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Dual frequency system for power-demanding measurement in the isolated areas

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Abstract. The paper presents solution for wireless and battery-less measurement in the enclosed areas. The principle is based on previous work, while this paper is focused on high power-demanding applications such as MEMS accelerometers, gas sensors, piezoresistive strain gauges, etc. It can be suitable for continuous wireless and battery-less measurement in isolated systems such as the rotating objects, concrete walls, enclosed barrels, high temperature chambers etc.

It is based on near magnetic field coupling in radiofrequency band. The principle is similar to the RFID, while it is more powerful and the powering and signal transfer is separated by the different frequencies. The antennas are designed for surface mounting.

The system is desired to be used in long-term monitoring of the environment.

Key words

Wireless powering, Battery-less powering, Wireless sensors, Long-term monitoring, Dual frequency operation

1. Introduction

Measurement in the isolated systems is crucial task in many areas of interest. Demand of wireless and battery-less powering can be caused by different reasons. When the powering wires can not be guided to the sensor (e.g. rotating device, homogeneity of the surface ...), usually the battery powering take place while this is not suitable for every application. Main disadvantage of the battery powering is the limited lifetime and sometimes an improper environment for the battery (e.g. high temperature). In those cases the wireless powering must be applied.

Wireless powering can be performed for instance using the solar cells, temperature difference cells or vibration harvesting. This paper focuses on the energy from the magnetic field which is injected to the system. This solution is proper only for short distances; typically several centimeters. The principle is similar to the RFID but it is more powerful and allows separated powering and communication.

2. Inductive Coupling

When two or more inductances partly share the magnetic field, the coupling is presented. The voltage transfer between the coils can be calculated using the Faraday's law. The secondary voltage depends on the secondary coils geometry and on the magnetic field distribution of the primary inductance.

A Coupling Coefficient

In terms of the circuit theory the inductance coupling can be described using the mutual inductance or using the coupling coefficient. The coupling coefficient is more suitable because the standard simulation tools can be used for a description of the powering. As well as the voltage transfer also the coupling coefficient is given by the coils geometry and the magnetic field distribution. Most important topology of the inductances is the axial orientation. Coefficients dependency versus the distance is given by the magnetic field intensity distribution and is given by the figure 1. It shows the measurement result of the coupling coefficient between the circular coil and the rectangular surface coil of similar overall dimensions (about 15 cm). This dependency is approximated using the exponential and the $1/x^3$ functions. Character of this dependency is changing approximately at the distance equal to the diameter of the bigger coil (vertical dash line in the picture). This knowledge of the coefficients character can be used for a prediction of the coefficients value for the other coils.

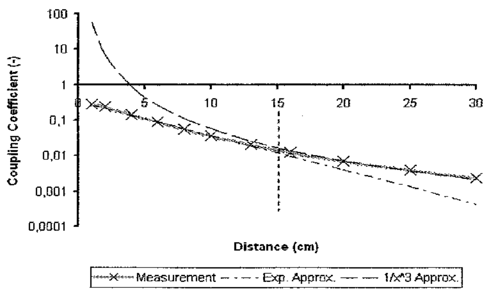

Fig. 1. Approximation by the exponential and $1/x^3$ functions for the coupled coils

The most important parameters of the coupled inductances are the voltage transfer (1) and the input impedance which can be seen on the inductor L_1 (2) [1].

$$\hat{V}_2 = \hat{V}_1 \cdot \frac{k \cdot \hat{Z}_L \cdot \sqrt{\frac{L_2}{L_1}}}{\hat{Z}_L + j\omega L_2 \cdot \left(1 - k^2\right)} \qquad (1)$$

$$\hat{Z}_{in} = \frac{\hat{V}_1}{\hat{I}_1} = \frac{j\omega L_1 \cdot \hat{Z}_L + j\omega L_1 \cdot j\omega L_2 \cdot \left(1 - k^2\right)}{\hat{Z}_L + j\omega L_2} \qquad (2)$$