Wireless Microwave Powering of Agricultural Sensors

Abbas Semnani*, Badri Baskaran, and Dimitrios Peroulis
Purdue University, West Lafayette, IN 47907, USA

Considering a network of different sensors working in an inaccessible area, like deep underground structures, replacing batteries of the sensors is quite challenging if not impossible. The typical solution for such scenarios is to employ rechargeable batteries and wirelessly charge them using electromagnetic waves. For this aim, a rectenna system should be utilized in place of sensors to convert high-frequency electromagnetic waves to dc power required for battery charging. However, for buried sensors, even for one meter deep in soil, providing enough power is not trivial due to very high (60-70 dB) transmission loss through soil. Considering that propagation loss also increases in the presence of water, wireless charging through soil seems to be quite inefficient.

On the other hand, in most of the United States Midwest, tile drainage networks have been employed, for many years, to remove excess water from soil and make it ready for agriculture. While tile drainage systems are mainly utilized to bring soil moisture level down to an optimum range, in this work, we showed the potential of using tile drainages for wireless powering of underground agricultural sensors. Since, with slight modifications, drainage tiles can perform as cylindrical waveguides, the whole drainage system can be considered as a network of connected microwave waveguides that can carry electromagnetic waves for long distances.

To prove this concept experimentally, in a sample 8-inch tile, a 1-GHz rectenna was designed and fabricated. The rectenna includes a patch antenna connected to a single shunt-element rectifier circuit. A 2-meter-long sample tile was covered with aluminum foil to behave like a microwave waveguide. Measured propagation loss of <0.5 dB/m and rectifier efficiency of $>70\%$ were achieved. The system performance for partial coverage of the tile and in the presence of different water levels was also experimentally evaluated. All results will be discussed in this presentation. Since typical power consumption of temperature and moisture sensors is in the order of sub-milliwatts, it is possible to wirelessly charge sensors over very long ranges, using this technique.