PIR Sensor Modeling and Simulation using COMSOL Multiphysics® and its Ray Optics Module

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Introduction: PIR (Passive Infrared) sensor is the most widely used motion sensor for occupancy detection. PIR sensor outputs a voltage corresponding to the temperature change of the sensor element. PIR sensor has two detector elements connected in series with opposite polarities. This arrangement prevents triggering to an event caused by the change of background IR.

PIR sensor was modeled and simulated using the Ray Optics Module and AC/DC Module with its electric circuit interface. The model includes the optics and the pulse shaping electric circuitry.

Computational Methods: The simulated case is a small size infrared source which is passing over sensor's field of view. Optics is a typical size composed of multiple lenses. Allowing random ray emission to all directions leads to an exhaustive simulation where only small fraction of the rays would reach the detector. To avoid this, only those rays which directs towards the sensor within a small solid angle Ω are included. By this way the source distance L_i and the angle of incident ray α have to be included for the calculation of absorbed radiation intensity I_i. A simple cosine-law is included. While the source traverses over the field of view, the sensor output voltage shows multiple positive and negative peaks. When the source is just ahead the sensor, equal amount of radiation absorbs both the detectors resulting in zero output voltage.

$$\frac{I_i}{I_0} = \cos(\alpha) \cdot \left(\frac{L_0}{L_i}\right)^2$$

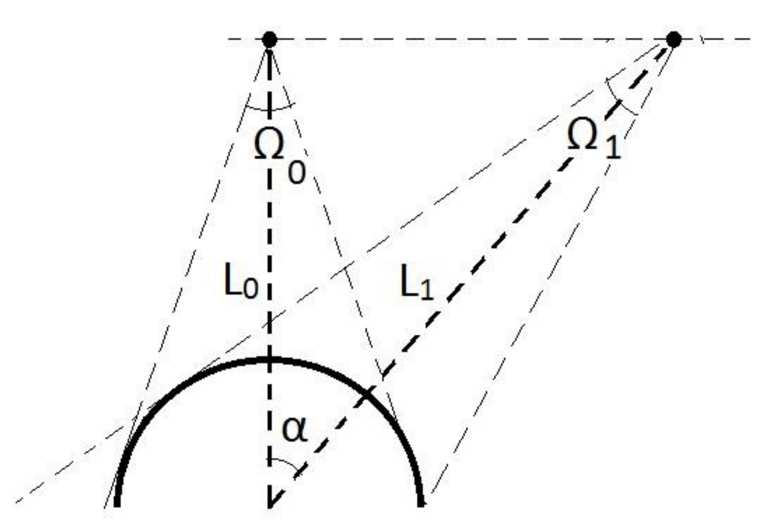

Figure 1. Geometry of the problem.

Detector signal, a current J_p depends on the temperature difference change versus time. Signal derivation can be done mathematically or alternatively including a derivation circuitry.

$$J_p = pA_s \, {}^{d(\Delta T)}/_{dt}$$

The motion speed of the IR-source has been converted to a nanosecond scale to limit the physical dimensions of light propagation. This requires also scaling of the electric circuit components.

Results: The simulation results in the ray paths, the absorbed IR-power and the shaped analog output signal.

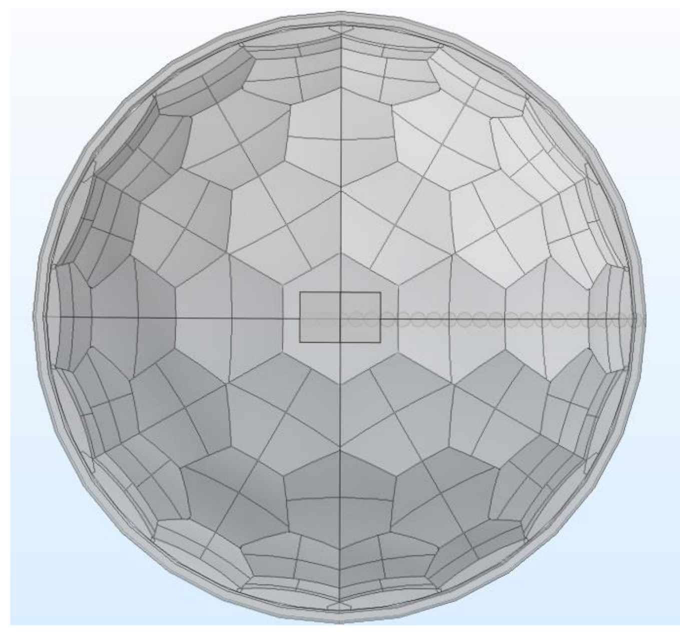

Figure 2. PIR optics.

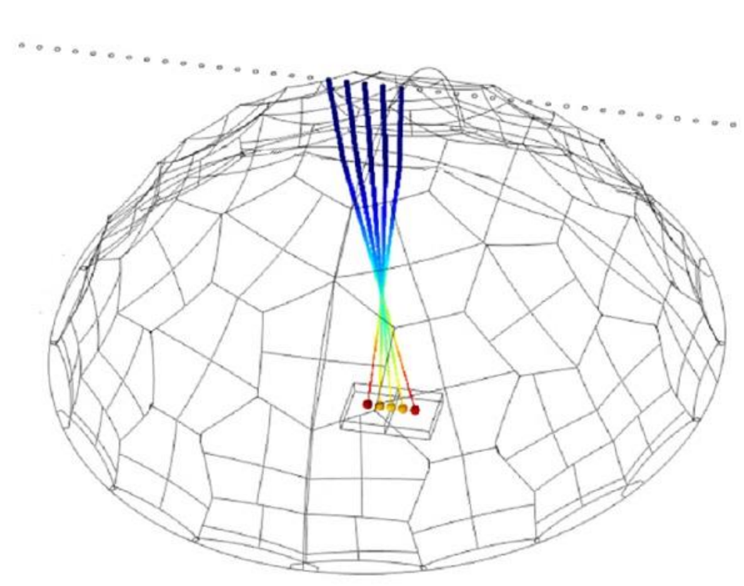

Figure 3. Ray optic simulation.

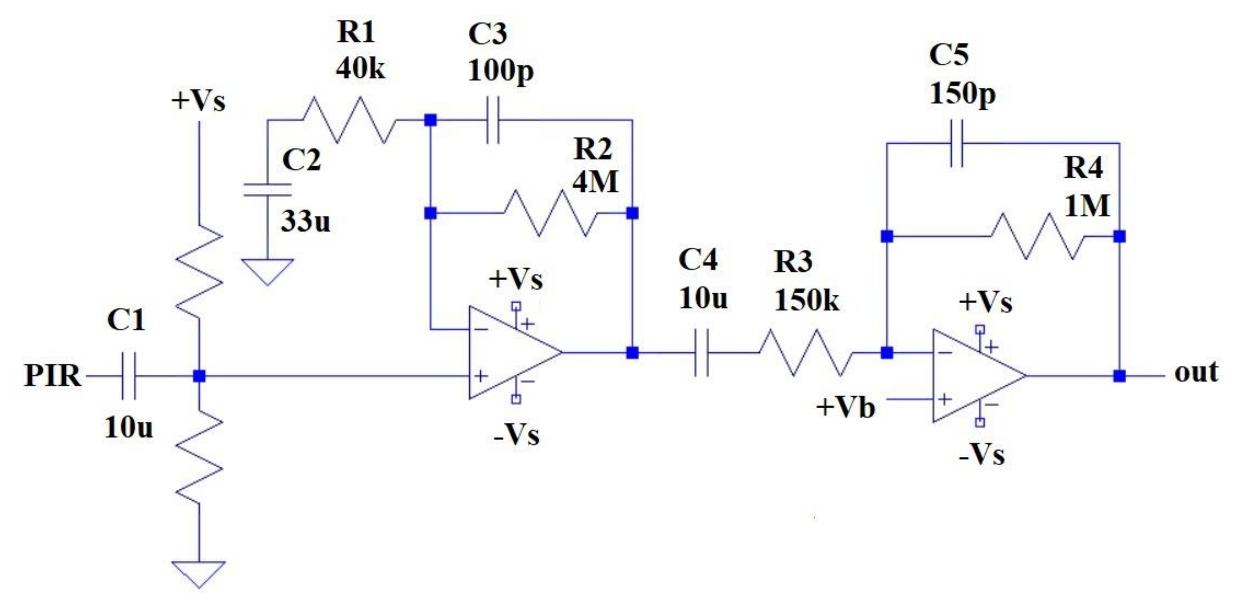

Figure 4. The electric circuitry.

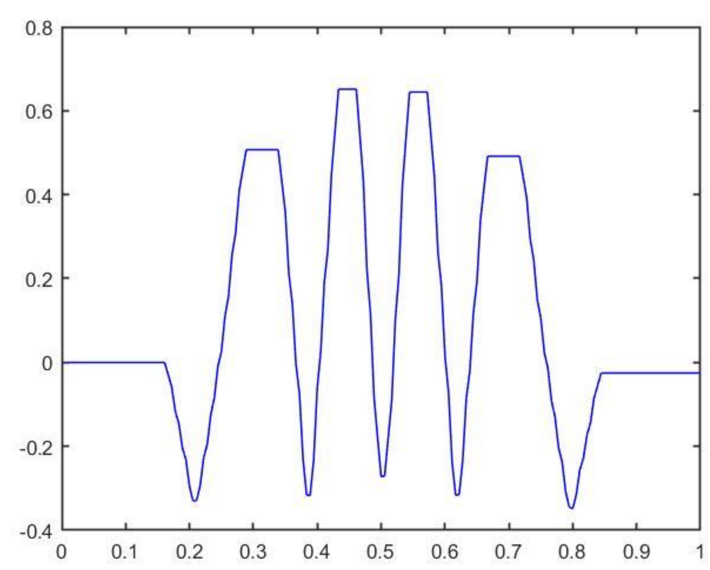

Figure 5. Simulated absorbed Radiation intensity.

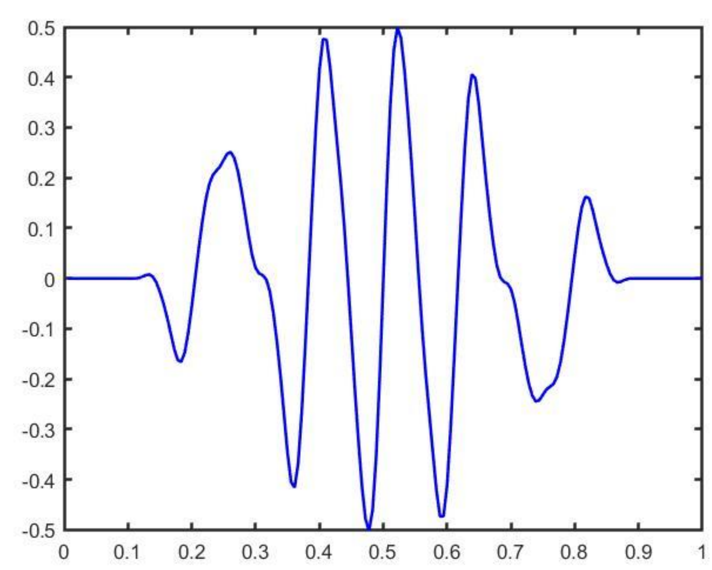

Figure 6. Simulated output voltage signal.

Conclusions: The simulation demonstrates the electric signal generation in a PIR sensor. The geometry and the material characteristics of the optics and the electrical circuitry are included. The output waveform is inversely symmetric to the center point. This indicates a PIR sensor is able to determine the moving direction of an IR source.

References:

1. M.Maaspuro, "Infrared occupancy detection technologies in building automation – a review", to be published in ARPN Journal of Engineering and Applied Sciences.