

Acoustic Wave (Acoustic Emission)

Monitoring and Detection of Bridge Cable Wire Breaks

1、Introduction

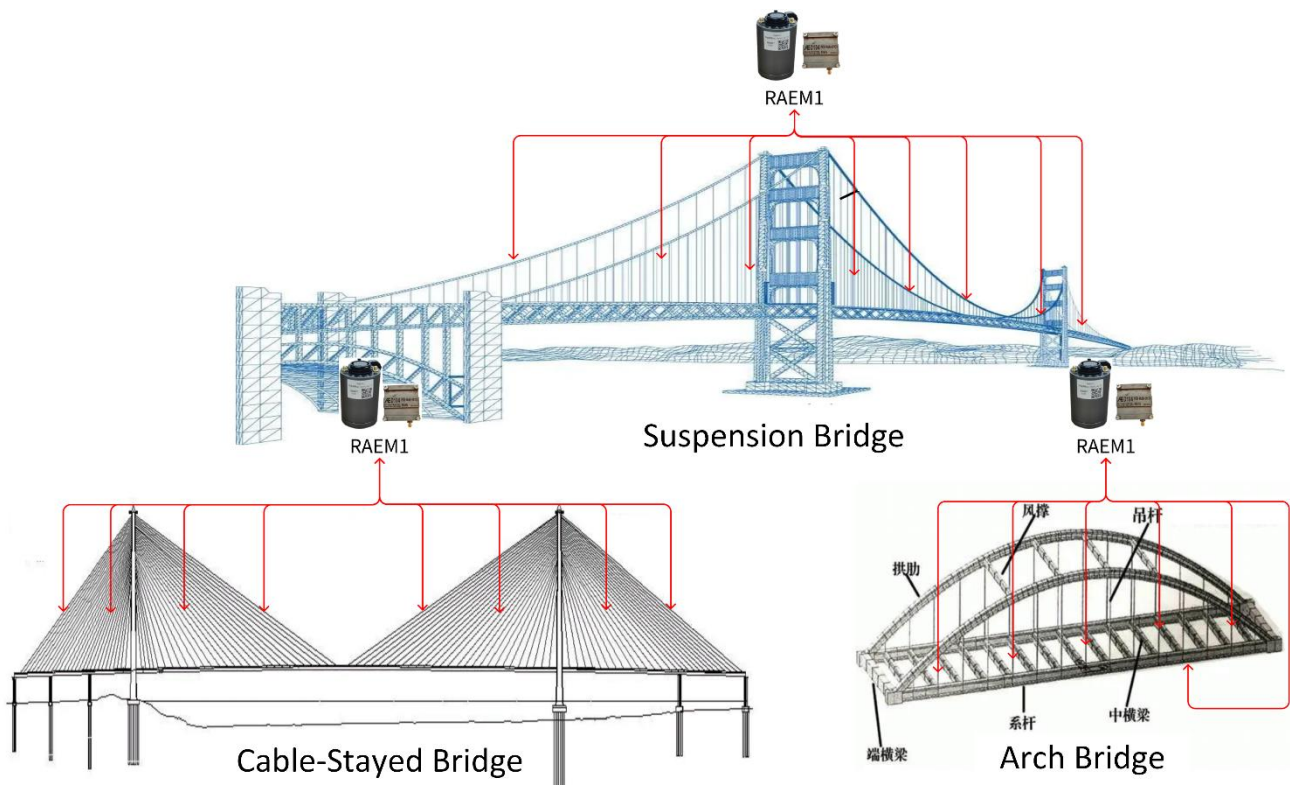
In the process of long-term use, the bridge is affected by heavy load, environmental corrosion, stress corrosion, corrosion fatigue, hydrogen embrittlement and so on, and it is easy to have cable breakage accidents.



Application:

Suspender of suspension bridge, main cable, cable-stayed bridge, arch bridge suspender (cable) or tie rod of bridge cable structure broken acoustic wave (acoustic emission) monitoring and detection.

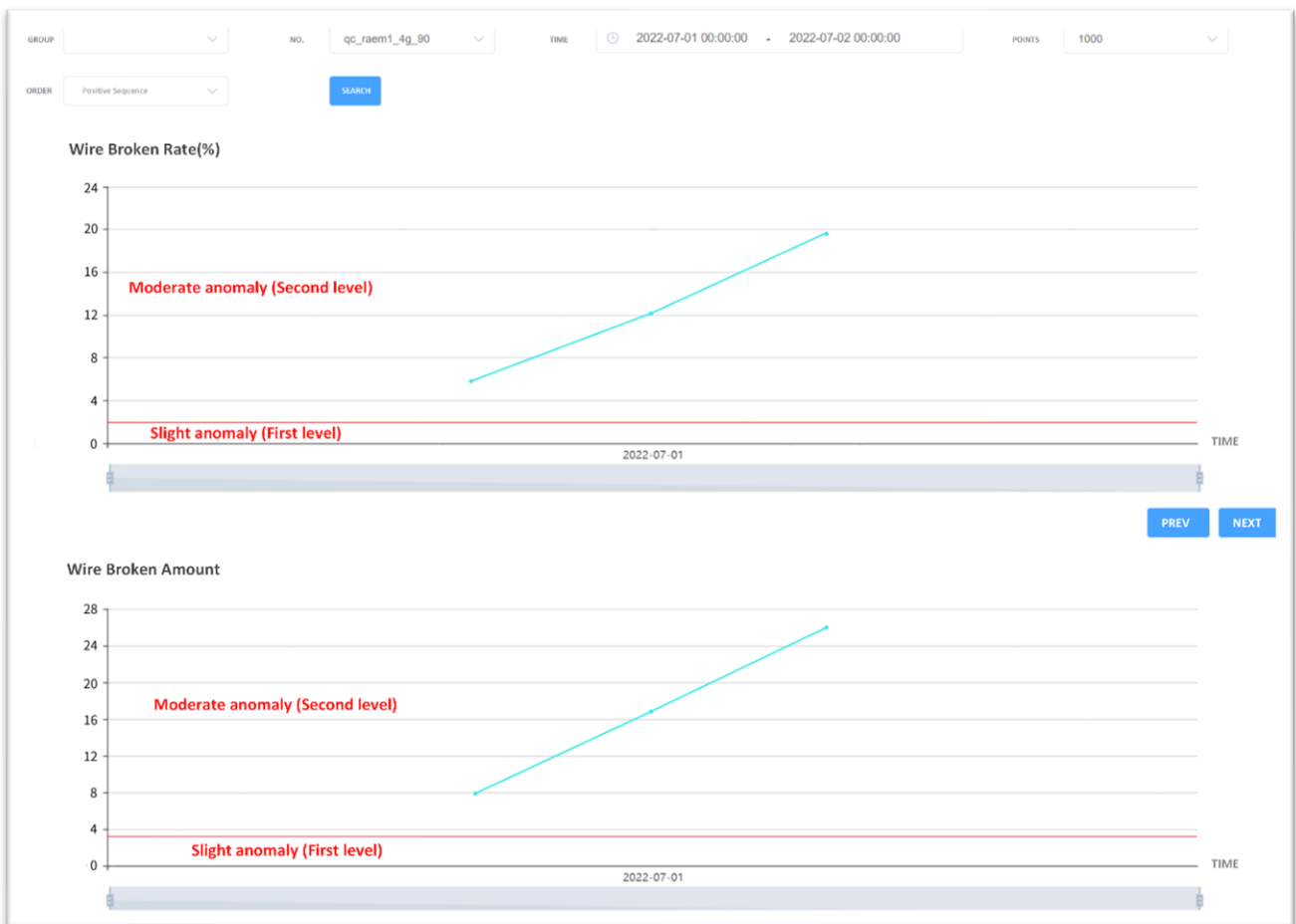
(The monitoring and testing described in this paper meets the relevant requirements of the JT/T 1037-2022 Technical specification method for highway bridge structure monitoring)



Installing position	Model and Parameter	Amount	Principle
Install on the sling, main cable, stay cable and tie rod that need to be monitored	RAEM1 collector. DC power supply.	Multiple. Broken wire measurement points can be arranged in the anchor head end or easy to corrode broken wire position.	At the moment of wire breaking of bridge wire rope, strong elastic wave will be generated and spread along the cable inside to the acoustic wave(AE) sensor installed on the cable. The system can identify and extract effective wire breaking signal and analyze the wire breaking condition of wire rope.

Application result:

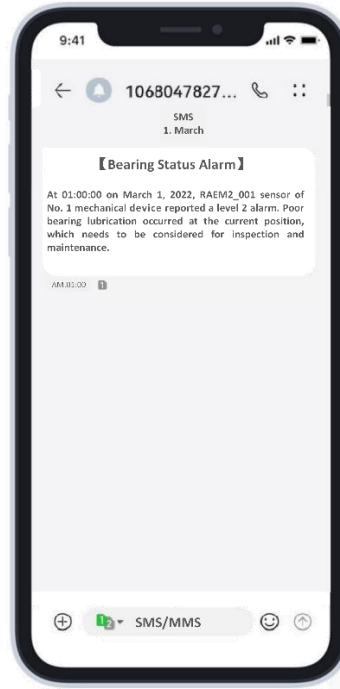
365 days of real-time online monitoring and detection, remote control and use of the Internet of Things, support for mobile phone Bluetooth onsite inspection, automatic analysis of results throughout the whole process, and mobile phone alarm push automatically.



Cloud platform data diagram



Inspection via Bluetooth



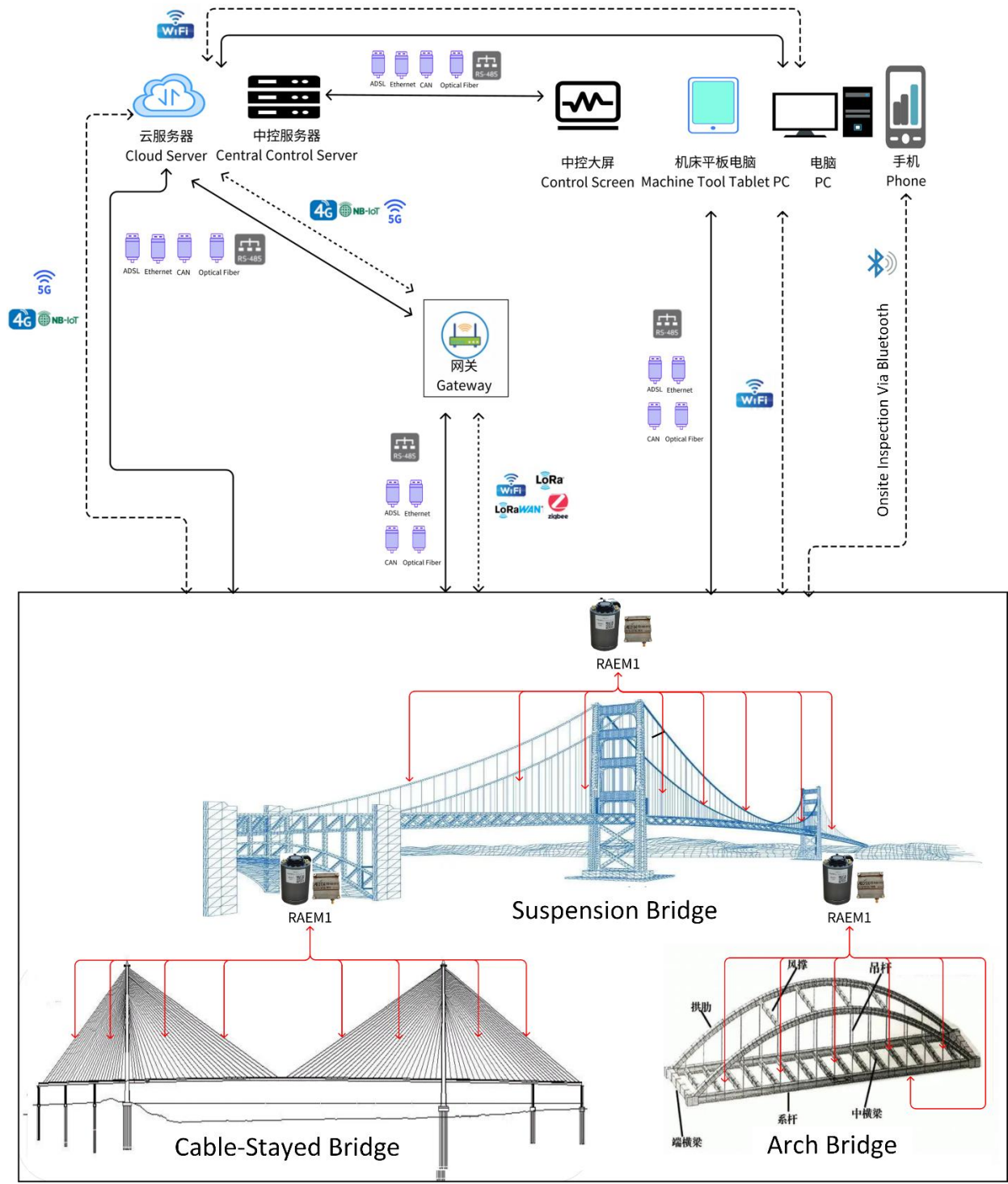
Alarm via SMS

- **Automatically provide monitoring and diagnosis results**
- **Online and historical data screen display**
- **Online mobile alarm push**

2、 Solution - RAEM1 remote acoustic wave (acoustic emission) monitoring system

A variety of data output communication modes (Wi-Fi, 4G, Ethernet, RS485, etc.) can be configured according to user requirements to achieve regular detection/local long-term monitoring detection/ remote long-term monitoring detection and other application modes.

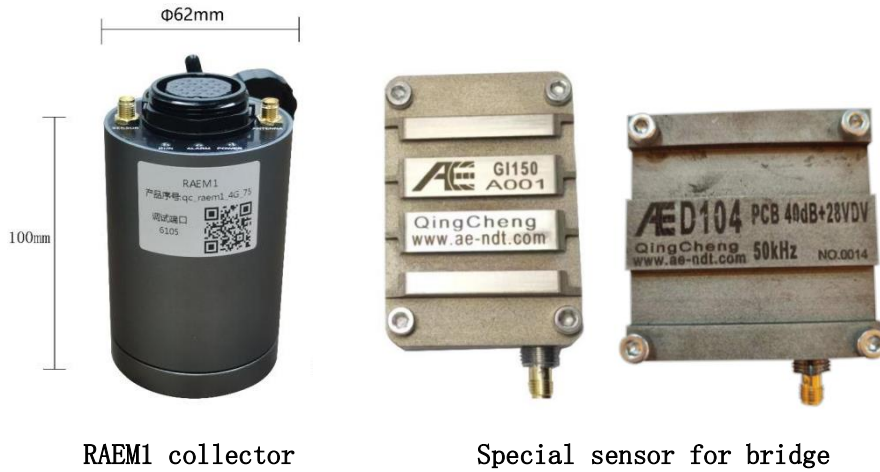
实线(Solid line): 有线连接(wired connection)
 虚线(Dotted line): 无线连接(wireless connection)



System diagram

Note: The above systems have the functions of onsite inspection and debugging via mobile app though Bluetooth.

RAEM1+ Special sensor for bridge:



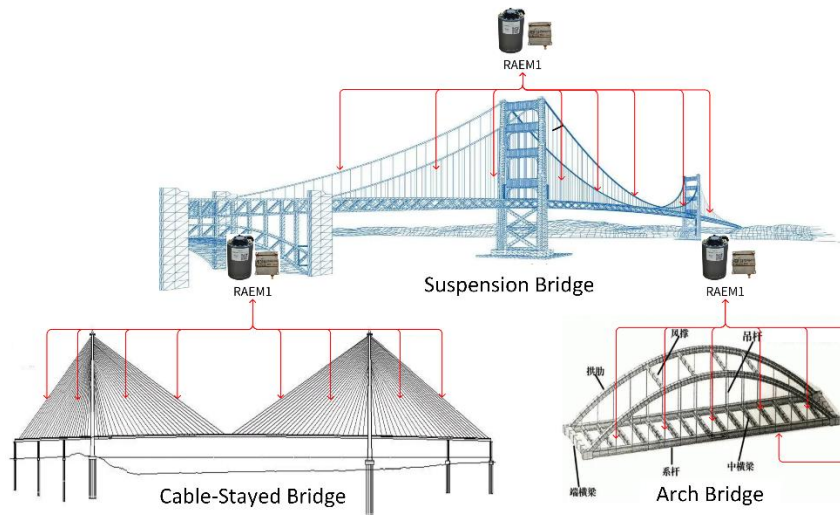
RAEM1 collector

Special sensor for bridge

Installation:

Install on suspension bridge slings, main cables, cable-stayed Bridges, arch bridge suspender (cable) or tie rods that need to be monitored.

Broken wire measurement points can be arranged in the anchor head end or easy to corrode broken wire position.



Characteristic	Process
<ul style="list-style-type: none"> • Signal and time trigger • Transient signal and continuous signal acquisition • Long-term monitoring and diagnosis • Remote monitoring and wireless single channel detector 	<ul style="list-style-type: none"> ◆ RAEM1 is installed in key parts to monitor wire rope breakage ◆ Start collection ◆ Analysis and verification, get the criterion standard ◆ Good verification effect, close waveform and parameter output ◆ Set criteria and push information on mobile phone platform

3、 Main hardware and software introduction

RAEM1 Series Remote acoustic wave (AE) monitoring System:

System composition	RAEM1 Collector, platform, client terminal
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1) Configuration table

Special Sensors for Bridge		GI50	
		G150/1	
Collector	Name	RAEM1 collector	
	Communication Mode	Wired	RS-485
			CAN
			LAN
			4G
	Wireless		WIFI
			Bluetooth (mobile phone Bluetooth inspection)
			LORA (Networking)
Terminal Output	Mobile Phone	APP	
		Mini program	
		SMS	
		E-mail	
	Cloud Platform	Qingcheng Internet of Things cloud platform	
		Ali Cloud platform	
		Amazon cloud platform	
	Computer Software	SWAE Software	
		RAEM1 configuring software	

Note: The cloud platform can be chosen with customer's private cloud platform or Qingcheng's private cloud platform according to the customer's requirements.

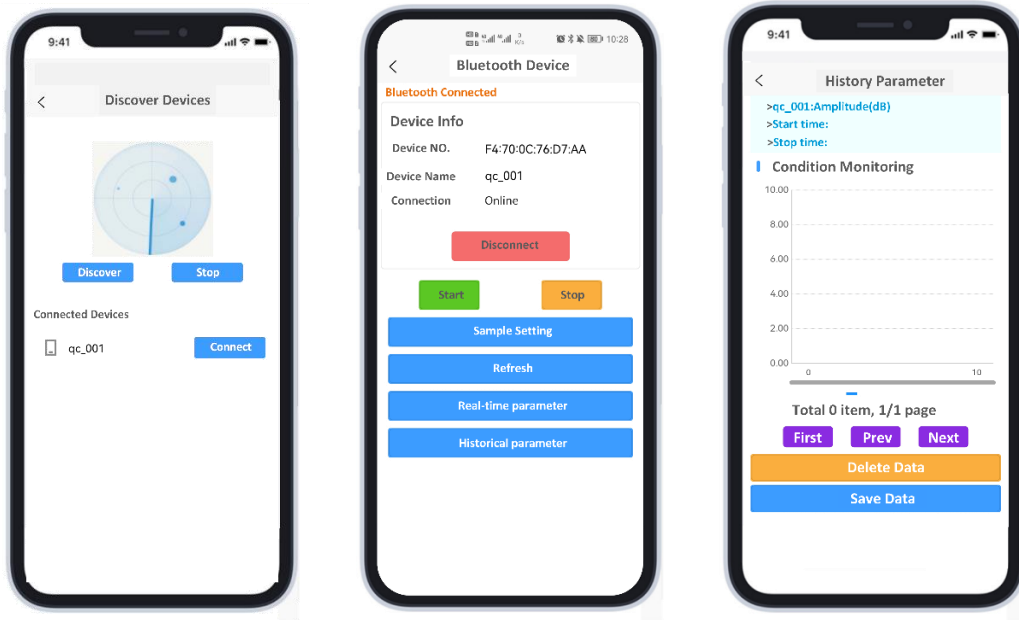
2) RAEM1 Collector Technical Specifications

RAEM1 acoustic wave (AE) collector integrates sensor, acquisition board, data communication (Bluetooth, etc.), battery power supply and wireless clock synchronization.

Channel	Single, or multiple-channel	Sample resolution	16-bit
Trigger	Threshold or time trigger	System noise	Better than 30dB
Sample rate	Up to 2M points per second	Dynamic range	70dB
Protection	IP65	Input bandwidth	10kHz-1000kHz
Supply	12V DC	Weight	220g
Analog filter	Two high-pass filters: 30kHz, 125kHz; two low-pass filters: 80kHz,175kHz; Factory default combinations: 30kHz~80kHz, 125kHz~175kHz.		
Digital filter	256-order FIR filter, in the frequency range of 0kHz~1000kHz, any value can be set as pass-through, high-pass, low-pass, or band-pass filters.		
Sensor	Integrated sensor series (3 types of integrated preamp available): 28V40dB, 12V34dB, 5V26dB		
Data output	Waveform, parameters, alarm ratings		
AE featured parameters	Arrival time, amplitude, counts, energy, rising time, duration, RMS, ASL		
Storage capacity	64G (expandable to 512G)		
Communication	4G, Ethernet, Wi-Fi, RS485 (can customize communication means according to requirements, e.g., NB-IOT, LoRa)		
Temperature	-20°C~60°C (Wi-Fi: 0°C~60°C)		
Dimension	Cylinder diameter ϕ 62mm, height = 100mm		
Installation	Magnetic base, which can be attached to the surface of magnetic absorption		

3) Onsite Inspection With Mobile Phone

This system supports onsite inspection by connecting devices with smart phone via Bluetooth for device Settings and data monitoring.



Interface of Bluetooth inspection APP

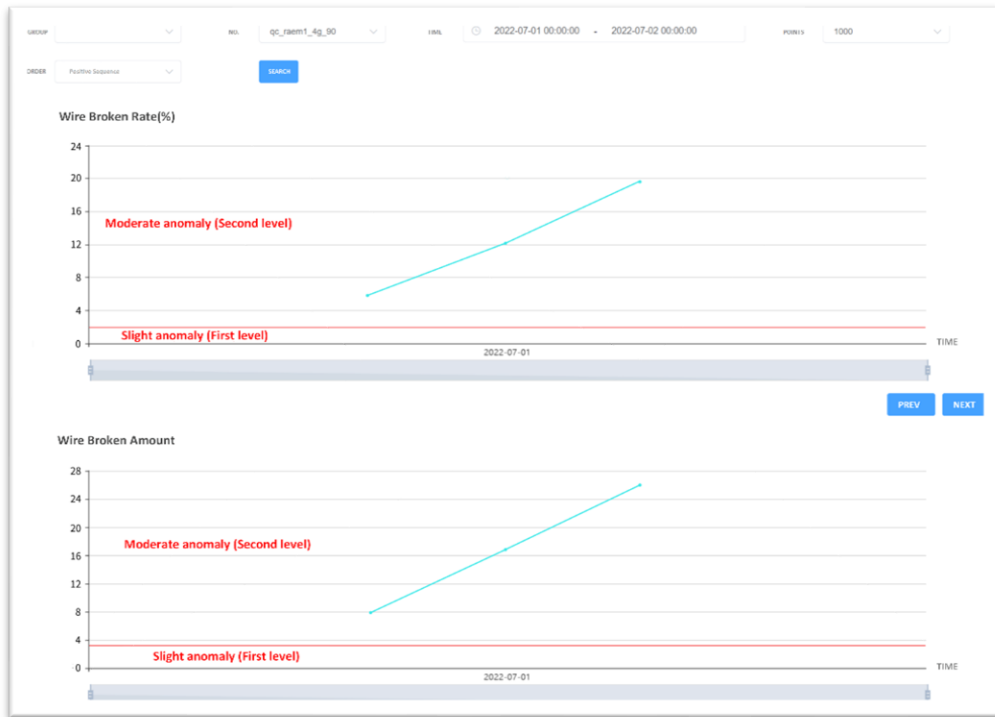
4) Cloud platform

Qingcheng IoT cloud platform, Ali Cloud platform, Amazon cloud platform, etc.



Note: The cloud platform can be customized according to customer requirements.

- ① **Real-time data display:** users can carry out remote monitoring through the cloud platform and the cloud platform can push alarm information to users automatically when the device is abnormal.



- ② **Remote system upgrade:** Users can download and install the upgraded software and system from the cloud platform.
- ③ **Sampling parameter setting:** Users can perform remote configurations on the cloud platform, such as parameter setting, timing configuration, and rating configuration.

The image shows a 'Rating config' dialog box with the following fields and controls:

- device NO.: qc_raem1_4g_191
- enable rating: on off
- intensity config: + add intensity
- activity config: + add activity
- activity1: activity1 (with a dropdown arrow and a delete activity button)
- rating time(s): 20 (with a dropdown arrow)
- rating report criteria: no report
- intensity reporting min. interval(s): 1 (with a dropdown arrow)
- Buttons: cancel, submit

Rating configuration

broken wire rate config

* device NO. qc_raem1_4g_191

enable broken wire function on off

wire amount 3

broken criteria intensity>=1 intensity>=2 intensity>=3 intensity>=4

broken wire rate reset cancel submit

Break rate configuration of bridge wire

broken wire alarm

device NO. qc_raem1_4g_191

notice type email sms

frequency(/5min) 1

cancel submit

Break rate alarm configuration of bridge wire

④ **Data download:** Users can download historical data remotely through the cloud platform.

zip

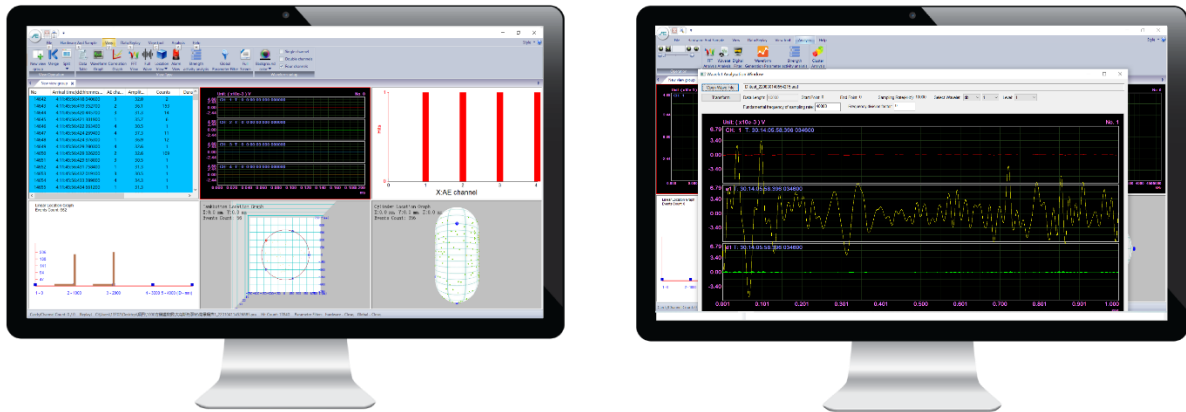
* device NO. qc_raem1_t_0001

* datetime-range 2023-01-05 17:46:23 - 2023-01-06 17:46:23

cancel start.zip

5) SWAE Software-Computer

The data can be downloaded from the cloud for further analysis by SWAE software, or sent directly to SWAE software for real-time analysis and processing to understand the defect details. Such as **defect location analysis, parameter analysis, correlation graph analysis, waveform analysis, FFT, wavelet transform, rating analysis**, etc.



4、Scheme Cases

Case:

The wire breaking test of a real bridge was conducted for 4 times, and the online acoustic wave (acoustic emission) monitoring of the bridge wire breaking was carried out.

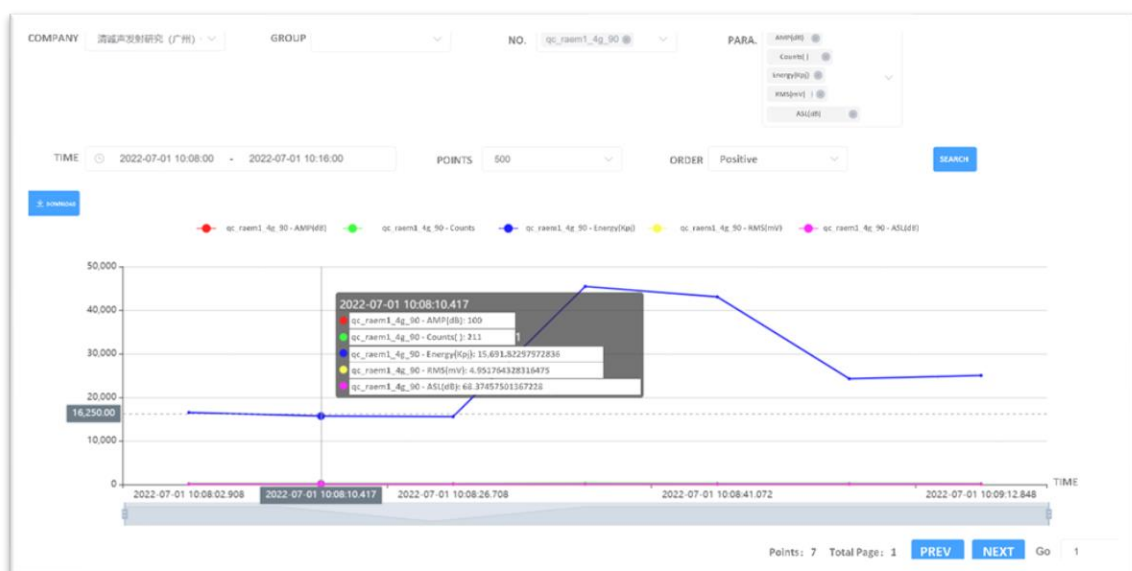
The first is the pre-test after adjusting the acquisition parameters. The broken wire alarm is not turned on to verify whether the broken wire criterion is reasonable.

The 2nd - 4th pull test is the verification of wire breaking monitoring and wire breaking rate monitoring alarm.

The known number of wires is 133, and the actual number of broken wires in 4 tests are: 7, 8, 9 and 9 respectively.

1) Cloud platform

Cloud platform Figure 1: Data chart of parameters during wire breaking in the first breaking experiment:



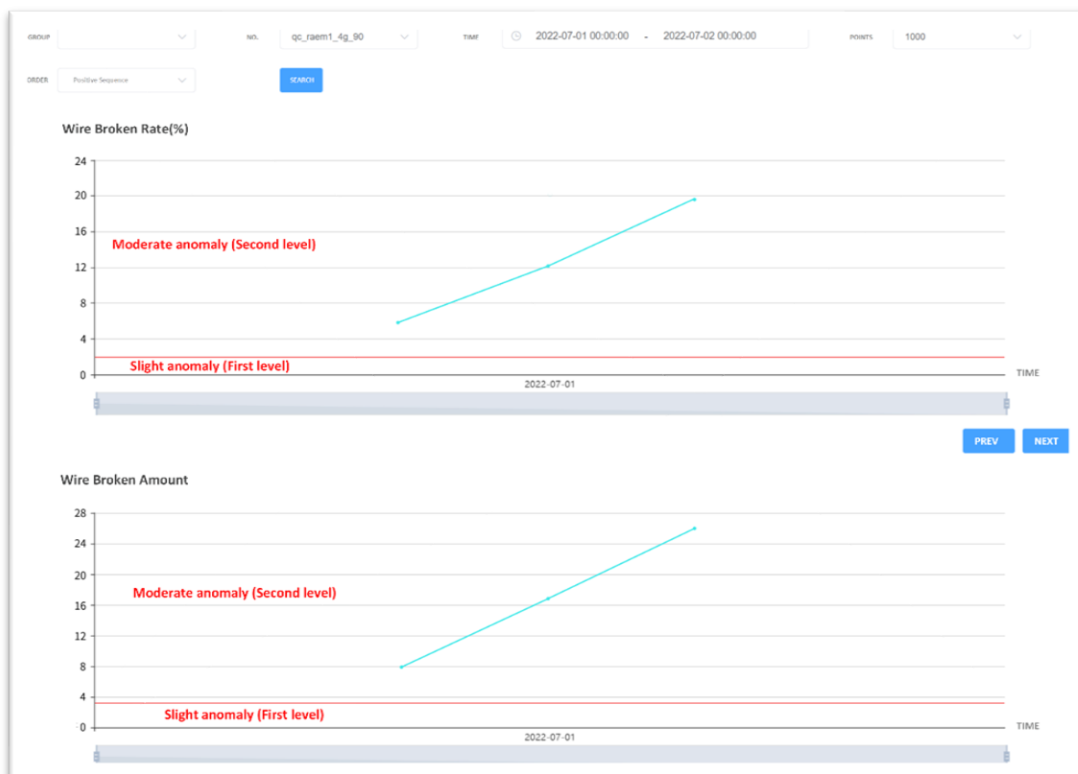
According to the data of the cloud platform, 7 broken wires were detected by the first breaking experiment system.

Statistical table of the first wire breaking experiment data drawn according to the cloud platform data

Broken wire number	Amplitude (dB)	Energy (kJ)	RMS (mV)	ASL (dB)	Counts
1	100	16502	5.1	68.4	206
2	100	15692	5.0	68.4	211
3	99	15551	4.9	68.6	211
4	100	45427	8.4	73.1	283
5	100	43030	8.2	72	252
6	100	24257	6.2	70.2	233
7	100	25005	6.3	70.5	218

It is speculated that the early warning setting of broken wire is reasonable.

Figure 2: Number and rate of broken wires in the 2nd ~ 4th breaking test:



Statistical table of the number and rate of broken wires, warning accuracy, health degree/over-limit grade in the 2nd ~ 4th breaking test

	Number of broken wires in the cloud platform	Cumulative number of broken wires	Breaking rate	Monitoring alarm accuracy	Health grade	Overrun level
The second breaking experiment	8	8	6.01%	100%	III	Level 2
The third breaking experiment	9	17	12.78%	100%	III	Level 2
The fourth breaking experiment	9	26	19.55%	100%	III	Level 2

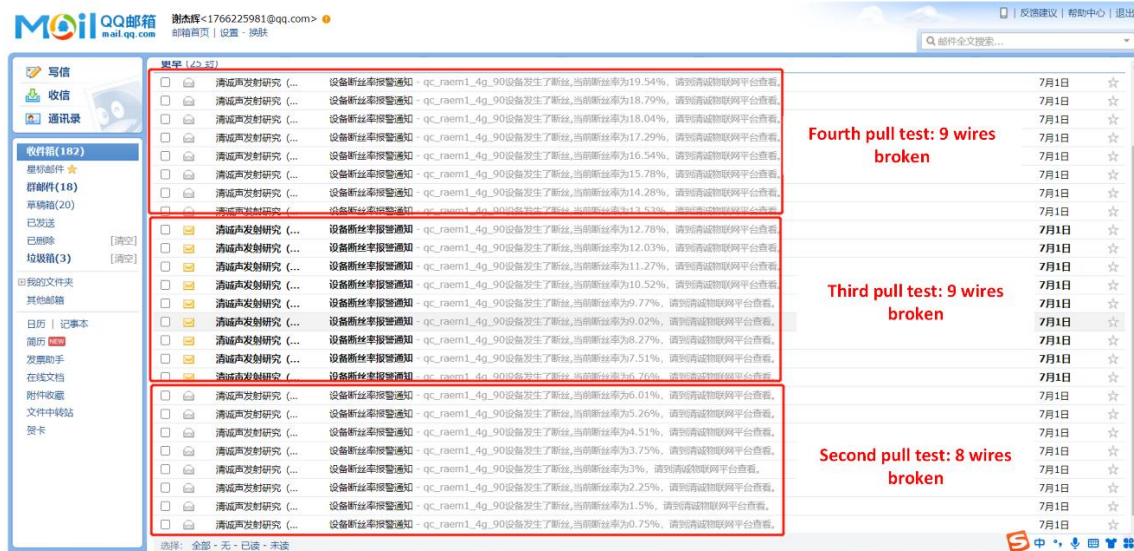
According to the standard JT/T 1037-2022 Technical Specification for highway bridge structure monitoring Article 11 monitoring application Table 9 overlimit alarm threshold setting table and Table 11 bridge result health grade evaluation criteria, when the wire break occurs, it is a slight anomaly (overlimit level 2); When the breaking rate reaches 2%, it is a moderate anomaly (exceeding grade 2). The grades of the tests obtained are shown in the table above.

The health level of the second, third and fourth tensile tests were all III medium abnormal, and the overrun level was all 2. **Special inspection is recommended** according to Table 10 of Monitoring data overrun inspection recommendations in the monitoring application of Article 11 of the standard JT/T 1037-2022 Technical Specification for Highway Bridge Structure monitoring.

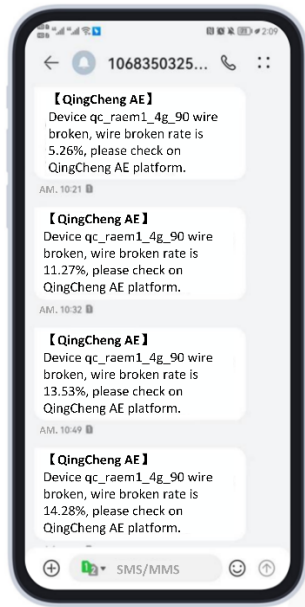
2) Alarm push

When broken wire occurs, automatic alarm push, and prompt current broken wire rate.

Alarm methods: email, SMS, Mini program /APP, etc.



Alarm via email



Alarm via SMS



Alarm via APP

5、 Conclusion

According to the standard (JT/T 1037-2022 Technical Specification for Highway Bridge Structure monitoring), the acoustic wave (acoustic emission) monitoring and detection of cable breakage of suspension bridge suspender, main cable, cable-stayed bridge, arch bridge suspender (cable) or bridge tie rod is realized.

The bridge structure health grade and over - limit grade is given according to the standard. Users can carry out inspection and maintenance in time according to the standard content, so as to prolong the life of the bridge and prevent the loss and accident caused by the cumulative development of damage.

Advantages:

- **Online** ---- acoustic wave (acoustic emission) collector is installed on the monitored and diagnosed object to realize all-weather condition monitoring and fault diagnosis in the whole period.
- **Intelligent** ---- automatically gives monitoring and diagnosis results, automatically analyzes the number and rate of broken wires and gives an alarm, without manual operation. Data collection and analysis report shows the whole process of monitoring and diagnosis is carried out automatically.
- **Remote** ---- With the help of the Internet of Things system, users can get the monitoring and diagnosis results of any monitoring and diagnosis points at any distance, online real-time results and historical process results.

6、 Practical Cases

1) Full-scale bridge cable break acoustic wave(acoustic emission) monitoring

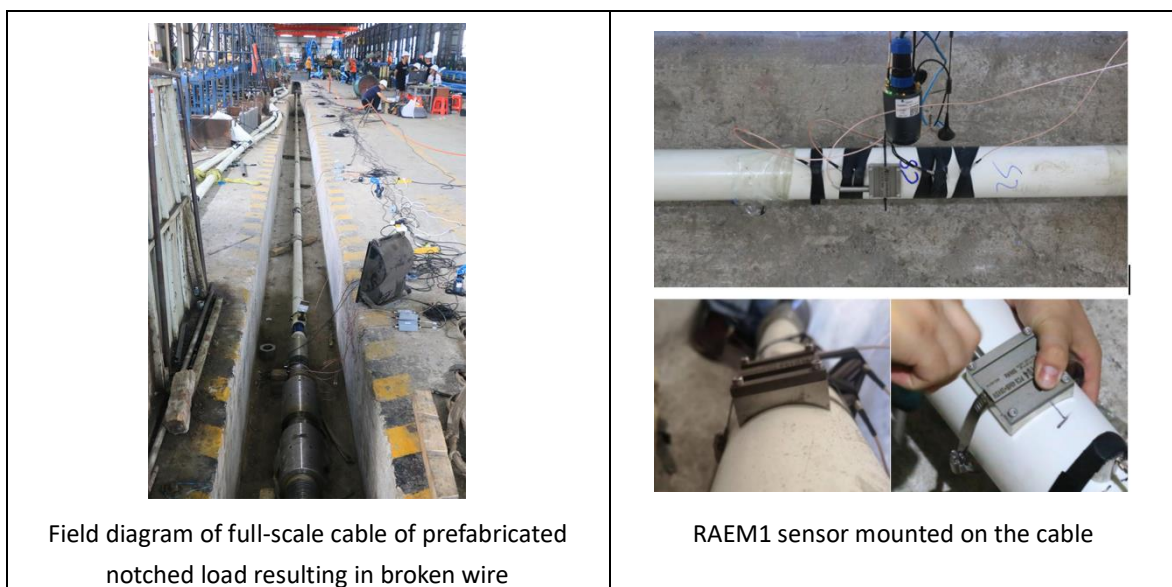
In June 2022, Qingcheng Company and its partners successfully carried out a full-scale acoustic wave monitoring test of bridge cable breakage in a bridge cable manufacturing company.



Diagram of the position of cable loading break groove and RAEM position
(P1 is the position of broken wire, and S is the position of RAEM1)

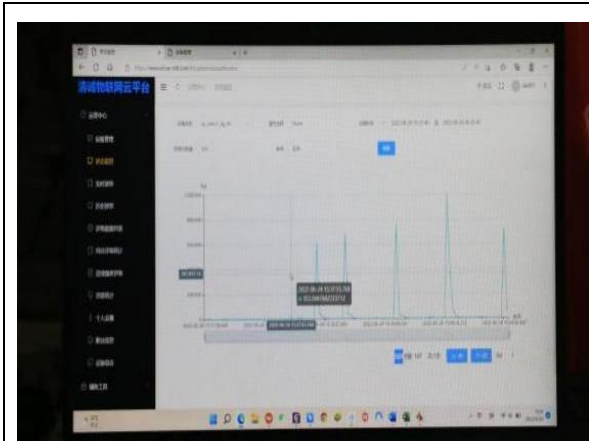
The actual full-scale cable is loaded with prefabricated grooves to generate broken wires. Sensors and RAEM1 are installed on the cable sheath and anchor head. The acoustic wave (acoustic emission) intelligent sensing alarm information of RAEM1 model of Qingcheng Company will be sent to the designated smart phone.

The RAEM1 sensor is about 40 meters away from the broken wire position. Dozens of broken wires are monitored in the test. The correct rate of broken wire monitoring is 100%, and no missing report is correct.

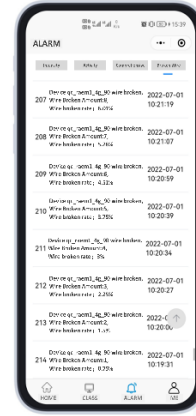


Field diagram of full-scale cable of prefabricated notched load resulting in broken wire

RAEM1 sensor mounted on the cable



Typical wire breaking data – Qingcheng Cloud 5 times wire breaking diagram



Alarm of broken wire and current broken wire rate via E-mail

2) Cable breaking monitoring of Taiping Lake Bridge

In 2021, the Ministry of Transport will monitor the structural health of 11 large highway Bridges as a pilot project. Among them, Taipinghu Bridge in Huangshan City, Anhui Province used intelligent acoustic wave (acoustic emission) monitoring system for the first time to monitor the broken wire of the suspender. Our company's RAEM1 intelligent acoustic wave (acoustic emission) monitoring system was honored to be selected by the design and maintenance unit to protect the health of the bridge.



Taiping Lake Bridge steel cable broken monitoring site