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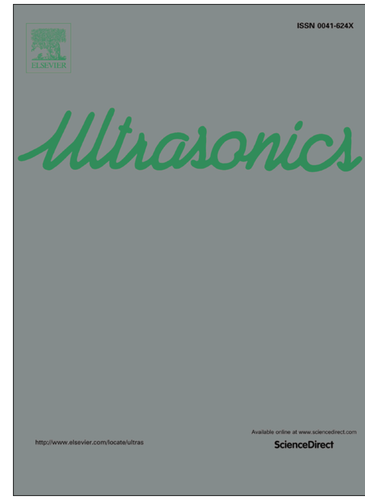

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Acoustic power delivery to pipeline monitoring wireless sensors

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Abstract

The use of energy harvesting for powering wireless sensors is made more challenging in most applications by the requirement for customization to each specific application environment because of specificities of the available energy form, such as precise location, direction and motion frequency, as well as the temporal variation and unpredictability of the energy source. Wireless power transfer from dedicated sources can overcome these difficulties, and in this work, the use of targeted ultrasonic power transfer as a possible method for remote powering of sensor nodes is investigated. A powering system for pipeline monitoring sensors is described and studied experimentally, with a pair of identical, non-inertial piezoelectric transducers used at the transmitter and receiver. Power transmission of 18 mW (Root-Mean-Square) through 1 m of a 118 mm diameter cast iron pipe, with 8 mm wall thickness is demonstrated. By analysis of the delay between transmission and reception, including reflections from the pipeline edges, a transmission speed of 1000 m/s is observed, corresponding to the phase velocity of the L(0,1) axial and F(1,1) radial modes of the pipe structure. A reduction of power delivery with water-filling is observed, yet over 4 mW of delivered power through a fully-filled pipe is demonstrated. The transmitted power and voltage levels exceed the requirements for efficient power management, including rectification at cold-starting conditions, and for the operation of low-power sensor nodes. The proposed powering technique may allow the implementation of energy autonomous wireless sensor systems for monitoring industrial and network pipeline infrastructure.

Keywords: wireless power transfer, ultrasonic, acoustic, pipeline, monitoring, sensor

I. INTRODUCTION

Remote powering of wireless sensors can resolve the main limiting factor in the widespread adoption of wireless sensor network (WSN) technologies. The maintenance and environmental burden of battery usage has become more important, despite the significant energy density increases of the last decade, because of the expansion of applications requiring the permanent installation of a large number of sensors. Examples include industrial monitoring for optimized maintenance and control, smart management of urban infrastructure, and monitoring of resource distribution networks for reliability and security.

Energy harvesting, the exploitation of environmental energy that is locally available to a sensor, has been demonstrated to considerably enhance energy autonomy of a diverse range of wireless systems. The available energy is adequate in a number of cases, but typically requires the development of bespoke harvesting devices. This requirement inhibits the adoption of energy harvesting solutions in commercial systems.

The case of motion energy harvesting is a representative example. Enough energy is available in a wide range of environments, including industrial, vehicle and infrastructure equipment. In addition, the micro-electro-mechanical systems (MEMS) technology required for the production of motion micro generators is sufficiently advanced. However, each application has a different vibration spectrum, and different power and size specifications, requiring a customized implementation. In order to solve this problem, a number of promising techniques have been proposed, such as frequency up-conversion based on bi-stable systems [1], non-linear (broadband) mechanical oscillators [2], pre-biasing of piezoelectric transducers [3], pre-loading of cantilevers with mechanical compression [4], and free-mass non-resonant devices [5]. Effectively, these approaches reduce the maximum possible energy density in exchange for broadband operation and hence broader applicability.

In a different approach proposed here, the high-performance of vibration energy harvesters at resonance can be exploited by inducing vibration at a suitably selected