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Author: Ms. Yayu Monica Hew
United States, ya-yu.hew@mavs.uta.edu

WIRELESS STRAIN SENSING SYSTEM FOR STRUCTURAL HEALTH MONITORING UNDER VARIOUS GRAVITY LEVEL

Abstract

The ongoing demand of the integrated space Vehicle Health Monitoring Systems (VHMS) has been boosted by the increasing global interests in space exploration. NASA has also highlighted the importance of space structural health monitoring in the Space Technology Roadmaps (STRs). The wireless sensor has the benefit of reducing the payload and the launch costs. In addition to the static strain measurement, the Wireless Strain Sensing System (WSS) will also reveal the impact of acoustics and vibration on vehicle or equipment during launching/ground test. The system has the potential to provide scalable static/dynamic monitoring of fatigue and other structural failures. The Parabolic Flight Opportunity program by NASA provides a space relevant environment with various gravity levels for the WSS. The WSS will enable the rapid assessment of the structure's integrity through measurement of strain and vibration response, which is essential for the safety and high performance operation of the space infrastructure. Both structural static and vibration tests will be done during various gravity levels, i.e. the near zero gravity at 0.00 g +/- 0.02 g, the lunar gravity at 0.16 g +/- 0.05 g, and the Martian gravity at 0.38 g +/- 0.05 g. Since the future application of the WSS for spacecraft health monitoring will be likely to take place in the Martian and Lunar environment, the relevant gravity levels provided by the Flight Opportunity Program will assist the understanding of the system performance, constraints, and possibly advance the WSS Technology Readiness Level (TRL) from TRL 4 to TRL 5/6 by providing the relevant experimental environment. In this paper, the WSS performance under various gravity levels will be presented based on the flight test result. The system includes a wireless strain sensor that consumes about 6 mW, a wireless solar energy harvesting unit, a frequency modulation/demodulation unit, and a Data Acquisition Unit (DAQ). To achieve an ultra-low power operation, a voltage-controlled oscillator (VCO) is used to convert the direct-current (DC) strain signal to a high frequency oscillatory signal. Next, this oscillatory signal is transmitted by an unpowered wireless transponder. A generic solar panel with energy harvesting circuit is used to power the strain sensor node. The frequency demodulation will be implemented as a frequency counter implemented in a microcontroller board (Arduino) and acquired using a PC-based MATLAB program. The system features ultra-low power consumption, completely wireless sensing, solar powering, and portability.