BWM1

Bridge Wire Monitoring System

User's Manual

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1. Technical Background

1.1. Acoustic Emission Technology Introduction

Acoustic emission (AE) is the phenomenon of transient elastic waves generated by the rapid release of energy from local sources in materials, sometimes also known as stress wave emission. The acoustic emission testing technology is the acoustic detection method by receiving and analyzing the acoustic emission signals to evaluate the material performances or structural integrity. The deformation and crack propagation of materials under stress are important mechanisms of structural failure. The source directly related to deformation and fracture mechanism is called acoustic emission source.

The principle of acoustic emission detection is shown in Figure 1-1. The elastic waves emitted from the acoustic emission source finally propagate to the surface of the material, causing the surface displacement that can be detected by the acoustic emission sensor. The sensor converts the mechanical vibration of the material into an electrical signal, which is then amplified, processed, and recorded. By analyzing and inferring the recorded acoustic emission signals, the mechanism of the acoustic emission of the material is understood.

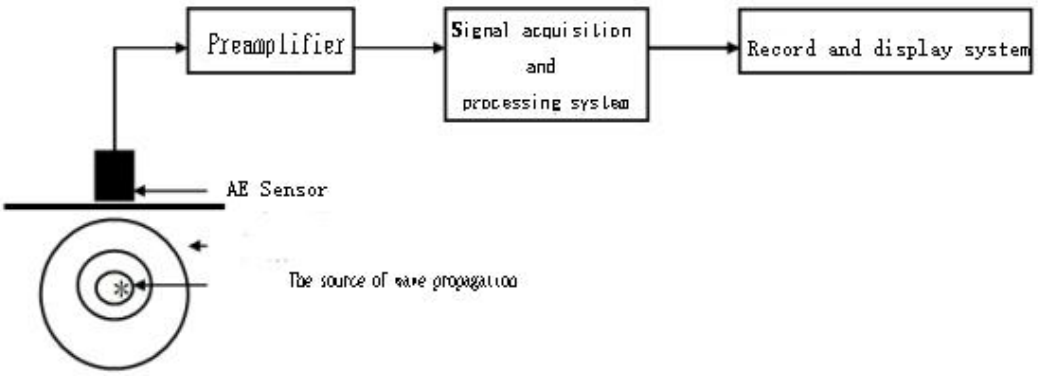


Fig. 1-1 Block diagram of acoustic emission testing principle

1.2. Main Purpose of Acoustic Emission Testing

- Locate the acoustic emission source.
- Analyze the properties of the acoustic emission source.
- Determine the time and load of the AE occurrence.
- Assess the severity of the acoustic emission source.

1.3. Characteristics of Acoustic Emission Testing

The discovery of each acoustic emission source indicates the application of AE system. The AE testing method is different from other conventional NDT methods in many aspects:

- It is a dynamic detection method. The detected energy comes from the object itself, not from the detection instrument.
- It is sensitive to linear defects and can detect the movement of the defects under external structural stress.
- It can detect and evaluate the state of the defects in the whole structure.
- The system can provide real-time or continuous information of the defects changing with the external variables, such as load.
- The requirement of approaching the detected objects is not high.
- It can be used for inspection of pressure vessels in service.
- When used in pressure tests of pressure vessels, it can prevent catastrophic failure of the inspected object caused by unknown discontinuous defects and limit its maximum working pressure.
- It is suitable for object detection with complex geometry.

By finding the hidden defects, even in some unreachable parts of the structure, the spread of the damages can be prevented. That is the main purpose of the AE detection/monitoring.

1.4. Applications of Acoustic Emission Technology

Currently acoustic emission technology has been applied in many fields, including the following aspects:

- The petrochemical industry
- The power industry
- Material test
- Civil Engineering
- The aerospace and aviation industry
- Metal Process
- The transportation industry

1.5. Key Terms of Acoustic Emission Technology

(1) **Starting point of AE signal:** the starting point of an AE signal recognized by the system processor, is usually when the amplitude begins to exceed the threshold.

(2) **End point of AE signal:** the end point of the AE signal, which is usually defined as the last time that the signal amplitude crosses the threshold.

(3) **Duration:** the time interval between the beginning and the end of the acoustic emission signal.

(4) **Rise time:** the time interval between the starting point of AE signal and the peak of the AE signal.

(5) **Sensor array:** a combination of two or more sensors placed on a component to detect and determine the position of the source in the array.

(6) **Attenuation:** the decrease of the AE amplitude per unit distance, usually expressed in dB per unit distance.

(7) **Average Signal Level (ASL):** the time average logarithmic value of the acoustic emission signal after rectification. The amplitude of the acoustic emission signal is measured in logarithmic scale, in unit of dB. At the input of the pre-amplifiers, 0dB = 1μV.

(8) **RMS**: Root mean square. The effective average value of the signal amplitude, in unit of V.

(9) **Channel:** a complete acoustic emission channel consists of a sensor, a pre-amplifier or an impedance matching transformer, a filter, a secondary amplifier, a connection cable and a signal detector or processor.

(10) **Counts:** also known as ring-down counts. In the selected detection interval, the number of times the AE signal crosses the present threshold.

(11) **Event:** a local material change giving rise to acoustic emission.

(12) **Event count:** the number of events that can be detected by the AE instrument.

(13) **Couplant:** the material filled between the contact surface of the sensor and test structure, which can improve the ability of sound energy passing through the interface in the process of acoustic emission monitoring.

(14) **Decibel (dB):** logarithmic measurement value of AE signal amplitude referring to 1μV, dB = 20lg(A/1μV), where A is the amplitude voltage value of the measured AE signal.

(15) **Dynamic range:** the decibel difference between the overload level and the minimum signal level (usually determined by one or more factors in the noise level, low-level distortion, interference, or resolution level) in a system or sensor.

(16) **Effective sound velocity:** the sound velocity calculated based on arrival time and distance determined by the artificial acoustic emission signal, for the use of source location.

(17) **Burst acoustic emission:** the qualitative description of the discrete signals related to an independent acoustic emission event in the material.

(18) **Continuous acoustic emission:** the qualitative description of the continuous signal level produced by the rapid occurrence of acoustic emission events.

(19) **Energy:** elastic energy released by acoustic emission events.

(20) **Threshold:** the threshold value for monitoring the triggered AE signal.

(21) **Monitoring area:** part of the structure monitored by AE sensors.

(22) **Detection range:** the part of the test object evaluated by acoustic emission technology.

(23) **Felicity effect:** the presence of AE at stress levels below the maximum previously experienced.

(24) **Felicity ratio:** the ratio of the stress at presence to the maximum stress applied last time.

(25) **Floating threshold:** a dynamic threshold established by the time average of the amplitude of the input signal.

(26) **Hit:** any signal that exceeds the threshold and causes a system channel to collect data.

(27) **Kaiser effect:** under a fixed sensitivity, there is no detectable AE signal before the stress level is exceeded.

1.6. Key Terms in BWM1 System

(1) Channel: a channel through which the acoustic emission signal enters the acquisition card through sensors, amplifiers, and data cables for independent processing.

(2) Sampling rate: also known as sampling speed, the number of sampling points per second of analog voltage signal acquired by the ADC module; for example, 10MSPS, means 10M (=10^6) points per second.

(3) Sampling accuracy: the sampling accuracy determines the minimum resolution of the signal within the input voltage range. For example, in the 20Vpp input range, the 16-bit sampling accuracy means that the voltage of 20V is divided into 2^{16} units, i.e., the step is about 0.305 mV. The higher the accuracy, the higher the resolution of the signal.

(4) TCP/IP: also known as network communication protocol, a data transmission protocol widely used by computers.

(5) AST: automatic sensor testing, which refers to the technology that the sensor transmits a mechanical pulse signal under a voltage excitation, and it is received by the adjacent sensors to evaluate the sensitivity of adjacent sensors.

(6) ADC: analog to digital conversion, i.e., analog voltage signal is converted into digital signal.

(7) **Analog filter:** filter applied in the analog circuit. The product uses 4th order Butterworth analog filter before ADC.

(8) **Pre-amplifier** amplifies the weak voltage signal output from the sensor and applies impedance transformation, to adapt to the electronic amplification circuit for long-distance signal transmission, and outputs analog signals.

(9) **Coaxial cable:** the signal cable that transmits the pre-amplifier output signal to the acquisition host. The inner layer is a single core wire, and the outer layer is a shielding coating layer. Generally, the impedance is 75 Ω.

(10) **IoT:** Internet of Things.

(11) **Hit extract sample mode** also known as **envelop collection**. It uses the threshold, HDT, HLT and so on to recognize or define a hit AE signal, including its start and end and length.

(12) **Time parameter sample mode**: the mode collects each AE hits by the set threshold and the sample length.

(13) **System rating**: users set the system rating rules by the parameters intensity (how big the parameter is) and activity (how many times it appears). If the sampled parameters exceed one rating level, it will be rate at that level.

(14) **EET**: enforced end time, in unit of micro-second (us). It ranges from 1 ~ 50000μs. When the AE hit is continuously higher than the threshold value, and the set HDT cannot define the end of the AE signal, the EET takes effect which means it is the duration of the current hit and other related AE feature parameters are calculated based on this duration. EET is effective only in Hit Extract sample mode, not in Time parameter sample mode.

(15) **HDT**: Hit definition time, also known as the envelop definition time, in unit of micro-second (μs). the setting range is 100 ~ 50000μs (positive integer), can be directly input in the text box. It refers to the waiting time interval of a hit signal to correctly determine the end point of that hit signal. When the set HDT value is greater than the time interval T between two adjacent wave packets that exceed the threshold, the two wave packets will be classified as one acoustic emission hit signal; if the set HDT value is less than the time interval T when the two wave packets cross the threshold, the two wave packets are divided into two acoustic emission hit signals. For the same signal, the greater the HDT is, the fewer the AE parameters are extracted, while the smaller the HDT is, the more AE parameters are extracted.

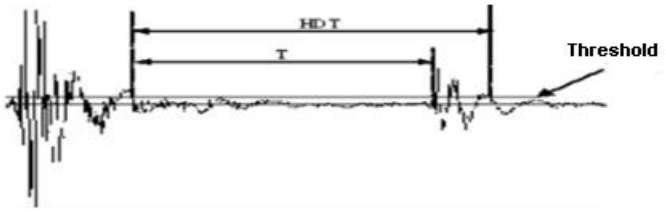


Fig. 1-2 HDT definition diagram

(16) HLT: Hit lock time, in unit of micro-second (μs). The setting range is 1 ~ 20,000,000 (positive integer), can be directly input in the text box. To avoid receiving the reflected waves or late waves, HLT is the set time window for closing the measurement circuit. At the end of the current acoustic emission event after a HDT time, there is a period (HLT) that the signal will be ignored. This window is called hit lock time. The value is affected by the signal attenuation, structure size, etc. If the setting value is too big, the subsequent AE signal will be missed. As shown in the figure below, the next AE signal T period has passed the threshold, but the HLT has not finished, so the signal in T period will not be collected.

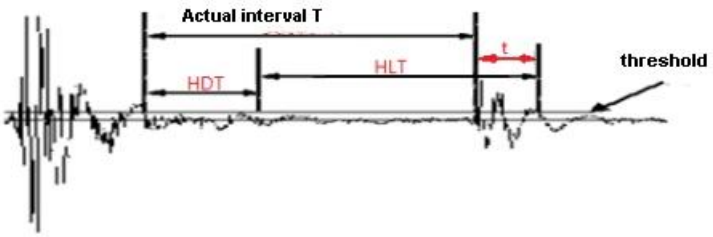


Fig. 1-3 HLT definition diagram

(17) POE: Power Over Ethernet. This refers to the technology that allows for the transmission of data signals to certain IP-based devices (such as the acoustic emission collectors mentioned later) while simultaneously providing DC power to such devices, all without making any modifications to the existing Ethernet Cat.5 cabling infrastructure.

2. Product Introduction

BWM1 adopts an ARM system architecture, featuring an embedded ADC (Analog-to-Digital Converter) circuit, filtering and conditioning circuit, and Ethernet communication. It can connect to a cloud platform via a router, with POE (Power over Ethernet) providing both communication and power supply. The BWM1 structure is designed as a strap-like integrated preamplifier circuit board.

2.1. BWM1 System Introduction

The BWM1 system consists of three parts:

- BWM1 Device (AST sensor, AE sensor, signal acquisition and analysis, communication)
- POE Power Adapter
- Client PC

BWM1 can be networked through switches, with multiple switches connected to a router to form a large-scale bridge monitoring system.

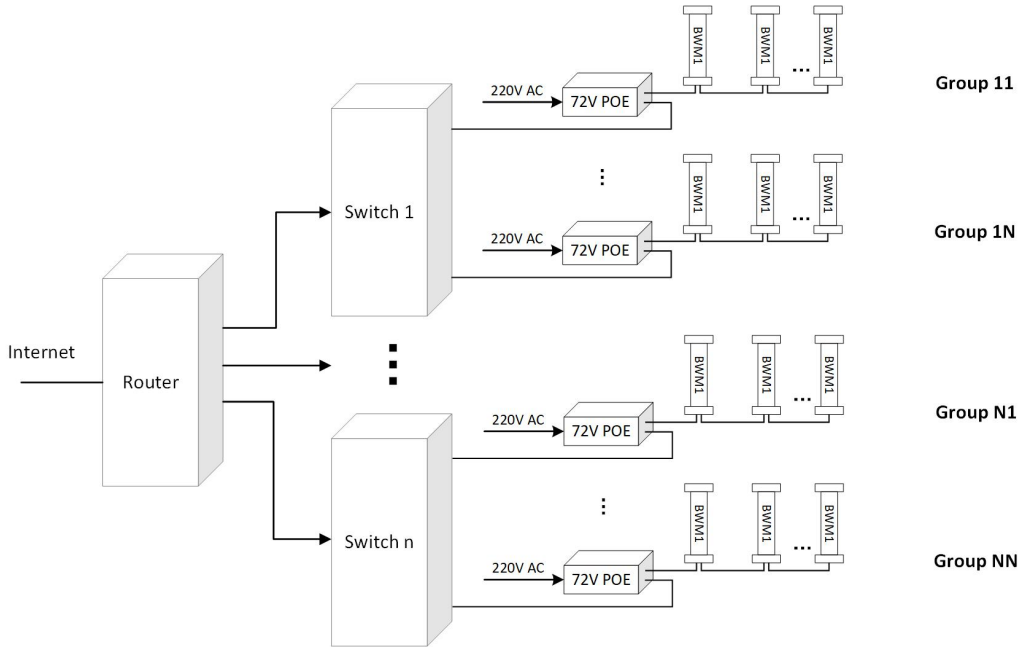


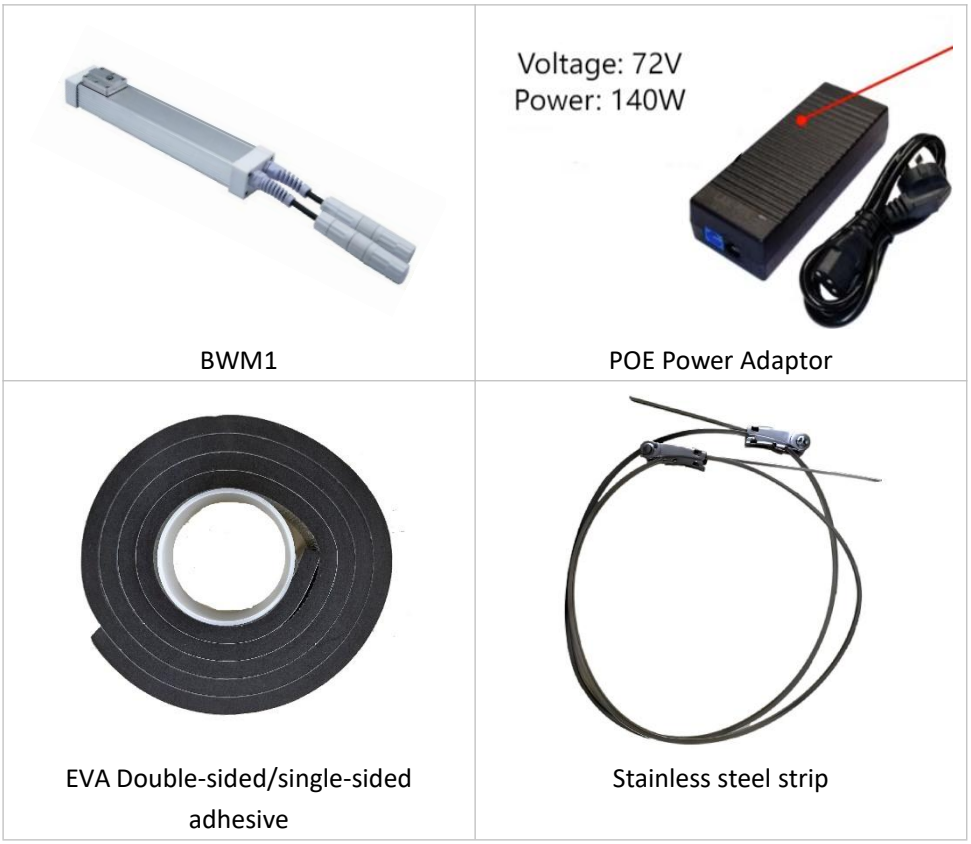
Fig. 2-1 BWM1 Network Connection Diagram

The output data types include parameters, waveforms, and parameter rating. The data can be uploaded to the cloud IoT platform for display and analysis, be downloaded to a client computer for in-depth analysis using SWAE software, or be sent directly to SWAE software for real-time analysis and processing.

This user manual will introduce the connection, configuration, and usage of the BWM1 device. It will start with an introduction to the product components and their connections, followed by system connection and configuration.

2.2. Hardware Introduction

Figure 2-2 shows a BWM1 hardware kit equipped with Ethernet communication, which includes a BWM1 device, a POE power adapter, and an Ethernet cable.



BWM1	POE Power Adaptor
EVA Double-sided/single-sided adhesive	Stainless steel strip

Fig. 2-2 BWM1 Hardware Kit

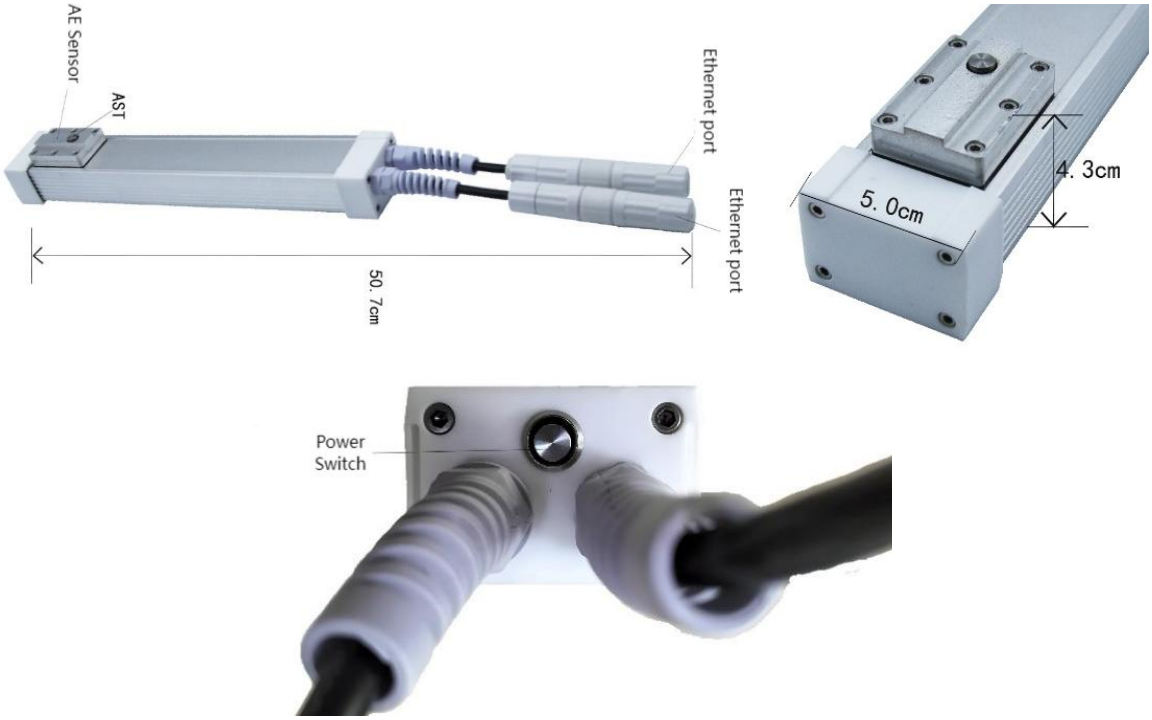


Fig. 2-3 BWM1 Parts

2.3. Technical Specifications

Table 2-1 BWM1 Hardware technical specifications

Channel	Single channel or multi-channel combination
Acquisition Mode	Signal triggered / Time triggered
Sampling Rate	Maximum sampling rate of 2M points/second for single channel
Sampling Precision	16-bit
System Noise	Better than 30dB
Dynamic Range	70dB
Input Bandwidth	10kHz-800kHz
Analog Filters	Combination of two high-pass filters at 30kHz and 125kHz, and two low-pass filters at 80kHz and 175kHz; default combinations are bandpass at 30kHz-80kHz or 125kHz-175kHz, fixed at the factory
Digital Filters	256-order FIR filter, configurable as pass-through, high-pass, low-pass, or band-pass within the 0kHz~1000kHz frequency range
Sensors	Selectable center frequency of 40/150KHz; two built-in preamp gains of 20/40dB available
Data Output	Waveform, parameters, parameter ratings

AE Parameters	Arrival time, amplitude, counts, energy, rise time, rise counts, duration, RMS, ASL
Built-in SD Card Capacity	64GB (expandable to 512GB)
Communication Method	Ethernet
Power Supply	POE power supply
Dimensions	507mm (including waterproof connector) * 50mm * 43mm
Weight	285g
Installation	Strap (clamp) structure
Protection Level	IP67
Working Temperature	-30℃ to +70℃
Single Node Wiring Distance	Maximum of 400 meters of network cable for connecting up to 6 devices in series

2.4. Software and Cloud Platform Description

After the BWM1 device is started, it automatically begins signal acquisition and communication connection based on the existing configuration and hardware connections. The current configuration of the BWM1 can be accessed and updated through the provided communication methods. Some communication methods support real-time parameter viewing and analysis, as well as online waveform and parameter viewing and analysis.

The default configuration of the BWM1 device is the recommended configuration, which has passed factory testing. If configuration changes are necessary, it is recommended to first save the original factory configuration as a configuration file on your computer before making any changes. For detailed instructions on saving and transferring configuration files, please refer to Chapter 5.

After the BWM1 is started, it automatically starts data collection. When a hit occurs, the BWM1 generates .PRA and .AED files. If no hit occurs, no .pra and .aed files will be generated. Depending on the communication method used, the data will be stored either on a local SD card or uploaded to the cloud. Once data collection is complete, the data package can be viewed and downloaded from the cloud by directly accessing the BWM1.

There are two ways to configure the BWM1: one is by using **RAEM1 Configuration Software**, and the other is

by remotely configuring it through the **Qingcheng IoT Cloud Platform**.

There are multiple ways to view and download data collected by the BWM1. The Qingcheng IoT Cloud Platform allows for real-time viewing of parameters, waveform data, and rating results, as well as data download and remote configuration of the BWM1. Alternatively, you can directly connect the BWM1 to **SWAE software** for real-time online professional acoustic emission signal acquisition, analysis, and storage of parameters, waveforms, and other data.

The table below shows the configuration and data access methods corresponding to various communication methods:

Table 2-2 BWM1 Communication Methods and Corresponding Software

Communication Method	Configuration method	Real-time data view	Data download
Ethernet connection	RAEM1config software	SWAE software	RAEM1config software
Router networking	RAEM1 config software or Qingcheng Cloud Platform	SWAE software or Qingcheng Cloud Platform	RAEM1 config software or Qingcheng Cloud Platform

- **RAEM1 Configuration Software:** This is a Windows executable software supporting for configuring the BWM1. It requires the BWM1 to be directly connected to a PC, either via a wired Ethernet connection or wirelessly through a router network. The **RAEM1 Configuration Software** allows access, modification, and downloading of BWM1's device information, acquisition settings, data storage, communication settings, system settings, and file viewing. For detailed instructions and usage, please refer to Chapter 5.

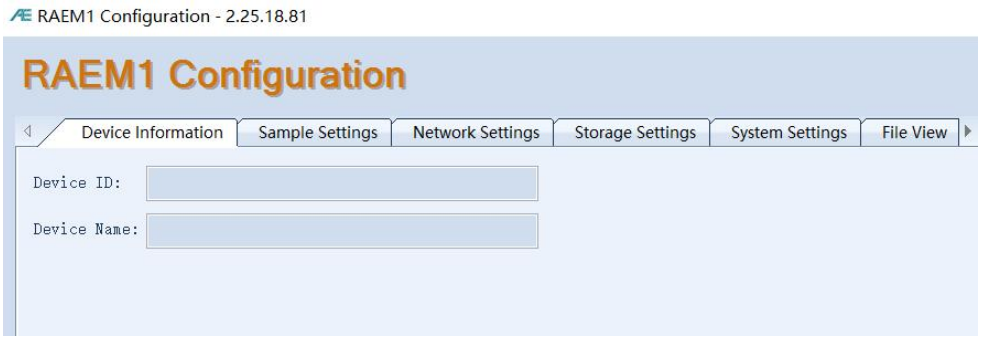


Fig. 2-4 RAEM1 Configuration Software

- **Qingcheng IoT Cloud Platform:** This is a cloud platform independently developed by Qawrums Ltd., specifically for IoT products. After logging into the Qingcheng IoT platform, you can remotely access and modify the BWM1 configuration, view parameters, waveforms, and rating data in real-time, and also remotely download data that BWM1 has uploaded to the Qingcheng IoT Cloud Platform. For detailed instructions and usage, please refer to Chapter 6.

- **SWAE Software:** SWAE Software is a professional acoustic emission analysis software. It works with the BWM1 device to allow real-time viewing and analysis of parameters and waveform data. For detailed instructions and usage, please refer to Chapter 7.

3. Installation Method

The BWM1 is a bar structure integrated with an AE sensor, AST, a built-in preamplifier circuit board and the data acquisition system and a POE model. During installation, all BWM1 can be connected in series using only POE network cables.

3.1. Method for Installation on the Steel Cable

Apply some acoustic couplants on the sensing surface of the BWM1. On the non-sensor end of the BWM1, there is a height difference between the sensing surface and the bar surface of BWM1. Use a length of some EVA double-sided or single-sided adhesive pads on the non-sensing end of BWM1. The height difference should be approximately 13mm (to level the BWM1 sensor). Place the BWM1 to the bridge cables or suspenders. Secure the BWM1 to the cable or suspender with one or two stainless-steel straps to complete the installation.

The installation diagram for a single structure is shown below:

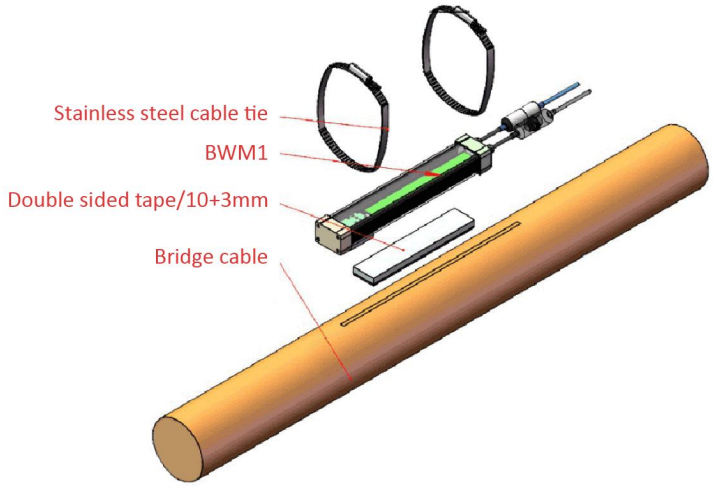


Fig. 3-1 Single Structure Installation Diagram

3.2. Overall Installation Method

Each POE power supply provides the power to a series of BWM1 devices, with a limited number of devices per series. Each series is networked through a switch, which is then connected to a router, as shown in the diagram below.

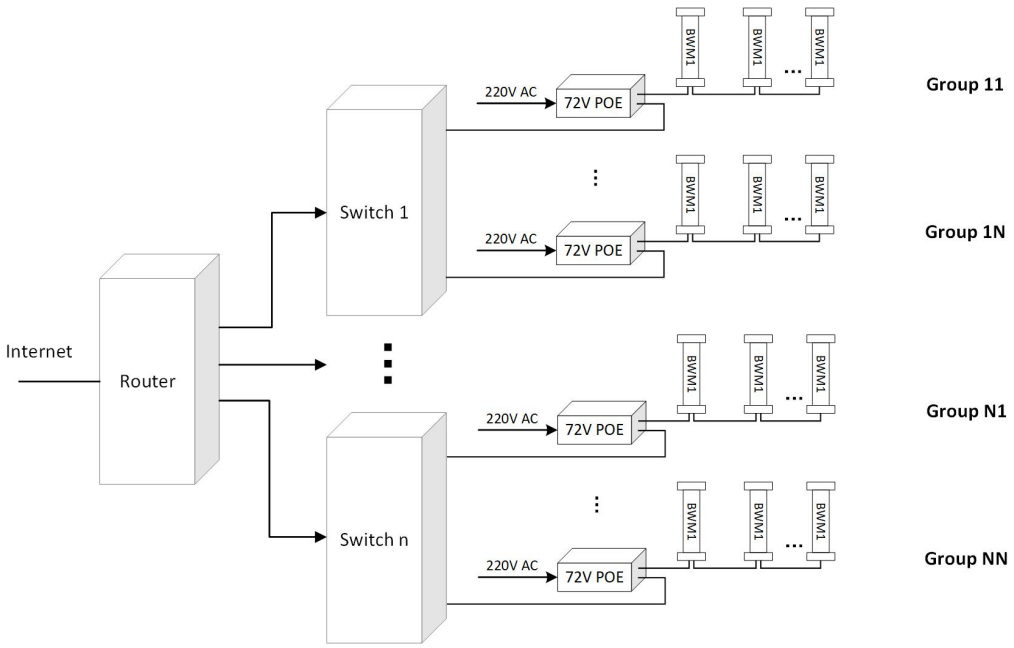


Fig. 3-2 Overall Structure Installation Diagram

4. Communication Configuration

4.1. Ethernet Connection

The computer is connected to the POE adapter's LAN port via an Ethernet cable, and the Ethernet cable from the adapter's POE port is connected to any network port on the BWM1 to enable normal operation and communication with the computer. If multiple BWM1 devices need to operate simultaneously, connect the other network port to the network port of the next BWM1 device to cascade the devices.

After the hardware is connected, the computer needs to be configured accordingly to successfully connect to the corresponding software listed in Table 4-1. You can then proceed with the corresponding operations. Refer to and follow the instructions in the relevant software chapters to connect and use the system.

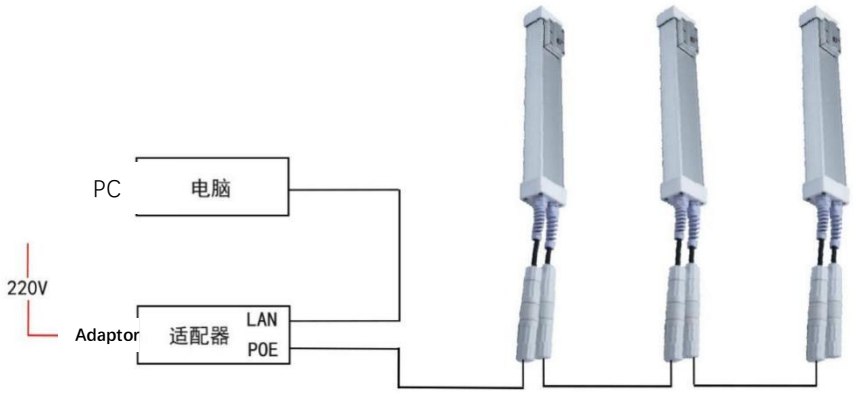


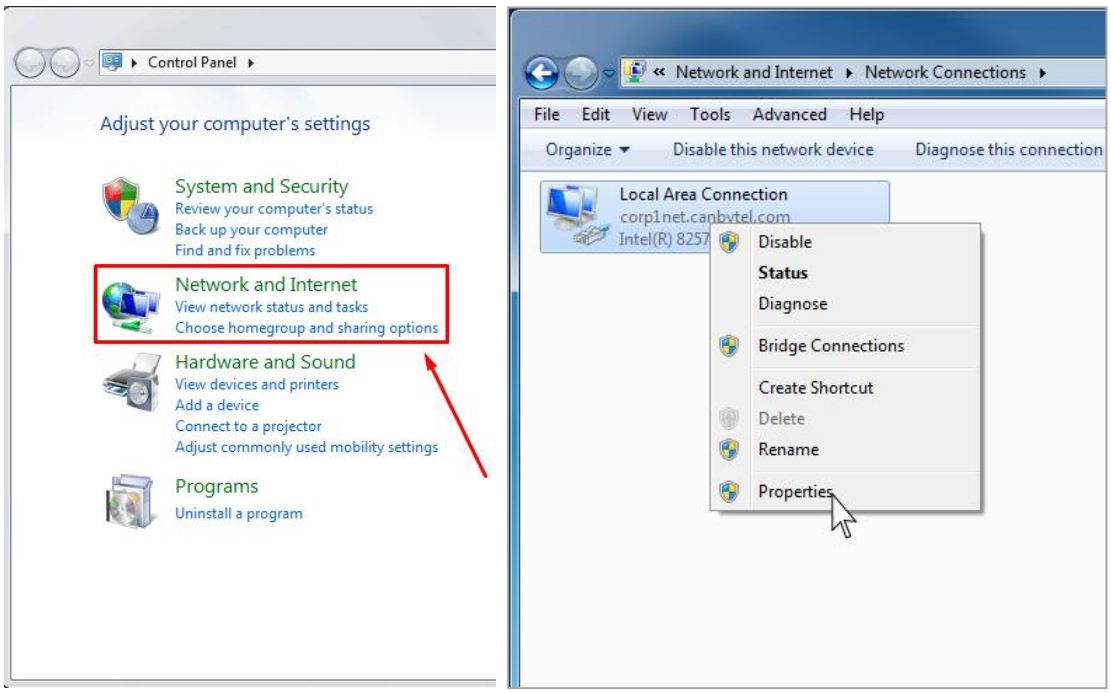
Fig. 4-1 BWM1 Ethernet Connection Diagram

Table 4-1 Ethernet Connection and corresponding software

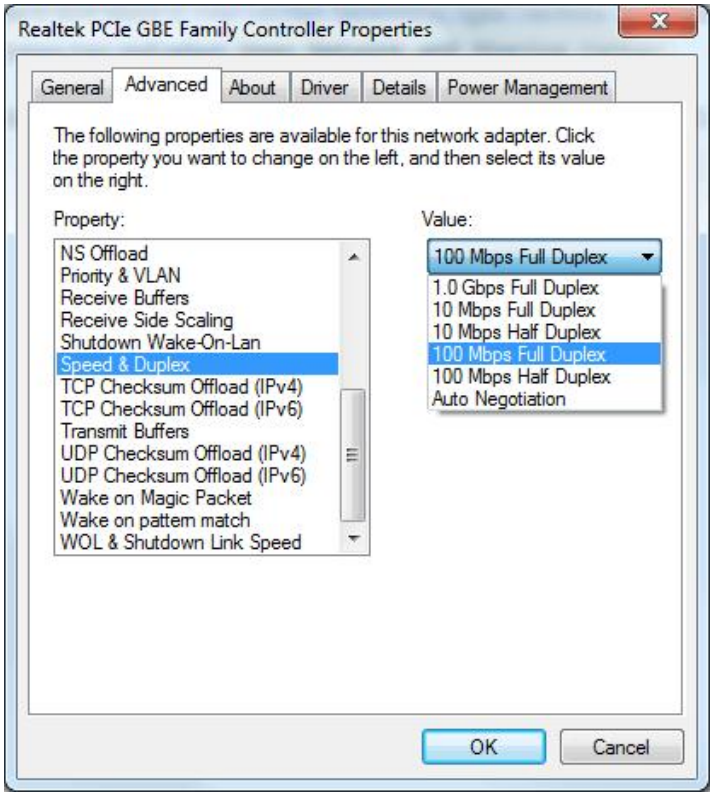
Communication	Configuration	Real-time Data View	Data Download
Ethernet	RAEM1 Configuration Software	SWAE	RAEM1 Configuration Software

The default Ethernet IP address of the BWM1 is 192.168.0.101 or 192.168.0.XXX. When connecting directly to PC but the connection fails, please follow the steps below to configure LAN attributes and then try to connect PC again:

- **Ethernet Duplex Mode:** open Control Panel >> Network and Internet>> Network Connections. Choose the local area connection. Right click and choose Properties and then choose Configure. In the Advanced Tab, choose Speed & Duplex. On the Value drop-down menu, select **100Mbps Full Duplex**. Click **OK** to confirm.



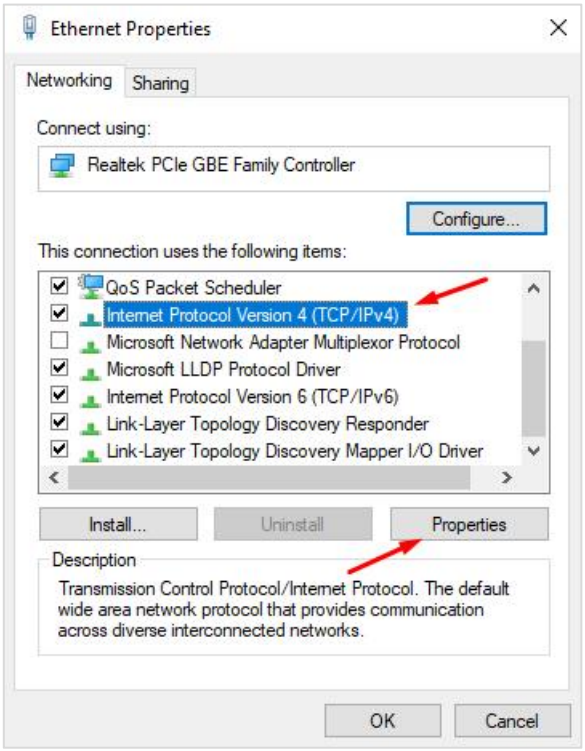
(a) (b)



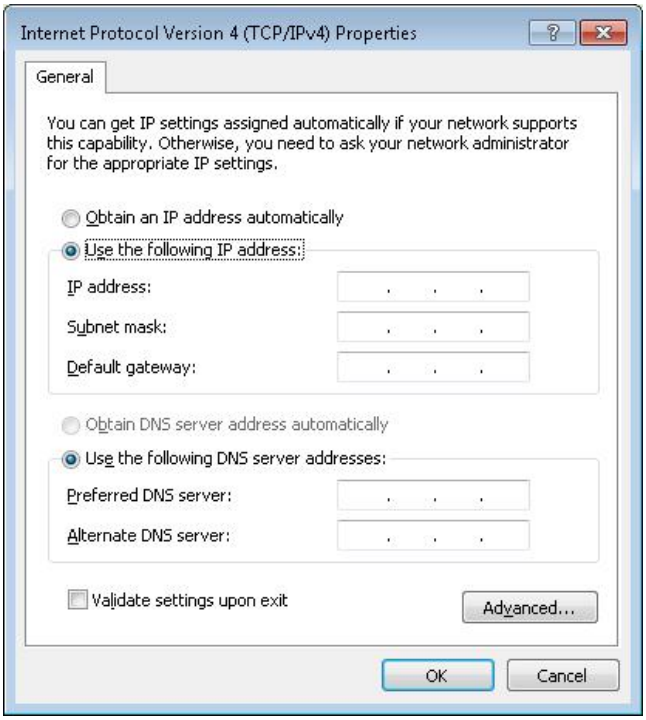
(c)

Fig. 4-2 LAN Full Duplex Mode (a/b/c)

- **Configure Ethernet IPv4:** choose Internet Protocol Version 4 (TCP/IPv4), and then click Properties. In the pop-up window, check Use the following IP address. Then enter the IP address as 192.168.0.XXX (XXX can be any digital numbers but never be the same as any BWM1's IP address). Subnet mask is 255.255.255.0. Default gateway is 192.168.0.1. Click **OK** to confirm.



(a)



(b)

Fig. 4-3 Ethernet IP Settings

4.2. Router Networking

After the BWM1 is connected to a router with external network functionality, it can access the Qingcheng IoT

Cloud Platform. This method is slightly different from the previous connection method; you only need to connect the adapter's LAN port to the router. The connection method can be referenced in the diagram below.

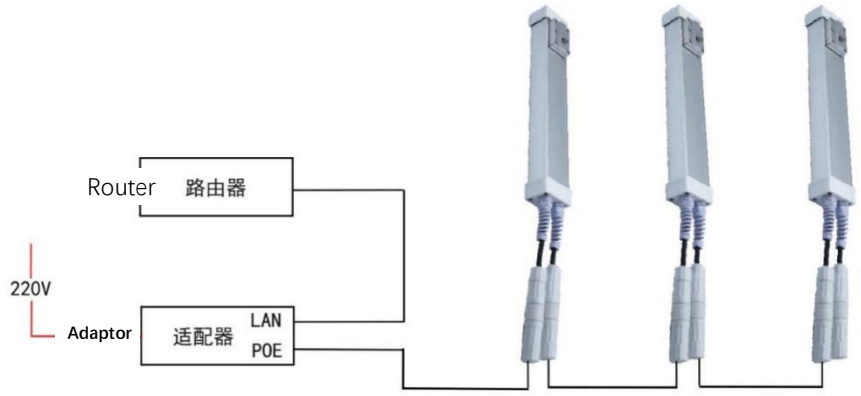


Fig. 4-4 BWM1 Connection Method for Router Networking

Table 4-2 Router Networking Communication Methods and Corresponding Software

Communication	Configuration	Real-time Data View	Data Download
Router Networking	RAEM1 Configuration Software/ Qingcheng IoT Cloud	SWAE/ Qingcheng IoT Cloud	RAEM1 Configuration Software/ Qingcheng IoT Cloud

5. RAEM1 Configuration Software

5.1. RAEM1 Configuration Software Introduction

The "RAEM1 Configuration Software" is a Windows executive program developed by Qawrums Ltd. for BWM1 configuration purpose. Users can use the software to configure BWM1 when it is operating.

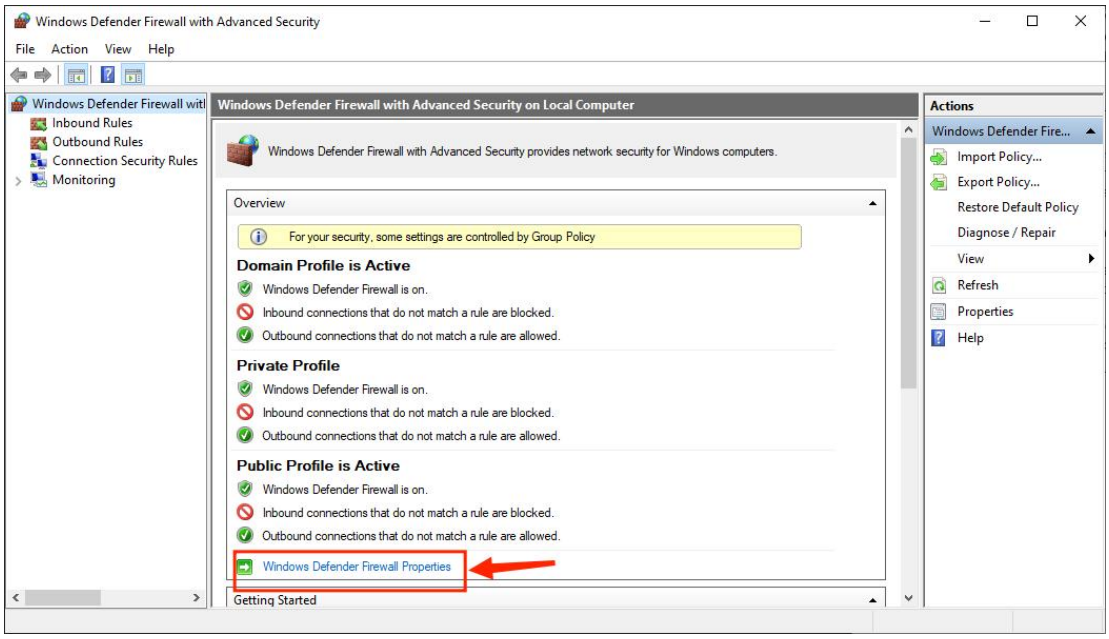
To use the "RAEM1 Configuration software", **the firewall function and the WLAN function on the computer must be turned off.** The following is to turn off the firewall.

① Open **Windows Defender Firewall with Advanced Security**.

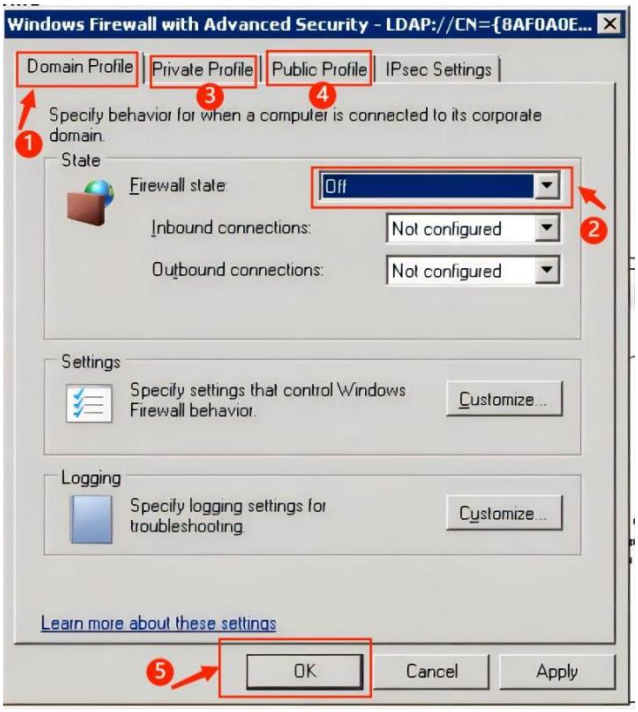
② Click **Windows Defender Firewall Properties.**

③ In the **Domain Profile** tab, change the **Firewall state** from **On** to **Off**.

④ Change the **Firewall state** to **Off** in the **Private Profile** and **Public Profile** tabs as well. Then click **OK** to take effect.



(a)



(b)

Fig. 5-1 Turn off Windows Defender Firewall (a & b)

Decompress and open the compressed *RAEM1 Configuration software* package. Double click to run the **RAEM1.exe** under the **RAEM1 Configuration x_x_x_x** folder, for example. There are 32-bit and 64-bit software (labeled with -x64) available. Choose one that works on your environment.

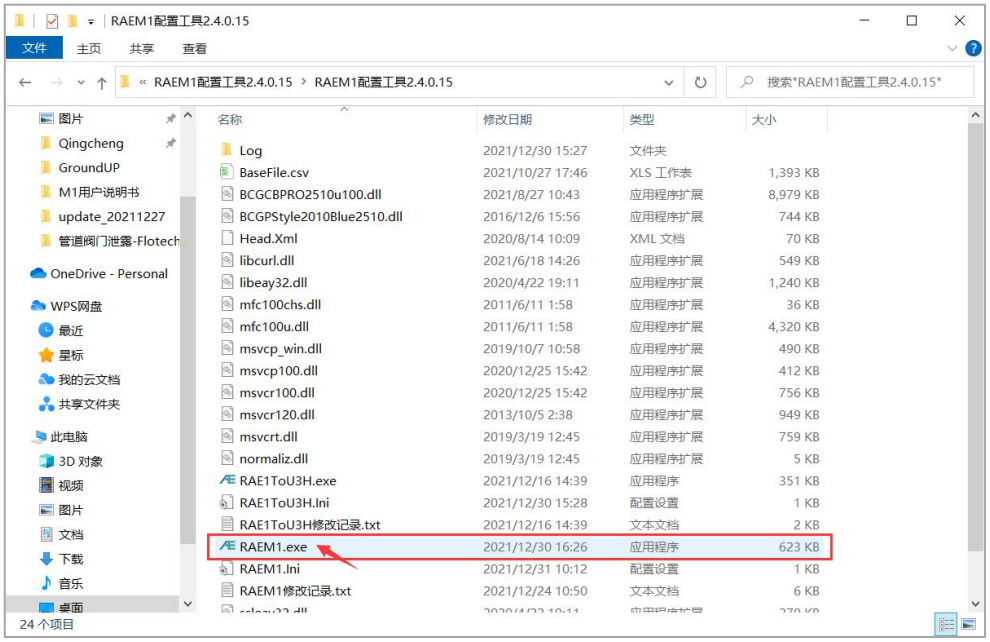


Fig. 5-2 RAEM1 Configuration software executive program location

The operation steps of *RAEM1 Configuration software* are:

① When the first time running, it might pop up a firewall warning window. It must check both the private and the public network options and then click **Allow access.**

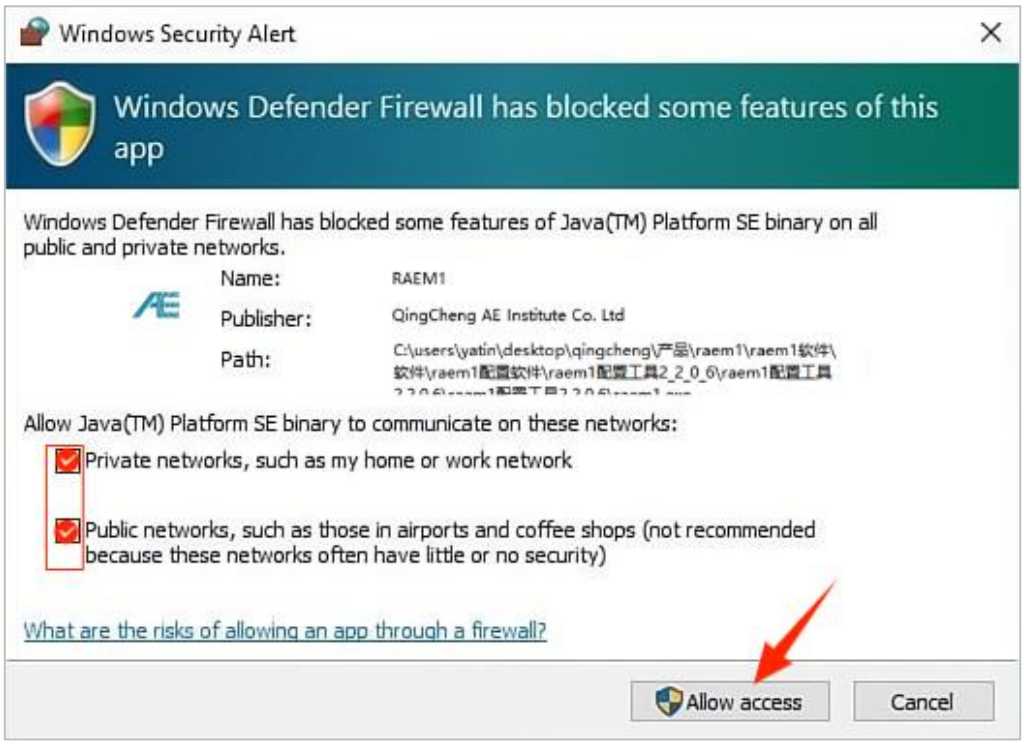


Fig. 5-3 Firewall Security Alert

② The *RAEM1 Configuration software* main interface is as shown in the figure below. It mainly consists of two big parts, the **Device Configuration Information** on the left window and the **Device List** including all the connectable devices on the right. The tabs of different pages are on top of the device configuration information window. Click on the tabs to switch to different pages. On top of the device list on the right shows the current selected device IP. All the device information on the left window is from this current IP device. The **Set Device** button on the top right corner is to send the configuration information to the selected devices. Normally once the configurations are sent to the devices, it will take effects immediately, except for some settings with the **Modify** buttons next to them. On the bottom left corner there are two buttons, **File Convert** and **Other**. In the **Device Information** page, it shows the device firmware version and the sampling status on the bottom left corner of the device information window.

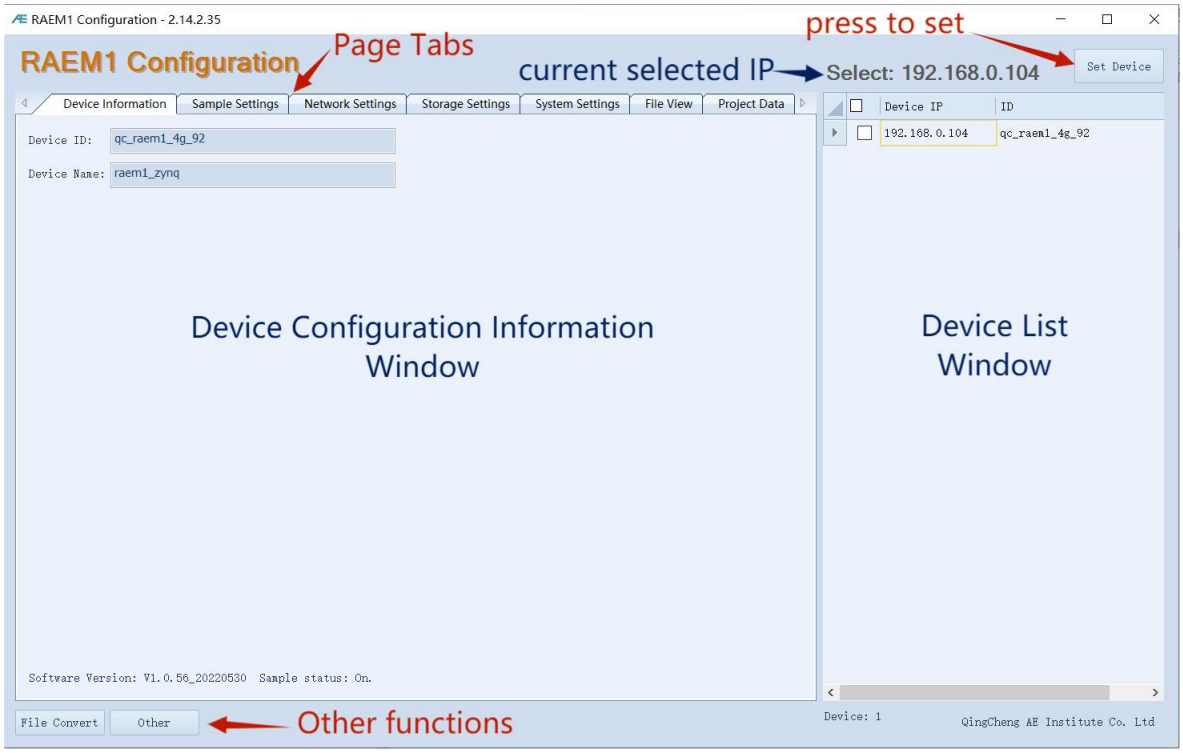


Fig. 5-4 RAEM1 Configuration Main Interface

③ The software should automatically list all the connectable BWM1 devices in the device list on the right window under the current connected network. If the device IP and ID are shown in red on the device list, it means the device is offline and its losses connection to the software currently. Follow the steps below to debug some common situations:

a. If the connection is through Ethernet cable, make sure the Ethernet cable connection and the PC configurations are correct, see Section 4.1.

b. If other connection methods are used, such as Wi-Fi Hotspot or Router mode, please check and debug the problems based on the connection methods mentioned in Section 4.2.

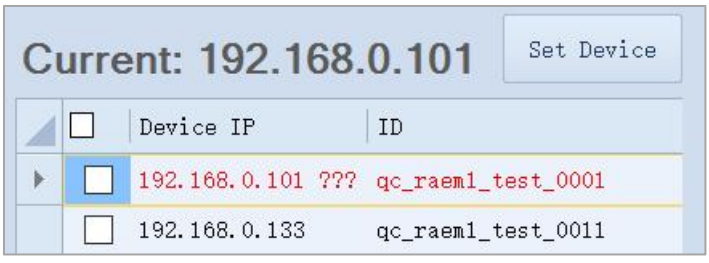


Fig. 5-5 RAEM1 Configuration Tool Device Offline

④ If you want to change the configuration settings, please first check the checkbox of the devices you want to update before modifying the settings in the left window. Click **Set Device** after modifications. Then the configuration settings will be updated to the checked BWM1s and take effects immediately. When multiple

BWM1s are selected, all the configuration settings in the left window (except for the **Device Information** page, **System Settings** page and part of the **Network Settings** page) are updated to the selected devices for batch operations.

⑤ The buttons in the **System Setting** page (see the red rectangle below) only take effects on the current selected device (see the **Current IP** on the top right corner), no matter it is checked in the checkbox or not. If you want the batch operation of those button functions to multiple BWM1s, you can right click on the device list to select the batch function in the context menu after selecting multiple BWM1s to be updated.

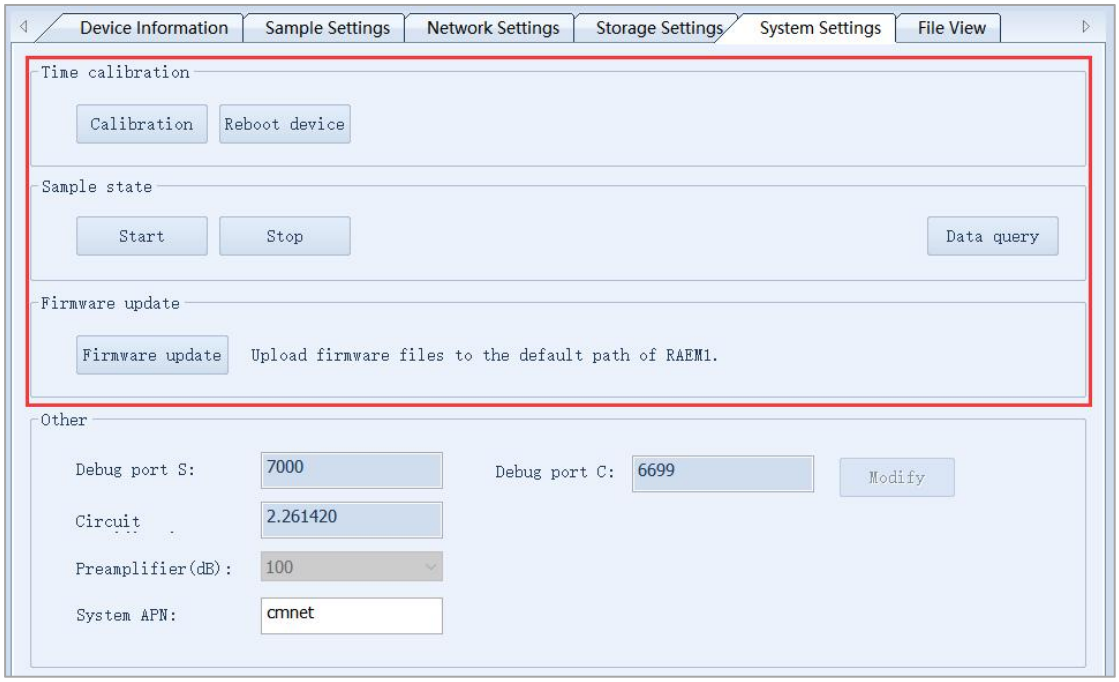


Fig. 5-6 RAEM1 Configuration Software System setting buttons.

⑥ In the device list, right click to show the context menu. The context menu is only effective on the selected devices in the list.

✧ **Start sampling**: send command to the device to require the device to start collecting.

✧ **Stop sampling**: send command to the device to stop it from collecting data.

✧ **Calibrate device time**: apply the current PC time to the device.

✧ **Reread device info**: read the device settings information again, whether it is checked or not.

✧ **Reboot device**: make the device restart.

✧ **Firmware file upload**: used to update the device firmware. It can choose one or multiple files at the same

time (maximum 20 files at a time).

✧ **AST check**: this function is exclusive for BWM1 and some types of RAEM1 series. It requires two sensors for Auto Sensor Test (AST) check. The device sends out the excitation signal to the transmitter sensor to generate the acoustic waves and the receiver sensor collects the acoustic signals. Based on the receiving signals, it can test out how the sensor sensitivity and coupling status.

✧ **Enter sleep mode**: by enabling the sleep mode, it stops acquisition, transmission, and communication to save power. But be careful with this function because it may require some efforts to wake up the device.

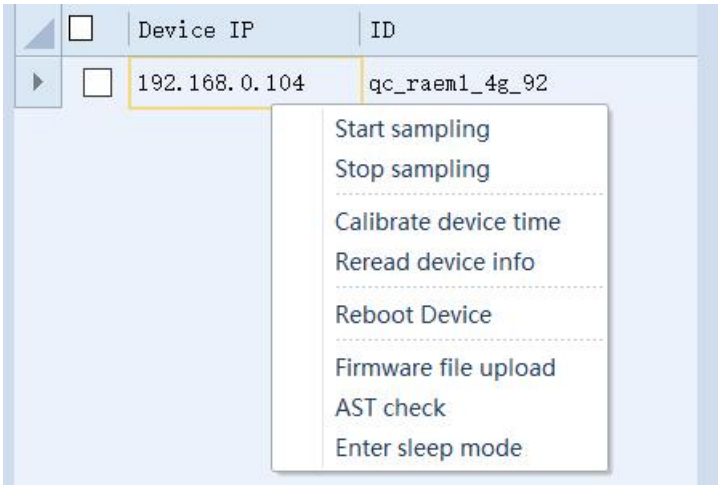


Fig. 5-7 RAEM1 Configuration Software context menu

⑦ In the **Network Settings** page, the **Modify** button is only to modify the current selected device's configurations, for example **Ethernet IP address**, and **Master/Slave** settings. After changing the values in those frames, click **Modify** buttons to pop out the window. Click the **Setup** button to send the device. No need to click **Set Device** button after.

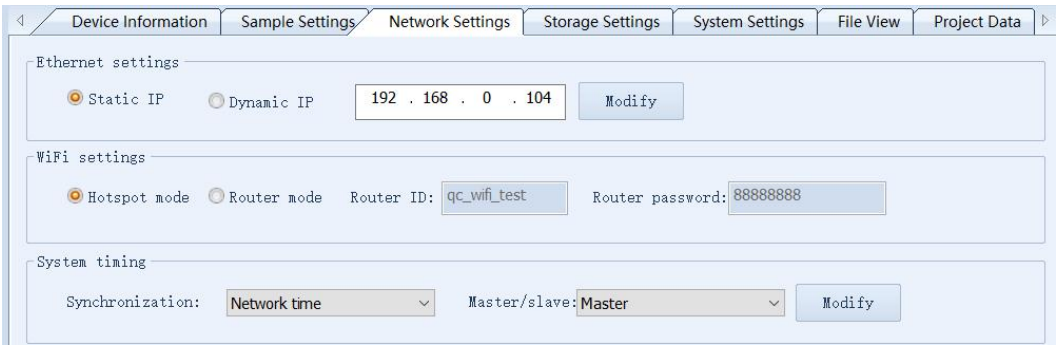


Fig. 5-8 RAEM1 Configuration Software **Modify** button.

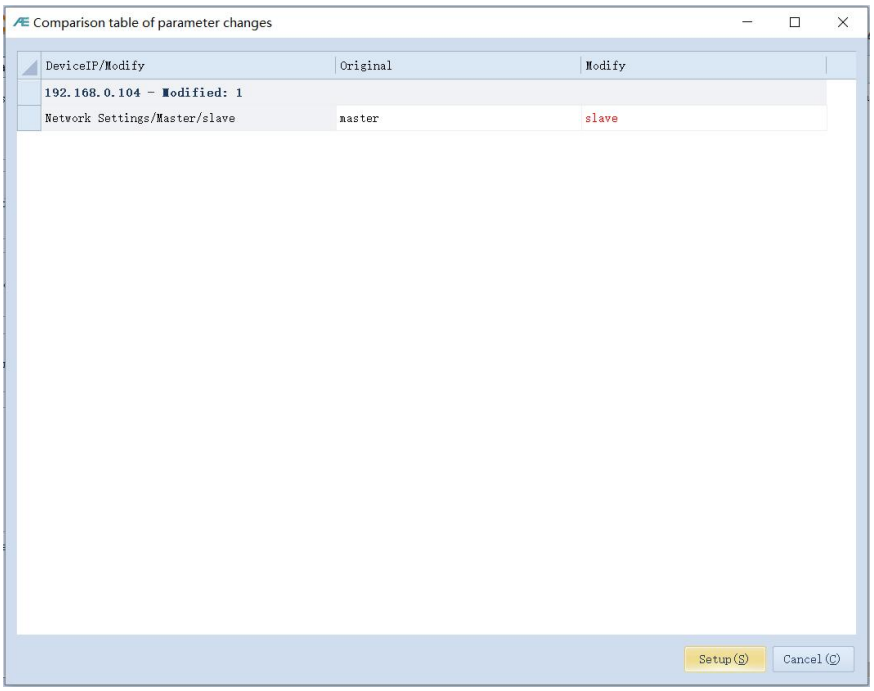


Fig. 5-9 RAEM1 Configuration Software **Modify** Confirmation window.

⑧ There are two buttons on the bottom left corner of the interface:

✧ **File Convert**: opens the **RAE1ToU3H.exe** program which converts the downloaded RAEM1 data packages to U3H format (.PRA & .AED) or CSV format. Please see **Section 9** for more detail.

✧ **Other**: there are a few options, one is to save the configurations as a file in the PC; the other option is to read the configuration file from the PC. It also can change the display languages, between Chinese and English. After selecting the language, it needs to click the **Reboot** button at the bottom to take effect. The software will restart and update the display language.

The following is the introduction of "RAEM1 Configuration Software" functions.

5.2. Sample Settings

5.2.1. Sample Parameters Settings

➢ **Sample length**: the length of each sample, in unit of points. It means the length of each waveform that can be recorded and stored. For example, if it is set to 4000, that means each waveform only records and stores the first 4000 points. This setting is only effective to **Time Parameters** mode, not for **Hit Extract**

mode.

- **Sample speed**: maximum speed is 2000K/s. The value means the maximum collectable points per second in the current channel during the AE signal collection. The higher the set value is, the higher the sample resolution is, but also the bigger the data size is. The recommended value is about 10 times the upper limit of the concerned frequency domain. For example, if it is set to 1000, it means it can sample 1000k points per second at its maximum.
- **Threshold**: system signal triggered threshold, in unit of dB. It is suitable for the burst AE signal acquisition. It is the voltage level that determines when the AE waveform signal should start to be recorded. When the channel is in standby state and the voltage level exceeds the set value, it triggers to start recording. If it is in **Time Parameters** mode, its end time is decided by the **Sample length**. But if it is in **Hit Extract** mode, its end time is decided by **HDT**. According to the AE system application environment settings, it is normally a few dB higher than the background noise. The set range is 1~100dB (integer). 40dB is the normal threshold in engineering.

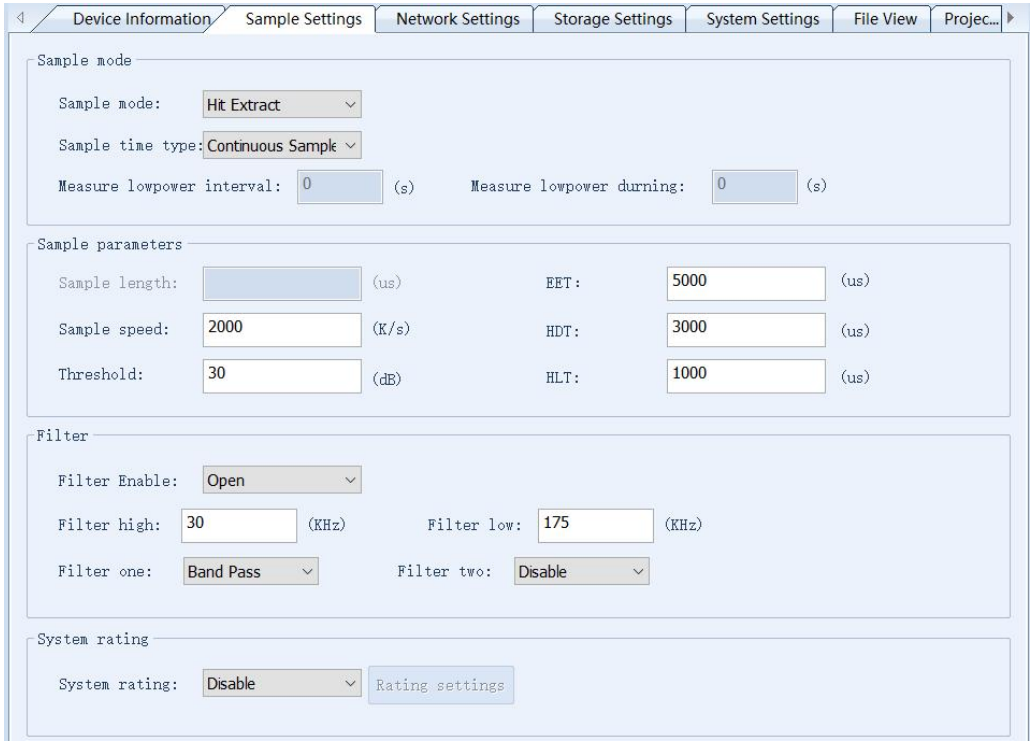


Fig. 5-10 RAEM1 Configuration software Sample Settings page

- **EET**: enforced end time, in unit of micro-second (μs). It ranges from 1 ~ 50000μs. When the AE hit is continuously higher than the threshold value, and the set HDT cannot define the end of the AE signal, the EET takes effect which means it is the duration of the current hit and other related AE feature parameters are

calculated based on this duration. EET is effective only in Hit Extract sample mode, not in Time parameter sample mode.

- **HDT**: Hit definition time, also known as the envelop definition time, in unit of micro-second (μs). the setting range is 100 ~ 50000us (positive integer), can be directly input in the text box. It refers to the waiting time interval of a hit signal to correctly determine the end point of that hit signal. When the set HDT value is greater than the time interval T between two adjacent wave packets that exceed the threshold, the two wave packets will be classified as one acoustic emission hit signal; if the set HDT value is less than the time interval T when the two wave packets cross the threshold, the two wave packets are divided into two acoustic emission hit signals. For the same signal, the greater the HDT is, the fewer the AE parameters are extracted, while the smaller the HDT is, the more AE parameters are extracted. HDT is only effective in **Hit Extract** mode, but not **Time Parameters** mode.

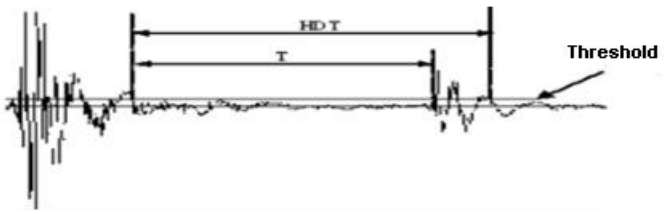


Fig. 5-11 HDT definition diagram

- **HLT**: Hit lock time, in unit of micro-second (us). The setting range is 1 ~ 20,000,000 (positive integer), can be directly input in the text box. To avoid receiving the reflected waves or late waves, HLT is the set time window for closing the measurement circuit. At the end of the current acoustic emission event after a HDT time, there is a period (HLT) that the signal will be ignored. This window is called hit lock time. The value is affected by the signal attenuation, structure size, etc. If the setting value is too big, the subsequent AE signal will be missed. As shown in the figure below, the next AE signal T period has passed the threshold, but the HLT has not finished, so the signal in T period will not be collected. HLT is only effective in **Hit Extract** mode, but not **Time Parameters** mode.

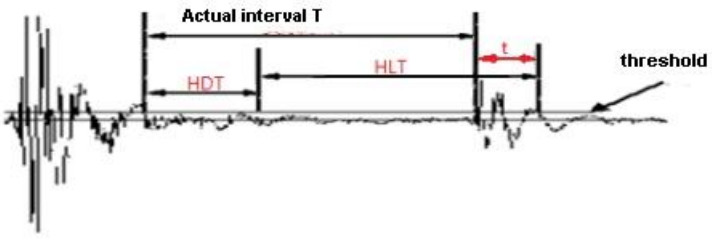


Fig. 5-12 HLT definition diagram

5.2.2. Sample Mode

There are 2 sample modes, Hit Extract mode and Time Parameters mode. The default mode is Hit Extract mode.

- **Hit Extract mode:** also known as Envelop Extract mode. An effective AE hit event is defined by threshold, HDT, HLT and EET and the shape of the hit signal is like the envelop. The HIT event is extracted and sampled based on the set threshold, EET, HDT and HLT.

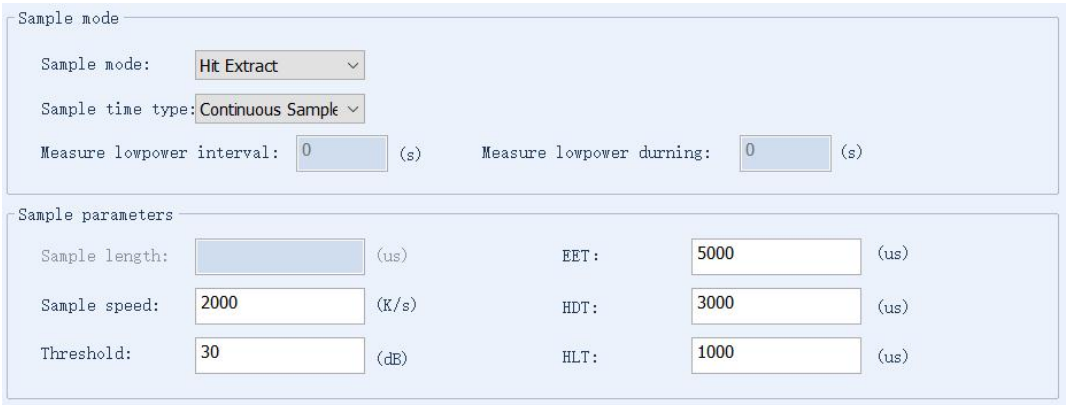


Fig. 5-13 Sample Mode - Hit Extract Mode

- **Time Parameters Mode:** The AE signals are continuously over the threshold, or it is the continuous AE signals. Then the Time Parameter mode defines each AE hit event and calculates the AE parameter values based on the sample length (in unit of us), sample times and the sample intervals.

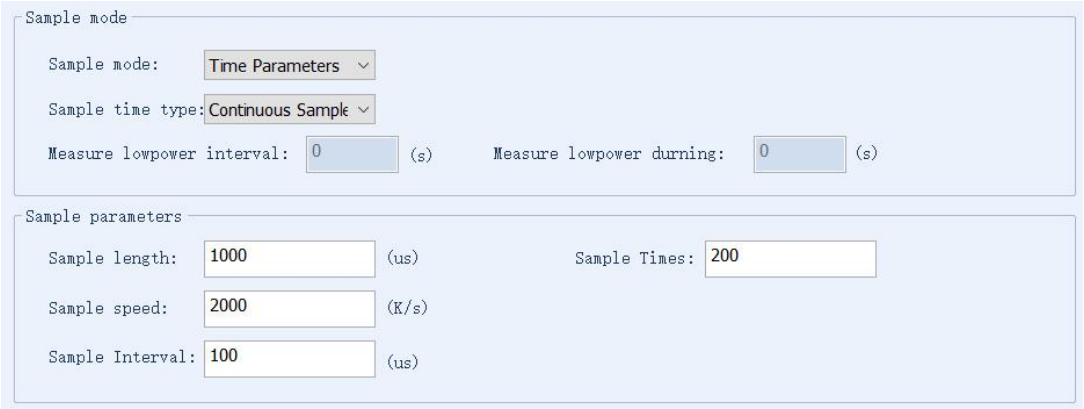


Fig. 5-14 Sample Mode - Time Parameters Mode

There are also 3 types of sample time modes, **continuous sampling**, **timing sampling** and **interval sampling**, respectively. The sample time mode decides when it starts sampling and how long it lasts for. The default timing mode is continuous sampling time.

- **Continuous Sample**: when there is a trigger signal inputs, it will start to sample since.

- **Timing Sample**: it can be set to sample data for a certain period in a specific date, accurate to the seconds. The interface is shown below.

Fig. 5-15 Hit Extract Mode - Timing Sample

Click **Timing setting** to add acquisition time periods:

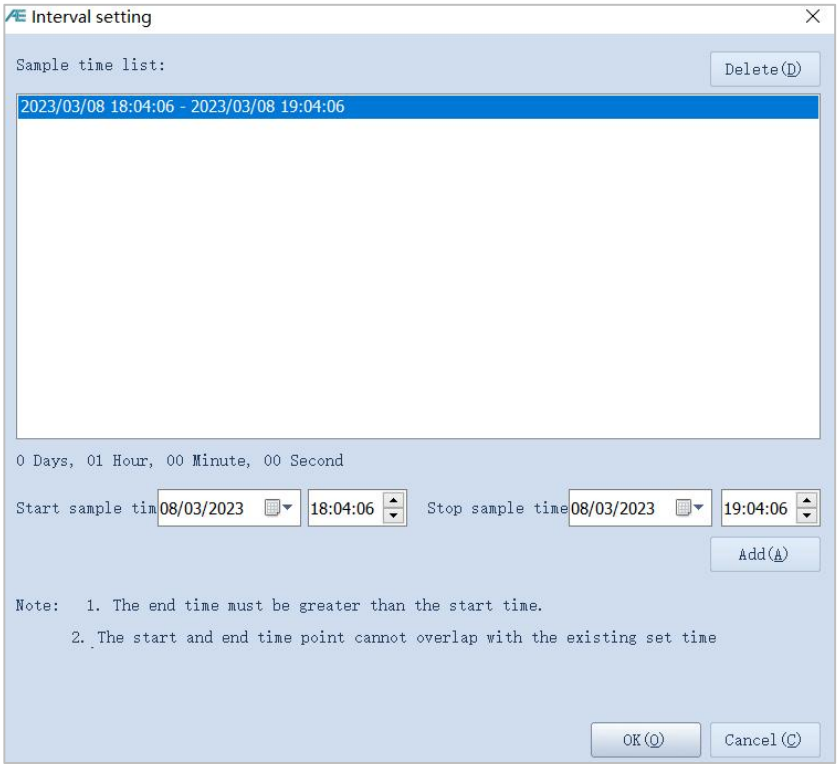


Fig. 5-16 Timing Sample settings page

- **Interval Sample**: it can set the sample intervals and the sample period duration.

Fig. 5-17 Interval Sample settings

- Sample duration: how long each sampling period lasts for, in unit of seconds. The minimum duration is 5 seconds, no upper limit.
- Interval duration: how long the intervals are between the sampling periods, in units of seconds. The

minimum duration is 5 seconds, no upper limit.

5.2.3. Filter

The filters in the software are the digital filters.

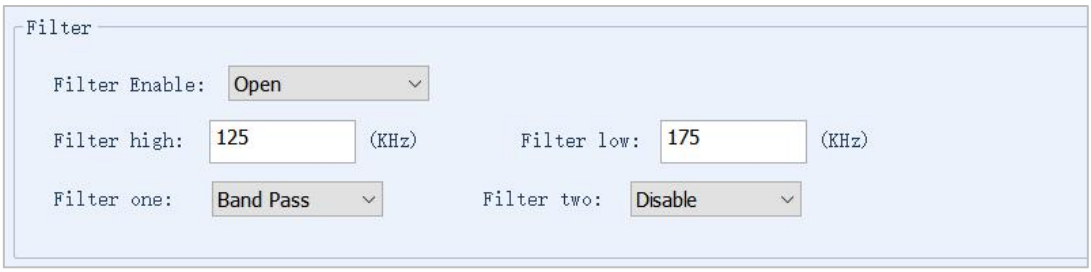
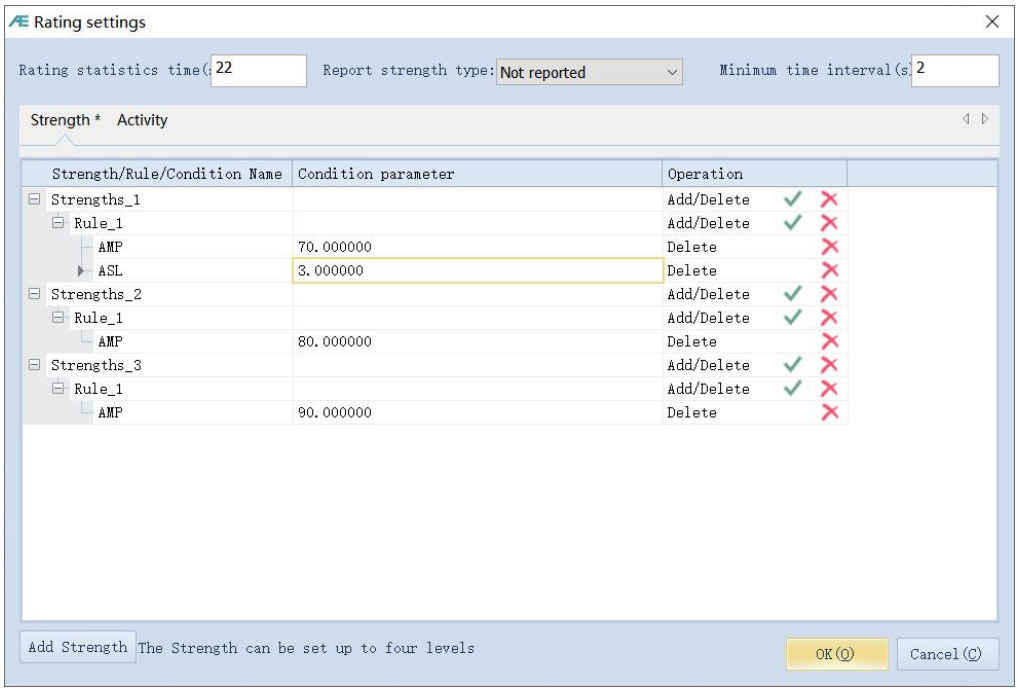


Fig. 5-18 Filer settings

5.2.4. System Ratings

System rating allows users to set different strength, activity, and rating rules based on their needs. The parameters collected will be classified into different levels according to the rating settings. Users can determine the next steps based on the result levels.

There are 9 rating parameters: hits, duration, rise time, rise count, ring count, amplitude, ASL, RMS, and energy. After establishing the rating rules, a final rating result for the period is determined based on the magnitude (strength) and frequency (activity) of the collected parameter values compared to the set rules.



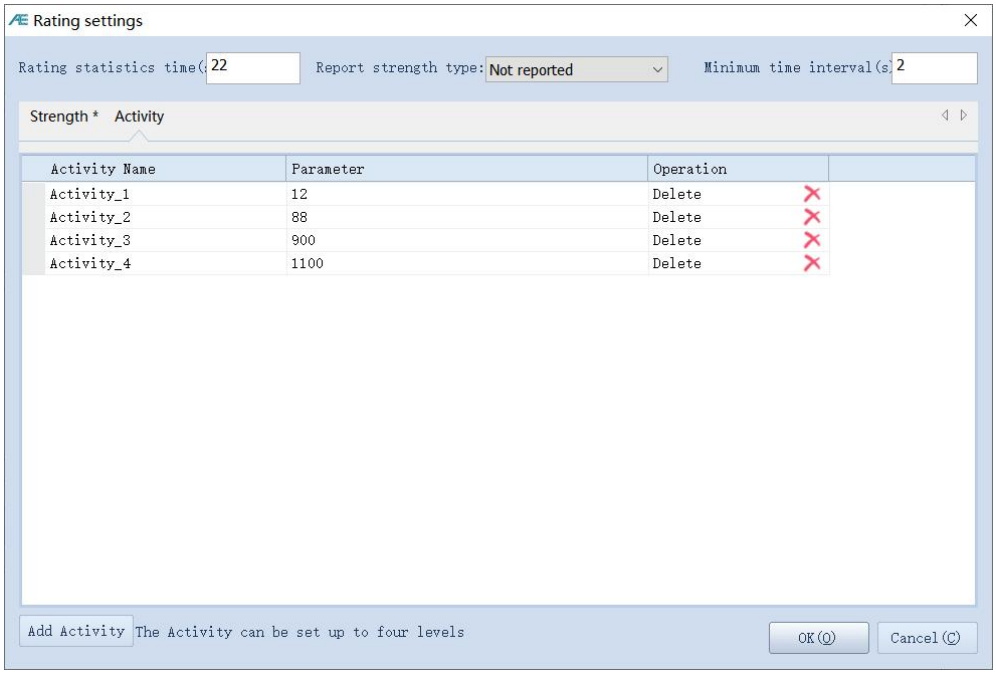


Fig. 5-19 System rating setting page

5.3. Network Settings

5.3.1. Ethernet Settings

The Ethernet can be set as static IP or dynamic IP. It can be achieved by using the RAEM1 Configuration Software.

- **Static IP**: the IP address in the text-box will be used as the device Ethernet target IP address.

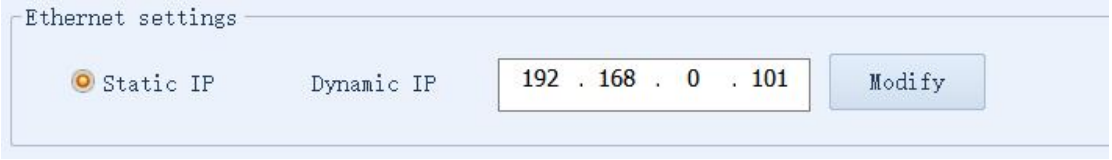


Fig. 5-20 Ethernet IP settings

The default setting is static IP, 192.168.0.101. That means when the computer is set to 192.168.0.xxx, but not the same as the device IP, for example setting as 192.168.0.20, it can connect to the device.

- **Dynamic IP**: it is normally used when the device is connected to a router and let the router assign the IP addresses to the devices. In the device scan list window of "RAEM1 Configuration Software", it lists all the connectable BWM1s that connects to the desired routers. If the device IP has changed from the static IP, it will appear in the device list again with a new device IP and it can be found by identifying the device name/ID in the scan list.

5.3.2. System Timing

System timing means the BWM1 clock synchronization method. It depends on the device hardware connection and communication methods.

- **Network time**: means to synchronize the clock with the network base time.
- **Local wired time sync.**: includes Ethernet. Local timing is that among the connected BWM1s in the local network, one BWM1 is chosen to be the master and others are the slaves to be synchronized with the master clock.
- **Wireless time sync.**: it is not available for BWM1.
- **Master/Slave**: choose to be the master or slave of the clock.

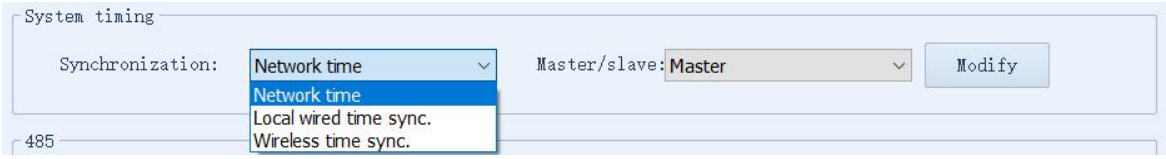


Fig. 5-21 System timing

5.4. Storage Settings

❖ Data storage:

➢ **Save Wave:** whether to save the waveform to the local storage card or not. If disabled, it will not save the waveform data. It is disabled by default.

➢ **Save Param:** whether to save the parameters to the local storage card or not. If disabled, it will not save the parameters. It is disabled by default.

Note:

1. ***The data storage mentioned above only means to the local memory card storage. When it is disabled, the data can still be uploaded to the Alibaba Cloud server/ TCP server/ SWAE software. It is just NOT stored in the local SD card, as well as NOT uploading to the Qingcheng IoT Cloud or AWS.***
2. ***The data will be packed as a zip file every 5 seconds when there are HITs. But no data packs if there are no HITs during the time.***

❖ **U3H Server:**

➢ **Send U3H:** whether to send the real-time data to the SWAE software. It is disabled by default.

➢ **Send Wave:** whether to send the waveform to the SWAE software. It is disabled by default.

➢ **Send Param:** whether to send the parameters to the SWAE software. It is disabled by default.

- **Address type:** the target PC address type. It can be auto, or user defined (Use IP). Auto type is the factory setup for testing. It means the PC address is already setup for factory settings and requires no manual input. But it is suggested to choose "Enter IP" always. Find the IP address of the PC that uses SWAE software and enter the IP address to the address textbox.
- **Address:** If Use IP is selected, it needs to enter the target PC address here.
- **Port:** can be configured. The default is 18883.

5.5. System Settings

5.5.1. Time Calibration

If the time stamp of the data package is incorrect, you can click **System Settings** page >> **Time Calibration** >> **Calibration** button to calibrate the selected BWM1's clock with the system clock of the computer. After calibration, the device may stop sampling data. In that case, click **Start** button below to restart sampling.

Reboot device button reboots the selected BWM1. **Rebooting takes some time, and it must NOT be interrupted or turned off during the rebooting. After reboots, it cannot be connected and controlled until the BWM1 restarts completely and the RUN light flashes again.**

5.5.2. Sample State

- **Start**: sends start acquisition command to the selected device and the device starts data acquisition immediately after clicking this button. By default, the device starts acquisition automatically after powering up.
- **Stop**: requests the device to stop data acquisition.
- **Data query**: click to enter the **Real time data** page where there are data reported in every second. Please note that the data is logged in every second randomly to test if the connection is normal.

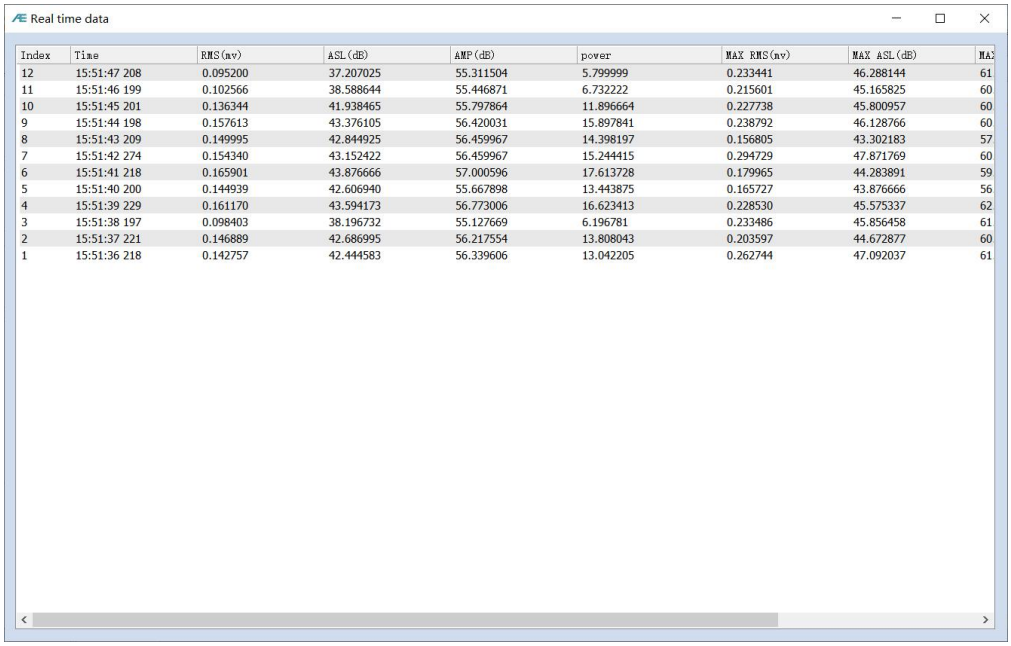


Fig. 5-22 Real time data page

5.5.3. Firmware Update

There are two files to update the firmware:

- update.zip
- md5sum.txt

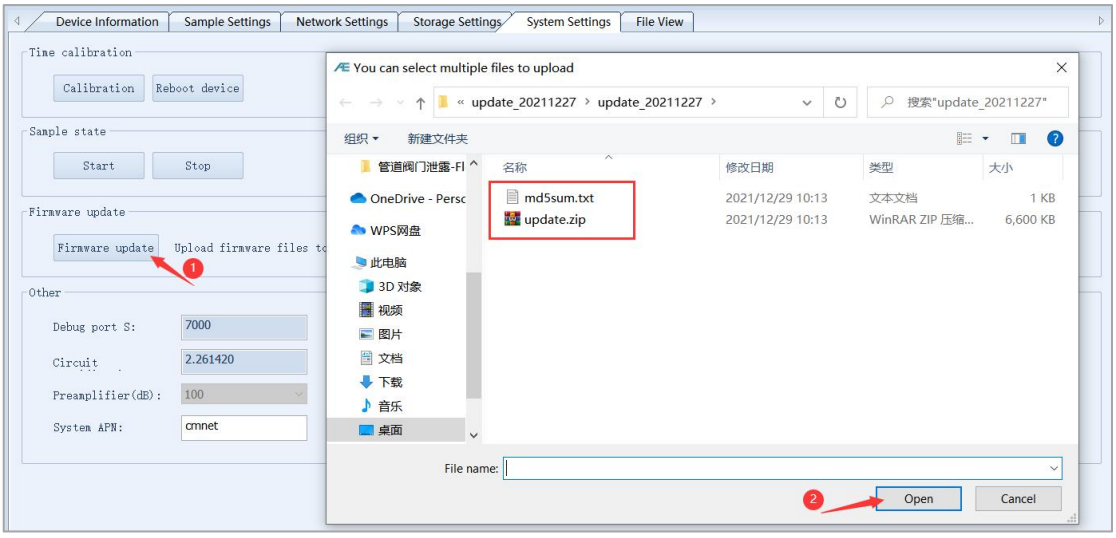


Fig. 5-23 Firmware update

Click **Firmware update** button to upload **update.zip** and **md5sum.txt** files in order. **After uploading the files, the system will update automatically followed by rebooting**. Please don't interrupt the process by disconnecting

the power or manual restart during the process.

It also supports multiple files for uploading. You can choose both files to upload at the same time.

5.5.4. Other

There are other information including: debug ports, circuit magnification, preamplifier, and system APN. Except for network APN, the other settings cannot be configured because they are for internal debugging and factory settings.

5.6. File View

Click **File View** tab to view the selected device's data packages stored in local storage card.

The files in the list can be downloaded, deleted, converted to CSV or U3H format, by clicking the right button of the mouse. The functions are:

- **Download selected files**: download the selected files. If the files are not selected, it will not be downloaded.
- **Download all files**: download all the files in the list.
- **Delete selected files**: delete the selected files. It would not delete the files if they were not selected.
- **Delete all files**: delete all the files in the list.
- **Covert to CSV format**: convert the selected files into CSV format. Each zip file converts into one CSV file. But if the data number is more than 830,000, it will be saved as multiple CSV files.
- **Merge multiple files and convert to CSV format**: merge and convert multiple selected files into one CSV file if it is possible. But if the number of data is more than 830,000, it will be saved into multiple CSV files.
- **Convert to U3H forma**t: convert the selected files into U3H format (. PRA &. AED). Each file is converted and saved as one U3H format file. If multiple files are selected, there are multiple U3H format files.
- **Merge multiple files and convert to U3H format**: convert the multiple selected files into one U3H format file. If all the files are wanted to be converted, press **Ctrl + A** to select all files and then select this function.
- **U3H conversion settings**: set the sample rate and sample length. Please note that the sample length means

the waveform length of U3H format after conversion, which is different from the sample length in "RAEM1 Configuration Software". The value should be equal to or greater than 1000, equal to or less than 100000.

- **Refresh file list**: If the file list is refreshing, the functions mentioned above will not be available.

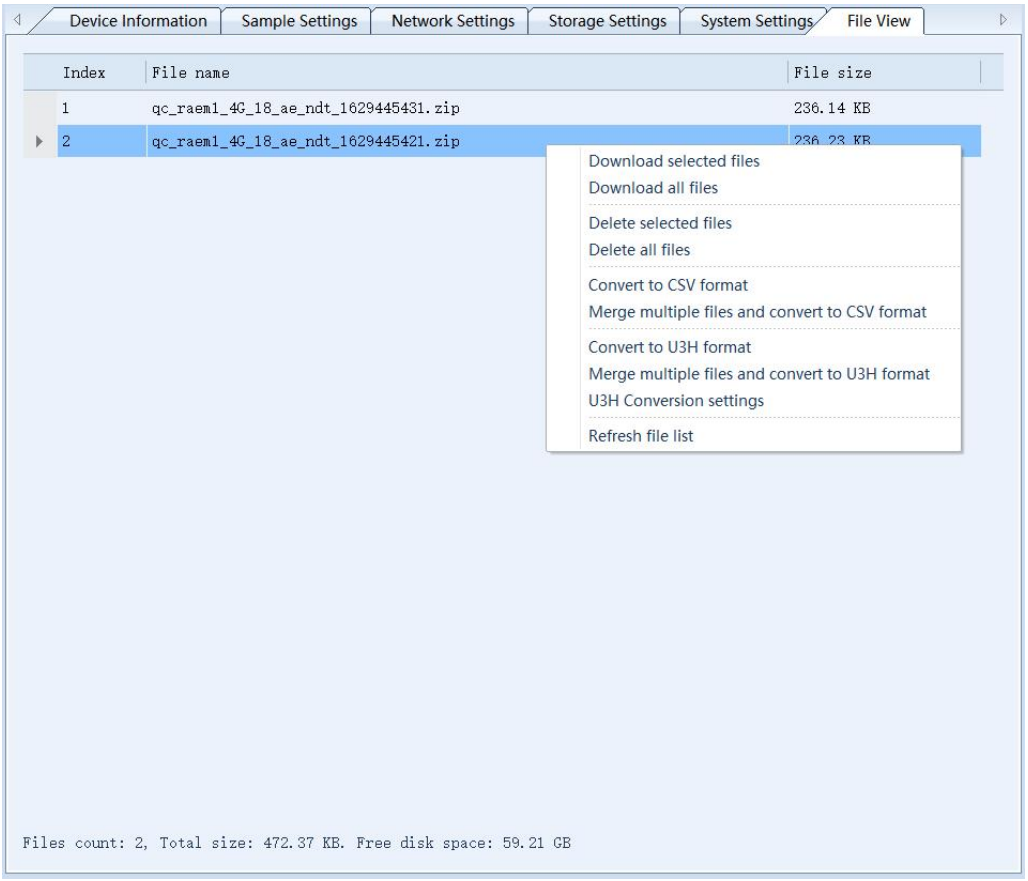


Fig. 5-24 File View

Press **Ctrl + A** to select all files. When using the mouse to drag and select multiple files, please make sure the mouse is in the file name column, not the empty column of the list.

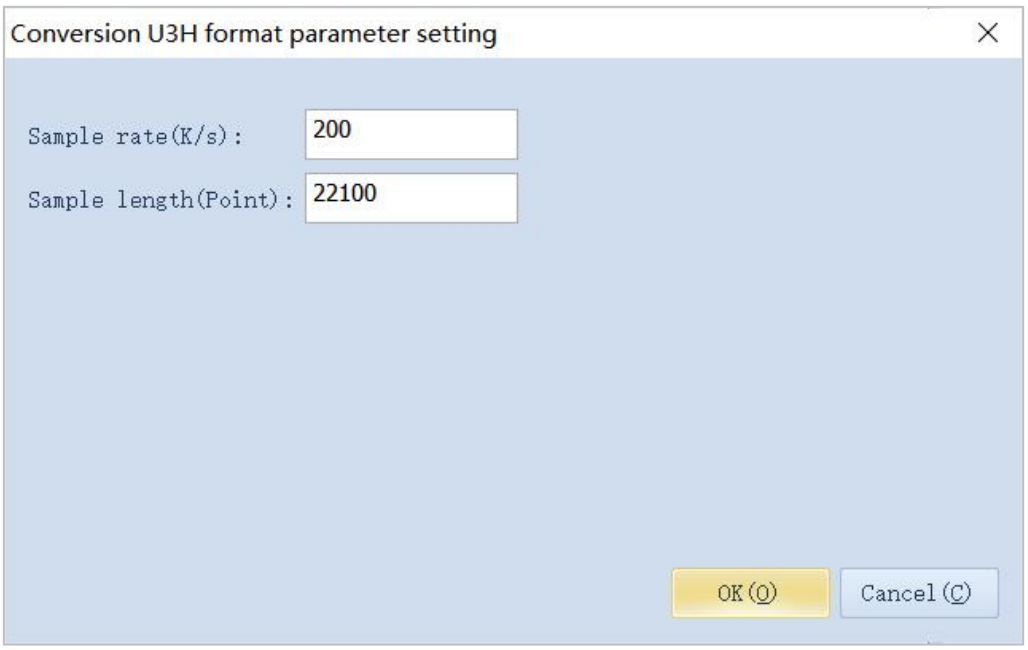


Fig. 5-25 U3H format conversion settings

5.7. Project Data

This section is designed for special projects in terms of the special data transmission methods or prototypes. There are TCP modes, QC Aliyun mode (Alibaba Cloud transmission) and other specific projects. Only TCP modes is introduced below.

- **Data reporting mode**: There are a few types of data reporting modes to servers, such as TCP mode, TCP mode v2, QC Aliyun mode and other specific server modes (specific server modes will not be introduced in the manual because they are designed just for the certain projects). Based on the selected report modes, it shows the server IP address and port, or the Aliyun key and Aliyun secret below. **(Note: After changing the reporting mode, restart the device for the setting to take effect.)**
- **Report interval**: the time interval between the two data reporting time. During this interval, it chooses the group of data with the maximum amplitude to report. The default report interval is 1000ms, i.e., 1s. The minimum interval is 200ms.

5.7.1. TCP Mode and TCP Mode V2

The TCP modes in the **Project Data** are defined TCP protocols by Qingcheng. The reported data stream is reporting with time intervals. For example, the reporting interval is 60000 ms by default. It means for every 60

seconds, the device will report one stream of data to the server using the TCP protocol and the data is the AE parameters of a single AE Hit with the maximum amplitude. All the other AE hits during that time are not reported. If all the AE hits data are wanted, please refer to Section 7 using the SWAE software or Section 8.

When it is configured to be TCP mode or TCP mode v2, it needs to configure the server address and the server port. The reporting interval is in unit of ms. The minimum of the reporting interval is 200.

TCP mode v2 is an additional version based on the TCP mode with more parameter types for communication supported. To be compatible with the older version of TCP mode, v2 is added as the new TCP mode name.

Table 5-1 TCP Mode setup

Protocol	Qty.	Parameters
TCP mode	4	Amplitude, ASL, power, RMS
TCP mode v2	9	Arrival time, AMP, Power, RMS, ASL, Rise time, Rise counts, Duration, Counts

Fig. 5-26 TCP Mode setup

The related TCP protocol is introduced in **Section 10**. Please contact Qingcheng company for more detail about the latest TCP protocol.

Under the TCP mode or TCP mode v2, if the server has background program, it can receive the corresponding data. Under TCP mode, 4 parameter data can be received, while in TCP mode v2, 9 parameter data can be received.

The TCP mode server test code as follow:

```python
import socket
import datetime
HOST = '192.168.0.30'
PORT = 18883
s = socket.socket(socket.AF_INET,socket.SOCK_STREAM)
s.setsockopt(socket.SOL_SOCKET,socket.SO_REUSEADDR,1)
s.bind((HOST,PORT))
s.listen(1)

while 1:
    print("get IP",datetime.datetime.now())
    (conn,addr) = s.accept()
    print('Connected by',addr)
    while 1:
        print("get Data",datetime.datetime.now())
        data = conn.recv(2048)
        print(data)
        print("\n")
conn.close()
```

Fig. 5-27 TCP mode test code

The context that the server receives is:

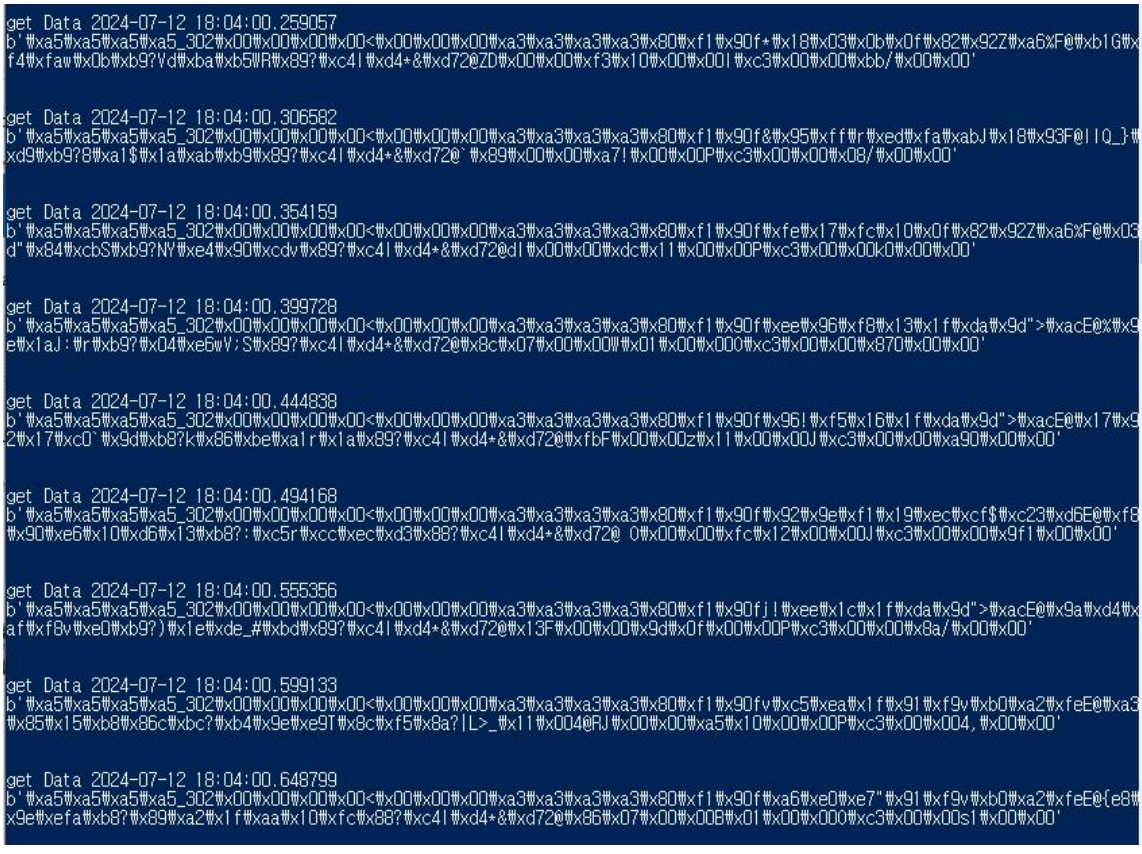


Fig. 5-28 TCP mode server receiving data

TCP Mode (not "TCP Mode v2") outputs 4 AE characteristic parameters, including amplitude, ASL, Power and RMS. The format of the output data is: device ID + amplitude + ASL + Power + RMS + timestamp, separated by comma.

```
qc_raem1_test_0001,36.390879,192.656167,4611614559298.000000,26844156.844411,162217050397547
qc_raem1_test_0001,43.579539,192.658916,4611679381904.000000,26844345.509581,1622170503113346
```

"TCP Mode v2" outputs 9 AE characteristic parameters, including amplitude, ASL, Power, RMS, Rise time, Rise ring-down counts, Ring-down counts, Duration, report time. The format of the output data is: device ID + amplitude + ASL + Power + RMS + Rise time + Rise ring-down counts + Ring-down counts + Duration + report time, separated by comma.

```
qc_raem1_4g_89,38.740266,17.501490,0.067384,0.025052,125,10,10,125,1694746199.984745
qc_raem1_4g_89,39.300841,15.917865,0.057709,0.023184,502,86,106,654,1694746201.99322
```

Note: When choosing "TCP v2" mode, the server IP address cannot be the same as the IP address of the computer/server for SWAE software.

5.7.2. QC Cloud Connection

Send parameter: After ticking, you can send parameter data to Qingcheng Cloud platform.

Send wave: After ticking, you can send waveform data to Qingcheng Cloud platform.

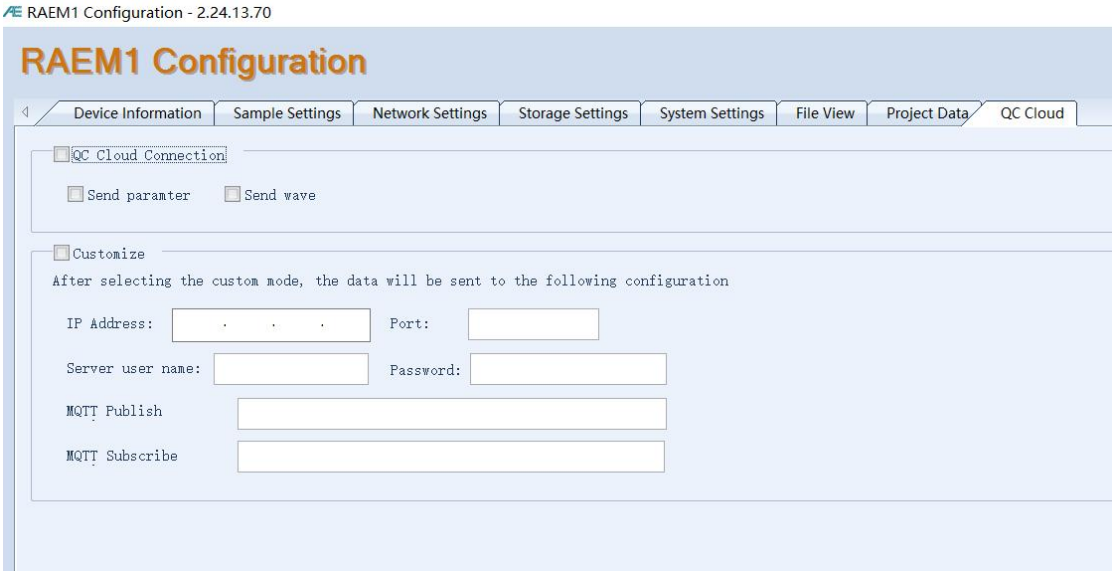


Fig. 5-29 QC Cloud Connection Operating Page

6. Qingcheng IoT Cloud Platform

Note: To use this function, you need to connect to a router and ensure the router has internet access. For details, please refer to Section 4.

Qingcheng Internet of Things (IoT) Cloud Platform is a cloud platform developed by Qingcheng AE Institute for our own Internet of Things acoustic emission products. Customers can log in to the platform to remotely check and modify the device configurations in real time, as well as real-time display of AE waveform, parameters, and the rating levels, alarms and reports, etc.

Log in to the Qingcheng IoT cloud platform (http://cloud.ae-ndt.com) and enter the account name and password. At present, the cloud platform does not support users to register their own accounts. All account registration needs to be operated through Qingcheng Company. Please contact us for user registration and login information.

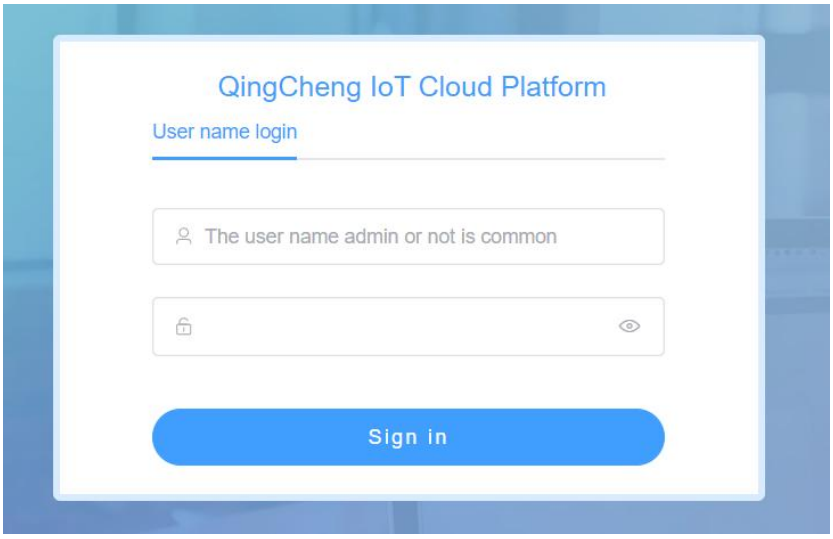


Fig. 6-1 Qingcheng IoT cloud platform login

After login, you can convert to Chinese/English, change the user interface, and change the password.

6.1. IoT Products

6.1.1. Device Groups

Group the devices to facilitate subsequent management of the devices. You can add groups through the device groups page to manage devices in groups.

The operation is as follows: click [Add], fill in the "Name", "Parent", and "Department" information (Note: When creating a new parent, the "Parent" column does not need to be filled in). "Purpose" can be "Default" or "AE Location Analysis". Choose "Default" in general.

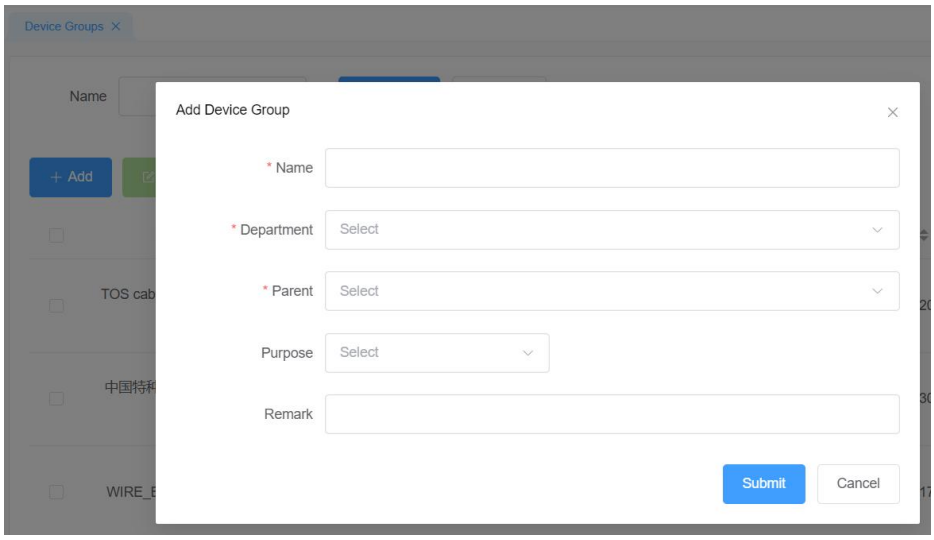


Fig. 6-2 Device Group "Add" window

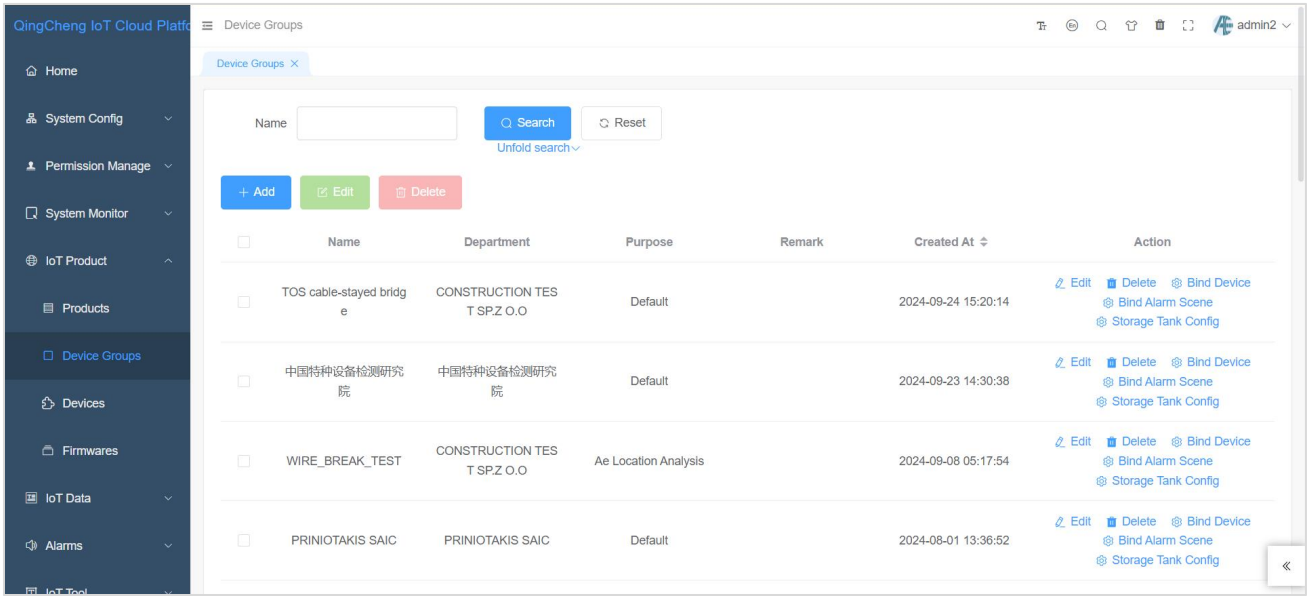


Fig. 6-3 Device Group page of Qingcheng IoT cloud platform

- **Bind Device**: Binding devices into this group for group managements.
- **Bind Alarm scene:** After grouping devices and binding alarm scenarios, users can receive alarm information for the grouped devices in this alarm scenario.
- **Storage Tank Config**: generally used for detecting the bottom plate of atmospheric storage tanks. After filling the information, a detection report can be automatically generated by clicking the **[Report]** button at the

bottom right corner;

- **Basic Information**

Fill in the relevant basic information based on the on-site inspection environment, and scroll down the page and click **[Submit]** on the bottom left corner after filling it out.

- **Sensor Layout**
  - **Tank Diameter (mm)**: the diameter and length of the tank bottom plate;
  - **Channel No.**: Click to select the device number, then click to add it;
  - **Add:** After selecting the device number in the channel number column, the device is added as a channel in the tank bottom location map;
  - **Delete:** After selecting the device number in the channel number column, the channel can be deleted from the map;
  - **Clear:** Clear all sensors from the map;
  - **Generate Graph**: save and generate the current location map on the left into the final report. If "Generate Graph" button is not clicked, the location map on the left will not be saved to the report.
  - **Move Left**: After selecting one of the channels above, the device can be moved left by one channel number;
  - **Move Right**: After selecting one of the channels above, the device can be moved to the right by one channel number;
  - **Submit:** Save the sensor layout plan.
- **Loading Sequence**
  - **Add:** to add a new load into the sequence.
  - **Duration (min):** Loading or load hold time;
  - **Height(m):** represents the loads;
  - **Refresh:** after filling the duration and height, refresh to update the loading sequence on the left;
  - **Delete:** delete one of the load sequence;
  - **Generate Graph**: save and generate the current loading sequence on the left into the final report. If the "Generate Graph" button is not clicked, the loading sequence on the left will not be saved to the report.
  - **Submit:** Save the loading sequence.
- **Attenuation Record**

- **Measurement Probe:** to specify one channel to do the attenuation test;
- **Add:** to add a recording point of the test.
- **Distance (m):** the distance from the probe to the simulation point location.
- **Amplitude (dB):** the amplitude of the received signal from the simulation point.
- **Delete:** delete one of the recording points;
- **Submit:** Save the record.

Report: Based on the information, the cloud will generate a storage tank test report which can be downloaded and saved.

6.1.2. Devices

The "Devices" page lists all IoT AE devices under the current account. Users can search for the desired devices by different search items, such as searching by device name and number, product, device group, status or product type. Users can also add new devices.

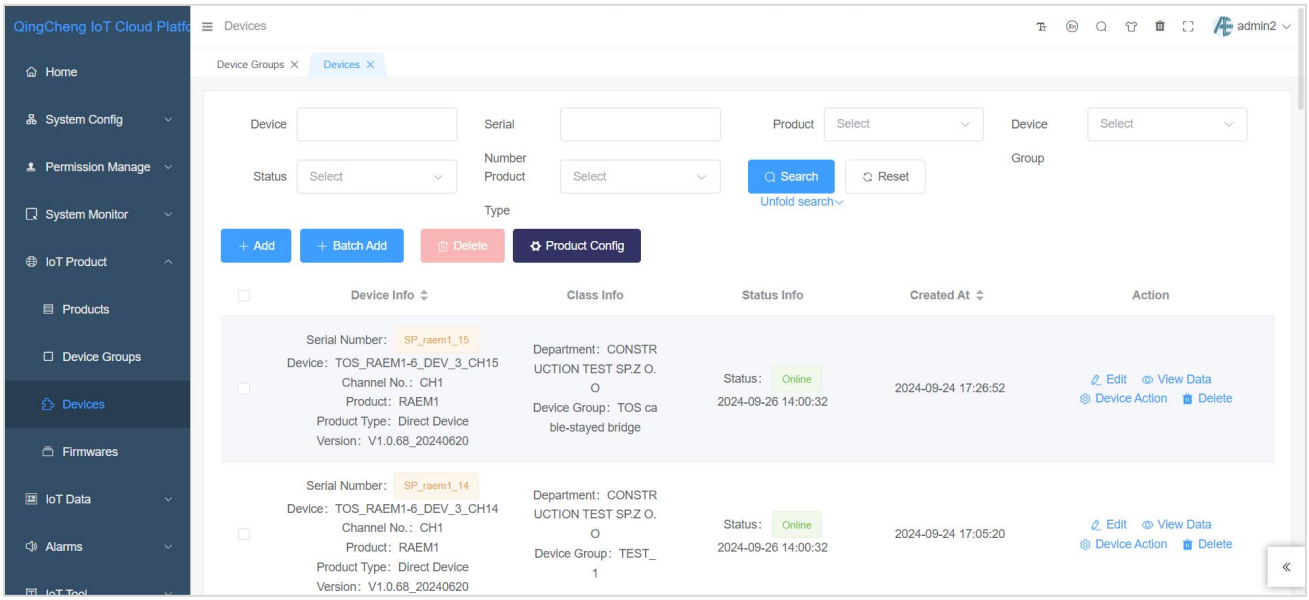


Fig. 6-4 Device Manage page

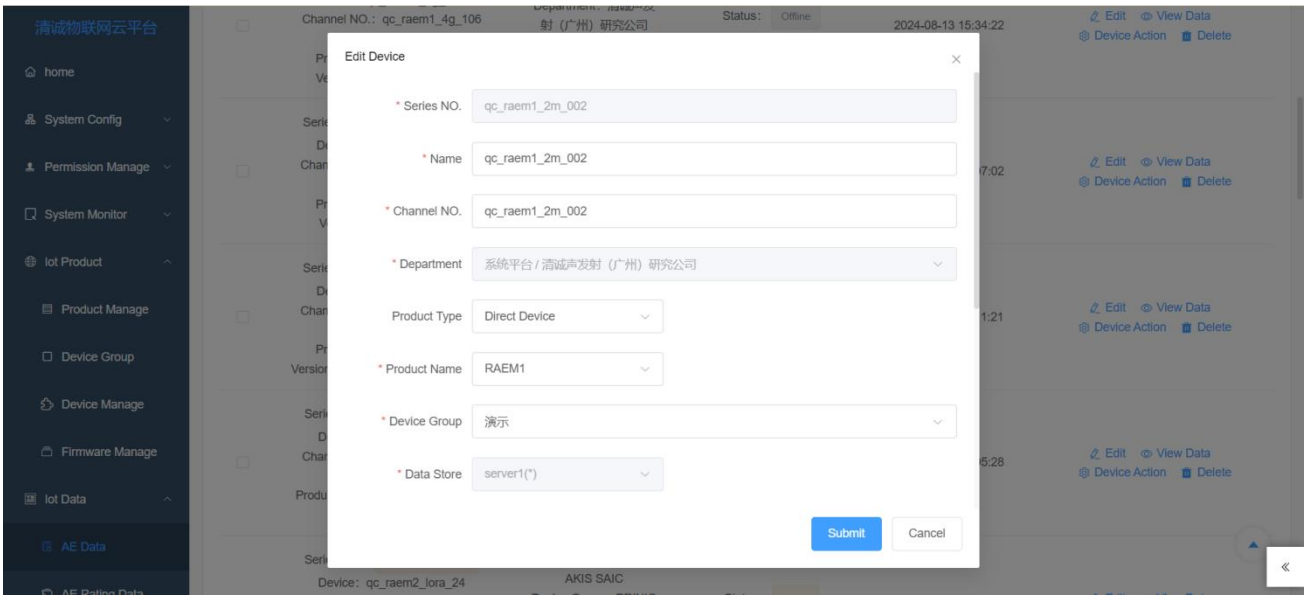


Fig. 6-5 Device Manage "Edit" or "Add" Window

[+Add]: You can add new devices or edit the existing devices.

- **Serial Number:** Fill in the device number on the product label (required)
- **Name:** User-defined (required)
- **Channel Number**: User-defined (required)
- **Department**: Select the department to which the device belongs (required)
- **Product Type/Name**: Select the corresponding product (required)
- **Device Group**: The group to which the newly added device belongs (required)
- **Data Store**: Select the server for data storage (required)
- **Server Connection**: select the server to connect the device to. (required)

After a new device creation, it will show up a new row for the created device. Under the "**Action**" column on the right, click "**Edit**" to modify the device information above.

Click **[Device Action]** button on the right menu bar of the desired device to open the "**Device Configuration**".

6.1.2.1. Device Configuration

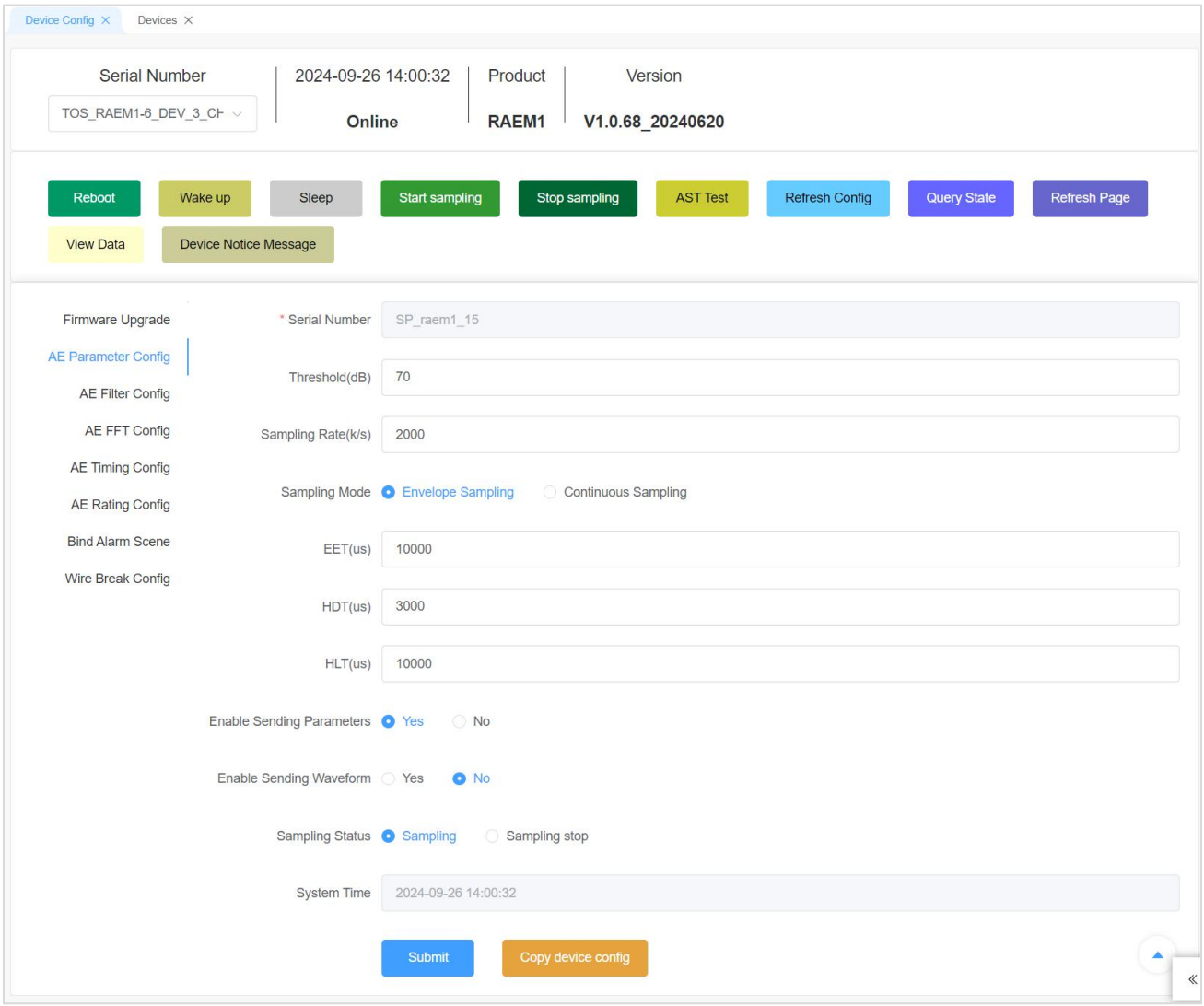


Fig. 6-6 Device Manage > Device Configuration page

Click "**Device Action"** to enter the device configuration page. In the device action page, you can see the colored button with **Reboot, Wake up, Sleep, Start sampling, Stop Sampling, AST test, Refresh Config, Query status, refresh page and View data** functions. And you can configure the device with **Firmware upgrade, Parameter config, Filter config, FFT config, Timing config, Rating config, Bind alarm scene, Wire break config.**

There are some device configuration page buttons description below:

- **Reboot**: Restart the device;
- **Wake up**: to wake up the device in sleep mode (currently only available in RAEM2);
- **Sleep**: to command the device to immediately enter sleep mode (currently only available in RAEM2);
- **Start Sampling**: to command the device to begin acquisitions;

- **Stop Sampling**: to command the device to stop acquisitions;
- **AST test:** Press to perform an AST test once (currently only available in RAEM2);
- **Refresh Config:** Read the latest device configuration and refresh the page;
- **Query state:** to obtain the device current status;
- **Refresh Page**: Refresh the current web page;
- **View data**: Go to the **'AE Data'** page to view the data;
- **Device Notification**: Click to obtain the notification messages of the device.

(1) **Firmware Upgrade**:

To upgrade the firmware, select the target device and click **[Device Action]** on the right. In the pop-up window, click **[Upgrade]** to upload the firmware package. Contact us for the firmware package. After the device receives the upgrade request, it will upgrade automatically and automatically reboot to take effect. Please don't interrupt the process until the device finishes rebooting and is back online again.

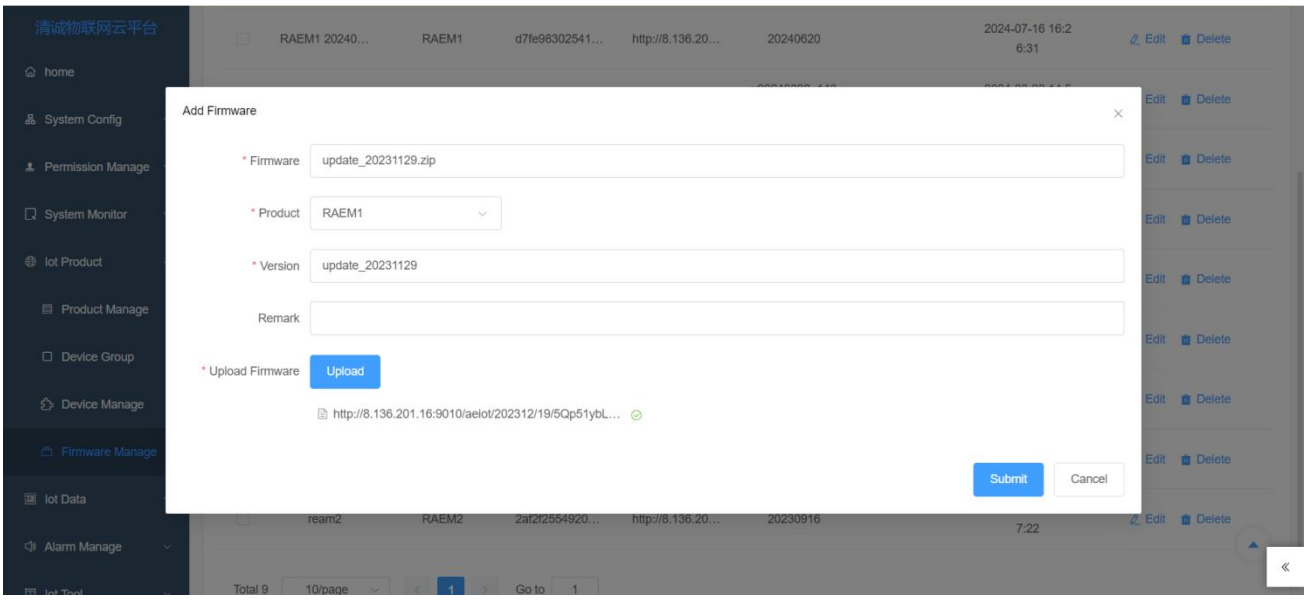


Fig. 6-7 Firmware Upgrade Window

(2) In the [**AE Parameter Config]** tab:

- **Threshold**

Preset trigger threshold, in unit of dB When the amplitude of the sampling signal exceeds this threshold, the starting point of the AE signal is identified by the AE processor. Only valid for the envelope sampling mode, not for the continuous (parameter) sampling mode.

- **Sampling rate**

Sampling rate is the number of points of the analog voltage signal sampled by the analog-to-digital chip every

second. The unit is k/s, indicating that N thousand points per second. For example, 1000k/s, that is, one million points per second (1MHz).

- **Sampling mode**

According to the selected mode, the start and end of the received acoustic emission signals are identified, in order to generate the corresponding AE feature parameter data. There are two modes available, **envelope sampling** and **continuous sampling**:

- **Envelope sampling**

The start and end points of a hit signal (envelope shape) are defined and identified according to the set threshold, HDT, HLT and EET parameters, in order to generate the corresponding AE feature parameter data.

Enforced End Time (EET)

The EET ranges from 1μs to 50,000 μs. When the acoustic emission signal amplitude is consistently higher than the threshold value, and the set hit definition time (HDT) cannot determine the intercepted acoustic emission parameters, the EET takes effect. The system breaks up the continuous signal by using EET as the "duration" of the current generated parameter, and other characteristic parameters is calculated based on this duration of waveform signal. EET is valid only for envelope sampling mode, but not for continuous (parameter) sampling mode.

Hit defined time (HDT)

Envelope definition time (or **hit definition time**), unit: microsecond (μs), abbreviated to HDT, ranging from 100μs to 50,000μs (a positive integer). It means the waiting interval of a hit signal for the correct determination of the end point of a hit signal. When the set HDT value is more than the time interval (T) between the threshold exceeding time of two adjacent signal envelopes, the two signal envelopes will be classified as an acoustic emission hit signal. If the HDT value set is less than the time interval (T) between two signal envelopes' threshold exceeding time, the two signal envelopes are divided into two acoustic emission hit signals. For the same signal, the larger the HDT value is, the fewer AE parameters will be extracted; the smaller the HDT value is, the more AE parameters will be extracted. HDT is only effective for envelope sampling mode, but not for continuous parameter sampling mode.

Hit lock time (HLT)

Hit lock time, unit: microsecond (μs), abbreviated to HLT. The value ranges from 1 to 20,000,000 (positive integer). To avoid receiving the reflected or post waves, the time window for turning off the measurement circuit is set. After the end of the current acoustic emission event, a signal for a period of time (HLT) after the HDT is ignored. This window is called the hit lock time, and the value set is affected by signal attenuation and structure size. If the setting value is too large, the subsequent acoustic emission signal will be missed. The next acoustic emission signal period exceeds the threshold, but the HLT has not ended. So the signal will not be collected at the period. HLT is only effective for envelope sampling mode, but not for continuous parameter sampling mode.

- **Continuous sampling**

According to the sampling length, sampling times and sampling interval, the acoustic emission signal

that exceeds the threshold is intercepted and analyzed, in order to generate the corresponding AE feature parameter data.

Sampling length

The length of each sample, in unit of microseconds (μs), is a signal for a set length collected each time. It is only valid for continuous (parameter) sampling mode, but not for envelope sampling mode.

Sampling times

The number of times a fixed-length signal is collected in continuous sampling mode. It is only valid for continuous parameter sampling mode, but not for envelope sampling mode.

Sampling interval

In continuous sampling mode, the interval stopping time after each sampling of a fixed-length signal, in unit of microseconds (μs). After the time is up, the fixed-length signal is collected again. It is only valid for continuous (parameter) sampling mode, but not for envelope sampling mode.

- **Enable sending parameters**

Whether to send parameters to the Qingcheng IoT cloud platform. Enabled by default.

- **Enable sending waveform**

Whether to send waveform to the Qingcheng IoT cloud platform. Disabled by default.

- **Sampling status**

Select **Sampling** or **Stop Sampling**, which indicates the current collection status of the device.

- **System time**

System clock, in seconds. The display format is yyyy-mm-dd hh:mm:ss.

After completing the settings, click **[Submit]**. If you see "OK" returned at the top of the page and the page parameters have been modified, it means the modification is successful.

Copy Device Config: Click and pop up a window to select the devices of the same group to have all the copied configurations. After submitting, the selected device will be updated synchronously.

(3) In the **[AE Filter Config]** tab:

- **Enable Filter**

Whether to enable the digital filter in the device or not.

- **High-pass Filter:** it means the lower limit of the frequency band. When the signal frequency is lower than this frequency, the signal will not pass. Unit of KHz.
- **Low-pass Filter:** it means the upper limit of the frequency band. When the signal frequency is higher than this frequency, the signal will not pass. Unit of KHz.

(4) In the **[AE FFT Config]** tab:

- **Enable FFT:** Whether to enable the FFT function or not.
- **Decimation Factor [1-10]:** choose an integer from 1 to 10 to decimate the signal by M. It means it keeps only every M^{th} sample to perform the FFT function.
- **Start Frequency (kHz)**: The start frequency of the partial power spectrum segment.
- **End Frequency (kHz)**: The end frequency of the partial power spectrum segment.

After filling, press "**Fast Input**" to auto proportionally allocate the frequency range set here.

- **Partial Power Segment 1 to 5**: check-box the **[Enable]** ☑ after the segment to enable the current frequency segment. Any segment can be selected as needed. After selecting a segment, set its frequency band upper and lower limits. Simply enter a positive integer in unit of "kHz";

(5) In the **[AE Timing Config]** tab:

You can choose to collect signals at regular intervals. The default is the **"Continuous Sampling"** mode, which means that the acquisition is continuous and uninterrupted. Another type is the **"Interval Sampling"** mode, which means that after collecting signals for a period of time, the collection is paused for a period of time, and then restarted for a period of time, repeating the cycle. If you choose the Interval Sampling mode, you need to set the duration of each collection (in seconds) and the duration of stopping (in seconds). The **"Scheduled Sampling"** mode, which means only start to collect data when the start time is up, and stopping the collection when the end time is up. Its minimum unit is days.

Operations:

Click **[Device Action] >> [AE Timing Config.]** button on the right menu bar of the desired device to open the "Device Configuration".

After completing the settings, click **[Submit]**. If you see "OK" returned at the top of the page and the page parameters have been modified, it means the modification is successful.

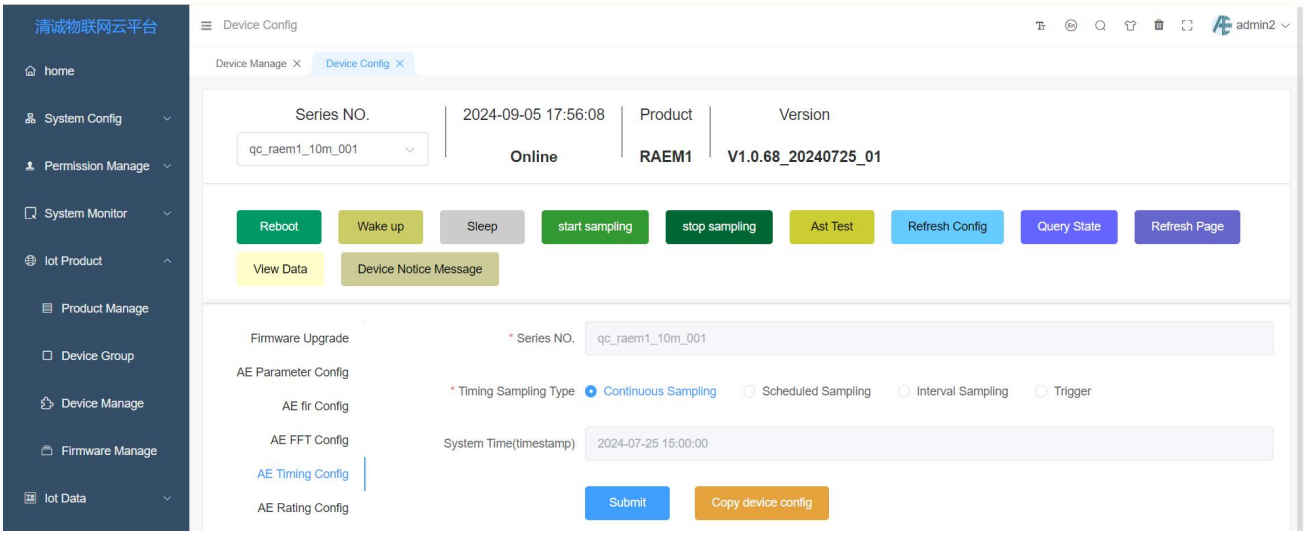


Fig. 6-8 Timing Configuration Page

(6) In the **[AE Rating Config]** tab:

Rating is to evaluate the overall performance levels of the current acoustic emission events according to the defined rating rules, so as to make alarms or action measures in response to different rating results. Select some parameters and set their values as different intensity levels, and specify the activity levels by the number of times that intensity levels report within a certain period. During the specified acquisition period, if any of the collected parameters exceeds a specified intensity or activity level threshold, it will be assessed and rated to a certain level of intensity or activity. Users can set the intensity or activity level for alarm reporting, or they can push alarm information according to the comprehensive rating levels.

The comprehensive rating level combines both the intensity and activity levels over a period of time and obtains the highest level of the comprehensive rating. The comprehensive rating level meets the NBT47013.9-2015 standard. It is important to note that the intensity level of the comprehensive rating cannot exceed 3 levels and the activity level cannot exceed 4 levels. Otherwise, a comprehensive rating cannot be obtained.

Table 6-1 Rating level standards

Comprehensive Rating Level		Activity Level			
		4	3	2	1
Intensity Level	3	4	4	3	2
	2	4	3	2	1
	1	3	3	2	1

- **Enable rating**

Whether the rating function is enabled.

- **Intensity config**

If a comprehensive rating is required, the intensity should not exceed 3 levels. Click "**Add intensity**" to add an intensity level. Under the same intensity level, you can add multiple rules. The relationship between different rules of the same intensity level is "OR" condition. That is, if one of the rules is met, the intensity of this level is reached. In the same rule, add one or more parameters as the intensity level conditions. The relation of all these parameters under the same rule is "AND" condition. That is, the rule can be considered as reached only when every parameter condition in this rule is met. For example, the intensity level 1 has two rules. Rule 1 is when the amplitude (AMP) exceeds 70dB and also the energy exceeds 500 KpJ at the same time. Rule 2 is when ASL exceeds 65dB. The intensity level 1 is considered reach if either rule is met. For Rule 1, both conditions are required to meet so that Rule 1 is met.

- **Activity config**

If a comprehensive rating is required, activity cannot exceed 4 levels. Every time when an intensity is greater than or equal to level 1, one activity is counted.

- **Rating Interval**

The data collected within this period are counted, and the rating results are given according to the intensity and activity rules. The unit is second. The default value is 20 seconds.

- **Rating report criteria**

Select **no report** or select to report a level of intensity. If you choose to report level 1 intensity, it will alarm when the intensity is equal to or greater than level 1.

- **Intensity reporting min. interval**

No more intensity alarm of the same level will be reported within this period of time after the first alarm is reported. However, if an intensity higher than this level occurs within that period of time, the system will also report an alarm. The default value is 10 seconds.

Operations:

Click **[Device Action] >> [AE Rating Config.]** button on the right menu bar of the desired device to open the "Device Configuration".

After completing the settings, click **[submit]**. If you see "OK" returned at the top of the page and the page parameters have been modified, it means the modification is successful.

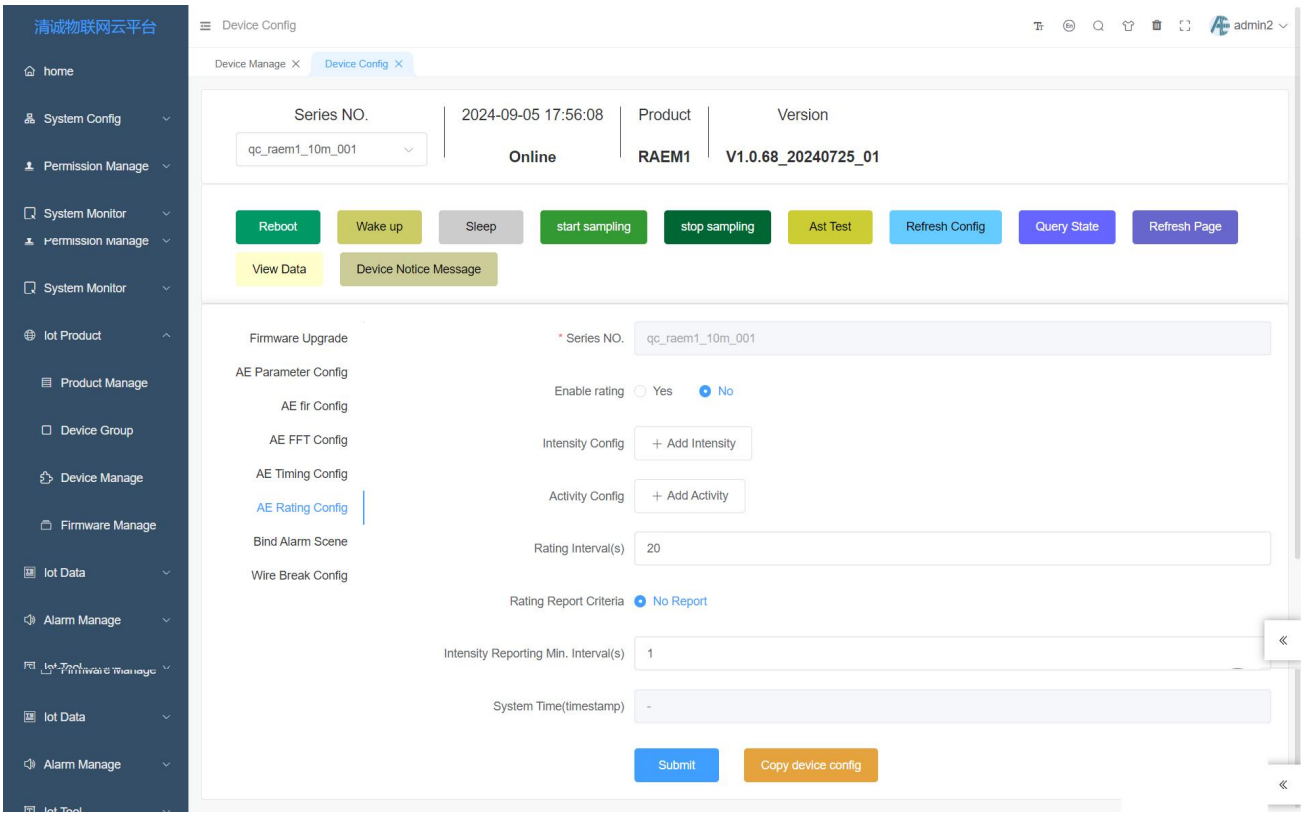


Fig. 6-9 Device Manage > AE Rating Configuration page

(7) In the **[Wire Break Config]** tab:

Wire break configuration is the setting of the calculation and determination function of wire break rate.

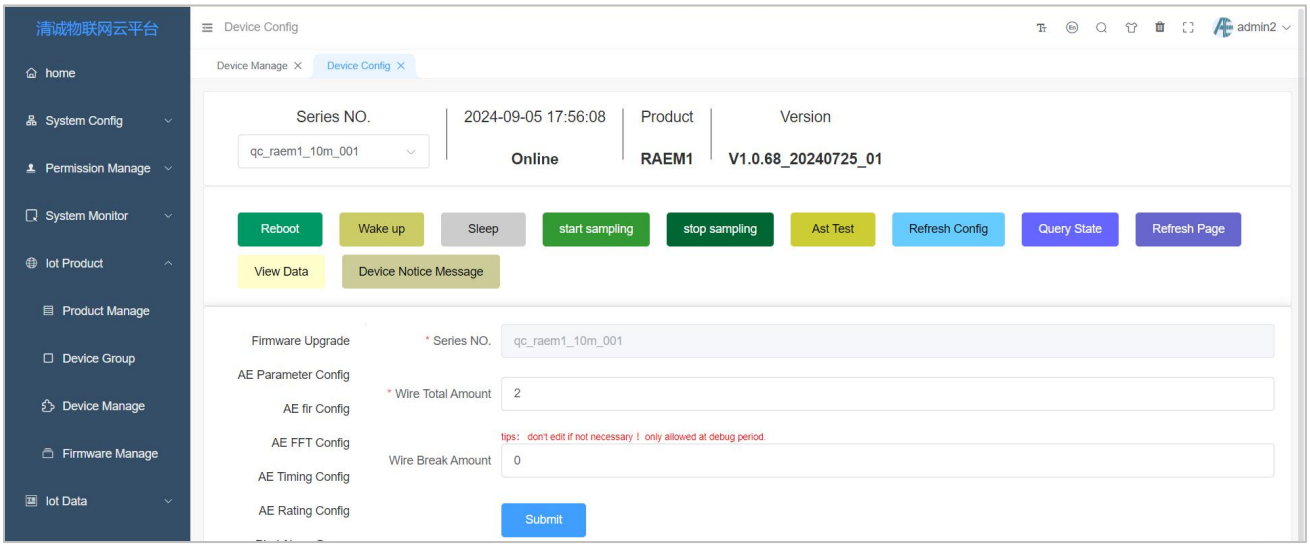


Fig. 6-10 Wire Break Configuration Page

6.2. IoT Data

6.2.1. AE Data

The **[AE Data]** page displays the time diagrams of the change of a few parameters of one or a few devices. You can click **[IoT Data]** → **[AE Data]** in the menu bar on the left side of the platform to enter. Or click the **[View Data]** button on the right side of the **[Device Manage]** page to enter the **[AE Data]** page of the device. The default is the correlation diagram of all parameters with time.

- **Product:** select the product type of the device.
- **Device:** Enter or select the device number. There can be more than one device.
- **Parameter:** View the relationship between the selected parameter and time. The optional parameters are: AMP (amplitude [dB]), ASL (average signal level [dB]), Power (energy [KpJ=10^3 pJ]), duration [μs], counts, rise time [μs], RMS (root mean square [mV]), rise counts.
- **Creation At:** You can choose the length of the time axis to be displayed, such as the last 10 minutes, one hour, one day, one week, etc. or set any time period.

(1) Viewing Data

Select "BWM1" for **[Product]**, select the actual equipment ID number for **[Device]**, and select **[Creation At]** according to your needs. After setting, click **[Search]** to update the chart display. When the mouse moves over on the charts, the reading and time of the parameter corresponding to the horizontal and vertical coordinate points will be displayed.

Or simply click on '**View Data**' on the '**Device Configuration Page**'.

Fig. 6-11 Data monitoring page

Double-click on any coordinate point, the pop-up window displays a waveform corresponding to that coordinate point (parameter). However, if "**Enable sending waves**" function is not enabled in **Parameter Config**, no waveform is uploaded and displayed here. On the top of the pop-up "**Wave**" window, the waveform arrival time and its other 8 parameters extracted from this waveform are displayed. When the mouse cursor moves over the waveform, its voltage value and the time coordinate at each closest data point will be displayed correspondingly. Click "**Previous**" or "**Next**" to display the adjacent waveform diagrams.

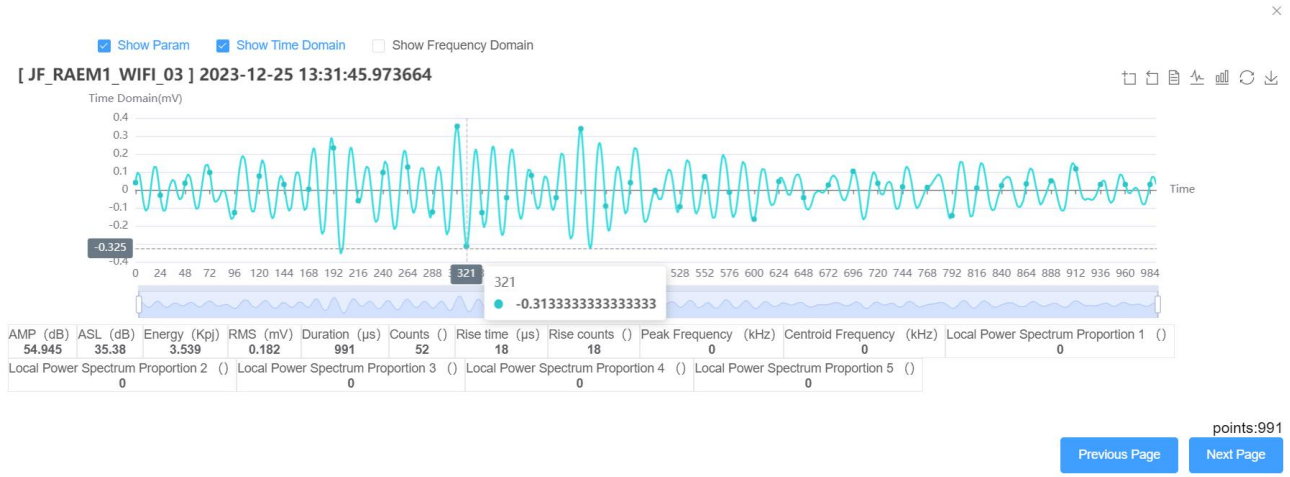


Fig. 6-12 Waveform page from the AE Data

The buttons in the upper right corner are: Region Zoom, Region Zoom Restore, Data View, Switch to Line Chart, Switch to Bar Chart, Restore, and Save as Image.

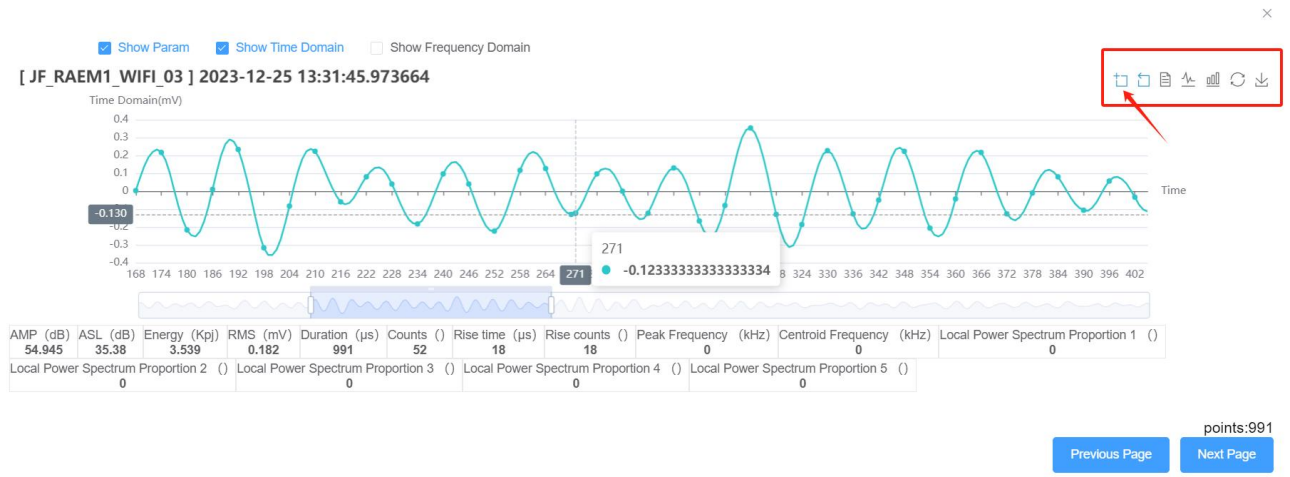


Fig. 6-13 Expand Waveform page from

- **Regional Zoom In**: Click "Regional Zoom-in" button, then use the mouse to pressure down and drag a rectangle area in the graph. Once releasing the mouse, only the selected area (in time domain) of the graph will be displayed.
- **Regional Zoom Out**: Click "Regional Zoom-out" button, the graph will restored to the previous zooming stage.
- **Data Table**: list all the data points in table list.
- **Switch to line chart**: display data in line chart.
- **Switch to bar chart**: display data in bar chart.
- **Restore:** Restore to default state.

- **Save as Image:** You can save the image to your computer.

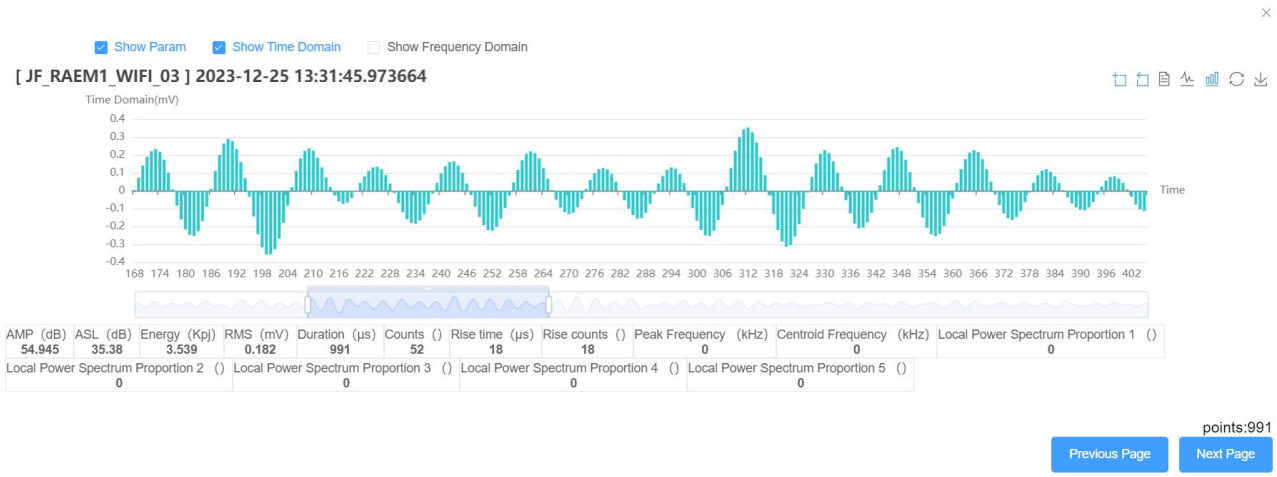


Fig. 6-14 Expand Waveform page from in bar diagram

(2) Data Download

- **Download (To SWAE)**: Download the parameters and the waveform data in the SWAE software readable format, which are .PRA and .AED format.
- **Download (To CSV)**: download the parameters data as a CSV file. The data are all the parameters in the selected time range.

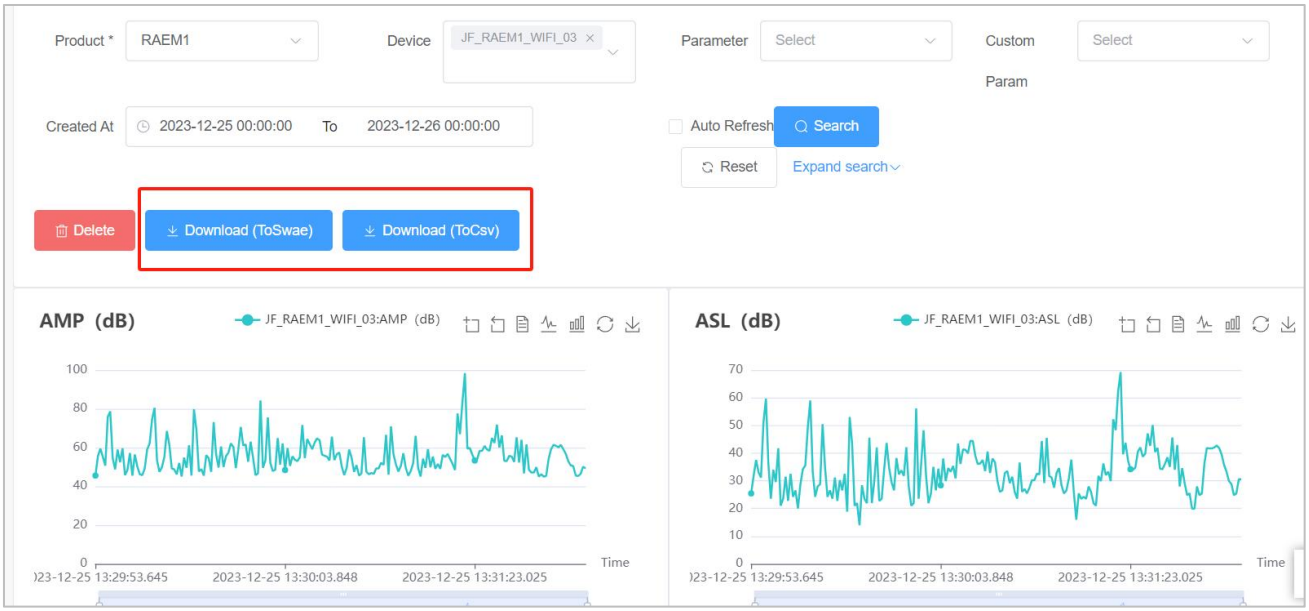


Fig. 6-15 Download Data

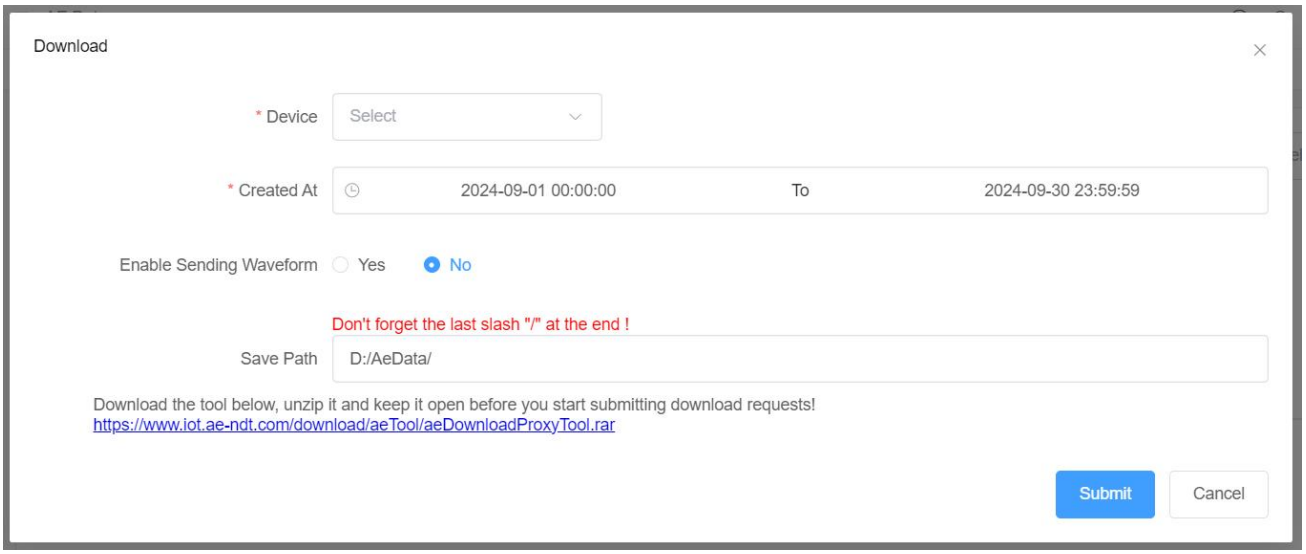


Fig. 6-16 Download to SWAE window

If **[Download To SWAE]** is selected, first download the "aeDownloadProxyTool.rar" by clicking the link at the bottom of the pop-up window and decompress the compressed file, run the "Tools". Select "Device" and "Creation Time". If you also need to download the waveform data, select "Enabling Sending Waves" and click "Submit" after completing the settings.

After submission, when the running 'Tools' page displays '**download finish!!!**', it indicates that the data download is complete.

Fig. 6-17 Finishing Download the AE tool

After downloading, you can see the downloaded data in the save directory.

Note: The saved directory is "D:/AeData/" (the file save path can be modified). The data will be stored in a

subfolders under this directory, named after the time when the data was downloaded.

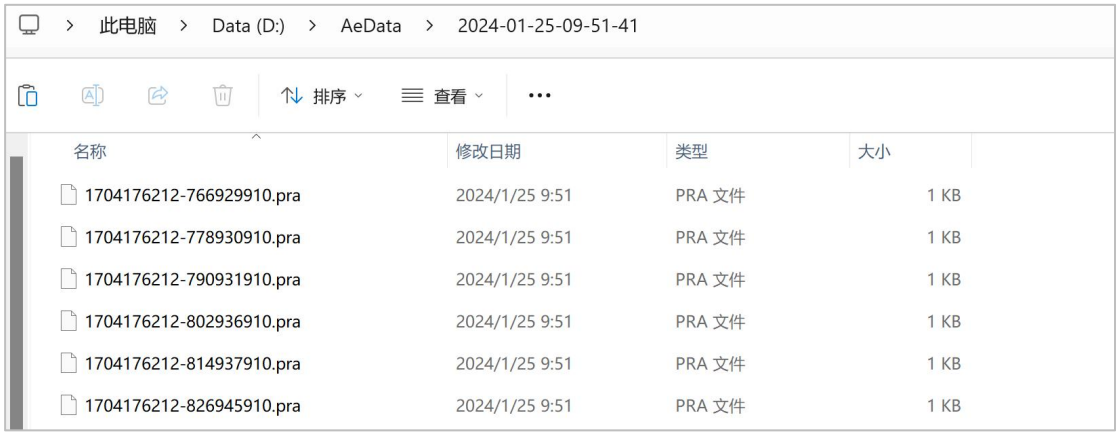


Fig. 6-18 Downloaded data in PRA format

Data format conversion operation:

Please refer to Chapter 9 for specific steps on data format conversion for the "RAE1toU3H" software conversion.

Data Replay operation:

Open the "SWAE software" and first confirm whether the devices supported by the software are RAEM1 devices (BWM1 is a special type of RAEM1).

Click on '**Data Replay**', then click on '**Replay Settings**'. In the pop-up file selection window, select the data file to be played back. The data files mainly include waveform files with a suffix of .aed and parameter files with a suffix of .pra.

Steps:

① By default, select '**Parameters**' and '**Waveform**', and choose the type of data playback as needed. When both are selected, both parameter files and waveform files will be played back simultaneously;

Note: If "waveform to parameters" is selected, a new parameter file will be automatically generated when replaying the waveform;

② Set playback speed (FPS) to a maximum of 100000; Set 200 here, click [OK] after setting is complete

③ Click on [**Replay**].

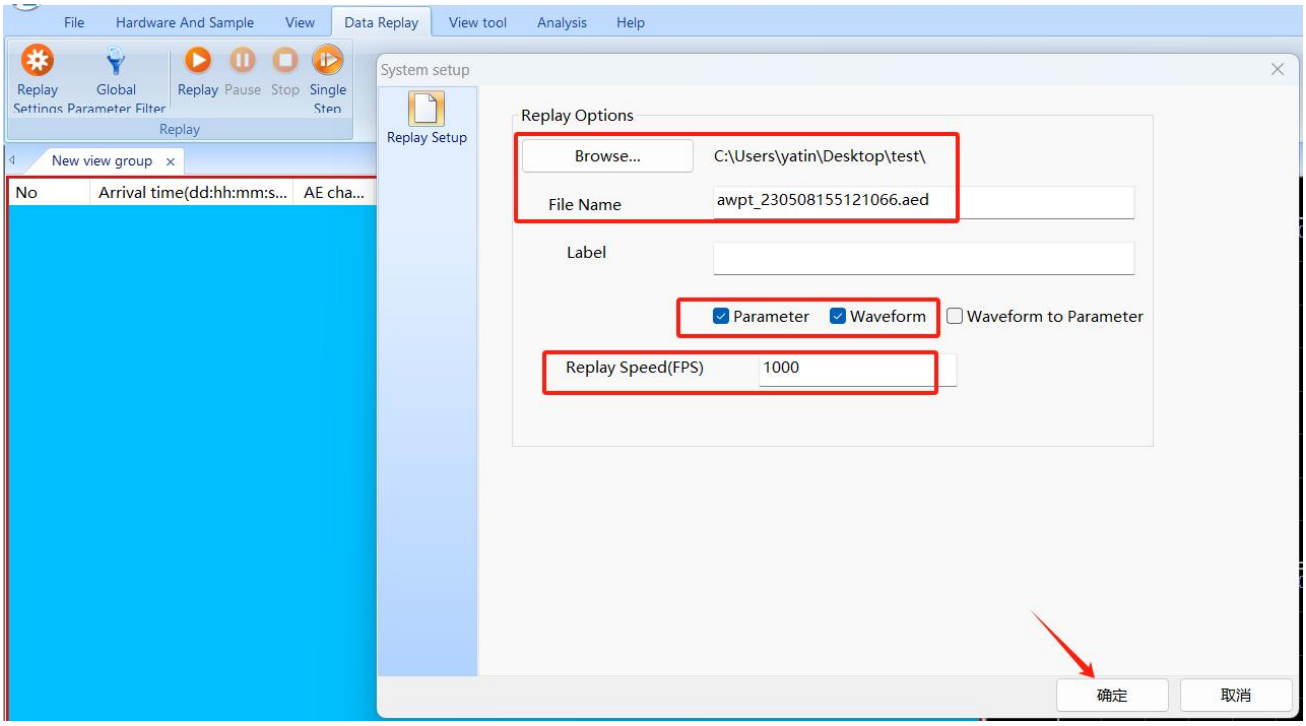


Fig. 6-19 Data Replay

(3) Data Delete

Delete: Delete the sound emission data.

Click on 'Acoustic Emission Data', select the product, device, and creation time, then click 'Delete' to delete the data of the selected device during this period. (Note: After selecting the parameters, click Delete to delete the data within the selected time period)

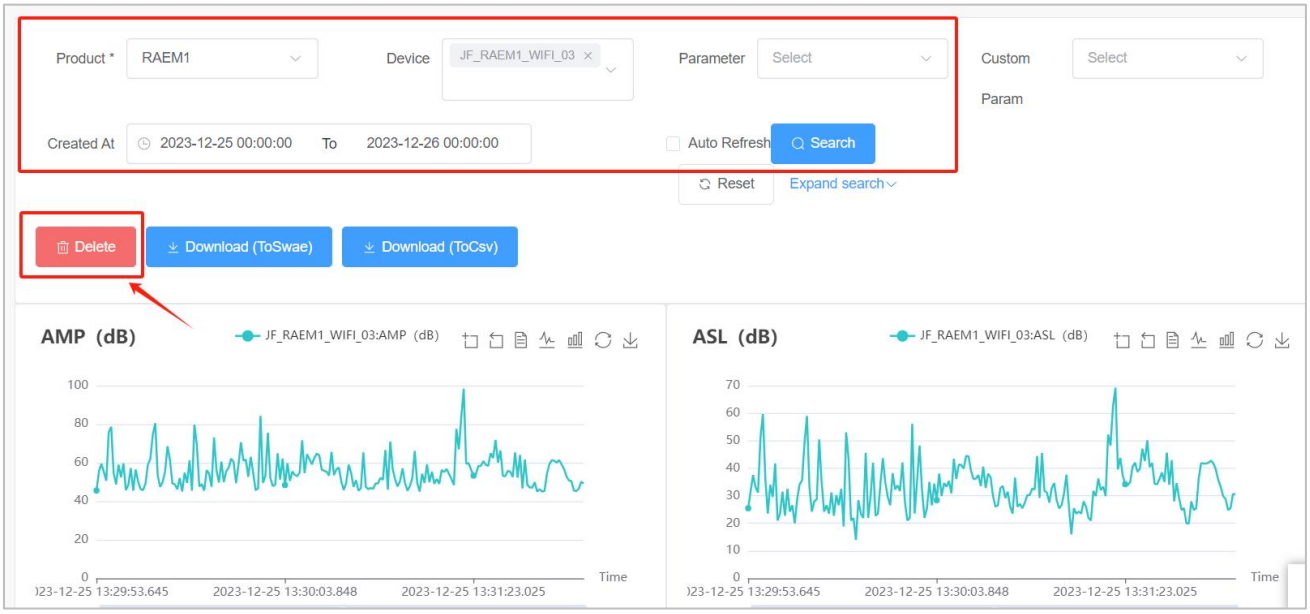


Fig. 6-20 Delete Data

6.2.1.1. AE Rating Data

Rating is to evaluate the overall performance levels of the current acoustic emission events according to the defined rating rules, so as to make alarms or action measures in response to different rating results. Select some parameters and set their values as different intensity levels, and specify the activity levels by the number of times that intensity levels report within a certain period. During the specified acquisition period, if any of the collected parameters exceeds a specified intensity or activity level threshold, it will be assessed and rated to a certain level of intensity or activity. Users can set the intensity or activity level for alarm reporting, or they can push alarm information according to the comprehensive rating levels.

The comprehensive rating level combines both the intensity and activity levels over a period of time and obtains the highest level of the comprehensive rating. The comprehensive rating level meets the NBT47013.9-2015 standard. It is important to note that the intensity level of the comprehensive rating cannot exceed 3 levels and the activity level cannot exceed 4 levels. Otherwise, a comprehensive rating cannot be obtained.

Table 6-2 Rating level standards

Comprehensive rating level		Activity level			
		4	3	2	1
Intensity level	3	4	4	3	2
	2	4	3	2	1
	1	3	3	2	1

Users need to choose **[IoT Product] > [Device Manage]**, select a device and click the **[Device Action]** to open the **[Device Config]** tab. In the **[Device Config] > [AE Rating Config]** to enable the rating function and set rating rules and levels. The device will get the rating results after the set time period, and the data is displayed in the rating related pages.

Rating result viewing operation:

In the **[IoT Data] > [AE Rating Data]**, select the device that needs to view the rating results. The rating types are optional: intensity, comprehensive, and activity. Click on **[Search]**.

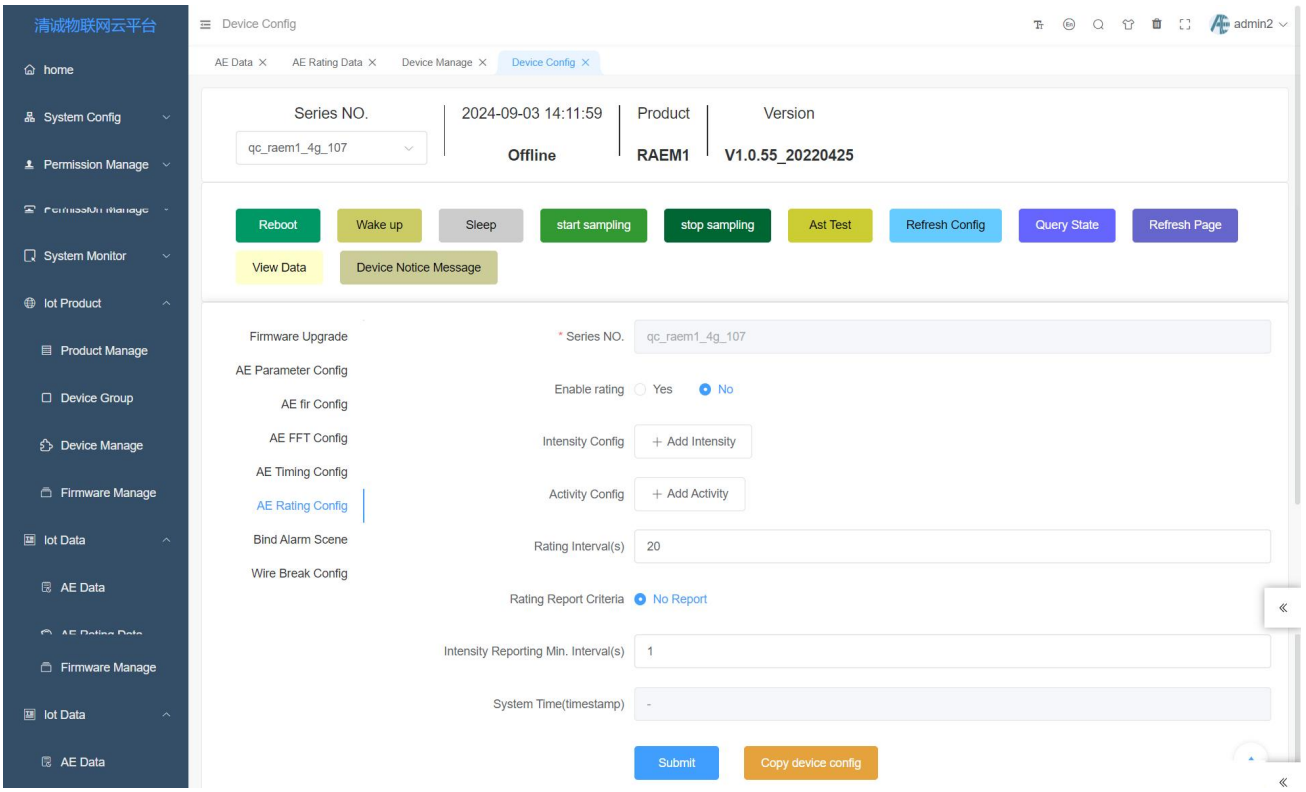


Fig. 6-21 Setup AE rating settings

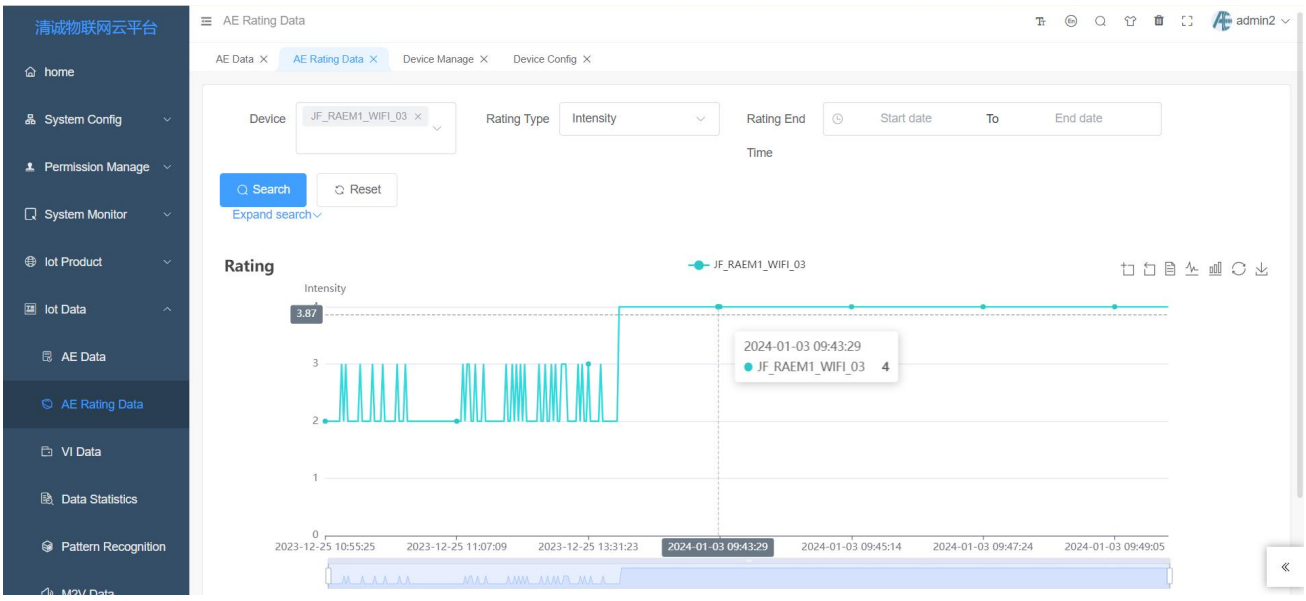


Fig. 6-22 AE Rating result view

6.2.1.2. Correlogram

Correlation graph refers to a type of relationship graph that uses two or more acoustic emission parameters as horizontal and vertical coordinates to draw correlation curves, distribution graphs, line graphs, etc., to

characterize acoustic emission signals. It is a major application tool for analyzing parameter data.

- **Add Graph**: Add a new AE correlation graph;
- **Save Settings**: Save existing settings;
- **Restore Settings**: Restore the settings of the last saved sound emission related image;
- **Points**: The number of points in the relevant chart can be selected from 100, 200, 500, 1000, 2000, 5000, 10000, and 20000;
- **Statistical mode**: There are two statistical methods to choose from: maximum value and average value;
- **Display mode**: includes three display modes: line chart, bar chart, and scatter chart;
- **[X] axis**: The X-axis parameters include arrival time, amplitude (dB), ASL (dB), energy (KpJ), RMS (mV), duration (us), counts, rise time (us), rise counts, peak frequency (KHz), frequency centroid (KHz), and 5 partial power spectrum segments;
- **[X] Range**: the range of X axis.
  - **[X] Auto**: The coordinate display range of the relevant graph will be automatically adjusted according to the data distribution situation;
  - **[X] Custom**: Filter out values that are not within this range based on the maximum and minimum values entered by the user;
- **[Y] axis**: The Y-axis parameters include arrival time, amplitude (dB), ASL (dB), energy (KpJ), RMS (mV), duration (us), counts, rise time (us), rise counts, peak frequency (KHz), frequency centroid (KHz), and 5 partial power spectrum segments;
- **[Y] Range**: The range of Y axis:
  - **[Y] Auto**: The coordinate display range of the relevant graph will be automatically adjusted according to the data distribution.
  - **[Y] Custom**: Filter out values that are not within this range based on the maximum and minimum values entered by the user.

Operation steps:

Select **[Device]** ->Select the time to be counted **[Create At]** ->Select **[Points]** ->Select **[Statistics Mode]** according to specific needs. Here, select the maximum value ->Select **[Display Mode]** ->**[X] axis** parameter selection. Here, select the arrival time ->**[X Range]**. Here, select automatic ->select the **[Y] axis** parameter ->**[Y Range]**. Here, select automatic ->After setting, click **[Start]**.

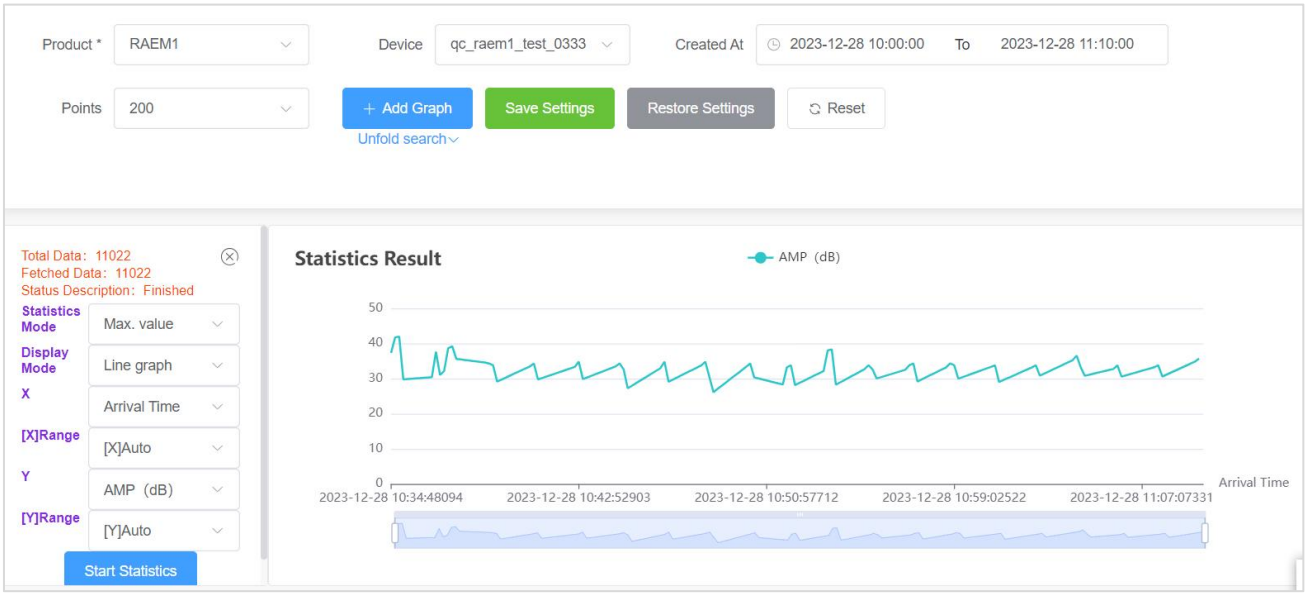


Fig. 6-23 Add a correlation graph

6.2.2. Alarms

6.2.2.1. Alarm Users

Alarm users are used to set alarm information output settings, and when an alarm is triggered, a message will be sent to the set phone or email.

Click on **[Alarms] > [Alarm Users]** to enter the alarm user page, click on **[Add]** to add a new user, and fill in the information.

- **Contact** (required): Alarm user name
- **Department** (required): Select the department user who needs to receive alarm information
- **Language**: Available in Chinese or English
- **Phone** (required): The phone number to receive alarms
- **Email**: Email for receiving alarm information
- **Receive Frequency(min)** (required) (Note: The receiving frequency depends on the frequency in the alarm scenario and the receiving frequency of the alarm user, with the maximum value being the frequency at which the user receives alarm information).

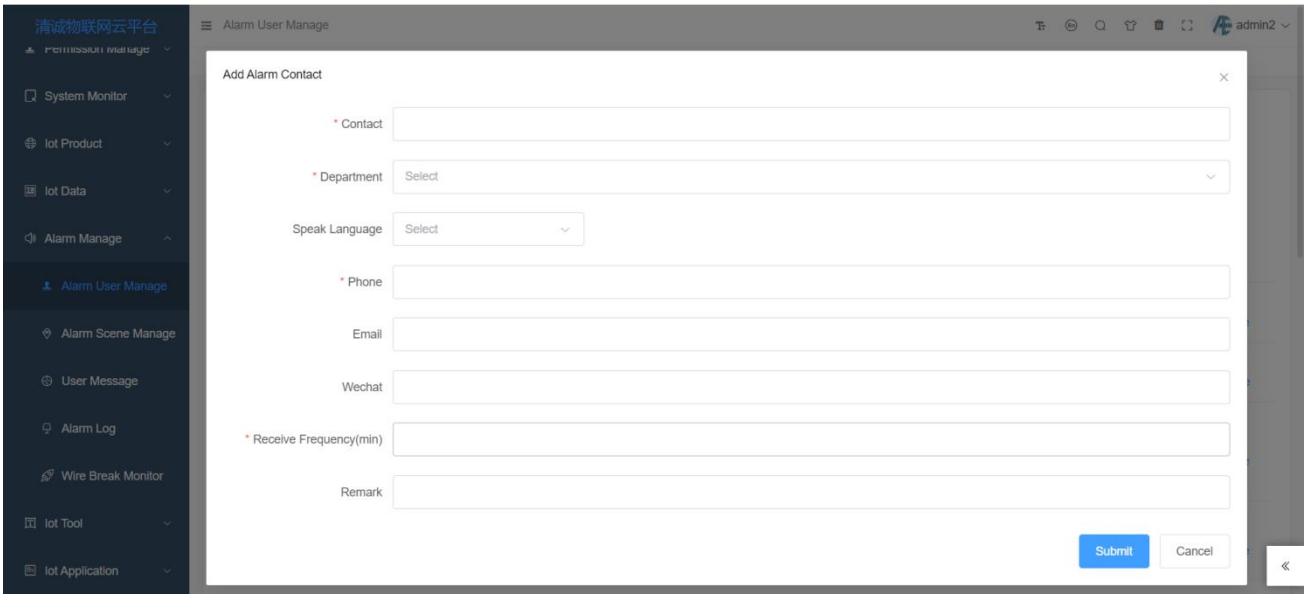


Fig. 6-24 Add alarm contact

Click on **[Alarms] > [Alarm Users]** to enter the alarm user page, click on **[Bind Alarm Scene]** on the right of the existing users to bind certain testing scenes to the user.

Fig. 6-25 Bind Alarm Scene

6.2.2.2. Alarm Scenario

Alarm Scenario: This page is used for users to customize alarm scenarios, such as in the application of bridge wire rope breakage monitoring, which can be customized as breakage monitoring.

Click on **[Alarms] > [Alarm Scenario]** to set up alarm scenarios. **[Add]** button can add alarm scenarios.

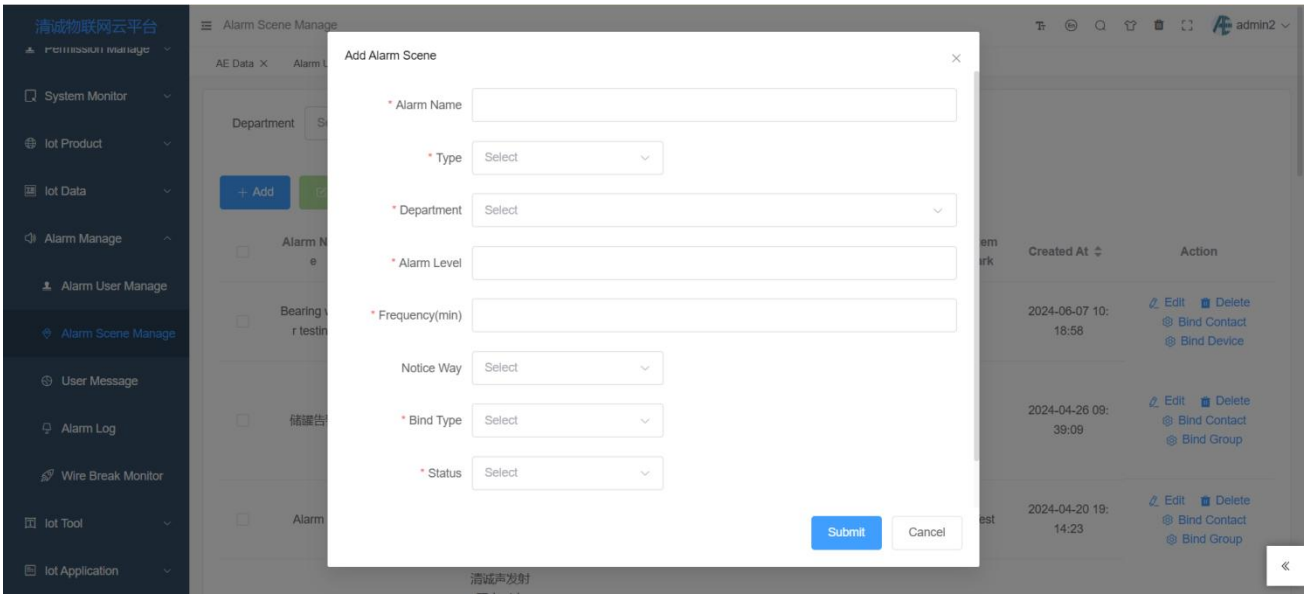


Fig. 6-26 Add Alarm Scene

- **Alarm Name** (required): Fill in the newly added alarm name;
- **Type** (required): optional strength, activity, comprehensive, broken wire;
- **Department** (required): Select the department that needs to add alarm scenarios, and only add alarm scenarios within that department after selection
- **Alarm level** (required): Select based on the selected type. The alarm levels for intensity and comprehensive types are 1-4 levels; Activity: Alarm levels are 1-3; wire break: The rated value of wire breakage depends on the strength rated value.
- **Frequency** (required): The frequency at which the platform sends text messages, with a minimum of 1 minute
- **Notice way**: receive notification by email or SMS.
- **Bind Type** (required): choose to bind to a device type or a device group.
- **Status**: Turn on or off the alarm.
- **Bind Contact**: select the users which are bonded to this alarm scene.
- **Bind Device**: select the devices which are bonded to this alarm scene.

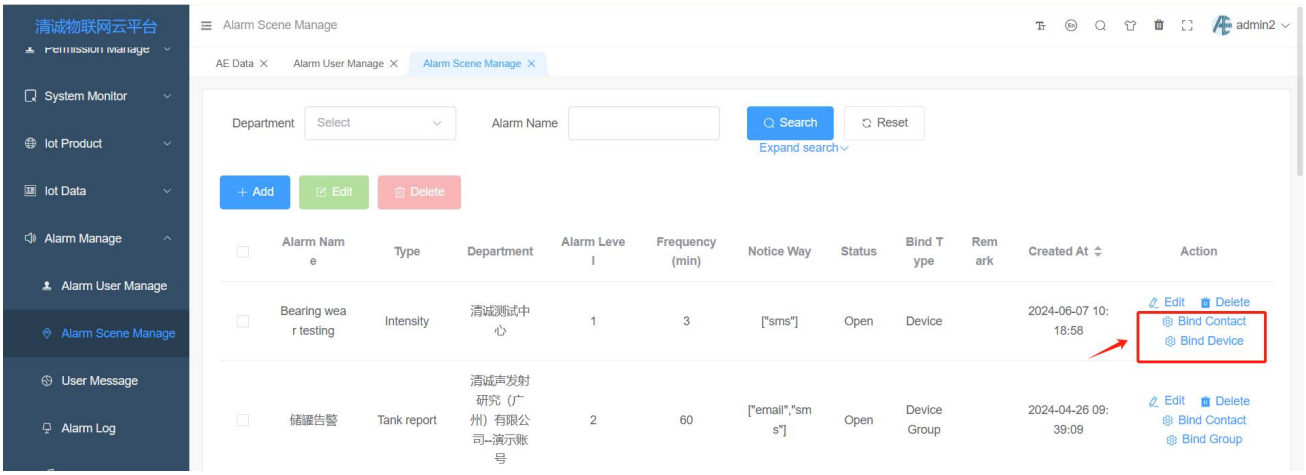


Fig. 6-27 Bind contacts or devices buttons

6.2.2.3. User Messages & Alarm Log

Click on **[Alarms] > [User Messages]** to view the user messages.

Click **[View]** under the **[Action]**, to open the **[Alarm Log]** tab.

In the **[Alarm Log]**, click **[Edit]** to mark the actions taken for that alarm notice.

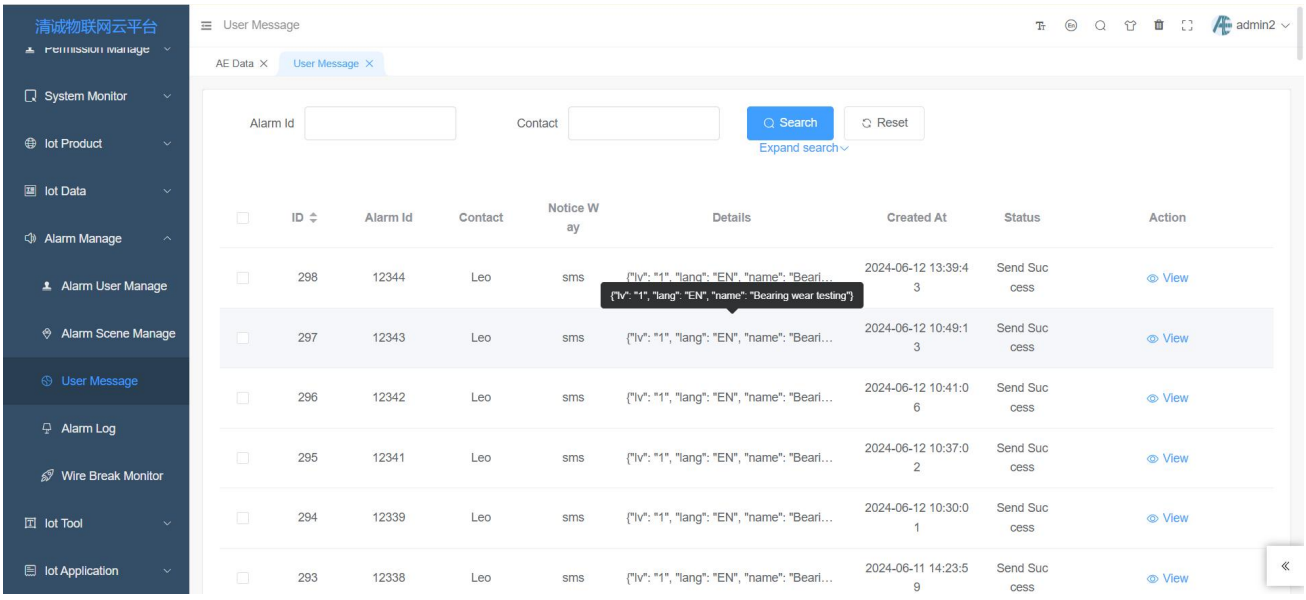


Fig. 6-28 User Messages

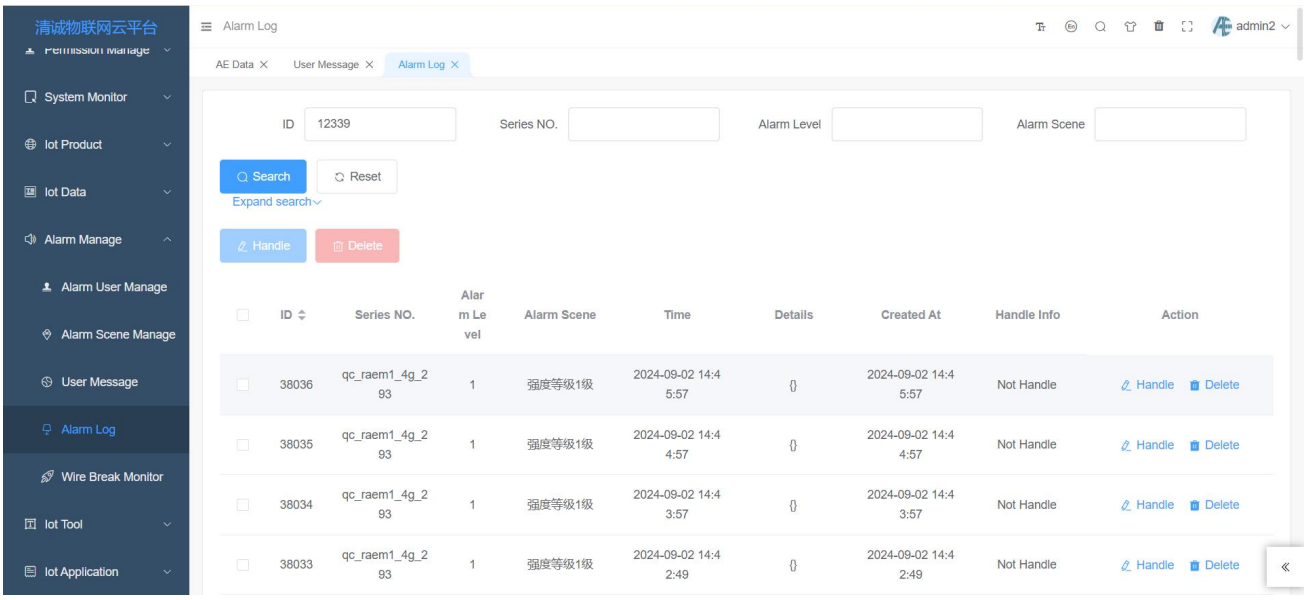


Fig. 6-29 Alarm Log

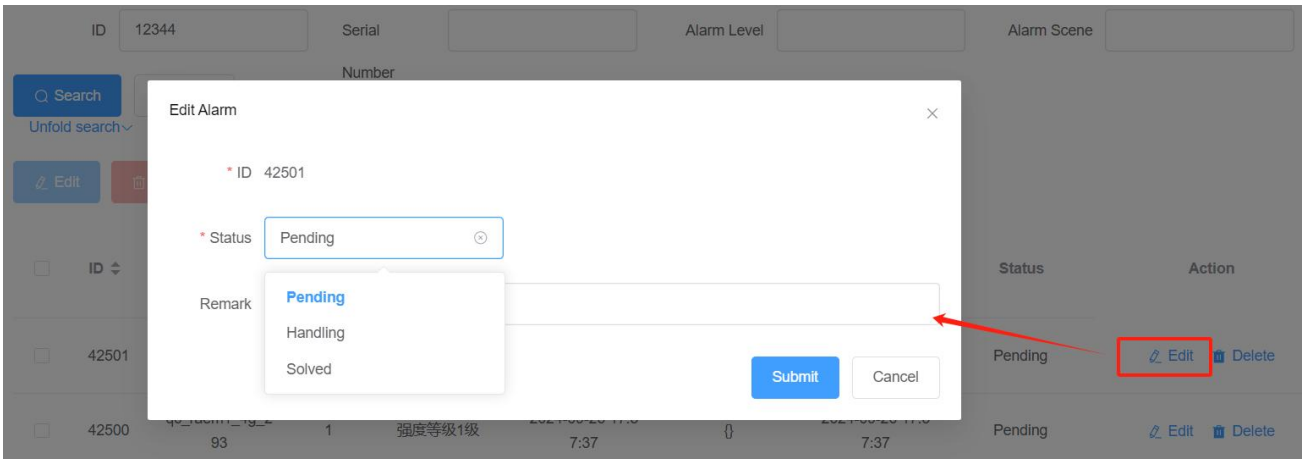


Fig. 6-30 Alarm Status Edit

6.3. IoT Tool

6.3.1. AST Test

Click on **[IoT Tool] > [AST Test]**. Choose the **[Device Group]** to list the available devices. Select the devices and then click on **[Submit]** and wait for a moment to receive the test results.

- **Get Result**: The most recent AST test results can be obtained.
- **Time interval (s)**: How many seconds should the AST test be sent once.

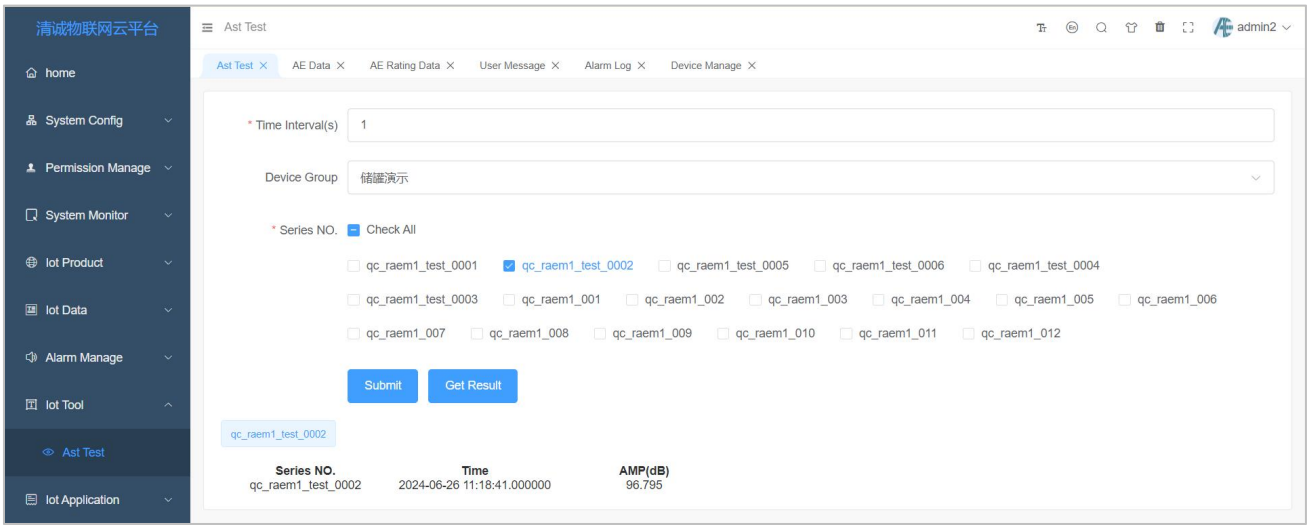


Fig. 6-31 AST Test

6.4. IoT Application

6.4.1. Storage Tank

6.4.1.1. Storage Tank Report

[IoT Application] → [Storage Tank] → [Storage Tank Report] to enter the tank inspection report page to set the scheduled inspection time and view the downloaded report.

- **Classification Settings**: Users set recommended values for acoustic emission source classifications based on the standard *"JB10764-2023 Non destructive Testing Atmospheric Pressure Metal Storage Tank Acoustic Emission Testing and Evaluation Method"*;
- **Add**: Newly added equipment for regular tank inspection, with automatic report output upon completion of the inspection;
  - **Add**: Add scheduled inspection time for storage tanks;
  - **Start Time**: Set the start time for tank detection;
  - **End Time**: Set the end time for tank detection;
  - **Delete:** Delete the scheduled detection time for storage tanks;
  - **Confirm**: Save settings.
- **Report status**: There are three optional statuses: incomplete, pending, and verified;
- **View Report**: Click to view and download this report;

- **Verify**: Review and verify newly issued reports (status as incomplete);
- **Status**: It is divided into two states: verified and pending. Newly issued reports (i.e. with a status of "incomplete") need to modify their status, otherwise they will be deleted by the system..

Operation steps:

1. **[IoT Products] → [Device Groups] → [Add]** to add a new group

2. In the new group, click **[Storage Tank Config]** and fill in basic information, sensor layout, loading sequence, and attenuation records. For specific operation steps, refer to 4.3.1.1 Device Groups;

3. **[IoT Application] → [Storage Tank] → [Storage Tank Report] → [Classifications]** Set the recommended values of acoustic emission source classification levels according to the standard JB10764-2023 Non destructive Testing Atmospheric Pressure Metal Tank Acoustic Emission Testing and Evaluation Method (click "Fill in Recommended Values" to directly fill in the standard recommended values). After setting, click **[Submit]**;

4. **[Add]** Select department, device group, and select device → **[Add]** Add tank inspection start time and end time → **[Submit]**;

5. Wait for the tank inspection to be completed;

6. Return to the tank report page, click on **[Search] ->** Find Report **-> [View Report] -> [Verify]** to change the report status to "Verified" or "Pending".

6.4.1.2. Storage Tank Data

[IoT Application] → [Storage Tank] → [Storage Tank Data] to enter the tank data page to view the rating results.

Users can select a device group to view the tank bottom plate rating results for that group.

If you are interested in other functions that are not introduced, please contact us for details.

7. SWAE Software Online Acquisition

Using our SWAE software, you can connect to the BWM1 for online data acquisition, including real-time parameter display and real-time waveform display. Install the SWAE software package and complete the software installation. Then, connect the BWM1 to the PC, configure the PC, hardware, and software settings. Once the BWM1 is running and collecting data, you can start real-time display of the collected data.

- **SWAE Software Version (Windows)**
- **Supported Online Transmission Method:** Ethernet Connection

NOTE:

✓ The BWM1 by default supports SWAE online transmission on two network segments: 192.168.0.XX and 192.168.100.XX. It is recommended to configure the computer Ethernet IPv4 address same as the two specific network segment above but with a different IP address from any of the BWM1 devices.

✓ In the configuration software, you can select "Enter IP" and then enter the computer IPv4 address. This ensures that the BWM1 will send data to that computer through Ethernet cable. Make sure that the configured BWM1 device address and the PC target IP address are on the same network segment but never have the same IP address.

Fig. 7-1 PC Target IP Address Setting in BWM1 Configuration Software

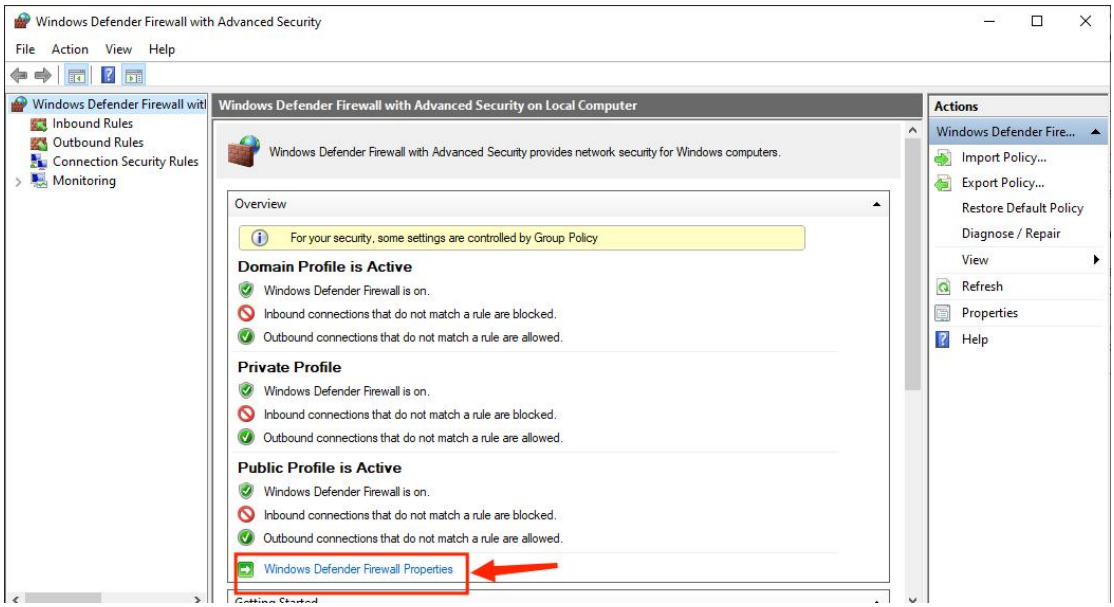
To use SWAE online data acquisition function, the firewall must be turned off:

① Open **Windows Defender Firewall with Advanced Security**.

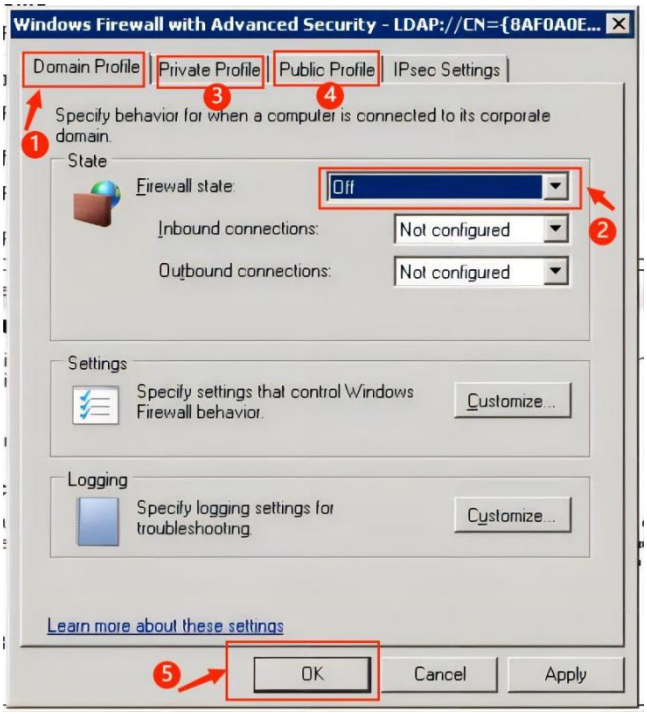
② Click **Windows Defender Firewall Properties**.

③ In the **Domain Profile** tab, change the **Firewall state** from **ON** to **OFF.**

④ Change the **Firewall state** to **Off** in the **Private Profile** and **Public Profile** tabs as well. Then click **OK** to take effect.



(a)



(b)

Fig. 7-2 Turn off Windows Defender Firewall (a & b)

7.1. Ethernet Transmission

- Refer to Section 4.1 for the device connection method.
- The default factory setting for the BWM1 IP address is 192.168.0.101 or similar IP. Therefore, when you first receive the device, you are recommended to change the computer's address to any between 192.168.0.20

and 192.168.0.30. For example, we configure the computer TCP/IPv4 address to 192.168.0.20.

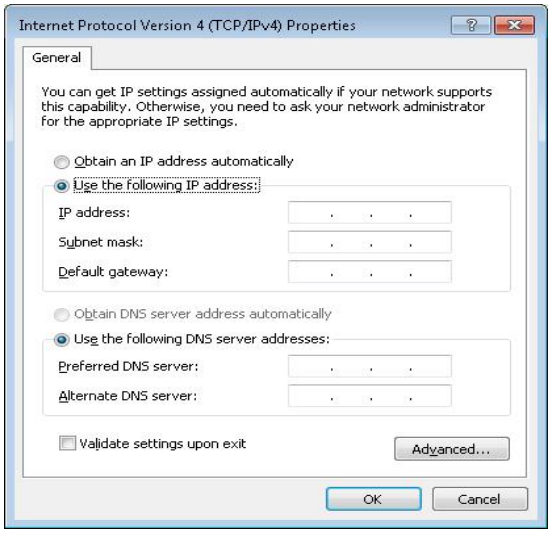


Fig. 7-3 Change Computer IP address

- In the **Storage Settings** of the BWM1 configuration software, disable **Save Wave**, **Save Param**.
- Ensure that the SWAE online transmission function of the device is enabled, and that the transmission of waveform and parameter data is enabled. Change the IP **address type** to **Enter IP** and enter the specific target IP address.

Note: Disabling local waveform and parameter saving is recommended because saving to the local SD card may slow down data transmission to SWAE, leading to data loss. As long as the transmission of waveform and parameters to SWAE is enabled, all raw data will be sent to SWAE and then saved as a U3H format file within SWAE.

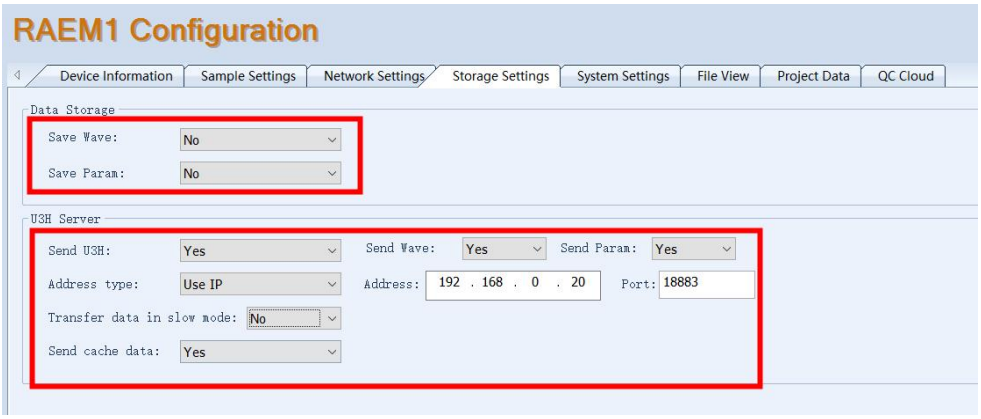


Fig. 7-4 Turn on **Send U3H**

- Turn on SWAE software, and click **Hardware and Sample** >> **Sample Setting**:

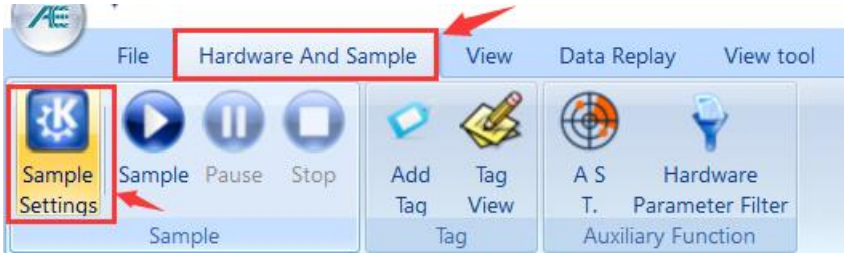


Fig. 7-5 SWAE software sample settings

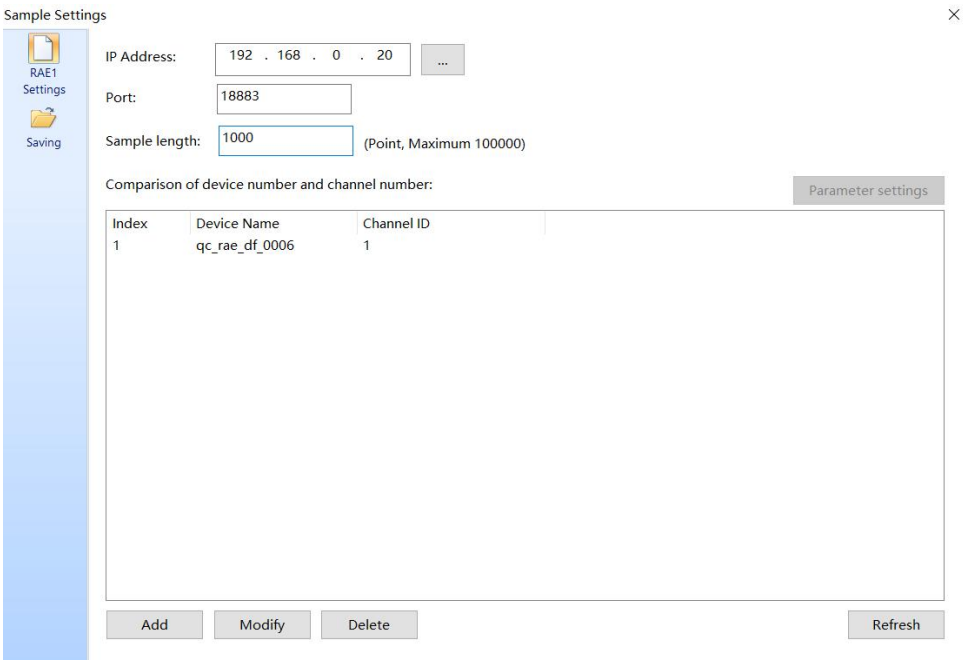


Fig. 7-6 Change Sample Settings

(1) **IP Address:** the IP address of the computer. It is set to be the same as the last step, 192.168.0.20

(2) **Port:** the default is 18883

(3) **Sampling Rate:** Consistent with the sampling rate set on the BWM1

(4) **Sampling Length:** This only affects the display in SWAE. It is recommended to set the value equal to the BWM1 sampling rate multiplied by the EET (Event End Time)

(5) Click **Add** button and set the **device number** and **channel number** in the pop-up window:

- **Device number**: enter the whole name of the BWM1

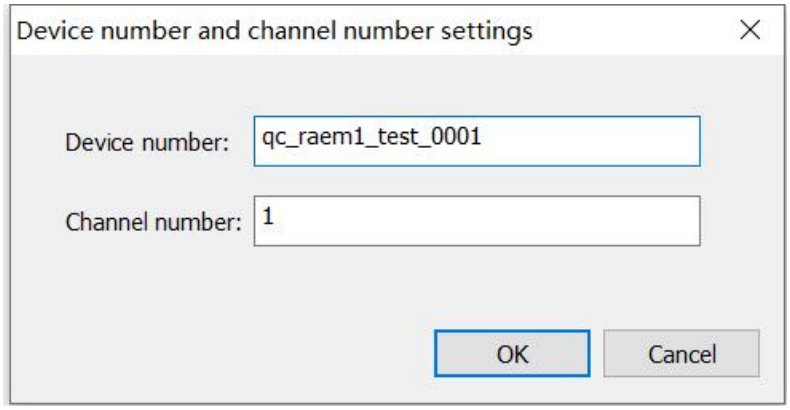


Fig. 7-7 Device number and channel number page

- **Channel number:** manually define the channel number. It can start with 1

- Click **OK** to save the changes and then click **Sample** to start data acquisition:

Fig. 7-8 Click Sample button

- **Define the data save path:** the data sent from BWM1 will be saved as U3H format (.PRA & .AED).

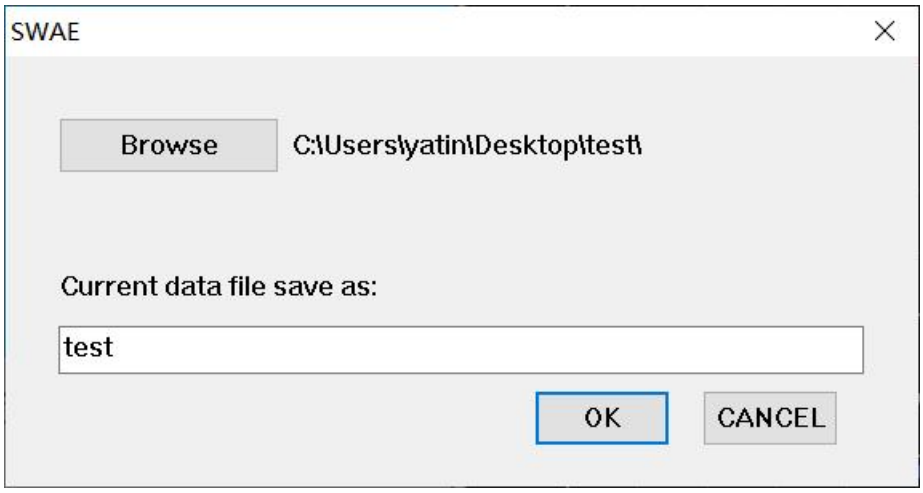


Fig. 7-9 Data save path

- After starting sampling, there will be a network matching process which might last for 1 to 30 seconds. Once the network is matched, there are parameters and waveform sending in and displaying in the software. The waveform will display first and after 3 seconds the parameters show up too.

No	Arrival time(dd:hh:mm:s...	AE cha...	Amplit...	Counts	Duration(us)	Energy(KpJ)	Rise counts
10	6:23:35:31:664 100000	1	95.2	23	1348	57142.525	1
11	6:23:35:31:667 241000	1	60.1	35	610	27.418	35
12	6:23:35:31:670 604000	1	58.9	10	239	18.840	0
13	6:23:35:35:088 760000	1	95.6	19	1456	52214.099	1
14	6:23:35:36:207 796000	1	94.2	36	1345	25639.810	0
15	6:23:35:36:871 860000	1	95.5	18	1520	58513.934	1
16	6:23:35:43:266 453000	1	95.5	27	1490	38946.721	2
17	6:23:35:44:039 742032	1	95.5	35	1397	44770.026	2
18	6:23:35:47:913 735000	1	92.8	20	952	11160.638	0
19	6:23:35:50:023 749000	1	89.2	21	1053	8872.437	1
20	6:23:35:50:999 584000	1	91.9	31	1099	14856.765	0
21	6:23:35:51:853 267000	1	94.3	30	1201	26540.397	1
22	6:23:35:52:442 258256	1	91.5	14	1054	8520.384	0
23	6:23:35:53:203 501000	1	95.0	31	1188	31687.641	2

Fig. 7-10 Data table in SWAE

- Scroll the mouse on the waveform view to switch channels:

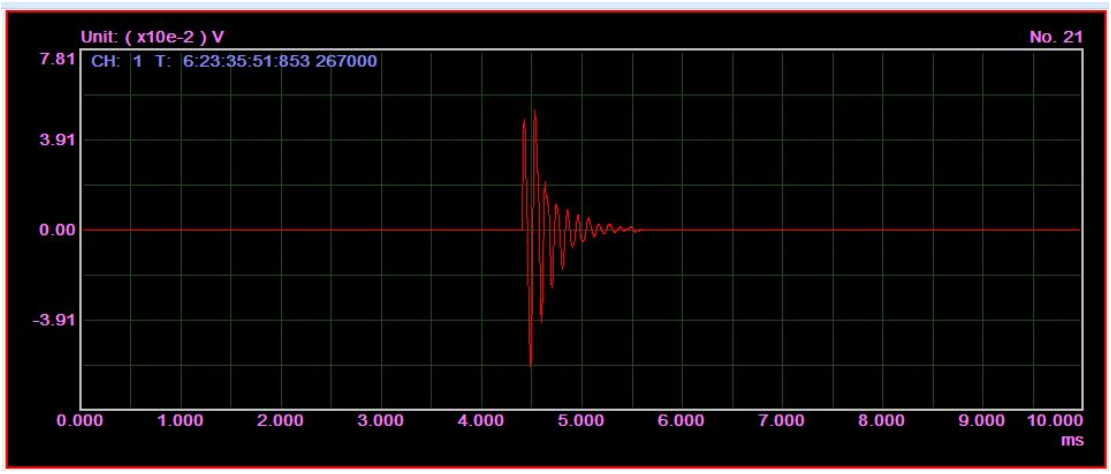


Fig. 7-11 Waveform View

7.2. Router Networking

- **Networking:** Device networking requires creating a local area network (LAN) using a switch or router. Refer to Section 4.1.2 for the connection method.
- There are two types of networks forming for multiple devices networking, **static IP** and **dynamic IP**. In **static IP** form, it must make sure each BWM1 has a different IP address; while the **dynamic IP** requires the router to assign the dynamic IP addresses.

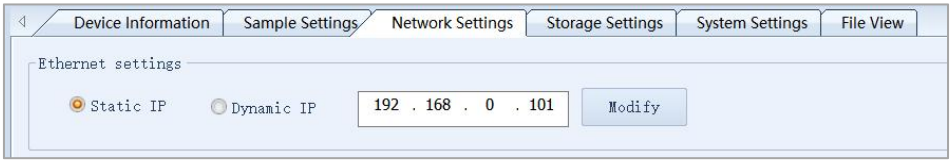


Fig. 7-12 Static IP setting

1) **Static IP networking:** in the network connection above there are three BWM1 and they can be configured as static IP:

ID	Static IP address
qc_raem1_test_0001	192.168.0.101
qc_raem1_test_0002	192.168.0.102
qc_raem1_test_0003	192.168.0.103

Table 7-1 Static IP address

2) **Dynamic IP networking:** change the settings to **Dynamic IP** and connect them to the router.

➢ In the RAEM1 Configuration software **Storage Settings** page, disable the **Data Storage** >> **Save Wave** and **Save Param** and **Upload original data.**

➢ Enable **Send U3H**, **Send Wave** and **Send Param**. Change the Address type to **Enter IP** and enter the target computer IP address. To check on the router assigned IPv4 address of the computer:

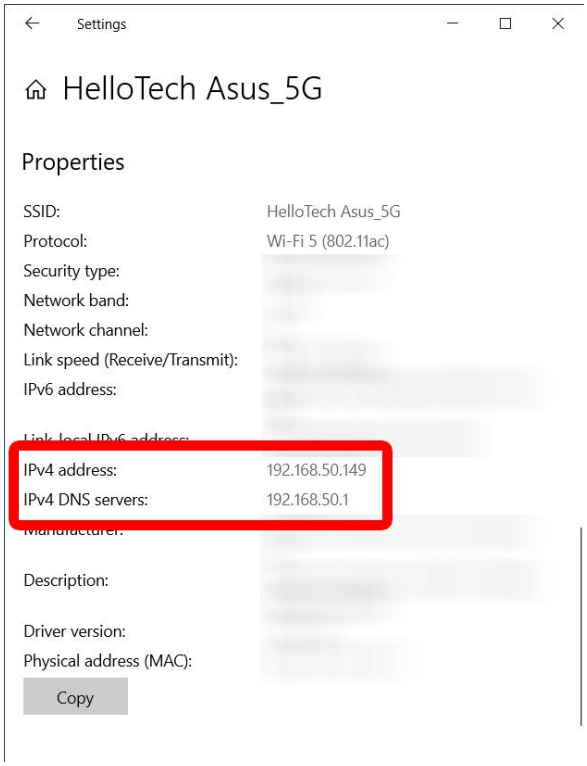


Fig. 7-13 Router Network Computer IP address

In the configuration software, set **Storage Settings** >> **IP Address** is the computer/server IP address to receive the data.

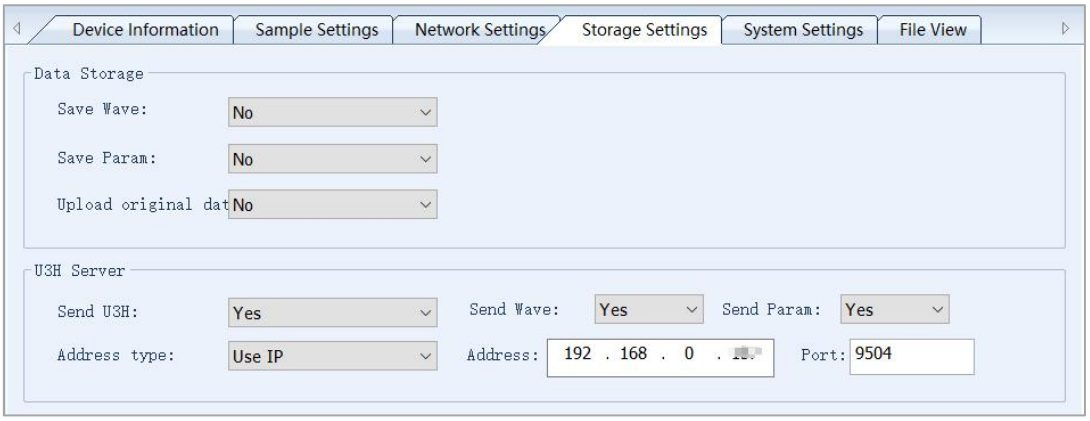


Fig. 7-14 Ethernet Multiple device networking IP setting

Note: The reason of disabling the data local SD card storage is because it may slow down the data sending to the target computer/server which could cause data lost. If the data is sent to SWAE, all the original data will be saved in U3H format files in SWAE software.

➢ Turn on SWAE software, and click **Hardware and Sample** >> **Sample Setting:**

(1) **IP Address:** the IP address of the receiving computer. It is set to be the same as the "**Enter IP**" address in the configuration software.

(2) **Port:** the default is 18883.

(3) **Sampling rate** Consistent with the sampling rate set by BWM1.

(4) **Sample length:** it only affects the display on SWAE software. It is suggested to set the value equal to RAEM1 sample rate times EET.

(5) Click **Add** button and set the **device number** and **channel number** in the pop-up window:

- **Device number**: enter the last 4 digit of the device number

- **Channel number**: manually define the channel number. It can start with 1. When adding a new channel, channel number increases by one.

(6) Click **OK** to save the changes and then click **Sample** to start data acquisition.

(7) **Define the data save path:** the data sent from BWM1 will be saved as U3H format (.PRA & .AED).

(8) After starting sampling, there will be a network matching process which might last for 1 to 30 seconds. Once the network is matched, there are parameters and waveform sending in and displaying in the software. The waveform will display first and after 3 seconds the parameters show up too.

Comparison of device number and channel number:

Index	Device Name	Channel ID
1	0001	1
2	0002	2
3	0003	3

Fig. 7-15 Channel number and device ID list

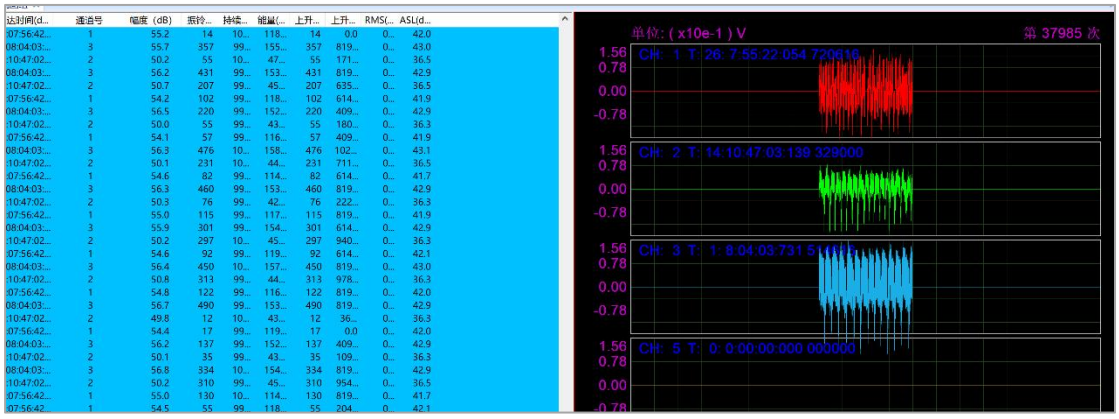


Fig. 7-16 Data Table and Waveform View

8. Data Access

There are 2 ways to access BWM1 data packages, **RAEM1 Configuration software**, and **Cloud platform**.

8.1. RAEM1 Configuration Software Access

RAEM1 Configuration software has the **File View** function to access the BWM1 data packages stored in the local storage card. It also supports the data downloads and format conversion. Please see **Section 5.6** for details.

8.2. Cloud Server Access

BWM1 supports data packet upload, storage, and download to the IoT cloud server. Generally, downloads are done through the Qingcheng IoT cloud platform.

8.3. Save Parameter and Waveform

Storage Settings: The settings on this page allow you to save data on your computer.

- **Save Wave**: When the status is set to "Yes," waveform data can be saved on the computer.
- **Save Param:** When the status is set to "Yes," parameter data can be saved on the computer.

For details on data transmission to the cloud server, please refer to sections 7.1 or 7.2.

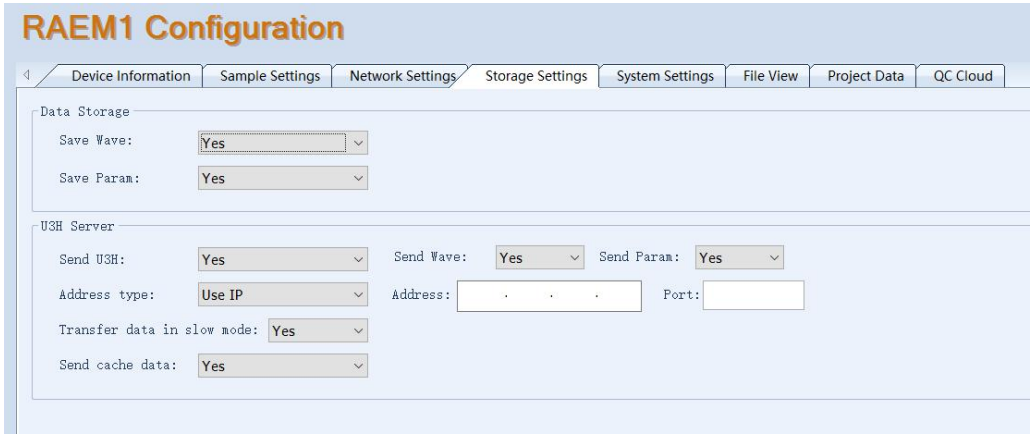


Fig. 8-1 BWM1 saves parameter and waveform data on the computer

9. Data Analysis

BWM1 data needs data format conversions to be able to display and be analyzed in Qingcheng SWAE software and the third-party analysis software. Currently there is no BWM1 analysis software available yet.

The data packs generated from BWM1 can be converted into the SWAE software readable formats using Qingcheng's **RAE1toU3H** software. It can also be opened through **RAEM1 Configuration software** >> **File Convert** button at the left bottom corner. The **File View** tab of the **RAEM1 Configuration software** also can download and convert the data. Please see Section 4.6 for detail.

The converted files (.PRA & .AED) can be replayed and analyzed in SWAE software. Please contact Qawrums Ltd. for the user's manual of SWAE software for detail. The conversion software also supports CSV format conversion which can be then imported and analyzed in the third-party software. Multiple BWM1 data conversion is also supported in this software.

After downloading the data using the **RAEM1 configuration software**, you can use the **RAE1toU3H software** to perform file conversion or merging operations. The converted data formats are **.pra** and **.aed** files. (Note: The software supports converting multiple **.pra** and **.aed** files together. Store all downloaded **.pra** and **.aed** files in one folder. If multiple **BWM1** units are converted into multiple channels, place the **.pra** and **.aed** files of each **BWM1** in a separate folder.)

The conversion steps of **RAE1toU3H** software:

1) Download the data packages. The downloaded packages are individual compressed zip packages. The software supports multiple zip packages conversion. Save all the zip packs in a file folder. If there are multiple data packs, save the compressed packages of each devices/channels in each separated file folder.

2) Open **RAE1toU3H.exe**. It can also be opened through **RAEM1 Configuration software** >> **File Convert** button at the bottom left corner. See Figure 9-1.

3) In the **RAE1toU3H** interface, click **Add directory** to add the folders to be converted. Each folder directory will be converted to one individual channel. Double click to modify the **channel ID**. Right click to delete the selected or all the file directories. Check the box to indicate that **File is in compressed format**. Choose the save directory. Make sure the sampling rate is the same as the BWM1 sampling rate. Click **Convert U3H** button to start

conversion.

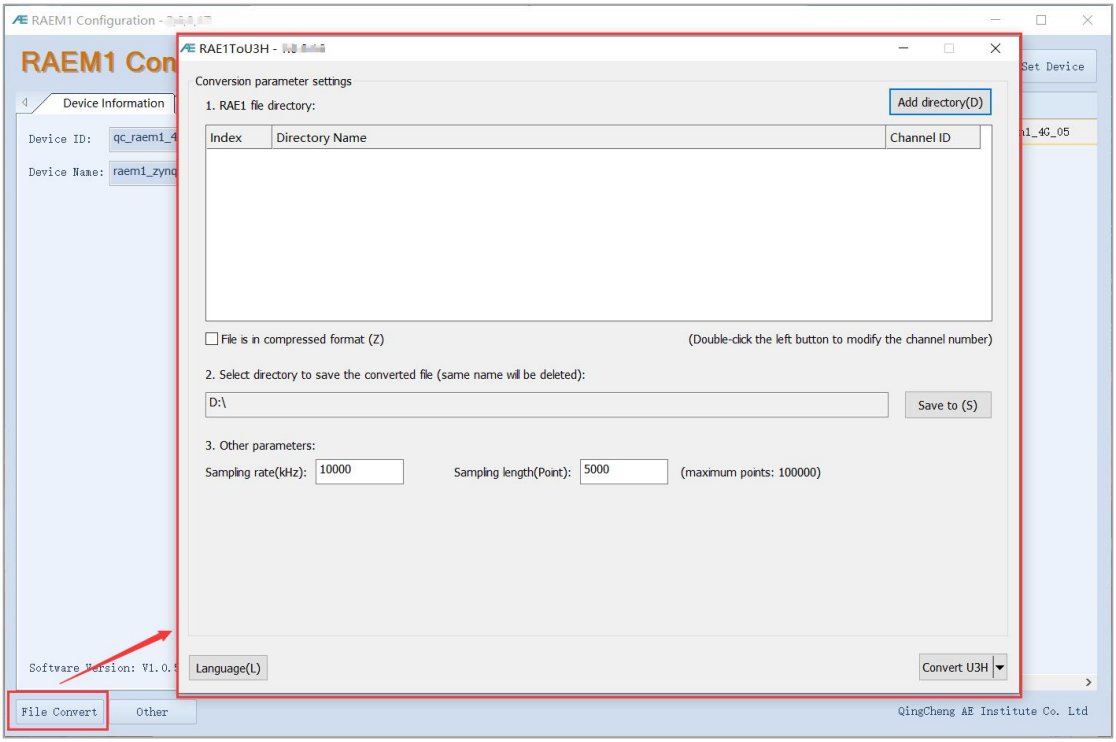


Fig. 9-1 Open **RAE1ToU3H**

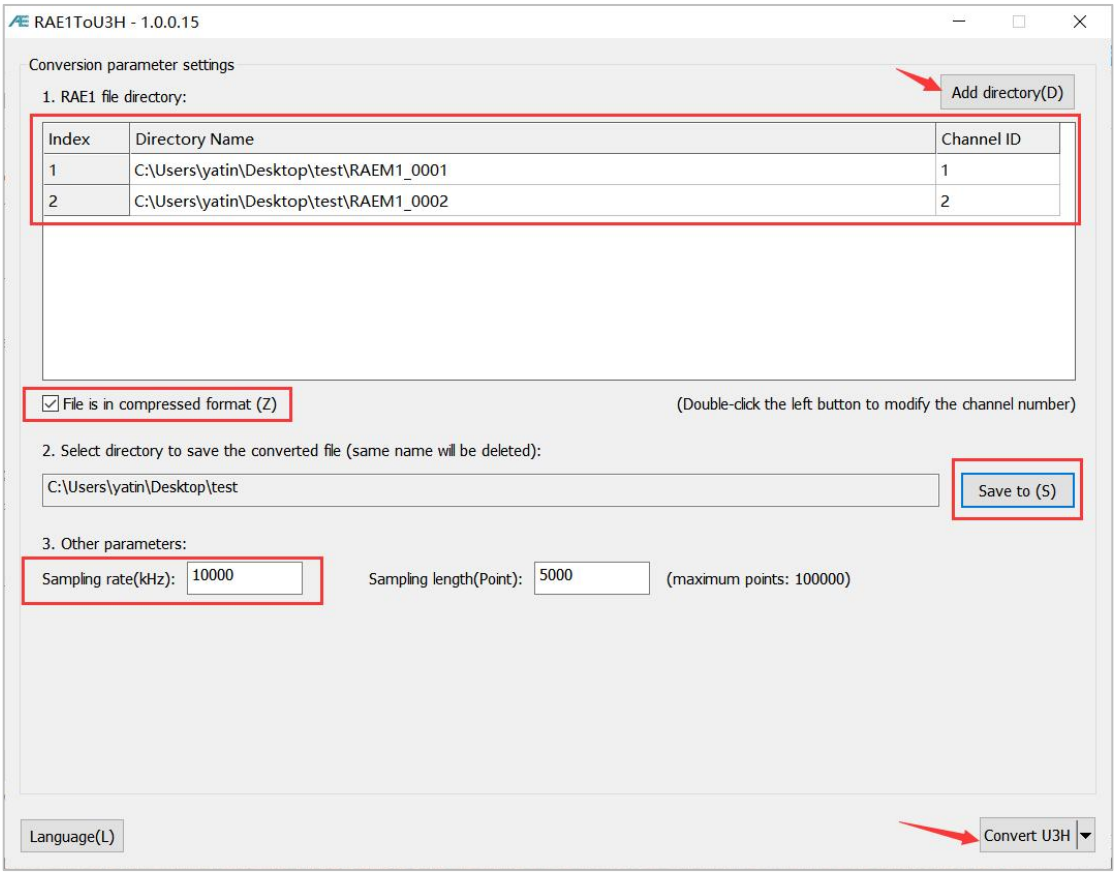


Fig. 9-2 RAE1ToU3H Interface

4) Once it starts conversion, there is a pop-up window to show the conversion process. After the conversion is done, it should look like below. Click **OK** to close the window.

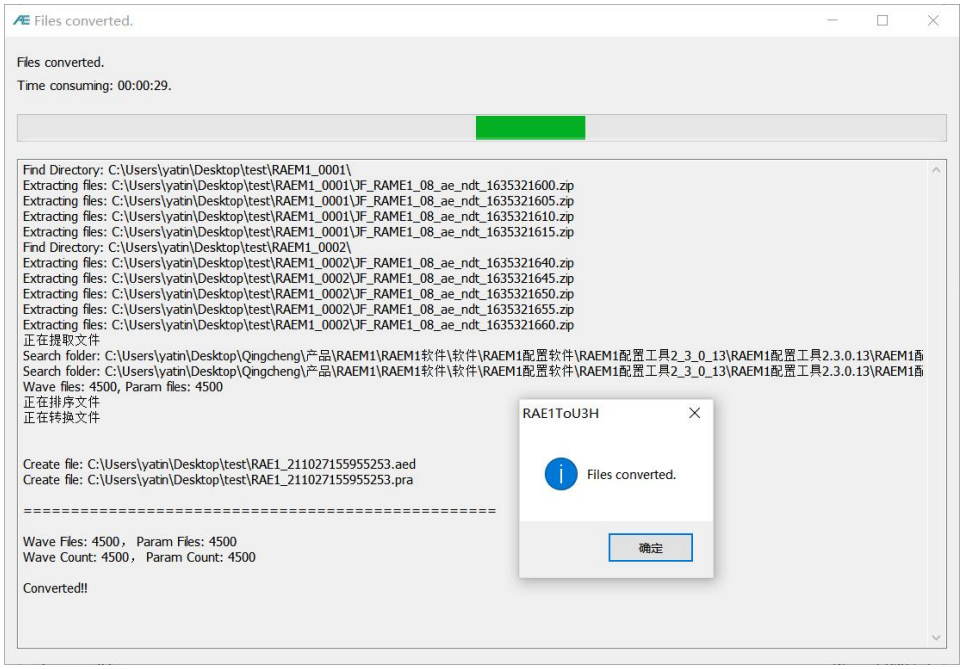


Fig. 9-3 RAE1ToU3H Conversion Window

5) In the target save directory, there will be two corresponding U3H format files, **PRA** and **AED** files respectively. They can be opened and replayed in SWAE software for data analysis.

Fig. 9-4 Convert to U3H Files

6) If CSV format is wanted, click the ▼ button next to the **Convert U3H** button. After conversion, there should be corresponding CSV files in the target directory. They should have **RAE1** prefixes. If there are more than 800,000 rows in a CSV file, it will automatically generate another new CSV file. In the result CSV files, the first column is timestamp, and the second column is the voltage values of each waveform sampling points.

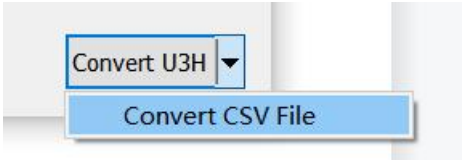
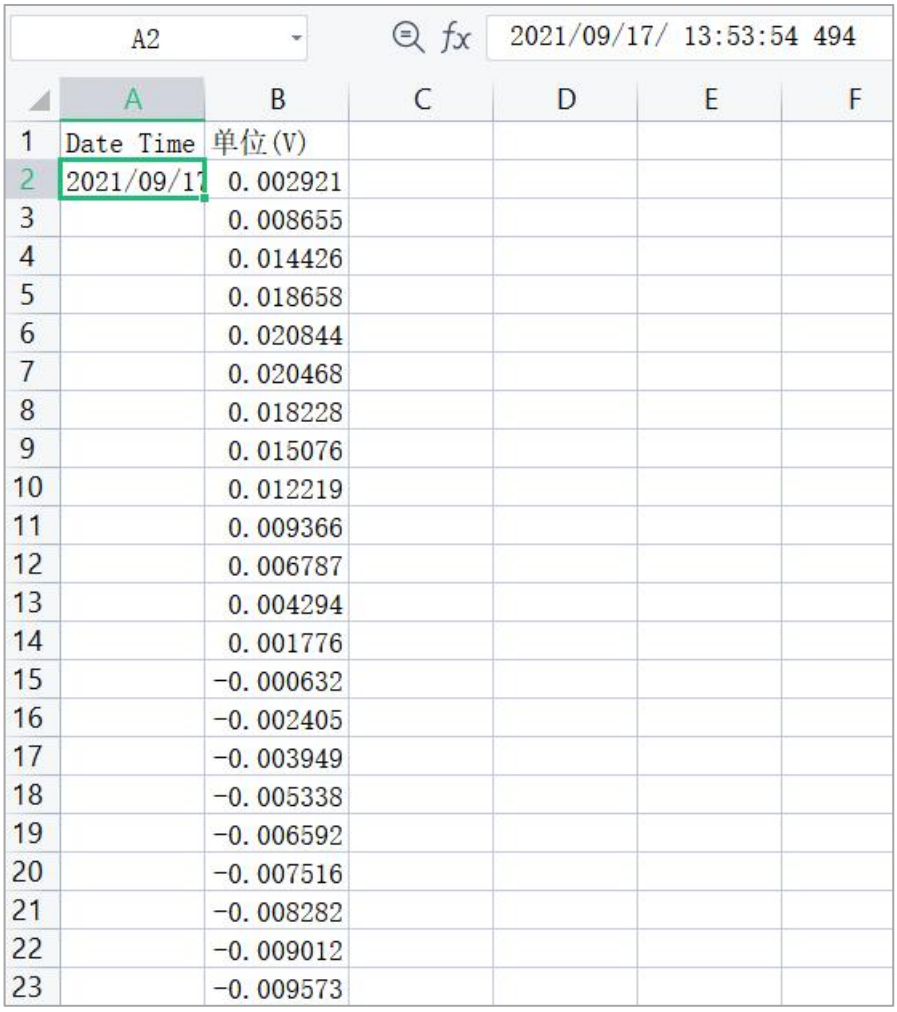


Fig. 9-5 RAE1ToU3H Convert to CSV format

名称	修改日期	类型	大小
qc_raem1_test_06_ae_ndt_16318580...	2021/9/17 14:01	WinRAR ZIP 压缩...	995 KB
qc_raem1_test_06_ae_ndt_16318581...	2021/9/17 14:01	WinRAR ZIP 压缩...	2,057 KB
qc_raem1_test_06_ae_ndt_16318581...	2021/9/17 14:01	WinRAR ZIP 压缩...	2,053 KB
qc_raem1_test_06_ae_ndt_16318582...	2021/9/17 14:01	WinRAR ZIP 压缩...	2,053 KB
qc_raem1_test_06_ae_ndt_16318582...	2021/9/17 14:01	WinRAR ZIP 压缩...	2,052 KB
RAE1_210917135354494.csv	2021/10/13 17:39	XLS 工作表	49,993 KB

Fig. 9-6 Result CSV file in the target directory



A2 fx 2021/09/17/ 13:53:54 494

	A	B	C	D	E	F
1	Date Time	单位(V)				
2	2021/09/17	0.002921				
3		0.008655				
4		0.014426				
5		0.018658				
6		0.020844				
7		0.020468				
8		0.018228				
9		0.015076				
10		0.012219				
11		0.009366				
12		0.006787				
13		0.004294				
14		0.001776				
15		-0.000632				
16		-0.002405				
17		-0.003949				
18		-0.005338				
19		-0.006592				
20		-0.007516				
21		-0.008282				
22		-0.009012				
23		-0.009573				

Fig. 9-7 CSV File Layout

10. Transmission Protocols for Third Party Development

BWM1 device can provide **local TCP** interfaces for third party development. Some protocol details are shown below:

10.1. TCP Integration Protocol and U3H mode

Using the TCP protocol, it outputs all AE hit parameters with the highest amplitude within the **Reporting Time Interval**.

U3H mode outputs all AE hit parameters and waveforms.

10.1.1. TCP Mode v2 Network Attributes

- **Address**: configurable, choose **Use IP** and enter the server IP address and port.
- **Port:** configurable.
- **Communication Protocol:** TCP protocol
- **Endianness:** Little Endian

10.1.2. TCP Mode v2 Parameter Transmission

The TCP mode v2 supports parameter transmission. It needs to select **Tcp Mode v2** under **Project Data** in **RAEM1 Configuration software**.

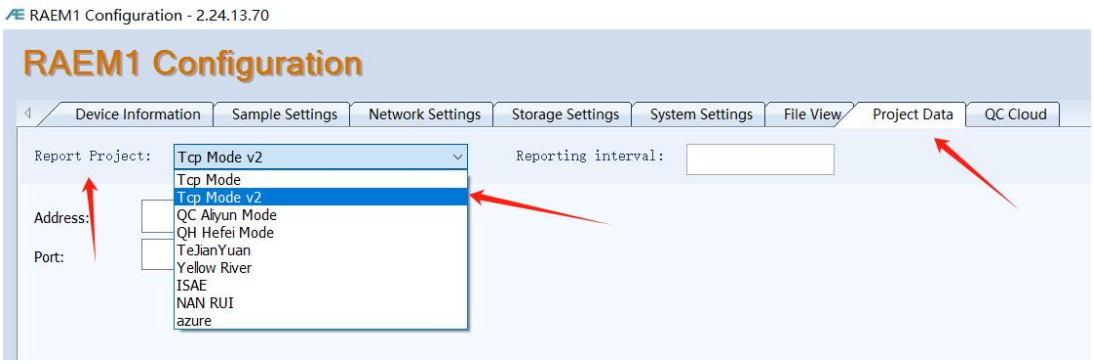


Fig. 10-1 RAEM1 Configuration software TCP Mode v2 function

The structure of the sent protocol is as follows:

Device ID
Amplitude, in dB
ASL, in dB
Power, in KpJ
RMS, in mV
Rise time, in μs
Rise counts
Counts
Duration, in μs
Report time. It includes a timestamp before the decimal point and the microseconds (μs) portion after the decimal point.

10.1.3. U3H Mode Parameter Transmission

The device supports parameter transmission. It needs to turn on the **Send Param** to **U3H serve**r function in **RAEM1 Configuration software**.

Fig. 10-2 RAEM1 Configuration software **Send Param** function

The protocol format is:

Protocol Header	Device ID	Data Type	Data Length	Data

- **Protocol Header:** 4 bytes, fixed, 0xA5A5A5A5
- **Device ID:** 4 bytes, the last 4 digits of the device ID
- **Data Type:** 4 bytes, 0x00000000 is parameter data
- **Data Length:** 4 bytes, length of the data content
- **Data Content:** parameters

The parameters data format is as followed:

Protocol Version	4 bytes
Arrival time (second)	unsigned int, 4 bytes
Arrival time (micro-second)	unsigned int, 4 bytes
AMP (dB)	Double, 8 bytes
Power (KpJ)	Double, 8 bytes
RMS (mV)	Double, 8 bytes
ASL (dB)	Double, 8 bytes
Rise time (us)	unsigned int, 4 bytes
Rise counts	unsigned int, 4 bytes
Duration (us)	unsigned int, 4 bytes
Counts	unsigned int, 4 bytes

10.1.4. U3H Mode Waveform Transmission

The device supports waveform transmission. It needs to turn on the **Send Wave** to **U3H server** function in **RAEM1 Configuration software**.

Fig. 10-3 RAEM1 Configuration software **Send Wave** function

The protocol format is:

Protocol Header	Device ID	Data Type	Data Length	Data

- **Protocol Header:** 4 bytes, fixed, 0xA5A5A5A5
- **Device ID:** 4 bytes, the last 4 digits of the device ID
- **Data Type:** 4 bytes, 0x00000001 is waveform data

- **Data Length:** 4 bytes, length of the data content
- **Data Content:** waveform

The waveform data contents format is:

Arrival time (second)	unsigned int, 4 bytes
Arrival time (micro-second)	unsigned int, 4 bytes
Protocol Version	4 bytes
Waveform points	unsigned int, 4 bytes
Sample speed (K/S)	unsigned int, 4 bytes
Gain, preamplifier, in unit of times	unsigned int, 4 bytes
Enlarge, circuit magnification, in unit of times	Double, 8 bytes
N numbers of waveform data	Each waveform has 2 bytes, i.e., there are 2N numbers of waveform data with 2N bytes of data size.