Effect of high-permeability backplate in the near-field wireless measurement of resistance

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This paper presents a wireless technique for resistance measurement using near-field magnetic coupling. A flexible nanocrystalline backplate is integrated with the reader coil to significantly enhance magnetic coupling strength. This improves both the accuracy and range of resistance detection without altering the coil geometry. The proposed approach enables reliable contactless measurement, with the backplate playing a key role in system performance.

Keywords: Wireless readout, ferromagnetic backplate, nanocrystalline material, resistance measurement, coupling factor.

1. Introduction

Accurate wireless measurement of resistance is very important in applications such as temperature sensing, biomedical implants, and structural health monitoring [1, 2]. This work presents a method for wireless resistance measurement and the use of a nanocrystalline backplate to improve detection range and accuracy. A dual-frequency excitation method is used to extract the sensor resistance from the reflected impedance seen from the primary side.

2. Proposed System and Experimental Results

Fig. 1 gives a pictorial representation of the proposed wireless sensing system. From the real and imaginary part of the measured input impedance seen from the primary side, we can evaluate the sensor resistance using,

$$R_s = \frac{\left(Re\{Z_{in}\} - R_1 - R_o\right)}{\frac{Im\{Z_{in}\}}{2\pi f_{ex} L_1 - 1}\left(2\pi f_{ex}\right)^2 L_1\, C_2}\left(1 - \left(\frac{f_{ex}}{f_r}\right)^2\right) - R_2 \qquad (1)$$

If L_1, R_1, R_o, C_2, R_2, f_{ex} and f_r are known, R_s can be evaluated independent of the coupling factor (k) between primary and secondary, using (1). However, it is observed that at high R_s values, the system enters the high-damping state, leading to weak coupling between the primary and secondary coils. This results in either a deterioration of accuracy or a reduced measurement range. To improve the range or enhance accuracy within the same range, it is necessary to increase the coupling between the primary and secondary coils while maintaining the same coil dimensions and parameters. This was achieved by incorporating a high-permeability backplate with the reader coil, which creates a single-sided flux topology. A thin, flexible five-layer nanocrystalline material VITROLAM® 800R 5L3000 from Vacuumschmelze is used as the backplate.

As expected, k increases when using a backplate with the reader coil. However, the L_2 changes when the distance between the reader and sensing coils varies, causing variations in L_2 in (1), resulting in erroneous R_s values. To address this, we excite the system using two different frequencies, allowing us to obtain two equations with two unknowns; L_2 and R_s. By solving these two equations, we can determine R_s at any k value (except at very weak coupling). It is also possible to estimate the distance between the coils using the calculated L_2.

The experiment was carried out in the laboratory using prototype setups with two identical coils (117.7 μH) as reader and sensing coils (set at a resonance frequency of 130.5 kHz). The system was energized at two different frequencies: 160 kHz and 180 kHz. The nanocrystalline backplate shows good ferromagnetic properties with relative permeability (μ_r) around 2700 at these frequencies. The impedance data were recorded using an SR865 lock-in amplifier. The proposed method was validated by testing with different values of R_s, and the results are presented in Table 1. The test results show that the accuracy of resistance measurement improves significantly with the use of the backplate, demonstrating the effectiveness of the proposed system.

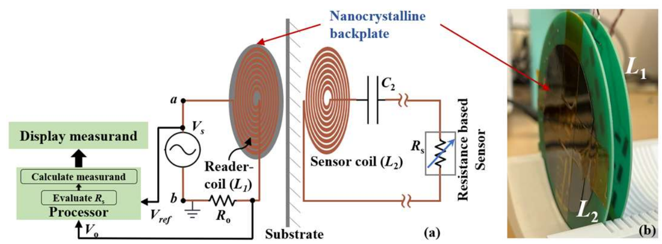

Fig. 1. The wireless readout system consists of a reader coil (L_1) with a nanocrystalline backplate and the sensor resistance (R_s) is connected to a series combination of reader coil (L_2) and capacitance (C_2). (a) Equivalent circuit. (b) Prototype unit.

Actual Resistance (Ω)	Without backplate		With backplate	
	MV (Ω)	Error (%)	MV (Ω)	Error (%)
5.5	4.88	-11.27	5.85	6.3
20	21.92	9.6	19.99	-0.075
30	28.51	-4.97	29.8	-0.7
43	41.12	-4.4	42.73	-0.63
47	44.71	-4.9	47.35	0.74
62	60.36	-2.6	62.98	1.58
75	79.09	5.5	76.86	2.5

Table 1. The measured resistance and the error is shown for the system with and without the magnetic backplate. MV represents measured value.

References

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