Electromagnetic signature of autonomous sensors based on the dielectric breakdown of air using triboelectric generators

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Study context

The powering of self-powered distributed sensors requires either the use of batteries that need to be renewed regularly or the harvesting and storage of energy over a long period of time, which does not allow real-time sensing. This thesis proposes to study a new type of self-powered wireless sensor including instantaneous wireless transmission thanks to the combined action of the triboelectric effect and the electrostatic breakdown of air.

This thesis will take place at ESYCOM lab which has more than 15 years of history in electrostatic kinetic energy harvesting with a recent focus on triboelectricity, and more than 20 years of history in antenna design. In a recent work, switches based on electrostatic discharged has been used in conditioning electronic for managing the high voltages in triboelectric kinetic energy harvesters [Zhan20].

Objective of the thesis

Triboelectric energy generators are electrostatic transducers which are self-polarized when two suitable materials are brought into contact [Zha18]. They have the particularity of allowing the generation of voltages of several hundred volts, sometimes in a single mechanical actuation. This high voltage, if applied to the terminals of a "switch" consisting of two conductors separated by a gap of a few microns, can be the cause of the "breakdown" of the ambient dielectric (here the air) if the limits of the Paschen law are reached. Consequently, an electromagnetic wave is generated by this micro-plasma according to the principle of the Hertz experiment [Jou89].

Converting mechanical energy into electromagnetic waves while encoding a data in the transmitted signal will allow to free the transmitter system from any electronics except for a few diodes and capacitors, which will greatly reduce the overall power consumption. Although it has been demonstrated that such a transmission system with a triboelectric energy generator with a surface area of less than one cm^2 can emit an electrical pulse that can be sensed at a distance of more than ten meters [Wang21], the exact mode of transmission and the means of influencing its characteristics are still largely misunderstood.

In this thesis, we propose to study in a first step how to maximize the propagation distance by introducing an antenna at the emission which is excited by the generated electric spark. In a second step, the candidate will define the best approach to modulate the emitted signal to transmit information. One possibility would be to add a capacitive sensor in the transmission loop to make the frequency modulation dependent on other mechanical parameters to be measured. Another option is to modulate the emitted spark by controlling the gap between the switch electrodes. This could be achieved by using a MEMS plasma switch [Zha20] with a moving electrode controlled by the capacitive sensor.

Candidate profile

Applicants should have followed a MSc degree related to electronics, microwaves and photonics or applied physics. Skills in optoelectronics and integrated components are beneficial. Experience and knowledge on CAD software, Maltlab, C/C++ programming language, Electromagnetic software will be strongly appreciated.

Contacts and application

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ESYCOM short description

ESYCOM Lab has a strong expertise in communication systems, sensors and MEMS (micro electro-mechanical systems). This expertise matches the labs project entitled *Communication systems and sensors for the city, the environment and people*. Six research areas are developed: antennas and propagation, architectures, microwave photonic devices, microsystem analysis, medical sensors, energy harvesting. Three well-equipped platforms are dedicated to the characterization of the developed components and systems. ESYCOM Lab is labeled CNRS.