Optimizing Transducer Configuration of Capacitive Sensors for Agricultural Applications

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Abstract

This work aims to determine optimized configuration (geometry and materials) using COMSOL Multiphysics® for a class of transducers. Two types of capacitive of sensors needed for monitoring and control in agriculture are investigated: a rain sensor and a soil humidity sensor. Since low cost, low power electronic is required, a set of design constraints is determined by the operation range of the analog front end as well as by the overall probe dimensions and encapsulation options. One important constraint is that the value of the capacitance should belong to the operation range of the capacitance to number converter, in this case the interval [6,25] pF.

For the rain sensor, based on theoretical and practical considerations discussed in previous studies, the preferred geometry of the model is chosen to be the comb sensor (Figure 1). The entire probe construction consists of a sandwich with the following layers: an FR4 circuit board having on one side the electrodes made of copper and a covering glass. For the simulation of the capacitive transducer response, a layer of water was also embedded in the simulation domain made of air. The end purpose is to obtain a sensor with improved sensitivity, i.e. to determine a geometry which displays a significant change in capacitance when the glass area is covered by the water drops.

The soil humidity sensor (Figure 2) works on the following principle: by measuring the capacitance of the transducer in a given soil, the humidity in the soil can be inferred based on previously known empirical formulae (e.g. Topp equation) which relates the soil permittivity to its water content. The construction consists of two electrodes. One has to be connected to the ground of the electronic block, with a lamellar shape and a pointed end, while the other has a cylinder shape and is covered in a polymer coating.

COMSOL Multiphysics® is used to test various configurations for both transducers, like the number of teeth in the comb, the depth of the teeth, the thickness of the covering glass, the relative permittivity of the glass in the case of the rain sensor, and the distance between the electrodes, electrodes lengths and diameters as well as the type of the covering polymer. The goal of the simulations was to determine the geometries that produces minimal and maximal capacitance values in the above mentioned range while maximizing capacitance variation in presence of water. After deciding upon the desired configuration by using COMSOL Multiphysics® (geometry and materials), two transducer prototypes were built and tested experimentally.

The results (the measured capacitances of the probes) were in excellent agreement with those obtained through the COMSOL Multiphysics® simulations. The transducers were embedded with the analog front end and a low power microcontroller into prototype sensors able to measure capacitance and temperature.

Reference

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Figures used in the abstract

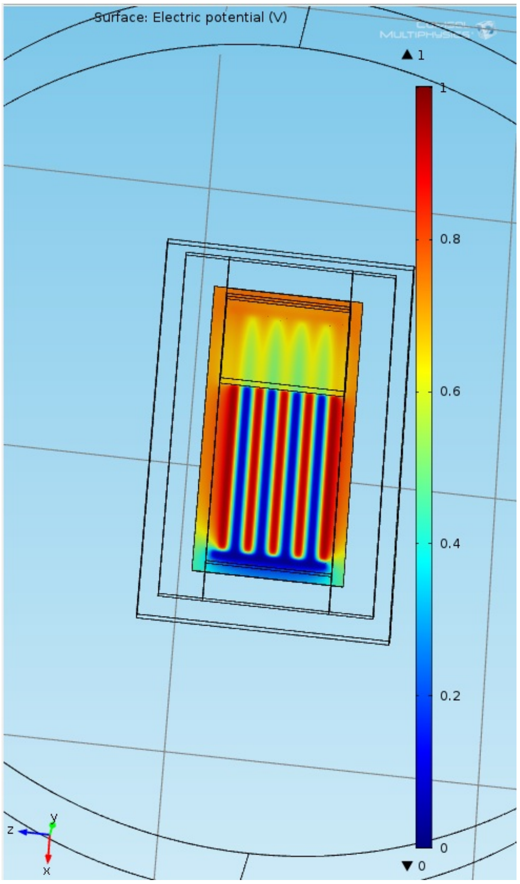
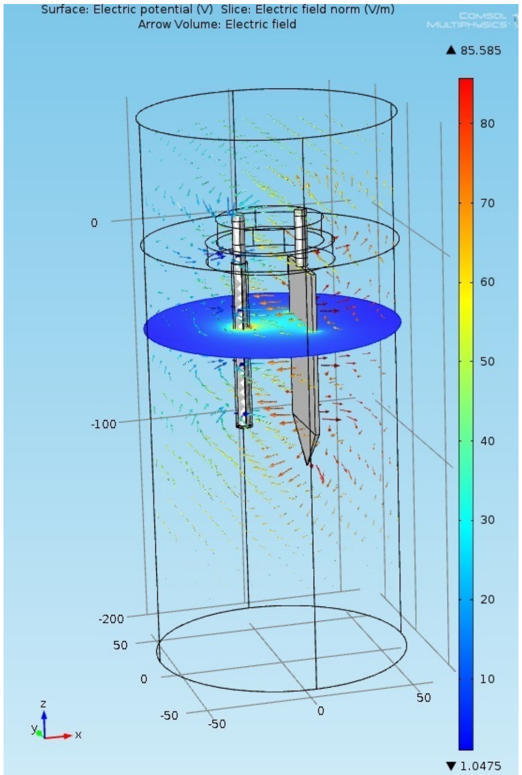


Figure 1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Arrow Volume: Electric field
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80
70
60
50
40
30
20
10
▼ 1.0475
0
-100
-200
50
0
-50
-50
0
50
z
y
x

Figure 2