Adaptive Wireless Energy Harvesting Systems using Focused Antenna Arrays

Daniel Schemmel and Payam Nayeri
EECS, Colorado School of Mines, Golden, CO 80401, USA

Wireless transmission of energy has no bounds. In wireless power transfer, a transmitter connected to a power source beams the energy to one or more receivers wirelessly, where it is converted back to an electrical current and then used. With the birth of the Internet of Things (IoT) and the growing popularity and applications of largescale, sensor-based wireless networks, the need to adopt inexpensive, green communications strategies is of paramount importance. Most of these devices need to operate without batteries, and as such require an energy harvesting circuit that captures the wireless power.

Efficient power transfer is achieved by selecting an appropriate scheme which is dependent on the distance between the receiver (Rx) and transmitter (Tx). In the reactive near-field zone, power is transferred via magneto-inductive coupling. At further distances, typically antennas are used to transmit the power into the far-field. In many instances, however, the Rx is in the radiative near-field region of the Tx, where the system efficiency can be improved by using focused antenna arrays.

The use of focused array antennas with energy harvesting circuitry not only serves to support the existing infrastructure of the IoT, but it allows for the development of more complex and capable wireless harvesting systems. The proposed energy harvesting system uses a focused array with adaptive circuitry, realized by a low-power microcontroller. The use of the microcontroller enables the system to perform basic computations, which is utilized to develop a “smart” adaptive energy harvester that responds to fluctuations in the environment with the goal of maximizing efficiency. As a consequence of improving the efficiency, more applications of energy harvesting systems become possible with the proposed system. One such example is the integration of a power amplifier in the system, which uses the harvested signal to retransmit a locally amplified version of the original signal on the same or different frequency band. A device like this would serve as a cost efficient and green alternative to commercial repeaters.

This presentation will demonstrate the improvement in wireless energy harvesting efficiency by using focused antenna arrays. Moreover, a novel energy harvesting circuit topology with high efficiency is proposed and integrated with a low-power microcontroller for adaptive matching of the RF circuitry and smart power management of the rectified power. We delineate the system requirements for smart energy harvesting circuits, and show that this adaptive capability can significantly enhance the efficiency of these systems.