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Design of Vibrating Signal Acquisition and Processing System Based on Wireless Transducer Network

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Abstract. This research aims at the problem in the vibration signal monitoring area that few of systems based on wireless sensing technology are developed to deal with the problem of vibration specially. The paper presents a system based on wireless acceleration transducer network, which integrated the function of vibrating signal acquisition and processing. The system is tested in vibration bench. The operation of the system is simple and intuitive. Researchers could achieve the operation of collecting and analyzing signal, setting the parameter of the sensor nodes and monitoring the state of the network. The presented system provides users friendly interface to make it easy to do some researches about vibration signal acquisition, processing and analysis. Additionally, the system provides some program interfaces, with which users can easily do secondary development work and perfect the system.

Introduction

The monitoring techniques in exited mechanical vibration monitoring system based on cable sensors are the most popular methods. To some extent, these techniques keep the critical equipment running steadily so far. But in some monitoring environments, the mechanical equipments, whose working state should be monitored, are at the scattered position, wide distribution and bad testing sites. So, the mechanical vibration techniques based on cable sensor nodes will face some serious problems like complex wires, high cost and lack of flexibility [1]. Among the ideas of solving the problems above, a kind of novel mechanical vibration system based on wireless sensor network is the most effective method of solving these problems.

Wireless sensor network is a self-organizing multi-hop network, which is made up of the sensor nodes that are deployed in the tested area [2]. Compared with the cable sensor monitoring system, wireless system has the merits of none cables, flexible installation and lower distortion. Therefore, characteristics of the wireless sensor monitoring system make itself popular in some poor industry environment like heavy-load, high-temperature and dusty conditions, where electric cables are not convenient to lay out [3,4,5].

In the process of monitoring the menchanical vibration signal, a friendly man-machine interaction interface is necessary for the researchers to monitor the status of wireless sensors and the signal collected. To obtain the valuable information from the collected signal, some necessary signal processing can be conducted through the system conveniently. This paper describes a system of wireless sensor vibrating signal acquisition and processing based on VC++. Researchers can observe the state of wireless sensor node and wireless network, set the acquisition parameters of

wireless sensor nodes and deal with data acquisition, signal processing and real-time display in the use of this system. In the last part of this paper, the designers tested the monitoring system on vibration bench.

Hardware of System

Introduction of Hardware. The hardware of the monitoring system is compsed of wireless sensor network, wireless gateway and PC, as shown in Figure 1. Wireless sensor network is made up of a large number of wireless sensor nodes. The wireless sensor nodes adopted in this paper are BeeData wireless acceleration sensors provided by Beijing Beetech Technology Corporation, as shown in Figure 2. There is a three-phase acceleration sensor in the node, which can support the range of 10g acceleration. The transmission rate of data frame can reach 250Kbps. The effective transmission distance outdoors can reach 100m. The gateway used in the designed system is virtual USB wireless gateway, as shown in Figure 3.

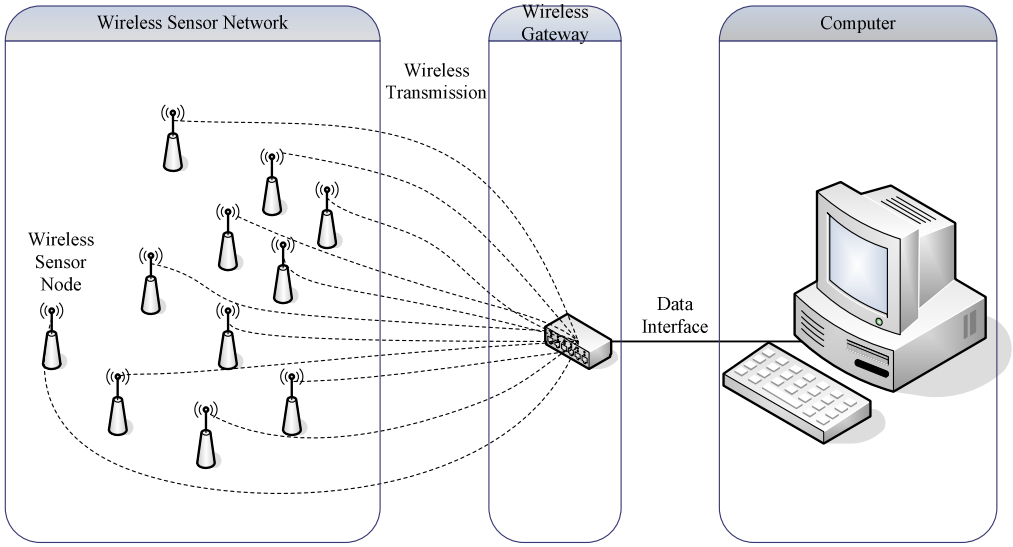

Fig. 1. Hardware of the monitoring system

Nodes transmit the acquired digital signal to wireless gateway of the monitoring centre through the wireless sensor network. The wireless gateway, which is a kind of virtual USB wireless gateway connected to the USB interface on PC, transmits the received digital data to the computer. The computer deals with data acquisition, signal processing, storage and real-time display in the use of this system.

Fig. 2. Wireless sensor node

Fig. 3. Wireless gateway

BeeNet Network Protocol. BeeNet network protocol is a wireless sensor network protocol based on IEEE 802.15.4 developed by Beijing BeeTech Technology Corporation. A self-organizing and self-recover multi-hop network could be organized by these nodes. It supports point to point, star,

line, tree and other network topologies. The number of sensor nodes which the network is able to support would reach 65535. A TDMA transmission mechanism based on time-synchronization and an innovative energy management algorithm is applied in the BeeNet protocol. The whole wireless network can work a number of years in periodic monitoring state using an ordinary battery. As the application of the time-synchronization TDMA transmission mechanism, the precision of time-synchronization can reach 0.1ms, which ensures the accuracy of the signal real-time synchronous acquisition synchronous. Since the multi-carrier inter caption technology based on collision avoidance is applied in the protocol, the robustness and reliability of data transmission in the network can be ensure. Additionally, AES 128 bit data encryption can ensure the security in the procedure of data transmission.

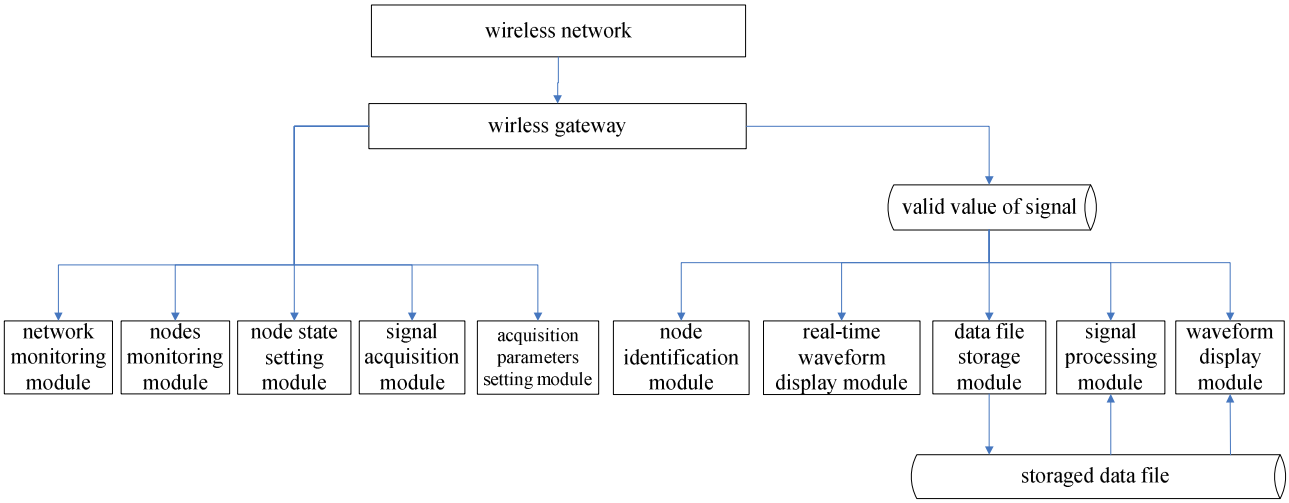

Fig. 4. Main function module and signal processing procedure

Software of System

Process of Signal Acquisition and Processing. With the develpment of the vibration signal acquisition and processing system based on cable sensor technology, reseachers should pay a lot of efforts on considering the hardware device driver technology. However, in the process of developing the monitoring system based on wireless network, the system developers need pay less effort on the hardware driving problems,which is meaningful to do the sencondary development work. The system integrates signal acquisition, processing and analysis. It is necessary to establish the main function modoule and the signal data collecting and processing processes in the system before creating the system architecture, as shown in Figure 4. The signal data, after a series of signal transform in the sensor node, is delivered to the wireless gateway which is connected with the computer via the USB virtual serial port, through the wireless communication module inside the sensor node. The computer extracts the valid part of the signal and stores in the temporary files. If users need to save these data, the corresponding modules of the system would read data from the temporary file and save it. Users can analyze and process the signal further through the system. The main interface is shown in Figure 5.

Main Modules of System. The main modules and their implementation are produced in this part.

(1) Signal acquisition module

The main function of this module is to make the computer exchange data with sensor nodes through the wireless gateway. Computer receives data from the nodes and saves it as a kind of temporary data file. Some sub-functions are included in the module, such as making

signal-acquisition start and stop, making synchronous acquisition start and stop, recording the digital signal and so on. Researchers usually need collect multi-signals data at the same time in mechanical vibration signal monitoring systems to acquire the running state of different positions of the mechanical equipment. Therefore, synchronous acquisition is very important in the whole system.

In this system, the synchronous acquisition function is implemented by using dynamic linkage store document of wireless sensor network serial port protocol and PC exchanges data with wireless gateway and sensor nodes by using callback functions [6,7]. Space lacks for a detailed description of the implementation procedure.

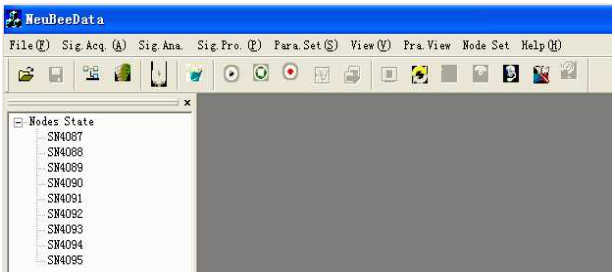

Fig. 5. Main interface of the system

(2) Signal Processing Module

The main function of this module is reading data from the saved files, processing these data and displaying the signal waveform after processing. Some sub-modules like analysis of amplitude spectrum, analysis of power spectral, analysis of auto-power spectrum, analysis of cross-power spectrum, analysis of autocorrelation, analysis of cross-correlation, analysis of probability density, wavelet transform, time-frequency distributions, bispectral analysis and statistical characteristics are included in the Signal Processing Module [8,9,10].

The analysis of amplitude spectrum is based on Discrete Fourier Transform (DFT). The mathematical formulation is shown as Eq.1, where *x(n)* is the sampling value in *T=0, Ts, 2Ts*…… , *X(k)* is the Fourier transformation of *x(n)* and $\omega_N = e^{-j2\pi/N}$.

$$X(k)=\sum_{n=0}^{N-1}x(n)\omega^{-nk} \quad (n,\ k=0,\ 1,\ 2,\cdots N\text{-}1) \tag{1}$$

The analysis of auto-power spectrum is based on Eq.2. and the analysis of cross-power spectrum is based on Eq.3.

$$S_x = |X(f)|^2 \tag{2}$$

$$S_{xy}(f) = |X_x(f)||X_y(f)| \tag{3}$$

The analysis of probability density is based on the definition of probability, which is shown in Eq.4, where $K = 1.87(N-1)^{0.4}$.

$$p(x)=\lim_{\Delta x\to\infty}\frac{P[x<x(t)\le x+\Delta x]}{\Delta x}=\lim_{\substack{\Delta x\to\infty\\ T\to\infty}}\left(\frac{1}{T\Delta x}\sum_{i=1}^{k}\Delta t_i\right) \tag{4}$$

(3) Acquisition Parameters Setting Module

The main function of this module is to set the acquisition parameters of the sensor nodes. The acquisition parameters of the node need to set include acquisition range, sampling frequency, transmission mode, storage method, triggering mode, triggering channel, triggering value, filter cutoff frequency of the channel and so on.

Experiment

In order to test the stability and practicability of the system, the authors attach the wireless sensor nodes to the top body of the vibrating screen. And the wireless gateway is connected with the computer. After starting the test system, the authors set the acquisition parameters to make the sampling frequency be 180Hz, filter cutoff frequency be 380Hz and range be 1g, and regulate the frequency converter to 6.3Hz to maintain the resonance state of the vibrating screen. The remote sampling workstation and experiment workstation is shown in Figure 6.

The waveform collected in time-domain of the top body of the vibrating bench in the vertical direction is shown in Figure 7. Authors analyze the signal of top body in the use of the developed system. The results after signal processing are shown in Figure 8(a), 8(b). After analyzing the collected signal, researchers learn that resonanse frequency of the vibrating bench is 5.6Hz, which is close to the valid value. The testing error is in the range of allowable, therefore, a result is achieved, the system is steady and practicabe for application.

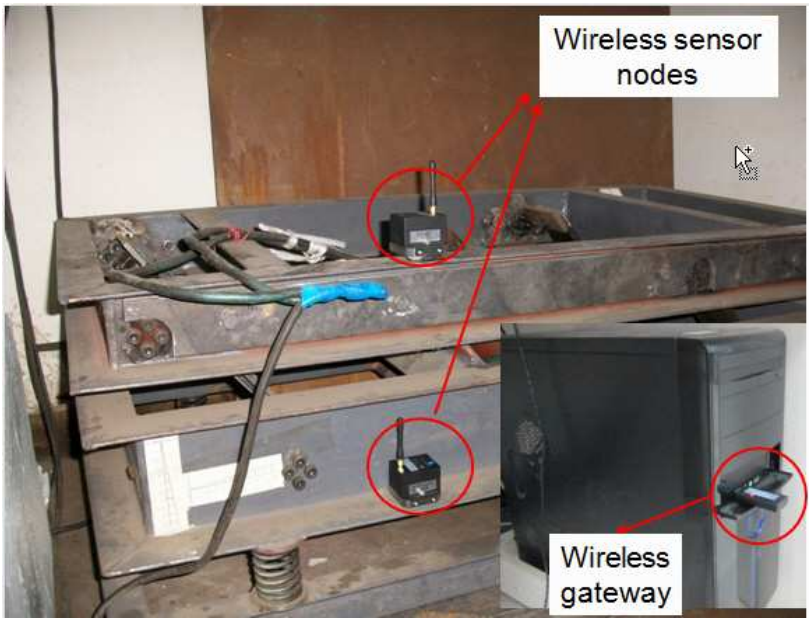

Fig. 6 Remote sampling workstation and experiment wokstation

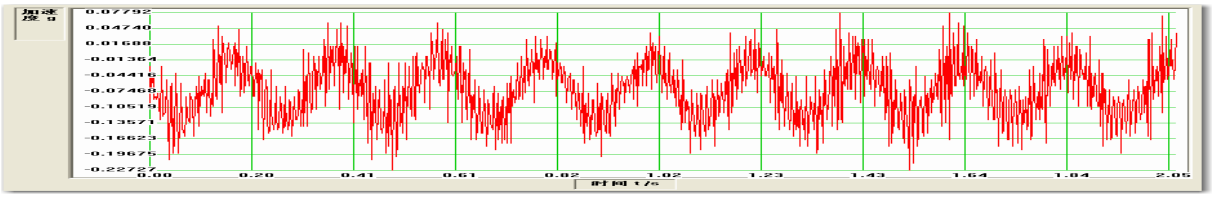

Fig. 7 Waveform in time-domain of the top body

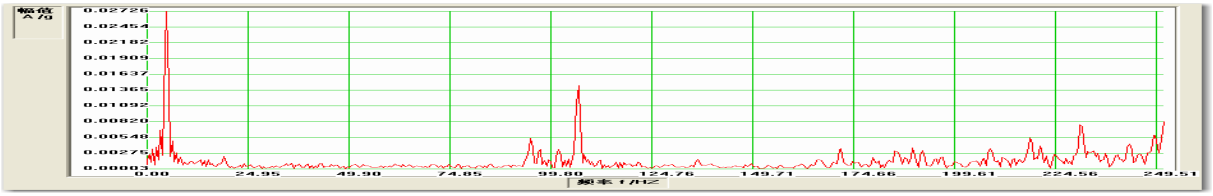

Fig. 8(a) Amplitude spectrum of the signal

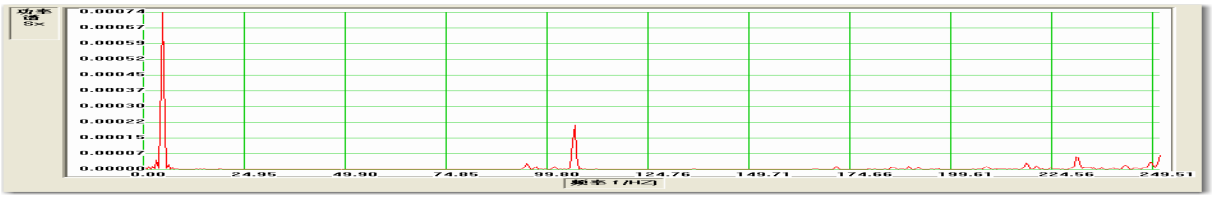

Fig. 8(b) Auto-power spectrum of the signal

Conclusions

A system of vibration signal acquisition and processing based on wireless transducer network is developed, which provides users friendly interface to make it much easier to do some research about vibration signal acquisition, processing and analysis than the traditional mechenical monitoring systems based on cable sensor nodes. Additionally, the system provides some interfaces and dynamic linkage store documents, with which users can easily do secondary development work.

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