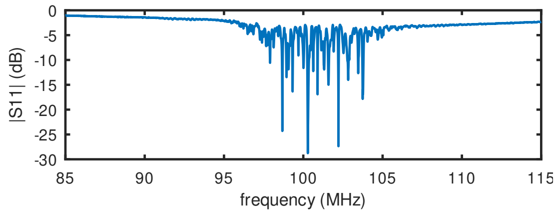
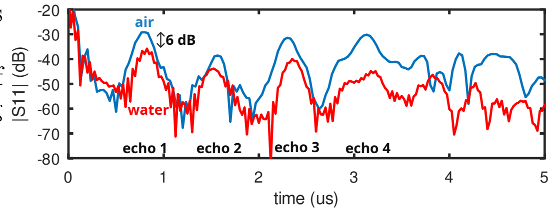
A lithium-tantalate based acoustic reflective delay line for chemical sensing in water

J.-M. Friedt[1], D. Rabus[1], L. Arapan[1], V. Luzet[1], F. Chérioux[1]
N. Nief[2], S. Dehez[2], J.R Ordonez-Varela[2]
jmfriedt@femto-st.fr, http://jmfriedt.free.fr
[1] FEMTO-ST, Besançon, France
[2] TotalEnergies, Pau, France

Outline

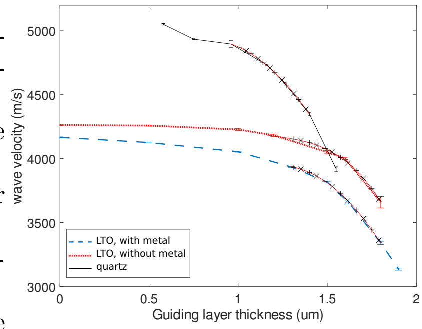
- Sub-surface pollution monitoring using **Ground Penetrating RADAR** (GPR) cooperative target
- Transducer: surface acoustic wave **reflective delay line**
- Mirrors located for echoes in the 0.8 to 3.2 μs range to avoid clutter
- Avoid capacitive short circuit when dipping sensor in water by selecting a **high permittivity** substrate: Lithium Tantalate ($\varepsilon_r \simeq 40$) leading to less than 6 dB loss when interdigitated electrodes covered with water ($\varepsilon_r \simeq 80$)
- compatible with commercial, **off the shelf GPR** with center frequency f_c of 100 or 200 MHz and bandwidth $0.14 \times f_c$ given by electromechanical coupling coefficient K^2



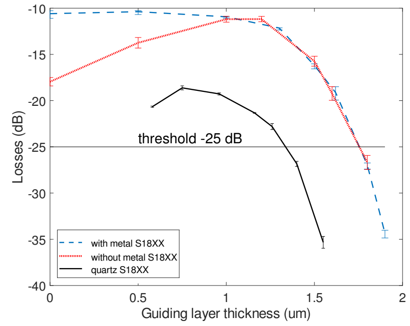


Lithium tantalate (LTO) shear wave gravimetric sensitivity

- **Shear wave** propagation on a high permittivity substrate to avoid capacitive short circuit and remain compatible with **measurements in liquid phase**
- Metallized acoustic path to slow the wave and keep the **pseudo-shear** wave from radiating in the bulk
- Mirrors designed either for **mechanical** reflection or **electrical** re-emission
- Dielectric guiding layer for confining the surface acoustic wave in a **Love mode**
- Gravimetric sensitivity $S = \frac{df}{f} \cdot \frac{dm}{A}$ given by the slope of the velocity as a function of guiding layer thickness



Velocity v.s guiding layer thickness



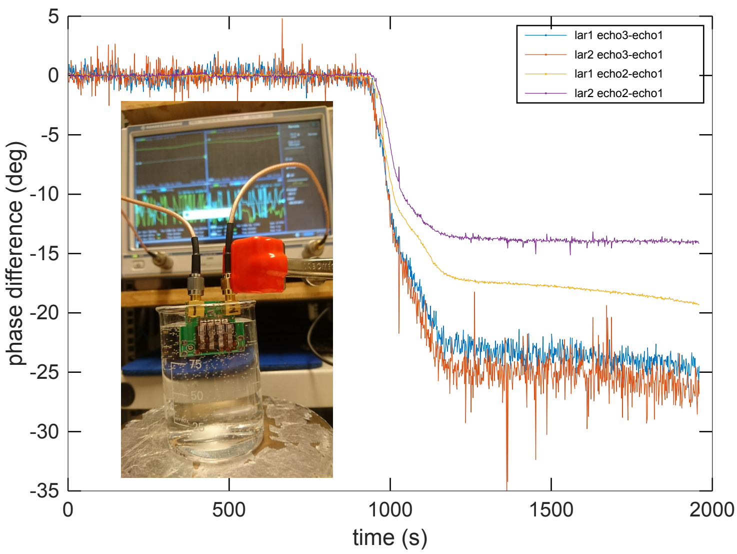
Insertion losses v.s guiding layer thickness

Experimental results

- Wafer backside **roughened** to avoid interference between bulk acoustic wave and surface acoustic wave
- Sensor glued to Printed Circuit Board and wire bonded for electrical connection
- **No fluidic** for water confinement, especially not on the acoustic path
- Demonstration using **non-specific protein adsorption** from dehydrated milk
- Frequency domain characterization using vector network analyzer (e.g. NanoVNA and FreeVNA) and inverse Fourier transform for time-domain response

$$S_{11}(t) = 20 \times \log_{10}(iFFT(fftshift(S_{11}(f))))$$

- Dedicated **functionalized polymer thin films** for specific pollutant detection and Love mode guiding capability spread by spin-coating for sub-micrometer thickness



Protein adsorption on LTO reflective delay line: experimental setup & result

Conclusions and perspectives

- Functional reflective delay line design on LTO
- Acceptable insertion loss when dipping sensor in water
- No microfluidic handling on the acoustic path
- Response compatible with commercial, off the shelf GPR
- Need for high long term stability of GPR timebase ⇒ selection of quartz-based clocked GPR (Sensors & Software) rather than RC-time constant circuit (Malå)

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