Locating Inductively Powered Wireless Sensors in Internally Illuminated Photoreactors

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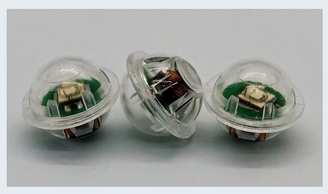
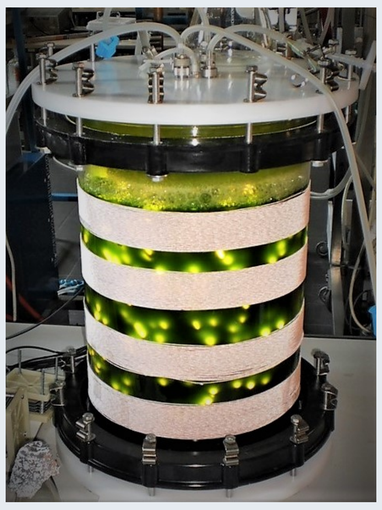
1. Internally Illuminated Photoreactors

- Internal illumination of photoreactors using WLEs (Wireless Light Emitter)
- The WLEs are inductively coupled with driving coils placed at the outer circumference of the reactor
- Driving coils are driven by a class-E amplifier



WLE (wireless light emitter)



Internally illuminated photobioreactor

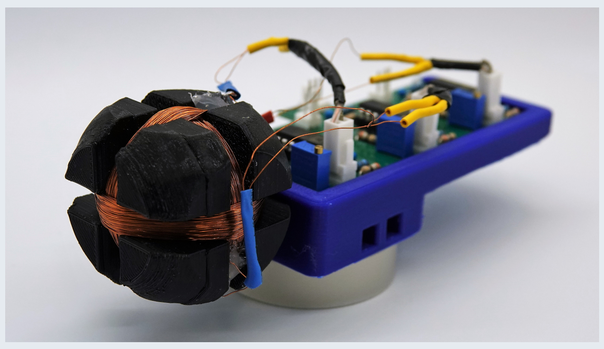
3. Wireless Data Transmisson

Low frequency **inductive data transmission** as a suitable transmission methodology for an underwater environment like inside the reactor:

- Quasi-static magnetic field approach: the attenuation factor has no influence if the wavelengh of the carrier signal is large compared to our setup dimensions
- Sensor data is modulated on the carrier signal using the On-Off-Keying
- Transmitter circuit can be realized as a LC oscillator like e.g. the Hartley-Oscillator or the Colpitts-Oscillator
- The inductance of the oscillator circuit is used as transmitter coil

5. Receiver Design

- Three orthogonally to each other placed coils in order to measure the magnetic field in every three cartesian directions and to prevent the receiver coils to influence each other
- The receiver signals are filtered and amplified at the trasmitting frequency using a bandpassfilter with mutliple negative feedback



Receiver hardware

7. Example Measurement and Conclusion

Example measurements (mean values over five single measurements each)

Coordinate	Inductive Loc.	Exact Position	Deviation
x	24.3 cm	24.7 cm	0.4 cm
y	-12 cm	-13.5 cm	1.5 cm
z	21 cm	23.3 cm	2.3 cm
x	30.4 cm	29.1 cm	1.3 cm
y	-11.5 cm	-13.7 cm	2.2 cm
z	17.5 cm	17.6 cm	0.1 cm

Conclusion:

We demonstrated a method with which sensors can be inductively localised. In first measurements, localisation accuracies up to a few cm were achieved. The first measurements were carried out with a cable-supplied transmitter without a real sensor. A simulated bit stream was sent. The next goals in the near future are the wireless power supply for the transmitter using the driving coils of the internal illumination also for the wireless sensors and the use of proper sensors.

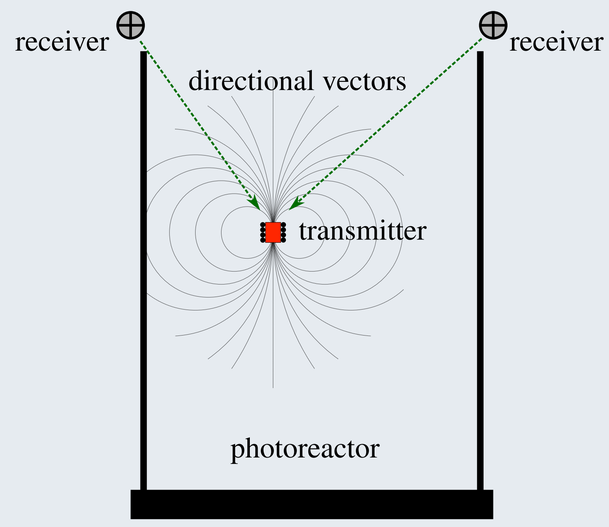
This research is funded by the Tyrolean Science Fund (TWF, Project No. 18689)

2. Inclusion of Wireless Sensors - Requirements

- Sensors are needed in order to get more insight into the processes inside the reactor
- Wireless and locatable unfixed sensors to get a spatial resolution of the measured parameter
- Example of parameters to measure:
  - temperature
  - carbon dyoxide concentration
  - oxygen concentration
  - pH-value
- Sensors should be passive and powered wirelessly in order to ensure the maximal flexibility and independency from an additional power supply

4. Localization Methodology

- The **magnetic dipole** equation is used to describe the magnetic field of the transmitter coil.
- Based on the simplification of an always vertical oriented transmitter coil, its position can be calculated in using the well known propagation properties of the magnetic dipole field
- The magnetic field needs therefore to be measured in all three cartesian spatial directions at least at two positions

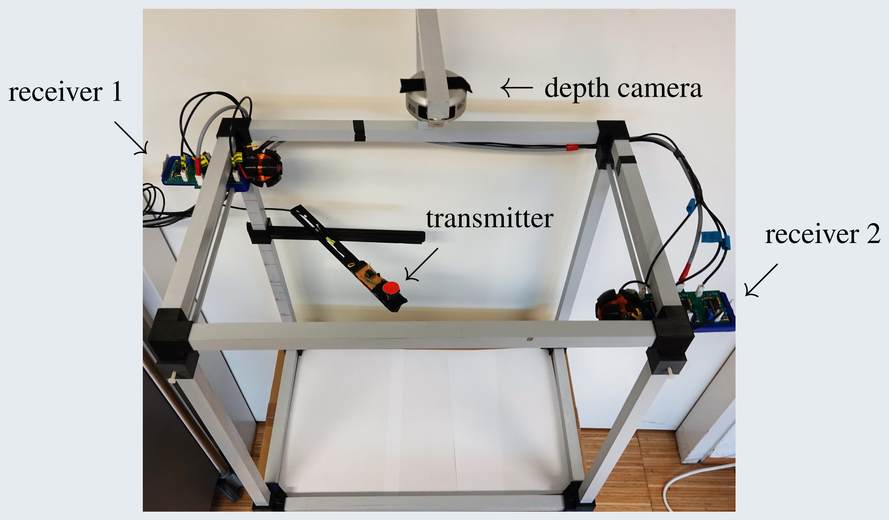


Localization methodology - schematic diagram

- From each magnetic field measuring point / receiver position a directional vector is calculated which points in the direction of the transmitter
- A minimum of two receivers are needed in order to locate the transmitter by finding the intersection of the directional vectors

6. Measurement Setup

- Setup with two receivers
- Localisation test measurements are performed in air since the difference in the relative permeability between air and water is neglibly low
- Receiver signals are digitalized with a IO-device and the directional vectors are calculated by solving the coupling equations based on the magnetic dipole field formula
- Receiver calibration is done using a LIDAR depth camera
- The transmitter position is measured with the camera and with the inductive system: the results are compared in order to adjust the signal amplification for each receiver channel (position measured with the camera is assumed to be the correct one)



Measurement setup

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