Simulation and Fabrication of Wireless Passive MEMS Pressure Sensor

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COMSOL CONFERENCE BOSTON 2012

Excerpt from the Proceedings of the 2012 COMSOL Conference in Boston

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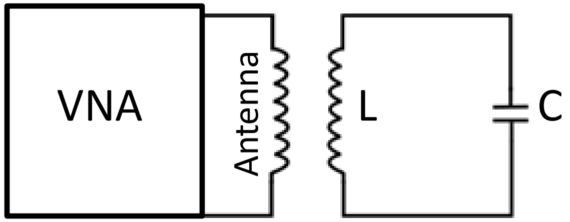
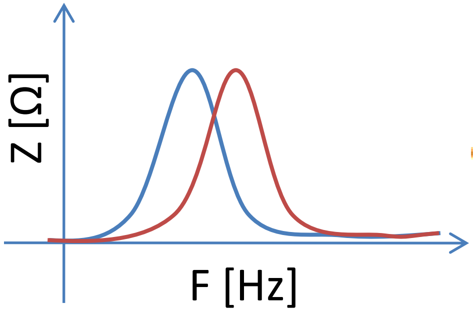
Problem Description

Wireless Passive Sensor

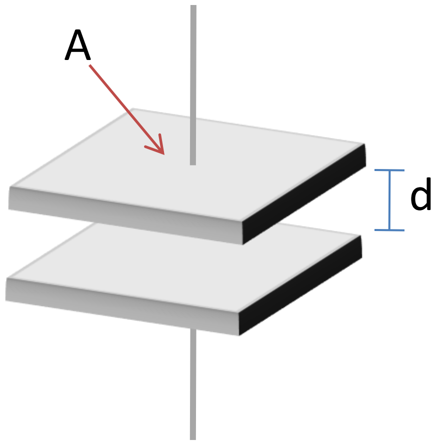
- Based on LC Resonators
- Does not Requiere Batteries or Maintenance
- Allow Remote Sensing





$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$C = \frac{\varepsilon A}{d}$$



- Based on Capacitance Variations

MEMS Pressure Sensor

Outline

- Sensor Design
- Sensor Fabrication
- Experimental Setup
- Problem Formulation
- Simulation
- Results
- Conclusions and Future Works

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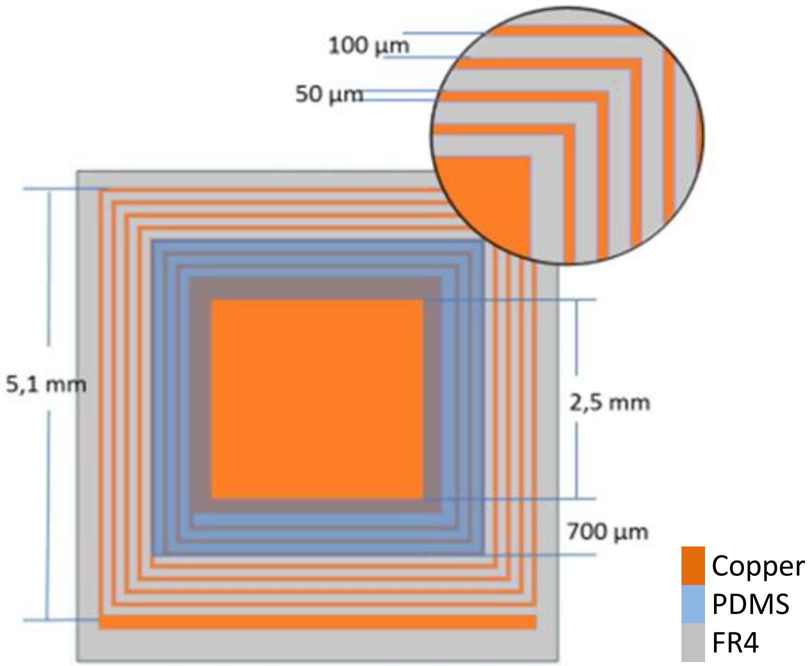
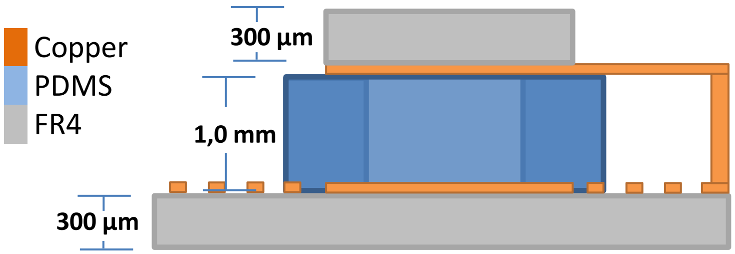
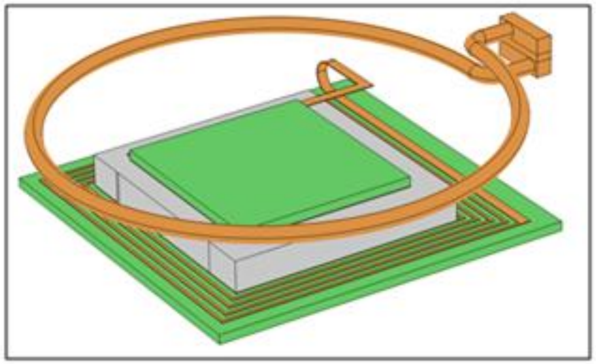
Sensor Design

- The sensor is based on MEMS capacitor attached to a planar inductor for wireless powering and readout.
- The capacitor has an internal PDMS support which gives structural support and mechanical memory to the sensor.
- The pressure sensor was design with a resonance frequency of 200 MHz.

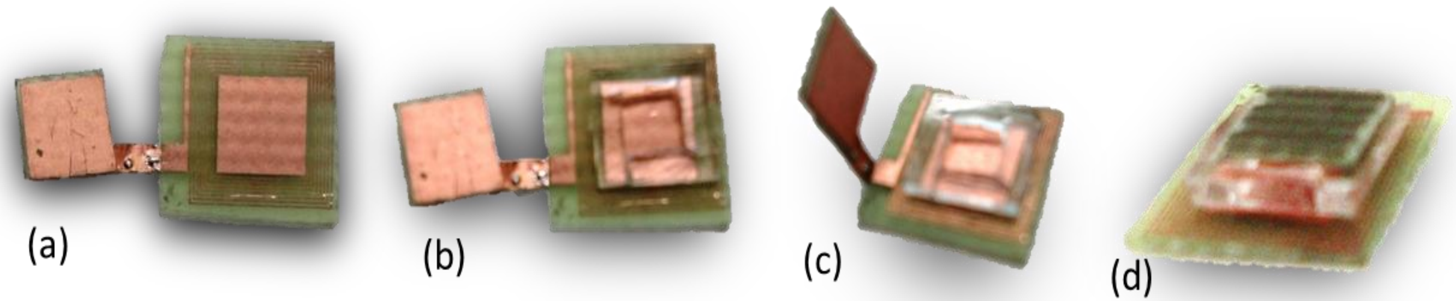






Sensor Fabrication

Softlitography	Copper Wet Etching	PDMS Curing
• Positive Photoresist SC1827 • Micropatterning System SF100	• $FeCl_3$ at 90°C • Desionized Water Rinse	• 10:1 base-curing agent PDMS mixture • Cured at 80 °C for 2 hours

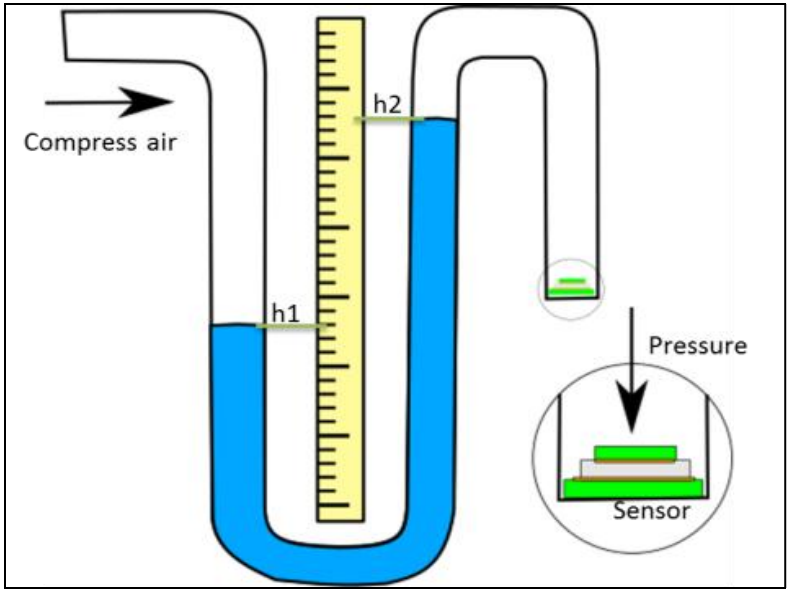


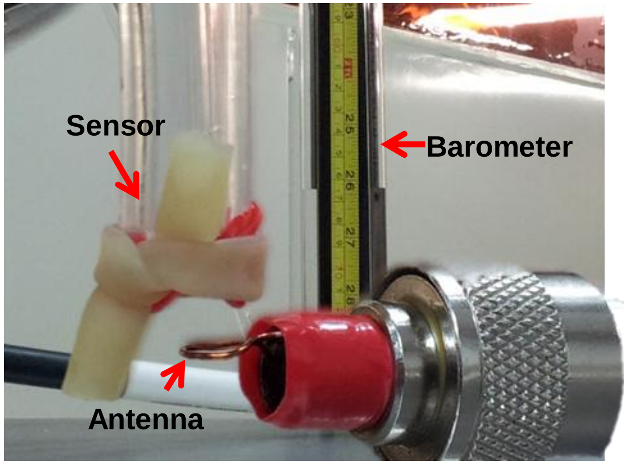
Pressure sensor assembling process. (a) MEMS capacitor and planar coil, (b) PDMS cavity bounded to the bottom plate of the sensor, (c) assembling of the sensor, (d) wireless pressure sensor.

Experimental Setup

- A water barometer is used to generate and measure a constant pressure over the sensor.

- The pressure variations were measured using a camera and a measuring tape.





- Measurements were done using a Vector Network Analyzer (VNA) (Anritsu, Japan).

$$P = \frac{\Delta h}{13.5951}\ [\text{torr}]$$

Problem Formulation

- Lumped Port:

$$z = \frac{V}{I} \qquad \mathbf{n} \times (\mathbf{H}_1 - \mathbf{H}_2) + \frac{1}{\eta}\mathbf{n} \times (\mathbf{E} \times \mathbf{n}) = 2\frac{1}{\eta} \times (\mathbf{E}_0 \times \mathbf{n})$$

- Electric field E inside the air sphere and the non-metallic elements:

$$\nabla \times \mu_r^{-1}(\nabla \times E) - k_0{}^2\left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}\right)E = 0$$

- Impedance boundary condition used for metallic structures:

$$\sqrt{\frac{\mu_0\mu_r}{\varepsilon_c}}\, n \times H + E - (n \cdot E)n = (n \cdot E_s)n - E_s$$

Problem Formulation

- Infinitesimal Strain for Continuous Bodys:

$$\varepsilon = \frac{1}{2}(\nabla u + \nabla u^T)$$

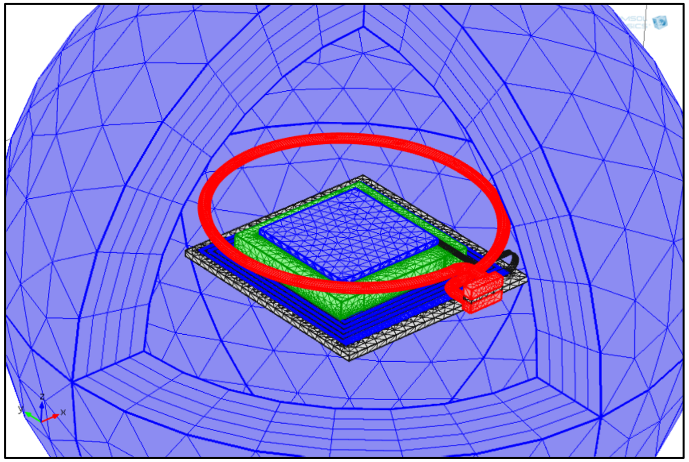
- Newton's Law in Stress Terms:

$$\nabla \cdot \sigma + \mathbf{F} = \rho \ddot{\mathbf{u}}$$

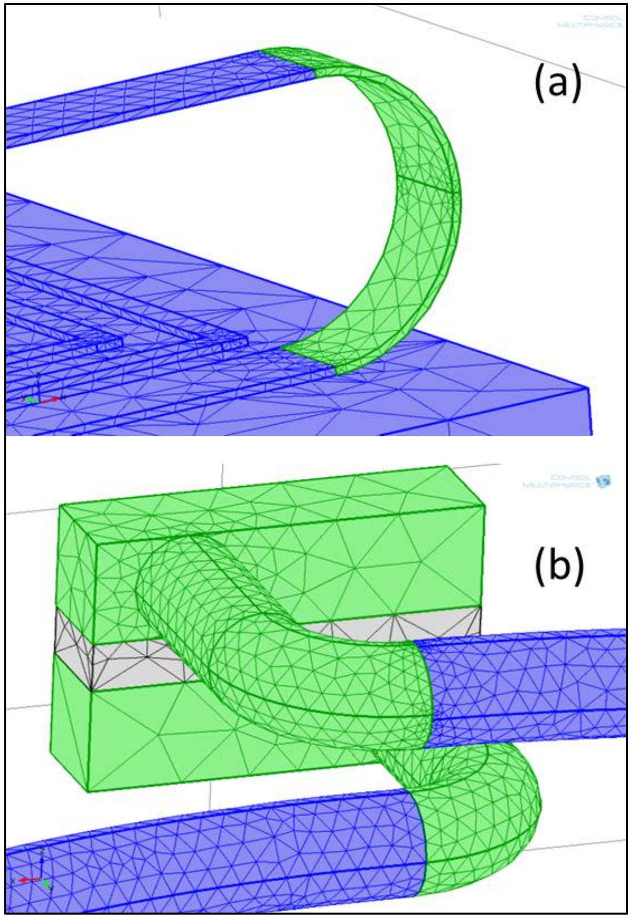
- Hooke's Law for Compressive Forces in Isotropic Materials:

$$\varepsilon_{ij} = \frac{1}{E}((1 + \nu)\sigma_{ij} - \nu \delta_{ij} \sigma_{kk})$$

Simulation Meshing



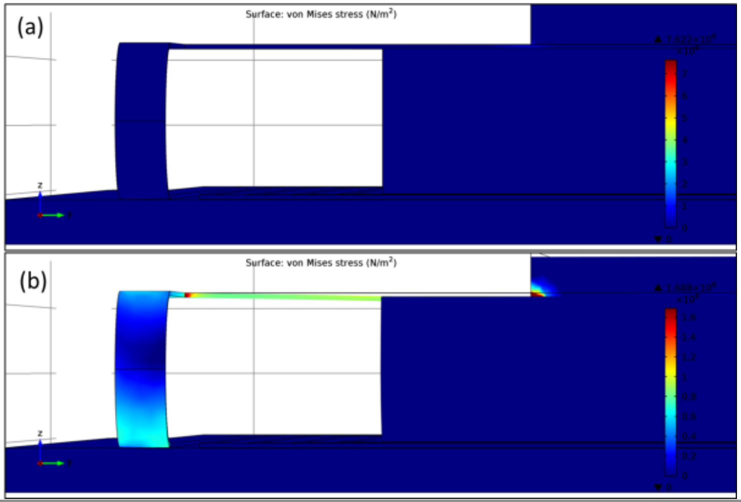
- The meshing process was customized taken in consideration the best properties for every domain and boundary in the model.
- The connections for the MEMS capacitor and the terminals of the antenna were simplified.

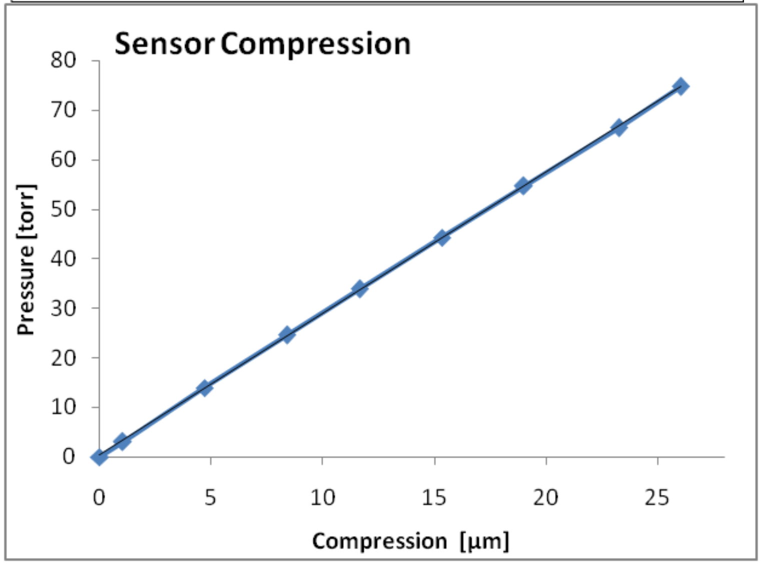


(a) Connections between the bottom and top plate of the MEMS capacitor (b) Connections between the two terminals of the coil.

Simulation Results – Solid Mechanics

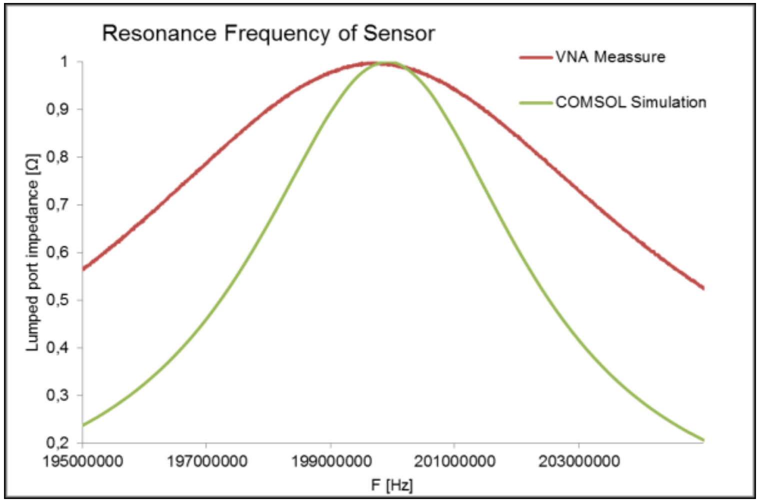
- The deformation caused by a constant pressure over the MEMS capacitor top plate was almost uniform.
- The displacement values were used on the electromagnetic simulation for the analysis on the resonance frequency caused by an external pressure.
- The displacement on the z axis was calculated evaluating the global displacement on the points of the boundary where the pressure was applied.

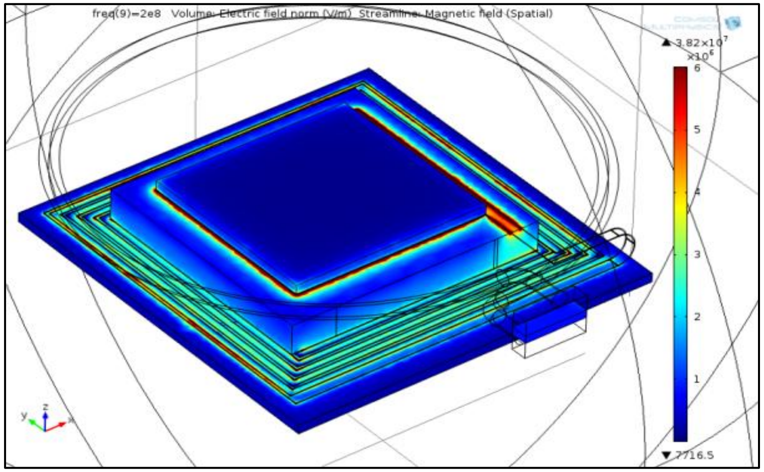




Simulation Results – RF Module

- The coupling effects caused by the sensor were similar in both real and simulated data.
- The resonance frequency of the simulated sensor was of 200.00 MHz, and the measured frequency was of 199.72 MHz.
- The resonance frequencies were used to obtain the pressure measurements.

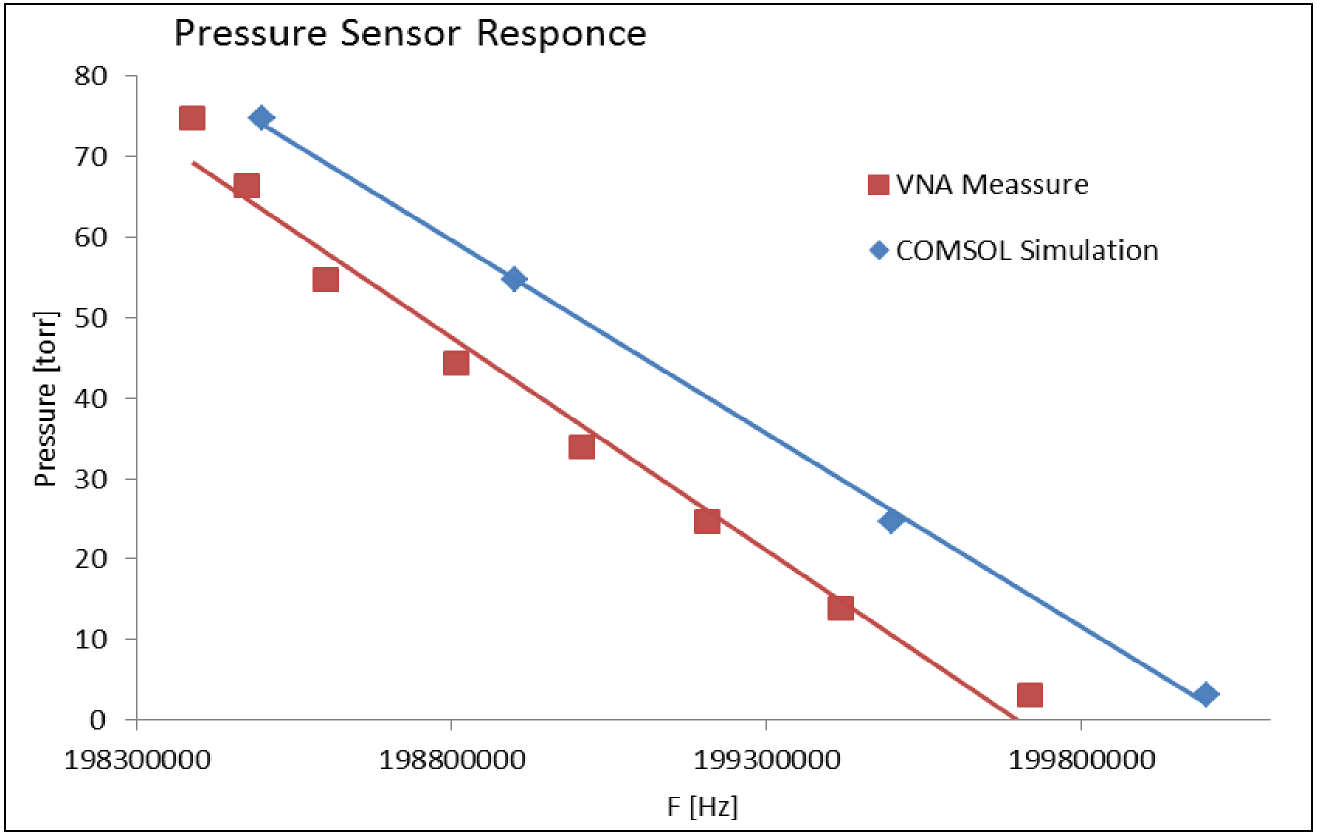




Energy induced on the sensor.

Results

Resonance frequency of the sensor with different pressures. Simulated data is shown in blue and measured data in red.



Conclusions

- The results of the sensor simulation were consistent with the experimental results.
- The compression on the sensor caused by an external pressure was properly simulated.
- The RF module show the behavior of the antenna coupling the sensor.
- The resonance frequency of the sensor had a 0.14% relative error caused by the fabrication processes.

Future Works

- Studying the parameters affecting sensor sensibility trough simulations.
- Design and fabrication of an smaller and more sensitive sensor.
- Perform simulations using the deformable mesh module.