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Multi-electrode capacitive and inductive sensing applied to level measurement of multiphase fluids

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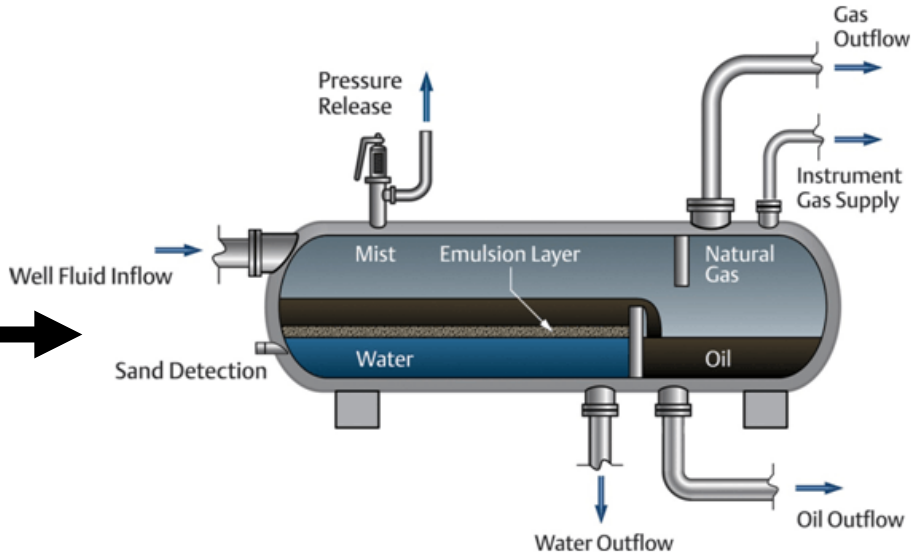
Motivation

- Separators reside on onshore facilities and offshore platforms and are deployed in upstream oil and gas applications.

- The separator vessel receives a mixture of crude oil, gas and water extracted from the subsea well.

- They are required to provide oil/gas streams that meet quality for further processing or sale as well as environment requirement for water disposal.



Motivation

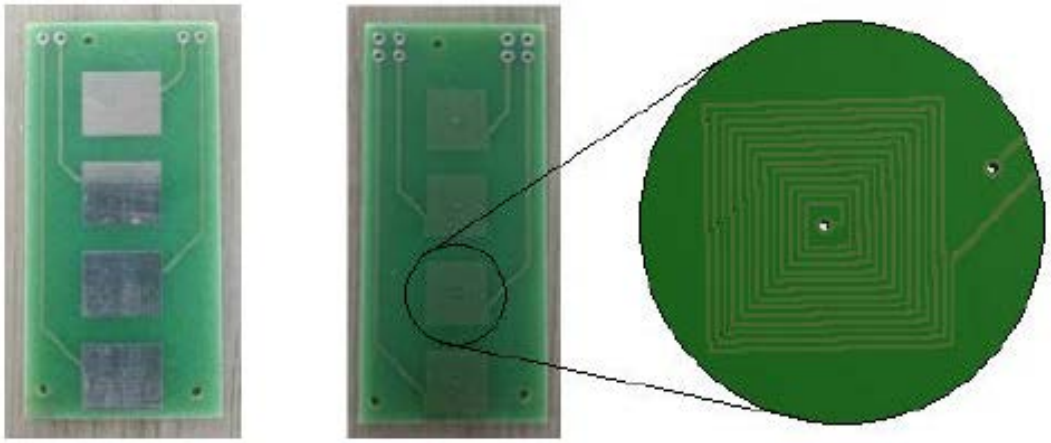
- **To ensure the quality/efficiency of the gravitational separators**
  - Precise monitoring is required of multiple separation interfaces and emulsions used as control variables in order to regulate the flow of the incoming stream and also the output flow of the single-phase compounds obtained from this process

- **Optimal control of interfaces level**
  - Development of a controller for optimize the utilization of the separator and increases the effectiveness of the entire asset.

- **This Work: Development of an hybrid technology to monitor substances with higher electrical conductivity values, for instance brine**
  - Multichannel inductance and capacitance measurements seem to be well suited

Preliminary tests

- 4-channel PCB prototype

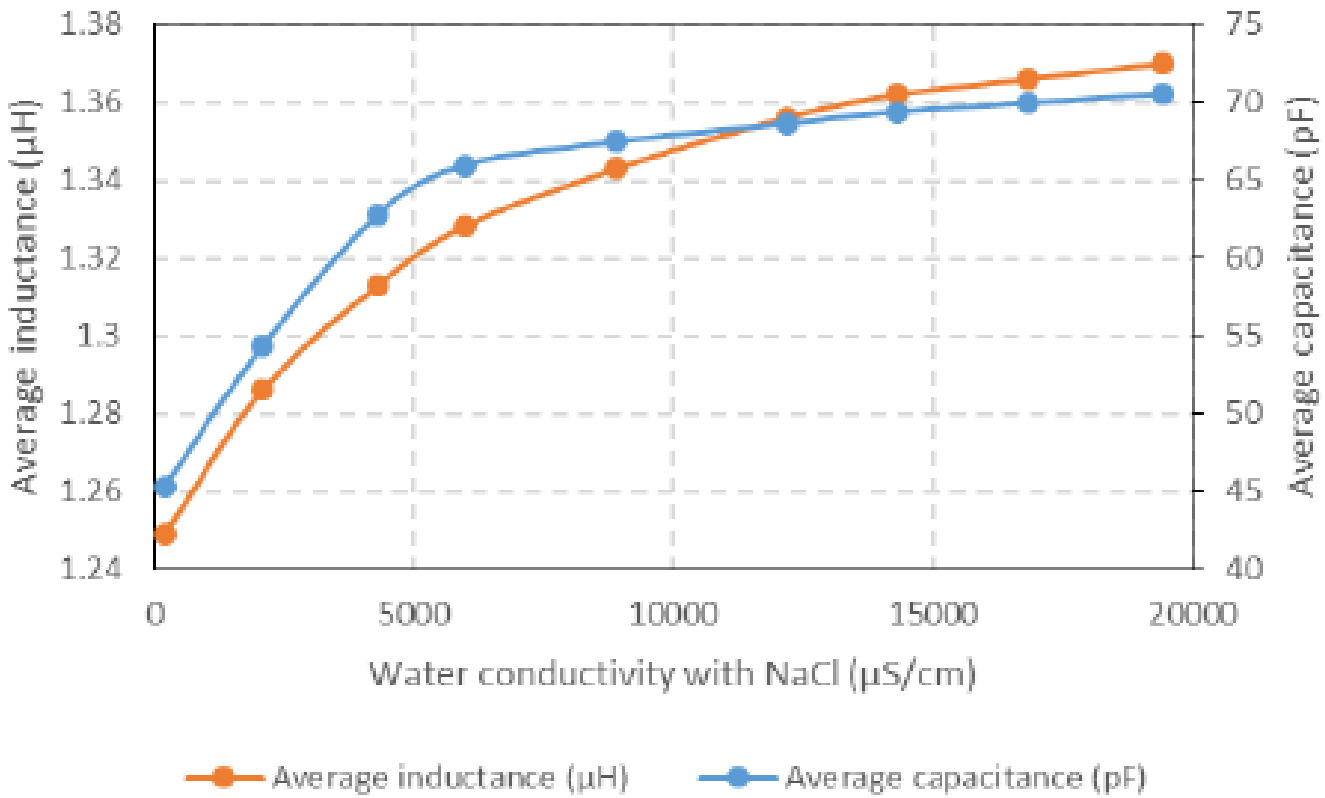


- LC measurements by resonant circuits
  - Up to 1000 readings/second per channel
  - Measurement resolution of 28 bits
  - High immunity to electromagnetic interference
- Several tests for oil/water emulsions under lab conditions

Results

Sensor Evaluation (prototype)

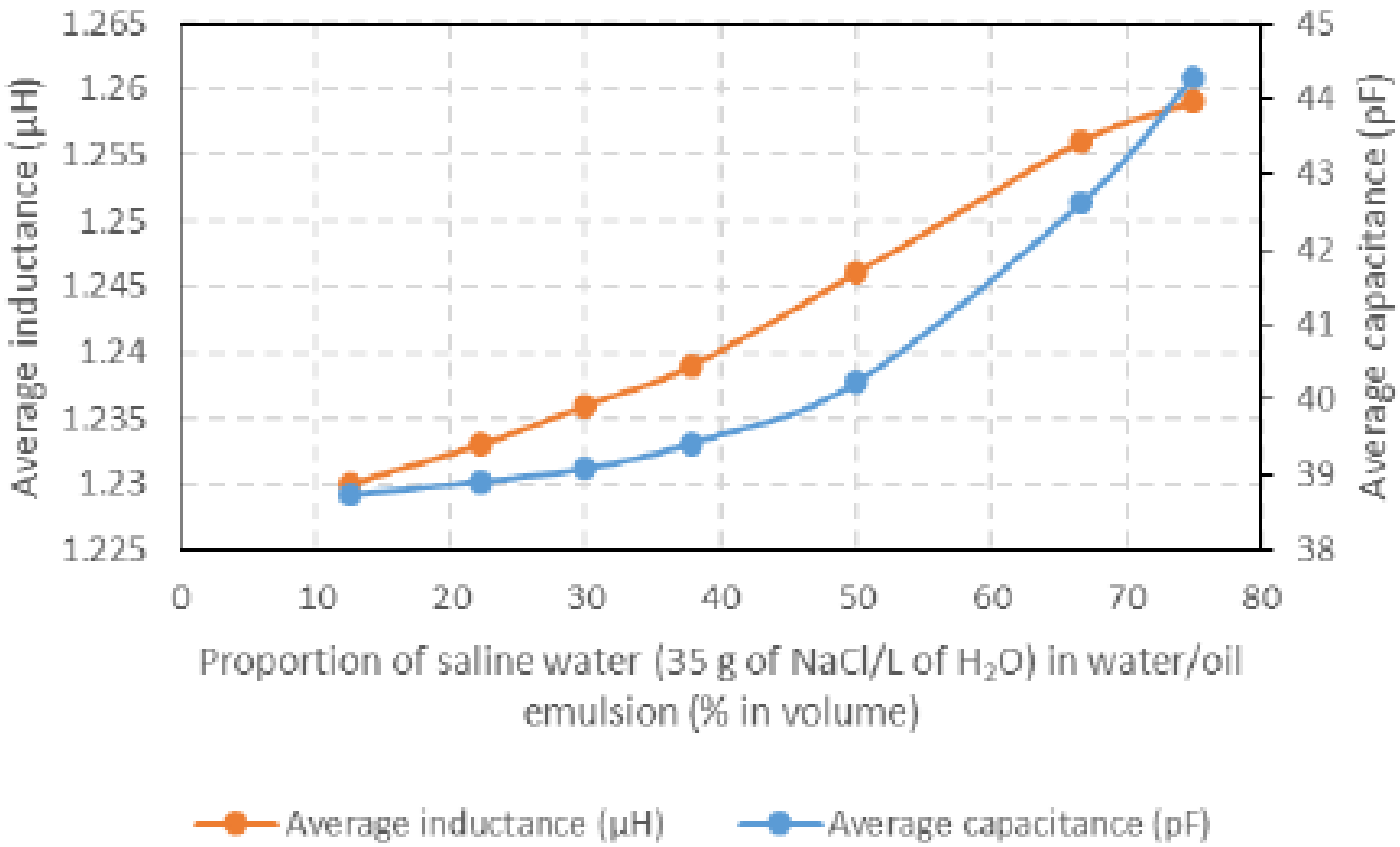
- Water conductivity was increased by adding NaCl up to 2 S/m corresponding to sea water
- Both electrode capacitance and coil inductance present an monotonic change with conductivity



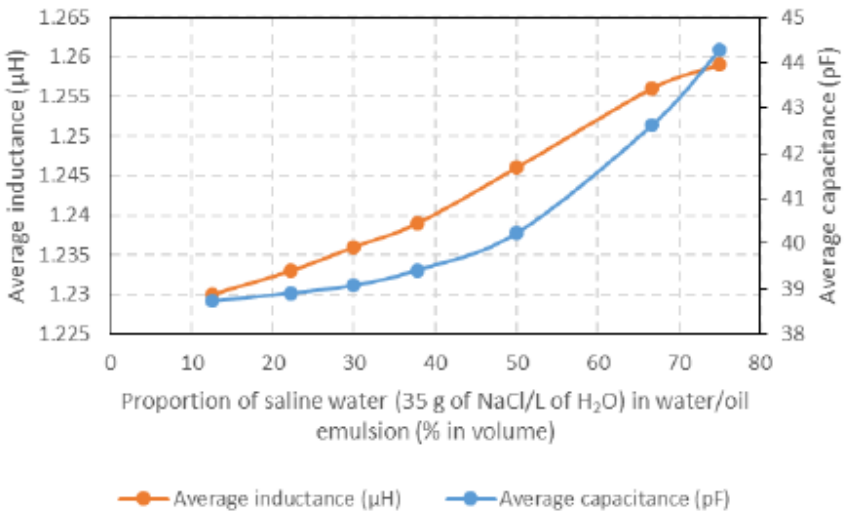
Results

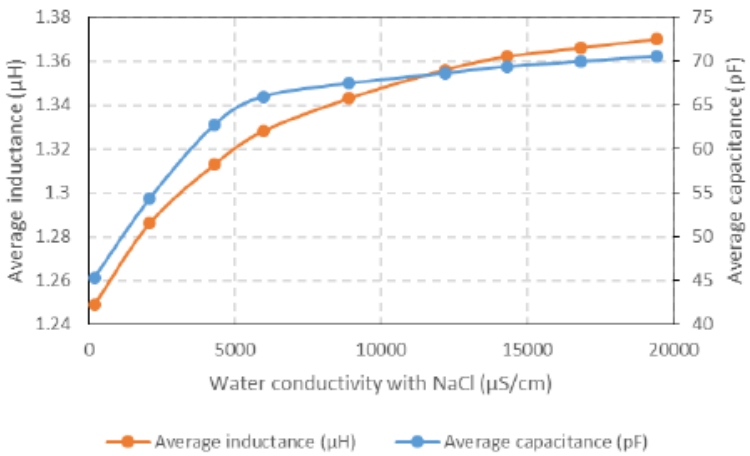
Sensor Evaluation (prototype)

- Emulsion was generated by mechanical agitation at defined oil/water concentrations by volume%
- Both electrode capacitance and coil inductance present an monotonic change water concentration in emulsions



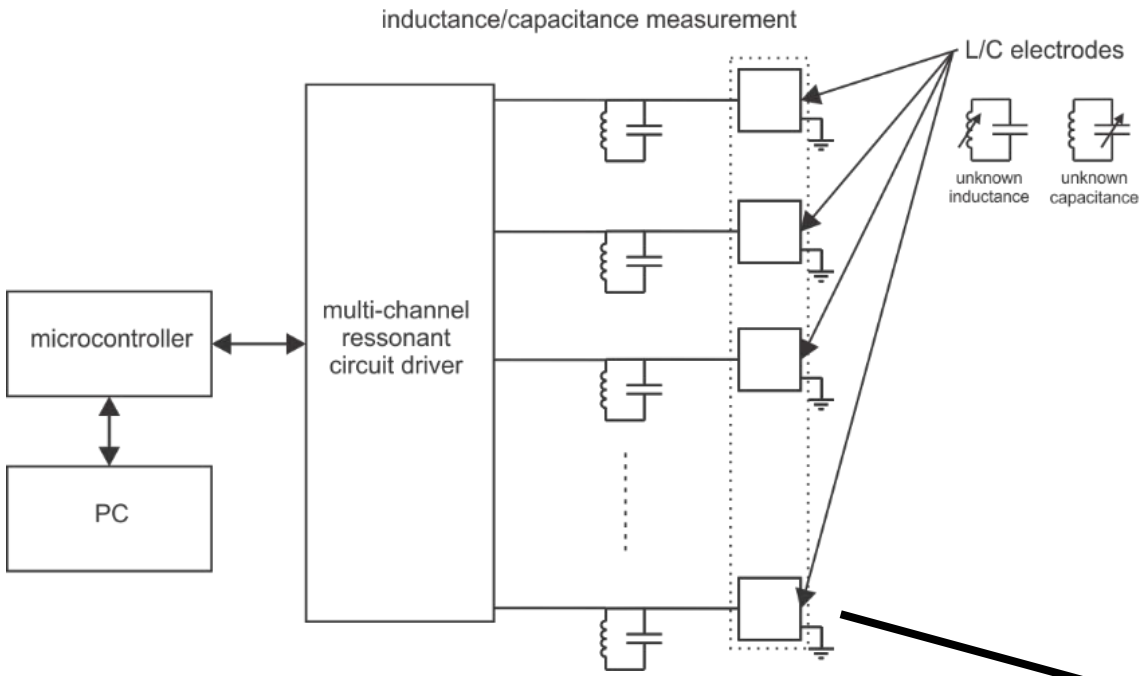
Summary of Results



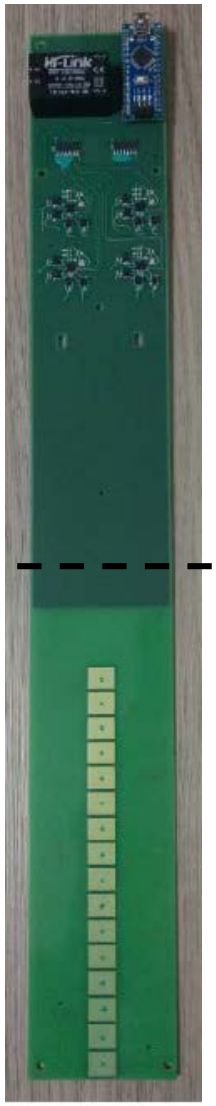


- By combining <u>electrode capacitance</u> and <u>coil inductance</u> measurementsit is possible to obtain water conductivity (salinity) and concentration

16-channel Sensor System



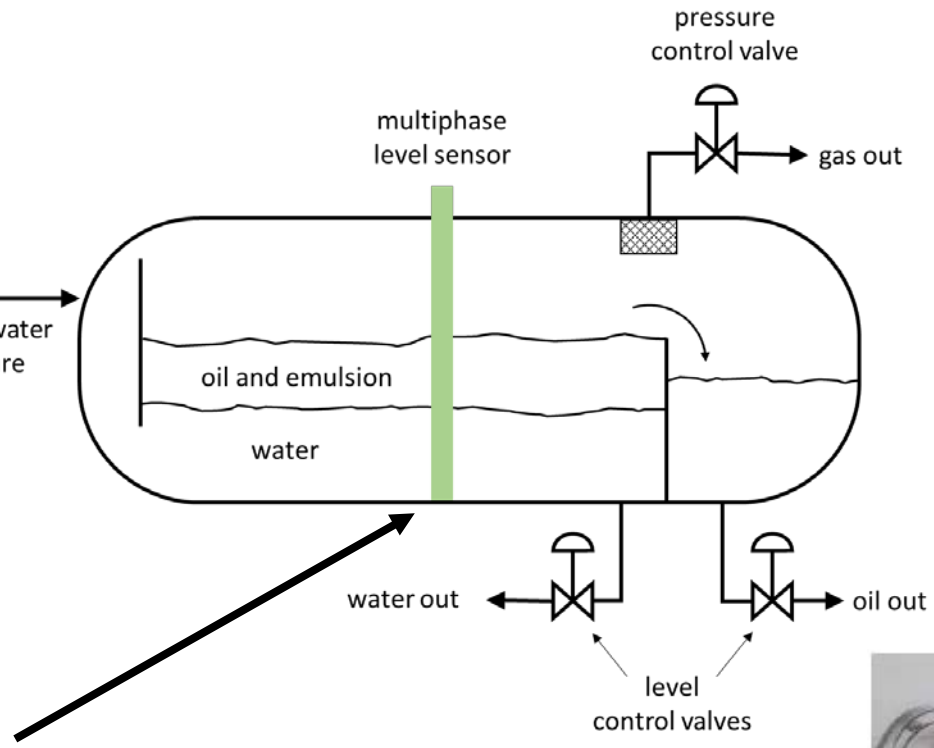
measurement electronics

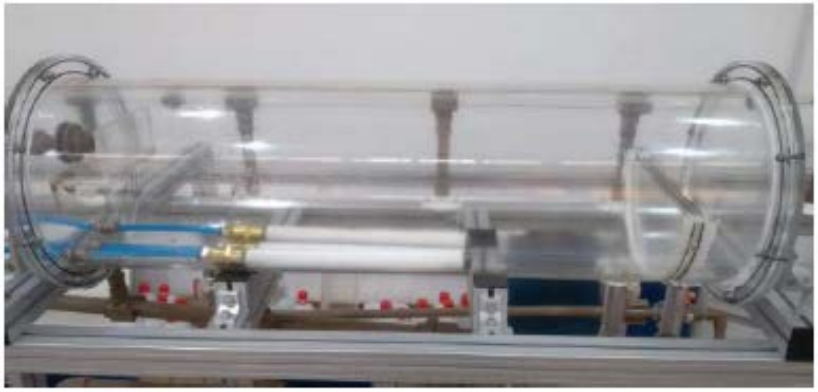


16-electrodes array

- It was designed to be applied in a test separator
- Use tap water, i.e. no coil inductance measurements are needed

Future Application to a Separator Prototype



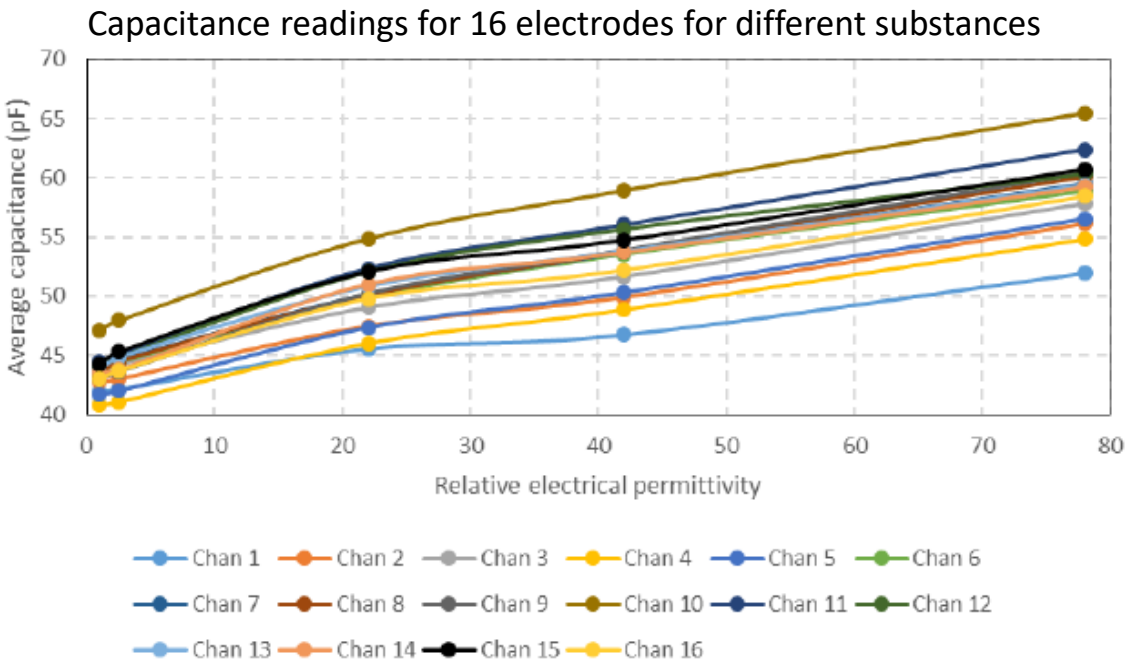


To be installed to a separator prototype

Results for 16 channel prototype

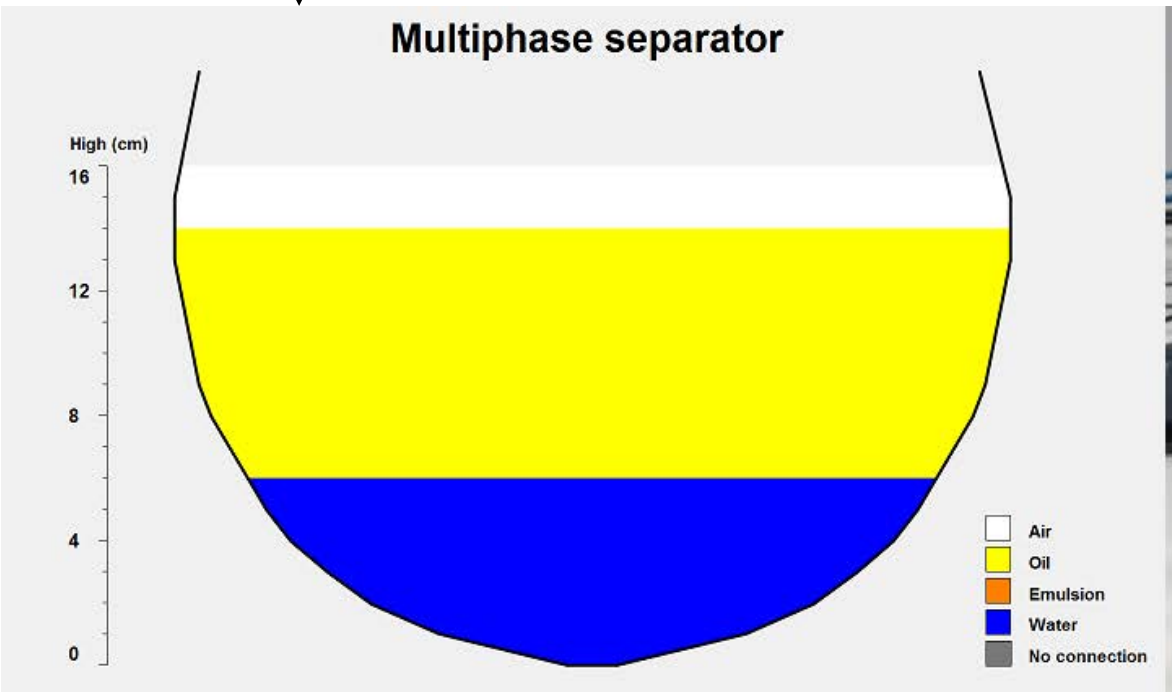
- Static tests with several reference substances to check accuracy
- Large range of electrical permittivity
- Good linearity with slight differences for each sensing electrode (may me compensated)

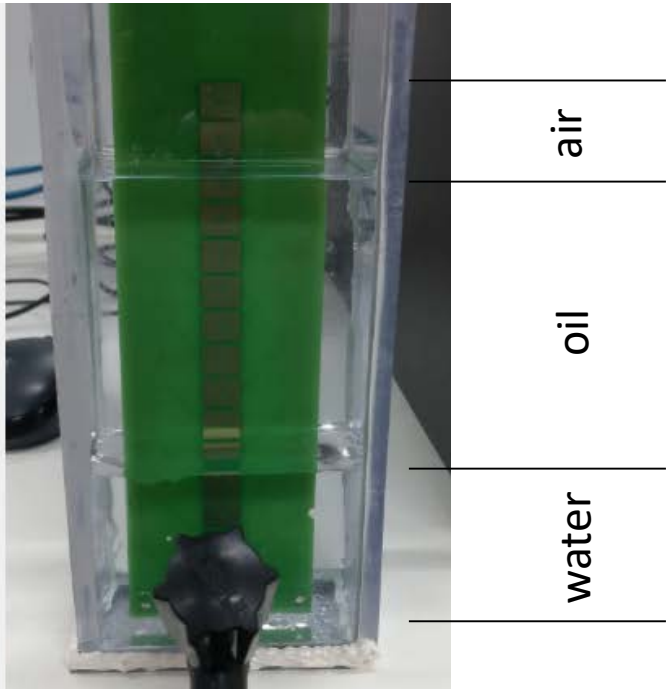
Substance	Relative Electrical Permittivity (εr)
Air	1.0
Mineral Oil	2.1
Isopropanol	20.1
Ethylene Glycol	40.3
Deionized Water	79.9



Results for 16 channel prototype

- Sensor was applied to monitor the level of pure substances (air, oil and water)
- Supervisory system for a test separator was developed





Conclusions

- Capacitance/Inductance measurements may be applied for the simultaneous determination of water salinity and concentration of water/oil mixtures.

- 16-channel capacitive-only prototype has been successfully applied to monitor the (yet) static level of tap water, oil and air.

- Results present good linearity for permittivity measurements and a dedicated level measurement routine was developed and tested.

Acknowledgments

CAPES

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