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WIRELESS STRAIN SENSING SYSTEM FOR SPACECRAFT HEALTH MONITORING

Abstract

With the increasing global interests in space exploration, the need of wireless space Vehicle Health Monitoring Systems (VHMS) is on the horizon. By elimination of massive wiring, the wireless sensor will reduce the payload and thus the launch costs. As one of the fundamental structural physical indicators, strain is of interest for many researchers studying spacecraft mechanical performance. For space shuttles and spacecrafts, the Wireless Strain Sensor (WSS) will reveal the impact of acoustics and vibration on vehicle or equipments during launching/ ground test. In the Rocket Acoustics Program, NASA used WSN to monitor the structure strength of the Composite Overwrapped Pressure Vessel (COPV). WSS also has the potential to provide scalable static/dynamic monitoring of fatigue and other structural failures. Though the space shuttle program had ended, future spacecraft still requires strain measurement for safety and assessment of structural performances. The ongoing space project, Composite Crew Module (CCM) by NASA, requires a detailed structural testing on ground. The WSS could potentially resolve the complex configuration of the wired sensing system. Additionally, the lunar programs under ESA, NASA, and the Indian Space Agency have also invested great interests in integrated wireless sensing system for space VHMS, including mechanical, thermal, and others environmental detection.

This paper presents the implementation and characterization of a wireless strain measurement system that is powered by solar energy. This system includes a wireless strain sensor that consumes about 6 mW, a wireless solar energy harvesting unit, and a frequency modulation/demodulation unit. To achieve such 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 for a short period of time. The frequency demodulation is based on a Phase Lock Loop (PLL) circuit that tracks the frequency of the received wireless signal and demodulates it into the original strain signal. The system features ultra-low power consumption, completely wireless sensing, solar powering, and portability. This system is capable of both dynamic and static structural measurement. Although the challenge of extreme operational condition for WSS in space and the strict performance requirements, the application of WSS in space is promising and bears the potential in reduction of costs and payloads with great scalability and sensor flexibility.

Assured Presentation.