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Microsensor for Atmospheric Electric Fields

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Many phenomena of atmospheric electricity are still not well understood, as most of the processes involved can only be observed in real nature. For this purpose, reliable and stable measurements of the electric field strength are mandatory. While for high-frequency fields, there exists a large variety of equipment, in the quasi-static and especially static regime, such systems are scarce. The „standard“ device for the application is the electrostatic field mill which uses a rotating, electrically grounded shutter electrode to alternatingly expose and shield measurement electrodes to/from the electric field. While they achieve good-enough resolution, there are many inherent problems associated with the measurement principle, such as mechanical wear, massive field distortions, size and weight. As a consequence, they are typically installed at a fixed points and cannot be easily moved or mounted. Miniaturised field mills have minimised some of these issues, the shutter priniciple leads to very fragile structures.

We present an alternative way of measuring low-frequency and static electric fields (E-field), which does not suffer from the hindering drawbacks of field mills. The underlying mechanism converts the E-field to a mechanical oscillation of a microelectromechanical system (MEMS). This is achieved by applying an AC voltage to a compliant mechanical structure. As a result of the AC voltage, alternating charges accumulate at the surface of the MEMS. When exposed to the E-field, this leads to a force deflecting the structure at a known frequency. For this kind of active mechanism, the power consumption is minimal, since the current flow is practically zero. Therefore, the system can be used in a floating way without grounded connections and therefore minimum field distortions. The mechanical motion can then be read out optically, also to avoid field distortions and backaction. If the system is driven at the mechanical resonance, the quality factor can be exploited to boost the sensitivity. In this case the bandwidth of the system ranges from 0 Hz to twice the resonance frequency.

Several MEMS sensors with different resonance frequencies (ranging from ~100 Hz to ~1 kHz) have been fabricated and tested in the laboratory. The sensors have been mounted between two parallel field plates supplied with a DC voltage, which provides the static electric field. A tiny hole in one of the field plates allowed for optical readout of the sensor movement with a laser-Doppler vibrometer (Polytec MSA-400). The sensors have been tested for different field strengths (10 V/m – 30 kV/m) and different AC voltages (0.02 V – 20 V) confirming linearity in both quantities. In terms

of field strength, a resolution as good as ~25 V/m was achieved for a sensor with a resonance frequency of 167 Hz. These promising results substantiate that this sensor is a potentially low-weight, low-cost alternative for classical field mills. The next steps will be to investigate long-term stability and environmental effects on the sensor (temperature, humidity) and, finally, installation and test in the open area during fair weather and thunderstorm activity.