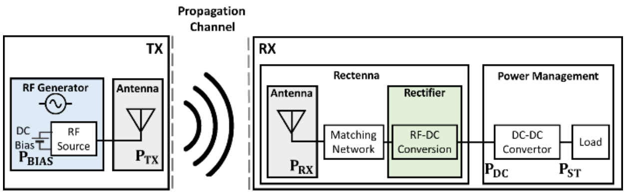

Figure 2: Typical RF-WPT block diagram.

The receiving chain includes a novel concurrent array structure, cross-coupled with harmonically terminated gates, to extract beneficial aspects of both synchronous and cross-coupled architectures. The key advantage of the proposed solution will be its flat efficiency curve over a wide input power range, as well as the superiority of existing designs in terms of adaptation to harsh radiation.

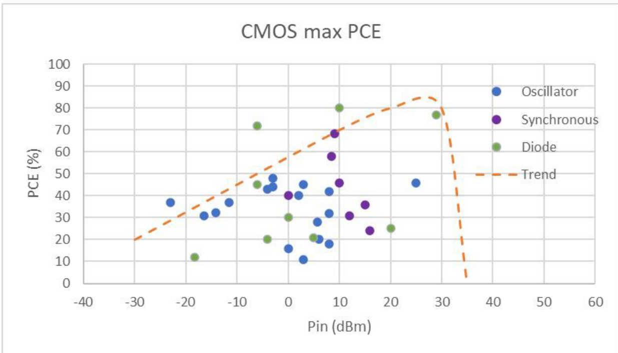

Figure 3: Power conversion efficiency comparison with respect to input level for different structures.

A 2-D beamforming network and antenna system will be implemented in TX, to allow for full coverage in indoor applications. The proposed antenna solution on the RX side is a relatively high-performance and wide-coverage antenna, which minimizes the importance of the device orientation.

In combination with the development of sustainable electronics, RF-WPT has the potential to achieve significant economic and societal impacts, including cost savings, environmental benefits, and improved convenience and safety. The disruption could be compared to the move from fixed-to-fixed points wireless links to fixed-to-mobile wireless links in telecommunication.

This project is still in its early phase. So far, a few novel rectifier subcircuit have been designed and successfully characterized (51.7% efficiency was attained, slightly below the theoretical estimate of 53%). These results will be used in advancing the development of a complete rectification chain. Additionally, a novel high-gain 3D-printed antenna concept has been designed and prototyped. The antenna characterization is ongoing.