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厦门大学

硕士学位论文

LC谐振式无线压力传感器信号拾取系统研究

Research on Signal Pickup System for the Wireless Passive LC Resonant Pressure Sensor

蔡建法

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摘 要

在高温、潮湿等恶劣的环境中以及眼内压测量、疤痕治疗等应用场合，不便利用有线有源的传感器进行压力监测，LC谐振式无线压力传感器采用无线无源方式实现对压力信号的提取，拓展了压力传感器的应用范围。目前，LC谐振式无线压力传感器的信号拾取主要使用网络分析仪或阻抗分析仪，不仅成本高，而且携带不便，极大限制了非实验室场合的应用。本文针对LC谐振式无线MEMS压力传感器的信号拾取现状，从理论分析、系统仿真、硬件设计、软件设计和实验验证等方面展开研究，设计了基于阻抗实部测量法的信号拾取系统。

基于电感耦合理论，从阅读天线和LC谐振式无线压力传感器耦合模型的等效阻抗出发，对相位测量法、阻抗实部测量法、S11测量法的拾取原理及相互参数影响关系进行了推导。结果表明阻抗实部测量法得到的谐振频率理论上几乎不随耦合系数的变化而变化，故本文采用该方法进行传感器谐振频率的提取。为了进行阻抗实部的测量，对比了向量分解法和乘法解调法两种硬件实现方案的区别，由于向量分解法测量电路的同步性要求较高，且电路设计复杂，故选用乘法解调法进行硬件电路设计，并利用ADS软件探究了耦合系数、传感器品质因数、阅读天线电感量和直流电阻对测量电路结果的影响。

为了缩短设计周期，传感器信号拾取系统设计前期，以PCB板上电感和贴片电容组合的LC谐振电路模拟LC谐振式无线压力传感器，并利用NI数据采集卡和LabVIEW工具取代DSP的数据采集和处理功能，搭建了测量系统，测试了利用乘法解调法搭建的电路对其谐振频率提取的可行性。利用LabVIEW数据采集系统探究了通过改变扫频时长和驱动电压增大乘法解调模块输出最大幅值来提高传感器耦合距离的方法。以TMS320F28335为主控芯片进行硬件设计，信号拾取系统包括高精度线性扫频源、跨导放大、乘法解调、DSP数据采集和处理以及电源管理等模块。结合DSP数据采集与处理能力以及扫频源的工作模式和控制特征，并基于阻抗实部法的测量原理，提出了单频法和三角扫频法两种传感器谐振频率的提取算法。在搭建的阻抗实部信号拾取系统上进行了基于MEMS工艺制作的LC谐振式无线压力传感器性能的测量，测量得到的谐振频率值和待测压力之间的线性度较好，压力测量精度高于5%，并且当阅

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读天线和传感器之间的耦合位置发生微小偏移时，测量结果变化较小，同时比较了三角扫频法和单频法的测量结果，单频法测量误差较大，抗噪声能力较差，相反，三角扫频法具有较强的抗噪声能力。

关键词：LC谐振式无线压力传感器；阻抗实部测量；乘法解调；三角扫频

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Abstract

In harsh environment such as high temperature and humidity, or applications like intraocular pressure measurement and scar treatment it's difficult to detect with wired and active sensors. LC resonant pressure sensor expands the application range of the pressure sensor by measuring pressure in a wireless and passive way. At present, The signal pickup instrument for the wireless passive LC resonant pressure sensor mainly relies on network analyzer or impedance analyzer. Although these devices are adaptable and accurate, they are bulky and expensive and thus restrict the use of this measurement method outside the laboratory. In this paper, studies were carried out on theoretical analysis, simulation, hardware design, software design and experiment verification aimed at the status quo of picking up the MEMS wireless passive LC resonant pressure sensor's signal. And a signal pickup system based on the real part of impedance measurement was designed.

Based on inductance coupling theory, three methods's principle and influencing parameters were derived according to equivalent impedance of readout antenna and the wireless passive LC resonant pressure sensor coupling model, those are phase measurement method, real part of impedance measurement method and S11 measurement method. It turned out that the resonance frequency gained by real part of impedance measurement is hardly changed in relation to coupling coefficient, the measuring method was accepted to pick up the resonance frequency of the sensor. There are two hardware design schemes to measure real part of equivalent impedance, including vector decomposition method and multiplication demodulation method. Differences between two methods was compared. Since vector decomposition method claims high synchronicity and complex circuit design, multiplication demodulation method was adopted and simulated by ADS software to explore the influence of various parameters

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including coupling coefficient, quality factor of sensor, inductance and dc resistance of readout antenna.

To shorten the design period, LC resonance circuit made up by PCB planar inductor and chip capacitor was used to imitate the wireless passive LC resonant pressure sensor,meanwhile LabVIEW and NI data acquisition card were used instead of data acquisition and processing functions of the digital signal processor in the early stage of the system design for sensor signal pickup.And the resonance frequency of LC resonance circuit was extracted to verify the feasibility of the circuit based on multiplication demodulation method.

TMS320F28335 was selected as the main control chip and the measurement circuit consists of high precision linear sweep frequency source, transconductance amplifier, the multiplication demodulation module, data acquisition and processing by DSP and power management. According to the operation mode of the frequency sweep source, two sensor resonance frequency extraction algorithm is proposed, namely, single frequency method and triangular frequency sweep method. Performance of the wireless passive LC resonant pressure sensor based on MEMS technology was tested under signal pickup system on account of real part measurement. The measured frequency had a good linearity across pressure with a pressure measuring accuracy higher than 5%. The measured results hardly changed when the coupling position between antenna and the sensor slightly shifted. The measure results of single frequency method and triangular frequency sweep method were compared. It turns out that the single frequency method has a bigger error and poorer ability to resist noise than triangular frequency sweep method.

Keywords: Wireless Passive LC Resonant Pressure Sensor; Real Part of Impedance Measurement; Multiplication Demodulation; Triangular Frequency Sweep

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