Development and application of intelligent on-line detection device for environmental noise monitoring system

Zhikai Zhang*[a,b,d,e], Shan He[b,d,e], Kexin Wang[c], Mingjun Cheng[b,d,e], Shuaijun Sang[b,d,e], Jianmin Qiu[b,d,e]

[a]China Jiliang University, Hangzhou, Zhejiang, China; [b]Zhejiang Institute of Metrology, Hangzhou, Zhejiang, China; [c]Wenzhou Institute of Metrology, Wenzhou, Zhejiang, China; [d]Key Laboratory of Acoustics and Vibration Precision Measuring Technology for State Market Regulation, Hangzhou, Zhejiang, China; [e]Key Laboratory of Acoustics and Vibration Precision Measuring Technology of Zhejiang Province, Hangzhou, China

ABSTRACT

More digital noise monitoring systems are put into use with the attention to environmental noise monitoring. In order to solve the problem of accuracy and traceability of acoustic performance of environmental noise monitoring system, it is necessary to design an intelligent online noise detection device based on Internet technology and develop technical research on acoustic performance of online noise monitoring system. The device provides a method for realizing the online automatic detection for acoustic performance of digital noise monitoring system and improving the automatic detection ability of environmental noise monitoring system. The experimental results show that the device meets the requirement of online detection of environmental noise monitoring system, makes up for the shortage of online detection ability of environmental noise monitoring system with better applications.

Keywords: Environmental noise monitoring system, Acoustic performance, Intelligent online detection device, Internet technology, Automatic detection

1. INTRODUCTION

The demand of environmental quality is ever-increasing with the improvement of city residents living standard, especially a quiet and comfortable environment for living and study has already a basic requirement of people. However, with the fast-developing economy, the pollution of industrial noise, traffic noise, construction noise and social activity noise is increasing seriously which has a significant impact on human life and health [1-2]. To meet the needs of people, several affirmative measures are taken by relevant government departments to strengthen the prevention of noise pollution, and monitoring departments are required to collect accurate and true noise monitoring data. At the same time, the remote and intelligence of noise monitoring has been promoted to reflect the noise characteristics of time, space, and frequency in the monitoring area accurately. Environmental noise monitoring system, as an important means of interaction with external environment and the main source of perception information, plays a significant role in noise monitoring. It integrates microphone, controller, processor, driver, communication interface and other modules, and has complete functions of data acquisition, information processing, information exchange and data storage. Meanwhile, the application of environmental noise monitoring system in the market expands explosively, which also marks it has become one of the core and foundation of the development of environmental noise monitoring industry [3-6].

The accuracy of the environmental noise monitoring system is necessary to ensure the accuracy of noise monitoring data, so the noise monitoring system should be measured [7-8]. The traditional periodical off-line measurement mode is to disassemble the noise monitoring instrument within the specified time interval and finish the performance detection in laboratory to determine the measure performance accuracy of it. However, this measurement mode not only has a long cycle and high transportation cost, but also lead to the monitoring system to be offline, which cannot meet the requirements of noise monitoring in the detection period.

*Email: zzkhello520@163.com, Phone: 0086-571-87206687

Seventh International Conference on Mechatronics and Intelligent Robotics (ICMIR 2023), edited by Srikanta Patnaik, Tao Shen, Proc. of SPIE Vol. 12779, 127791J · © 2023 SPIE · 0277-786X · Published under a Creative Commons Attribution CC-BY 3.0 License · doi: 10.1117/12.2689080

In order to solve the problem of off-line instrument data collection, the requirements to accelerate the informatization construction process of testing institutions are put forward by government agencies. And the intelligent detection of instrument and equipment can serve as an important window for the development and information of social economy, which is supported by the new generation of information and detection technology, integrate information management system based on database, and establish intelligent detection system. Furthermore, testing instruments contacted via internet are promoted and the online control or virtualization technology are used to realize the automatic collection and processing of detection data. Against this background, an online detection technology has emerged in metrology by combining detection technology, Internet, and communication technology, which makes the detection efficiency higher and cost-effective [9-12].

To build the online detection of environmental noise monitoring system, Internet technology, digital processing technology and synthetic instrument technology are utilized in this paper to develop an intelligent online detection device to realize an online automatic detection of acoustic performance for environmental noise monitoring system, which ensures the measurement performance of the online noise monitoring system, as well as the accuracy and reliability of environmental noise monitoring system.

2. DESIGN SCHEMES OF ONLINE DETECTION DEVICE

2.1 The composition of online detection device

As shown in Figure 1, the detection device is mainly composed of signal generator, prestage adapter, electrostatic actuator [13], control bus, environmental monitoring module, database, instrument communication port and intelligent mobile terminal.

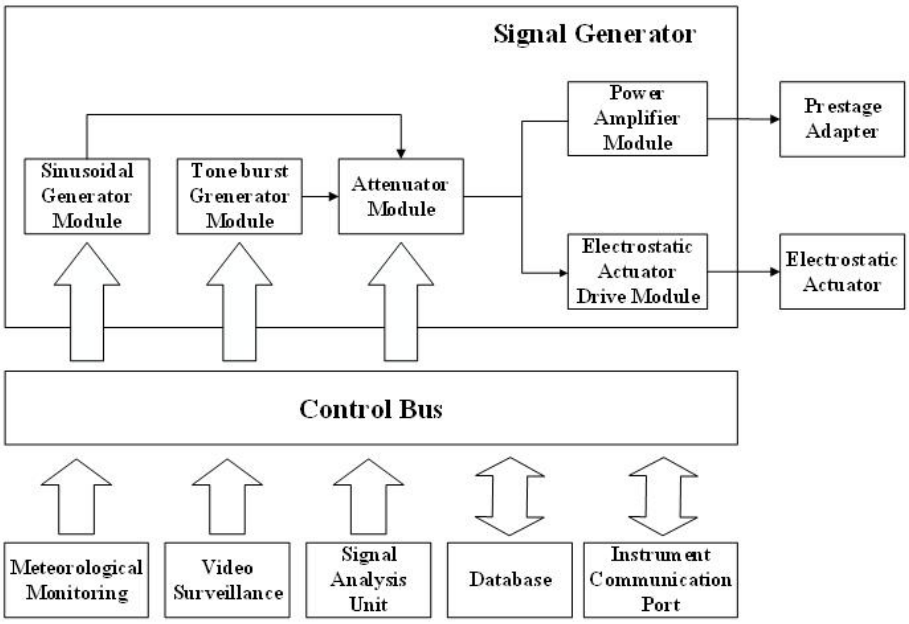

Figure 1. The structure of online detection device

The signal generator includes sinusoidal generator module, tone burst generator module, attenuator module, power amplifier module and electrostatic actuator drive module. Environmental monitoring module includes meteorological monitoring module and video surveillance module. The technical parameters of the online detection device are shown in Table 1.

Table 1. List of measuring modules technical parameters

Serial number	Measuring modules	Technical parameters	Amount	Function
1	Signal generator	MPE：±0.1 dB	1	standard device
2	Electrostatic actuator	MPE：±0.1 dB	1	standard device
3	Prestage adapter	MPE：±0.1 dB	1	standard device
4	Environment monitoring module	/	1	environment monitoring
5	Intelligent mobile terminal	/	1	signal control

The online measure detection device of environmental noise monitoring system is composed of several independent functional modules. Instrument synthesis technology is adopted between each module, and unified control by the control bus through standardized interfaces, by which realize that the output, frequency, amplitude, and type of multiple signals can be controlled by intelligent mobile terminals.

The attenuator module receives the electrical signal generated from the sinusoidal generator module and tone burst generator module, the processed signals output to the power amplifier module and electrostatic actuator drive module. The prestage adapter receives the gain signal from the power amplifier to analyze the electrical properties of the instrument being measured, and the electrostatic actuator module is used to analyze the acoustic performance.

The environmental monitoring module transmits the collected video signal of meteorological to the control bus. The database and instrument communication port communicates and exchanges information with the control bus.

2.2 Design of online detection device

In order to realize online intelligent and accurate measurement of environmental noise monitoring system, ensure versatile functions, miniaturization and convenient carrying, the design of detection device is mainly considered from the following five aspects:

(1) A unified interface standard is adopted to connect each independent module and software to form a measuring device through synthetic instrument technology. Afterwards the digital signal processing technology is used to generate signals for measurement;

(2) The principle of electric signal on-line detection is consistent with the laboratory detection method;

(3) The structure of electrostatic actuator is designed for environmental noise monitoring system with different structure;

(4) The acoustic signal is detected by using the method of electrostatic actuator and microphone free field response correction to obtain the database correction value and the sound pressure level of the instrument being measured.

(5) Intelligent measurement functions are completed.

Through the utilization of intelligent mobile terminals and measuring instruments, the measurement and control software based on operating system is developed to realize the online detection of acoustic performance of online noise monitoring system, which supports the remote reading and analysis of noise measurement data in various network modes. The design flow diagram of online detection device for noise monitoring system is shown in Figure 2.

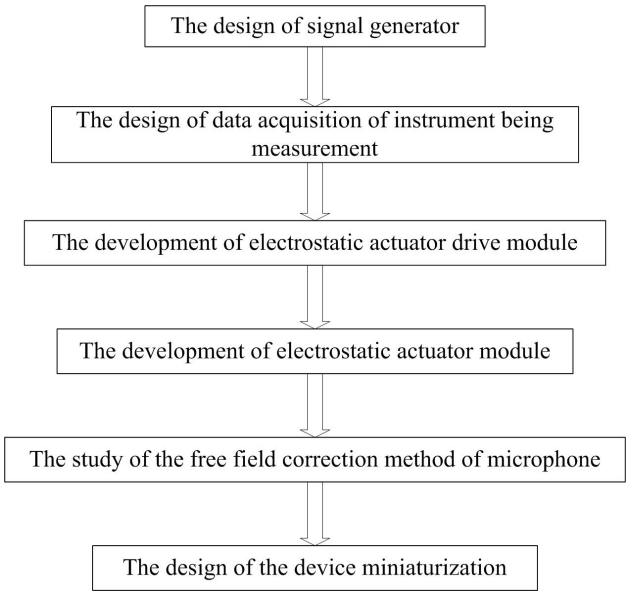

Figure 2. The design flow diagram of online detection device

3. DETECTION STEPS AND METHODS

3.1 Detection Requirements

According to the requirements of environmental noise standards, combined with the current measurement status of environmental noise monitoring system and to ensure the accuracy and efficiency of online measurement and detection, the detection frequency range of acoustic performance frequency weight was determined (20 Hz~ 20 kHz). Acoustic signal and electrical signal were used. The online detection process flow is shown in Figure. 3.

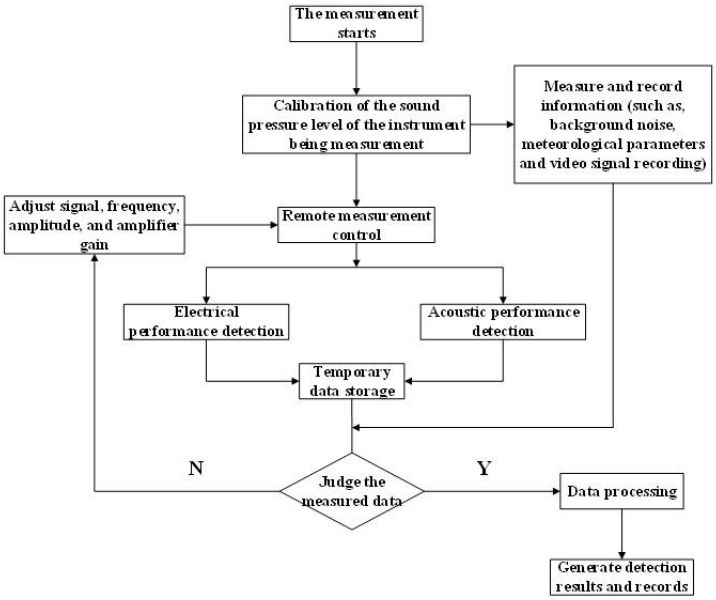

Figure 3. Flow chat of the online detection process

3.2 Acoustic signal detection

The schematic diagram of the acoustic signal detection structure for the environmental noise monitoring instrument is shown in Figure 4.

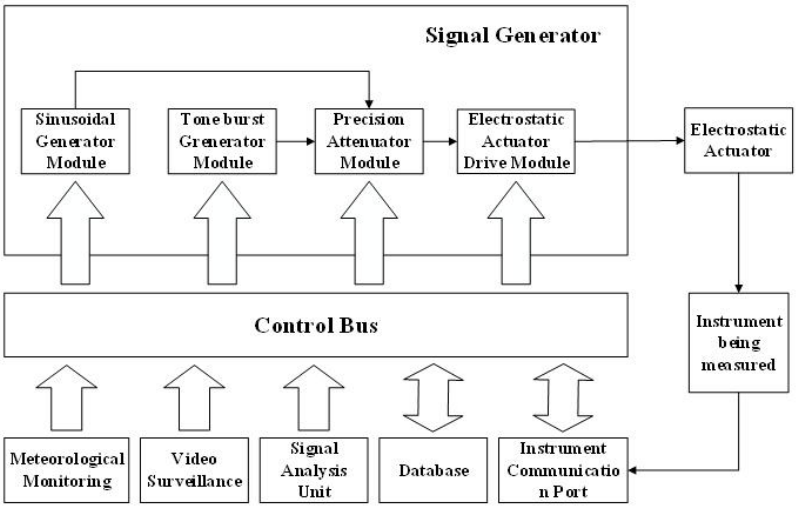

Figure 4. Structure diagram of measurement and detection (Acoustic signal)

Firstly, the microphone protection grid of the instrument being measured is removed, and the electrostatic actuator is placed on the surface of the microphone, and makes its reference axis 90° to the horizontal plane.

Adjust the amplitude of sinusoidal signal generator module to make it within the frequency range of being detected. The response level of electrostatic actuator is 25 dB higher than the ambient noise sound pressure level. Set the sinusoidal signal generator module at the reference frequency and record the signal response level L_0 Sinusoidal signal generator module is successively placed on 1/3-octave frequencies within the frequency range under detection, and sound pressure level signal L_i of each frequency is recorded. The response level of electrostatic actuator of the instrument being measurement is calculated according to formula (1), in which Δ_i represents the electrostatic actuator response stage at the frequency to be detected, dB; L_i represents the sound pressure level at the frequency being detected, dB; L_0 is the sound pressure level at the reference frequency.

$$\Delta_i = L_i - L_0 \tag{1}$$

Change the relative coupling position of the microphone and the electrostatic actuator, as rotate the electrostatic actuator about 120° and 240° respectively to measure the electrostatic actuator response level of the instrument being measured. Repeat the above steps and take the arithmetical mean of measurement for 3 times as the response level of the electrostatic actuator of the instrument being measured.

Finally, according to the correction values of the electrostatic actuator response level and the sound field frequency response level in the database, the acoustic signal frequency response of the instrument being measured is obtained.

3.3 Electrical signal detection

The schematic diagram of the electrical signal detection structure of the environmental noise monitoring instrument is shown in Figure 5.

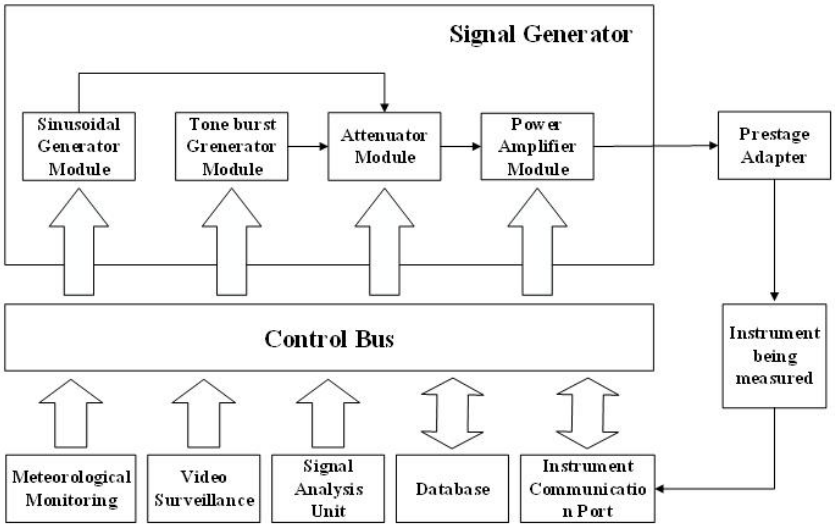

Figure 5. Structure diagram of measurement and detection (Electrical signal)

Set the instrument being measured to the frequency weighting mode that has detected the acoustic signal. At the reference level range, the signal generator module is adjusted so that the indicator value of the instrument being measured is 60 dB above the lower limit. Then the corresponding input signal level and the indicator value of the monitoring instrument are recorded.

Adjust the different frequency weighting modes of the monitoring instrument, keep the input signal level to the same as the reference signal input level, and record the corresponding indication value of monitoring instrument. Adjust the frequency of sinusoidal signal generator module in the frequency range of the detected, then the difference between the indicated value of the monitoring instrument and the reference signal is the frequency weighting of the instrument being measured.

Same as above, other electrical performance of environmental monitoring instruments is measured, such as step linearity, time weighting, tone burst response, repeated tone burst response, C Peak sound level, statistical calculations, flat response, relative attenuation, etc.

4. CONTROL SOFTWARE AND DETECTION RESULTS

4.1 Control software

In the process of detection of environmental noise monitoring system, the control software based on the mobile terminal is essential, which implement various functions, as the remote control of signal, the detection of sound pressure level, the detection of electrical signal, the detection of acoustic signal, the real-time monitoring of environmental conditions, the operation status of instrument being measured, and the whole detection process. The function selection of the detection control software is shown in Figure 6.

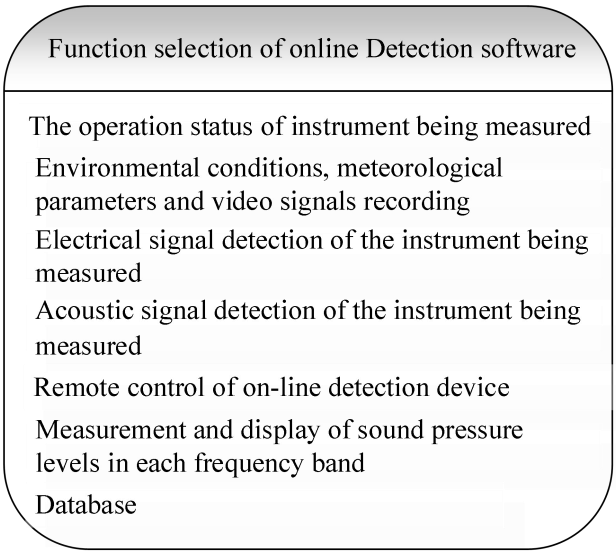

Figure 6. Function selection of the detection control software

4.2 Detection results

The acoustic signal of environmental noise monitoring instrument（Type: AWA6218J）was selected as the measured object, and the detection process is carried out as the requirements of 3.2. Different software functions were selected via intelligent mobile terminal to detect various parameters, and the results are shown in Figure 7.

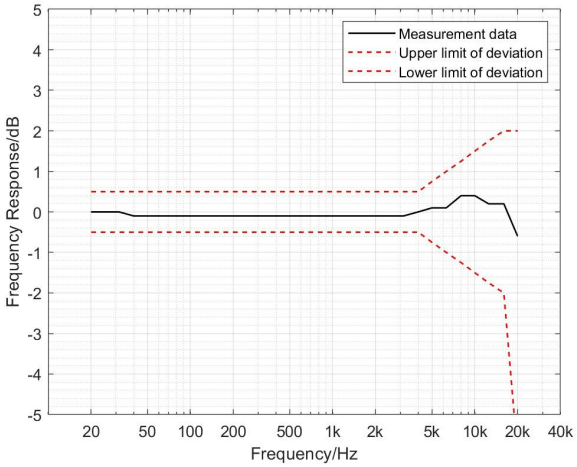

Figure 7. Measure detection results of the frequency response (acoustic signal)

5. CONCLUSION

Aiming at the online detection of acoustic performance of environmental noise monitoring system, an online detection device based on intelligent mobile terminal is put forward, and a uniform interface standard has been developed to link the individual measurement modules for different functions of environmental noise monitoring system performance detection. This detection device not only meets the requirements of JJG 1095-2014 Environmental noise automatic monitor verification regulation and IEC 61672.1-2013 electro-acoustic sound level meter Part 1: Specification, but also improves the accuracy and reliability of acoustic performance detection results of environmental noise monitoring

system. The detection device realizes the application of Internet technology in acoustic detection, and the detection results can be obtained in real time through the communication interfaces. Furthermore, the real-time transmission to the intelligent mobile terminal is realized through the Internet for analysis and processing. This device simplify the detection methods and greatly improve inspection efficiency. At the same time, the operating status of the online detection device and video collection information can be transmitted to the intelligent mobile terminal for real time recording, which ensure the accuracy, reliability and effectiveness of the data and information obtained from the device.

ACKNOWLEDGEMENTS

This work is supported by Zhejiang Provincial Administration of Market Regulation Research Project under Grant No. ZC2021A011 and No. CY2022350.

REFERENCES

[1] Mann, S., Singh, G., Traffic noise monitoring and modelling - an overview, Environmental science and pollution research international, 29(37), 55568-55579(2022).
[2] Domazetovska, S., Petreski, Z., Gavriloski, V., Design of low-cost wireless noise monitoring sensor unit based on IoT concept, Journal of Vibroengineering, 23(4), 1056-1064(2021).
[3] Chen, R., Research and application of environmental noise on-line monitoring system, Environment and Development, 32(10), 167-168(2020).
[4] Yan, M. F., Cheng, G. X., Overview of Automatic Monitoring System for Environmental Noise, China Environmental Protection Industry, 06, 40-42(2022).
[5] Ma, L. K., Qiao, G. S., Shi, R. D., Causes and Main Monitoring Techniques of Urban Environmental Noise Pollution, Value Engineering, 40(1), 178-179(2021).
[6] Jiang, S. X., Weng, S. X., Che, Y. H., Wang, C. Q. and Gong, J. X., Design of noise automatic monitoring and calibration system based on wirelesssensor network, Electronic Design Engineering, 30(17), 95-99(2022).
[7] General Administration of quality supervision inspection and Quarantine of the people's Republic of China, JJG 1095-2014 Verification Regulation of Environmental Noise Automatic Monitors (2014).
[8] International Electrotechnical Commission, IEC 61672.1: 2013 Electro-acoustics sound level meters Part 1 : Specifications (2013).
[9] Chen, C. M., Wu, Y., Yao, D. F., Song, Y. J. and Zhao, L., Design of On-line Monitoring and Remote Diagnosis System for Electric Energy Metering Device, Power Capacitor & Reactive Power Compensation, 42(4), 203-208(2021).
[10] Luo, L. C., Xing, X., Zhu, J., Qi, N. W. and Wang, G., Research and application of online measurement and calibration test technology for steam flowmeter in industrial field, China Measurement & Test, 46(S1), 89-94(2020).
[11] Yue, Y. J., Wang, Z. Z., Ye, Q., Wang, D. F., Yu, R. and Wang, S., Research on Remote Online Intelligent Calibration System for Air Quality Monitoring, Metrology Science and Technology, 66(12), 27-35(2022).
[12] Yao, S. N., Design of On-line Rotating Speed Detection System for Speedometer Inspection Table, Automation & Instrumentation, 37(10), 56-60(2022).
[13] nternational Electrotechnical Commission, IEC 61094-6:2004 Measurement microphones - Part 6: Electrostatic actuators for determination of frequency response (2004).