Wireless Structural Health Monitoring System Using ZigBee Network and FBG Sensor

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Abstract

In this paper, we develop wireless optical monitoring system using ZigBee network and Fiber Bragg Grating (FBG) sensor. FBG sensors are manufactured using the 248nm excimer laser and phase masks. The adopted wireless networking between PC and FBG interrogator is ZigBee, because ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks. Experimental results show that reflected wavelength values from FBG interrogator are well passed through ZigBee network.

Keywords: *ZigBee Network, FBG sensor, FBG Interrogator, Wireless Remote monitoring*

1. Introduction

Structural health monitoring (SHM) is a term increasingly used in the last decade to describe a range of systems implemented on full-scale civil infrastructures and whose purposes are to assist and inform operators about continued ‘fitness for purpose’ of structures under gradual or sudden changes to their state, to learn about either or both of the load and response mechanisms. Arguably, various forms of SHM have been employed in civil infrastructure for at least half a century, but it is only in the last decade or two that computer-based systems are being designed for the purpose of assisting owners/operators of ageing infrastructure with timely information for their continued safe and economic operation [1].

The electric strain gauge is one of the most widely used in structural health monitoring system. However, the electromagnetic environment, moisture, corrosion caused by humidity, *etc.* have been pointed out several problems. With the alternative, there is proposed electromagnetic and optical sensor of no oxidation in a way.

Fiber optic sensors have the ability to modulate some properties of the light that is launched by a source into the core of the fiber. This modulation can be caused by changes in strain, temperature and pressure experienced by the sensor through which the light travels. In consequence, an optical signal is generated and reflected towards a demodulation device to be translated into a measurement of the gauged quantity [2].

Fiber optic sensors is light amplitude, phase, polarization of light such as the optical phenomena though the optical fiber using to detecting for physical quantity to be measured by detecting changes in the structure displacement, temperature, pressure, water level, sound and physical quantity. A Fiber Bragg Grating (FBG) by G. Meltz in 1989 has developed among fiber optic sensors that domestically and internationally widely using study in secure management of the structure. FBG sensor is achieved by creating a periodic variation in the refractive index of the fiber core. Due to their low loss optical fiber sensor technology, most of the research is in progress technology.

It show change by linear Bragg wavelength with respect to stress and temperature by characteristic of the FBG, small size and the type of behavior have characteristics of wavelength encoding, It’s real-time detection that deformation by environmental factor for installed in internal and external of structure etc. The phase mask has proposed K. O. Hill and D. Z. Anderson *etc.*, in 1993. It's method to make large quantity production more easily than the conventional method. This method is currently being studied in a wide range of worldwide [3-5]. Recently, FBG has been accepted widely throughout the civil infrastructures, especially for bridges. A new case study, FBG-based intelligent monitoring system of the Tianjin Yonghe Bridge is introduced [6].

But, generally monitoring center is far away from the surveillance target structures. In this case, it is preferable to apply wireless network. Recently, various wireless networks have been applied to various fields.

In this paper, adopted wireless networking between PC and FBG interrogator is ZigBee, because ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks.

2. Optical Sensor Manufacture

We manufacture FBG sensor using foundation optics theory and principle with respect to optical fiber and FBG. We manufacture polyimide patch type of sensor for understanding by characteristic of the manufacture FBG, and the sensor were tested for stress and temperature change. Based on the results of experimental measurements used in structures with electric strain gauge sensors measured by comparing the likelihood of structures using FBG was verified [7].

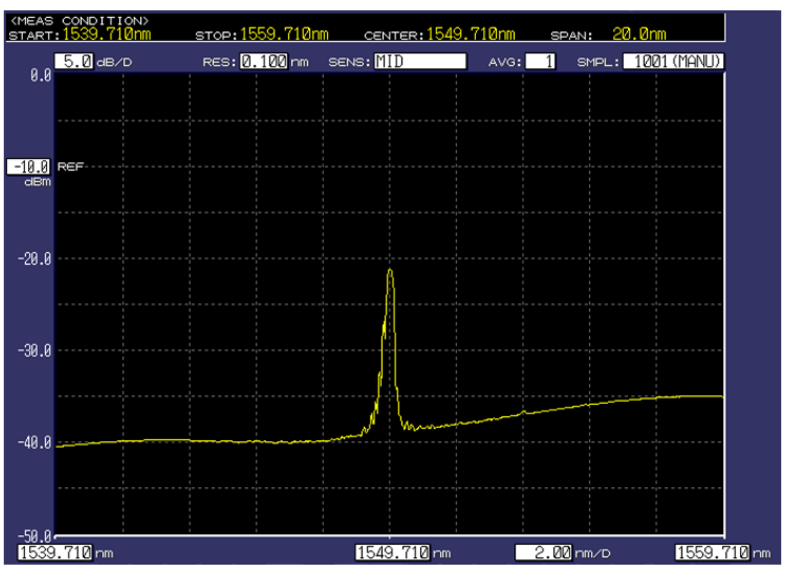

Figure 1. Designed wavelength of FBG (OSA Output)

We used phase mask that FBG wavelength is 1550nm. It is shown actual manufactured FBG in Figure 1 for center wavelength of 1549.710nm and Reflection level of about -20dBm.

It estimates of error for stress by optical fiber with distance by optical fiber and phase mask. FBG fiber is formed by using a polyimide patch type FBG sensors were fabricated.

3. ZigBee Analysis

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks. ZigBee devices are often used in mesh network form to transmit data over longer distances, passing data through intermediate devices to reach more distant ones. This allows ZigBee networks to be formed ad-hoc, with no centralized control or high-power transmitter/receiver able to reach all of the devices. Any ZigBee device can be tasked with running the network [8-9].

ZigBee is targeted at applications that require a low data rate, long battery life, and secure networking. ZigBee has a defined rate of 250 kbps, best suited for periodic or intermittent data or a single signal transmission from a sensor or input device. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range wireless transfer of data at relatively low rates. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other WPANs, such as Bluetooth or Wi-Fi.

ZigBee is a low-cost, low-power, wireless mesh network standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications. Low power-usage allows longer life with smaller batteries. Mesh networking provides high reliability and more extensive range. ZigBee chip vendors typically sell integrated radios and microcontrollers with between 60 KB and 256 KB flash memory.

ZigBee operates in the industrial, scientific and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in the USA and Australia and 2.4 GHz in most jurisdictions worldwide. Data transmission rates vary from 20 to 250 kilobits/second.

The ZigBee network layer natively supports both star and tree typical networks, and generic mesh networks. Every network must have one coordinator device, tasked with its creation, the control of its parameters and basic maintenance. Within star networks, the coordinator must be the central node. Both trees and meshes allow the use of ZigBee routers to extend communication at the network level.

ZigBee protocol stack is shown in Figure 2. ZigBee builds upon the physical layer and medium access control defined in IEEE standard 802.15.4 (2003 version) for low-rate WPANs. The specification goes on to complete the standard by adding four main components: network layer, application layer, *ZigBee device objects* (ZDOs) and manufacturer-defined application objects which allow for customization and favor total integration.

4. System Configuration

Configuration for developed system is shown in Figure 3. The interrogator (Micron Optics, sm125) used to the system has Ethernet module inside. MCU has also Ethernet module. MC U with Ethernet module communicated with the interrogator using LAN cable. Here interroga tor server was set up with IP: 10.0.0.122, Subnet Mask: 255.255.255.0. MCU was set up usin g IP: 10.0.0.121, Subnet Mask: 255.255.255.0. Data Graph is drawn using the received data to the MCU from server is shown in Figure 3. This system is applied to the field of surveillance structures. Therefore does not require high-speed data transfer. But interrogator supply appro ximately 32,000 Byte data to MCU during a second. A word length is 16 bit (2 Byte). It is sho wn in Figure 5.

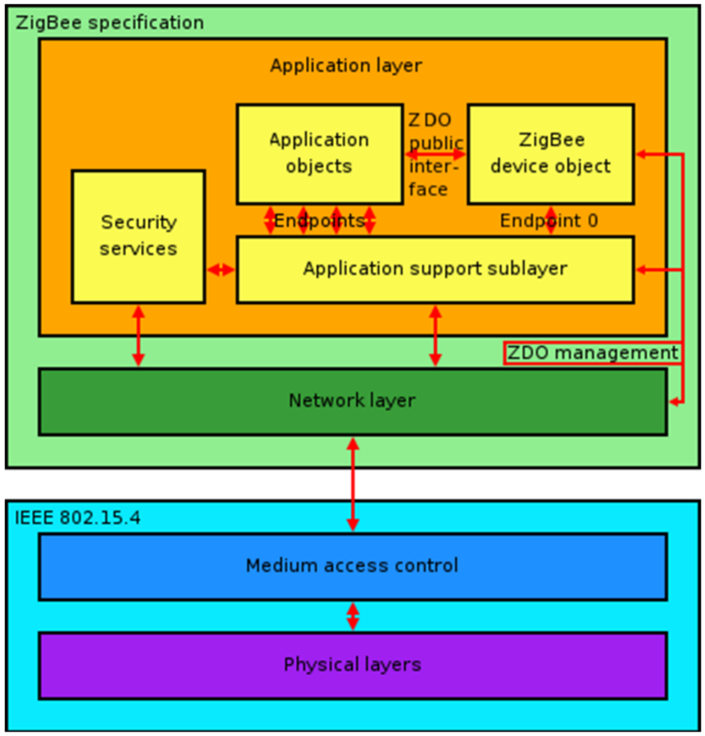

Figure 2. ZigBee protocol stack

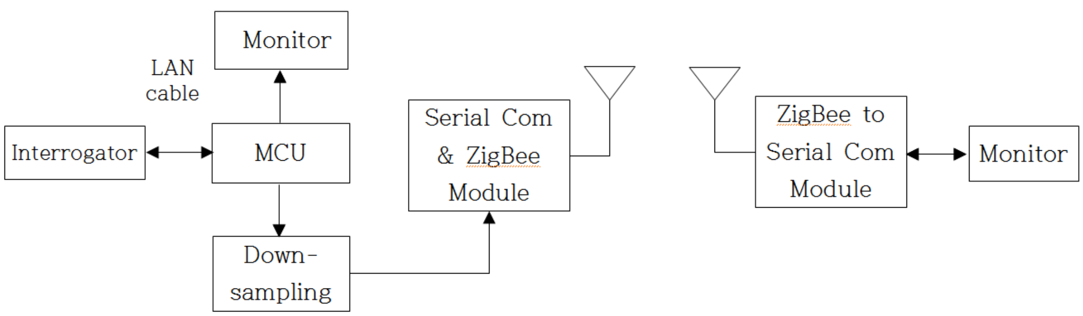

Figure 3. A wireless structural health monitoring system configuration

We hope to use ZigBee wireless network. Because ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks. ZigBee devices are often used in mesh network form to transmit data over longer distances, passing data through intermediate devices to reach more distant ones. This allows ZigBee networks to be formed ad-hoc, with no centralized control or high-power transmitter/receiver able to reach all of the devices. Any ZigBee device can be tasked with running the network. ZigBee is targeted at applications that require a low data rate, long battery life, and secure networking.

ZigBee has a defined maximum rate of 250 kbps. Therefore, it is impossible to send 32,000 Byte data during a second. To solve the problem, down-sampling methods were applied.

Down-sampling rate were set to 100, so 16,000 data reduced to 160. Finally Zeebee to serial peripheral interface buffers are able to gather the data during about 2 second.

Data received from the MCU accepts data through serial communication using the Zigbee module (XBee). XBee 802.15.4 OEM RF modules are embedded solutions providing wireless end-point connectivity to devices. These modules use the IEEE 802.15.4 networking protocol for fast point-to-multipoint or peer-to-peer networking. They are designed for high-throughput applications requiring low latency and predictable communication timing. Its performance is in below:

- Power output:: 1mW (+0 dBm) North American & International version
- Indoor/Urban range: Up to 100 ft (30 m)
- Outdoor/RF line-of-sight range: Up to 300 ft (90 m)
- RF data rate: 250 Kbps
- Interface data rate: Up to 115.2 Kbps
- Operating frequency: 2.4 GHz
- Receiver sensitivity: -92 dBm

Draw a graph using the data received from the serial communication. When you see the results of the sampled data from the client to the server from which the data was sent, you can see a result similar to that of the original data. The result is shown in Figure 6.

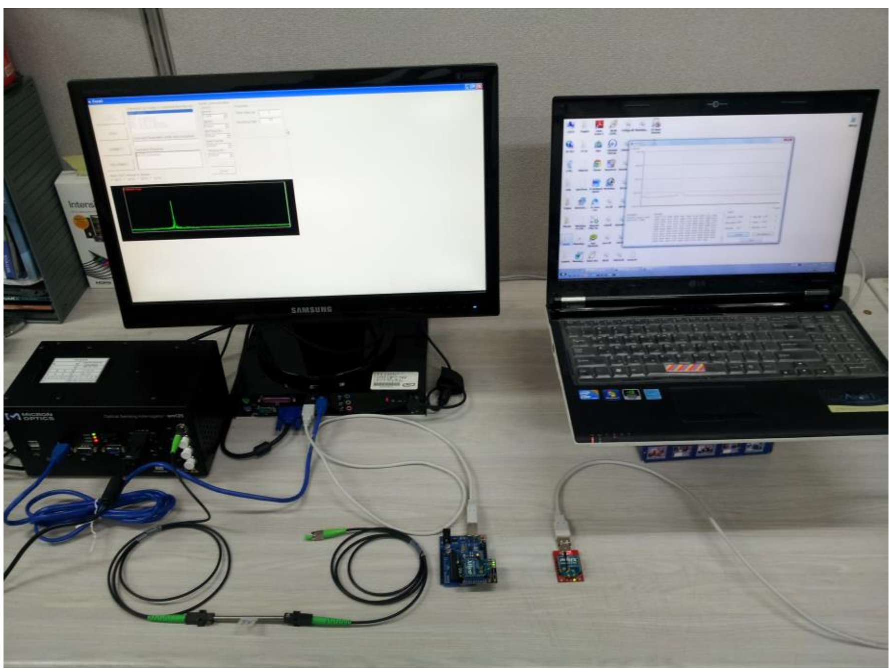

Fig. 4. The overall configuration

5. Experiment result

For measuring structure deformation and wireless remote monitoring, FBG sensor, interrogator, MCU with TCP/IP module, ZigBee pair, and a laptop are configured as shown in Figure 4.

The sm125 optical sensing interrogator is built upon the Micron Optics x25 optical interrog ator core, featuring a high power, low noise swept wavelength laser, realized with Micron Opt ics patented Fiber Fabry-Perot Tunable Filter technology. It has 1Hz scan frequency, 1520-1580nm wavelength, 10 pm wavelength accuracy, 1 pm at 1Hz wavelength repeatability, 40dB dynamic range, 15 typical FBG sensor capacity, full spectrum measurement and internal peak detection mode included.

Figure 6 show that reflected wavelength values from FBG interrogator are well passed through ZigBee network.

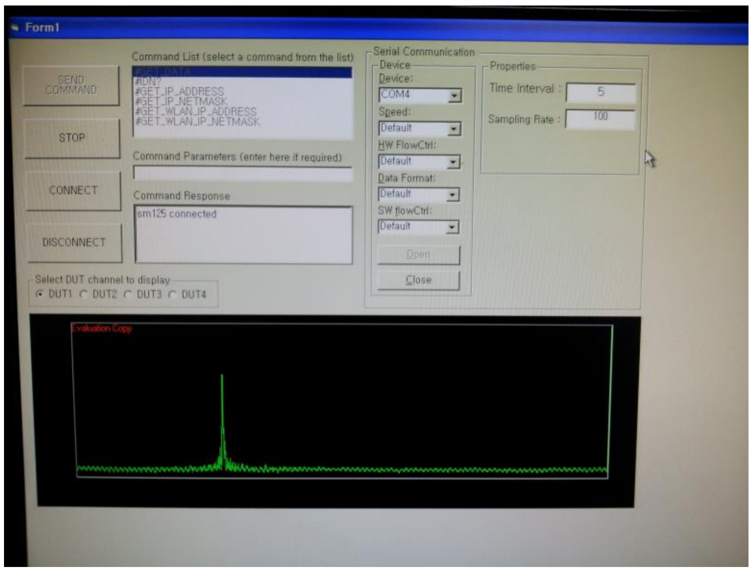

Figure 5. Reflected wavelength values transferred from Ethernet port in FBG interrogator

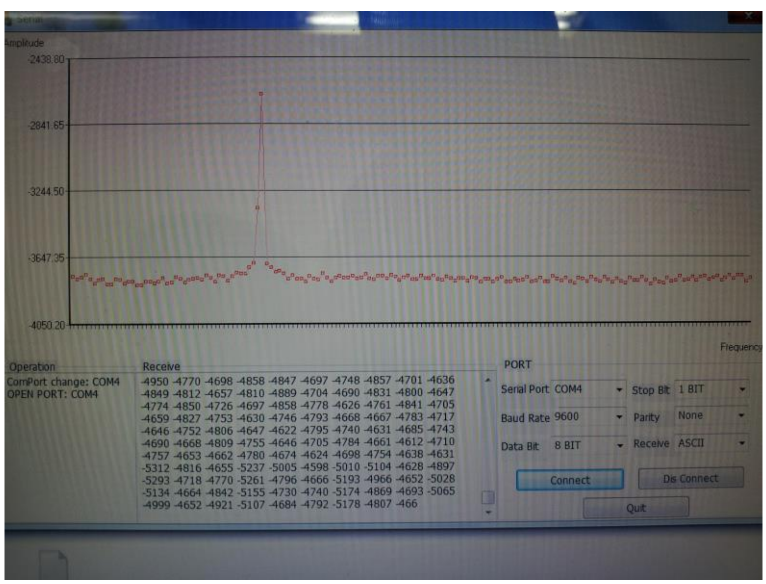

Figure 6. Reflected wavelength values transferred from wireless remote FBG interrogator

6. Conclusion

In this paper, for more effective structural health monitoring, wireless remote monitoring systems based on ZigBee network were developed. Experimental results show that reflected wavelength values from FBG interrogator are well passed through ZigBee network. Many Applications such as wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that require short-range wireless transfer of data at relatively low rates can use ZigBee. Sooner or later, we hope that ZigBee solutions are widely applied in many areas.

Acknowledgments

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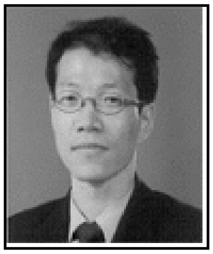

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