The XS770A Wireless Vibration Sensor for the Industrial IoT

Shouji Nagano [*1] *Daisuke Kaneko* [*1]
Keiichi Sasaki [*1] *Yuuji Aono* [*1]

Yokogawa Electric Corporation has developed the Sushi Sensor series of compact wireless sensors for maintenance, environmental monitoring, and energy management. The first product in the series is the XS770A wireless vibration sensor, which is robustly designed to be used for Industrial IoT (Internet of Things). This battery-driven sensor can monitor the vibration and surface temperature of manufacturing facilities for a long period, significantly reducing the cost of such monitoring. This paper introduces the XS770A's excellent durability, vibration sensing performance, wireless function, and battery system, all of which are built into its compact, light-weight body.

INTRODUCTION

To improve the efficiency of plant maintenance and prevent unplanned shutdowns that lower productivity, there is an increasing need for low-cost wireless vibration and temperature sensors that can be easily mounted on facilities. Vibration and surface temperature are crucial variables that indicate the state of equipment. By mounting a number of such sensors on the surface of the equipment and measuring these variables for a long period, the conditions of manufacturing equipment can be monitored remotely at low cost. Although many kinds of inexpensive sensor are available in the market, most of them are for indoor applications and cannot be used in plants for which durability is essential.

Yokogawa has developed Sushi Sensor, a wireless sensor as the industrial internet of things (IIoT)[(1)] ideal for plants. Sushi Sensor has various user-friendly functions and can be mounted and set up easily in plants. The sensor was developed to enable a large number of products to be mounted and operated in harsh environments, thus creating new value in combination with the flexible, powerful data processing capability provided by the cloud.

This paper describes the XS770A wireless vibration sensor, which achieves the concept of Sushi Sensor by integrating the sensor section and the wireless section in a single body. The paper also describes the sensor's features such as ease of mounting, the ability of the vibration sensor and temperature sensor to monitor equipment conditions, the wireless performance to cover a wide area, and ease of maintenance, in addition to excellent environmental resistance, and the compact, lightweight design.

DEVELOPMENT CONCEPT

The XS770A is a compact, battery-powered wireless sensor with built-in vibration and temperature sensors. The development requirements are described below.

Sensors that are deployed in plants must have high durability and environmental resistance including being waterproof and dustproof. In addition, to monitor the vibration of target instruments, the sensor must be compact to allow easy mounting on the instruments, and the sensor section must be securely fixed to the main body to prevent resonance within the measurement range. The sensor also must be lightweight for easy handling.

To achieve a lightweight design, it is necessary to make the mechanism simple and minimize the number of parts. The battery capacity determines the size and weight of the sensor. The XS770A was designed to be powered by a dedicated AA battery. To meet this restriction, the LoRaWAN wireless communication method was used for data transmission, considering its low power consumption. In addition, near-field communication (NFC) was used for the display and setting interface, and a resin casing was used to reduce the weight of the body.

*1 Wireless Development Department, New Field Development Center, IA Products & Service Business Headquarters

DESIGN

With an elaborate design that makes the most of the resin casing, the necessary functions and performances were achieved in the minimum volume.

Figure 1 shows an external view of the XS770A. The sensor has a characteristic design, starting as an octagonal base and ending as a square top. The octagonal base allows screw mounting to fasten the base onto the measured object by using a wrench. and the square top enables efficient storage of circuit boards, battery, and antennas in the body.

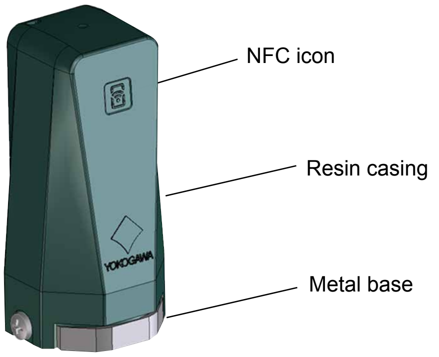

Figure 1 External view of the XS770A

The front and rear faces of the casing have a sufficient area. An icon on the front face indicates the position of the NFC interface; users can communicate with the sensor by holding their mobile terminals close to this icon.

HOUSING DESIGN

In addition to being lightweight, resin allows electromagnetic waves to pass through. This advantage allows antennas to be built into the casing, making the sensor structure simpler than those with external antennas.

Table 1 shows the housing specifications. Reinforced plastic is used for the main part of the housing to ensure environmental resistance. The base is made of metal to reliably sense the vibration and temperature of the measured object. Corrosion-resistant stainless steel is used to enhance environmental resistance.

Table 1 Casing specifications

Item	Specifications
Weight	260 g
Dimensions	46 mm × 46 mm × 97 mm
Materials	Casing: PBT Base: 316 SST
Mount	M6 screw thread or a magnet
Degrees of protection	IP66/67

Figure 2 shows the inside of the casing. The dedicated battery is held loosely; the top is placed in a recess formed on the inner side of the casing and the bottom is on a cushion inside the battery holder, to allow dimensional tolerance and easy replacement of the battery. The sensor board is fixed firmly to the metal base with two screws to prevent its rattling from affecting the frequency response.

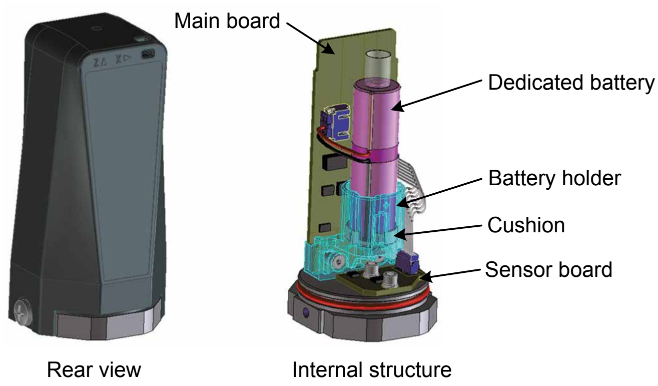

Figure 2 Structure of the XS770A

Figure 3 shows the bottom view of the XS770A. The battery is replaced easily by loosening the two screws fixing the casing at the sides of the base, removing the casing from the base, and then disconnecting the electrode wiring from the connector.

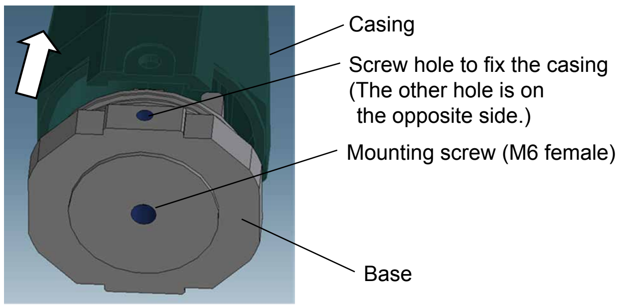

Figure 3 Removing the casing to replace the battery

Table 2 shows the power supply specifications. Although the battery life depends on the data updating cycle and the amount of measured data based on measurement axes, the power-saving design enables the XS770A to keep working under steady monitoring conditions for at least 4 years, which is the most common periodic maintenance cycle of plants.

Table 2 Power supply specifications

Item	Specifications
Power supply	Built-in battery (nominal voltage: 3.6 V)
Battery	Dedicated lithium thionyl chloride battery
Replacement	Possible
Battery life	4 years (data update cycle: 1 hour for 1 axis at room temperature)

Wireless sensors offer a substantial advantage for equipment maintenance. However, deploying numerous battery-powered sensors in the field gives rise to the new problem of battery replacement. To reduce the workload of sensor maintenance and management, the XS770A is electrically designed for low power consumption and extended battery life, and is mechanically designed for easy battery replacement.

INTERFACE FOR SETTINGS AND MAINTENANCE

An NFC-compliant interface is used for settings and maintenance. This interface consumes less power than LED or LCD displays, or infrared communication. Through this interface, the XS770A can communicate with smartphones with a built-in NFC function, making the user interface more flexible and expandable.

Through a smartphone, the user can set up the sensor, check information such as remaining battery level, and read indications regardless of the preset update cycle. Thus, in addition to collecting sensor data from a remote location, sensor conditions can be checked in the field with a smartphone, just like a conventional operator round.

SENSOR

The XS770A has two built-in sensors for vibration and temperature. The vibration sensor measures acceleration and velocity along up to three axes (X, Y, and Z) separately and calculates their combined values. The temperature sensor measures the surface temperature of the measured object.

Table 3 shows the sensor specifications. The vibration measurement range meets the requirement for detecting abnormal conditions in small- to medium-size rotating machines, which are widely used in plants. The vibration severity standards set by ISO 10816-1 (JIS B 0906) were also consulted when setting the vibration measurement range to be achieved in development.

Table 3 Sensor specifications

Item			Specifications
Vibration measurement	Measurement data		Acceleration (peak), velocity (RMS)
	Range	10 Hz to 100 Hz	Acceleration (peak): 0 to 50 m/s^2 Velocity (peak)*: 0 to 20 mm/s
		100 Hz to 1 kHz	Acceleration (peak): 0 to 130 m/s^2 Velocity (peak)*: 0 to 20 mm/s
	Accuracy (each of X, Y, and Z axes)		±10% FS @ 100 Hz
	Frequency range		10 to 1,000 Hz (±3 dB)
Temperature measurement	Range		–20 to +85 °C
	Resolution		0.1 °C

* In the case of a sine wave, 20 mm/s (peak) is equivalent to 14 mm/s (RMS).

If the sensor resonates with the measured object, it greatly affects the accuracy of vibration measurement. The sensor of the XS770A is fixed firmly to the metal base so that its resonance frequency is 2.5 times higher than the upper limit of the frequency measurement range.

Figure 4 shows the frequency response in acceleration measurement. Signals are corrected by a filter to make the frequency response fall within the specifications in the measurement frequency range of 10 Hz to 1 kHz.

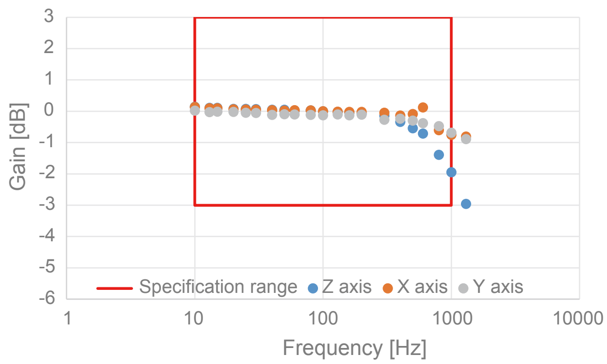

Figure 4 Frequency response in acceleration measurement

WIRELESS INTERFACE

Communication Method

The XS770A uses the LoRaWAN standard for wireless transmission of sensor data. The frequency band at 920 MHz is permitted for this communication protocol in Japan. Although LoRaWAN can cover a wide area with low power consumption, it has low data throughput and thus is not ideal for mission-critical applications which require a fast response. However, this communication method is suited to monitoring slow events such as mechanical wear and degradation of equipment, which are the targets of operator rounds for maintenance, environmental monitoring, and energy management.

The LoRaWAN wireless communication protocol is a relatively simple asynchronous communication method, and strict real-time processing is not required in the firmware. Thus, the power consumption of the processor can be reduced, and the sensor can be made compact and lightweight.

Table 4 shows the wireless communication specifications of the XS770A. The free space path loss in the 920 MHz band is 8.5 dB smaller than in the 2.4 GHz band. When the output power is up to 7 dBm as shown in Table 4 and the line of sight is not blocked, the communication distance is as far as 7 km thanks to the high sensitivity of LoRaWAN. This long communication distance means that the whole plant area can be covered without repeaters even though there are many structures on the premises. This is crucial for enabling the XS770A to be deployed easily. In a field test performed in an actual plant, a single gateway successfully covered an area of several hundred meters square to one thousand meters square, which is a typical area for a plant site.

Table 4 Wireless communication specifications

Item	Specifications
Protocol	LoRaWAN class A, AS923 for Japan (ARIB STD-T108)
Modulation	LoRa
Frequency	920.6 to 928 MHz (38 channels at 200-kHz intervals)
Bit rate	293 to 5470 bps
Security	AES 128-bit encryption
Output power	Max. 7 dBm
Update cycle	1 min to 3 days

Antenna Characteristics

It was necessary to mount the two antennas for LoRaWAN and NFC in a compact body, so the internal layout was designed to minimize the degradation in wireless performance due to mutual interference. Figure 5 shows the antenna characteristics in the 920 MHz band for LoRaWAN communication.

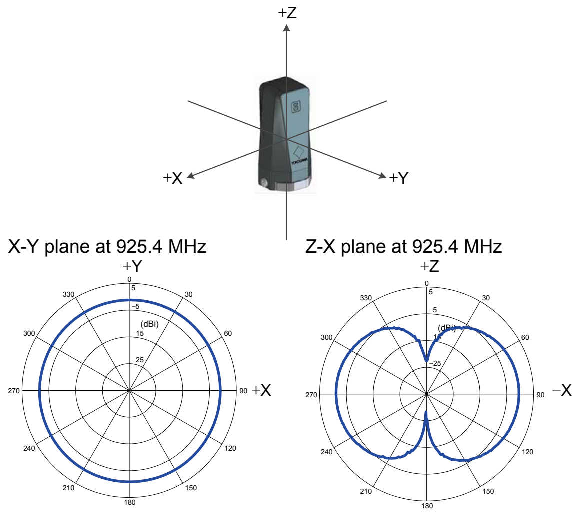

Figure 5 Directional characteristics of the XS770A antenna (LoRaWAN)

The antenna for LoRaWAN communication has omnidirectional characteristics on the horizontal plane similar to half-wavelength dipole antennas, so users do not have to consider carefully the direction of sensors; radio wave transmission is ensured as long as the sensors are mounted vertically. Thanks to the uniform directional characteristics of the antenna, the XS770A can be used even in plants with many structures, in which multipath propagations may significantly affect communication quality.

CONCLUSION

Sushi Sensor is a compact wireless sensor that is ideal for the Industrial IoT and can be used in a plant thanks to its excellent environmental robustness. Although rotating machines are low priority in terms of equipment monitoring due to high prices, the XS770A enables remote, continuous monitoring of such equipment by measuring their vibrations and temperatures. Moreover, large amounts of data can be automatically acquired and accumulated in the cloud, which enables the skills and know-how of veteran maintenance staff to be used not only within a plant but also at other facilities both in and outside Japan.

We expect Sushi Sensor to replace conventional operator rounds and drastically improve equipment maintenance. We also expect knowledge and know-how on equipment maintenance accumulated in the field to be used more efficiently. With Sushi Sensor, Yokogawa will improve the efficiency of maintaining plants and infrastructure in society.

REFERENCES

(1) Shuji Yamamoto, “Small Wireless Sensor for Achieving the IIoT,” Measurement Technology, Vol. 46, No. 2, 2018, pp. 41-46 (in Japanese)

* Sushi Sensor is to be released outside Japan soon. For details, please visit Yokogawa’s website.