DESIGN AND EXPERIMENTAL VALIDATION OF LOW-FREQUENCY WIRELESS VIBRATION DATA ACQUISITION SYSTEM

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Low frequency detection is very important for some structures, such as offshore platform, high buildings. Usually, fixed platform structure detection, conventional NDT methods, such as eddy current, magnetic powder, permeate, X-ray and ultrasonic, etc, are generally used. These techniques are more mature, intuitive, but underwater detection needs underwater robot, the necessary supporting tools of auxiliary equipment, and trained professional team, thus resources and cost used are considerable, installation time of test equipment is long.

In this paper, Low-frequency wireless vibration data acquisition system is designed and validated for the sake of cheap, fast, low frequency detection. The designed system consists in intelligence acquisition equipment and 5 wireless collection nodes, every wireless collection node has eight 16-bit accuracy of A/D channels. Wireless collection node, integrated with low frequency vibration sensing unit, embedded low-power micro-processing unit, wireless transceiver unit, large-capacity power unit, can finish the functions such as vibration data collection, initial analysis, data storage, data wireless transmission. Intelligence acquisition equipment, integrated with high-performance computation unit, wireless transceiver unit, mobile power unit and embedded data analysis software, can totally control multi-wireless collection nodes, receive and analyze data, parameter identification. To verify the designed wireless inspection system, experiment on the standard horizontal vibration table (shake table □) was constructed.Experimental results show that the system has good application prospects and practical value with fast arrangement, high sampling rate, high resolution, capacity of low frequency inspection.

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ABSTRACT: Low frequency detection is very important for some structures, such as offshore platform, high buildings. Usually, fixed platform structure detection, conventional NDT methods, such as eddy current, magnetic powder, permeate, X-ray and ultrasonic, etc, are generally used. These techniques are more mature, intuitive, but underwater detection needs underwater robot, the necessary supporting tools of auxiliary equipment, and trained professional team, thus resources and cost used are considerable, installation time of test equipment is long. In this paper, Low-frequency wireless vibration data acquisition system is designed and validated for the sake of cheap, fast, low frequency detection. The designed system consists in intelligence acquisition equipment and 5 wireless collection nodes, every wireless collection node has eight 16-bit accuracy of A/D channels. Wireless collection node, integrated with low frequency vibration sensing unit, embedded low-power micro-processing unit, wireless transceiver unit, large-capacity power unit, can finish the functions such as vibration data collection, initial analysis, data storage, data wireless transmission. Intelligence acquisition equipment, integrated with high-performance computation unit, wireless transceiver unit, mobile power unit and embedded data analysis software, can totally control multi-wireless collection nodes, receive and analyze data, parameter identification. To verify the designed wireless inspection system, experiment on the standard horizontal vibration table(shake table □) was constructed. Experimental results show that the system has good application prospects and practical value with fast arrangement, high sampling rate, high resolution, capacity of low frequency inspection.

1 INTRODUCTION

The large offshore platform structure used for the development of ocean oil and gas resources is always used of decades, even centuries. Because of long-term effects of environmental erosion, materials aging and loading and coupling of disasters such as fatigue effects and sudden change, it is hard to avoid the damage accumulation and decay resistance of structure and system[1]. Offshore platform structure inspection and monitoring generally is artificial non-destructive inspection and wired acquisition[2-4], which need special test equipment and professional personnel. And it made offshore platform inspection inconvenient and expensive. Compared with the above method, non-destructive inspection technology based on vibration testing is more simple and low cost. Vibration testing generally uses various parameters collected by the sensor structure, processes collected data with intelligent algorithm, and then gets the status of offshore platform and appropriate measures which should be taken. Generally the sensor structure is wired. But wired offshore platform acquisition is huge consumption of wires and very difficult for cabling work. And because there are lots of wires, it is hard to find out the broken wire, which leads to high maintenance costs. At the same time it will consume large amount of manpower and capital during the cabling work. All of these issues lead to practical application problems. The development of wireless sensor network technology is accompanied by the development of sensor technology, wireless communication technology and MEMS technology. The application of wireless sensor networks technology in structure inspection has been a hotspot. Compared with wired sensor technology, wireless sensor technology can avoid the drawback such as huge consumption of wires and high maintenance costs. Based on this, a fast wireless inspection system for offshore platform structure inspection is designed and validated in this paper.

2 SYSTEM ARCHITECTURE

The system architecture of the acquisition system is shown in Figure 1. The designed system consists of one intelligence acquisition equipment and 8 wireless collection nodes, the whole system has 64 collection channels, namely every wireless collection node has eight 16-bit A/D channels. Data is transmitted at the 2.4GHz wireless channel, every sensing data channel in charge of data transmission is in a stable frequency band.

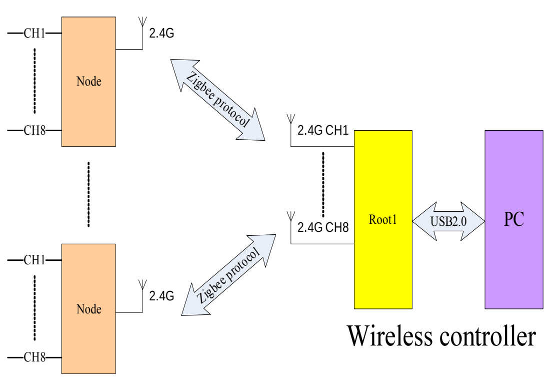

Figure 1. The system architecture of the acquisition system

3 DESIGN OF THE LOW-FREQUENCY WIRELESS ACCELERATION SENSOR

Studies show that it is possible to get safety assessment of the platform based on the modal information by making overall dynamic inspection to the offshore platform regularly. And the overall structure inspection technology of offshore platform can overcome the limitations of local structural inspection. The overall structure inspection technology can verify design assumptions, monitor construction quality and make real-time safety status assessment; especially it can work without external auxiliary excitation based on dynamic inspection technology. So the overall structure inspection technology which is indispensable technical means to the structure inspection of offshore platform has great advantages. Figure 2 shows the low-frequency wireless acceleration sensor structure. The wireless acceleration sensor nodes which is modular designed consists of low-frequency acceleration sensor, sensor interface unit, micro processing unit, wireless transceiver unit, storage unit and power management unit [5-6].

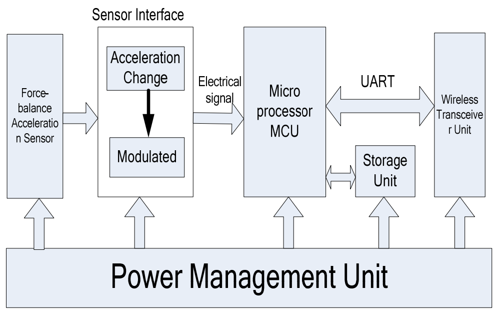

Figure 2. The low-frequency wireless acceleration sensor structure

3.1 Selection and analysis of force-balance sensor

In the designed system force-balance sensor is used for the low frequency vibration measurement unit. Force-balance acceleration sensor is closed-loop one which converts data to force or moment of force firstly, then adjusts the balance system with feedback force. Force-balance acceleration sensor with huge dynamic range and high measurement precision is used in low frequency and low-g measurement, and is the crucial unit in inertial navigation system. With the good performance in ultra-low frequency, force-balance acceleration sensor can meet the needs of low frequency vibration inspection.

3.2 Sensor Interface

Collection nodes support force-balance acceleration sensor input which outputs analog voltage (±2.5V or ±5V).Force-balance sensor needs ±12V power supply, and outputs ±2.5V or ±5V analog voltage signal. Collection nodes use multi-way switch chip MAX4051 to process 8 channels selection firstly, and then use 24bit high accurate ADC chip ADS1248 to convert analog signal to digital signal. ADC system has to generate ±2.5V and ±5V power supply using LM4040A to generate all kinds of power supplies.

3.3 Micro processor and storage unit

Micro processor use TI high performance 16bit micro processor MSP430F5438. The series micro processor has the lowest operating power consumption; the performance is up to 25MIPS at 1.8V-3.6V operating voltage range, and can meets the needs of wireless sensor design in low power consumption and high rapid data processing. Storage unit uses NAND large capacity flash memory.

3.4 Wireless transceiver unit

Wireless transceiver unit is for data wireless interactive, uses Zigbee wireless chip and consists of CC2520 RF chip and enlarge front CC2591. CC2520 RF chip is 2.4GHz license-free ISM band ZigBee/IEEE 802.15.4 second generation RF transceiver of TI Company. CC2591 is most integrated 2.4GHz RF front end for low power consumption and low voltage wireless application, can improve the transmit power and receiver sensitivity and increase the wireless signal strength and transmission distance.

3.5 Power management unit

Different from the normal wireless collection node, in the designed system collection node is 24v battery powered for rapid measurement and continued power supply. Because each unit in the system needs different power supply, such as ±12V、±12V、+3.3V, and analog circuits require a higher voltage ripple, so energy-saving design has two-stage transformation structure. The first stage uses DC/DC chips for the transformation from +24 V to ± 15V and +3.3 V. The second stage uses LDO chips 7812 and 7912 for the transformation from ±15V to ±12V.

The collection node, shown in Figure 3, is integrated using the above units.

Figure 3. Wireless sensor node

4 SOFTWARE DESIGN OF WIRELESS LOW-FREQUENCY VIBRATION ACQUISITION SYSTEM

The software of wireless low-frequency vibration acquisition system for offshore platform inspection consists of two parts: the embedded program of wireless vibration sensor and the host PC acquisition software.

4.1 The embedded program of wireless vibration sensor

The embedded program, integrated with ADC driver, storage driver, wireless driver, preliminary data analysis and diagnosis and so on, can control circuits, receive command from the host for parameters setting, set parameters and do data acquisition, processing, storage and transmission.

The wireless vibration sensor’s workflow is as follows: after power up the wireless sensor in the wireless receiving state, not work until receiving the command from host. Among acquisition, host firstly finishes the parameters setting to all wireless sensors, then sends start command to do data acquisition, and end data acquisition until receiving stop command. It can collect the vibration data of the offshore platform for inspection.

4.2 The host acquisition software

The host acquisition software mainly completes the parameter setting of the wireless vibration sensor, data collection, data export, data storage, data analysis and process. Using a modular design consists of the basic setting, real-time waveform monitoring, history waveform playback, data export, help document and other modules. The acquisition software's module and interface are shown in Figure 4.

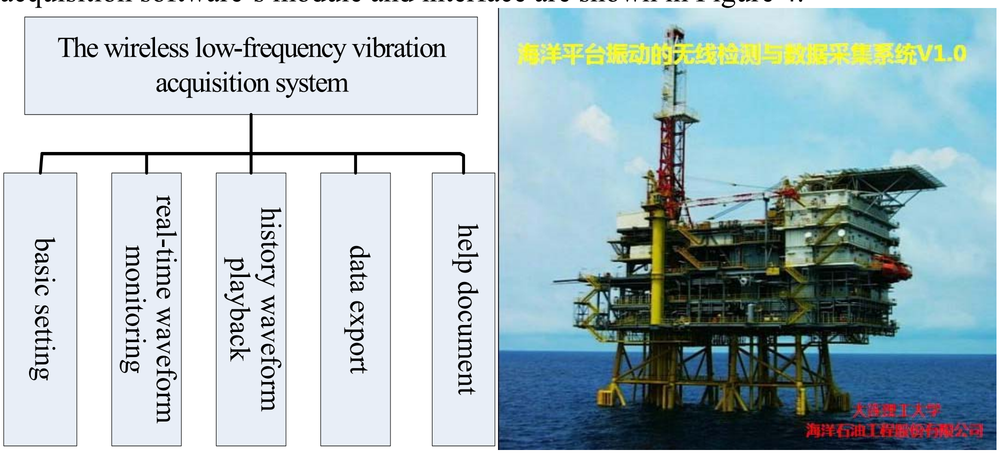

Figure 4. The host acquisition software

Basic setting is used to set the state of wireless sensors, wireless transmission channels, sampling frequency, file storage path and other parameters on demands. Real-time waveform monitoring can display the collected data's real-time waveform, and write the data in database. History waveform playback could show a playback of history waveform based on the data collected, to facilitate analysis. Data export could export the data collected from a specific wireless sensor at certain channel and time to a certain file for further analysis and process. Help document give some help information for the users who use this acquisition software.

5 EXPERIMENTS AND DATA ANALYSIS

To verify the designed wireless low-frequency vibration sensor has a good reliability and good low-frequency performance, experiment on the standard horizontal vibration table(shake table □) was constructed. The wireless sensor is arranged in the horizontal vibration table's center at X- direction, communicate with the host's wireless receiver unit, and capture the horizontal acceleration signal. Composition and field test of experimental are shown in Figure 5.

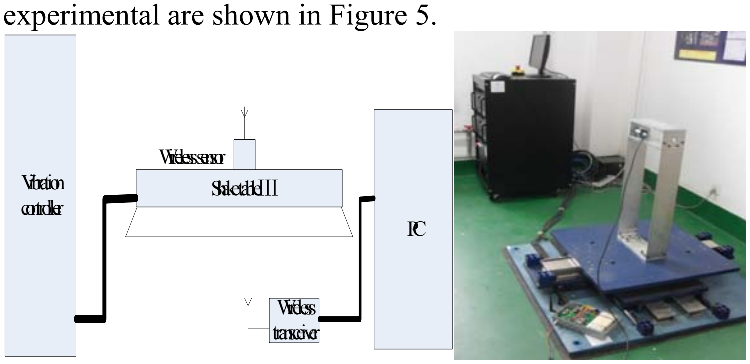

Figure 5. Horizontal vibration experiment

Vibration control device produce the amplitude 0.03m, frequency 0.1Hz and 0.5Hz horizontal vibration to simulate the waves of offshore platform. The host set the sampling frequency as 100 Hz for data acquisition. After acquisition, Matlab is used for the collected acceleration data's processing, analysis its time and frequency properties. It can be concluded the reliability and low frequency sensitivity of the wireless low-frequency vibration sensors. Time and frequency analysis of 0.1Hz and 0.5Hz are shown in Figure 6 and Figure 7.

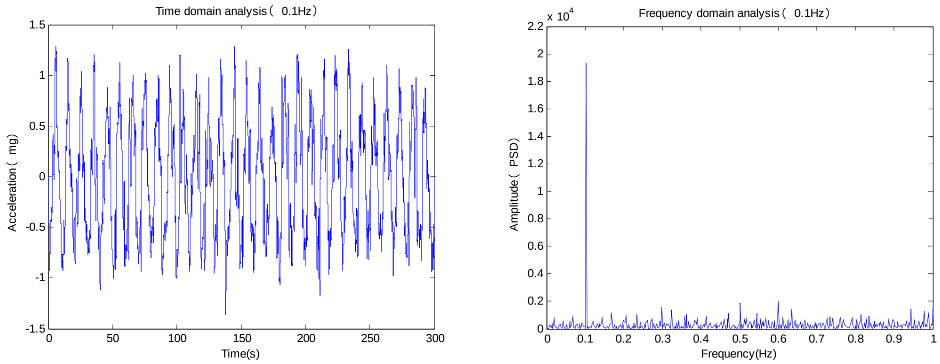

Figure 6. Time and frequency analysis of 0.1Hz

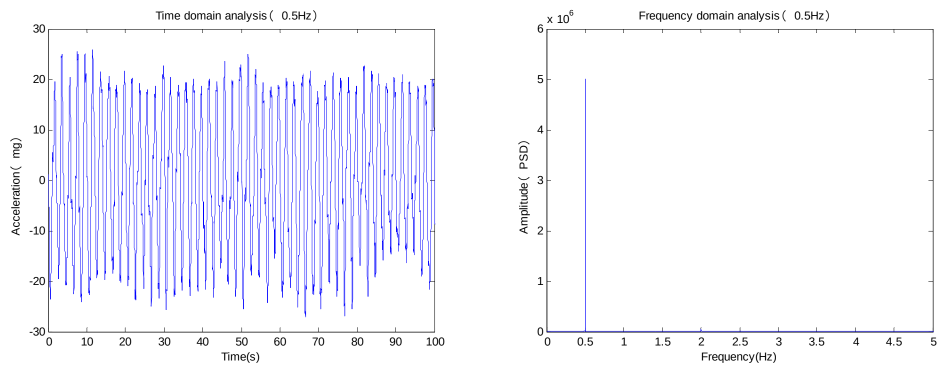

Figure 7. Time and frequency analysis of 0.5Hz

Through the time and frequency analysis of 0.1 Hz and 0.5Hz vibration signal, shows that the wireless vibration sensor has high reliability and good low-frequency performance, especially in frequency, as shown in table 1. The experiment result shows that the wireless low-frequency vibration sensor and its acquisition software can collect acceleration data to reflect the real low-frequency horizontal vibration. It is suitable for the offshore platform's low frequency vibration detection.

Table 1. Error analysis of frequency

Reference frequency	Wireless measured frequency	Relative error
0.1Hz	0.102Hz	2%
0.5Hz	0.504Hz	0.8%

6 CONCLUSIONS

In this paper, the wireless low-frequency vibration sensor and acquisition software are designed by the offshore platform structure's low-frequency characteristics for rapid detection. The horizontal vibration of shaking table simulates the waves of offshore platform to verify its reliability and excellent low frequency performance. The results show that the designed wireless sensor with high reliability, no wiring, low-frequency vibration detection and other characteristics, suitable for use in offshore platforms for vibration detection and has broad application prospects.

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