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Space Structures I - Development and Verification (Space Vehicles and Components) (1)

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WIRELESS AND BATTERYLESS VIBRATION TESTING OF SPACE STRUCTURES WITH IMPLANTED LSI SENSORS

Abstract

The structural integrity of space structure has to be qualified through a modal survey or vibration testing at several stages in the development. Since attaching accelerometer and routing their wire harnesses demand delicate and time-consuming labor, we limit the number of such testing at minimal presently. The purpose of this research is to drastically facilitate the ground testing and even to realize on-orbit testing to check the structural integrity of space structures with wireless and batteryless LSI sensors which are implanted to components at their production.

The principal challenges of wireless and batteryless vibration testing are the power supply to sensors and the concurrent collection of multiple accelerometer data streaming. The latter is essential to correlate the acceleration measurement and the excitation force to derive the transient matrix. In this paper, we propose to employ the passive RFID mechanism to power up LSI sensors by a radio wave transmitted from an interrogator. The radio reflection from an LSI sensor is either analog or digital modulated with the accelerometer in the sensor. To separate the response from multiple LSI sensors at the interrogator, we assign non-orthogonal subcarrier to each LSI sensor. Although the non-orthogonal subcarriers can be produced only with a constant rate of sensor's antenna switching, they interfere each other because of the nature of the switching. To cancel the interference, we are developing a novel interference cancellation method using digital signal processing with Hilbert and inverse-Hilbert transformation in the interrogator.

The practicality of the proposal, particularly the performance of the cancellation method, is evaluated with simulation and experiments. In the experiment, three custom-made wireless sensor prototypes are installed to a cantilever, which is mechanically excited by a vibration testing equipment at a fixed frequency. The responses of the three sensors are retrieved with the said interference cancellation method implemented in a software defined radio platform, USRP and Labview Communications. The recovered data streams are compared with the measurements with conventional wired accelerometers. It is shown that the interference cancellation method achieves 14dB gain in the carrier to interference ratio in an actual wireless propagation environment. It is also verified that the measured mutual phase difference among accelerometers can be preserved even after the interference rejection processing.

From the evaluations, we conclude the wireless and batteryless vibration testing with the proposed concurrent data streaming method is promising as candidate future ground and on-orbit vibration testing of space structures.