SDR processing delay estimation applying correlation detection for Structure Health Monitoring using Multi-subcarrier Multiple Access*

Extended Abstract†

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ABSTRACT

Wireless and battery-less structural health monitoring (SHM) that detect structural damage at low cost are required. To achieve this, the use of multi-subcarrier multiple access (MSMA) communication method is being considered. In MSMA, time synchronization of sensing data is shifted owing to software defined radio (SDR) processing. Therefore, when an SHM monitoring method requiring time synchronization of sensing data is used, time synchronization taking SDR processing delay into account is necessary. In this study, we propose a system that estimates SDR processing delay by correlation detection and acquires time synchronization of sensing data. We measured SDR delay estimation with time accuracy by installing this system on an experimental object. Results showed that the error of the allowable processing delay estimation was different, and time synchronization can be achieved by performing sensing once by the SDR processing delay estimation method using correlation detection.

CCS CONCEPTS

• **Hardware → Sensor applications and deployments**; **Wireless devices**;

KEYWORDS

structural health monitoring; multiple access; multi-subcarreier multiple access; SDR; RFID

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1 INTRODUCTION

The aging of social infrastructure (bridges, tunnels, etc.) built in large numbers during high economic growth is concerning. Twenty years later, approximately 50% of 700,000 bridges in Japan will be built for 50 years. In 2004, 27% of bridges in the US is over 40 years old after construction. Sensing a structure using a sensor has attracted interest in the field of SHM[1], and a distortion and acceleration sensor[2] is used in a sensor node. Some studies [3, 4] on SHM have used the wireless sensor while considering the cost of cable laying, among others. In addition, since there are cases where the structure is large or the service life is long, replacing the battery or charging sensor devices in SHM[5] is expensive when many sensor devices are installed. The sensor node, which is battery-less and wireless, is being used in SHM. The development of a battery-less wireless radio sensor node, which combines a system and sensor of passive radio-frequency identification, (RFID) and the study on MSMA communication method [6], which enable real-time communication with multi sensors at many spots, have been implemented. However, when a monitoring method requiring time synchronization with SHM is used, MSMA needs to estimate the SDR processing delay and perform time synchronization. Therefore, the objective of this study is to implement SHM using battery-less sensor nodes. We propose to perform SDR processing delay estimation by utilizing correlation detection for structure health monitoring.

2 CHALLENGES IN USING MSMA IN SHM INCLUDING TIME SYNCHRONIZATION

We have assumed that SHM uses sensor nodes that incorporate sensor functions in passive RFID to enable low power consumption and wireless communication [5]. In SHM, damage to the structure is detected by data sensed simultaneously at multi points and at any given time. The number of sensors and the installation location depend on the application, and the receiver is fixed. However,

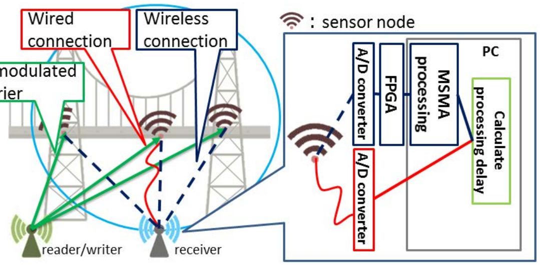

Figure 1: SDR processing delay estimation system

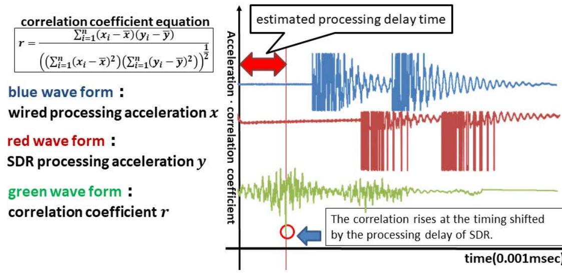

Figure 2: Correlation detection of SDR processing delay

since the communication system of the conventional passive RFID uses TDMA, the communication system cannot synchronize sensed data in multiple locations. Based on this, MSMA, which can handle multipoint data was applied as the communication method of SHM. In MSMA, it is necessary to perform SDR processing to handle multiple sensors. When a monitoring method that requires time synchronization is used, MSMA needs to estimate the SDR processing delay in advance and perform time synchronization. MSMA has a processing delay when SDR is used to flexibly deal with the number of sensor nodes. If a = scale and b = offset are obtained by comparing the peaks of the waveforms of a wired signal and a wireless signal outputted after SDR processing, and Y = processing delay time and X = time without SDR processing, the processing delay time can be calculated using Y = aX + b. SDR processing delay estimation for time synchronization requires the measurement of scale and offset.

3 SDR PROCESSING DELAY ESTIMATION USING CORRELATION DETECTION

The processing delay estimation system for SHM is shown in Figure 1. The SDR processing delay estimation system connects the cable for wired connection to one of the wireless acceleration sensors installed in the assumed SHM structure and acquires sensing data by hammering. The data is subjected to SDR processing delay estimation, and delay estimation is made in advance once before monitoring. After sensing (computation of correlation system value by LabVIEW, MATLAB, etc.), the delay is outputted. The number of subcarriers allocated to the sensor, the amount of interference cancellation, and the performance of the computer are considered to affect SDR processing delay. The output waveform of approximate shape was delayed due to the processing delay of SDR. Based on this, it is appropriate to use a method of detecting waveforms of approximate shapes that have been delayed. General correlation detection is used in abnormality detection. Correlation coefficient values are calculated using the correlation coefficient equation in Figure 2; x is the acceleration of the wired sensor, y is the SDR processed acceleration, and n is the number of sampling data in one measurement.

4 EVALUATION

Since the processing delay can be calculated by acquiring and comparing the peaks of wired and SDR processed signals, we investigated methods to obtain signals with wired and SDR processing included. The signal from the acceleration sensor was input to a PC through a DAQ (A/D converter). Signals from the prototype sensor nodes (RFID + acceleration sensor) were input to a PC through USRP. We compared wired and wireless connection waveforms and measured the processing delay. Using a suitable detection method to create an experimental environment, the NI USB 6210 was used for wired DAQ and the NI 2952R for USRP for SDR processing. For each data, hammering was performed twice, data was acquired 50 times, and the correlation coefficient between wired and SDR processing signals was calculated. The absolute value of the correlation coefficient was used and the acquisition time of the maximum correlation coefficient value was used as the processing delay. One measurement time was approximately several seconds and the measurement was conducted 50 times. Processing of delay estimation was performed offline and the processing time was approximately 3 minutes per processing delay estimate; however, it can be processed in parallel. Owing to processing delay estimation from data measured 50 times, the processing delay was approximately 345 ms on the average because of withdrawing outliers (described later). The delay was measured before monitoring and the acquired signal was returned by delay.

5 CONCLUSION

In this study, we discussed SDR processing delay, which is a challenge when MSMA is used for SHM. In MSMA, since the time synchronization of input and output signals is shifted by SDR processing, estimation of delay of SDR processing is required when the SHM monitoring method, in which synchronization of input data and output signals of the sensing data, is used. Therefore, in this study, we proposed a time synchronization system by estimating the delay in advance by SDR processing using correlation detection, and estimating the delay time by practically installing this system on a beam and measuring the accuracy. As a result, prior to SHM monitoring, it was necessary to attach a cable for wired connection to one of the prototype sensor nodes, and once the object to be monitored has been sensed by SDR processing delay estimation using correlation detection, this study emphasized that calibration is possible by the method.

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