An embedded algorithm for detecting and accommodating synchronization problems in wireless structural health monitoring systems

Kosmas Dragos, Kay Smarsly
Bauhaus University Weimar, Germany
kosmas.dragos@uni-weimar.de

Abstract. In wireless structural health monitoring systems, the inherent processing power of wireless sensor nodes enables the execution of structural health monitoring tasks in a decentralized manner. Decentralization may result in non-synchronized sets of structural response data, for example due to non-simultaneous triggering of the sensor nodes. Lack of synchronization is detrimental to the output of operational modal analysis (OMA), which is frequently applied in SHM, leading to erroneous structural mode shapes. From a computer science perspective, synchronization approaches in wireless SHM systems center around clock synchronization schemes. In this paper, an embedded algorithm is presented that enables wireless sensor nodes to detect and to accommodate synchronization problems. The proposed algorithm draws from the theory of OMA and the expected relationship between the phase angles of frequency components corresponding to mode shapes obtained from different sets of structural response data. The embedded algorithm is implemented into a wireless SHM system and validated through laboratory tests on a shear frame structure.

1. Introduction

Over the past decades, structural health monitoring (SHM) has been widely studied to assess the condition of large-scale engineering structures (Smarsly et al., 2012a,b). The advances in embedded processing technologies have enabled wireless sensor nodes to perform on-board computational tasks of increasing complexity. In wireless structural health monitoring, the enhanced computational capabilities of embedded microcontrollers take wireless sensor nodes one step further from serving merely as easy-to-install sensing devices that collect and communicate structural response data. Rather, in an attempt to address reliability issues associated with wireless communication, developing embedded algorithms to execute part of the monitoring process on board the sensor nodes has been the focus of extensive research (Dragos and Smarsly, 2015). Furthermore, it has been proven that on-board processing is less power-consuming than the wireless transmission of raw structural response data (Lei et al., 2010; Smarsly and Law, 2013).

Despite the merits of eradicating cables in SHM systems in terms of cost efficiency, the decentralized nature of wireless SHM systems may lead to synchronization discrepancies among different sets of structural response data. Specifically for system identification methods employed in SHM, which are typically based on the accumulation of different sets of structural response data, absolute synchronization is a prerequisite. For example, in operational modal analysis, which is applied in this paper, synchronization discrepancies may lead to erroneous mode shapes (García-Palacios et al., 2015).

In the field of computer science, research on synchronization in wireless SHM systems has been focusing on clock synchronization schemes. A comparison between various clock synchronization schemes along with discussion on clock synchronization problems, such as shifting and drifting, is given by Youn (2013). Moreover, a detailed survey on synchronization protocols can be found in Sundararaman et al. (2005). From an operational modal analysis (OMA) viewpoint, the characteristics of asynchronous structural response data, expressed through the respective power spectral density functions, has been investigated