TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

DFG Deutsche Forschungsgemeinschaft
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MSELab

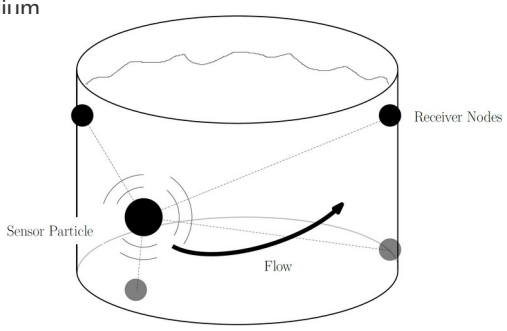
ACOUSTIC BEACONS

Acoustic Communication and Localization of Sensor Particles

BACKGROUND

While most modern communication systems rely on electromagnetic waves, their effectiveness in dense or opaque media is severely limited due to strong attenuation. Acoustic waves, however, can propagate efficiently under such conditions. As a result, acoustic communication is widely used in medical implants, industrial sensor networks operating in closed systems (e.g., tanks), and underwater communication.

In this project, we aim to extend and advance these acoustic communication techniques toward a novel application: the localization of and communication with freely moving sensor particles. These particles are miniature electronic devices that follow the flow within a medium, perform in-situ measurements, and transmit the data wirelessly in real time. Once their position can be determined, each individual measurement can be spatially resolved, providing unprecedented insight into the internal structure and local variations of physical properties within the medium.



PROJECT GOALS

Localization of a moving node relative to a set of stationary anchors can be achieved through multilateration – a principle also used in global positioning systems (GPS). By evaluating the differences in the time-of-flight of acoustic signals between the sensor node and multiple anchors, the particle's position can be determined.

Adapting this concept to the case of millimeter-scale sensor particles requires:

- A fundamental understanding and modeling of sound propagation in realistic media,
- The development of tailored acoustic localization and data transmission schemes, and
- Experimental validation of these concepts in controlled environments.

KEY ACTIVITIES

To achieve these goals, the project will:

- Develop a parametric channel model that captures the relevant sound propagation phenomena and medium characteristics. This model will serve as the foundation for the simulation and evaluation of different localization and communication strategies.
- Establish an experimental setup using software-defined radios (SDRs) and a controlled particle suspension. The use of GNU Radio enables a seamless transition between simulation and experiment and allows integration of existing signal processing modules for modulation and coding.
- Explore the realization of acoustic transmission from a physical sensor particle, including the design of the system architecture, electronics, and firmware/gateware, all optimized for highly constrained environments in terms of power, mass, and size.

Responsible Body
Deutsche Forschungsgemeinschaft (DFG)

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571041517

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2025 – 2028

Collaborators
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