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Wireless Measurement Technique for Telemetry Low-Value Resistive Sensors

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Abstract

The measurement of different quantities in harsh environments, such as those at high temperatures and/or in hermetic environments, presents considerable difficulties due to various factors, including the characteristics of the harsh environment itself, which do not allow the proper use of the electronics and / or using connection cables between the harsh and the safe environment. An adoptable solution is given by passive telemetry systems that include a passive sensor placed inside the harsh environment. Non-contact techniques are adopted to read the quantities. The measurement technique that is proposed may be adopted for resistive sensors. The system consists of a resistive sensor that is connected to an inductor and coupled to a second inductor positioned externally. The external inductor is connected to the readout electronics and permit, using the proposed technique, to calculate the value of the sensor resistance. The adopted telemetric technique is based on a measurement of the impedance at the terminals of the readout inductor and on a mathematical elaboration to extract the sensor resistance. The circuit model of the telemetric system is presented, several consideration on the telemetric technique are reported based on simulations and experimental results.

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Keywords: autonomous sensor; harsh environment; passive wireless sensor; telemetry; resistive sensor; telemetric system.

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1. Introduction

Literature reports growing interest in telemetric measurement systems that provide a wireless measurement of a passive sensor placed in a protected environment, for example inside the human body [1] and/or in environment where the correct functioning of electronics is not possible [2, 3, 4]. A readout electronic, located in a safe area outside the protected environment, is inductively coupled with the sensor itself. In this paper, a new method for measuring sensors based on resistive transduction is presented. The

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technique has been tested by fabricating prototypes where resistances of different values, simulating the sensor, have been used. The proposed solution is presented for low-value resistive sensors, which cover many solutions from different fields.

2. Telemetric technique

A circuit modeling the telemetric system is proposed; the configuration reported in Fig 1 is for sensors with low resistance values (tens of ohms). The symbol are defined as follows: Rp and Rs are the parasitic resistances of the readout and sensing inductor; Cs and Cp are the parasitic capacitances of the readout and sensing inductor; Lp and Ls are the readout and sensing leakage inductances; Lm is referred to coupled flux; N1 and N2 are the equivalent number of the inductor windings; Rx and Cr are the sensor resistance and the fixed capacitor. Since the working frequency is high, Rp and Rs are neglected, a circuit simplification is reported below in Fig. 1. The configuration has a typical diagram of the modulus and phase of impedance Z measured at the terminals of the readout (Fig. 1) reported in Fig. 2; four frequencies were analyzed (f_{ra}, f_a, f_{rb} and f_{min}). f_{min} represents the frequency at which is minimum the impedance phase in a short interval.

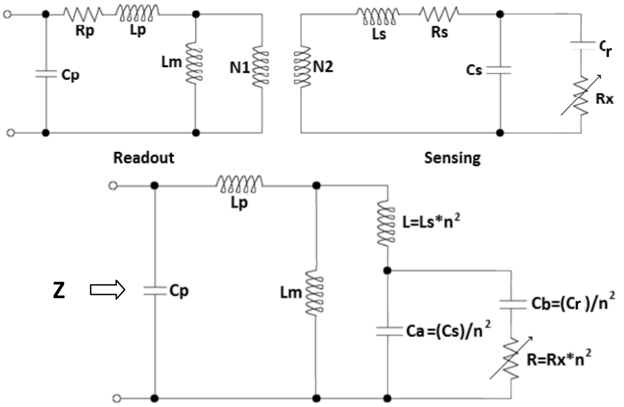

Fig. 1: Circuit model of a telemetric system suitable for resistive sensors with low values of Rx.

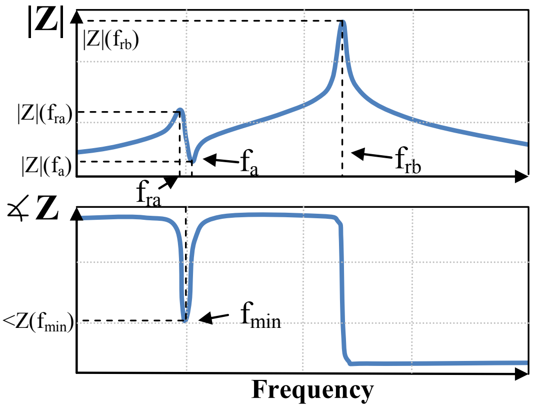

Fig. 2: Modulus and phase diagrams of the impedance at the terminal of the readout inductor.

A mathematical expression of the impedance was obtained permitting an analysis of the model components, thus:

$$Z(s)=\frac{(L_m+L_p)R\cdot s+(L_mL_p+(L_m+L_p))s^2+C_a(L_mL_p+(L_m+L_p))R\cdot s^3}{R+(L+L_m)s+(C_a(L+L_m)+C_p(L_m+L_p))Rs^2+C_p(L_mL_p+L(L_m+L_p))s^3+C_aC_p(L_mL_p+L(L_m+L_p))Rs^4}$$

The sensitivity analysis allowed the evaluation of the resonant frequency changes (f_{ra}, f_a, f_{rb} and f_{min}) due to a variation of the Rx, permitting to identify the dependencies of the frequencies, amplitudes and phases, from Rx variations. The sensitivity analysis was done by Wolfram Mathematica; the adopted component values of the model are presented in Table 1. The analysis showed a changing of all the resonant frequencies due to a variation of the sensor resistance. In Table 2 the Rx values adopted for the mathematical and experimental analysis are reported. The telemetric technique has been identified, which consider to measure the phase value at f_{min}.

Table 1: Values of the model components used for mathematical analysis.

Components	Values
Lp	31.94 µH
Lm	16 µH
Ls	12.58 µH
Cp	3.58 pF
Cs	1.73 pF
Cr	33.11 pF
N	1

Table 2: Values of the resistance sensor Rx used for mathematical and experimental analysis.

Rx Values
13.3 Ω
16.2 Ω
18.9 Ω
21.3 Ω
22.1 Ω
24.2 Ω
27.8 Ω

3. Preliminary experimental results

An experimental system has been developed to test the mathematical analysis. Two planar inductors, one for the sensing circuit and one for the readout circuit (Fig. 4) was fabricated in PCB technology and an experimental system for the mechanical positioning was developed (Fig. 4). The experimental system is composed by a wood structure with a micrometric screw for the correct positioning of the readout inductor respect the sensing inductor, at which Rx and Cr are connected. The impedance at the terminal of the readout inductor is measured using an impedance analyzer (HP4194A) and a PC (Personal Computer) with a LabVIEW program for the control of the measurement process. The mathematical results, briefly reported in Fig. 5, reveal a linear dependency with the phase measured at f_{min}. The calculated sensitivity is about 2 °/Ω. In Fig. 6, the experimental results obtained for the proposed configuration are reported; the data shows a good linearity and sensitivity, comparable with the data obtained with the mathematical analysis. Further experimental results concerning commercial sensors are in progress.

The preliminary experimental results demonstrate that the technology under study can be a viable solution for applications in hermetic and / or harsh environments that require the use of resistive sensors.

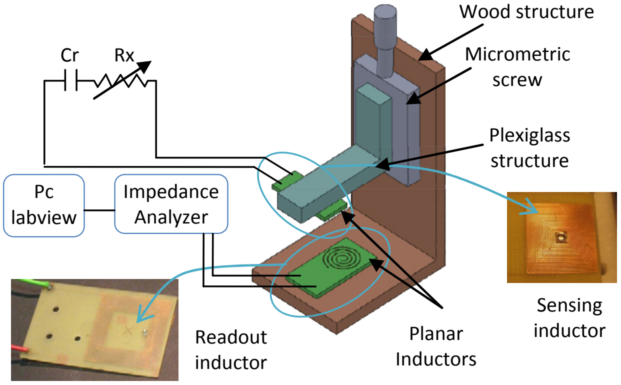

Fig. 4: Photos of the fabricated inductors and block diagram of the realized experimental setup.

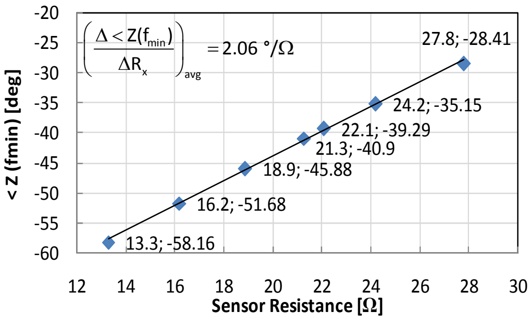

Fig. 5: Values of the min-phase as a function of Rx resistance obtained by mathematical analysis.

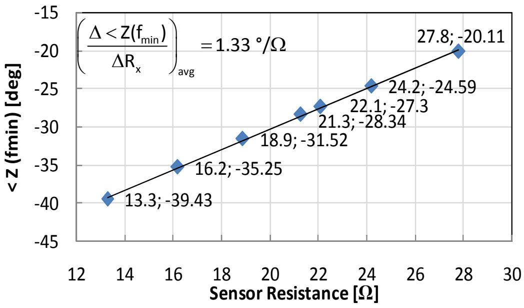

Fig. 6: Values of the min-phase as a function of Rx resistance obtained by the proposed experimental system.

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