proceedings

Abstract

Co-Design and Characterization of a Differential Wireless Passive Micro-Electromechanical System Pressure Sensor †

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† Presented at the XXXV EUROSENSORS Conference, Lecce, Italy, 10–13 September 2023.

Abstract: We present a differential wireless passive sensor based on a miniature antenna associated with a MEMS capacitive pressure sensor. In this configuration, a change in the external pressure results in a shift of the antenna resonance frequency and, thus, a variation in the antenna Radar Cross Section (RCS) detectable from a distance of a few meters. The MEMS and the antenna are modelled and simulated, and a co-design procedure is developed to optimize their performance. The MEMS are fabricated on a 200-mm technological platform and characterized. A specific setup was conceived to characterize the antenna sensor as a function of pressure in an anechoic chamber.

Keywords: sensor; MEMS; miniature antenna; pressure; RF

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Citation: Alcesilas, R.; Bastien, J.C.; Sansa, M.; Jouvaud, C.; Rey, P.; Delaveaud, C. Co-Design and Characterization of a Differential Wireless Passive Micro-Electromechanical System Pressure Sensor. *Proceedings* **2024**, *97*, 24. https://doi.org/10.3390/proceedings2024097024

Academic Editors: Pietro Siciliano and Luca Francioso

Published: 15 March 2024

1. Introduction

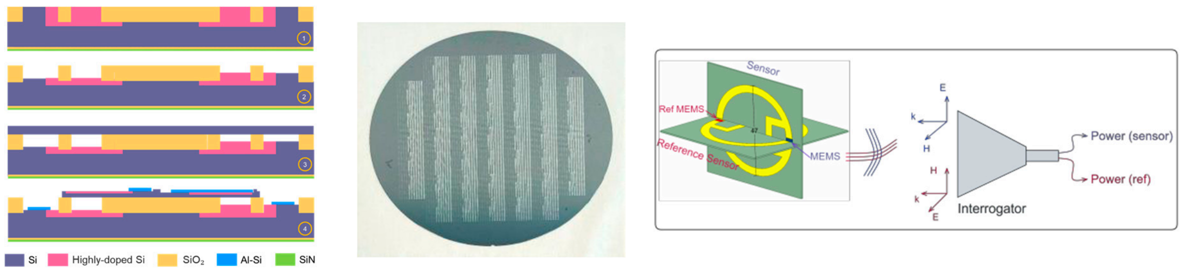
Wireless passive sensors are a field of interest due to the increased necessity of sensors operating in harsh environments. Current technologies such as LC sensors [1] or acoustic sensors [2] are limited either in terms of range or design flexibility. Here, we focus on a Micro-electromechanical system (MEMS) based on a wireless approach, in which a MEMS sensor locally modifies the properties of an antenna and its response to an incident signal. This approach combines good sensitivity with an interrogation distance of up to a few meters in accordance with communication standards.

This article presents the co-design, the fabrication, and the characterization of a differential MEMS capacitive pressure sensor and a miniature planar antenna, working around 868 MHz and in the 1 mbar—1 bar pressure—range. We previously presented a reading procedure with the same sensor geometry based on the variation in the antenna resonance frequency [3]. Here, the reading is performed at a fixed frequency by assessing the Radar Cross Section (RCS) of the antenna, which is its ability to backscatter electromagnetic waves. A higher RCS means a higher amount of reflected power. A change in the MEMS impedance modifies the antenna-impedance-matching condition, which modifies the current distribution of the antenna, and, therefore, its RCS. This method is faster than tracking the resonance frequency, but it requires the measurement of a reference sensor to obtain a differential measurement in order to correct the possible signal level alterations linked to the wave propagation in a more or less disturbed environment.

2. Materials and Methods

The wireless passive sensor is based on the association of a MEMS pressure sensor and a planar miniature antenna, co-designed in order to optimize their impedance matching and the performances of the global system. The MEMS, designed to work in the UHF band, is made of an electrode on a high-resistivity silicon membrane above a fixed electrode, resulting in a variable capacitor, fabricated in the CEA-Leti clean room. The fabrication process flow of the MEMS is shown in Figure 1a with one of the wafers in Figure 1b.

The antenna is a circular PIFA-inspired geometry [4]. The MEMS were wire-bonded in parallel on the antenna, with a measured impedance equivalent to a 135 Ohm resistor and a 2.4–2.8 pF capacitor in series. The differential measurement is shown in Figure 1c; the reference sensor is rotated 90° resulting in a different polarization of the antenna, and it has the same MEMS as the sensor, but with a pierced membrane to make it insensitive to pressure.

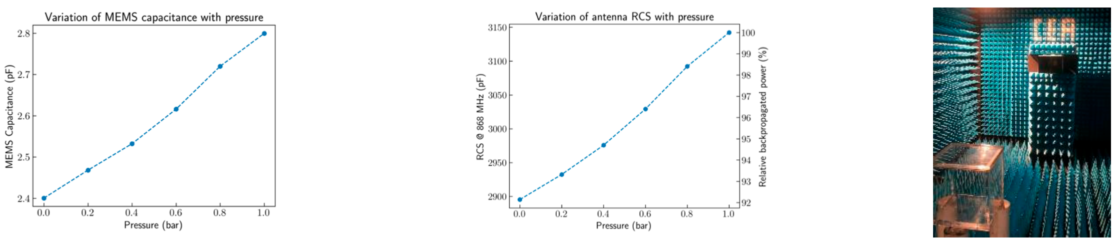


(**a**) (**b**) (**c**)

Figure 1. (**a**) Overview of the MEMS process flow. (**b**) A 200 mm silicon wafer with the different MEMS sensors. (**c**) Working principle of the differential measurement. Dimensions are in mm.

3. Discussion

An automatic 200 mm prober with a VNA was used to characterize the impedance of the MEMS between 500 MHz and 3 GHz; the capacitance is shown in Figure 2a. It was then imported to Ansys HFSS to tune the shape and dimensions of the antenna. The simulated antenna RCS at 868 MHz varies from 2895 mm^2 to 3142 mm^2 when the pressure varies from 1 mbar to 1 bar (8%/bar) (Figure 2b).



(**a**) (**b**) (**c**)

Figure 2. (**a**) Measured capacitance of the MEMS. (**b**) Simulated RCS variation at 868 MHz and equivalence in terms of relative back-propagated power. (**c**) Picture of the anechoic chamber with the interrogation antenna in the background and the plastic vacuum chamber in the foreground.

To characterize the antenna sensors, a plastic vacuum chamber was specifically fabricated in order to be transparent to electromagnetic waves. The setup is shown in Figure 2c. The pump is placed outside of the anechoic chamber to avoid disturbing the measurement.

Author Contributions: Conceptualization, R.A., M.S., P.R., J.C.B. and C.J.; Methodology, R.A., M.S., P.R. and C.J.; Validation R.A., M.S., P.R., J.C.B., C.J. and C.D.; Formal Analysis, R.A., M.S., P.R. and C.J.; Investigation, R.A., M.S., P.R., J.C.B. and C.J.; Data Curation, M.S. and C.J.; Writing—Original Draft Preparation, R.A.; Writing—Review & Editing, R.A., M.S. and C.J.; Supervision, M.S., P.R., J.C.B. and C.J. All authors have read and agreed to the published version of the manuscript.

Funding: This study is part of a PhD thesis under funding from AID/DGA (Defense Innovation Agency). The authors would like to thank AID/DGA for their support.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

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