Impact of the environment on a sensor response

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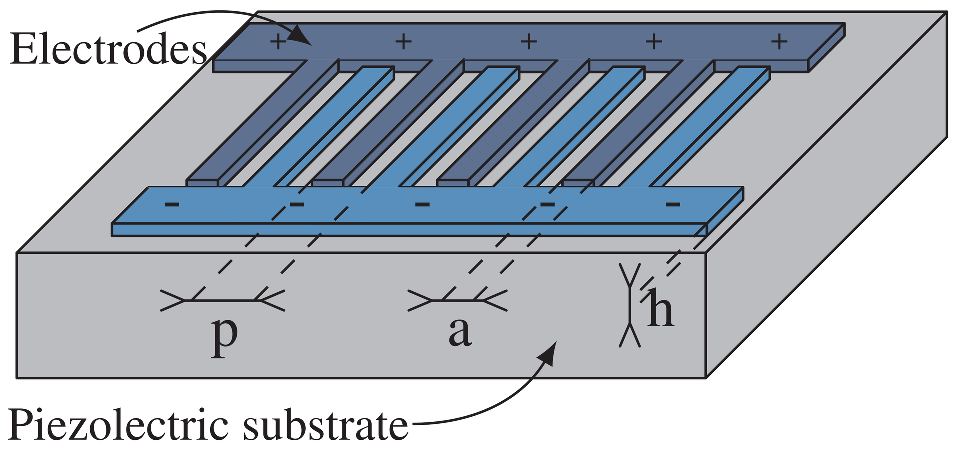
Introduction [1, 2, 3]

Harsh Environments :



- Resilent (temperature, stress...)
- Passive devices
- Remotely controlled (ISM bands)

Principle of SAW devices :



Usual measurement means:

- Delay lines / resonators

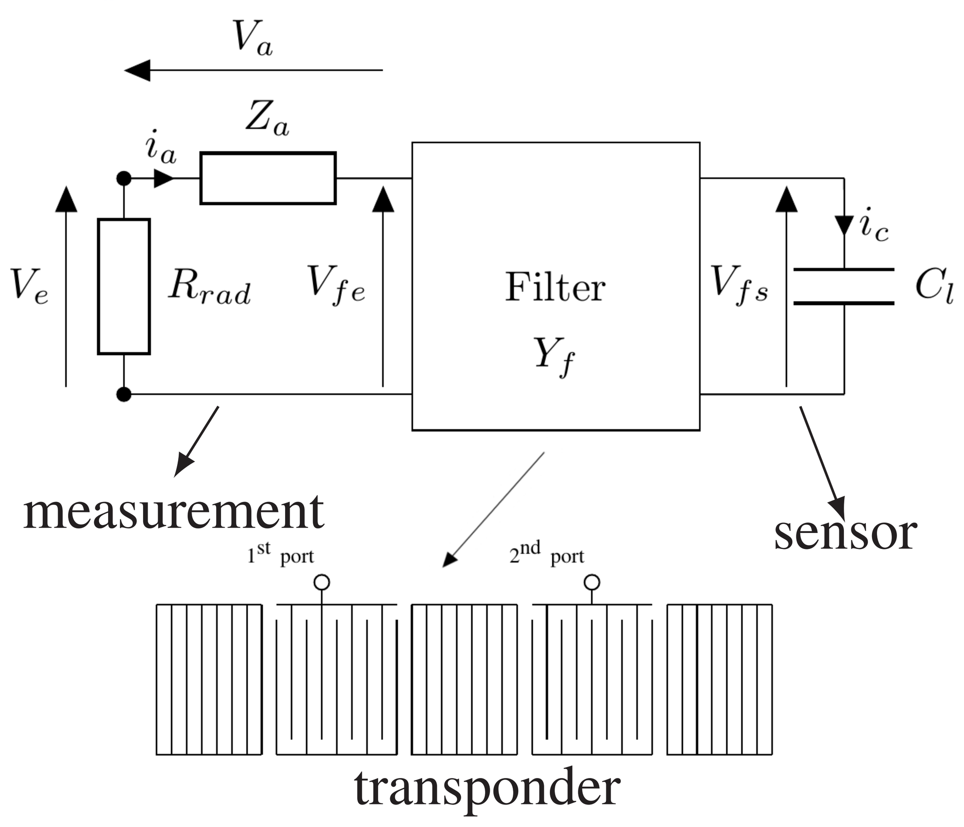
  $\Rightarrow$ sensible zone = piezo material

Drawbacks:

The quantities that damage the working of the SAW can not be measured.
ex: ground hygrometry (throught the variation of ε_r)

Frequency response analysis

Diagram of the sensor:



Filter and load for wired measurements:

- The signal is picked up at the left of the filter
- equations:

$$\begin{cases} \begin{pmatrix} i_a \\ -i_c \end{pmatrix} = \begin{bmatrix} Y_{f11} & Y_{f12} \\ Y_{f21} & Y_{f22} \end{bmatrix} \begin{pmatrix} V_{fe} \\ V_{fs} \end{pmatrix} \\ V_{fs} = Z_c i_c \end{cases}$$

- system response:

$$i_a = \underbrace{(Y_{f11} - Z_c \frac{Y_{f12}Y_{f21}}{1 + Z_c Y_{f22}})}_{Y_{FL}} V_{fe}$$

Antenna and wired sensor block:

- System for wireless hygrometry measurements
- equations:

$$\begin{cases} i_a = Y_{FL} V_{fe} \\ V_{fe} = V_e - V_a \\ V_a = i_a Z_a \end{cases}$$

- response of the whole sensor:

$$i_a = \frac{Y_{FL}}{1 + Y_{FL} Z_a} V_e$$

Working principle of an hygrometer [4]

Ground properties:

- dry earth: $\varepsilon_r = 3$
- wet soil: $\varepsilon_r = 30$

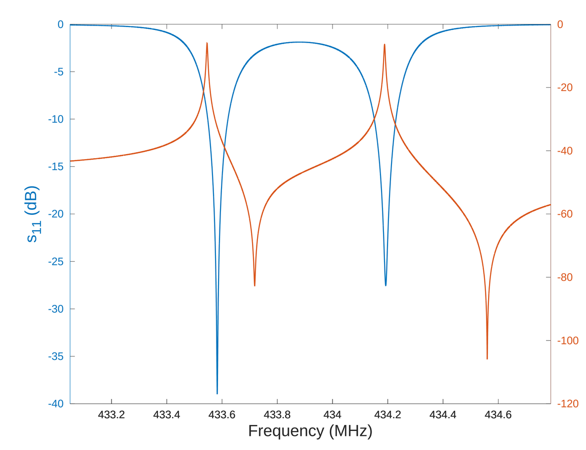
Load capacitance for humidity detection:

$$C_l = \varepsilon_0 \varepsilon_r (\frac{A}{d})_l$$

- C_l sized to be 4 pF in dry soil
- $(\frac{A}{d})_l$ fixed (dimensional parameter)
- C_l linearly evolves from 4 to 40 pF when $\varepsilon_r \in [3; 30]$

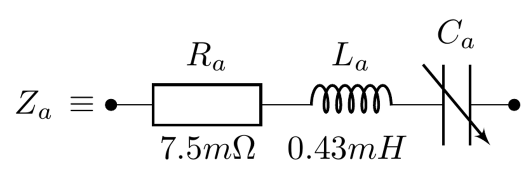
Response of the LCRF filter:

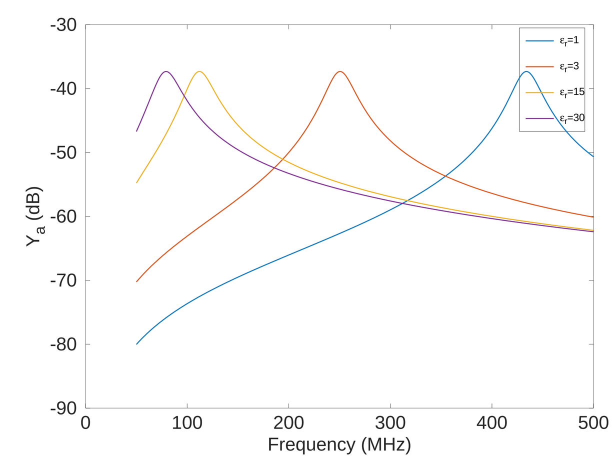
- Encapsulated SAW filter
- $LiNbO_3$ (YXl)128^o cut / Al
- Works in the ISM band (434MHz)
- Design without any load impedance



Antenna parameters:

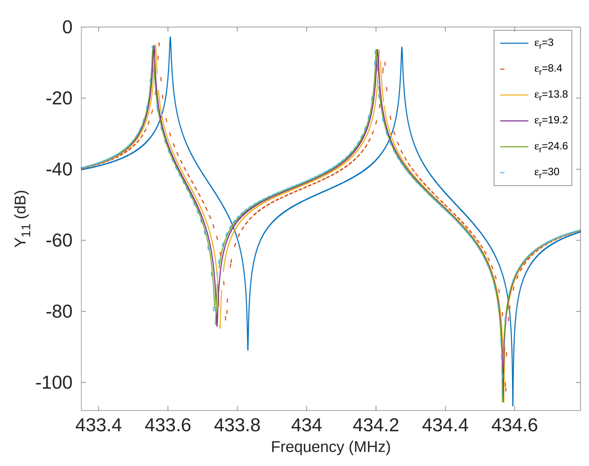
- Half dipole wavelength
- $R_{rad} = 73.5\Omega$ in series with an *RLC* circuit

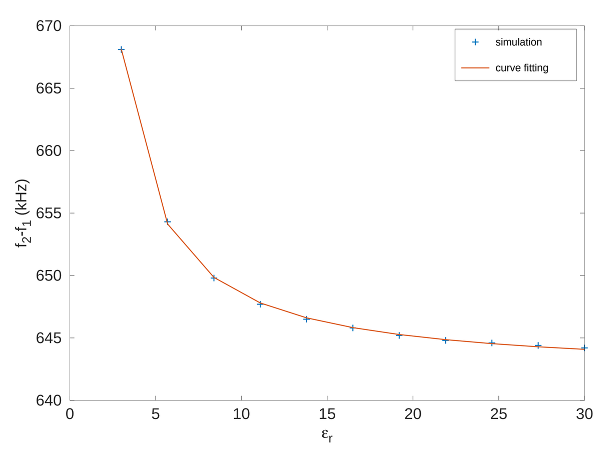




Unwanted mode shifting: from 434 MHz to 79 MHz when $\varepsilon_r \in [1; 30]$ (air $\rightarrow$ wet soil)

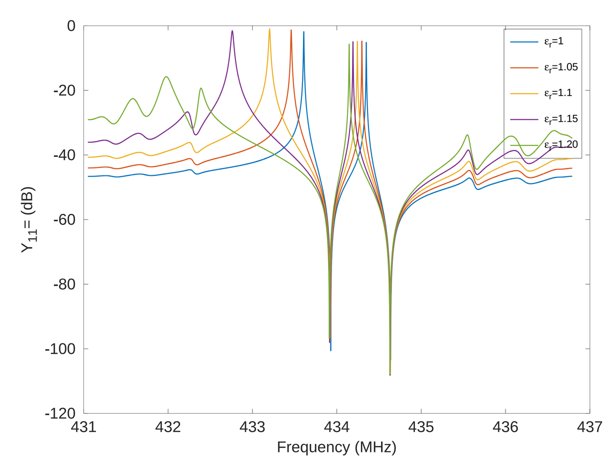
Results : wired sensor [5]





- Frequency shift to lower frequencies when $\varepsilon_r \nearrow$
- Behavior $f_1 \neq f_2 \Rightarrow$ Calibration then hygrometry measurement
  $\Rightarrow \Delta f = 668.13 + 98.25 \times (\frac{1}{\varepsilon_r} - \frac{1}{3}) + 60.372 \times (\frac{1}{\varepsilon_r} - \frac{1}{3})^2$

Results : wireless sensor [5]



- test
- test
- test

References

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[4] Max Born, Emil Wolf, A. B. Bhatia, P. C. Clemmow, D. Gabor, A. R. Stokes, A. M. Taylor, P. A. Wayman, and W. L. Wilcock. *Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light*. Cambridge University Press, 7 edition, 1999.

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