INSTRUCTION MANUAL

SAEU3H Digital AE Testing System

QingCheng AE Institute (Guangzhou) Co., Ltd

Version: 2.0.1

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This manual is a general manual of SAEU3H series digital acoustic emission testing system. The description of some functions is only applicable to the products with this function. Please refer to the function of purchased products to use this manual.

The contents of this manual will be updated regularly according to the requirements. You can download the latest version of the manual from Qingcheng science and technology website at: https://www.aendt.com

QingCheng AE Institute (Guangzhou) Co., Ltd

May, 2023

Content

Preface

Overview of SAEU3H acoustic emission system

With the continuous development of communication interface between computer and peripherals, data communication technology is constantly updated in the instruments with computer as data processing and display equipment. PCI bus interface data acquisition system based on desktop PC used to be the most widely used data acquisition system, but now it has been replaced by high-performance USB communication interface data acquisition system of desktop or notebook PC. Qingcheng AE Institute (Guangzhou) Co., Ltd.(Previous company name: Beijing Soundwel), launched the first SAEU2S series of acoustic emission system based on USB2.0 in 2007, which increased the actual data passing rate of the acoustic emission system to more than 30MB / s, and the parameter passing rate exceeded 400000 groups / s, Acoustic emission system far surpasses other data communication interface, and brings the development trend of acoustic emission system USB; with USB communication stepping into the era of 3.0, SAEU3H digital acoustic emission detection system is also produced, realizing ultra-high speed data transmission. The maximum real-time continuous passing rate of single USB3.0 interface connecting computer is higher than 300MB / s, which can meet the characteristic parameters of 3 million groups / second acquisition or 300MB / s continuous waveform acquisition. The SAEU3H digital acoustic emission detection system can be applied to a wider range of application scenarios by adopting a brand-new 4-channel / board acoustic emission acquisition board, a new aluminum alloy chassis, enhanced software processing capacity, multiple data acquisition modes, full wave acoustic emission signal processing and other functions.

Basic Composition Mode

SAEU3H series digital acoustic emission detection system is composed of several

parallel detection channels, each channel is composed of similar measurement components, signal processing units, calculation programs and complete peripheral components, and is composed of powerful computers. Each channel measuring component mentioned here includes acoustic emission sensor, preamplifier and acquisition board.

SAEU3H digital acoustic emission detection system can sample and display acoustic emission waveform and parameter signal in real time, so it can fully meet various application requirements of field and laboratory (based on waveform data analysis and characteristic parameter analysis). Due to the ability to sample and record all the original acoustic emission waveform, users can use other signal processing and analysis tools for further research, including defining more targeted AE parameters, wavelet spectrum analysis, etc. Of course, SWAE software can also be used to reasonably sample and process the waveform and parameter data of AE signals in the early stage.

The acoustic emission acquisition board of SAEU3H digital acoustic emission detection system is installed in a special independent main box, which can transmit the data to the computer equipped with special software for display and storage by using USB3.0, LAN, Wi-Fi, optical fiber and other communication modes.

Characteristic:

- The host machine consists of several SAEU3H acoustic emission acquisition boards and special case;

- The main cabinet is independent of the computer and can be connected through USB3.0, LAN, Wi-Fi, optical fiber, etc.;

- The main box can supply power independently without mutual interference with the computer, which makes the operation more stable and low noise;

- The acquisition board is far away from the computer, and the electromagnetic interference from the computer is reduced;

- The maximum data transmission rate of 600MB / s continuous waveform data and 1.2 million sets / s continuous characteristic parameter data can be realized;

- Program controlled optional analog filter and program-controlled digital filter with arbitrary settings have powerful functions

Characteristics of Acquisition Board

- Each board has 4 independent channels, each channel is 10MHz, with 16bit precision;

- Each channel has 3 kinds of high pass and 3 kinds of low-pass filters, model. Butterworth, or user-defined combination mode;

- The range of multi -gear input is adjustable, ± 10V, ± 5V, ± 2V, ± 1V, ± 0.1V, and the channel can be set independently

- The real-time acoustic emission waveform acquisition and feature parameter extraction;

- It is equipped with front position indicator and signal threshold indicator;

- Each channel has 1GB on-board memory;

Acoustic Emission Sampling/Analysis Software

- The latest versions of 64-bit win7, win8 and win10 are supported;

- It can install multiple computers at the same time without limiting the number of users;

- It can carry out linear, plane, cylindrical, spherical, cube Location, column Location and tank bottom Location;

- The continuous sampling rate can be set;

- The digital filtering modes such as band-pass, high pass, low-pass and band stop can be selected, and the filtering frequency band can be set arbitrarily;

- The data format can be converted into TXT, Excel format and output;

- The driver and dynamic library can be provided to users, which is convenient for secondary development of software.

Part 1 Acoustic Emission Hardware

1. Technical Background

1.1. Brief Introduction of Acoustic Emission

Acoustic emission (AE) is the phenomenon of transient elastic wave generated by the rapid release of energy from local sources in materials, sometimes also known as stress wave emission. The detection method by receiving and analyzing the acoustic emission signal to evaluate the material performance or structural integrity is called acoustic emission testing technology. 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 wave emitted from the acoustic emission source finally propagates 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 signal, the mechanism by which materials produce acoustic emission is understood.
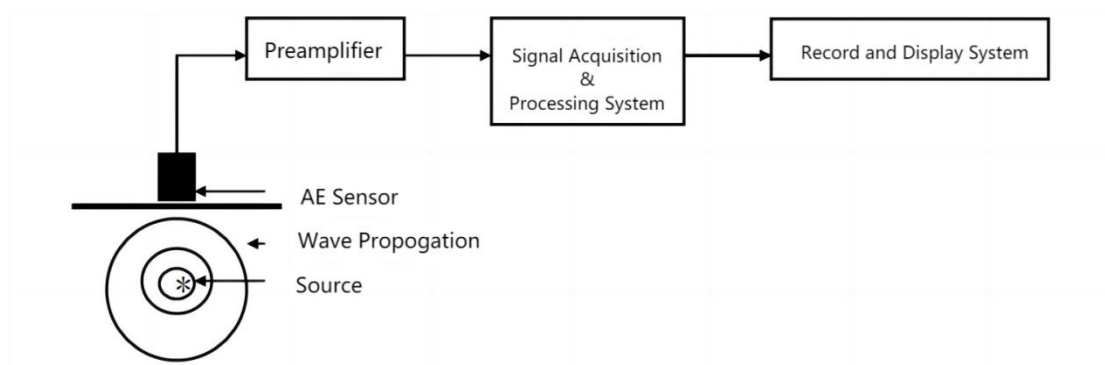
Fig. 1-1 Block diagram of acoustic emission testing principle

1.2. Main Purpose of Acoustic Emission Testing

- The location of acoustic emission source shall be determined

- Analyze the properties of acoustic emission source

- Determine the time and load of AE occurrence

- Assess the severity of acoustic emission sources

1.3. Characteristics of Acoustic Emission Testing

The discovery of each AE source means 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 defects under external structural stress;

- It can detect and evaluate the state of defects in the whole structure;

- The system can provide real-time or continuous information of defects changing with external variables such as load;

- The requirement of approaching the detected object is not high;

- It can be used for the inspection of pressure vessels in service;

- When used in pressure test of pressure vessel, 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 hidden defects, even hidden defects in some parts of the structure that cannot be touched, the spread of damage can be prevented. This is the main function of AE detection / monitoring.

1.4. Application of Acoustic Emission Technology

- At present, 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 Processing

  - The transportation industry

2. Acoustic Emission Terminology

2.1. Technical Terms of Acoustic Emission Technology

1. Duration of acoustic emission signal: the time interval between the beginning and ending of acoustic emission signal;

2. Acoustic emission signal termination point: the identification end point of acoustic emission signal, which is usually defined as the last intersection point between the signal and the threshold;

3. Rise time: the time interval between the starting point of AE signal and the peak value of AE signal;

4. Starting point of AE signal: the starting point of AE signal recognized by the system processor, usually defined by an amplitude exceeding the threshold;

5. Sensor array: a combination of two or more sensors placed on a component to detect and determine the internal position of the array;

6. Attenuation: the decrease of AE amplitude per unit distance, usually expressed in decibels per unit distance;

7. Average signal level (ASL): acoustic emission logarithmic signal with time average after rectification. The amplitude of acoustic emission is measured with logarithmic scale, expressed in unit of dB. At the input of preamplifier, 0dB = 1uV;

8. Acoustic emission channel: a system consisting of a sensor, preamplifier or impedance matching transformer, filter, secondary amplifier, connecting cable and signal detector or processor;

9. Acoustic emission counts (counts): also known as ringing counts. In the selected detection interval, the number of times the AE signal exceeds the preset threshold;

10. Event count: calculate the value of each distinguishable AE event one by one;

11. Couplant: the material filled between the contact surface of the sensor and the test piece, which can improve the ability of sound energy passing through the interface in the process of acoustic emission monitoring;

12. Decibel (dB): logarithmic measurement value of AE signal amplitude with reference to 1uV, dB = 20lg (A / 1uV), where A is the amplitude voltage value of the measured AE signal;

13. 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;

14. Effective sound velocity: the sound velocity calculated on the basis of arrival time and distance determined by artificial acoustic emission signal, used for Location calculation;

15. Burst acoustic emission: qualitative description of the discrete signals related to an independent acoustic emission event in the material;

16. Continuous acoustic emission: a qualitative description of the continuous signal level produced by the rapid occurrence of acoustic emission events;

17. Acoustic emission event energy: elastic energy released by acoustic emission event;

18. Evaluation threshold: the threshold value for monitoring data analysis;

19. Acoustic emission event: local material change causing acoustic emission phenomenon;

20. Monitoring area: part of the structure monitored by acoustic emission;

21. Detection range: the part of the test object evaluated by acoustic emission technology;

22. Felicity effect: under the condition of fixed preset sensitivity level lower than the

last time stress level, detectable acoustic emission signal appears;

23. Felicity ratio: the ratio of the stress at the time of felicity effect to the maximum stress applied last time;

24. Floating threshold: a dynamic threshold established by the time average of the amplitude of the input signal;

25. Hit: any signal that exceeds the threshold and causes a system channel to sample data;

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

2.2. Product Terms of SAEU3H AE System

1．Channel: a channel through which the acoustic emission signal enters the acquisition board 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 by exponential mode chip; 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 16bit sampling accuracy represents that the voltage of 20V is divided into $2^{(16)}$ units, that is, the step is about 0.305mV. The higher the accuracy, the higher the resolution of the signal;

4．USB3.0: a kind of USB communication protocol. The maximum theoretical transmission bandwidth of USB3.0 is 5.0Gbps (640MB/s);

5．TCP/IP: also known as network communication protocol, a data transmission protocol widely used by computers;

6．Communication board: it refers to the SAEU3H communication board. The communication board is inserted into the chassis, and the network cable can be used to connect the equipment and the upper computer;

7．AST: automatic sensor testing, which refers to the technology that the sensor transmits pulse mechanical signals under voltage excitation and they are received by the adjacent sensors to evaluate the sensitivity of adjacent sensors;

8．AD/C: analog to digital conversion, that is, analog voltage signal is converted into digital signal;

9．DDR2: refers to the data cache board specification used by the SAEU3H acquisition board;

10．Analog filter: filters in the analog circuit. Before AD/C, this product uses 4th order Butterworth analog filter;

11．Preamplifier: amplify the weak voltage signal output from the sensor and do impedance transformation, so as to adapt to the electronic amplification circuit of signal long-distance transmission and output analog signal;

12．Coaxial cable: the signal cable that transmits the preamplifier 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 Ohms.

3. Hardware of SAEU3H AE System

3.1. Composition of SAEU3H Acoustic Emission System

Fig. 3-1 SAEU3H digital acoustic emission testing system

A complete SAEU3H system is composed of a certain number of AE acquisition boards including 4 channels each, SAEU3H Chassis, AE sensor, preamplifier, coaxial cable and upper computer; the standard configuration of AE instrument host has 10M/s sampling rate per channel, 16-bit sampling accuracy, low system noise and high dynamic range acquisition board, and each acquisition board is provided with 1GB waveform buffer. It can perfectly realize full waveform acquisition without losing data.

SAEU3H acoustic emission system uses USB3.0 (or TCI/IP, optical fiber) communication mode to connect the acoustic emission host computer and the upper computer, with a data passing rate of up to 600MB/S; multiple acoustic emission hosts of the same model can be cascaded through standard HDMI data lines, thus forming a super large system with more than 100 channels; SAEU3H system has strong data acquisition and data processing capabilities, which is suitable for The vast majority of industrial testing sites, as well as laboratory research with high requirements for waveform data.

3.2. SAEU3H Acoustic Emission Acquisition Board

3.2.1. Signal data link

The signal processing flow of each channel is roughly as follows: after the signal is received by the front-end sensor and amplified by the preamplifier, it is connected to the channel interface through the coaxial cable and enters the acquisition board. The signal is modulated to ± 10V, ± 5V, ± 2V, ± 1V, ± 0.1V by the gain of the acquisition board set by software. The adjusted voltage signal enters the analog filter. The whole analog filter circuit consists of three high-pass and three low-pass filters. It is composed of the 4-order Butterworth filters with 9 filtering bands that can be set by software. After filtering, the signal enters into A/D conversion chip. The A/D chip is of 10M 16-bit specification, and the sampling rate can be set by software to convert voltage signals into digital signals; the converted digital signal enters FPGA chip for data processing; the high-speed FPGA chip is equivalent to the CPU of computer. The signal is processed by a large number of calculations, such as digital filters, calculation of characteristic parameters, FFT calculation, spectrum parameter calculation, etc. The calculated data enters the communication motherboard through the motherboard slot, and then integrates the data, which is transmitted to the computer by the communication chip of the motherboard through USB3.0 or the network interface of the communication board.
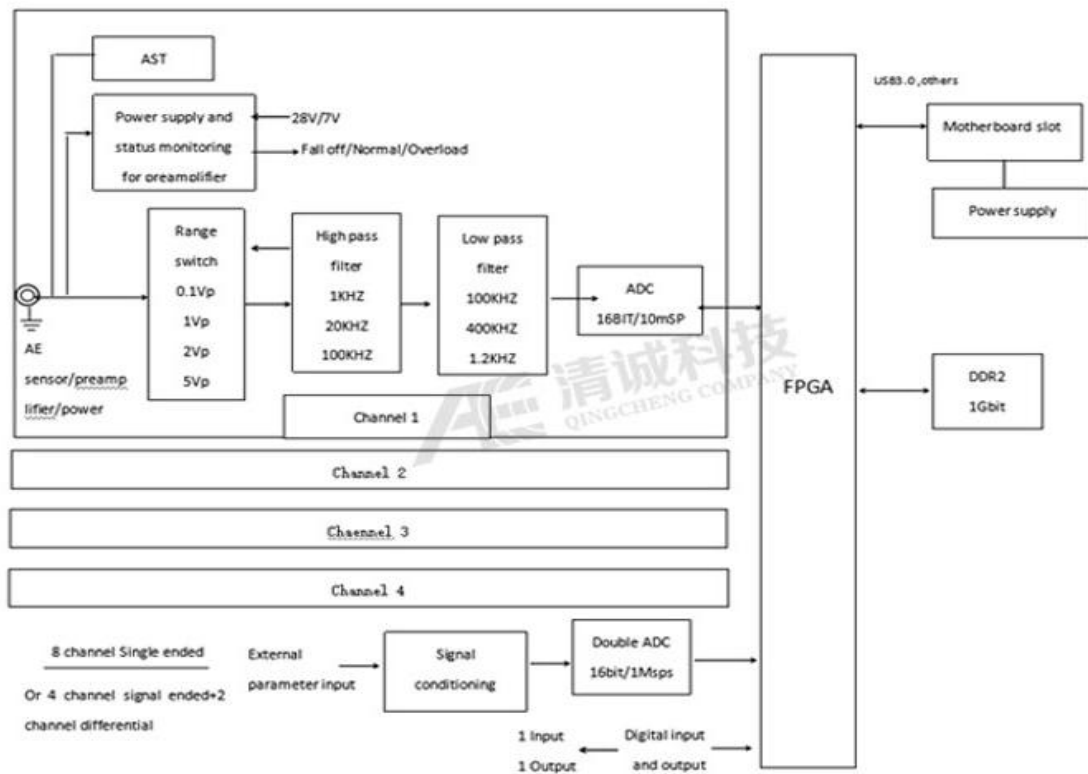
Fig. 3-2 Structure Diagram of SAEU3H acquisition board
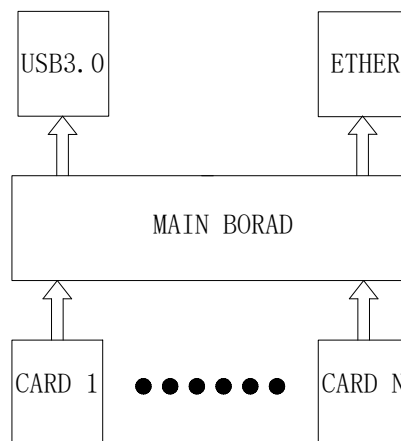
Fig. 3-3 Data Link Diagram

3.2.2. Technical Specifications of Acquisition Board

SAEU3H acquisition board adopts the design of 4 channels per board, each channel has 10M/s, 16-bit independent ADC, high-speed FPGA chip signal processing, 1GB independent cache board, to ensure that data is not lost; unique hardware real-time digital filter, can arbitrarily control the signal bandwidth; SAEU3H acquisition technical

specifications are shown in Table 3-1:

Table 3-1 SAEU3H Acquisition Board Specifications

| Sampling Specs:	
Sampling Rate	Each channel maximum sampling rate of 10MSP/second, the sampling rate is continuously adjustable, each channel can be set independently
Sampling Accuracy	16 bits
Dynamic Range	85dB
Noise Level	<15dB (No load)
Maximum Signal Amplitude	100dB (40dB gain, corresponding to the sensor output of 100mV)
Waveform Sampling Length	The maximum single waveform sampling length, each channel can be up to 128k sampling points; the channel can be set independently
Trigger Mode	Threshold trigger, time trigger, external trigger, manual trigger
Analog Filter	20kHz, 100kHz, 400kHz three high-pass filters; 100kHz, 400kHz, 1200kHz three low-pass filters; choose any combination in the software; each channel is independent
Hardware Real-time Digital Filter	From 1KHz-2.5MHz frequency range, any value can be set as the pass-through, high-pass, low-pass, band-pass or band-stop filter.
AE Module Memory Capacity	1Gb each AE acquisition board
AE Signal Processing	Each acquisition board hardware has AE feature parameters real-time extraction function; the channel can be set independently
Waveform Pre-sample Function	Pre-sample length can be up to 128k sampling points. The channel can be set independently
AE Feature Parameters	Arrival time, amplitude, counts, duration, energy, rise counts, rise time, RMS, ASL, 12 external parametric, center frequency, peak frequency, 5 partial powers
Electrical Specs	
Board Input Voltage	5V DC
Number of Channels per AE Board	Each acquisition board has 4 independent channels

AE Signal Input Range	±10V, or adjust the signal input voltage range down to ± 5V, ± 2V, ± 1V, ± 0.1V; the channel can be set independently
Response Frequency	1kHz-2.5MHz (-3dB bandwidth)
Preamplifier Power Supply	28V or 5V phantom power through coaxial cables to the preamplifier, or turn off (0V)
Input Impedance	50Ω
Power Consumption	10.5W (4 channels for continuous sampling)
External Parameter Acquisition	Supports up to 12 analog external parameters input channels, total external parametric sampling rate 1M
External Input Range	±10V
LED Indicator Light	Each channel has two indicators, green LED for exceeding the threshold and yellow LED for preamplifier supply
Physical	
Dimension	300mm X 100mm
Weight	186g
Environment:	
Operating Temperature	-10℃ to +45℃

3.3. Communication network board

SAEU3H acoustic emission detection system supports USB3.0 and Gigabit Ethernet. The standard products are configured with USB3.0 interface by default. When Ethernet port is needed, users need to select it by themselves. Only one interface can be used to connect with PC at the same time.

The following points should be paid attention to when using network communication board:

1) The communication board occupies one acquisition board slot, and only one board slot can be used;

2) After using the communication board, the 3H-A chassis can support up to boards with 16 channels, and the 3H-B chassis can support up to 11 boards and 44 channels;

3) Disconnect the USB interface first, and then connect the Ethernet interface;

4) When using the Ethernet interface of communication board to connect PC, it should be noted that it takes a certain time to establish the connection and identify the acquisition board, which is about 3 seconds per board;

5) The data bandwidth of USB3.0 port is not less than 300MB, and the data bandwidth of Gigabit Ethernet port is not less than 80MB;

6) The indicator light of communication board is integrated into RJ45 socket, and its definition is the same as that of standard network board;

7) Please preferentially use the network cable delivered with the device. If you purchase the network cable by yourself, select the network cable above Grade 5.

3.4. SAEU3H Chassis

3.4.1. Chassis Specification

According to the communication mode, SAEU3H AE host can be divided into two types, which only support USB communication and those with network communication. The network communication board needs to occupy a slot in the mainframe, which reduces the maximum number of channels in the chassis by 4 channels. Qingcheng SAEU3H series acoustic emission system chassis has three models, the specifications are as follows:

Table 3-2 SAEU3H Chassis Specifications

Module / Specification	4 channel chassis	3H-A	3H-B
Maximum number of channels	Total 1 slots 4 channels	Total 5 slots 20 channels	A total of 12 slots of 48 channels
physical dimension	Width 125mm × length 310mm × height 50mm	Width 225mm × length 363mm × height 150mm	Width 368mm × length 363mm × height 150mm
weight	700g（No card）	3700g（No card）	5160g（No card）
Power consumption	2.4W（No card）	9.5W（No card）	22W（No card）
Material	Aluminum alloy	Aluminum alloy	Aluminum alloy
Applicable environment	-5℃～ + 45℃	-5℃～ + 45℃	-5℃～ + 45℃

Fig. 3-4 Four channel chassis

Fig. 3-5 Chassis 3H-A
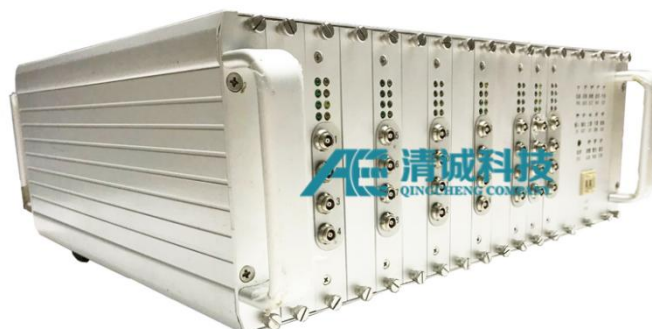
Fig. 3-6 Chassis 3H-B

3.4.2. Structure and Characteristics

chassis - with network card

chassis - No network card
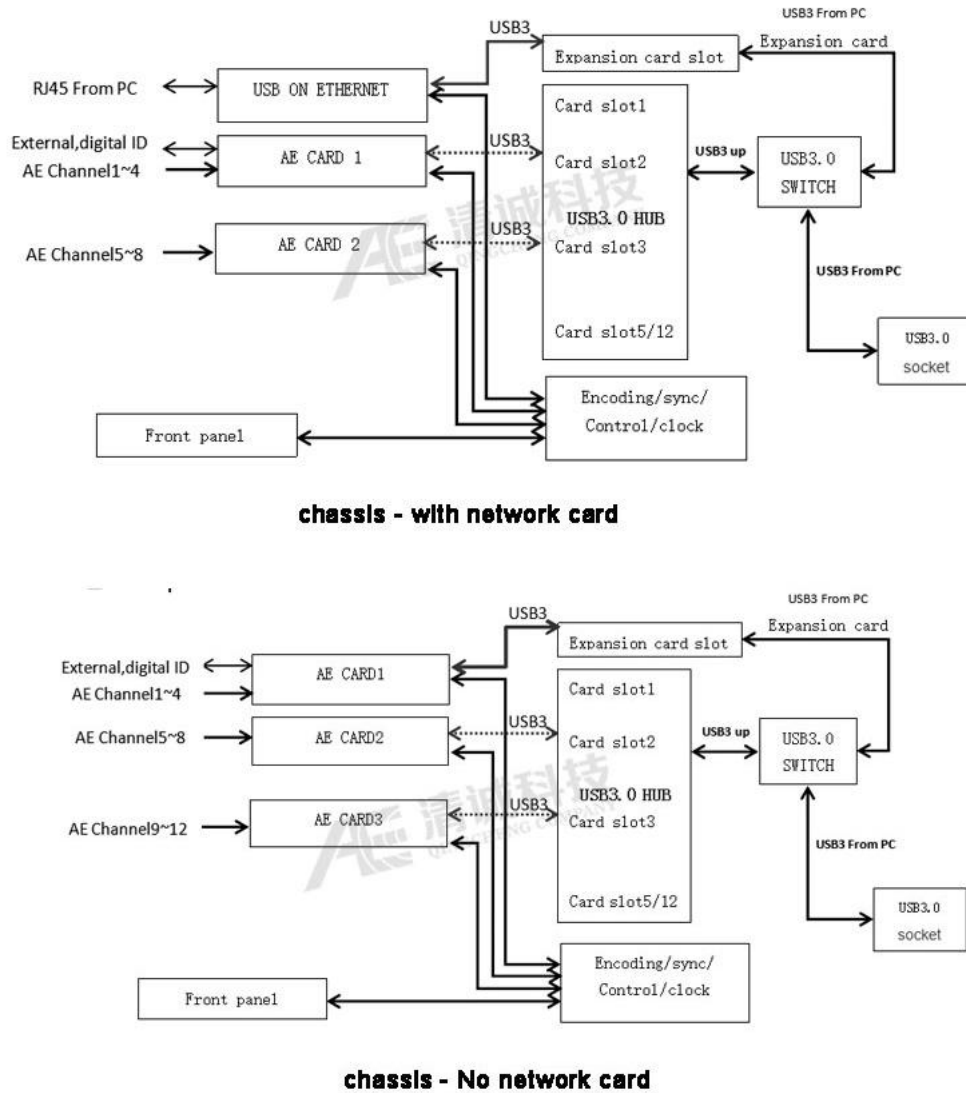
Fig. 3-7 SAEU3H chassis structure block diagram

SAEU3H chassis has the following characteristics:

● High integration, easy to carry;

● It can configure the chassis model, the number of chassis and the number of acquisition boards to form a multichannel model system;

● Multiple independent hosts can be cascaded to form a large channel number system through standard interfaces, which can be extended to more than 100

channels;

- USB3.0 interface, LAN port, optical fiber and other connection modes can be selected for data communication between AE host and computer;

- The innovative motherboard bus design can intelligently manage the data of each acquisition channel, and expand other types of boards to realize the functions of long-term monitoring, storage and long-distance transmission;

- The chassis is made of all aluminum alloy, and the whole chassis frame and panel are conductive and interconnected, and the full screen cover design enhances the anti-electromagnetic interference capability;

- Stable and reliable heat dissipation under the most rigorous thermodynamic conditions;

- The high-grade PXI plug-in functional module structure is standard industrial chassis with good expansivity. The function module boards such as acquisition board are relatively independent from the chassis, which is convenient for equipment maintenance and upgrading;

- The panel has power supply, USB communication, operation, parameters, waveform, alarm, external reference, cascade and other groups of indicators to display, convenient to observe the operation status of the equipment. External trigger, alarm output.

3.4.3. SAEU3H Chassis Panel Instructions

3.4.3.1. Chassis Front Panel

SAEU3H acoustic emission chassis support board mainly includes: standard acoustic emission acquisition board, acoustic emission acquisition board with external parameters, network communication board, and its panel structure is as follows:
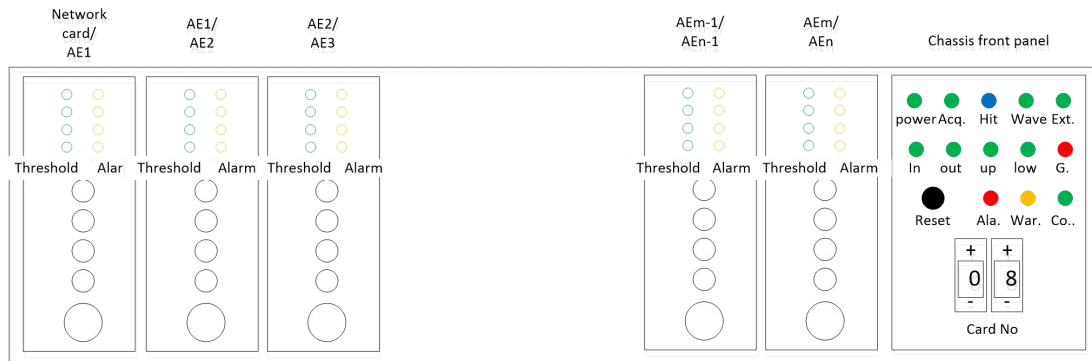
Fig. 3-8 Sketch Graph of SAEU3H Chassis front panel

1) Communication network board: the left side of the front panel of the chassis is the acquisition board slot, and the left most slot can be inserted with communication network board or AE board, and the network transmission of data can be realized by inserting the communication network board;

2) There are 8 indicator lights on the top of each acquisition board. Each row of two LED lights correspond to each channel from top to bottom. The green light on the left is the signal threshold indicator light, which will be flashing along when the AE signal exceeds the threshold; the yellow light on the right side is the preamplifier status indicator light. After the board identified correctly, the preamplifier is connected correctly and the indicator light will be solid on;

3) LEMO connectors with "CH" plus the channel number on the side is the input port of acoustic emission channels;

4) If there is a 16 pin LEMO socket under the AE channel of the acquisition board, it means that the acoustic emission chassis has the function of external parameter acquisition, which can synchronously sample the external ± 10V voltage signal and acoustic emission signal;

5) The dial in the lower right position of the front panel is the initial setting of the chassis acquisition board number. With the use of multiple chassis cascading, the setting rule is that the dial value should be the total number of AE boards before this chassis in the cascaded chain. For example, if a 20-channel chassis is the first chassis, i.e. five AE boards. The dial code of this 20-channel chassis is set to "00",

and the next cascaded chassis dial should be set to "05", and so on；

6) The working status indicator area above the dial switch is as follows:

Table 3-3 Status description of front panel indicator light of chassis

Indicator	Status Illustration
Power supply	Once power on, the green light is on
Acquisition	Enter the acquisition state, the green light is on
Upper cascade	The upper level connects to the upper deck and the green light is on
Down cascade	The upper level connects to the upper deck and the green light is on
Ground	AC power supply alarm red light. If there are serious problems such as ground wire open circuit, fire line and the ground reversing connection and null-line open circuit, it will be on and accompanied by buzzer sound

3.4.3.2.   Chassis Rear Panel
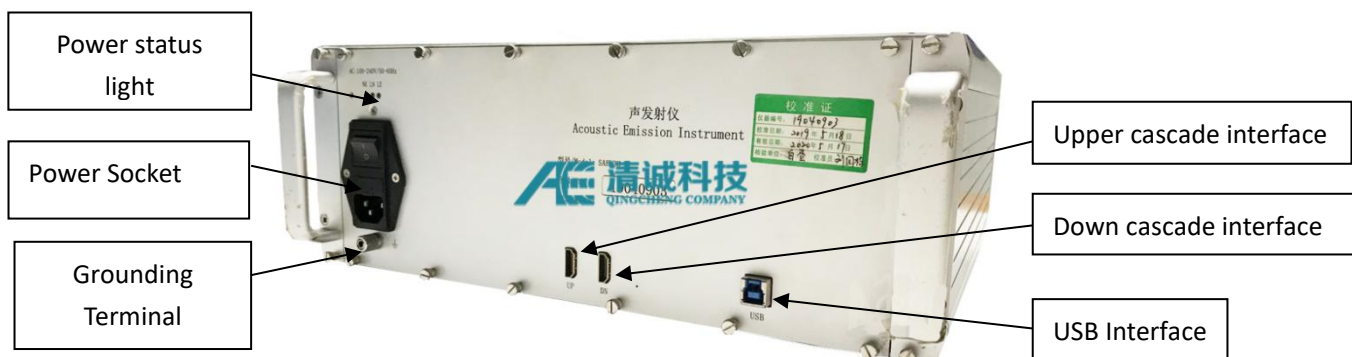
Fig. 3-9 Rear Panel of SAEU3H Chassis

The rear panel of the chassis provides some interfaces, which are described as

follows:

1) Power supply: AC 100-240V / 50-60Hz; there is a fuse on the power switch base. In case of power failure, the fuse status can be checked and replaced with the same specification if necessary;

2) Grounding column: when used on site, when there is no reliable ground wire for the AC power supply provided, it is necessary to connect the host and the ground through the matching ground wire;

3) UP and DN: used for cascading multiple chassis. The master chassis or the previous chassis is connected with the "DN" port through HDMI interface, and the next slave chassis or lower-level box is connected to the "UP" port. The whole cascaded system has one and only the first one chassis as the master;

4) USB port: USB3.0 interface, which is connected to PC. when cascaded, the data cable of each chassis should be connected to the computer.
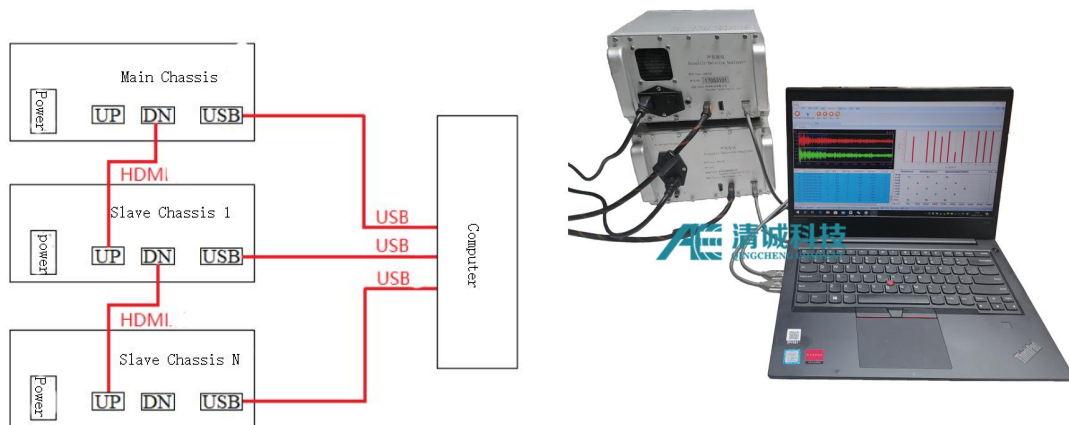
Fig. 3-10 Multi chassis cascade diagram

3.4.3.3. Interface Technical Specifications

SAEU3H chassis panel has a variety of interface types, providing interface information for reference.

Table 3-4 SAEU3H chassis interface specification list

Interface	Specification
Channel interface	Standard connector of LEMO C5
Network interface	8-Pin standard RJ45 connector
Cascade interface	Standard HDMI connector
USB interface	USB3.0 Type B connector
Power supply Connector	Standard ICE320 C14 female socket, AC 100-240V / 50-60Hz
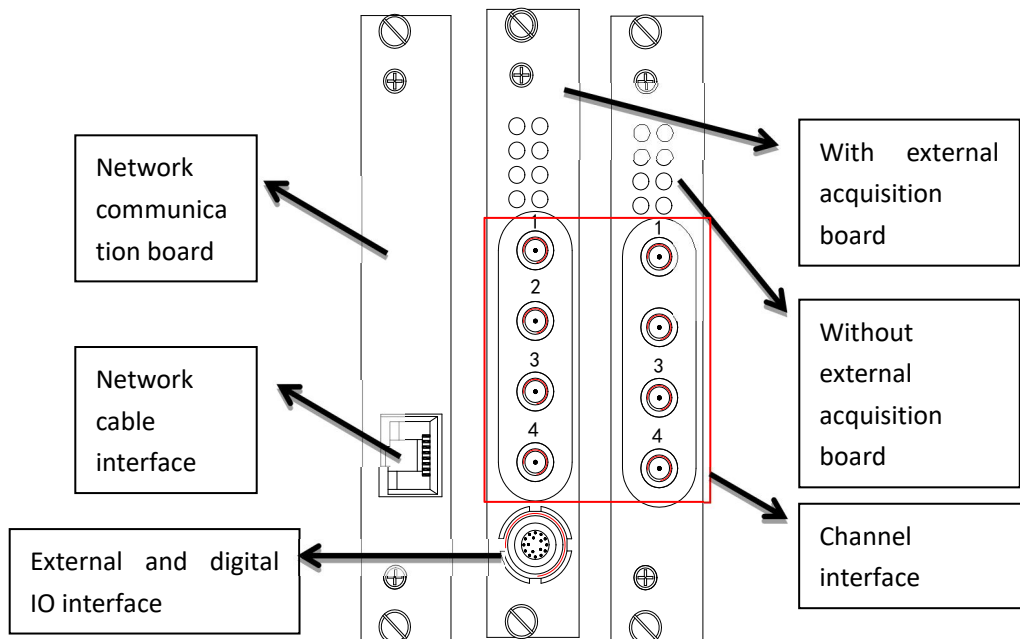
Fig. 3-11 Acquisition board and communication board panel

3.5. Sensor

3.5.1. Sensor Technology

Sensors are based on the principle that the physical properties of certain substances (such as semiconductors, ceramics, piezoelectric crystals, strong magnets and superconductors) change in response to the action of the outside world to be

measured. It takes advantage of many effects (including physical effects, chemical effects and biological effects) and physical phenomena, such as piezoresistive, humidity sensitive, thermal sensitive, photosensitive, magnetic sensitive and gas sensitive effects of materials, to convert strain, humidity, temperature, displacement, magnetic field, gas and other measurements into electricity. Therefore, it is very necessary to understand, develop and apply sensors based on various effects. Piezoelectric effect is usually used in acoustic emission detection.

Piezoelectric effect is reversible, it is the general term of positive piezoelectric effect and inverse piezoelectric effect. It is customary to call the positive piezoelectric effect piezoelectric effect.

When some dielectrics are deformed by external force along a certain direction, positive and negative charges are generated on two surfaces of the dielectric. After the external force is removed, it returns to the uncharged state. This phenomenon is called positive piezoelectric effect. The electric charge generated by dielectric force is proportional to the magnitude of external force, and the proportional coefficient is the piezoelectric constant, which is related to the direction of mechanical deformation, and is constant for a certain direction of the certain material. The polarity of the charge generated by a dielectric force depends on the form of deformation (compression or elongation).

Materials with obvious piezoelectric effect are called piezoelectric materials. The commonly used single crystals are quartz crystal, LiNbO3, ligao3, bi12geo20 and polycrystalline after polarization treatment, such as barium titanate piezoelectric ceramics, lead zirconate titanate series piezoelectric ceramics PZT. New piezoelectric materials include polymer piezoelectric films (such as PVDF) and piezoelectric semiconductors (such as ZnO, CDs).

The piezoelectric sensor made of positive piezoelectric effect can convert non electric

quantity such as pressure, vibration and acceleration into electric quantity, so as to carry out precise measurement.

When an electric field is applied in the polarization direction of dielectric, some dielectrics will produce mechanical deformation or mechanical stress in a certain direction. When the external electric field is removed, the deformation or stress will disappear. This physical phenomenon is called inverse piezoelectric effect. Ultrasonic generator, piezoelectric loudspeaker, crystal oscillator with high frequency stability (such as quartz clock and watch with error less than $2 \times 10\text{-}5\text{s}$ per day and night) can be made by using inverse piezoelectric effect. The inverse piezoelectric effect can be used to generate acoustic emission signals.

The piezoelectric transducer has two important properties of self-generation and reversibility, as well as its advantages of small size, light weight, simple structure, reliable operation, high natural frequency, high sensitivity and high signal-to-noise ratio, the application of piezoelectric sensor has been developed rapidly. In the testing technology, piezoelectric transducer is a typical force sensor, which can measure the physical quantities that can be transformed into force, such as pressure, acceleration, mechanical shock and vibration. Therefore, piezoelectric transducer can be used in acoustic, mechanical, medical and aerospace fields. What is more important is: according to the results of biological piezoelectricity, we realize that all living things have piezoelectricity, and all kinds of human sensory organs are actually piezoelectric sensors. If the fracture is treated according to the positive piezoelectric effect, the recovery can be accelerated; if the reverse piezoelectric effect is used, the bone can be electrified to correct the deformity of bone.

The main drawback of piezoelectric conversion elements is that there is no static output, high electrical output impedance is required, and low-noise cables with low capacitance are required. The working temperature of many piezoelectric materials is only about 250 ℃.

There are many kinds of sensors and they are widely used. However, in order to meet the detection of various parameters, in addition to developing new sensitive elements, increasing the variety of components and improving their performance, it is also necessary to establish a correct method of sensor, that is to use different combination methods of sensitive elements, conversion elements and conversion circuits to achieve the purpose of detecting various parameters.

3.5.2. Sensor Structure

The split single ended AE sensor has a simple structure and is generally composed of shell, protective film, piezoelectric element, damping block, connecting wire and high frequency socket. Lead zirconate titanate, barium titanate and lithium niobate are usually used as piezoelectric components. The negative electrode surface of piezoelectric components is pasted on the base with conductive adhesive; a thin lead wire is welded on the other side to connect with the core wire of high frequency socket, and the shell is grounded.

In order to reduce the complexity and improve the stability of the sensor, a preamplifier is built in on the basis of the split sensor to form a built-in gain type integrated sensor. According to different detection purposes and environment, different sensors with different structures and performances are used. Among them, split resonant sensor is the most widely used one in acoustic emission detection.
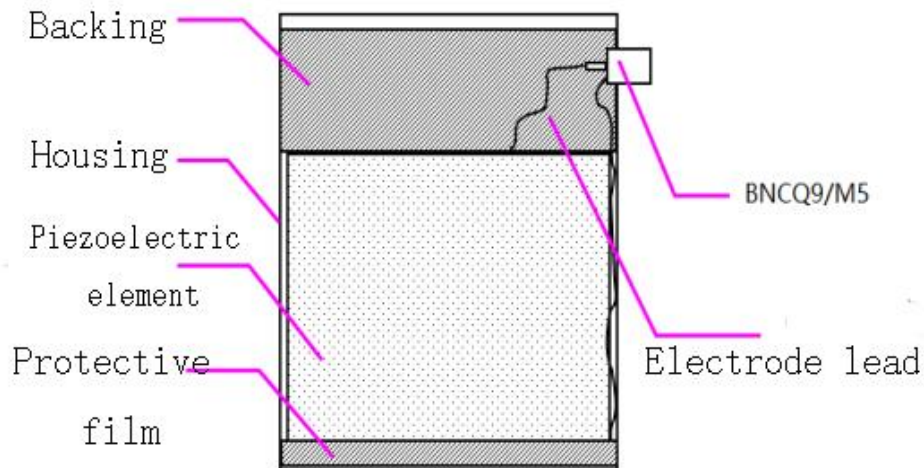
Fig. 3-12 Structure diagram of split single ended sensor
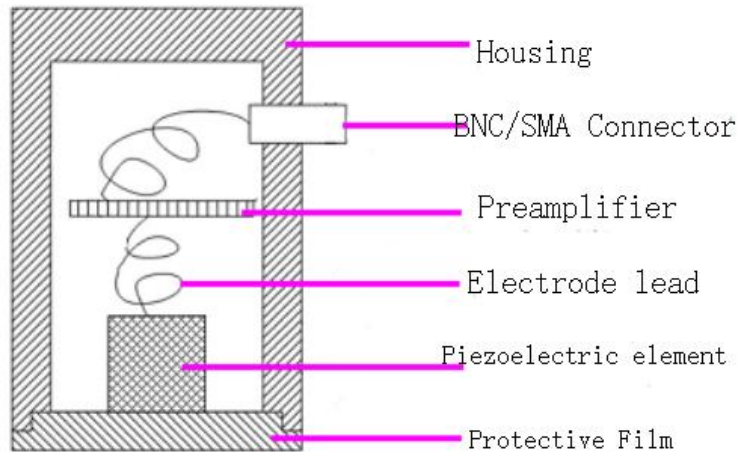
Fig. 3-13 Structure of built-in preamplifier sensor

3.5.3. Sensor Characterization

There are two main technical specs of the sensor: sensitivity and bandwidth.

Sensitivity calibration method: surface wave acoustic field calibration, longitudinal wave acoustic field calibration.

When the surface wave propagates along the surface of acoustic medium, the vibration phase of each point is different when it passes through the sensitive surface of the sensor.

Fig. 3-14 Schematic diagram of surface wave received by sensor

When the plane P-wave propagates perpendicular to the medium surface, the vibration phase of each point is the same when it passes through the sensitive surface of the sensor
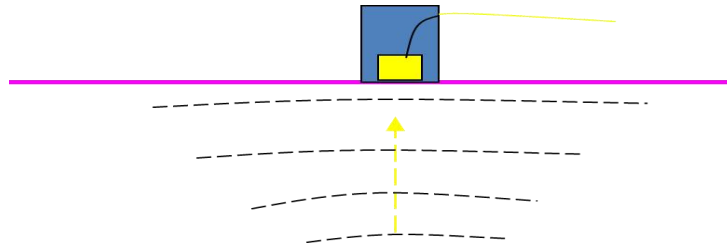
Fig. 3-15 Schematic diagram of P-wave received by sensor

In the practical application of AE, a large number of metal structures with stable structure, such as pressure vessels, are encountered. In such applications, a frequency sensor with resonance frequency of 150KHz is often used to receive AE signals. For corrosion, leakage and other AE signals, resonant sensors with resonant frequency of 40KHz are used.

Bandwidth and sensitivity are a pair of contradictory indicators. The larger the bandwidth, the lower the sensitivity, and the narrower bandwidth is easier to obtain higher sensitivity. The ultimate purpose of application is the high sensitivity. Because the response sensitivity of broadband sensor is relatively consistent in a wide frequency band, the broadband sensor should be used in spectral analysis in principle.
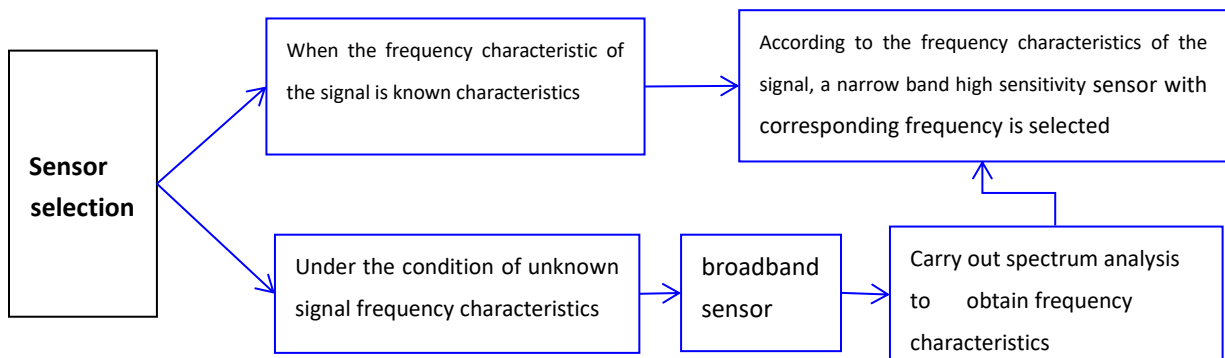
Fig. 3-16 Basic principle of sensor selection

3.5.4. Sensor Calibration

According to ISO12714 (ASTM E1781, GB/T 19801), the standard sensor calibrated by the official metrology institute is used as the reference sensor, and the acoustic emission calibration system developed by Qingcheng company is used for secondary calibration. The calibration system consists of test bench, acquisition instrument and test software. The calibration method is surface wave acoustic field calibration.
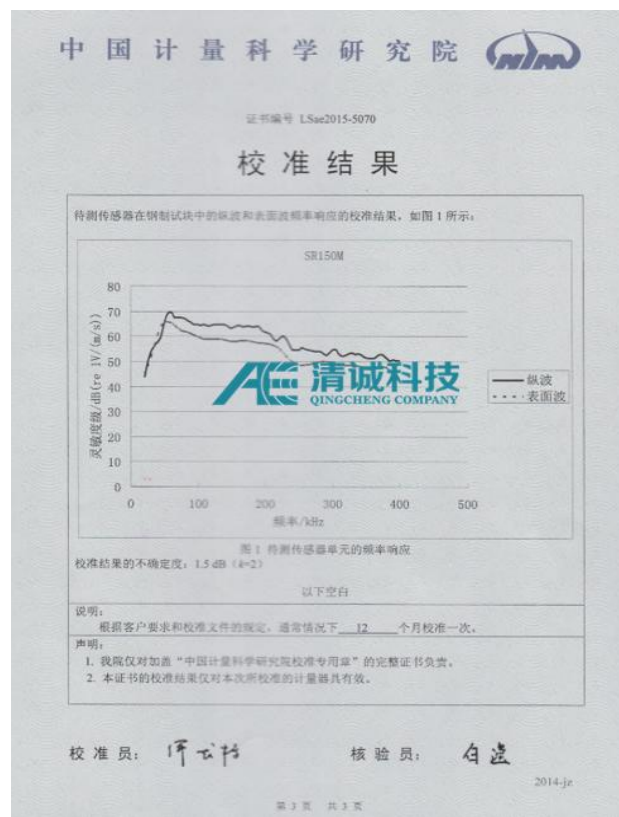
Fig. 3-17 Standard sensor curve generation
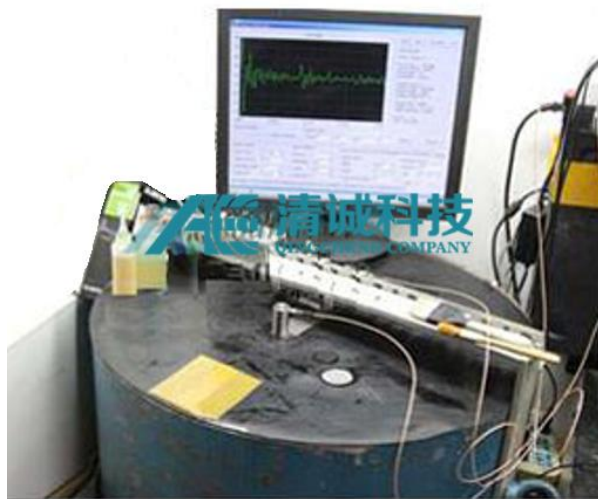
Fig. 3-18 Acoustic Emission Sensor secondary calibration platform

1) On the test bench, a 0.3 mm hollow glass tube is used to send out acoustic emission signal to provide the reference calibration source;
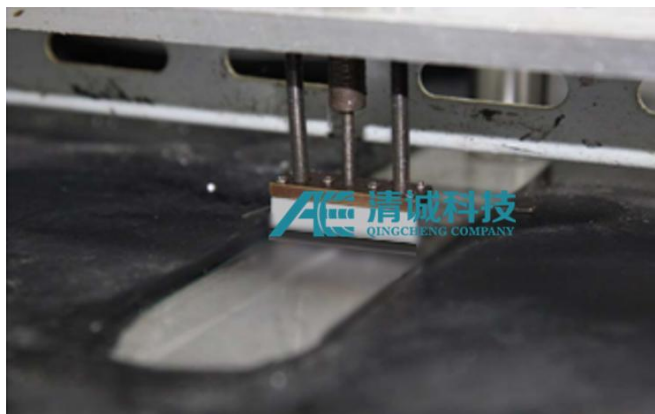
Fig. 3-19 Crushing capillary glass tube device

2) The standard sensor receives the signal, which is received by the special data acquisition board of Qingcheng technology. The frequency spectrum is analyzed by the test software, and directly converted to dB value and recorded;
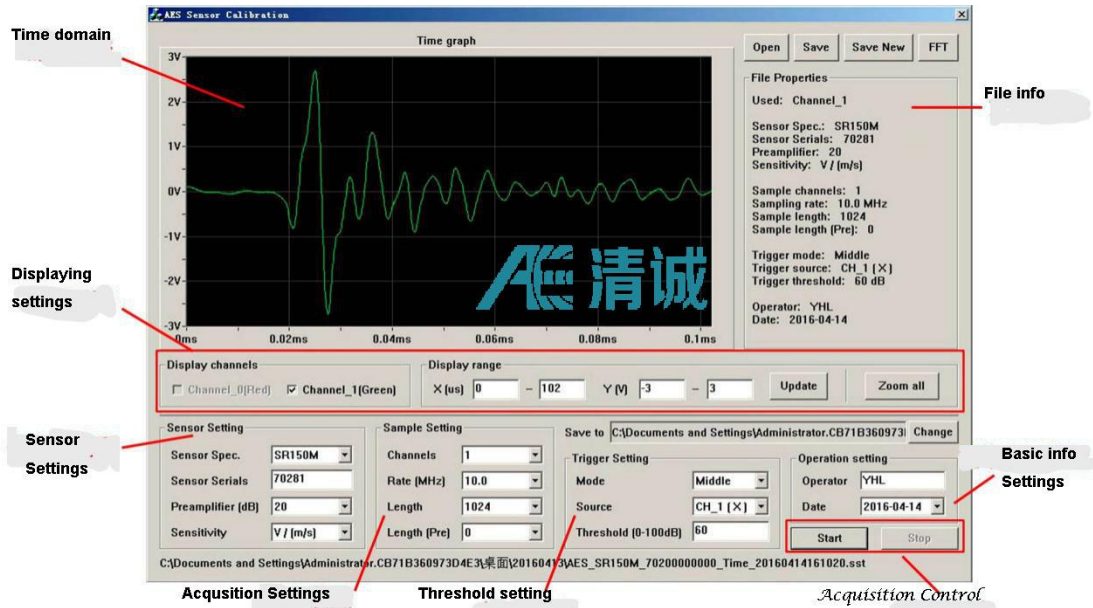
Fig. 3-20 Signal acquisition interface of special software for secondary calibration

3) The sensor to be calibrated receives the signal from the same signal source synchronously with the standard sensor, and the signal is received by another channel of the acquisition board. The spectrum is analyzed by special test software, and directly converted into DB value and recorded;
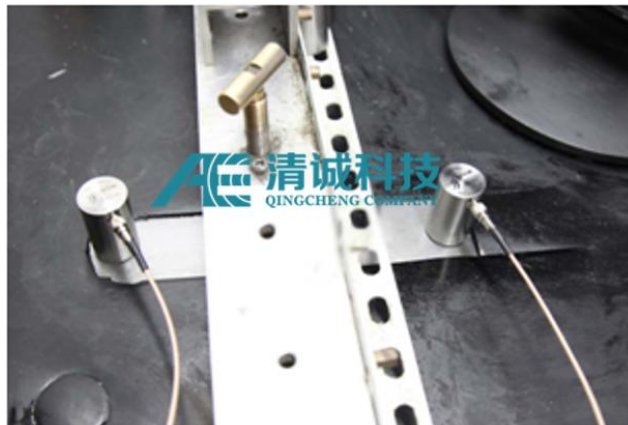
Fig. 3-21 Sensor Installation

4) Using the spectrum value of standard sensor given by the Metrology Institute, subtracting the spectrum value of the received signal of the standard sensor in this test, the calibration coefficient of each frequency point of this measurement is generated;
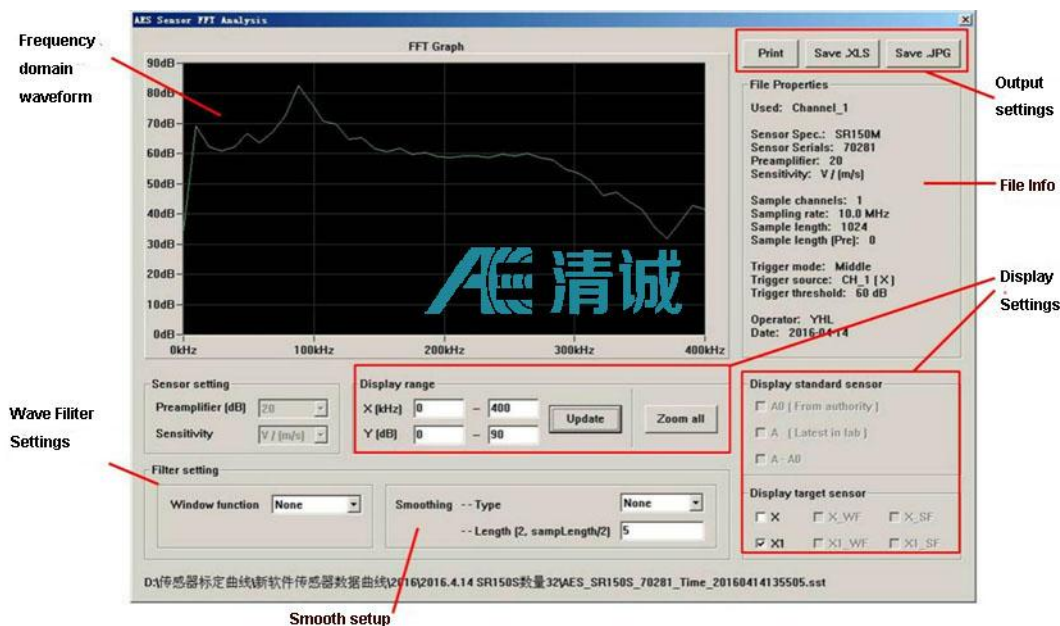
Fig. 3-22 Signal analysis interface of special software

5) The frequency spectrum value of the signal received by the calibrated sensor in this test is added with the above calibration coefficient to obtain the secondary calibration value of each frequency point in the corresponding frequency domain, archive, draw the curve, and deliver it to the user for reference.
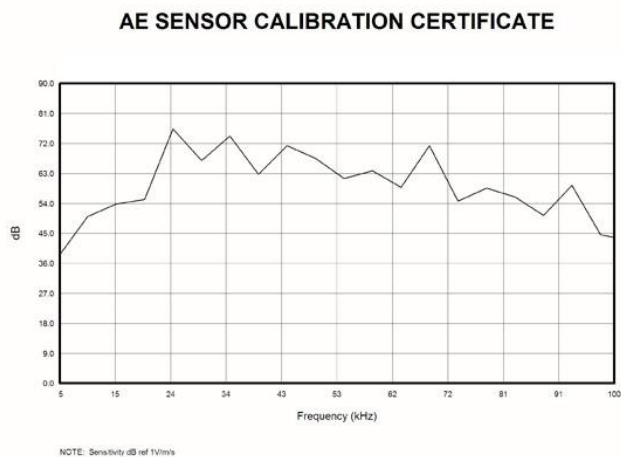
Fig. 3-23 Sensor frequency response curve after secondary calibration

3.5.5. Acoustic Emission Sensor of Qingcheng

Qingcheng has designed and developed a variety of acoustic emission sensors based

on a large number of acoustic emission application experience for a long time and according to the actual needs, so as to meet the application of acoustic emission detection in different fields. For general acoustic emission applications, the signal frequency band range is mostly 25kHz ~ 750kHz, so the resonant sensor is more suitable. Metal materials and other applications often use the resonant narrow-band sensor with the universal broadband frequency of 150kHz; for the corrosion, leakage and other acoustic emission signals, the resonant sensor with resonance frequency of 40KHz is often used; because the response sensitivity of broadband sensor is relatively constant in a wide frequency band, the broadband sensor is selected for spectrum analysis.

The narrow-band resonant sensor has high sensitivity and high signal-to-noise ratio. It is cheap and has many specifications. For example, it is better to select the appropriate resonant sensor, such as sound source location, when knowing the basic characteristics of sound source propagation, and if you want to obtain the acoustic emission signal in a certain frequency band for processing or to improve the system sensitivity. It should be pointed out that the so-called resonant narrow-band sensor is not only sensitive to a certain frequency signal, but also sensitive to a certain frequency band, and the sensitivity of other frequency bands is relatively low. The user can select the appropriate sensor according to the use environment and the desired signal characteristics.

According to the structure and performance, Qingcheng sensors can be roughly divided into: single ended resonant type, differential type, waterproof type, high temperature type, built-in high gain type, built-in low gain type and intrinsically safe explosion-proof type. Generally, single ended resonance and built-in high gain type are used.

The sensor shell adopts high-quality stainless steel material with overall shielding design to effectively reduce interference; the contact surface is made of ceramic

material to make the shell electromagnetically isolated from the measured object; each product has a unique serial number, which can track the production and test process; before leaving the factory, each sensor is tested for sensitivity according to the GBT.19801-2005 standard, and the products goes with the calibration curve.

3.5.5.1.   Sensor List

The AE sensors on sale by Qingcheng are shown in the table below. Users can choose according to the actual situation.

Table 3-5 Sensor Selection Guideline

Model (New)	Model (Old)	Resonant frequency	Frequency range	Sensitivity peak	Built-in Preamp	Size (mm)	Applicable Temp. (℃)	Housing material	Face material	Protection grade	Connector type	Product Features	Application
W800/1	CG80	600KHz	50KHz-800KHz	＞65dB	/	Φ19×15	-20～80℃	SUS-304	ceramic	IP68	BNC	Broadband waterproof	Spectrum research, composite materials
W800	SR800	600KHz	50KHz-800KHz	＞65dB	/	Φ19×15	-20～80℃	SUS-304	ceramic	IP62	M5	Broadband	Spectrum research, composite materials
W500/1	CG50	500KHz	100KHz-1000kHz	＞65dB	/	Φ19×15	-20～120℃	SUS-304	ceramic	IP68	BNC	Broadband waterproof	Spectrum research, composite materials
WM500/1	MG50	500KHz	100KHz-1000kHz	＞65dB	/	Φ4.7×4.0	-20～50℃	SUS-304	ceramic	IP68	BNC	Broadband mini type	Spectrum research, composite materials
W500	WG50	500KHz	100KHz-1000kHz	＞65dB	/	Φ19×15	-20～120℃	SUS-304	ceramic	IP62	M5	Broadband	Spectrum research, composite materials

G150	SR150M	150KHz	60KHz～400KHz	＞75dB	/	Φ19×15	-20～120℃	SUS-304	ceramic	IP62	M5		Metal crack, fault diagnosis, etc.
G150/1	CG15	150KHz	60KHz～400KHz	＞75dB	/	Φ19×15	-20～120℃	SUS-304	ceramic	IP68	BNC	Waterproof	Metal crack, fault diagnosis, etc.
GIS150	LS150 5VDC	150KHz	60KHz～400KHz	＞65dB	26dB5V	Φ22×25.5	-20～50℃	SUS-304	ceramic	IP62	SMA	Intrinsically safe explosion proof	Metal crack, fault diagnosis, etc.
GIS150/2	LG15	150KHz	60KHz～400KHz	＞65dB	26dB5V	Φ22×25.5	-20～50℃	SUS-304	ceramic	IP62	SMA	Built-in preamplifier	Metal crack, fault diagnosis, etc.
GI150/1	PG15	150KHz	60KHz～400KHz	＞115dB	40dB28V	Φ22×25.5	-20～50℃	SUS-304	ceramic	IP62	SMA	Built-in preamplifier	Metal crack, fault diagnosis, etc.
GI150	SRI150	150KHz	60KHz～400KHz	＞115dB	40dB28V	Φ30×36.5	-20～50℃	SUS-304	ceramic	IP62	BNC	Built-in preamplifier	Metal crack, partial discharge、fiber
G150/2	XG15	150KHz	60KHz～400KHz	＞70dB	/	Φ19×19.5	-20～120℃	SUS-304	SUS-304	IP68	BNC	All metal	Metal crack, partial discharge、fiber
GH150	HG15c	150KHz	60KHz～400KHz	＞63dB	/	Φ19×19.5	-20～600℃	Stainless invar	Stainless invar	IP68	BNC	High temperature	High / low temperature environment

GD150	DG15	150KHz	60～400KHz	> 65dB	/	Φ19×19.5	-20-120℃	SUS-304	ceramic	IP68	BNC with two cores	Differential	Crack detection under high noise
GM150	SR150S	150kHz	70kHz-280kHz	> 68dB	/	Φ7.8×19	-20～120℃	SUS-304	ceramic	IP62	M5	Miniature	Axial placement
G80	G8	80KHz	20KHz～180KHz	> 70dB	/	Φ19×19.5	-20～80℃	SUS-304	ceramic	IP62	M5	Low frequency	Rock and partial discharge detection
GI40/2	BF40	50KHz	15KHz～70KHz	> 115dB	40dB28V	Φ41×92	-20～50℃	SUS-304	SUS-304	IP68	BNC	Embedded	Partial discharge, leakage and corrosion of transformer
GI40	SRI40	50KHz	15KHz～70KHz	> 115dB	40dB28V	Φ30×57	-20～50℃	SUS-304	ceramic	IP62	BNC	Built-in preamplifier	Partial discharge, leakage and corrosion of transformer
G40	SR40M	40KHz	15KHz～70KHz	> 75dB	/	Φ22×36.8	-20～120℃	SUS-304	ceramic	IP62	M5	Low frequency	Rock, partial discharge, leakage, corrosion
GIS35	LS35 5VDC	35KHz	15KHz～70KHz	> 65dB	26dB5V	Φ22×36.8	-20～50℃	SUS-304	ceramic	IP62	SMA	Intrinsically safe explosion proof	leakage, corrosion
GIS35/1	LG3	35KHz	15KHz～70KHz	> 65dB	26dB5V	Φ22×36.8	-20～50℃	SUS-304	ceramic	IP62	SMA	Built-in preamplifier	Partial discharge, leakage and corrosion of transformer
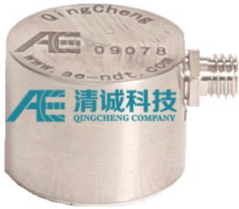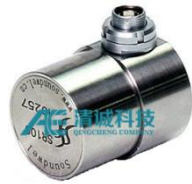
GI35	PG3	35KHz	15KHz～70KHz	＞115dB	40dB28V	Φ22×36.8	-20～50℃	SUS-304	ceramic	IP62	SMA	Built-in preamplifier	Partial discharge, leakage and corrosion of transformer
GD40	DG4	35KHz	15KHz～70KHz	> 65dB	/	Φ22×25	-20-120℃	SUS-304	ceramic	IP68	LEMO with multi-cores	Differential	Partial discharge, leakage and corrosion of transformer
G10	SR10B	/	1Hz-15kHz	> 80dB	/	Φ31×38	-20-120℃	SUS-304	ceramic	IP62	BNC	Super-low frequency	Partial discharge, leakage and corrosion of transformer
G10/1	SR10C	/	1Hz-15kHz	> 80dB	/	Φ31×38	-20-120℃	SUS-304	ceramic	IP62	LEMO with single core	Super-low frequency	Leakage、Slope detection
GI10	BE10	/	1Hz-15kHz	＞115dB	26dB5V	Φ38.5×85	-20～50℃	SUS-304	SUS-304	IP68	BNC	Embedded	Buried pipeline leakage, slope geology
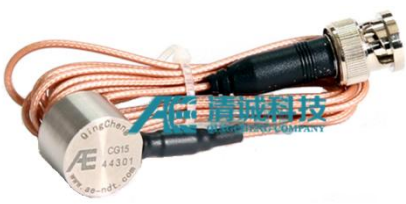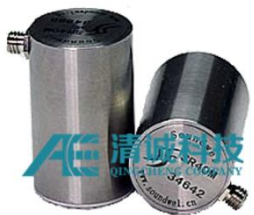
3.5.5.2.　　General Sensor

The general type sensor is mainly composed of piezoelectric crystal, shell and different types of interfaces. It does not include electronic amplification devices. The maximum output voltage of the sensor is tens of millivolts, and the output of some special large excitation signal can be several volts. The use of this kind of sensor generally needs to be equipped with a preamplifier, otherwise the signal transmission distance will be limited or the acquisition board cannot be recognized. The appearance drawings of common sensors are listed for reference only.

Table 3-6 List of the general type of AE sensors of QingCheng

Sensor Model #		Sensor Model #	
New	**Old**	**New**	**Old**
G150	SR150M	GM150	SR150S
G150/2	XG15	Reference picture	
W500	WG50		
W800	SR800		
G80	G8/SR150N		
Reference picture			
		G10	SR10C
		Reference picture	
WM500/1	MG50		
W800/1	CG80		
W500/1	CG50	GD40	DG4
G150/1	CG15	GD150	DG15

Reference picture		Reference picture	
G40	SR40M	GH150	CG15
Reference picture		Reference picture	

3.5.5.3. Integrated Sensors

In order to facilitate field application and improve system stability, Qingcheng packaged the split sensor and preamplifier together, and designed an integrated acoustic emission sensor. According to the driving voltage, it can be roughly divided into standard voltage type and low voltage type. The standard voltage type generally adopts 24-30V DC power supply, which can be used with the general acoustic emission detection system of our company and other companies. The low-voltage type generally uses 5-7v DC power supply, which can be applied with corresponding power supply and acquisition circuit design. The appearance drawings of common sensors are listed for reference only.

Table 3-7 List of integrated acoustic emission sensors of QingCheng

Standard voltage sensor model		Low voltage sensor model	
Old	New	Old	New
GI150	SRI150	GIS150	LS150 5VDC
GI40	SR40M	GI150/2	LG15

Reference picture		Reference picture	
GI35	PG3	GIS35	LS35 5VDC
GI150/1	PG15	GI35/1	LG3
Reference picture		Reference picture	
GI40/2	BF40	GI10	BE10
Reference picture		Reference picture	

3.6. Preamplifier

Sometimes the output signal voltage of the sensor is as low as micro-volts. If the weak signal is transmitted over a long distance, the signal-to-noise ratio will be reduced. The preamplifier is set near the sensor to improve the signal transmission to a certain extent, which can effectively avoid the problem. The preamplifier gain of Qingcheng can be 20dB or 40dB or 60dB, respectively. The input of preamplifier is the analog voltage signal output by the sensor, and the output is the analog signal after amplification. The working power supply of the

preamplifier is in collinear transmission with the signal line.

In the acoustic emission system, preamplifier plays an important role. The noise of the whole system is controlled by the performance of the preamplifier. The function of preamplifier in the whole system is to improve the signal-to-noise ratio (SNR), to have high gain and low noise performance. In addition, the acoustic emission detection is usually carried out in the environment of strong mechanical noise (frequency band is usually lower than 50KHz), liquid noise (frequency band is usually between 100kHz and 1MHz) and electrical noise, so the preamplifier should also have strong anti-interference ability and noise elimination ability.

Qingcheng has two types of preamplifiers, one is type PAV with a fixed 40dB gain, the other is PAS type with adjustable gains and frequency filter bands, and supports single ended and differential signal input. The two types of preamplifiers are universal and can be applied in most applications.

3.6.1. PAV Preamplifier

Fig. 3-24 Preamplifier with fixed gain

Main performance characteristics

● The PAV preamplifier is a broadband universal type, which can be applied to most types of sensors and acoustic emission acquisition boards of various manufacturers;

● The phantom power supply is supplied through the collinear signal line;

● It has the protection ability against electric shock and the recovery ability against blocking phenomenon;

● Automatic sensor test (AST) function, which can send a test signal source to the sensor;

● Metal shell, shielding electromagnetic interference, anti-hit;

Basic technical parameters

● Gain: 40dB

● Response frequency: 10kHz ~ 1.2MHz

● Noise: < 28dB (input short circuit)

● Output range: ± 10Vpp

● Supply voltage: 24-30V DC

● Rated load: 50Ω

● Working temperature: - 20 ℃ ~ + 60 ℃

● Size: 21mm × 45mm (40g)

● Protection grade: IP62

● Service temperature: - 20 ℃ ~ 60 ℃

● Shell material: stainless steel

● Interface type: BNC - BNC

3.6.2. PAS preamplifier

Fig. 3-25 Preamplifier with selectable gain

Main performance features:

● The PAS preamplifier is a broadband universal type, which can be applied to most types of sensors and acoustic emission acquisition boards of various manufacturers;

- The gain of preamplifier is 20 / 40 / 60dB;

- Single ended or differential signal input modes;

- Two power supply modes can be selected: phantom power supply, which is carried by the signal line; or external power supply directly.

- Built-in filters, the corresponding frequency can be divided into 4 levels for selection;

- It has the protection ability against electric shock and the recovery ability against blocking phenomenon;

- Automatic sensor test (AST) function, which can send a test signal source to the sensor (in the case of phantom power supply);

- Metal shell, shielding electromagnetic interference, anti-hit.

Basic technical parameters:

- Gain: 20 / 40 / 60 dB optional

- Response frequency: 1.3khz ~ 1.2MHz

- Noise: < 24dB (40dB gain input short circuit)

- Built-in filter: 20kHz-1200kHz, (20kHz-630kHz at 60dB gain),100kHz-400kHz, 20kHz-120kHz, 1kHz-40kHz

- Output range: ± 10V (VPP)

- Input capacitive reactance: 15pF

- Working voltage: 28V DC (24V-32V)

- Rated load: 50 Ω

- Quiescent current: 31 mA

- Maximum output current: 100 mA

- Working temperature: - 20 ℃ ~ + 60 ℃

- Size: 110mm × 65mm × 37mm

- Protection grade: IP65

- Shell material: cast aluminum

- Interface type: BNC (Q9) interface 2, differential BNC interface, power interface

Usage method and precautions:

1) PAS preamplifier is designed as a general amplifier, which can be applied to various data acquisition boards. It should be noted that the power supply requirements and output impedance should be well matched, otherwise the gain of the preamplifier will deviate from the nominal gain value, resulting in signal amplitude deviation.

2) Both ends of the preamplifier adopt the same BNC interface. The end marked with "single end" is connected with the sensor output end, and the end marked with "power / output" is connected with the saeu3h series acquisition board of our company through the coaxial cable of BNC connector. If the universal acquisition board is used, the power supply signal separator is required to supply power to the preamplifier separately.

3) The preamplifier must be connected correctly according to the label. The following three wrong operation conditions may cause damage to the preamplifier:

   1. The input voltage is 25% higher than the required value of power supply;

   2. Connect the power supply to the input terminal;

   3. The positive and negative polarity of the power supply is reversed.

3.7. Other Accessories

3.7.1. Coaxial Cable

From the preamplifier to the acquisition unit of acoustic emission system, a long signal transmission cable is often needed to provide power for the preamplifier while transmitting the acoustic emission signal. The signal cable includes coaxial cables, twisted pair cables and optical fiber cables. Qingcheng company provides the coaxial cable for SAEU3H series acoustic emission system.

Coaxial cable is composed of a hollow outer cylindrical conductor and an inner conductor located at the central axis. The inner conductor and cylindrical conductor are separated from the outside by insulating materials. A single copper conductor is used as the inner core of

coaxial cable, which is wrapped with a layer of insulating material and covered with dense mesh conductor. The outer layer is a layer of protective plastic. Because the metal shielding layer can reflect the magnetic field back to the central conductor and protect the central conductor from external interference, the structure of coaxial cable makes it have high bandwidth and excellent noise suppression characteristics.

Fig. 3-26 Coaxial cable

Performance characteristics

High quality 50Ω coaxial cable is used in acoustic emission system, and its basic performance is shown in table 3-8.

Table 3-8 performance parameters of coaxial cable

Average characteristic impedance	50±2Ω	
Periodic variation of impedance	Sine Wave	
Attenuation (measured for 500 m long cable)	10MHz Sine Wave	≤8.5dB(17dB/Km)
	5MHz Sine Wave	≤6.0dB(12dB/Km)
Transfer rate	≥0.77C (C is the speed of light)	
Sum of resistance of central conductor and shield (measured at 20 Ω)	10Ω/m	

Application and selection

One is 50 Ω (refers to the ratio of electromagnetic voltage to current at each point along the cable conductor) coaxial cable, which is used for digital signal transmission, namely baseband coaxial cable; the other is 75 Ω coaxial cable, which is used for broadband analog signal transmission, namely broadband coaxial cable.

Note:

If it is necessary to use a signal cable with a length of more than 150m, a signal compensation device shall be installed during transmission;

The signal cable is a vulnerable part, especially the two interfaces. Avoid bumping and squeezing when using.

3.7.2. Sensor Signal Line

In order to distinguish the signal cable between the preamplifier and the acquisition board, the signal cable between the sensor and the preamplifier is called the signal line. Its length is generally not more than 2m and can shield electromagnetic interference. The length of the signal cable equipped with SAEU3H acoustic emission system is 1m, and its two ends are M5-KY port and BNC interface.

The signal line is consumable and easy to be damaged, so extra care should be taken when using it, especially the two interfaces of the signal line are easy to deform, avoid bumping and squeezing.

Fig. 3-27 Sensor Signal Line

3.7.3. Couplant

Fig. 3-28 Couplant

The quality of the coupling agent is closely related to the quality of the signal obtained. The coupling agent should be able to maintain good acoustic coupling effect during the test. The coupling agent with poor quality can cause energy loss, resolution reduction and even damage the sensor. According to the temperature of vessel wall, the coupling agent without bubble and suitable viscosity is selected. At present, Qingcheng is equipped with high temperature vacuum grease, which has the following properties:

- The acoustic impedance is between the surface material of the sensor and the surface to be tested, with small sound attenuation coefficient and good sound transmission.

- The adhesion is low and easy to be wiped off;

- The viscosity is moderate, it will not flow when using, and it is easy to extrude;

- The moisture content is moderate and it is not easy to dry;

- The appearance has bright color, high transparency and no bubbles

- The uniformity is good, no particles or impurities are contained, and the nozzle is not blocked during use;

- Good stability, no color change, no change of consistency, no stratification, no precipitation, no deterioration, no corruption;

- The sensor will not be corroded or damaged.

Effects:

- The micro gap between the contact surfaces is filled to avoid the influence of micro air on the penetration of sound waves;

- The sound resistance between the sensor and the detected surface is reduced, and the energy reflection loss at this interface is reduced;

- Through its lubrication, the friction between the sensor and the detected surface is reduced.

Remarks:

For general emergency use, Vaseline and butter can be used instead. It is necessary to consider that the components of the substitutes shall not react with the tested materials or the scene cannot be recovered. For example, compounds containing "fluorine" and "chlorine" elements cannot be used in stainless steel testing.

3.7.4. Sensor Gripper

The sensor gripper is mainly designed to cooperate with ferromagnetic materials to assist in fixing the sensor, which is basically composed of permanent magnet and shell. The specifications and models and the sensor information of our company are shown in the table below:

Table 3-9 Sensor gripper table list

	Model and Size: M20, inner cavity diameter 20mm, depth13mm; **Applicable sensor models:** G150, G150/1, W800, W800/1, W500, W500/1
	Model and Size: M20A, inner cavity diameter 20mm, depth 17mm; **Applicable sensor models:** G150/2, GD150, G80

	Model and Size: M36, inner cavity diameter 32 mm, depth 35mm; **Applicable sensor models:** G40, GIS35, GI35, GI35/1
	Model and Size: M36A, inner cavity diameter 32mm, depth 55mm; **Applicable sensor models:** GI40
	Model and Size: M36B, inner cavity diameter 32mm, depth 35mm; **Applicable sensor models:** GI150
	Model and Size: M36C, inner cavity diameter 32mm, depth 35mm; **Applicable sensor models:** G10, G10/1
	Model and Size: M36B, inner cavity diameter 32mm, depth 35mm; **Applicable sensor models:** GI150
	Model and Size: H20A, inner cavity diameter 20mm, depth 17mm; **Applicable sensor models:** GH150

3.7.5. Calibration tools

Fig. 3-29 Calibration Pencil

The acoustic emission system needs to be calibrated before the detection, such as channel sensitivity, location calibration, attenuation test and others. At present, manual simulation source is basically used. The most widely used analog source is a pencil lead break signal with a diameter of Φ 0.3mm, a hardness of 2H or a pencil lead break signal with a diameter of

Φ 0.5mm and a hardness of HB, at the angle of 30 degrees between the surface and the pencil.
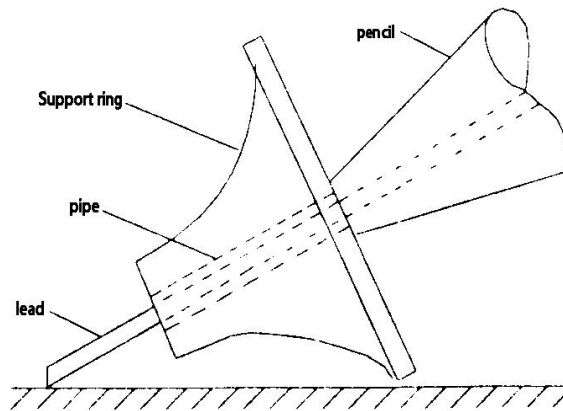
Fig. 3-30 Pencil lead analog acoustic emission signal device

Attentions:

Pencil lead break method is easy to be affected by the operator and the surface condition of the material, therefore, the lead core with good quality should be selected as calibration when selecting, and the same angle and force should be kept as far as possible when breaking lead.

3.7.6. High Temperature Wave Guide Rod (HTWGR)

In some cases, the acoustic emission sensor cannot directly contact the surface of the object to be detected, such as high temperature, high pressure, low temperature, loose surface, etc., so it is necessary to conduct the acoustic signal through the wave guide, that is to connect the acoustic signal with the sensor through the wave guide rod as the medium. The common wave guide rod has metal rod or metal tube, one end is fixed (welded or mechanically connected) on the surface of the object to be detected, and the coupling agent is used to couple the two, and the acoustic emission sensor is coupled and fixed on the other end face. Figure 3-31 shows the external structure of the wave guide rod.
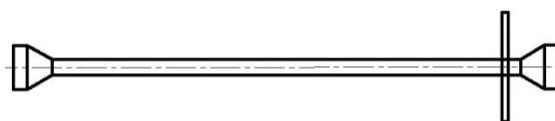
Fig. 3-31 Structure of wave guide rod

Basic requirements:

• The material and structure of wave guide rod should have small acoustic resistance to sound wave, and the structure will not produce reflection and refraction as far as possible;

• The middle of the wave guide rod is a metal rod with a diameter of 10-15mm, which should not be less than the crystal diameter of the AE sensor;

• Involving temperature factors, under 100 ℃ / 100 mm temperature decay can be referred under good ventilation conditions;

• The part favorable for fixing the wave guide rod.

3.7.7. External Parameter Signal Acquisition Box

SAEU3H acoustic emission detector supports the functions of external parameter data acquisition and external control signal input and output. The above functions need the support of external reference acoustic emission acquisition board and external reference signal acquisition box. The function and configuration are non-standard configuration, which need to be configured by users according to actual requirements.

The external reference acquisition box has the following functions:

① It supports 4-channel external analog voltage signal input, which can be synchronously sampled with acoustic emission signal;

Fig. 3-32 External reference signal acquisition box

Wiring method:

1) "External parameter 1-4" corresponds to the external parameter input variables 1-4, "GND" is the negative analog voltage signal "-" and IN is the positive signal "+", respectively corresponding to the "external parametric" parameter of software interface acoustic emission parameters; the input signal range is ± 10V;

2) When multiple external reference AE acquisition boards are used, the serial number will be postponed, for example, "external reference 1" on the second acquisition board corresponds to "external parameter 5"; all external parameter channels share 1MSP/s sampling rate.

4. Hardware Connection

SAEU3H acoustic emission testing system is composed of acoustic emission detector acquisition host, sensor, preamplifier, coaxial cable and PC software. In the process of acoustic emission detection test, in addition to the necessary hardware physical connection, it also needs to set the communication between the computer and the acoustic emission detector host.
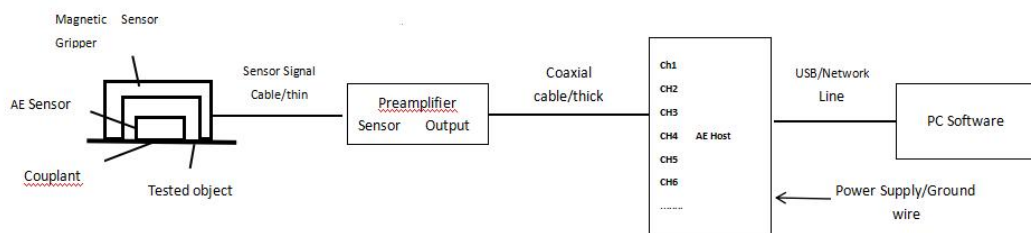
Fig. 4-1 Connection Diagram of General Sensor
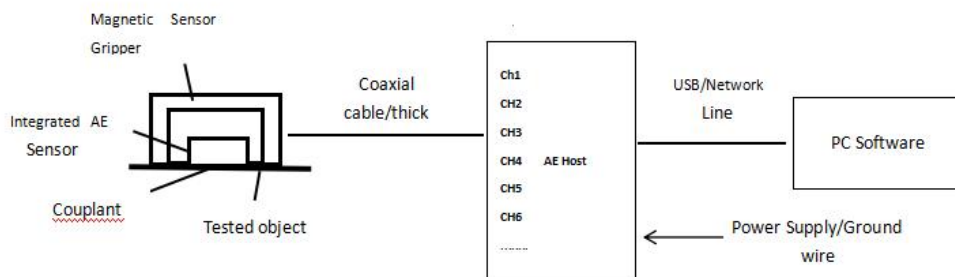
Fig. 4-2 Connection Diagram of Integrated Sensor

4.1. Instrument Connection

Figure 4-1 and Figure 4-2 are the schematic diagrams of hardware connection of the acoustic emission detection system. The difference is that the selected sensors are different. The former is that the sensor and preamplifier are independent products, while the latter is of integrated structure.

4.1.1. When the sensor and preamplifier are independent products, refer to the connection method in Fig. 4-1

1) Connect one end of the matching signal line small port (M5-KY or SMA) with the sensor output interface and tighten it;

2) The receiving surface (white) of the sensor is coated with appropriate amount of coupling agent and installed on the surface of the object to be measured. The ferromagnetic material can refer to the use of magnetic gripper;

3) The BNC-Q9 interface at the other end of the signal line is connected with the input end (sensor) of the preamplifier, and the connection is confirmed to be good;

4) The BNC end of coaxial cable is connected with the output of preamplifier;

5) The LEMO interface at the other end of the coaxial cable (or after connection) is connected to the corresponding interface of the acoustic emission main box;
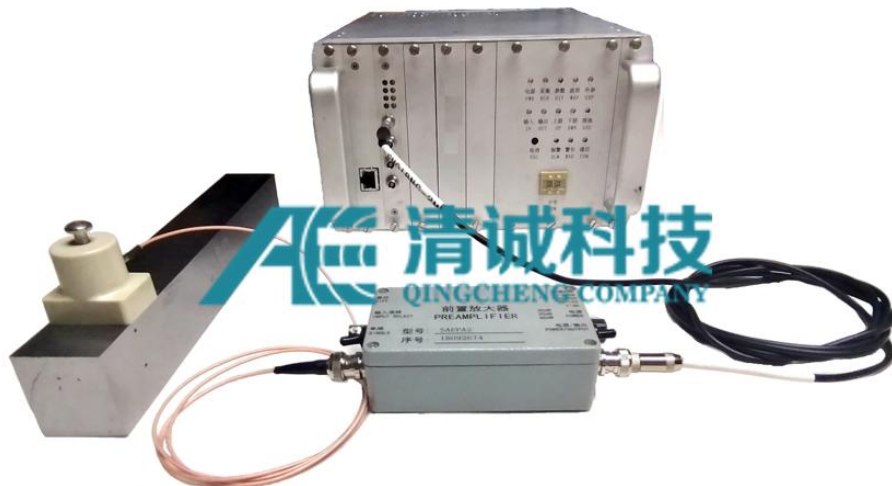
Fig. 4-3 Connection diagram of split front end Hardware

4.1.2. When the sensor is integrated built-in preamplifier AE sensor, connection method refers to the in Figure 4-2

1) Connect the BNC (or SMA) end of the coaxial cable with the output end of the sensor, and make sure that the connection is good;

2) The receiving surface (white) of the sensor is coated with appropriate amount of coupling agent and installed on the surface of the object to be measured. The ferromagnetic material can refer to the use of magnetic gripper;

3) The LEMO interface at the other end of the coaxial cable (or after switching) is connected to the corresponding interface of the acoustic emission main box.

4.2. AE Host Communication

4.2.1. AE Host Power Supply

SAEU3H AE host requires three phases AC 220V / 50Hz power supply and reliable grounding; when there is no grounding wire connected to the power supply, it can be externally grounded through the grounding terminal on the chassis panel.

4.2.2. Computer communication

The standard configuration of the connection between the computer and the acoustic emission host is USB 3.0 data line. When the user requires custom-made, the network cable or Wi-Fi mode can be selected. When USB or network cable is selected for transmission, the computer can be connected to the acoustic emission host through the configured data line. When Wi-Fi is selected for connection, the communication plug-in program shall be installed after the computer driver is installed.

4.2.3. Installation of PC Software

The acquisition of acoustic emission data is based on the correct communication between acoustic emission acquisition instrument and computer, which needs the support of computer software and driver software; the post data analysis only needs PC software.

Note: The computer must be a 64-bit operating system of windows, and 32-bit system will cause software installation failure.

Double click **[setup_x64 V4.X.X.X]** to install the software package. The installation dialog box will pop up. Click **[Next] – [Next] – [Install] – [Finish]**. The default installation path is **[C:\ProgramFiles\SWAE]**, and **[Complete Installation]** is selected by default. During the installation process, you can input letters or Chinese characters in the input box. If you encounter the prompt or block of the security software, please select **[Release] or [Allow]**. The hardware driver files will be generated in the installation folder after the PC software is installed.

4.2.4. USB Driver Program Installation

The correct connection between the acoustic emission acquisition instrument and the computer is the premise of installing the driver
① Connect the USB cable to the computer;
② Open the SWAE software;
③ Turn on the power supply of the acoustic emission acquisition instrument host;
④ The system will prompt to install the driver;
⑤ Install the driver for each AE board of the chassis, plus another one bus board to be installed for the communication between the AE instrument and the PC.

$$\text{The number of AE boards } = \text{ （ total channel number） } / 4$$

The following describes the instructions of the driver installation of Win7 and Win10 operating systems that are commonly used:
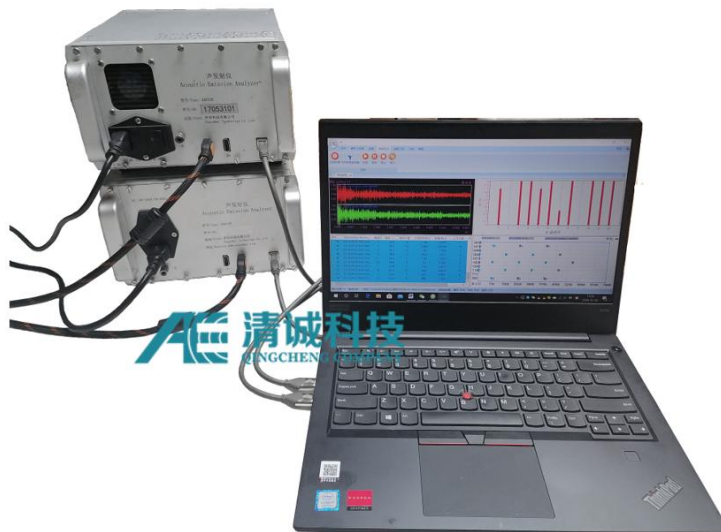
Fig. 4-4 Hardware connection diagram of cascaded chassis

1) Win7 operating system installation hardware driver

a. Enter the "Device Manager"

The general method is to right-click on [Computer] and select "Attribute" and then select **[Device Manager]**. Generally, the newly added acoustic emission hardware is under the **[Other Device]** item, as shown in the figure. For example a 20-channel acoustic emission detector, i.e. 5 acquisition boards in SAEU3H, 1 bus board (SoundWel FX2 oioi), with yellow "!" at the right Indicating that the driver is not installed or installed incorrectly.

Fig. 4-5 Status and location of driver without hardware Installed

b. Driver software selection

Right click the "SAEU3H" position and select **[Update Driver Software]**. Due to the difference of computer system environment, it is recommended to select **[Browse my**

computer for driver software] in the pop-up dialog box, and then find the folder where the driver is located (the default path of win7 64-bit operating system hardware driver is "C: \ program files \ SWAE \ driver \ win7 \ x64".

b. Drive installation

Click **[Next]** until the installation of the hardware is completed. If you are prompted or blocked by the security software, please select **[Release] or [Allow]**. For the first installation, it is necessary to install drivers for each hardware device, as shown above, until all acoustic emission hardware is installed, and the hardware for correct installation of drivers is displayed under the "universal serial bus controller" project.
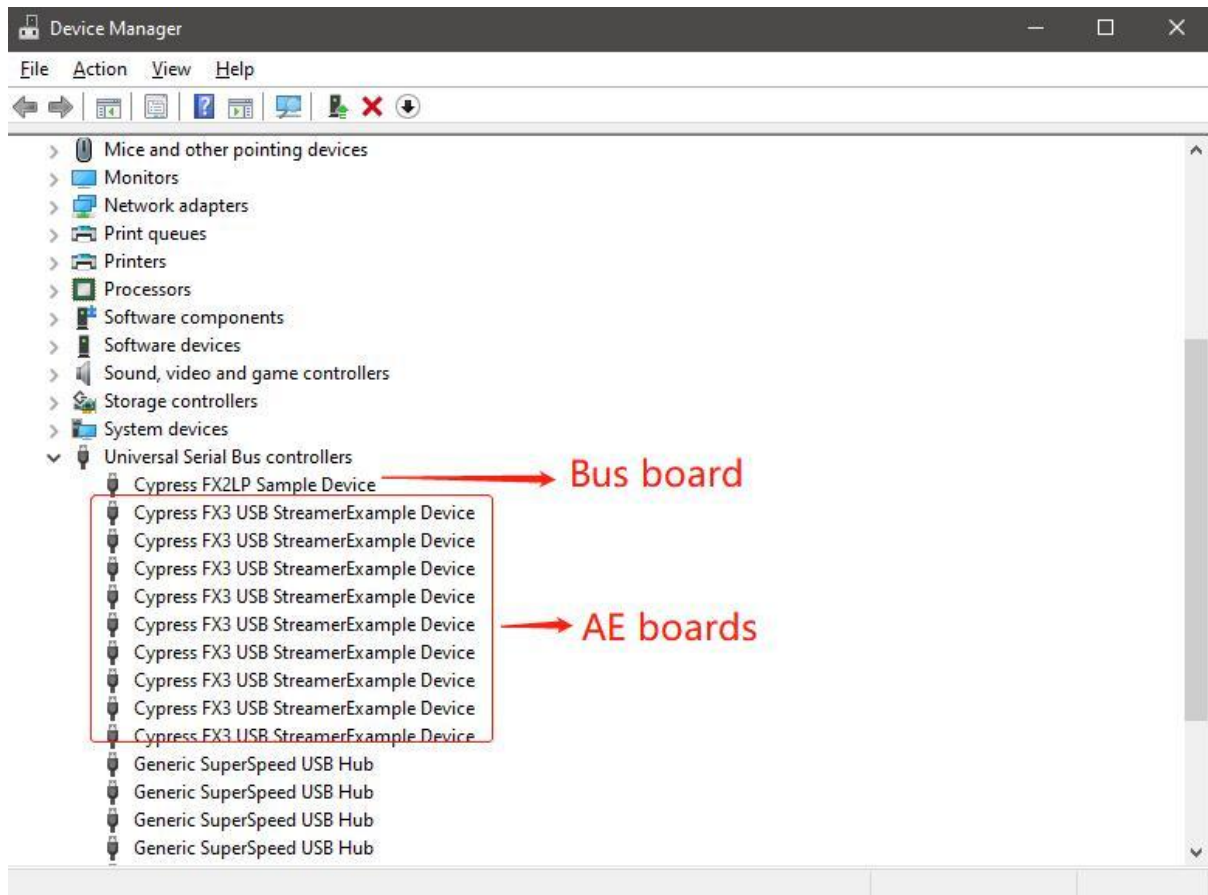
Fig. 4-6 Hardware Identification Status and Location After the Installation of Drivers

2) Hardware drive installation of Win10 Operation System

The driver installation process is similar to that of Win7 mentioned above. The default path of the

driver is 【C: \ program files \ SWAE \ driver \ win10 \ x64】.

Under the Win10 (Win8) operating system, user needs to turn off the "digital signature authentication" before installing the driver. The general process of "turning off the digital signature authentication" is: enter the computer, update and security > > recovery > > advanced starting-up > > restart now > > restart the computer > > Advanced > > troubleshooting > > Advanced Options > > starting-up Settings > > Restart > > press 7 or F7 to disable the driver forced signature after the restarting.   For detailed method, users can search "win10 turn off digital signature" on the Internet.

4.2.5.   Installation of LAN and Wi-Fi Drivers

When the SAEU3H acoustic emission testing system is equipped with network communication board and needs to use LAN or Wi-Fi for communication, it is necessary to install the network communication board plug-in. This process is realized under the condition of normal USB communication between AE host and computer.

1) On the premise of turning off the power supply of the acoustic emission instrument, the acoustic emission host is connected with the computer through the network cable. At the same time, ensure that there is no USB cable connection between the AE host and the computer.

2) The IP address of the network communication board is 192.168.0.240 by default. The IP address of the computer needs to be set to 192.168.0. X. At this time, the computer needs to be disconnected from the Internet.

3) Install "SX virtual link" virtual connection software on the computer, and start "SX virtual link" after successful installation. Click the "options" button, select the "general" tab, and select all the options in "basic settings", as shown in Figure 4-7.
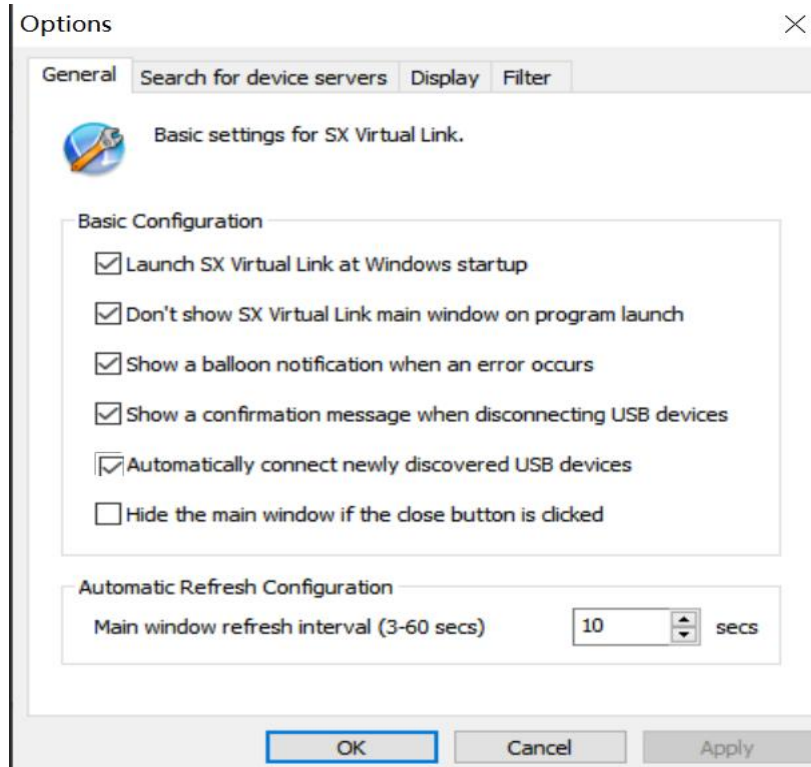
Fig. 4-7 SX virtual link software setting interface

4) Turn on the power supply of the AE host. After the AE instrument is started and stabilized, the USB communication device nodes included in the AE instrument will be listed in "SX virtual link", as shown in Fig. 4-8. The number of devices displayed in the window is equal to that of USB connection and the number of AE acquisition boards + 1. The name of AE main board is "FX2 Oioi", and the name of AE acquisition board is "saeu3h". When all equipment status is "connected", the acoustic emission instrument can be used normally.
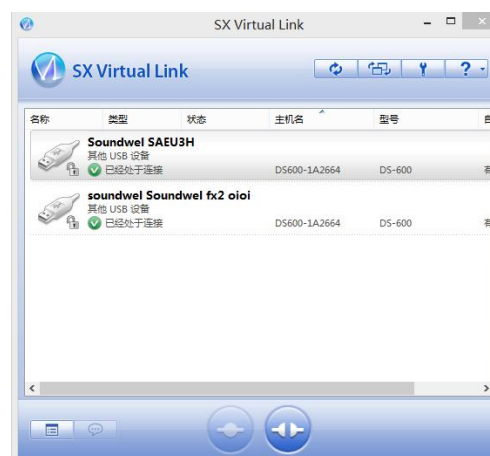
Fig. 4-8 Acquisition Board Connection status display

5) When the status of all devices is "received", right-click the mouse in the device section, and then select "connect" to use the device to enter the connection state. At this time, acoustic emission can be carried out through the network to communicate with the computer.

Note: when using network communication, the hardware identification process is relatively slow, and the refresh time of each hardware needs about 10 seconds; the "SX virtual link" software cannot be closed during the use process.

Part 2 SWAE4 Software

Suitable for acoustic emission system

SAEU2S, SAEW, SAEI, SAEU3H, SAEU3S, RAE, RL, ISAE, RAEM
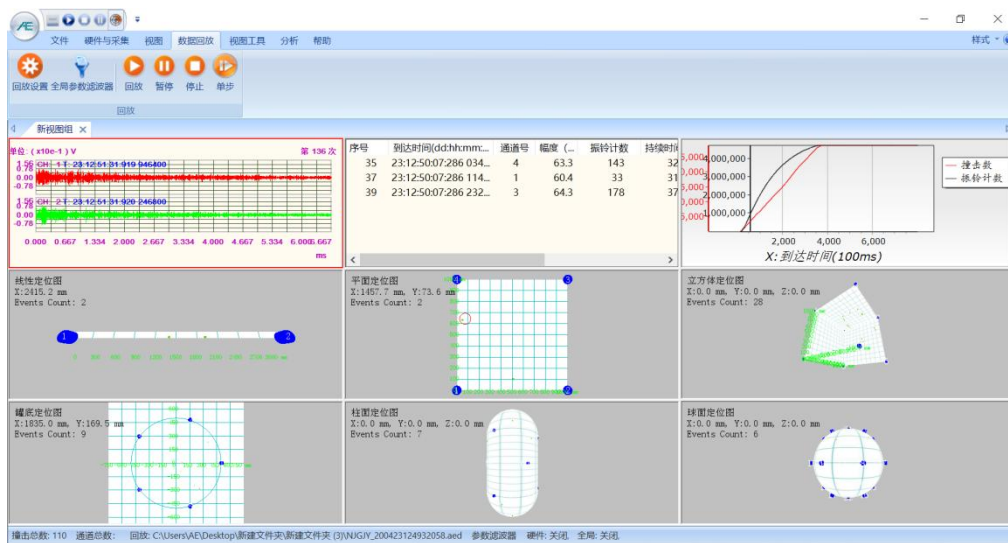
Note:

This manual is the general software manual for SAEU series digital acoustic emission testing system, SAEW wireless acoustic emission system, SAEI explosion-proof acoustic emission system and RAEM remote acoustic emission system software. The description of some functions is only applicable to the products with this part of function. Please refer to the function selected when you purchase the product.

5. Basic Information

SWAE acoustic emission system software is a collection of real-time acquisition / analysis software and post analysis software. It is designed based on Windows operating system and can run normally in 64-bit Windows 7/8/10. The operating system is suitable for the acoustic emission detector of SAEU series, SAEW series, SAEI series and intrinsically safe explosion-proof series of our company. It can sample and play back the data of the equipment. It is easy to operate and learn. At the same time, it supports the installation and use of multiple computers. The number of users is unlimited, which is convenient for joint analysis and research after the event.

The main features of the software are as follows:

1) It is suitable for windows 64-bit operating system;

2) Multiple client end installation without encryption is convenient for multiple computers to use at the same time;

3) Similar to Windows Office operation style, easy to use;

4) The shortcut tool menu can be customized manually to operate the software conveniently and quickly;

5) Various 2D and 3D graphics display;

6) A software built-in all Location modules;

7) Software is upgraded free of charge for life;

If there are any problems or other special needs in the use of the software, we hope you can put forward your valuable opinions, so that we can provide you with free upgrade service after improving the version of the software.

As the software is constantly updated, the software interface or settings may change slightly.

5.1. Computer Hardware Requirements

Acoustic emission software and driver must be used in Windows operating system with 64-bit hardware. In order to improve the efficiency of data acquisition and transmission, it is recommended to use high-frequency multi-core processor and high-speed and large-capacity memory as far as possible; and the selection of large-capacity hard disk can provide convenience for data storage; when there are high requirements for acoustic emission waveform acquisition or the number of acoustic emission host channel is greater than 48, in addition to the above requirements, the motherboard and solid-state hard disk with USB3.0 interface should be selected to significantly increase the number according to the transmission and storage rate.

The following Table 5.1 can be referred to when selecting a computer for the acoustic emission host.

Table 5-1 Recommended Computer Configuration

Application	AE Channel	Minimum computer configuration
Scientific research experiment	4 Channel	I5 processor, 8G memory, 500G mechanical hard disk, 1024x768 resolution
Scientific research experiment	4 < Channel Qty≤16	I5 processor, 8G memory, 500G mechanical / 128G SSD, USB3.0 interface, 1024x768 resolution
Scientific research experiment	Channel Qty > 16	I7 processor, 16G memory, 1TB mechanical / 256G SSD, USB3.0 interface, 1280 x1024 resolution
Engineering inspection	16≤Channel Qty	I5 processor, 4G memory, 500G mechanical hard disk, 1024x768 resolution
Engineering inspection	Channel Qty≥16	I5 processor, 8G memory, 1TB mechanical hard disk, 1280 x1024 resolution

5.2. Software Upgrade

QingCheng AE institute (Guangzhou) Co., Ltd. promises to upgrade permanently free of

charge for all SWAE series acoustic emission software. The installation of upper computer software and driver has been introduced in "Part 1 > Chapter 4.2 AE Host Communication". If the operating computer is provided by our company, the driver and software have been pre-install at the factory. The installation method of the upgrade software is automatic coverage installation. Users can consult or visit Qingcheng website to view the relevant software upgrade information.

Notes:

1. If it is not connected to the AE hardware, the software can only replay and analyze the data, and some hardware settings will not be visible.

2. If the driver is not installed, the system cannot run in acquisition mode.

5.3. Document Types

SWAE AE file type includes configuration file and data file. The former suffix is. AEC, and the latter includes parameter file (.pra) and waveform file (.aed).

5.3.1. Configuration File

The configuration file suffix is .aec. Users can quickly complete the parameter settings and view settings by transferring the existing configuration files in the software. If no file is available, the system will default the initial settings stored in the root directory of the program installation, and the hardware and view settings will revert to the default value of the program.

The general settings file contains the following file contents:

● Save all the setting data related to the acoustic emission acquisition instrument hardware to the file;

● Save the type and use rules of parameter filter;

● View setting and view group setting;

● Save statistics settings;

● Storage and Location related settings

5.3.2. Parameter File

The parameter file is an independent data file with suffix of **.pra**. The data is presented in the form of "parameter table" in the software. The parameter types include: arrival time, amplitude, (ring) counts, duration, absolute energy, rise counts, rise time, RMS, ASL, 12 external parameters, centroid frequency, peak frequency, 5 partial power spectrum, etc.

The parameter file name can be named in the file storage path. If it is not named manually, the program uses the default name and the tag generated by the computer system time to automatically generate, and automatically changes the time tag after a file end to ensure that the file is stored and not covered;

The encoding format of parameter file is described in detail in SWAE software secondary development package provided by QingCheng.

5.3.3. Waveform File

Waveform file generally refers to time domain waveform file with suffix of **.aed**, which takes up more storage space than parameter file, and is affected by many conditions such as sampling rate and sampling accuracy. The data is presented in the form of "waveform" in the software. Waveform file is not only limited to the original waveform file, but also includes the following post-processing waveform: time-domain waveform, frequency-domain waveform, wavelet, etc.

The waveform file is generated together with the parameter file after the waveform collection function is turned on. The file name and storage path are also consistent with the parameter file and do not need to be specified manually; only in full waveform mode, it needs to be set manually; **Automatic file naming method: name + "_" + sample time**, for example: CJ2(70dB) _220630153540436.aed, so as to ensure the uninterrupted data collection

process.

The coding format of waveform file is described in detail in the secondary development package of SWAE software provided by QingCheng.

6. Interface and Functions

6.1. Main Interface Menu

The first step in the process of using SWAE is to start the program. Double click the **[SWAE]** icon on the windows desktop to load the default configuration after the software starts. If the default configuration is not saved, you need to set the required view in the View menu. The main interface of the software is shown in Figure 6-1, which generally includes four parts: main menu area, secondary menu area, view area and Statistics area.
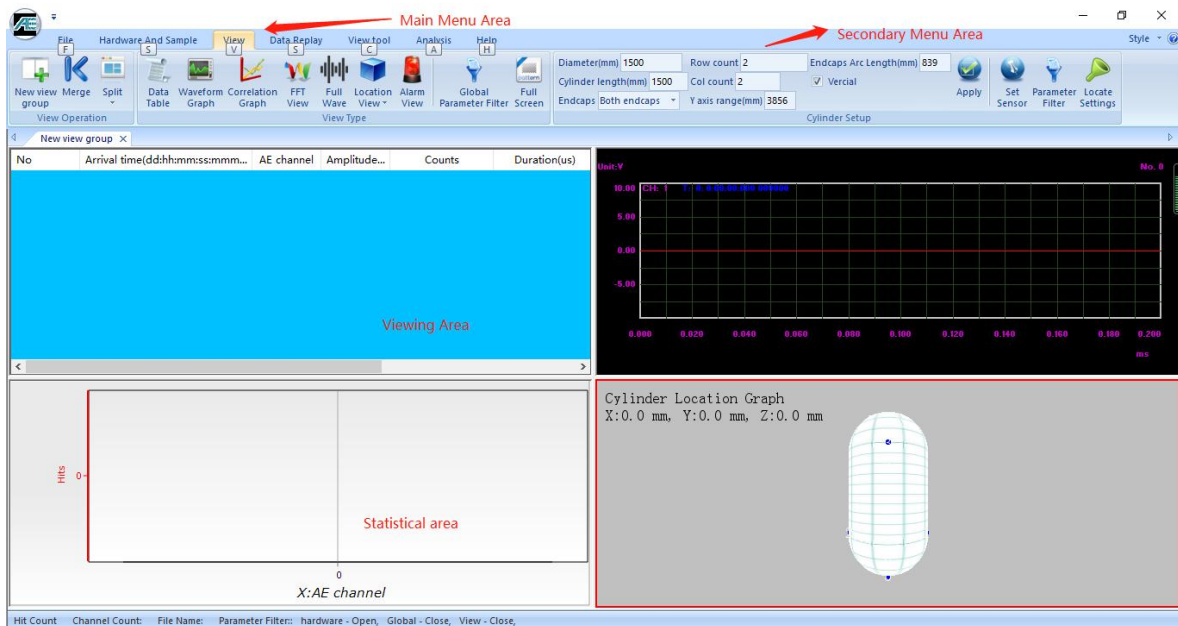
Fig. 6-1 Software Main Interface View

The main display areas of the software interface include:

1) The software title bar is the windows standard title bar, with Qingcheng AE institute icon on the left. The minimize, maximize and close buttons on the right. The shortcut toolbar position can be set on one side of the icon. The main menu bar is a level-1 menu option;

2) The second level menu bar is the operation option of the office style;

3) View group title bar: SWAE software can create multiple view groups, and each view group can be set with up to 80 views. Each view group can be named and arranged in

parallel with the view group title bar. Click on each view group to switch the view display;

4) The view area is the display area of each view under the view group;

5) Statistics column and status bar area, located at the bottom of the software interface, can manually set different equipment real-time statistical information.

Fig. 6-2 First Level Menu of the Software

6.2. Menu Function

The menu area includes the main menu area and the secondary menu area. The main menu includes seven parts: **[File], [Hardware and Sample], [View], [Data Replay], [View Tool], [Analysis] and [Help]**. Each sub-menu contains menus with different functions. There is a convenient menu setting window in the upper left corner of the software. The operator can customize the display of common shortcut keys and display methods in the lower area according to the usage habits.

6.2.1. View/ Switch Devices Supported by the Software

Software supported devices include SAEU3H and RAEM1. During acquisition, the current software supported devices must correspond to the connected acoustic emission devices. Data replay, data analysis and other operations are consistent of both two modes.

You can click the "AE" icon in the upper left corner to view the current supported devices. To switch, click the "AE" icon in the upper left corner, then click the "Yes" button in the popup window, and wait for the software to start.

Note:

The interface and function introduction of the software in this paper is the description of the

support device for SAEU3H.
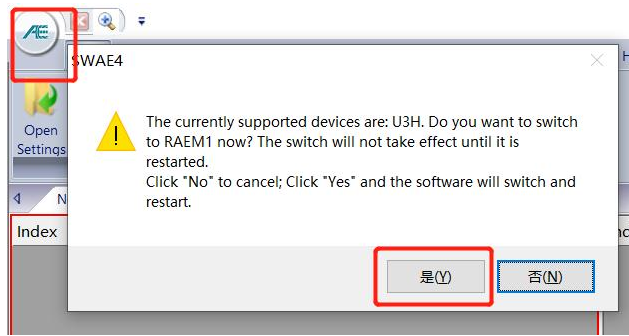
Fig. 6-3 AE software supported device interface

6.2.2. Shortcut Key Settings

Click the drop-down button on the right side of the "AE" icon to pop up the **"Custom Quick Access Toolbar"**. After selecting **[More Commands]**, the interface shown in Figure 6-5 appears. Select the function keys to be added under various menus on the left side, and click add in the middle to add the function keys to the display area on the right side. Click OK to see the newly set functions on the shortcut toolbar on the main page Button. The deletion method is similar. Select the item to be deleted in the right display area and click delete.
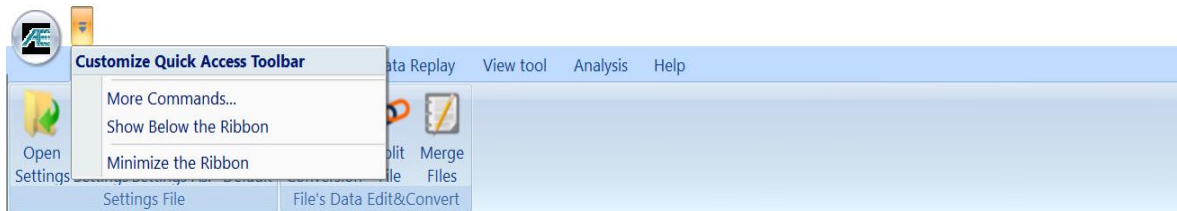
Fig. 6-4 Quick Access Toolbar
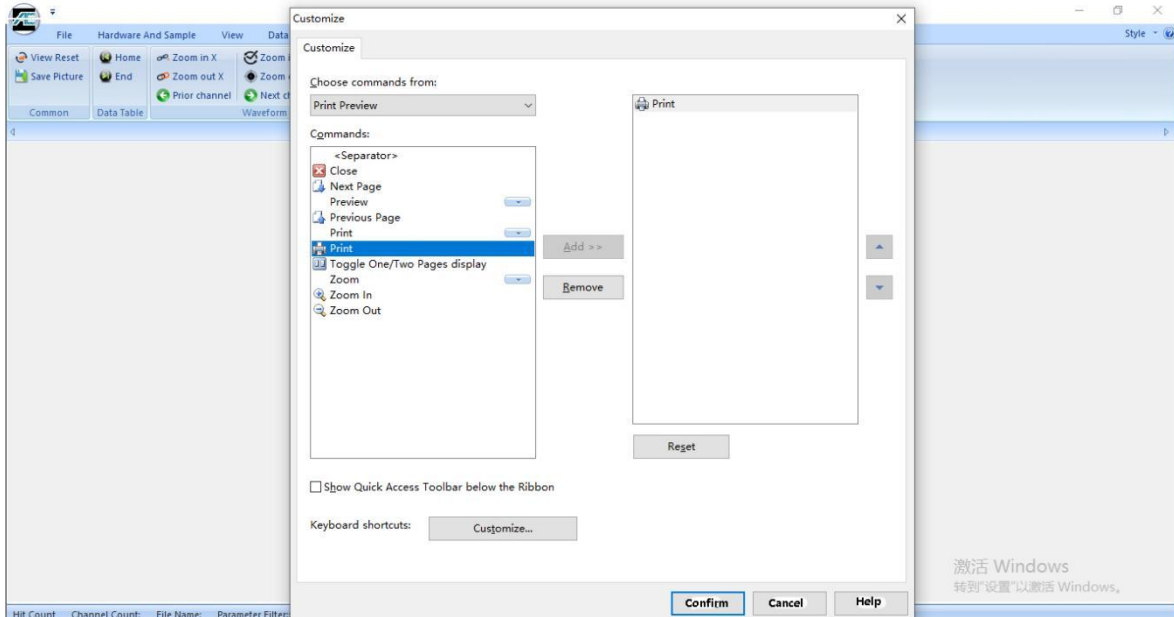
Fig. 6-5 Shortcut toolbar setting interface
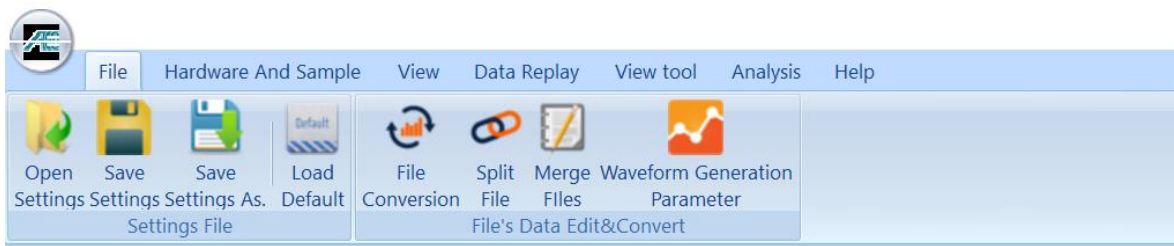
Fig. 6-6 Shortcut Toolbar Adding Interface

In the user-defined Quick Access Toolbar menu, there is "display below the ribbon", which affects the display position of shortcut buttons on the software status bar, as shown in the figure:
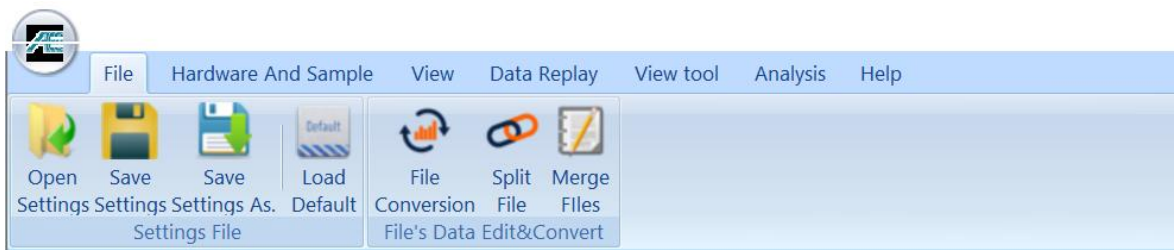
Fig. 6-7 Display interface at the bottom of the function area

6.2.3. Hide Secondary Menu

Click the drop-down button on the right side of the "AE" icon to pop up the "custom Quick

Access Toolbar", and select the minimize function area. The secondary menu will be hidden to display the view area in a larger area.
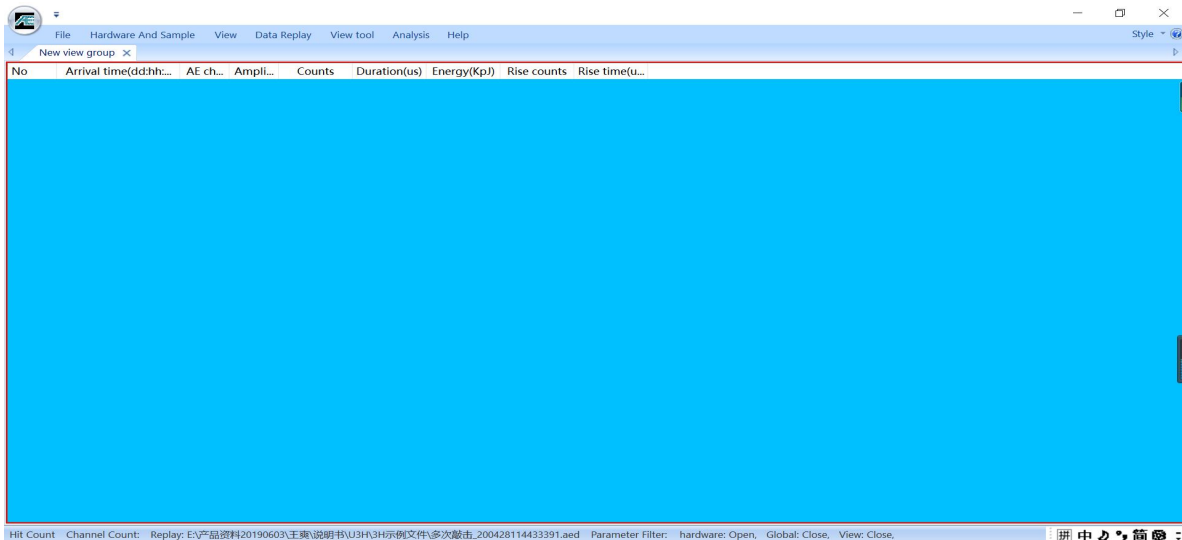
Fig. 6-8 View Display After Minimizing the Ribbon

6.2.4. File Menu
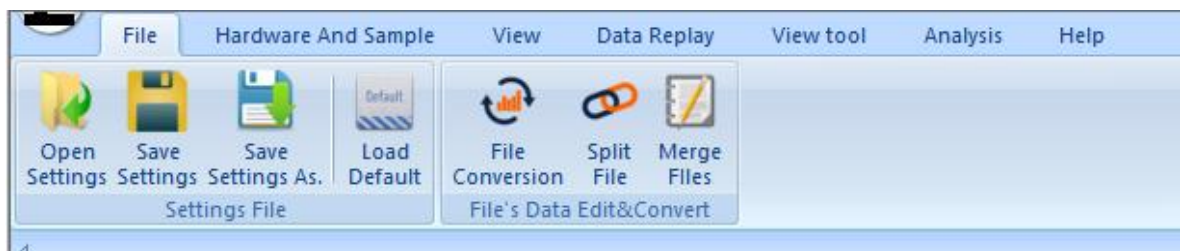
Fig. 6-9 File menu

6.2.4.1. Settings File

Open Settings: open and load one of the saved setting (configuration) files. Click [Open Settings] and a dialog box will pop up. Locate the file path, and select the corresponding name and the suffix is .AEC file, and then [Open]; for the information contained in the configuration file, see Chapter 5.3.1;

Save Settings: save the current configurations including the hardware and sample settings, views and view settings. This setting file will be opened and loaded automatically when the software starts in the future. It is generally used for continuous testing under the same

conditions, which is convenient for debugging. But it will be overwritten by the most current configuration settings when pressing the button again.

Save Settings As: save the current completed configurations as an independent file, and it can be retried and loaded without being overwritten; click [Save Settings As.] to set the storage path and file name; when typing the file name, the * needs to be removed, but the suffix ".aec" must be reserved.

Load Default: click [Load Default] to automatically load the default ".aec" file in the default storage of the software.

6.2.4.2.   File Conversion and Edition

6.2.4.2.1.   File Conversion

The file convert function can batch convert AE parameter file (.PRA) and AE waveform file (.AED) generated by software into common file format .TXT or .CSV. Users can use other drawing or analysis software for post processing of data. In "Open Data Files", you can batch select the original data to be converted and check the file type to be.

Note: You can convert the file during data replaying; do not operate during conversion.
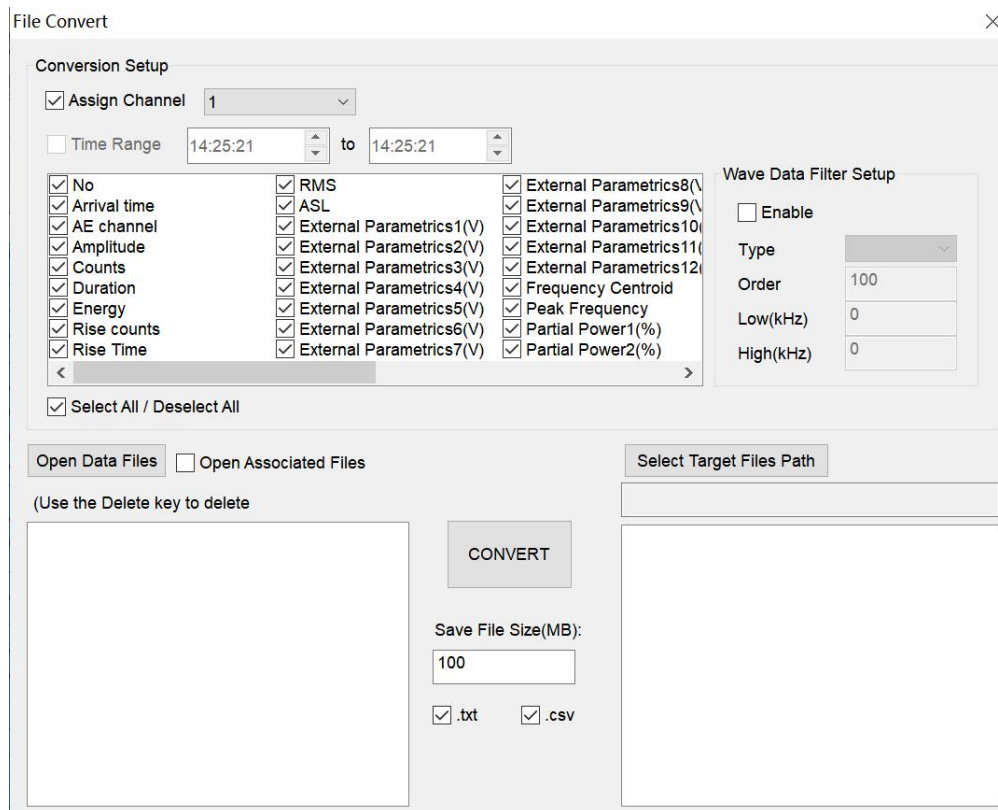
Fig. 6-10 File Conversion Set up Interface

Conversion of acoustic emission parameter file:

1) Click "Open data files " to select the AE parameter file to be converted; Multiple files can be selected for batch conversion. At the same time, you can choose whether to open the associated file;

2) In the upper setting area, you can choose to export the specified channel file, time range for exporting the file, arrival time setting of exporting parameters, and parameter type of exporting the file;

3) Click "Select Target Files Path" to select the location where the converted file needs to be saved;

4) Select the. txt file or. csv file, click "Convert". The software will automatically display the conversion progress. After the conversion is completed, the software will pop up a prompt box, and the converted new file will be displayed in the right file box.

6.2.4.2.2. Split Files

The file splitting function can extract and generate a new waveform file (.aed) or a new parameter file (.pra) according to the time range, data frame range or channel range in the larger waveform file (.aed) or the parameter file (.pra) generated by the software. The naming method of the new file is: "to" + the original file name and time tag.

After selecting the original data, the software automatically identifies the time and data frame range, and users can modify it according to their needs. You can check the channel number to determine whether the data of the channel needs to be split. If not, there is no data of the channel in the newly generated file.
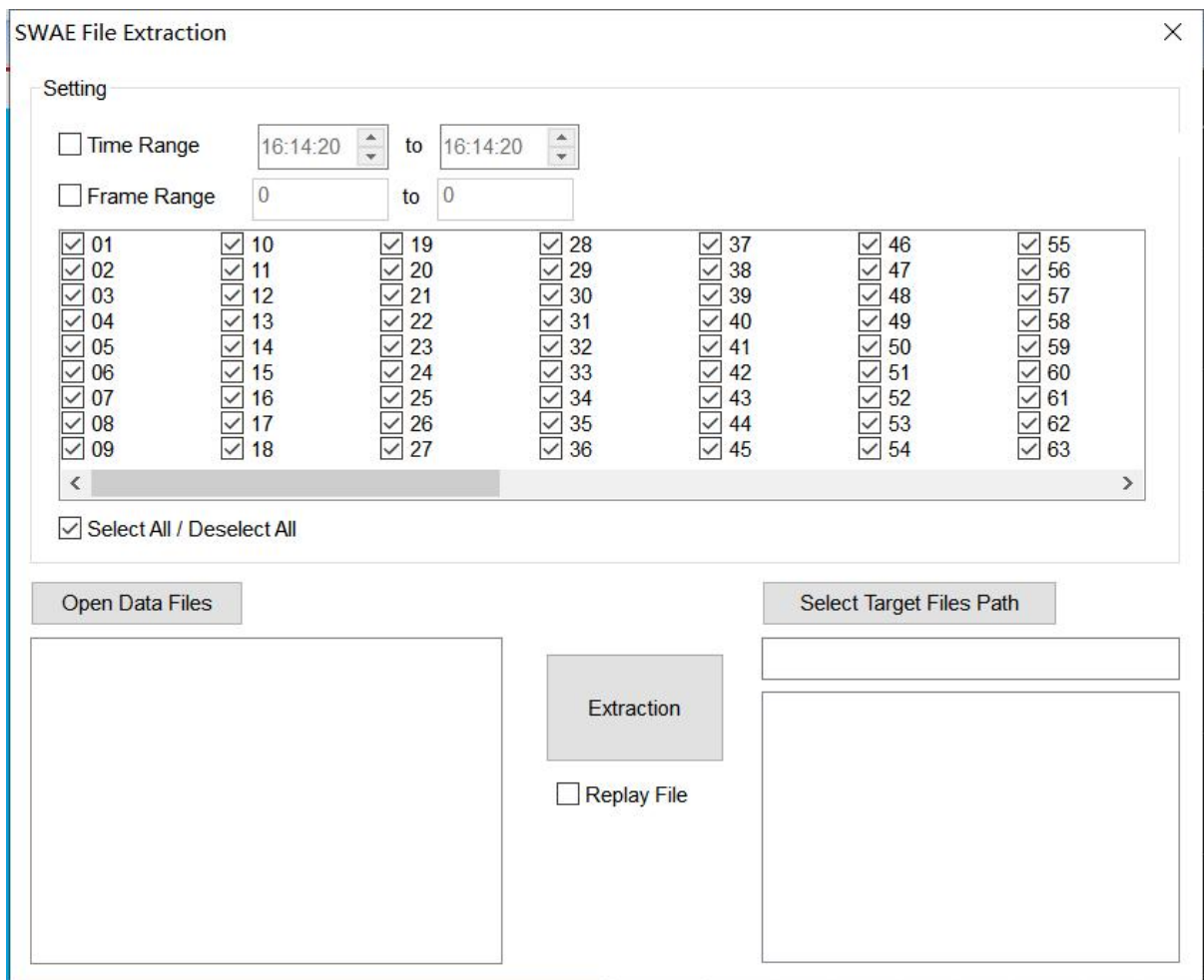
Fig. 6-11   File Splitting Interface

6.2.4.2.3. Merge Files

The file merge function can combine several AE parameters files (.pra) or AE waveform files (.aed) generated by the software to produce a new AE parameter file (.pra) or AE waveform file (.aed).

As shown in Figure 6-12, merge the file name by adding "Merge-" before the file # "1". It should be noted that in addition to the same type of merged files, the parameter settings during data collection must also be consistent.

Click [Add Merge File] to select the files to be merged. You can choose whether to replay it after the merge, and then click [Start Merge].
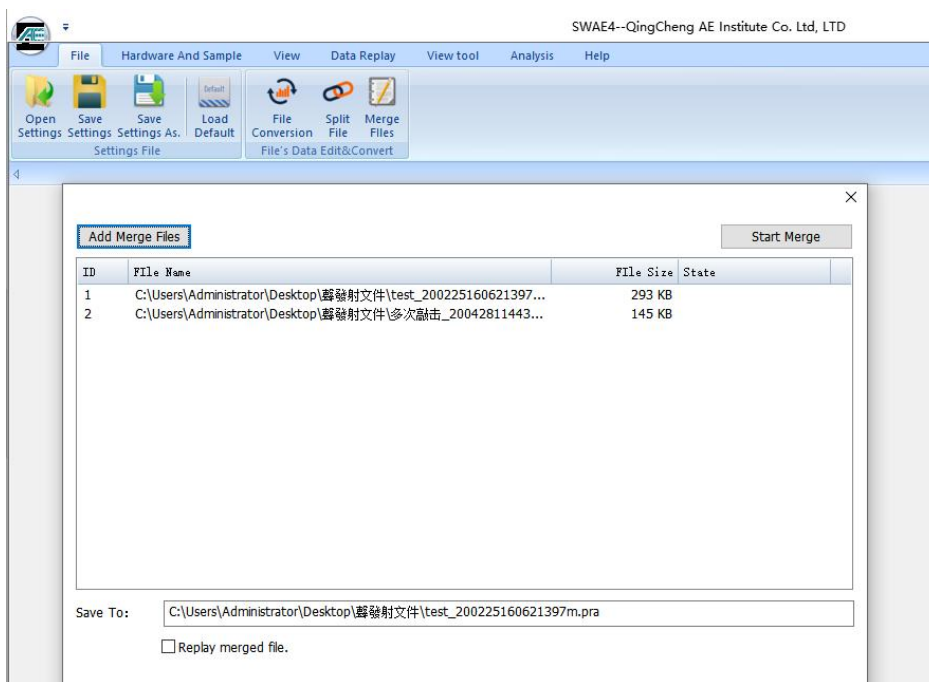
Fig. 6-12 File Merge Interface

6.2.4.2.4. Waveform Generation Parameter

Waveform to parameter function can regenerate the AE parameter file (.pra) based on the original AE waveform file (.aed) with new configuration settings.
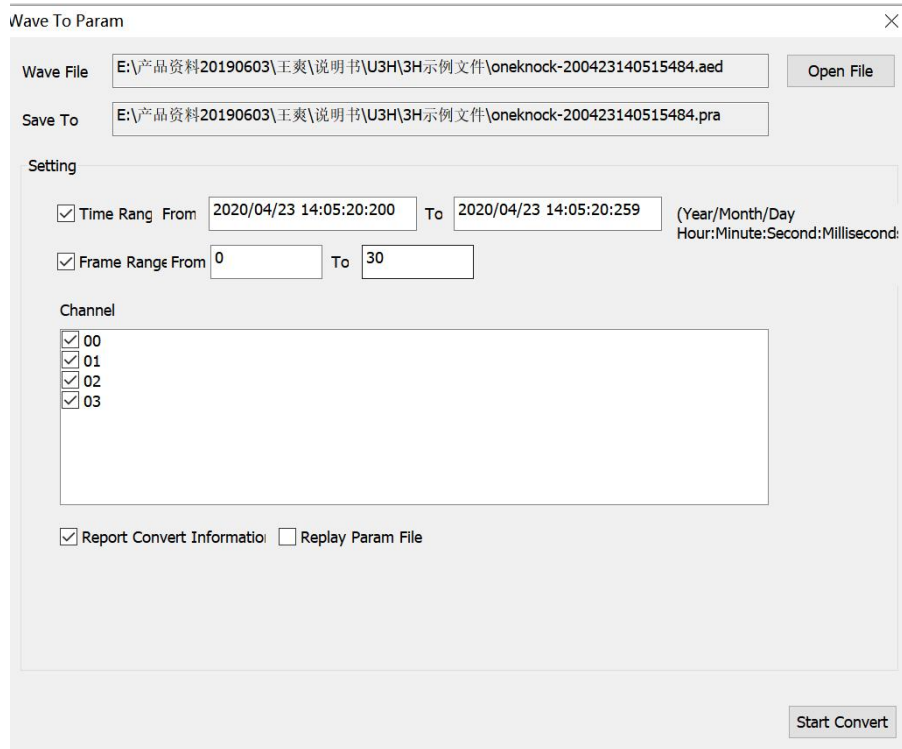
Fig. 6-13 Waveform to parameter interface

6.2.5. Hardware and Sample Menu

Fig. 6-14 Hardware and Sample

6.2.5.1. Sample

6.2.5.1.1. Sample Settings

The "Sample settings" includes the following function setting interfaces: **[Hardware Setup],**
[HIT Feature], [Waveform], [Saving], [FFT Setup], [Ex-Parameter Setup], [Others setup].
The first four items are common settings in the process of acoustic emission test, also known

as general settings, and the last three items are optional settings in some tests, which can be called auxiliary settings.
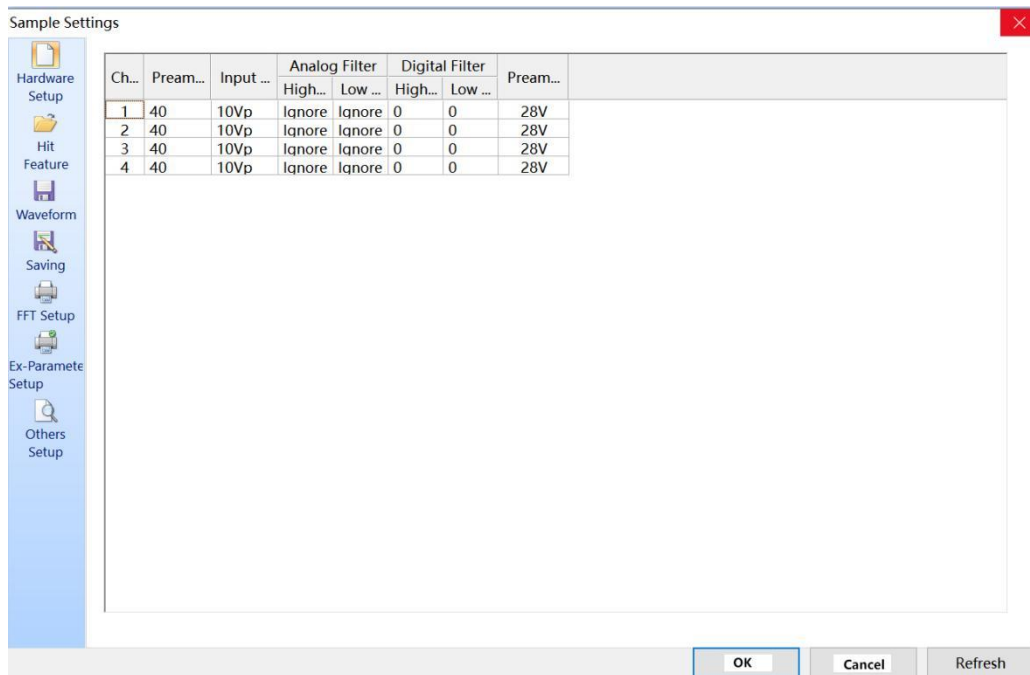
Fig. 6-15 Sample Setting Interface

6.2.5.1.1.1. **Hardware Setup**

Click [Hardware Setup] on the left side of "Sample Settings" interface, and the interface as shown in Fig. 6-15 appears. In this interface, it is necessary to set "Preamplifier (dB)", "Input range", "Analog filter", "Digital filter" and "Preamplifier power".

Definition and setting rules of nouns:

● **Channel**: The number of the channel correctly identified by the hardware corresponds to the channel number of the AE system chassis panel;

● **Preamplifier gain:** it is the actual calculated gain. In order to keep the signal traceable, generally set it same as the actually applied "preamplifier" gain, and the default 40dB is the common gain. The user can input the gain value according to the actual situation;

● **Input range**: it refers to maximum single side amplitude voltage input range accepted by acquisition board, default value is 10V; according to the application needs, there are five options for selection: "10Vp", "5Vp", "2Vp", "1Vp", "0.1Vp". In acoustic emission system,

the maximum output voltage of preamplifier is generally referred to. If the actual input voltage exceeds the set value, the signal will be clipped.

- **Analog filter:** an analog circuit fixed on the acquisition board to process the analog voltage signal. The appropriate filter combination can be selected according to the actual site. There are four high pass (allow to pass if higher than) filters: Ignore (0) / 20kHz / 100kHz / 400kHz, and four low-pass (allowed to pass if lower than) filters: 100kHz / 400kHz / 1.2MHz / Ignore (infinite). Low-passed filter allows the signal lower than the reference frequency to pass through; while the high-passed filter filters out the signal lower than the reference frequency to pass through, but allows the signal higher than the reference frequency to pass through. The "High Pass" column sets the lower limit of frequency domain, while the "Low Pass" column sets the upper limit of frequency domain; the selection of frequency band should be considered comprehensively with the frequency response of the sensor used and the expected signal frequency band.

Table 6-1 Example of analog filter type

Analog Filter		Analog Filter		Analog Filter		Analog Filter	
High Pass	Low Pass	High Pass	Low Pass	High Pass	Low Pass	High Pass	Low Pass
100kHz	400kHz	400kHz	100kHz	100kHz	Ignore	Ignore	100kHz
100kHz	400kHz	400kHz	100kHz	100kHz	Ignore	Ignore	100kHz
100 ~ 400kHz Band Pass Filter		100 ~ 400kHz Band Stop Filter		> 100kHz High Pass Filter		< 100kHz Low Pass Filter	

- **Digital filter**: carrying out frequency filtering on the digitized signal, which can be activated or not according to the actual situation. The setting rules can refer to "analog filter". The lower limit of frequency domain is set in the high pass column, and the upper limit of frequency domain is set in the low-pass column. When the "digital filter" is not enabled, the values can be set as follows: high pass: 0, low-pass: 2500;

- **Preamplifier power supply**: with the driving voltage of the preamplifier, the acquisition board supports two kinds of external power supply voltage, which are 28V and 5V DC power supply respectively, and the selection is consistent with the voltage of the

preamplifier, the default value is 28V; when it is set to 0V, it is an oscilloscope mode and can be directly connected to a third-party signal generator. **Note** that it cannot be modified directly. You need to click the table header and then click the pop-up menu "Allow power before modification" to click the edit box to modify.

6.2.5.1.1.2. Hit Parameter

Click [Hit parameters] on the left side of "sample setting" interface, and the following interface will appear. This interface mainly introduces the settings related to the extraction of acoustic emission parameters, including "Channel", "Parameter Threshold", "Floating threshold", "**HDT** (Hit Definition Time")", "**HLT** (Hit Lock Time)" and "**PDT** (Peak Definition Time)". The last three items are also called timing parameters. Whether the settings are correct or not is correct, it is very important to analyze the characteristic parameters of acoustic emission.
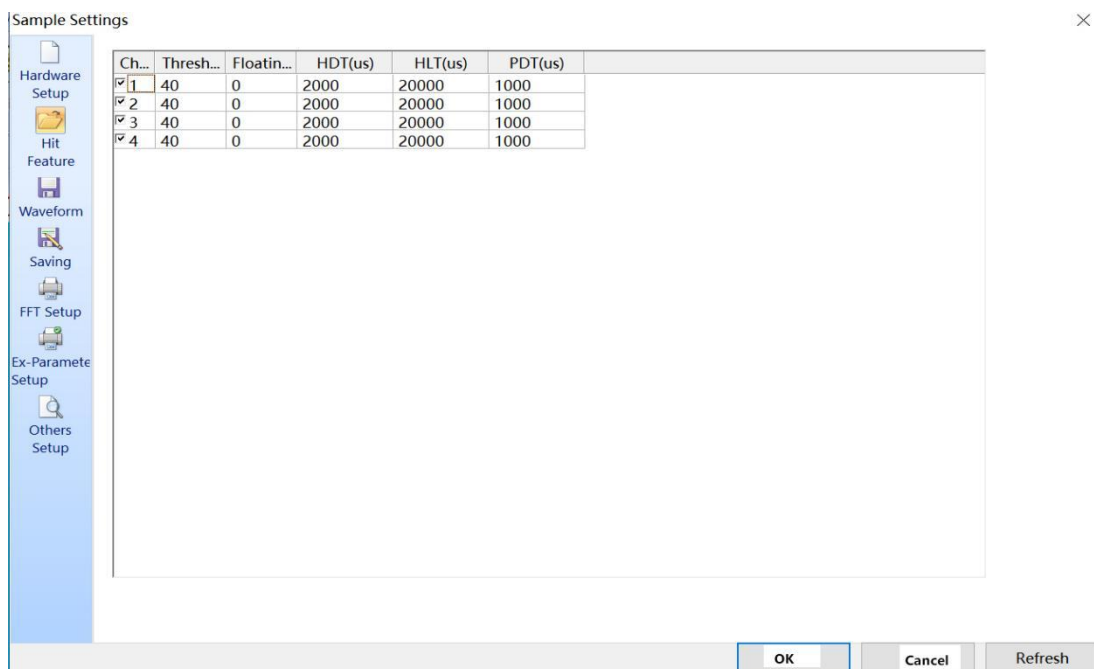
Fig. 6-16 Hit parameter setting interface

Definition and setting rules of nouns:

Channel: the default "√" selection number under the channel corresponds to the channel number that has been correctly identified, and corresponds to the hardware number of the chassis panel interface. The "√" in the selection box represents that the current channel enables the function of extracting acoustic emission parameters. If it is canceled the parameters will not be generated; after selecting, the parameter file with suffix of. pra will be

generated.

Parameter threshold: determine the voltage level of acoustic emission parameter data to be recorded. When the channel is in standby state and the voltage level exceeds the set value, the record will be triggered, and then controlled by timing parameters. According to the application environment setting of acoustic emission system, the noise level is generally higher than dB, and the setting range is 1-100 (integer). Generally speaking, 40dB is the common threshold;

Floating threshold: it is suitable for working conditions with complicated noise environment. Generally, the floating range of 0-6db is set. Most working sites do not need to enable this function, that is, it is set to "0"; after start-up, when the "parameter threshold" set is lower than the current "ASL" for a period of time, the actual threshold will increase the value within the "floating threshold", and the updated threshold value will be consistent with the original fixed "parameter gate". The maximum value of the two is taken as the final threshold.

HIT Definition Time: unit of microseconds (us), abbreviation HDT, the setting range is 1 ~ + ∞ (positive integer), can be directly input in the text box. It refers to the waiting time interval of hit signal set to correctly determine the end point of a hit signal. When the set HDT value is greater than the time interval T between two adjacent wave packets passing 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 larger the HDT is, the less the AE parameters are extracted, and the smaller the setting is, the more AE parameters are extracted.
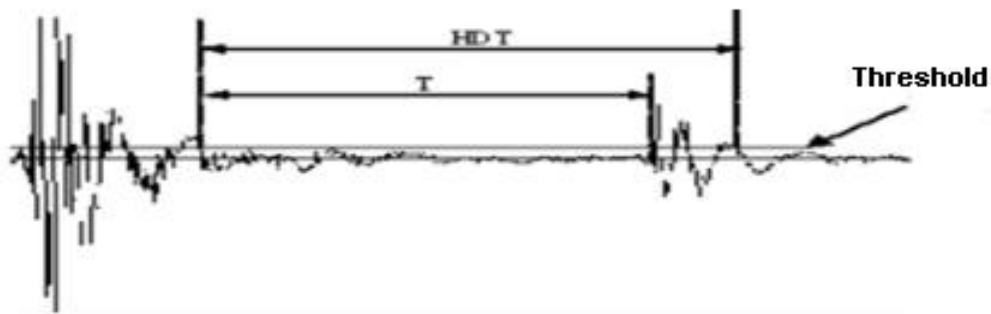
Fig. 6-17 Diagram of HDT

HIT Lock time: unit of microseconds (us), abbreviation HLT, the setting range is 1 ~ + ∞ (positive integer), can be directly input in the text box. In order to avoid receiving the reflected wave or late wave, the time window for closing the measurement circuit is set. After a HDT time after the end of the current acoustic emission event, there is a period of time (HLT) signal being ignored. This window is called hit look time. The value set is affected by signal attenuation, structure size, etc. If the setting value is too large, 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, and the signal in T period will not be sampled.
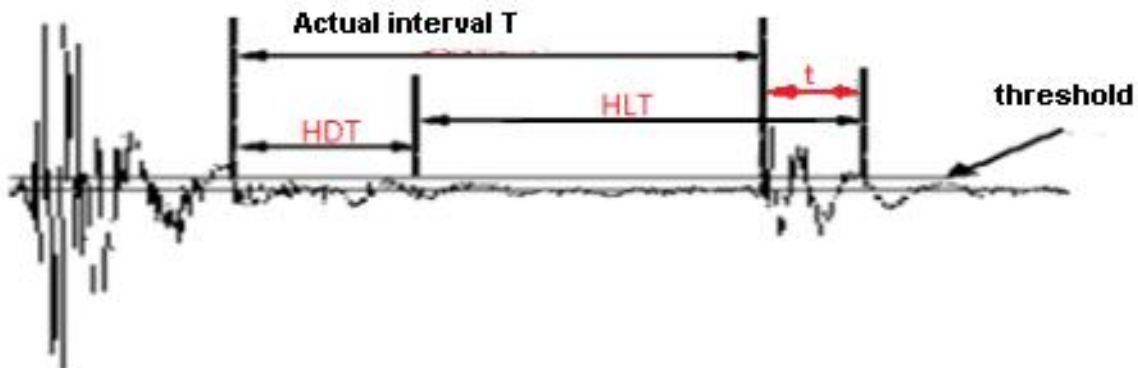
Fig. 6-18 Diagram of HDT

Peak definition time: unit of microseconds (us), abbreviated as PDT, the setting range is 1 ~ + ∞ (positive integer), which can be input directly in the text box. The new maximum peak waiting time interval set to correctly determine the rise time of the hit signal. If it is too short, the high-speed and low amplitude precursor wave will be mistaken as the main wave, which is generally taken as **20-50%** of the hit definition time (HDT);

Convenient operation:

Modify single column parameters: first, complete the setting of "channel 1", and then click the column name, such as "parameter threshold dB", and the "set current column" pop-up box appears, select and click;

Modify all channel parameters: first complete the setting of "channel 1", then click "channel" in the project name to open the "set all columns" pop-up box, select and click;

6.2.5.1.1.3. Waveform

Click [**Waveform**] on the left side of "Sample setting" interface to display the following interface. This interface is mainly related to acoustic emission waveform and is the basis of acoustic emission waveform analysis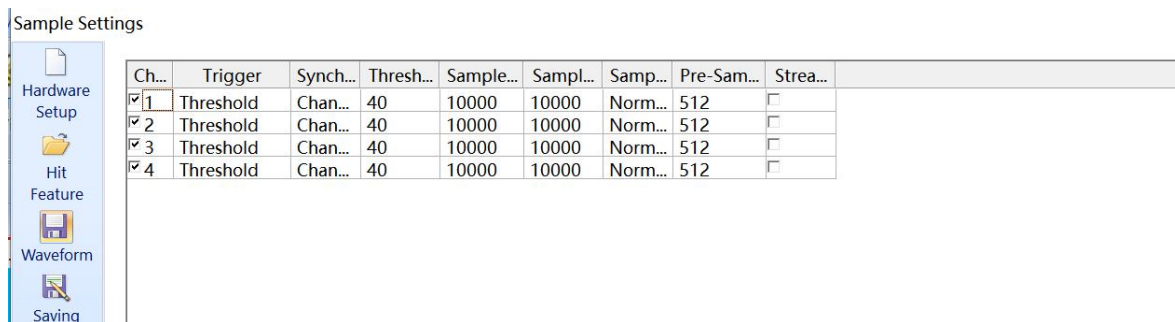 method in later stage, such as FFT analysis, wavelet analysis, waveform generation parameters, etc. It includes **"channel", "trigger mode", "synchronous mode", "waveform threshold", "sampling rate", "sampling length", "sampling mode", "pre-sample length", "streaming"**.

Note: To ensure that the Settings of each channel in the same acquisition board are consistent, when the waveform sampling rate and sampling length of a channel are changed, other channels in the same sampling card with the channel will also be modified.

Fig. 6-19 Waveform Setup Interface

Definition and setting rules of nouns:

● **Channel**: the default "√" option number under the channel corresponds to the channel number that has been correctly identified, and corresponds to the hardware number of the chassis panel interface. The "√" in the check box represents that the current channel enables the waveform sample and recording function. If it is canceled, the record will not

be sampled; after selecting, the file with suffix. aed will be generated.

● **Trigger mode**

Double click any "threshold trigger" box under the [trigger mode] column to open a drop-down window, including five modes: **"Threshold", "Parameter Trigger", "External Parameters", "Manual " and "Switch"**; each channel can be set independently.

For the application of non-oscilloscope mode or full waveform, select threshold trigger and channel asynchronous; for the occasion of sampling full waveform function or using it as oscilloscope function, select channel synchronous trigger;

Fig. 6-20 Trigger mode

1) **Threshold trigger:** it is generally applicable to the acquisition of burst acoustic emission signal, and it is used to determine the voltage level at which AE waveform data begins to be recorded. When the channel is in standby state and the voltage level exceeds the set value, the recording will be triggered, and the end time is controlled by the "sampling length". According to the application environment setting of acoustic emission system, it is generally dB higher than the noise level, and the setting range is 1-100 (integer). Generally speaking, 40dB is the commonly used threshold in engineering;

2) **Parameter trigger:** when any AE channel receives the recorded parameters, the AE starts to enter the sample state; the waveform threshold is invalid and controlled by the HIT DATA threshold, and the waveform corresponding to the parameters is generated. The channel selection is independent and the others are invalid.

3) **External Parameters trigger:** External Parameters input controls waveform acquisition. Select "**External Parameters**" in sample settings / **External Parameters set up**, set

"threshold", whose input range is 5-100% of **External Parameters** range, and the out-parameter range is - 10V - + 10V. When the effective external parameter is sampled and the waveform is higher than the set threshold, the corresponding channel starts to collect waveform.

4)   **Manual trigger:** Manually control the start and stop of the sampling process.

5)   **Switch trigger:** select trigger level in sampling setting / other settings / trigger switch, then external switch input control waveform sampling.

●   **Synchronization mode**: set the subordinate relationship between the current channel and other channels, double-click any "Channel Independent" box under the [Synchronization mode] column to open a drop-down window, including three items: "Channel Independent", "Master" and "Slave"; the default is "Channel Independent", which needs to be selected in combination with the "trigger mode" type.
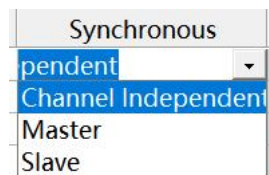
Fig. 6-21 Synchronization mode

1)   **Channel Independent:** default setting, no subordination relationship with other channels, only controlled by "trigger mode" and "waveform threshold", and can be used with any trigger mode.

2)   **Master channel**: it can be defined as trigger channel, and one or more can be set. When any master channel receives acoustic emission signal, other slave channels can sample acoustic emission signal synchronously.

3)   **Slave channel**: it is subordinate to the "Master". When the master channel is triggered, data will be sampled together with the master channel. If both are set to "Slave", no data will be sampled.

●   **Threshold**: it refers to the voltage level at which AE waveform data is recorded. When

the channel is in standby state and the voltage level exceeds the set value, recording will be triggered. According to the application environment setting of acoustic emission system, generally its setting dB is higher than the noise level, and the setting range is 1-100 (integer). Generally speaking, 40dB is the commonly used threshold in engineering; if "Streaming sampling" is ticked, the "Threshold" of acquisition can be set to 1.

- **Sample rate:** its unit is kHz, and the <mark>range is integer from 1000 to 10,000</mark>. The value represents the maximum number of points per second that can be sampled by the current channel in the process of sampling acoustic emission signal. The larger the setting value, the higher the accuracy of the acquisition signal, and the larger the amount of data. Generally, it is recommended to set it to about 10 times of the upper limit of the frequency domain concerned. If it is set to 1000 (in kHz), it means that up to 1000K points can be sampled per second.

- **Sample length**: its unit is the number of points, which refers to the length of a single frame waveform that can be recorded and stored. If 4000 is set, it means that only the first 4000 points are stored in each frame waveform. This setting is only valid for generating waveform and does not affect parameter generation.

- **Sample mode**: double click any "normal" box under the [sample mode] column to open a drop-down window, including "Normal", "Pre-sampling" and "Post- sampling". The default value is "Normal".

① **Normal:** it is to start sampling once the signal exceeds the threshold. The data starts at the time when the acoustic emission signal passes the threshold and ends at the sample length.

② **Pre-sampling:** a section of data is sampled before the acoustic emission signal exceeds the threshold. The data length of this section is determined by the value set in the column "pre-sampling and post-sampling length", and the data is composed of "pre- sampling section data" and "normal- sampling section data".

③ **Post-sampling:** after the AE signal is officially lower than the threshold, a section of

data is sampled. The data length of this section is determined by the value set in the column of "pre-sampling and posting sampling length", and the data is composed of "normal sampling section data" and "post sampling section data".
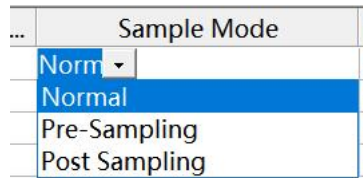

Fig. 6-22 Sampling modes

- **Pre/Post sampling length:** sample length points, only applied to "pre-sampling" and "post -sampling". If the combination of "pre-sampling" mode and "pre-sampling length 512" is set, it means 512 points of pre-sampling data; if it is calculated in time, it is to set the number of points / sample rate. This setting is only effective for generating waveform and does not affect parameter generation.

- **Streaming sampling:** "if" √ "is selected, it takes effect. The original threshold is triggered. The threshold is only valid when the trigger is triggered for the first time. After the channel is triggered for the first time, the waveform data will be continuously sampled, which can be understood as the full waveform mode, which is affected by the sampling rate, waveform threshold (only for the first trigger) and synchronization mode. It is suitable for the situation where ultra-long wave needs to be sampled. It is usually used in combination with spectrum research or waveform re generation parameter function.

Note: It is necessary to consider the relationship between the actual bandwidth of computer communication, the remaining space of hard disk partition and the amount of AE data. The actual communication bandwidth should be much larger than the waveform data per second; the remaining space of hard disk partition should not be less than [the waveform data per second] × [acquisition time(s)], and the acoustic emission [waveform data per second] = [the sampling rate] × 2 × [channel number used], in unit of MB.

Configuration combination list: in view of the combination relationship between the items in the interface, the following table is listed for reference only:

Table 6-2 Combination List of Waveform Acquisition Project

Trigger mode	Synchronization mode	Waveform threshold	Sampling rate	Sampling length	Sampling mode	Length of pre &post sampling
Threshold	Channel Independent	O	O	O	O	O
	Master	O	O	O	O	O
Parameter	X	X	X	X	X	X
External Parameters (External parameter trigger)	Channel Independent	O	O	O	O	O
	Master	O	O	O	O	O
Manual	X	X	X	X	X	X
Switch (high) trigger	X	X	X	X	X	X
Streaming sampling (original threshold trigger)	Channel Independent	O first	O	X	X	X
	Master	O first	O	X	X	X
"O" is on behalf of the item is valid，"X" represents that the item is invalid.						

6.2.5.1.1.4. Saving

Click **[Saving]** on the left side of "Sample settings" interface to display the following interface. This interface is mainly related to the settings of acoustic emission data storage. Acoustic emission data files are generally divided into two categories: acoustic emission parameter data (.pra) and acoustic emission waveform data (.aed). **Automatic file naming method: file name + "_" + sample time**, for example: CJ2(70dB) _220630153540436.aed
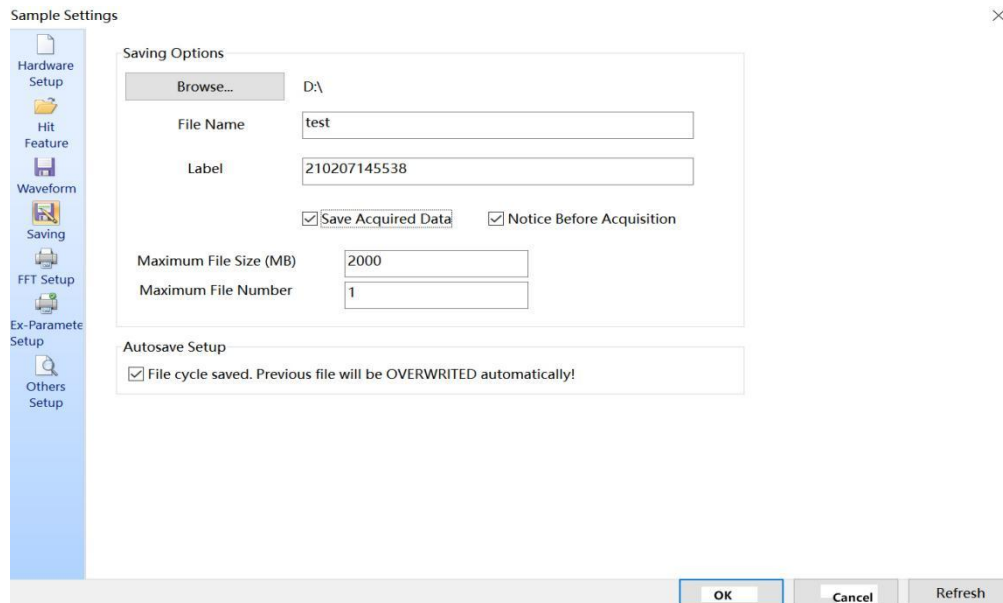
Fig. 6-23 Data Saving Interface

Definition and setting rules of nouns:

- **Data file path:** need to create a destination folder in advance. Click this button to select a path for storing data files.

- **Data file name**: letters, numbers and characters can be input directly in the text box, but special characters such as _ \ / : * ? " < > | etc. cannot be included, except for the "_" before the time label.

- **Label:** the time mark of data generation time, in form of "YYMMDDHHMMSS". For example "200220143359" means that the file generation time is "(20)20 February 20, 14:33:59", which is derived from the computer system time and is not recommended to be changed, otherwise the data cannot be replayed.

- **Save Acquired Data**: if "√" is selected, the data file will be saved to the computer, otherwise the data will not be saved.

- **Notice Before Acquisition**: it is only used to notice whether to save data or not. If "√" is selected, it will prompt to notify every time after clicking **[Sample]**.

- **Maximum file size (MB):** setting this item can make the data sampled after the data file reaches the specified capacity be stored in a new file. The setting range is 1-4000 (positive integer, unit: MB), which can be input directly in the text box.

- **Maximum file number:** setting this item can make the data no longer be saved after the

number of data files reaches a certain number (stop in the collection state) or continue to store after covering the previously stored data. The product of this value and the setting value of "maximum storage amount of sampling file" shall not exceed half of the available capacity of the storage disk. The setting range is 1-1000 (positive integer), can be entered in tot the text box.

- **Autosave set up:** Files are stored circularly and automatically overwritten, which is enabled when "√" is selected. After the activation takes effect, when the "**Maximum file number**" is reached, the software will write the previous stored files with the same name to the disk in turn, and only record the acoustic emission data of the relative time before the end.

6.2.5.1.1.5. FFT settings

Click **[FFT setup]** on the left side of the "Sample Settings" interface to display the following interface. This interface introduces the settings related to the extraction of acoustic emission frequency domain parameters, including "Window Function", "FFT Sampling Decimation Rate" and "Partial Power Setup". The output results related to the waveform are displayed in the "FFT View"; the output results related to the parameters are displayed in the "Data Table" 。
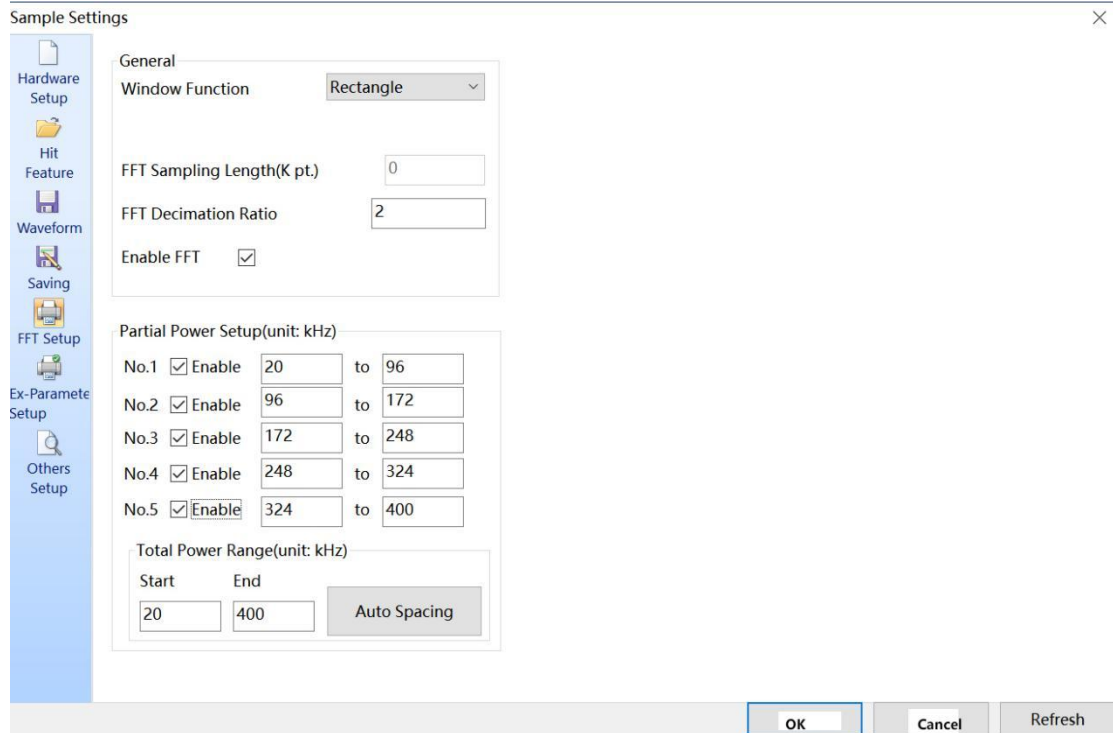
Fig. 6-24 FFT Setup Interface

Window function: the drop-down menu contains five window options: rectangular/Gauss/Hanning/Hamming/Blackman. Users can select the type of window according to the analysis needs. Generally, rectangular window and Gaussian window are commonly used;
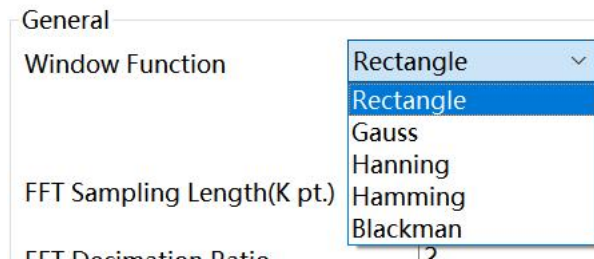
Fig. 6-25 FFT window function Interface

FFT sampling length: this position is displayed as 0 by default, the sampling length in "frequency domain waveform diagram" = FFT sampling rate / FFT Sampling decimation ratio;

FFT Sampling decimation ratio: the decimation ratio means that one of every few original sampling point (the sampling rate of waveform sampling) is taken for FFT calculation, as shown in Figure 6-24, which 2 means that one sample is extracted from every two original

sampling points for FFT calculation, which is equivalent to that the FFT sampling rate is reduced to half of the original sampling rate;

Enable FFT: "if" √ "is selected, the" **Partial Power** "will be calculated;

Partial Power Setup: this part is used to set the requirements for generating local power spectrum parameters, including 5 frequency bands, namely "No.1" ～ "No.5". The box after the parameter name of "√" will enable the current parameter. It can be checked as required, and 5 parameters can be set at most. After selecting a certain parameter, the upper and lower limits of the frequency band can be set directly, and the unit is kHz. The frequency domain distribution of AE signals is generally below 500KHz.

Total power range: input positive integer directly in the text box, set the start frequency and end frequency, and click the "Auto Spacing" button, and the set value range will be automatically evenly divided according to the number of selected local power spectrum parameters. The value after automatic distribution allows users to modify it again.

6.2.5.1.1.6. Ex-Parameter Setup

Click [**Ex-Parameter Setup**] on the left side of "Sample settings" interface to display the following interface, which is related to external parameters. For specific wiring method, please refer to hardware part of **[Chapter 3.7.7]** or contact our technicians; for synchronous acquisition of external parameters and acoustic emission signal, please refer to Chapter **6.2.5.1.1.3 Waveform > "External parameters trigger"** in "trigger mode".
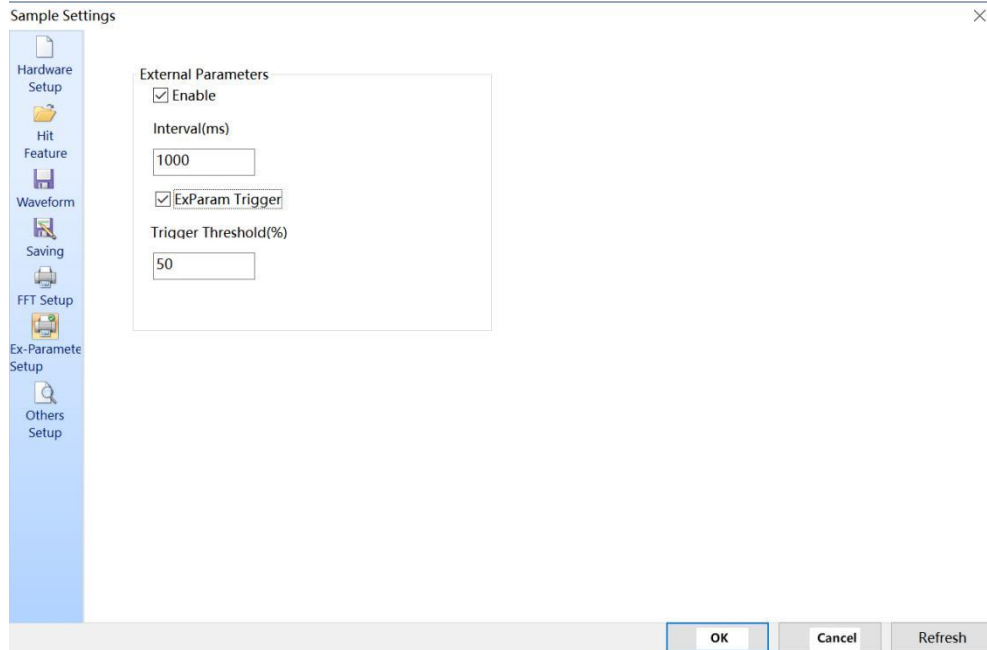
Fig. 6-26 External Parameters setting interface

External Parameters: if "√" is selected, the function of "timing sampling" will be turned on after it is enabled, and the value setting range of the latter is 5-1000 (positive integer), which can be directly input in the text box; this moment, the collected external parameter variables (analog voltage - 10V - + 10V) will be displayed in the same step with the acoustic emission signal; the interval value is the external parameter variable updating cycle, for example 1000ms, that is, the voltage value is collected every 1000ms, which is synchronized with the acoustic emission hit parameters. If there is no acoustic emission signal in this period, only the external parameter voltage is collected;

Ex-Param trigger: "if" √ "is selected, it is enabled, and must be used together with" External Parameters ". Waveform acquisition of control channel is controlled by external parameter input. Set" Trigger Threshold "in" Sample settings "/ Waveform sampling "/" Trigger mode ". The input external parameter range is 5-100%, and 5-100 (positive integer) can be directly input into the text box; the external parameter range is - 10V - + 10V, when effective external parameters are collected and the waveform is higher than the set threshold, the corresponding channel starts to collect waveform.

6.2.5.1.1.7.　Others Setup

Click **[Others Setup]** on the left side of the "Sample settings" interface to display the following interface, including "max parameter time" and " trigger switch".
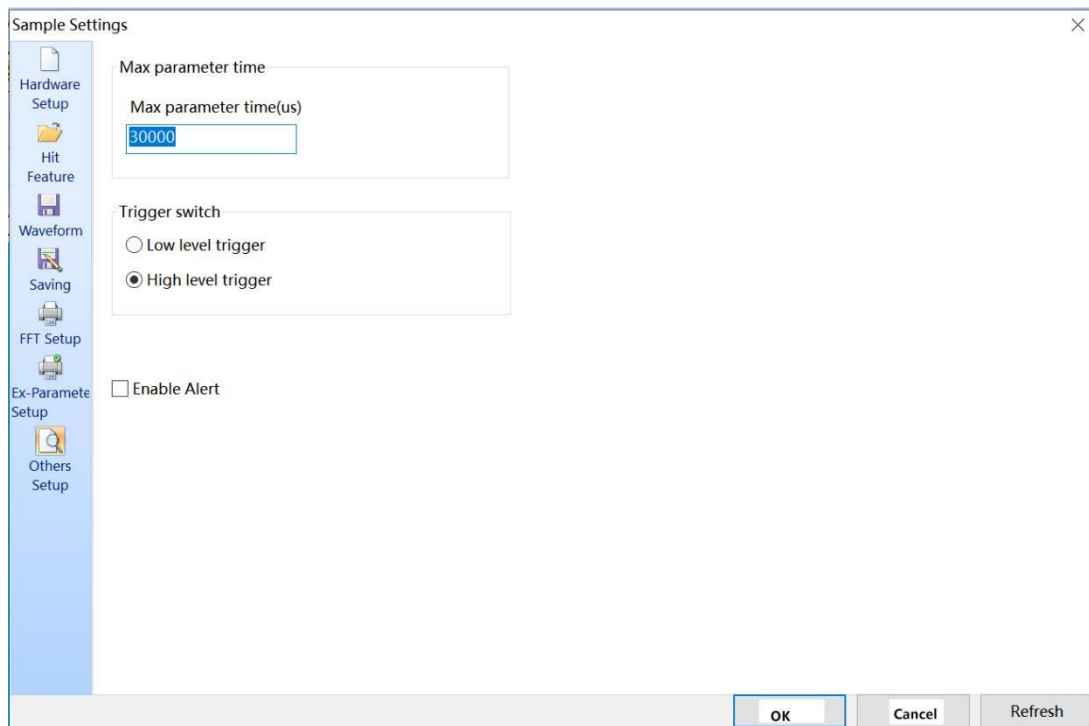
Fig. 6-27 Others setup interface

Max parameter time(us): when the acoustic emission signal is continuously higher than the threshold value, and the stated HDT cannot determine the intercepted acoustic emission parameters, the **max parameter time** takes effect, that is, the rest of the parameter futures are all calculated in the unit of the "duration" in the current generation parameter line,

Switch trigger: the AE system is controlled by external hardware input of high and low levels for signal acquisition. The setting here corresponds to the "trigger mode" in waveform sampling. When using, it needs to select "**Switch trigger**", and the input interface is the "Din" connection port in the acoustic emission external reference box. When the level signal received by the hardware is the same as the software setting, the AE system will get into sampling state.

6.2.5.1.2. Recommended Inspection Setup on Site

Acoustic emission technology is widely used in various industries and covers a wide range of fields. The settings of "hardware settings", "hit parameters" and "waveform sampling" are provided for reference only:

6.2.5.1.2.1. Testing of pressure Vessel

Table 6-3 Hardware Parameter Setting of Pressure Vessel

Hardware setup	Channel	Preamplifier gain （dB）	Input range	Analog filter		Digital filter		Power supply of preamplifier
				High Pass	Low pass	High pass (kHz)	Low pass (kHz)	
	Default	40	10Vp	100kHz	400KHz	100	400	28V

HIT feature	Channel	Parameter threshold （dB）	Floating threshold (dB)	HDT （us）	HLT （us）	PDT （us）
	All selected	Between 35～45	0	2000	20000	1000

Waveform	Channel	Trigger mode	Synchronization mode	Waveform threshold	Sample rate	Sample length	Sample mode	Pre&post sampling length	Streaming Sampling
	Demand decides （Generally no selected）	Threshold	Channel Independent	Between 35～45	>3000	Above 20000	Normal	Default	Don't tick

6.2.5.1.2.2. Inspection of Atmospheric tank floor corrosion / leakage detection / high attenuation metal components

Table 6-4 Hardware parameter setting for corrosion / leakage detection of atmospheric tank bottom plate/high attenuation metal components

Hardware setup	Channel	Preamplifier gain（dB）	Input range	Analog filter		Digital filter		Power supply of preamplifier
				High Pass	Low pass	High pass (kHz)	Low pass (kHz)	
	Default	40	10Vp	20kHz	100KHz	20	80	28V

HIT feature	Channel	Parameter threshold（dB）	Floating threshold （dB）	HDT（us）	HLT（us）	PDT（us）
	All selected	Between 35～45	0	1000	2000	400

Waveform	Channel	Trigger mode	Synchronization mode	Waveform threshold	Sample rate	Sample length	Sample mode	Pre&post sampling length	Streaming Sampling
	Depends on demand (Generally don't tick)	Threshold	Channel Independent	Between 35～45	>1000	2000	Normal	Default	Don't tick

6.2.5.1.2.3. Small metal specimens / metal matrix composites

Table 6-5 Hardware parameter setting inspection of metal small specimen / metal matrix composite

Hardware setup	Channel	Preamplifier gain（dB）	Input range	Analog filter		Digital filter		Power supply of preamplifier
				High Pass	Low pass	High pass (kHz)	Low pass (kHz)	
	Default	40	10Vp	100kHz	400KHz	100	300	28V

HIT feature	Channel	Parameter threshold (dB)	Floating threshold （dB）	HDT（us）	HLT（us）	PDT（us）
	All selected	Between 40～45	0	600	1000	300

Waveform	Channel	Trigger mode	Synchronization mode	Waveform threshold	Sample rate	Sample length	Sample mode	Pre&post sampling length	Streaming Sampling
	Depends on demand	Threshold	Channel Independent	Between 40～45	>4000	>20000	Normal	Default	Don't tick

6.2.5.1.2.4. Non-metallic matrix composites (except ceramics)

Table 6-6 Hardware parameter setting for inspection of nonmetallic matrix composites

Hardware setup	Channel	Preamplifier gain (dB)	Input range	Analog filter		Digital filter		Power supply of preamplifier
				High Pass	Low pass	High pass (kHz)	Low pass (kHz)	
	Default	40	10Vp	20kHz	400KHz	20	300	28V

HIT feature	Channel	Parameter threshold (dB)	Floating threshold (dB)	HDT (us)	HLT (us)	PDT (us)
	All selected	Between 45～65	0	150	300	50

Waveform	Channel	Trigger mode	Synchronization mode	Waveform threshold	Sample rate	Sample length	Sample mode	Pre&post sampling length	Streaming Sampling
	Based on demand	Threshold	Channel Independent	Between 45～65	>4000	>20000	Normal	Default	Don't tick

6.2.5.1.2.5. Filament wound Composites

Table 6-7 Hardware Parameter Setting for inspection of Filament wound Composites

Hardware setup	Channel	Preamplifier gain (dB)	Input range	Analog filter		Digital filter		Power supply of preamplifier
				High Pass	Low pass	High pass (kHz)	Low pass (kHz)	
	Default	40	10Vp	20kHz	400KHz	20	300	28V

HIT feature	Channel	Parameter threshold (dB)	Floating threshold (dB)	HDT (us)	HLT (us)	PDT (us)
	All √ selected	Between 55～65	0	150	300	50

Waveform	Channel	Trigger mode	Synchronization mode	Waveform threshold	Sample rate	Sample length	Sample mode	Pre&post sampling length	Streaming Sampling
	Depends	Threshold	Channel Independent	Between 55～65	>4000	>20000	Normal	Default	Don't tick

6.2.5.1.2.6. Rock mechanical test (hard rock)

Table 6-8 Hardware parameter setting for Inspection of rock mechanical test

Hardware setup	Channel	Preamplifier gain (dB)	Input range	Analog filter		Digital filter		Power supply of preamplifier
				High Pass	Low pass	High pass (kHz)	Low pass (kHz)	
	Default	40	10Vp	10kHz	400KHz	100	400	28V

HIT feature	Channel	Parameter threshold (dB)	Floating threshold (dB)	HDT (us)	HLT (us)	PDT (us)
	All √selected	Between 40～55	0	600	1000	300

Waveform	Channel	Trigger mode	Synchronization mode	Waveform threshold	Sample rate	Sample length	Sample mode	Pre&post sampling length	Streaming Sampling
	Depends on demand	Threshold	Channel Independent	Between 40～55	>4000	>20000	Normal	Default	Don't tick

6.2.5.1.2.7. Concrete / synthetic / sandstone mechanical tests

Table 6-9 Hardware parameter setting for inspection of concrete / synthetic / sandstone mechanical test

Hardware setup	Channel	Preamplifier gain (dB)	Input range	Analog filter		Digital filter		Power supply of preamplifier
				High Pass	Low pass	High pass (kHz)	Low pass (kHz)	
	Default	40/60	10Vp	20kHz	100KHz	20	100	28V

HIT feature	Channel	Parameter threshold (dB)	Floating threshold (dB)	HDT (us)	HLT (us)	PDT (us)
	All selected	Between 35～50	0	150	300	50

Waveform	Channel	Trigger mode	Synchronization mode	Waveform threshold	Sample rate	Sample length	Sample mode	Pre/post sampling length	Streaming Sampling
	Depends on demand	Threshold	Channel Independent	Between 35～50	>2000	>10000	Normal	Default	Don't tick

6.2.5.1.3. Sample Control

The three buttons **[Sample], [Pause]/[Continue] and [Stop]** are only effective in the process of acoustic emission data acquisition. When the color is dark blue, it means that the button operation can be performed.
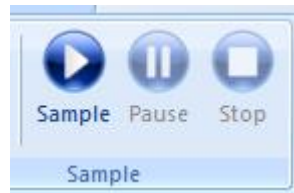
Fig. 6-28 Sample control interface

● **Start Sampling**

When the system hardware is set correctly and the sensor is connected right with preamplifier, press [Sample] to start sampling. If the system is not installed or the acoustic emission acquisition board is not selected in the "Hardware Setup", the system will have an error prompt when doing this operation;

● **Pause sampling**

Click [Pause] once take effect, and continue to perform preset operation on the data uploaded to the computer. The AE host will no longer transmit data and enter into the stage of sampling waiting state, and the button will turn into **[Continue]**;

● **Continue Sampling**

Click [Continue] to resume data acquisition and transmission. The button will turn into [Pause].

● **Stop sampling**

When the stop command takes effect, the acquisition board stops generating new data, data uploading and upper computer processing continue until all data are processed to generate data files.

6.2.5.2. Tags

It can be used in the data collection and replay period of time. The annotation content of the

tag is bound with the data file, and the time point is the effective time of the tag; users are allowed to add, modify and delete at any time;

● **Add tags**

In the process of signal acquisition or data replay, if there is interference or special waveform, you can choose to add tag function. Operation: in the "Tag" menu, select **"Add Tag"** sub-menu, and the dialog box as shown in Figure 6-29 will pop up. Users can add notes in the note's information.
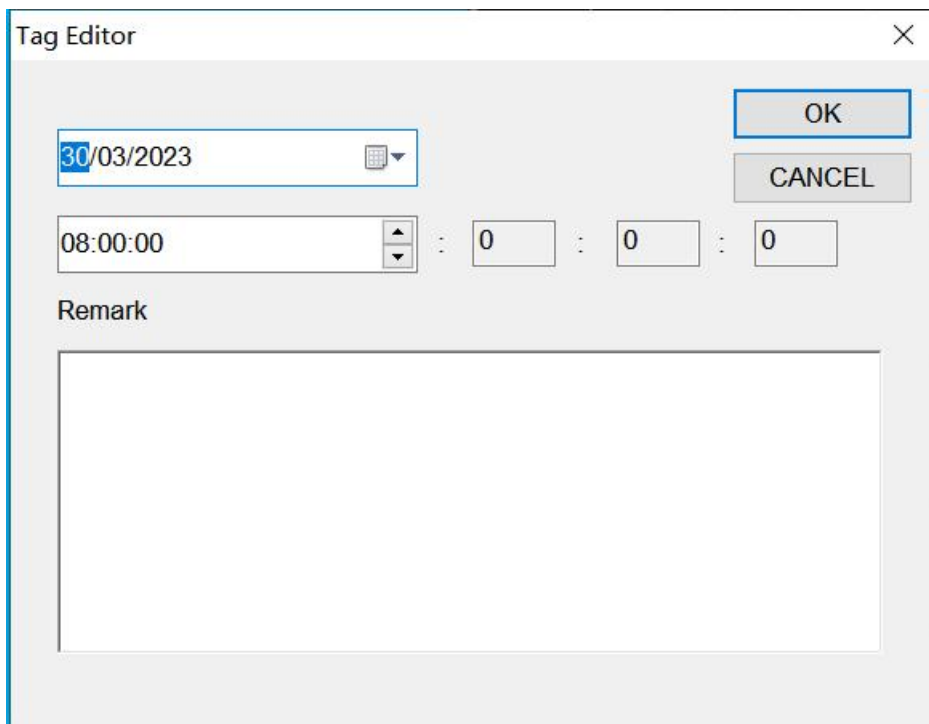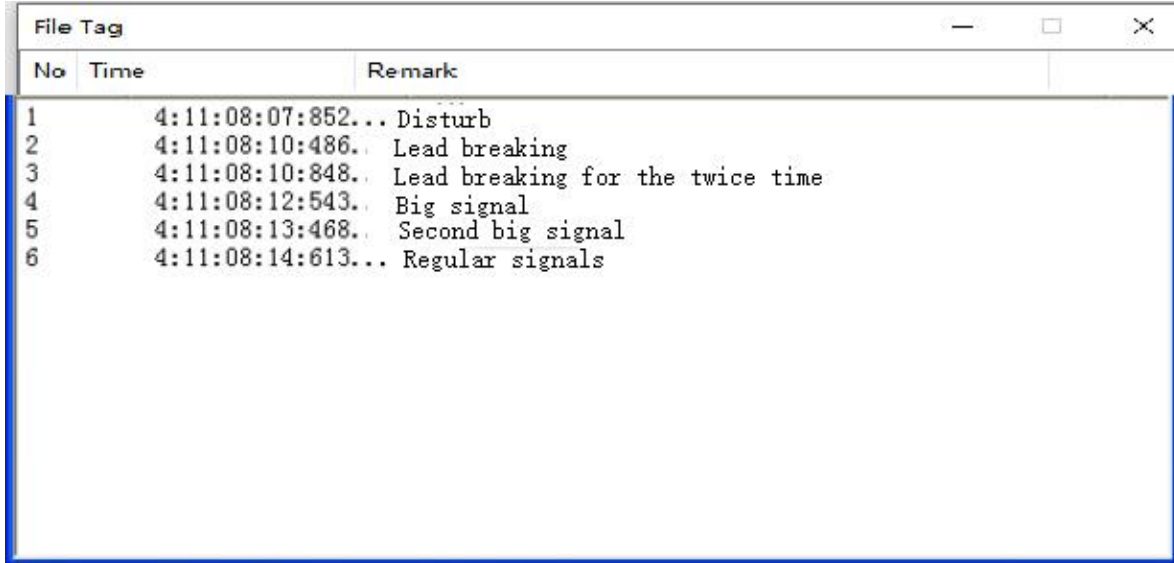
Fig. 6-29 Label editing interface

● **View tag**

During data replaying, you can browse through the tags. Operation: in the "Tag" menu item, select the **"Tag View"** sub-menu to pop up the dialog box as shown in Figure 6-30. Users can double-click a label randomly to view its corresponding waveform and parameters for analysis; modify the label content, delete the label, and select the tag to jump to the view position of the corresponding time tag. The label corresponds to the first frame of the data segment;

File Tag			— □ ×
No	Time	Remark	
1	4:11:08:07:852...	Disturb	
2	4:11:08:10:486.	Lead breaking	
3	4:11:08:10:848.	Lead breaking for the twice time	
4	4:11:08:12:543.	Big signal	
5	4:11:08:13:468.	Second big signal	
6	4:11:08:14:613...	Regular signals	

Fig. 6-30 Tab view interface

6.2.5.3.   Auxiliary functions

6.2.5.3.1.   Auto Sensor Testing

Through the pulse transmission function of automatic sensor testing (AST, auto sensor testing). The function process is that the system sends out electrical pulse signals to through a certain channel. The emission channel generates acoustic waves and propagates in the material surface and received by all channels. The signal reception of all channels is observed to check the connection of each channel, the coupling status of sensors and the sensor sensitivity.
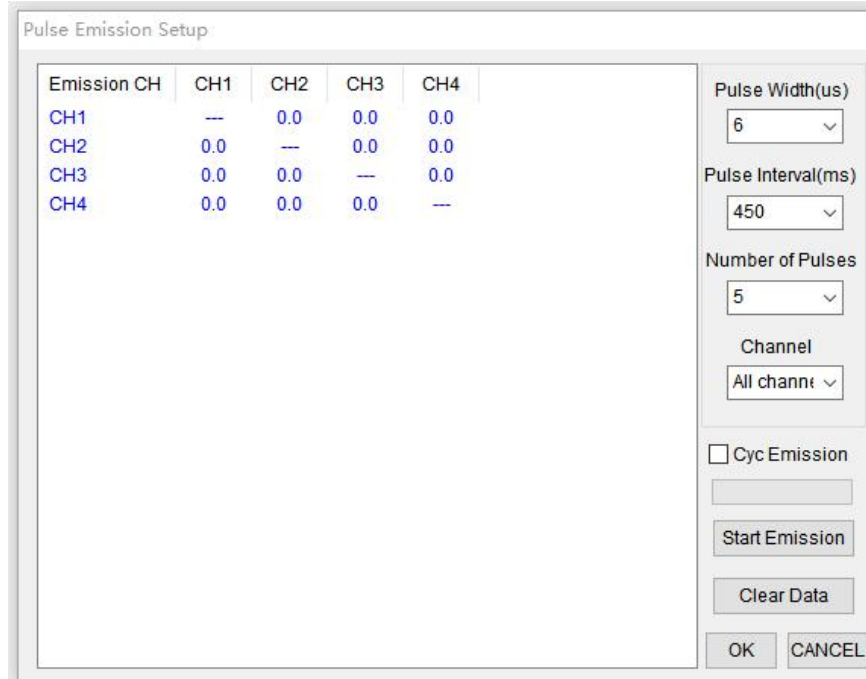
Fig. 6-31 Pulse Emission Setup Interface

- Pulse width: refers to the duration of a single pulse, which can be selected from 1 to 20, unit: μs;

- Pulse interval: refers to the interval time between two adjacent groups of pulses (number of pulses indicates how many pulses that one signal channel continuously transmits). The purpose of setting pulse interval is to prevent the influence of echo. There are 20 options from 400 to 1350 ms;

- Number of pulses: refers to the number of pulses emitted by a single channel, from 1 to 32;

- Channel selection: select the channel to transmit pulse signal. The selected channel and other channels will receive the pulse signal. Selecting "all channels" means that all channels transmit pulse signals one by one in turns. The drop-down setting shows how many channels are available here;

- Cycle Emission: It refers to that the pulse signal is continuously emitted in a cycle. If a single channel is selected to emit, that single channel will emit pulse signals periodically (the number of pulses will be ignored in that case); if all channels are selected, every channel will emit the pulse signals one by one in turns until the last channel completes and it will cycle and restart from Channel 1 again. Click this button if needed;

- Start Emission: Click this button to start the pulse transmission;

- Clear data: click this button to clear the completed self-calibration data for the next self-calibration task;

- Cancel: click this button to close the window;

- OK: click this button to indicate that the task is complete and close the window.

6.2.5.3.2.　Hardware Parameter Filter

Click "**Hardware Parameter Filter**" button to pop up the interface as shown in the figure. This function sets the filters at the hardware level of the AE boards when sampling, and the filtered data will not be displayed and stored in the software.
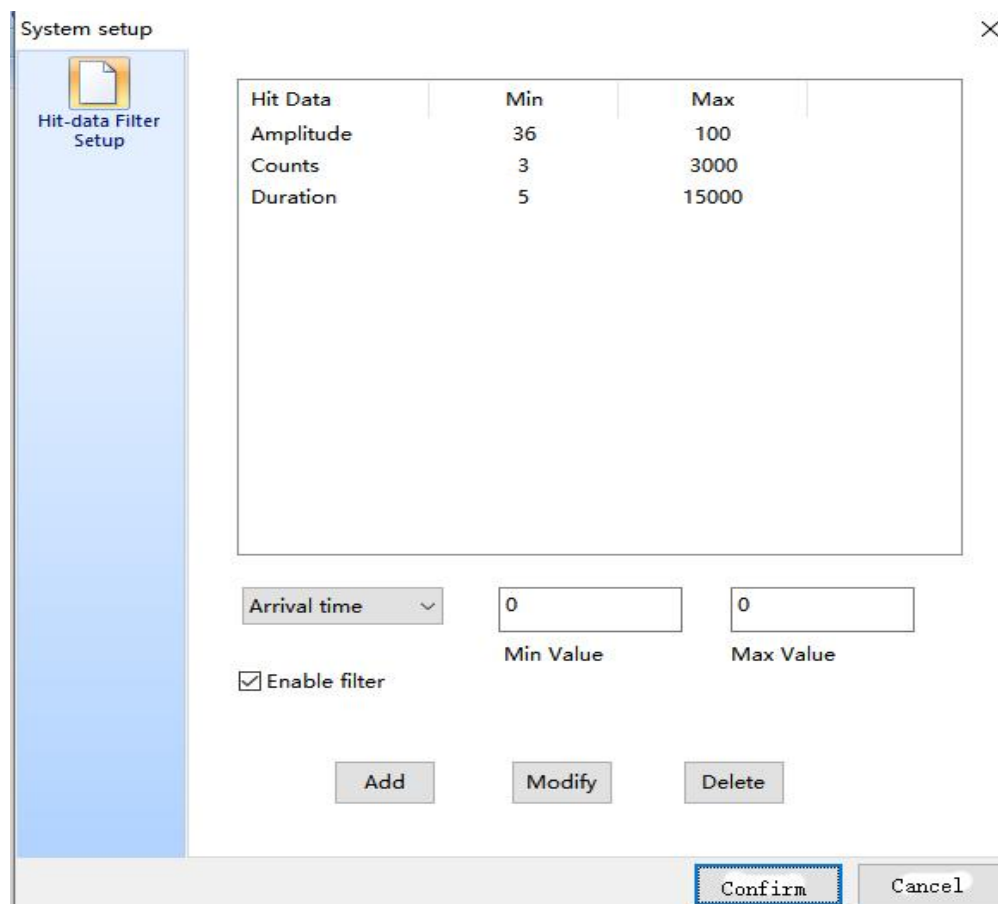
Fig. 6-32 Hardware HIT-Data Filter setup

Parameter selection: select a parameter as a filter. The arrival time, channel number, amplitude, counts, duration, energy, rise counts, rise time, RMS and ASL parameters can be selected from the drop-down menu. The parameter within the minimum and maximum value

range will be retained. When multiple filters are set, only the data meeting all filters range will be recorded and displayed.

Add: to add a new parameter filter, select the corresponding AE characteristic parameters from the drop-down menu, then input the minimum value and maximum value in the text box, and click the "add" button to add the parameter filter to the list.

Modify: to modify the set parameter filter, click the set parameter filter row in the list (the line turns blue after selection), and then re-enter the minimum value and maximum value in the text box, and then click the "modify" button.

Delete: to delete the set parameter filter, click the parameter filter row in the selected list (the line turns blue after selection), and then click delete.

Enable filter: if this option is clicked, all parameter filters in the list will be effective during data replay analysis, otherwise they will not work.

6.2.6. View Menu

The view is a visual window of AE data. Selecting a certain type of view in the process of sampling and analysis will make the result display more intuitive and easier to understand and analyze. The View menu function is mainly used to set the view area, mainly including "view operation" and "view type". The view operation function is to set the frames of the display view window area, and the view type is to specify the data representation form in each view area.

Fig. 6-33 View Menu Interface

6.2.6.1. View Operation

6.2.6.1.1. New view group

A view belongs is subordinate to a view group. Multiple view groups can be established at the same time. Each view group can contain one or multiple view window. Different view types can be assigned to each window according to the actual needs.

Click **[View]** in the main menu to switch to the view setting interface. Select and click **[New View Group]**, and a complete gray area named "new view group" will appear, double click the title location to rename it; repeat this operation to create multiple new view groups.
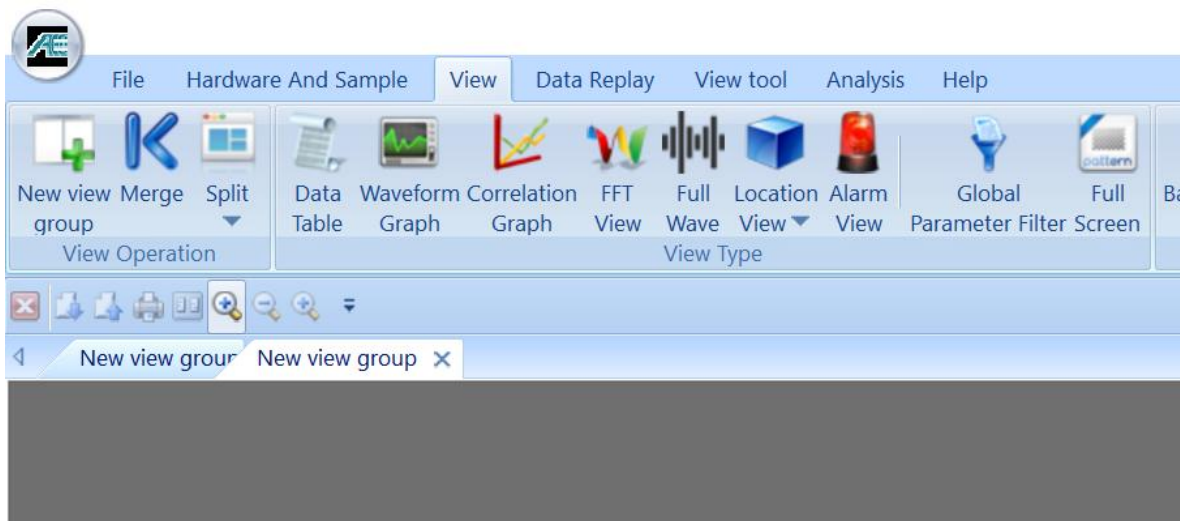
Fig. 6-34 Creating a new view group

6.2.6.1.2. View Split

Select a new view group in the graphic display area (after selection the window frame turns red), click **[Split]**, and select the array size (such as 2 rows x 3 columns) according to the demand, as shown in the figure. Click the left button again to complete the view group segmentation and generate a multiple views window. In the same way, any view can be divided and split again;
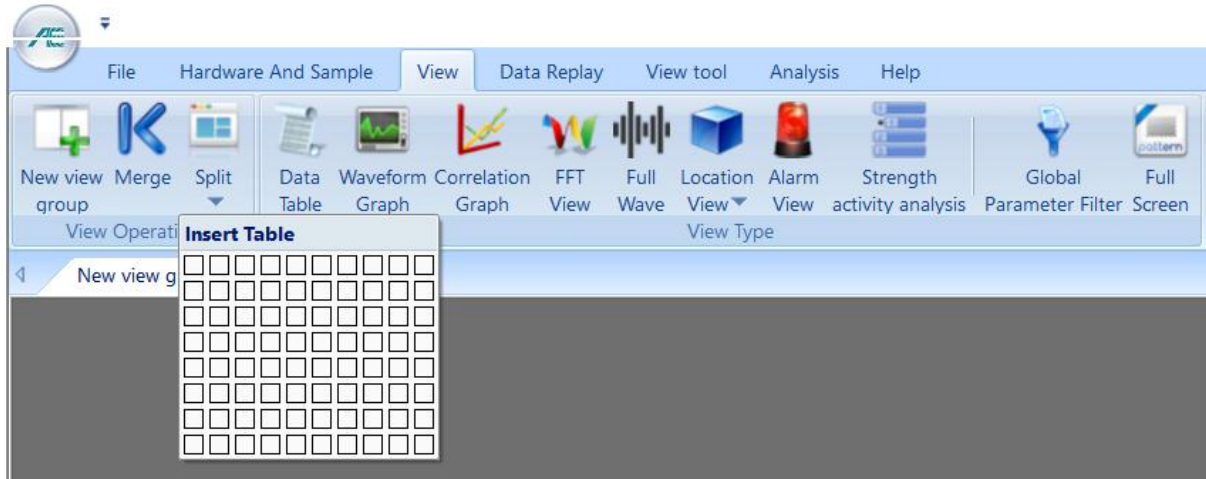
Fig. 6-35 View Slip

Window attribute: any window can be split again; each window can be defined as any view type; double clicking any window can be used to maximize and minimize the display of the current view.

6.2.6.1.3.   View Merging

Only two or more views of the same view group can be merged. After merging, these areas can be set again. After merging, no view information will be retained in this view area.

Select any view in the area to be merged (red border appears after selection). For example: as shown in Figure 6-36, the six small views are in the same view group. Select one of the small view; click **[Merge]** to complete the view merging, and the completed view interface is shown in Figure 6-37: (After merging, no view info will be retained at this level.)
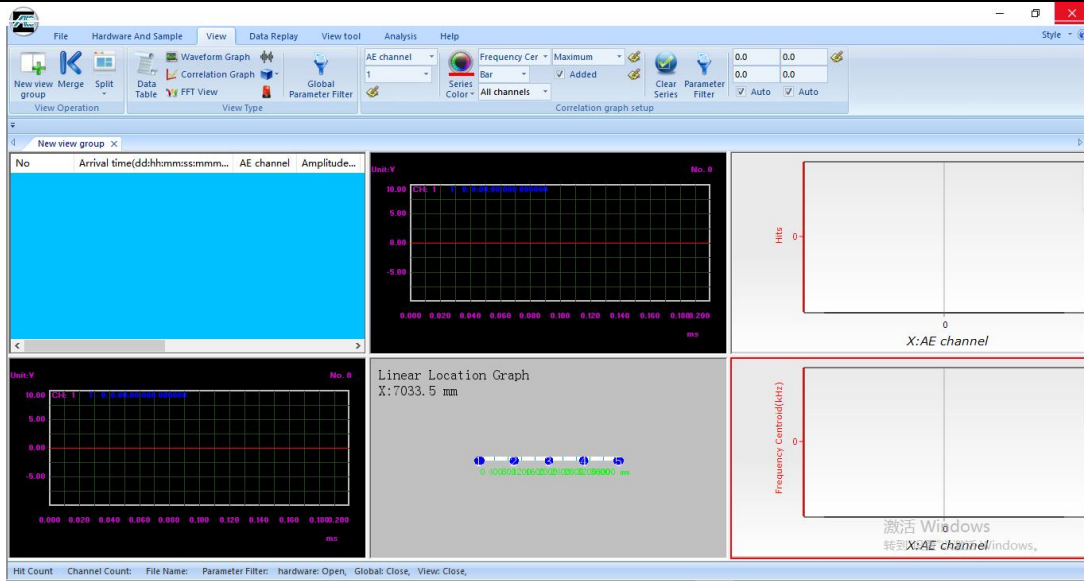
Fig. 6-36 Before View merge (selected)
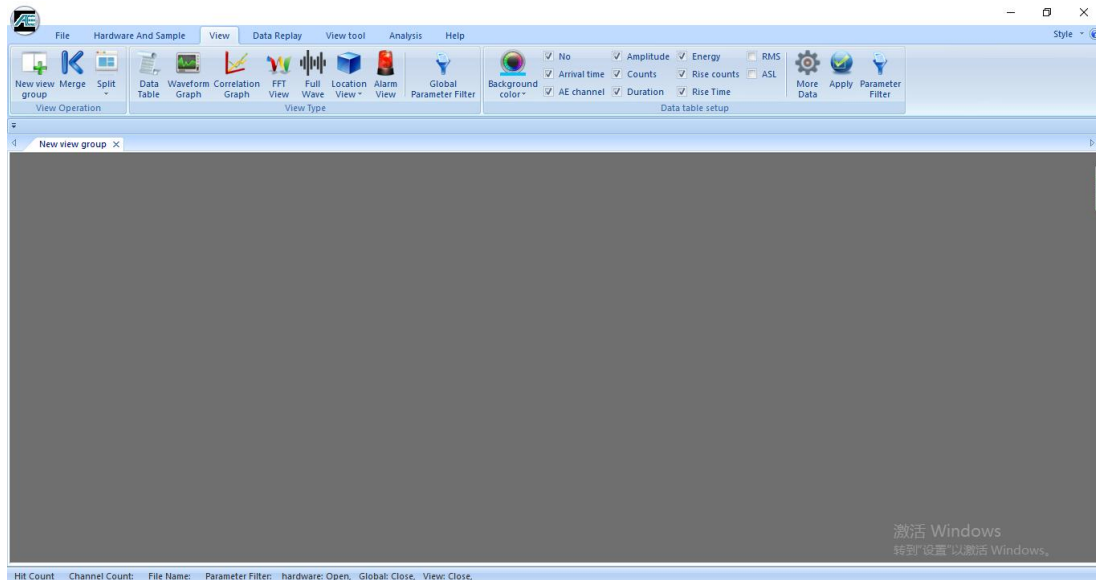
Fig. 6-37 After View Merge

6.2.6.2. View Types

The view types can be customized for each window area, and each view has different settings. The view types include: data table, waveform graph, correlation graph, FFT view, full wave, location view, alarm view, intensity activity analysis, etc. This function can be used before data sampling and during data analysis. According to the usage of view data, it can be roughly divided into "Basic view" and "Derivative graph". Among them, "Data Table" and "Waveform Graph" are the basic views, while "Correlation graph", "Location view", "Alarm

View" and "Intensity Activity Analysis" are derivative graphs of "Data Table". These 5 views share the parameter files with suffix of .PRA; "FFT View" is the derivative diagram of "Waveform Graph", with the suffix of .AED. Only when the basic view is established in the process of AE data acquisition, can the data processing and analysis be carried out later.

6.2.6.2.1.   Data Table View

6.2.6.2.1.1. Set up of data table

Select a blank view (with red border) and click "Data Table" in view type of the View menu to add the default data table view. The default data table includes the following parameter information: serial number, arrival time, AE channel number, amplitude, counts, duration, energy, rise counts, rise time, etc. For most applications, it can be used by default. For continuous acoustic emission signals such as leakage, it is also needed to add more parameters, such as ASL or RMS. Click [More Data] and check "ASL" and "RMS" in the list, and click [OK] to complete the parameter adding (this setting is commonly used in engineering detection).
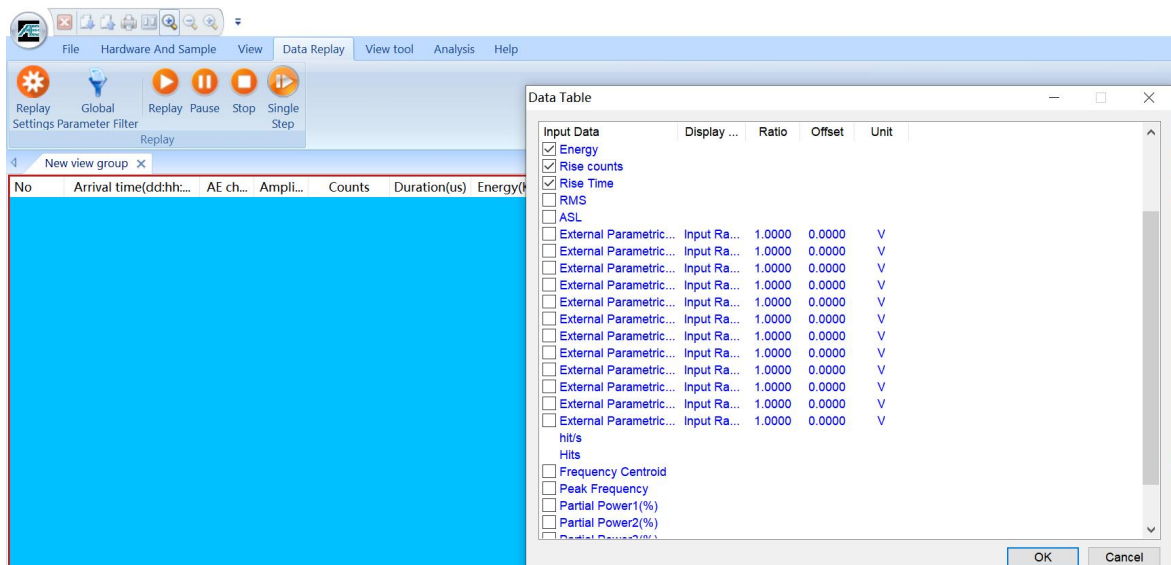
Fig. 6-38 Default parameters and optional parameters interface

6.2.6.2.1.2. Data table settings

1) **More parameters:** however, if the default AE parameter type cannot meet the actual

needs, click the **[More Parameters]** button to enter the parameter selection interface and check the required parameters to enable it in the "Data Table"; in the parameter selection, there are "No.", "amplitude", "arrival time", "counts", "duration", "energy", "rise counts" "rise time", "RMS", "ASL", "external parameters 1-12", "Hit/s", "HITS", "frequency centroid ", "peak frequency" and "partial power 1-5" available for selection.

2) **External parameter setting:** the display name of the external parameter can be modified in the [More Parameters] window. Double click the corresponding position of "display name" column of the external parameters and enter the display name. The reference linear relationship is: Y = KX + B, where X is the input voltage, Y is the display value. The ratio [K] is the proportion of the external parameter display value and its actual input value; the offset [B] is the offset value, similar to zero point calibration, that is, when there is no voltage input for an external reference channel, the voltage display of the channel in the parameter table should be zero by adjusting [B]. In the actual acquisition process, it is necessary to calibrate the set coefficient K, that is to adjust the coefficient K by comparing the measured value of the external parameter system with the actual value until the measured value of the external parameter system is close to or consistent with the actual value. Refer to figure 6-38.

3) **Frequency Centroid:** represents the frequency corresponding to the mass center of the power spectrum.

4) **Peak frequency:** refers to the frequency corresponding to the maximum value of power spectrum.

5) **Partial power** 1 / 2 / 3 / 4 / 5: i.e., Partial power 1 / 2 / 3 / 4 / 5. When "partial power 1-5" is clicked, it is necessary to cooperate with **[FFT setup]** in the "Sample Settings". For specific setting method, see Chapter "6.2.5.1.1.5 FFT Settings".
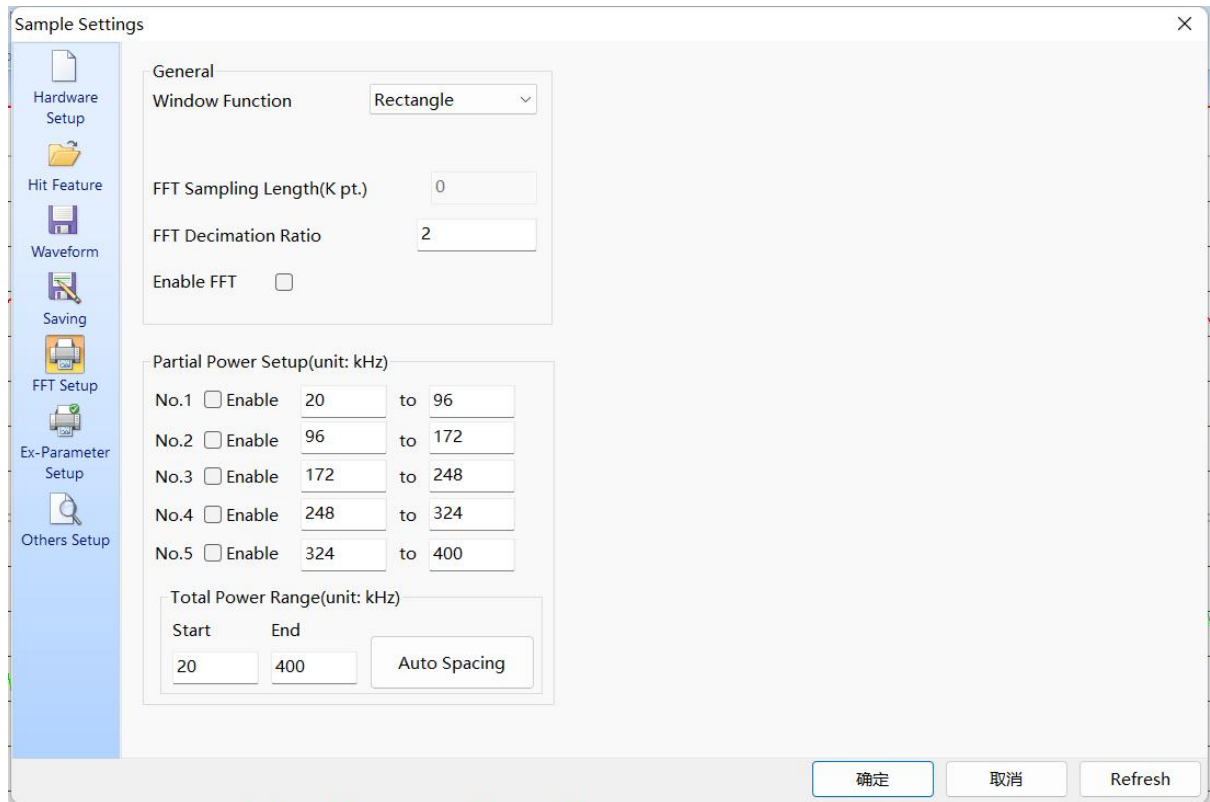
Fig. 6-39 FFT Partial Power Setup Interface

The partial power parameters are shown in the "Data Table" in the form of percentage, indicating the percentage weight of the parameter spectrum corresponding to the set frequency range in the overall signal frequency domain. For example, the sampling rate set in the "Waveform" interface is 4000kHz, the current "FFT decimation rate" is 2, "Partial power No.2" is enabled, and the frequency band setting is 96-172kHz. If the value of "Partial power2 (%)" is 25 in the Data Table, it means that the 96-172kHz frequency spectrum power of this hit signal accounts for 25% of the total signal bandwidth 2000kHz (4000 / 2) spectrum power.

6) **Background color:** select Data Table view and click "Background color" to select different colors. The default color is blue.

7) **Apply:** after modifying the data, the settings will take effect after clicking **[Apply].**

6.2.6.2.1.3. Parameter Filter

Click **[Parameter filter]** to pop up "Hit Data Filter setup" interface. The filter is a view specific

filter, which is only effective for the current view. Refer to Chapter "6.2.5.3.2 Hardware parameter filter" for setting methods. After the function is enabled, the parameter data conforming to the setting rules will be displayed in the "Data Table" view window. The rejected data will not be displayed and the stored data files will not be changed.

6.2.6.2.1.4. View attribute function
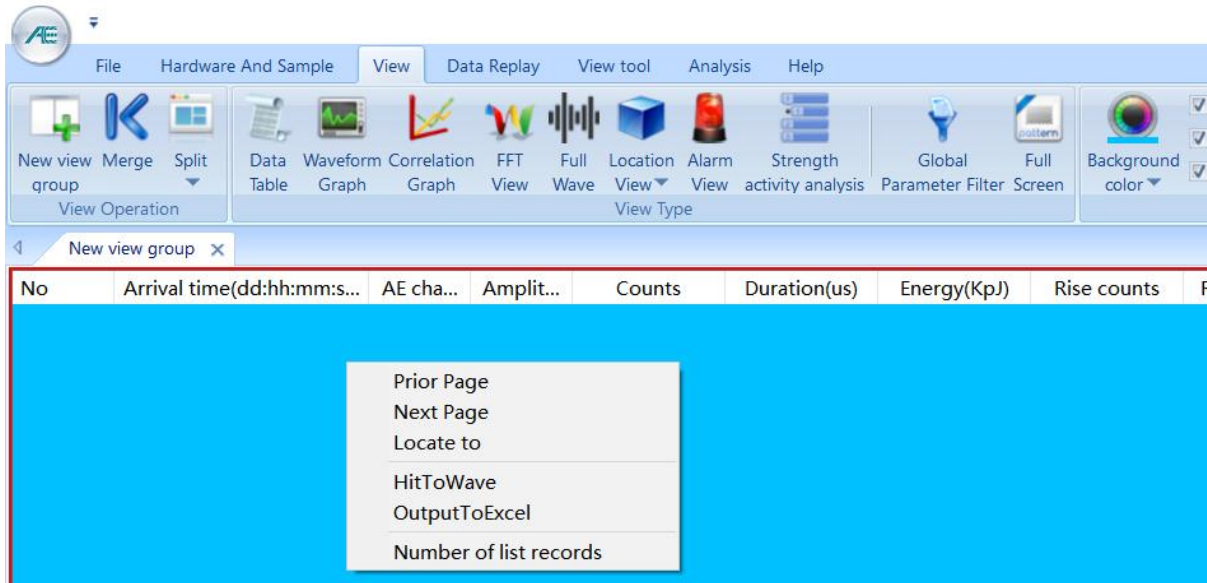
Fig. 6-40 Parameter Filter interface

Parameter No.: in the parameter filter view, all parameters are arranged in the order of "arrival time" by default. By clicking the parameter name, all parameters under the parameter name can be arranged in the ascending or descending order. For example, click "Amplitude" or "Counts" in the top row of parameter filter.

No matter what the current setting of "Data Table" is, the right-click menu on its view interface is the same. Through this menu, you can perform operations such as "Prior page", "Next page", "Locate to", "Hit to Wave", "Output to excel" and "Number of list records".

Prior page: select the parameters in the first row of the window with the mouse and click "**Prior page**" to turn the page to the previous page;

Next page: select the parameters in the last row of the window and click "Next page" to turn the page to the next page;

Locate to: when the data replay operation is paused or finished, select this option and the following window will appear. The number behind the "Parameter number" is the value range that are available to enter. For example, No. 458 are the last row number, and No.100 is the parameter row to locate. After clicking [OK], the cursor will be located to the 100th line.
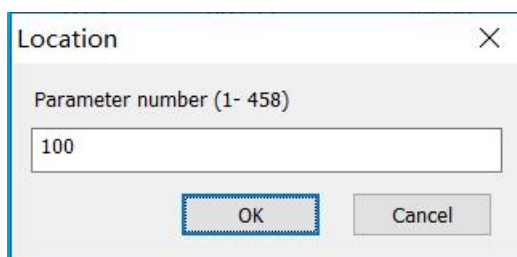
Fig. 6-41 Locate to the Specified Line Parameter

HitToWave: select a row of parameters in the "Data Table". Right click to select "HitToWave" function. This function is to find the corresponding waveform that generated this row of parameter. If the waveform file is found, it will be displayed in the waveform diagram, including channel information and time information. If there is no corresponding waveform found, the software will give a prompt message that "Hit to wave is not found". To use this function, you need to pay attention to the following:

1) Parameter data (.pra) and waveform data (.aed) must have the same file name and time tag, and in the same storage path;

2) The priority of parameter format data uploading to the computer is higher than that of waveform. So the maximum instantaneous data is far less than the actual communication bandwidth;

3) The current channel must enable the saving function for both waveform file and parameter file at the same time;

Output to Excel: after selection, export all the parameter data that are displayed in the current table to the Excel format. If you need to convert all parameter data to the Excel format, please refer to Chapter "6.2.4.2.1 File Conversion".

Number of list records: Specifies the maximum number of parameters that can be displayed in the Data Table. A maximum of 80,000 records can be set.
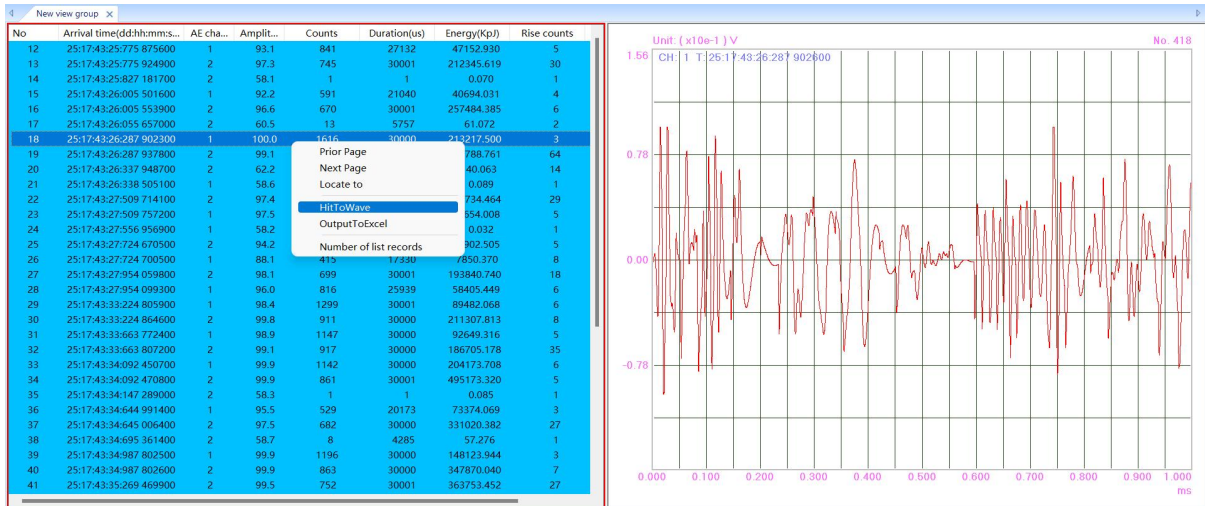
Fig. 6-42 Prompt info of Hit to Wave

6.2.6.2.2.   Waveform View

The waveform view is a time domain diagram, whose X-axis is time and Y-axis is voltage (sensor output, before the preamplifier) with the ordinate unit is initially set to Volt (also **can be modified to dB**). It takes the sampling length of waveform as the display time. The waveform display length of time: is equal to (=) sampling length (points) / sampling rate (points per second).

6.2.6.2.2.1.   Establishment of Waveform View

Select a blank view (red border appears), and click **[View],** then click **[Waveform Graph]** to complete the addition of default waveform.
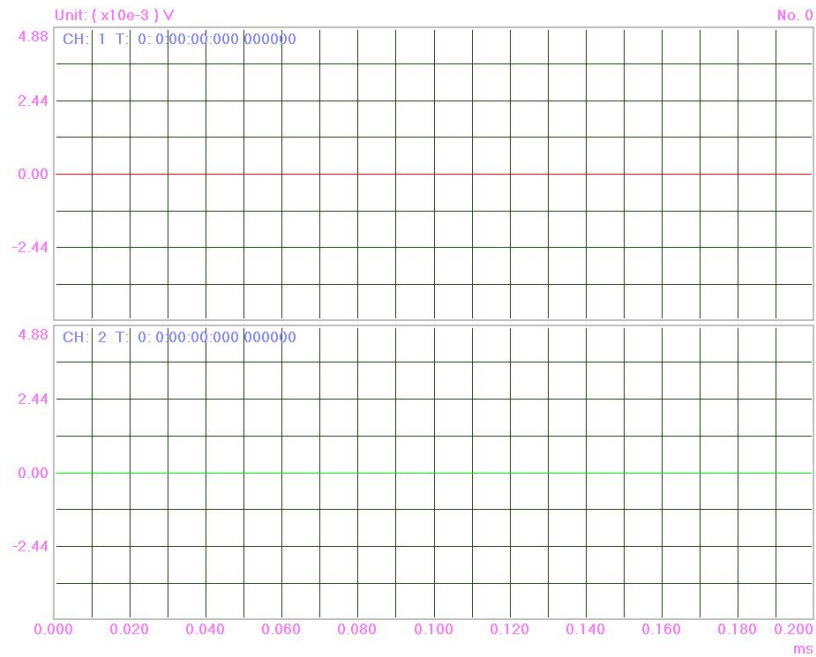
Fig. 6-43 Waveform of Double Channels

6.2.6.2.2.2. Waveform setting

Background color: select the waveform view and click **[Background Color]** to select different view colors. The default color is black;

Single channel / Double channels / Four channels: select the number of channels displayed in a single waveform view window, and check it after the view is selected; scroll the mouse wheel when the mouse is on top of the waveform, and it will switch through the channels.

6.2.6.2.2.3. View Attribute Function
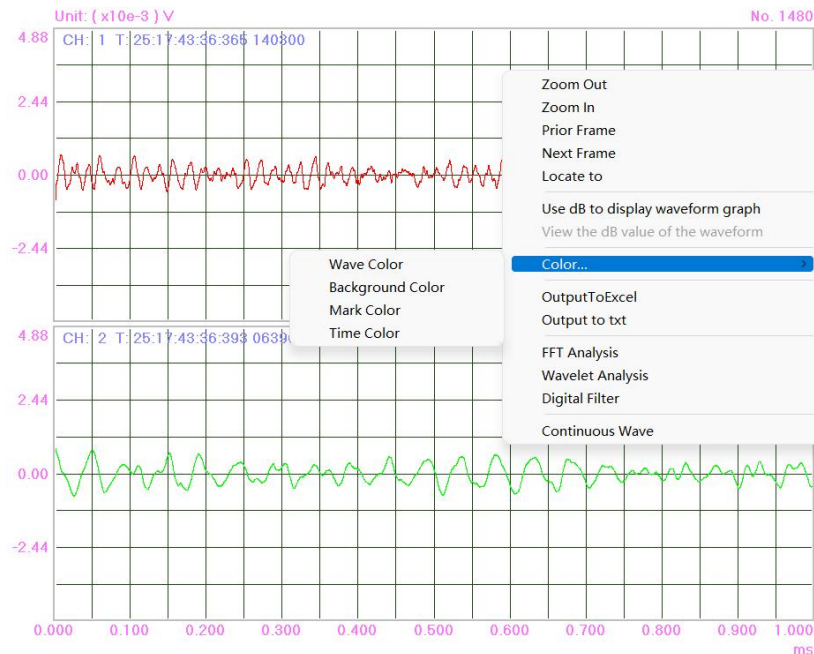
Fig. 6-44 Right click interface of Waveform

● **Zoom Out:** enlarge the voltage value (Y-axis direction) of all channels in the window, which is equivalent to keyboard **UP** key **[PgUp]**;

● **Zoom In**: reduce the voltage value (Y-axis direction) of all channels in the window, which is equivalent to keyboard **DOWN** key **[PgDn]**;

● **Prior Frame:** if the current sequence number of the current waveform diagram is "**No. K**" in the upper right corner, the No. **"K-1"** waveform is filtered out from the waveform file and displayed, including the channel number and arrival time, equivalent to the keyboard **LEFT** key. The data may not be in the current channel and need to be queried by switching channel number via scrolling the mouse wheel;

● **Next Frame:** if the current sequence number of the current waveform diagram is "**No. K**" in the upper right corner, the No. **"K+1"** waveform is filtered out from the waveform file and displayed, including the channel number and arrival time, equivalent to the keyboard **RIGHT** key. The data may not be in the current channel and need to be queried by switching channel number via scrolling the mouse wheel;

● **Locate to**: when the data replay operation is suspended or finished, select this option and the following window will appear. The number range in the bracket is the frame range

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available to be located in. For example, (1 - 1480) is the waveform frame range available, and No. "800" is the sequence number of the waveform frame to be located. After clicking [OK], the No.800 frame of the waveform will be displayed in the window.
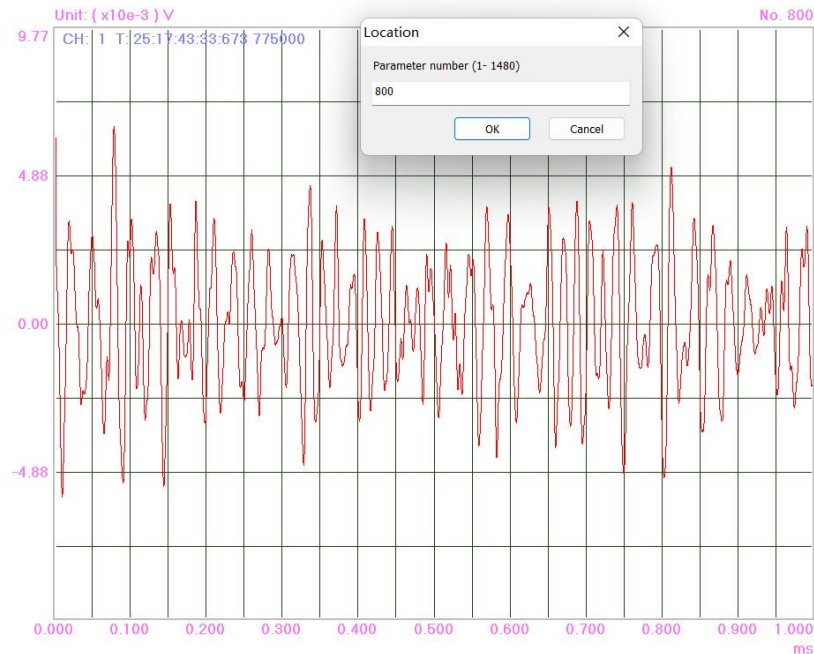
Fig. 6-45 Locate to the specified frame waveform

● **Use dB to display waveform graph:** after selected, the Y coordinate unit changes to dB (the initial unit is Volt);

● **View the dB value of the waveform:** If [Use dB to display waveform graph] option is selected, you can select [View the dB value of the waveform]. When the mouse is moved to the waveform, the dB value corresponding to the current point of the mouse is displayed right above the waveform.

● **Color:** You can choose to modify waveform color, background color, mark color, and time color. Click to enter the color table and modify the color in the channel window where the cursor stays;

● **Output to Excel:** export that frame of waveform displayed where the cursor stopped, to the .CSV format, including the channel number, arrival time, voltage value and other information; the time interval T = 1 / sampling rate;

● **Output to TXT:** export that frame of waveform displayed where the cursor stopped to .txt format, and the information included is equivalent to exporting to the Excel format;

Fig. 6-46 Waveform output to excel File fragment capture

● **FFT Analysis:** converts the current time-domain waveform data into the corresponding frequency domain according to the extraction rate ([Sample Settings] > FFT Setup > FFT Decimation Ratio). For details, see Chapter "6.2.9.2 FFT Analysis".

● **Wavelet Analysis:** The current time-domain waveform data is processed in different layers according to different frequencies and displayed in several waveform of different frequencies at the same time. For details, see Chapter "6.2.9.3 Wavelet Analysis".

● **Digital Filter:** Set the type and frequency range of the digital filter, and then filter the current time domain waveform data. For details, see Chapter "6.2.9.4 Digital Filter".

● **Continuous Wave:** Displays multiple waveform frames of the current waveform file in a single window. You can view a maximum of 80 consecutive frames. At the same time, the channel can be switched and the wave frame number can be located. After relocation, the wave frame on the left of the window is the located wave frame.

● **View mouse operation**: The scaling of the waveform can be accomplished with the help of the mouse operation by drawing the rectangle on the waveform. The scaling area is the area within the rectangle, as illustrated by the Figure 6-48 below.
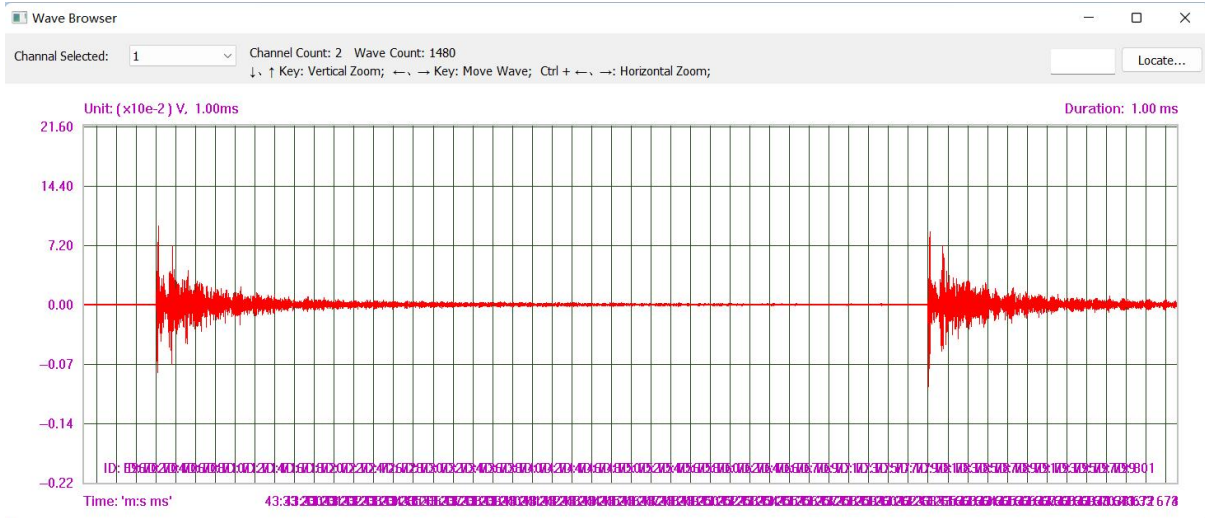
Fig. 6-47 Screen for viewing continuous waveform
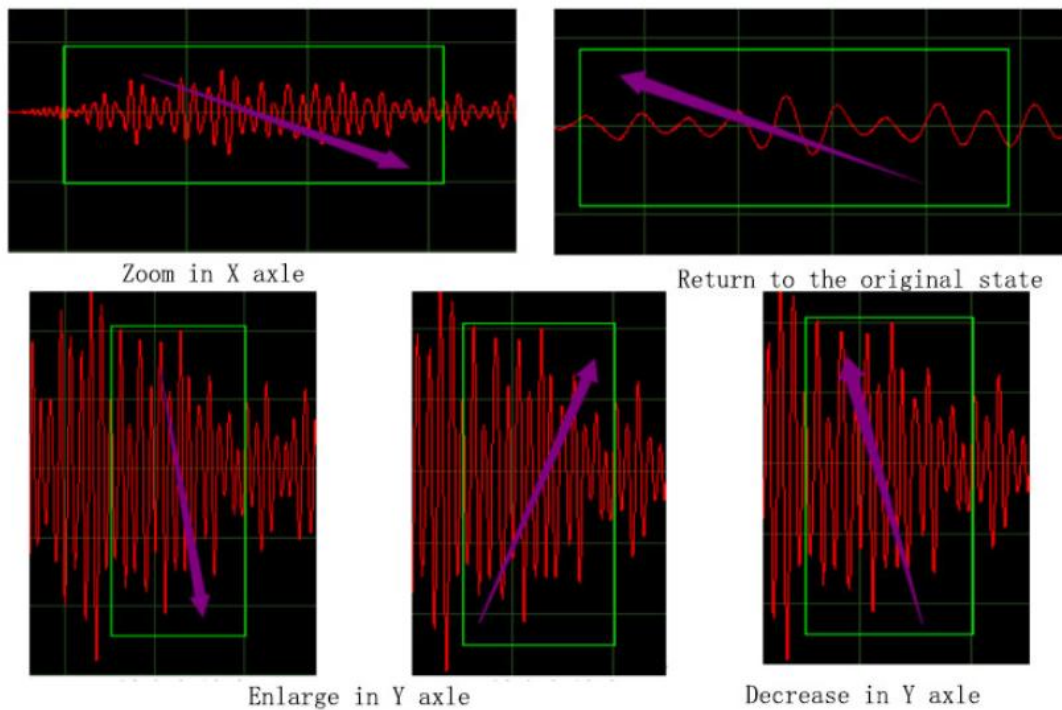
Fig. 6-48 Mouse Operation Diagram of Waveform

6.2.6.2.3. Correlation Graph

Correlation Graph is a kind of relationship diagram that uses two or more AE parameters in data table as the horizontal and vertical coordinates to draw the correlation curve, distribution point diagram, or line diagram, etc., which is used to characterize the acoustic emission signals and is a common tool for the analysis of parameter data.

6.2.6.2.3.1. Establishment of correlation diagram

Select a blank view (with a red border), and click **[View]**, then click **[Correlation Graph]** to complete the addition of default correlation graph. The default channels v.s. hits correlation graph is a commonly used view.
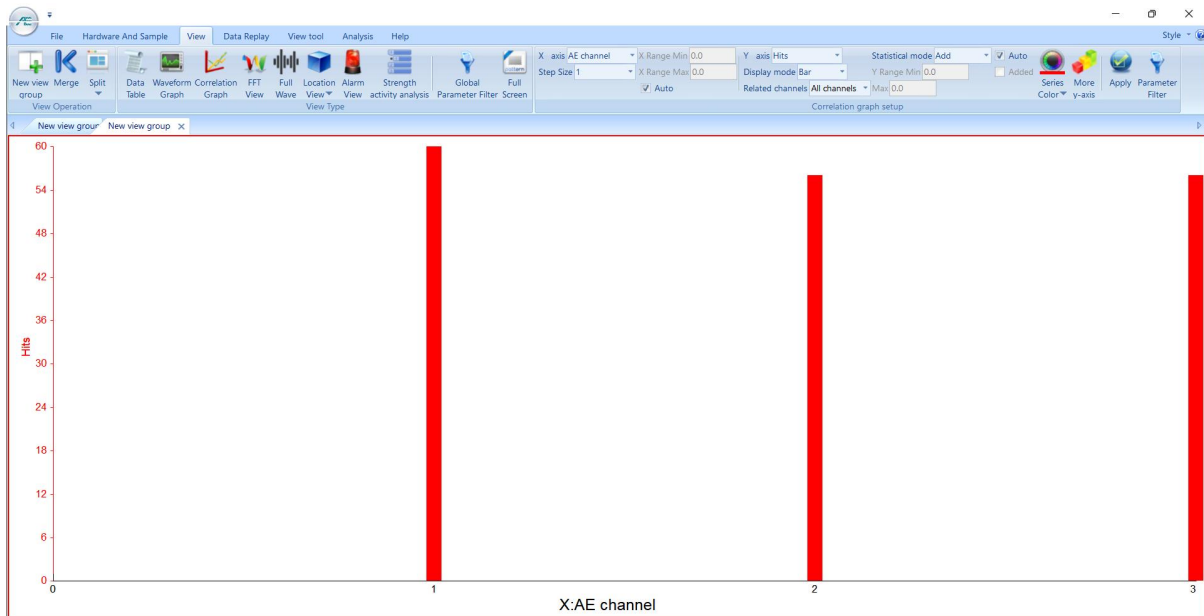
Fig. 6-49 Default Correlation Graph

6.2.6.2.3.2. Parameters Modification of Correlation Graph

After the correlation graph is selected, you can modify the settings of the correlation graph.

Note: After modifying the settings, you must click the **[Apply]** button on the right side of the view menu to update the modified settings in the graph.

● **X-axis:** click the drop-down button on the right side of [AE channel], and it contains multiple parameters for selection, including "arrival time", "AE channel ", "amplitude", "counts", "duration", "energy", "rise counts", "rise time", "RMS", "ASL", "External Parametrics1-2", "Hits", "Frequency centroid", and "peak frequency";

● **(X-axis) step size:** The interval value between the two adjacent points on the X-axis. When the X-axis parameter is modified (not "AE channel"), there will be multiple corresponding optional values available;

● **Y axis:** click the drop-down button on the right side of [Hits], and there are "Amplitude", "Counts", "Duration", "Energy", "Rise Count", "Rise time", "RMS", "ASL", "External

Parametric 1-12", "Hit/s", "Hits", "Frequency Centroid", "Peak Frequency" and "Partial power 1(%)-5(%)" to be selected;

● **Display mode:** there are four kinds of display modes: "Dot", "Line", "Bar" and "FastLine". When the parameters of X and Y axes are determined, the software will automatically match the available display modes;

● **Related channels:** including "all channels" and single channel number from 1 to 128. When a channel is specified, the current correlation graph will only count the data of the specified channel;

● **Statistical mode:** "Maximum", "Average" and "Add" are options. When the X-axis parameter is set as "Arrival Time", the step size set in X-axis will be taken as the statistical time;

● **X/Y Range:** the maximum and minimum values of the axis range, which can be customized by the user according to the data distribution;

● ☐ **Auto**: after ☑Auto selected, the coordinates display range of the correlation graph will be automatically adjusted according to the data distribution;

● ☐ **Added:** if ☐Added is not selected, values displayed in the graph are calculated based on each step size of X axis. When ☑Added is selected, the values are accumulated.
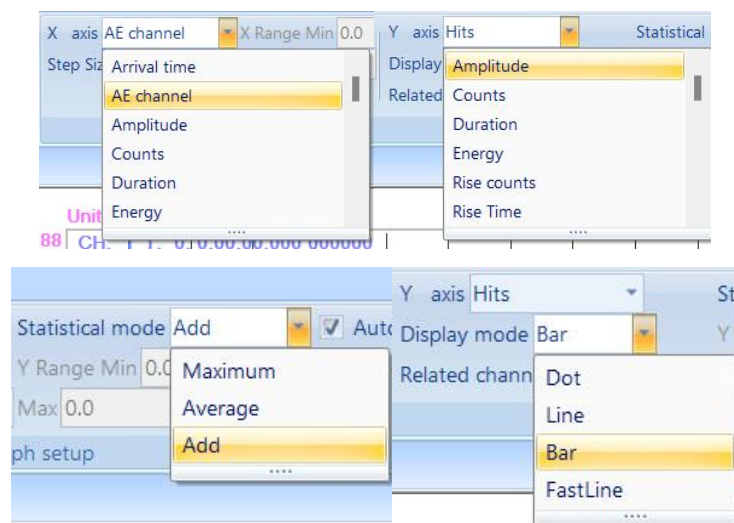
Fig. 6-50 Parameter Modification Sub menu of Correlation Graph

For example: take the "arrival time - (hits + energy + counts)" Correlation Graph as an example:

1) Select a blank view (red border appears) and click "Correlation Graph" in "View" menu to complete adding the default correlation graph.

2) **Modify X-axis:** first, click "AE Channel", select "Arrival time". Then select "step size" in the drop-down menu in the next line, such as "100ms"; if the current relevant graph setting is completed, but you need to modify the X-axis again, and you can repeat Step 2) without modifying the subsequent Y-axis.

3) **Modify Y-axis:**

a. First, select "Hits" in the Y-axis drop-down menu, then select "Display mode" >> "Line", and then select "Related channels" >> "All Channels";

b. In the "Statistical mode", select "Added", combined with X-axis info, that is, the hit number is accumulated and counted every 100ms;

c. ☐ Added: when ☑ Added, the Y-axis value is added, that is to say, the statistical value obtained from step b is superimposed step by step according to the step size as the the Y-axis display value.

d. Click "More Y-axis" button to pop up the window. Refer to Step 3) > a ~ c to complete the settings of "total energy accumulation" and "total counts accumulation" in the pop-up window, and click "OK";

e. Click the **[Apply]** button on the right side of the menu to update the graph. At this point, the correlation graph " Arrival Time - (Hits + energy + Counts)" view is complete.
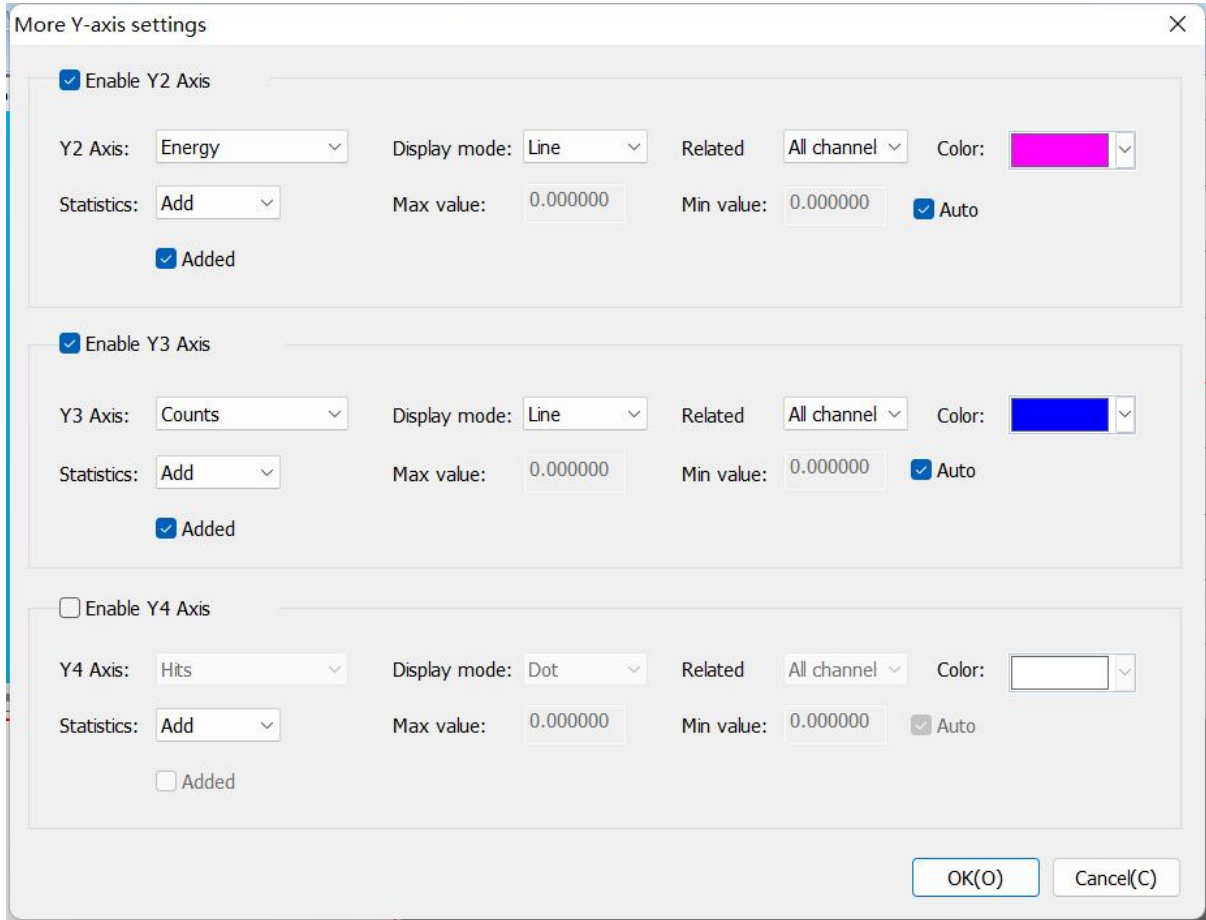
Fig. 6-51 More Y-axis Settings page
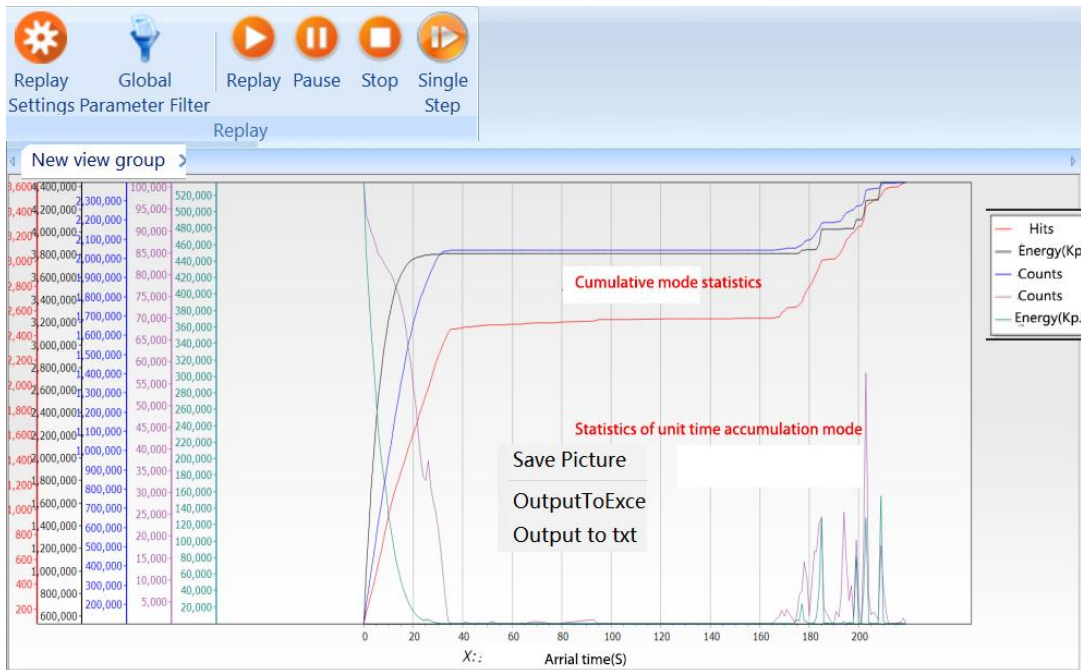
Fig. 6-52 Data Display of Multi-Y-axis Correlation Graph

6.2.6.2.3.3. View Attribute Function
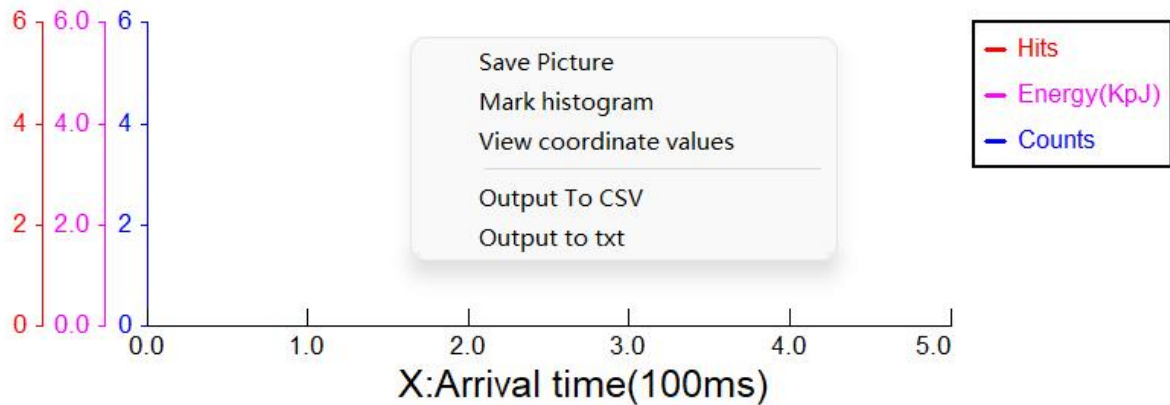
Fig. 6-53 Correlation Graph Attributes

- **Save picture:** save the current correlation graph in the form of a picture;

- **Mark histogram:** After selection, the corresponding value of the bar chart will be marked;

- **View coordinate values:** After the acquisition or data replay, you can view the values of the graph where the cursor points;

- **Output to CSV**: select to export the current correlation chart data to CSV format;

- **Output to TXT:** select to export the current correlation chart data to TXT format.

6.2.6.2.3.4. Recommendation of Correlation Graph

Signal Distribution Graph

The signal distribution Graph generally establishes a two-dimensional coordinate system by comparing the number of the acoustic emission hits or events with other acoustic emission characteristic parameters for distribution statistics. The vertical axis generally selects the number of hits or events, while the horizontal axis selects any acoustic emission parameter. The distribution graph is defined by the (X-axis) parameter name, such as amplitude distribution graph, energy distribution graph, counts distribution graph, duration distribution graph, rise time distribution graph, etc., among which the amplitude distribution is the most widely used. Distribution analysis can be used to find the characteristics of AE sources, so

as to identify the types of AE sources, such as crack propagation and plastic deformation of metal materials, fiber fracture and substrate cracking of composite materials, etc. This method is also often used to evaluate the intensity of AE sources. For example, Figure 6-49 correlation diagram is one of the distribution graphs, the channel distribution graph, showing the activity of the signals received by channels. If the number of AE hits is high, the activity is strong.

Table 6-10 Recommended Settings of Common Distribution Graphs

X-axis parameters	X-axis step	Y-axis parameters	Display Mode	Name or application
AE channel	Default or 1	Hits	Bar	AE Channel- HIT distribution, used for area location
Amplitude	1	Hits	Bar, Line	Amplitude distribution Graph
Counts	1/10/100	Hits	Bar, Line	Counts distribution Graph
Energy	0.1 /1/10	Hits	Bar, Line	Energy distribution Graph
Duration	10/100	Hits	Bar, Line	Duration distribution Graph
Rise time	10/100	Hits	Bar, Line	Rise time distribution Graph
Arrival time	1/10/100	Hits (Accumulation, maximum, average)	Line	HIT histogram, signal stages and trends

Time history chart

The X-axis is the "arrival time", and the Y-axis is the other parameters of acoustic emission, which is also known as experience diagram or time history diagram. The experience diagram can directly reflect the change of acoustic emission signal with time, and can be used to evaluate the activity of acoustic emission source or analyze the signal characteristics of a certain experimental stage combined with other external data. It is generally used for the evaluation of Felicity Ratio, Kaiser Effect, transverse load evaluation of acoustic emission and crack initiation monitoring. According to the different signal types, different AE parameters can be used to make a variety of history diagrams.

Y-axis added: once this option is clicked, the data will be accumulated and displayed as

step-up status, which can be used according to the actual application.

Table 6-11 Recommended settings of common histogram

X-axis parameters	X-axis Step	Y-axis parameters	Y-axis Statistical mode	Display Mode	Name or application
Arrival time	1/10/100ms	HITS	Add	Linear	Determination of signal hit rate, stage and degree
Arrival time	1/10/100ms	Counts	Maximum/Add		
Arrival time	1/10/100ms	Amplitude	Maximum/Average		
Arrival time	1/10/100ms	ASL	Maximum		
Arrival time	1/10/100ms	Energy	Maximum/Add		
Arrival time	1/10/100ms	Duration	Maximum		

Correlation Graph

Correlation analysis method is also the most commonly used method in acoustic emission signal analysis. For any two acoustic emission characteristic parameters, the correlation diagram can be analyzed between them. The two-dimensional coordinate axis represents a parameter, and each display point corresponds to an AE signal hit or event. Therefore, the correlation diagram in acoustic emission generally adopts the dot display mode. The characteristics of different AE sources can be analyzed by making the correlation diagram between different parameters, so as to identify AE sources.

Table 6-12 Recommended settings of common Correlation Graph

X-axis parameters	Y-axis parameters	Name or application
Amplitude	Energy	Signal type, identification of electrical noise
Duration	Amplitude	Distinguish leakages
Duration	Energy	Distinguish leakages
Duration	Rise time	Distinguish crack and friction signal
Duration	Counts	Distinguish crack, friction and leakage signals
Rise time	Amplitude	Identification of electrical noise

6.2.6.2.3.5. Parameter filter settings

Click [**Parameter Filter**] to pop up "Hit-data setup" interface. The filter is a view specific filter, which is only effective for the current view. Refer to Chapter "6.2.5.3.2 Hardware Parameter Filter" for setting methods. After the function is enabled, the parameter data conforming to the setting rules will participate in the drawing of relevant graphs, and the stored data files will not be changed.

6.2.6.2.4. FFT Wave

It is frequency domain distribution graph. Its X-axis is the frequency (kHz), and the Y-axis is voltage (amplified by preamplifier). It is the data restoration view of waveform data after "Fast Fourier transform". The corresponding frame of time-domain waveform is transformed by "Fast Fourier transform" into a frequency domain graph. The use of this view needs to be combined with "waveform diagram", that is, the "waveform diagram" needs to be established at the same time when the "frequency domain waveform diagram" is established. The two views do not have to be in the same view interface, but can be in different view groups.

6.2.6.2.4.1. Establishment of frequency domain waveform

Select a blank view (red border appears), click **[View]**, then click **[FFT Wave]** to complete the default frequency domain waveform. Frequency domain waveform display is the most important tool of Fourier transform (spectrum analysis) in advanced waveform analysis tools, and is one of the most commonly used means of waveform spectrum characteristics analysis.
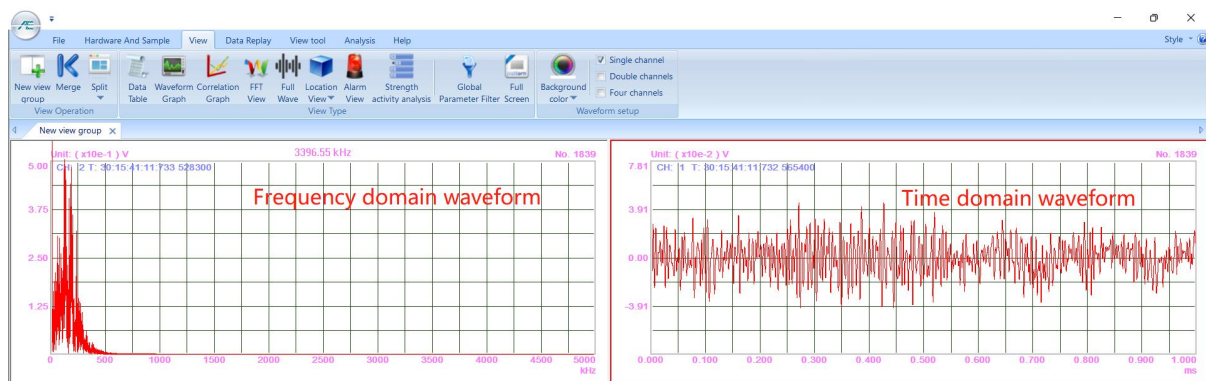
Fig. 6-54 Interface of frequency domain and time domain waveform

6.2.6.2.4.2. FFT setup

Background color: select the FFT view area, then click [Background Color] to select different background colors. The default is black color;

Single channel / Double channels / Four channels: select the number of channels displayed in a single view window, and check it after the view is selected; the channel where the cursor is located can be switched by scrolling the mouse wheel;

Original frequency domain range: maximum frequency range of original frequency domain graph = time domain waveform sampling rate / FFT decimation ratio;

Waveform zooming: The mouse operation is similar to that in Waveform View. For details, see Figure 6-48;

Keyboard operation: After the window is selected, the [UP] key (or [DN] key) can zoom in (or zoom out) the voltage value (in the Y-axis direction) of all channels in the window.

6.2.6.2.5. Full Waveform

The "Full Waveform" is set up to cooperate with the full waveform data acquisition. During the acquisition process, the user can observe the waveform changes in the whole process of acoustic emission. In the replay phase, by resetting configurations such as the threshold and hit definition time, the full waveform data will be selected by the new configuration filter and be replayed. After replaying, the new HIT parameters are generated according to the new parameters generation conditions.

6.2.6.2.5.1. Establishment of Full Waveform

Select a blank view (red border appears), and click **[View]**, then click **[Full Wave]** to complete the default full waveform graph addition. The full waveform view is a display of waveform for the whole acquisition period, instead of displaying the waveform in a single frame. The starting time of the time coordinate is fixed and the collected waveform data is compressed to the left.
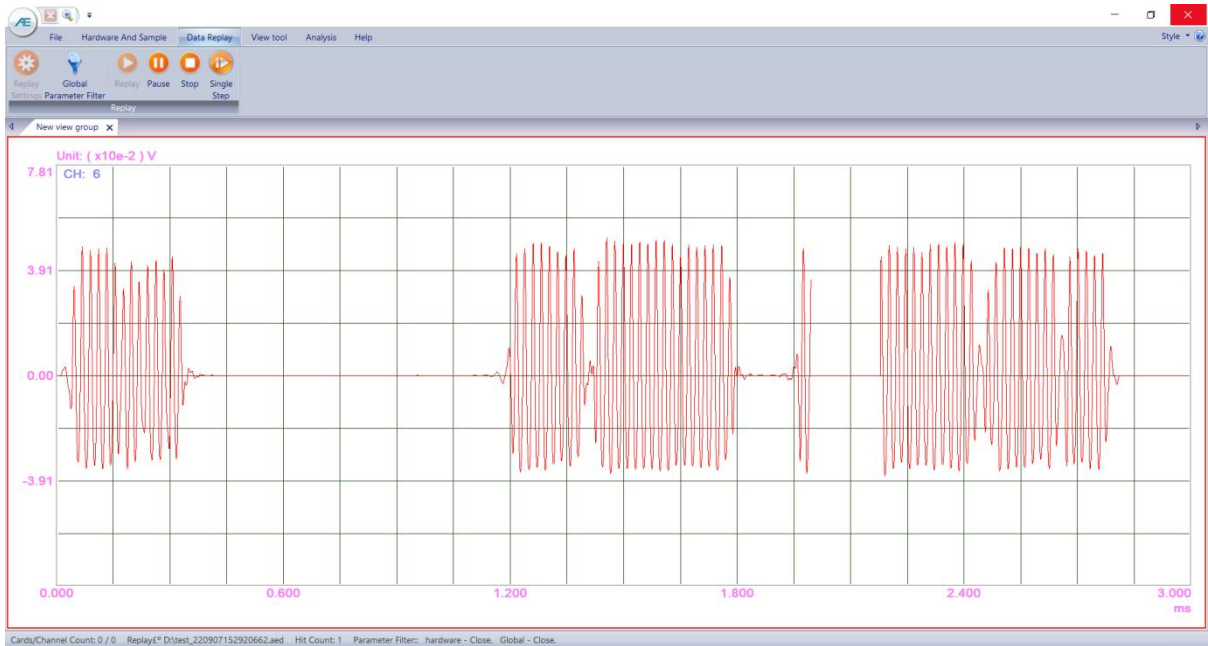
Fig. 6-55 Full Waveform setting interface

6.2.6.2.5.2. Full Waveform Analysis Function
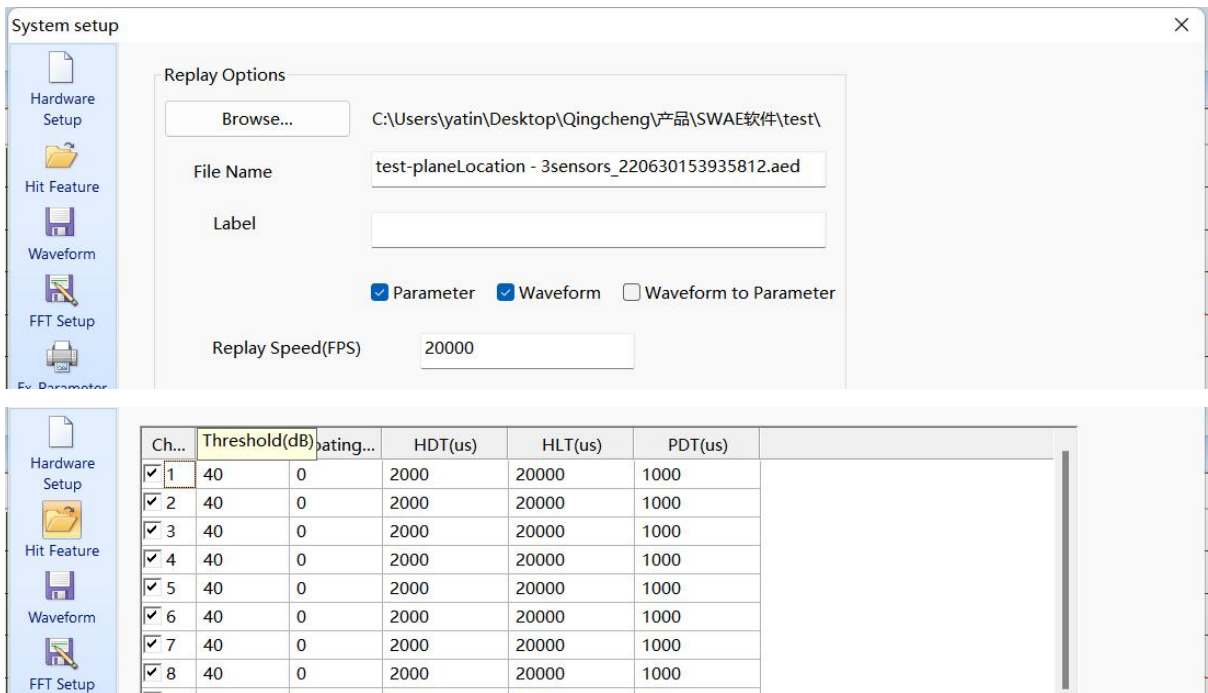
Fig. 6-56 Full Waveform Function Regeneration Parameters

Independent full waveform analysis has the following functions:

1) After opening the file, the static wave panorama can be displayed directly, and the

current position of waves can be displayed in the panorama during replay; Synchronous

waveform display of all channels;

2) Static waveform is the main part of full waveform analysis, and dynamic play is an extended function of static analysis.

3) Zoom in any waveform interval and zoom out to the panorama of waveform with one key. The processing method of waveform zooming is similar to that of "Waveform Graph". Please refer to Figure 6-48 "Mouse Operation Diagram of Waveform". The mouse wheel can switch the channels. Keyboard operation: select the window, press [UP] key (or [DN] key) to enlarge (reduce) the window Y axis; [Ctrl] + [right] key ([left] key) to enlarge (or reduce) the X-axis of the window; Move the waveform with the [left] and [right] keys.

4) Any number of channels can be selected for full waveform acquisition and synchronous acquisition.

6.2.6.2.6.   Location View

Location view analysis is a means of acoustic emission data analysis, which can more directly show the location of acoustic source signal, and more intuitively evaluate the severity of damage combined with physical structures. Firstly, build the approximate model based on the sensor array layout on the measured object. Then the acoustic emission data are visually displayed on the location view model. The location view types in SWAE includes: Linear Graph, Planar Location Graph, Tank bottom (circular surface) Location Graph, Cylinder Location Graph, Spherical Location Graph, Cube Location Graph, Solider cylinder Location Graph, etc.

Each location Graph can be set with independent parameter filters and location event parameters, which supports the simultaneous calculation and display function of multiple location graphs. The view can be zoomed in and zoomed out through the mouse wheel. The "R" button can restore the original view under any condition.
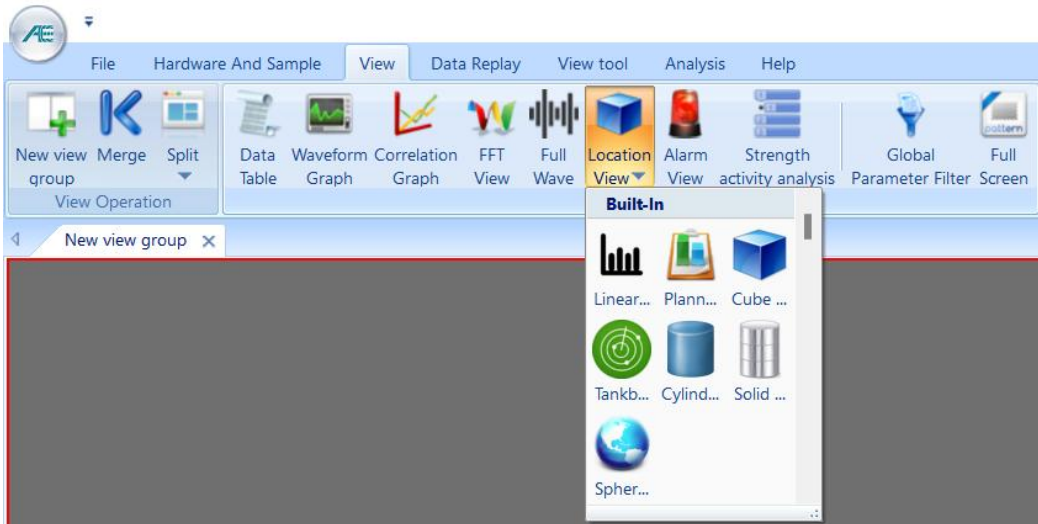
Fig. 6-57 Location view types

6.2.6.2.6.1. Linear location Graph

Linear Location is generally applicable to pressure pipes, trailer cylinders or pressure equipment and vessels with an aspect ratio of length and width greater than 3; and it is suitable for location requirements limited to one-dimensional structural or material mechanics experiments.

1) **View creation:** select a blank view (with red border), click **[View]**, then click **[Location view]**, then choose **[Linear location Graph]** to create the default line Location view;
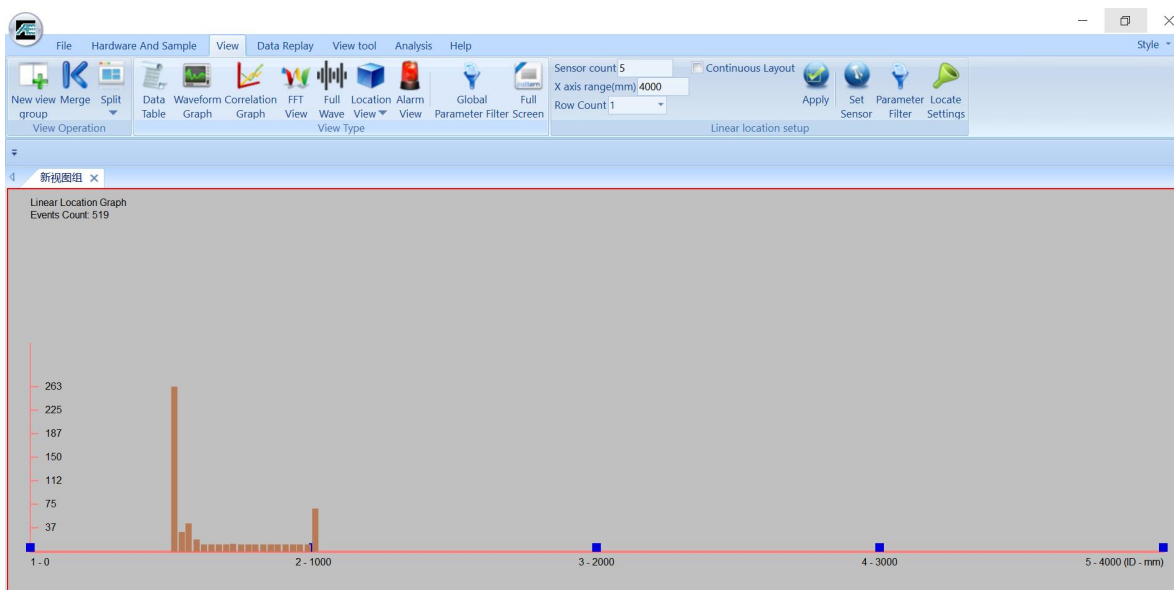
Fig. 6-58 Default view of Linear Location Graph

2) View modification

The modification of linear Location Graph only involves the coordinate settings of sensors. The software supports quick modification, that is, input the total length and the number of sensors, and then the software will distribute them with the equal spacing; or it can manually set the number and coordinates of sensors according to the actual situation.

Quick modification: select the default location view (red border appears), and then modify the "X-axis range" (total length of measurement) and the actual number of sensors, and click **[Apply]**; then the software will distribute them with the equal spacing. Refer to the coordinates given by the software to install the sensors.

Manual setting: first, you need to know the distances between all sensors to Sensor#1. After the quick modification, click the **[Set Sensor]** button to pop up the dialog box as Fig. 6-59. The number under the "channel" column is the sensor number, which is generally consistent with the channel number to the AE host, or can also be changed to the user's desired number. Select the number under the channel directly for modification (note that the modified number should not be repeated with the existing number). The column "X(mm)" is the distance of each sensor away from sensor#1. Modify it according to the actual situation. After modification, click the **[OK]** button to update the view.
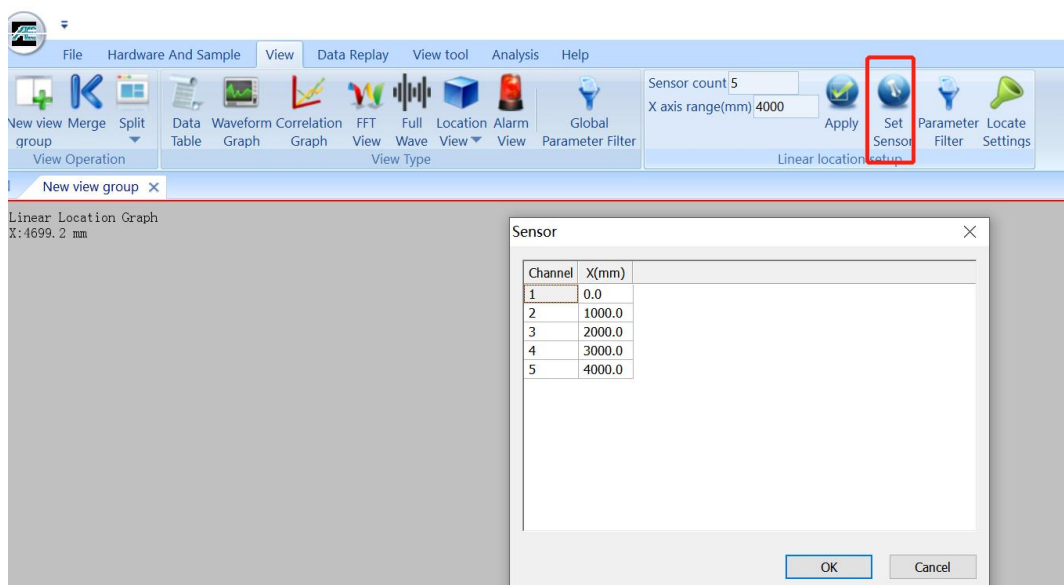
Fig. 6-59 Manual modification coordinate position

3) Explanation of interface terms
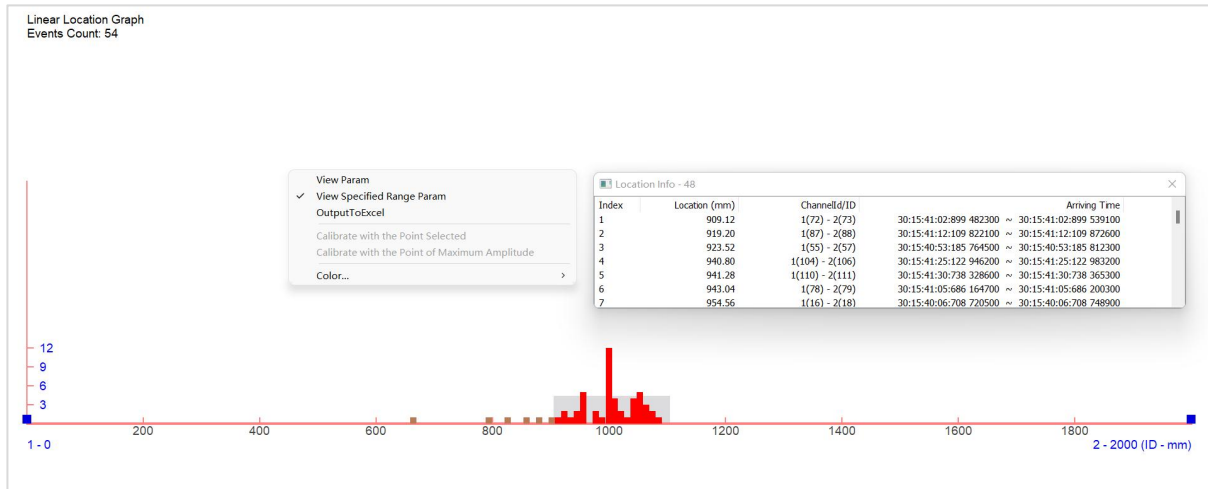
Fig. 6-60 Linear Location Graph View range parameters

Sensor count: it refers to the total number of sensors to be arranged in the linear Location, which can be input directly in the text box;

X axis range(mm): when the sensors are equally divided, it refers to the total length to be detected. When the sensor is used to set and modify the coordinates, this value is not less than the detection length, which can be input directly in the text box;

Row Count: the row numbers of linear arrays in the linear location view. It will require the sensor number is at least 3 or more to be valid.

Continuous Layout: when there is more than 1 row, it determines if the last sensor of the current row should also be the first sensor in the next row. See figure 6-61 for example. There are four sensors and two rows. If the "Continuous Layout" is not enabled, the first row has Sensor#1 and #2, and the second row has Sensor#3 and #4. But when the "Continuous Layout" is enabled, the first row has Sensor#1, #2 and #3, and the second row has Sensor#3 and #4.

Events count: the number of valid location events generated on the current location Graph;

X: 500 mm: the current horizontal (x axis) coordinate where the mouse cursor stays on the view, which is shown at the upper left corner of the view under the "Events count".
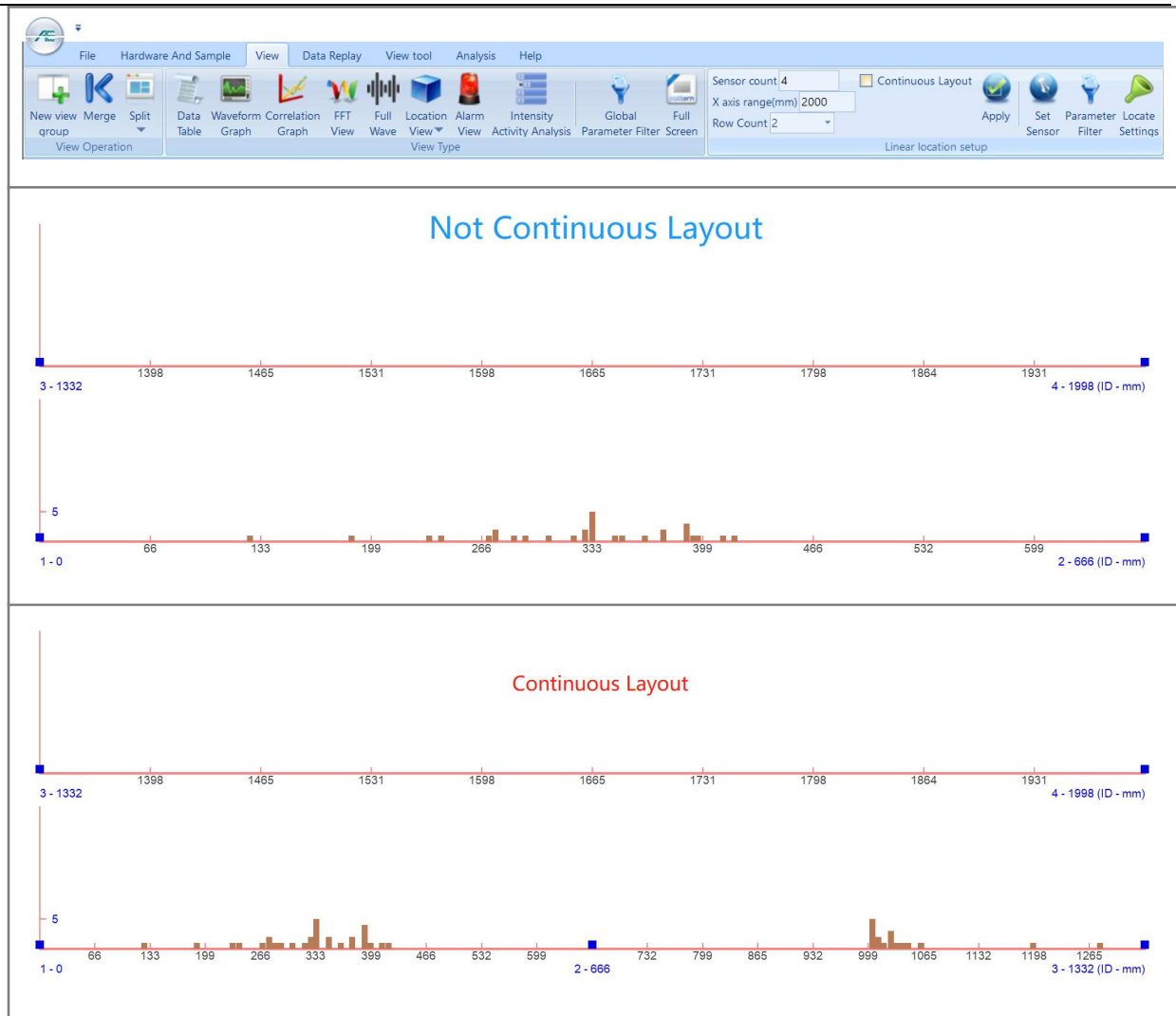
Fig. 6-61 Linear Location Graph Continuous layout difference

4) View property function

Right click on the view to open the view property menu.

View Param: after enabling, click on any valid data points on the location view. Parameter information of the position point will be displayed including the location coordinates, channel ID and the arrival time.

View Specified Range Param: after enabling, enter the covering range width (mm) from the interested position, by default 200mm. Then click on any valid data points on the location view. Parameter information of the position point and the nearby 200mm area points will be displayed including the location coordinates, channel ID and the arrival time. The points shown in Figure 6-60 are calculated based on the channel parameters in the location

parameter table.

Output to Excel: export the location info, including coordinate info and parameter info to excel format;

Color: to modify the background color and modify the selected range background color.

6.2.6.2.6.2. Planar Location Graph

Planar Location Graph is generally suitable for planar structure detection and local detection of large curved surface radius.

1) **View creation:** select a blank view (with red border), click **[View]**, then click **[Location View]**, then select **[Planar Location Graph]** to create the default planar location view;

Fig. 6-62 Default Planar Location Graph

2) **View modification**

The modification of Planar Location Graph involves the number of sensors, coordinates and detection size. The software supports simple modification mode, that is, input the range of area and the number of sensors, and it automatically distribute the sensors with equal sensor spacing; the number and relative distance of sensors can also be manually set according to the actual situation.

Simple modification

a. Select the default Location view (red border appears), and then modify "X-axis range" and "Y-axis range". The maximum range can be up to 500 meters;

b. Input the number of rows and columns of the sensor array; this function can only be arranged in horizontal and vertical straight lines; the horizontal sensor spacing between the adjacent sensors = X-axis range / column number; the vertical sensor spacing = Y-axis range / (number of rows-1);

c. Select whether to click "☐**Right**" and click **[Apply]**; if it is selected, the first sensor in the second row is to the right side of Sensor #1, in the middle between Sensor #1 and #2, and Sensor #1 is located at the coordinate origin; if it is not selected, the first sensor in the second row is to the left side of Sensor #1, and the horizontal coordinate of Sensor #1 and the coordinate origin is half of the distance between Sensor #1 and #2;

d. When there is a difference between the actual sensor positions and the sensor coordinates in the software, click **[Set Senor]** and select "Add" or "Delete" to adjust the sensor number;

e. Click **[Apply]** to update the settings.

Manual setup

a. First, confirm the the X-axis and Y-axis coordinates of all sensors relative to Sensor #1, and then after the simple modification, click the **[Set sensor]** button to pop up the dialog box as shown in Figure 6-63.

b. The number under the "Channel" column is the sensor number, which is generally consistent with the channel number connecting to the AE host, or change to the user's desired number. Note that the modified number should not be repeated with the existing number;

c. The value below the "X(mm)" column is the horizontal distance from the coordinate origin, and the value under the "Y(mm)" column is the vertical distance from the coordinate origin, which can be directly input according to the actual situation.

d. After modification, click the **[OK]** button to update.
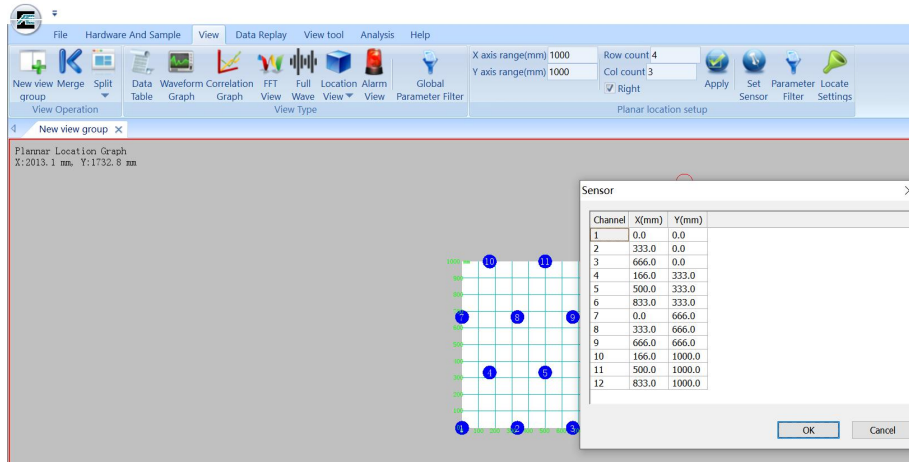
Fig. 6-63 View coordinate modification of Planar Location Graph

3) **Explanation of Interface terms**

X-axis range / Y-axis range (mm): "X-axis range" and "Y-axis range" refer to the length and width of the detected area, which can be input directly in the text box, the maximum value is 500m(500000mm).

Number of rows / columns: "Row count" and "Col count" refer to the number of horizontal rows and vertical columns of the sensor array respectively. The horizontal distance between adjacent sensors = X-axis range / column count; vertical spacing = Y-axis range / (number of rows-1);

☐ **Right:** if it is selected, the first sensor in the second row is to the right side of Sensor #1, in the middle between Sensor #1 and #2, and Sensor #1 is located at the coordinate origin; if it is not selected, the first sensor in the second row is to the left side of Sensor #1, and the horizontal coordinate of Sensor #1 and the coordinate origin is half of the distance between Sensor #1 and #2;

Events count: the number of valid location events generated on the current location Graph;

X/Y coordinates: the current X and Y coordinates where the mouse cursor stays on the view, which is shown at the upper left corner of the view under the "Events count".

4) **View Attribute function**

View Param: enable it to call out the red circle used to filter out the parameters within the circle area. Move the red circle to the interested area, if there are location points, the

parameters of the circled location points will be filtered and displayed in the "Data Table"; as shown in Figure 6-64;

Output to Excel: to export the location info, including coordinate info and parameter info to Excel format;

Calibrate with the Point Selected: when there is any point selected by the red circle, select this option to open the calibration window as Figure 6-65. The selected point location is calculated in the software and it should be same coordinates as the actual source position. If they are different, by adjusting the X or Y coordinates of the point as well as the sound velocity to make it closer to the actual source location coordinates.

Calibrate with the Point of Maximum Amplitude: similar to "Calibrate with the Point Selected", but the select point is with the maximum amplitude.

Color: click "Color" to modify the background color.

View Coordinate: open the window to show all the location points coordinates.

3D Coordinates: change the planner view in 3D dimensions.

Fig. 6-64 View Para of Planar Location Graph
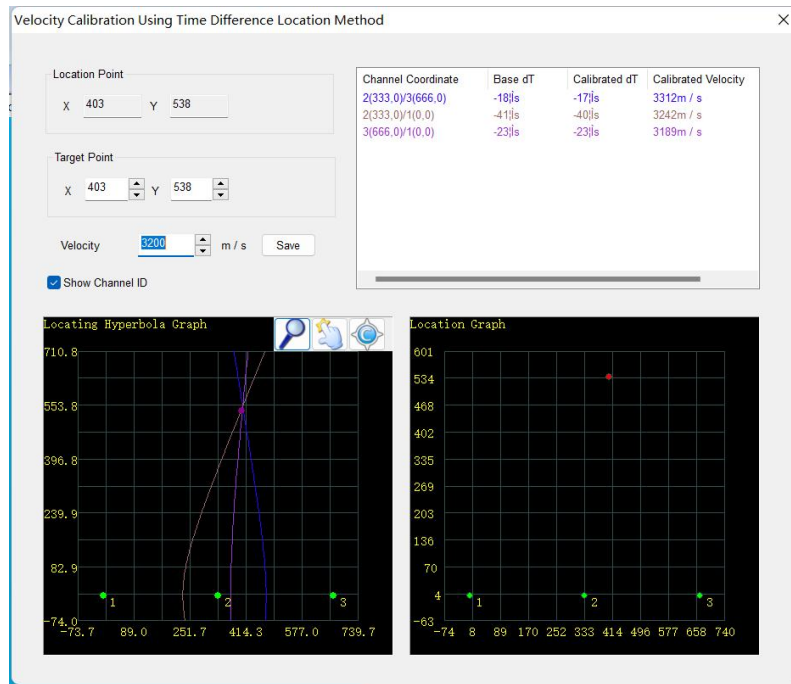
Fig. 6-65 Planar Location Graph Point Calibration
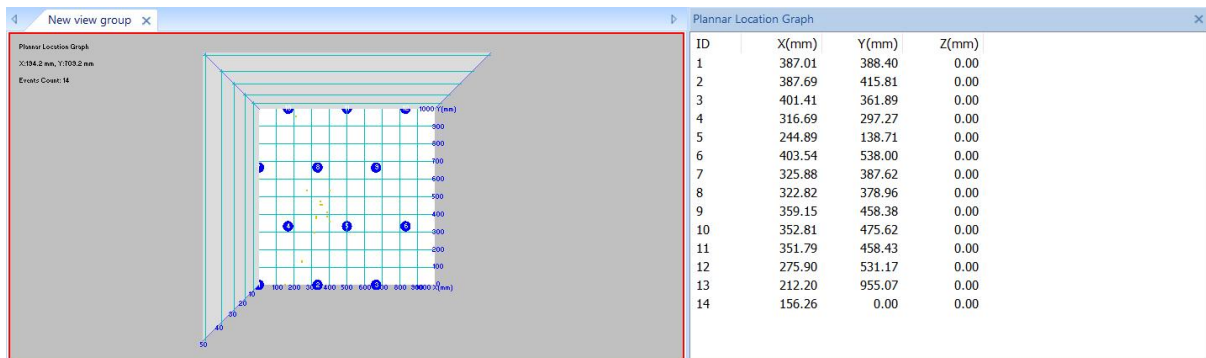
Fig. 6-66 View Coordinates and 3D dimension of Planar Location Graph

6.2.6.2.6.3. Cube Location Graph

Cube Location is generally applicable to the detection of solid cube like cubic structure, and is widely used in laboratory research direction, such as mechanical experiment process, rock block mechanical experiment, etc. The average density of the measured object and the installation position of the sensors have great influence on the location results.

1) **View creation:** select a blank view (with red border), click **[View]**, then **[Location view]**, and then select **[Cube Location Graph]** to create the default cube Location view;

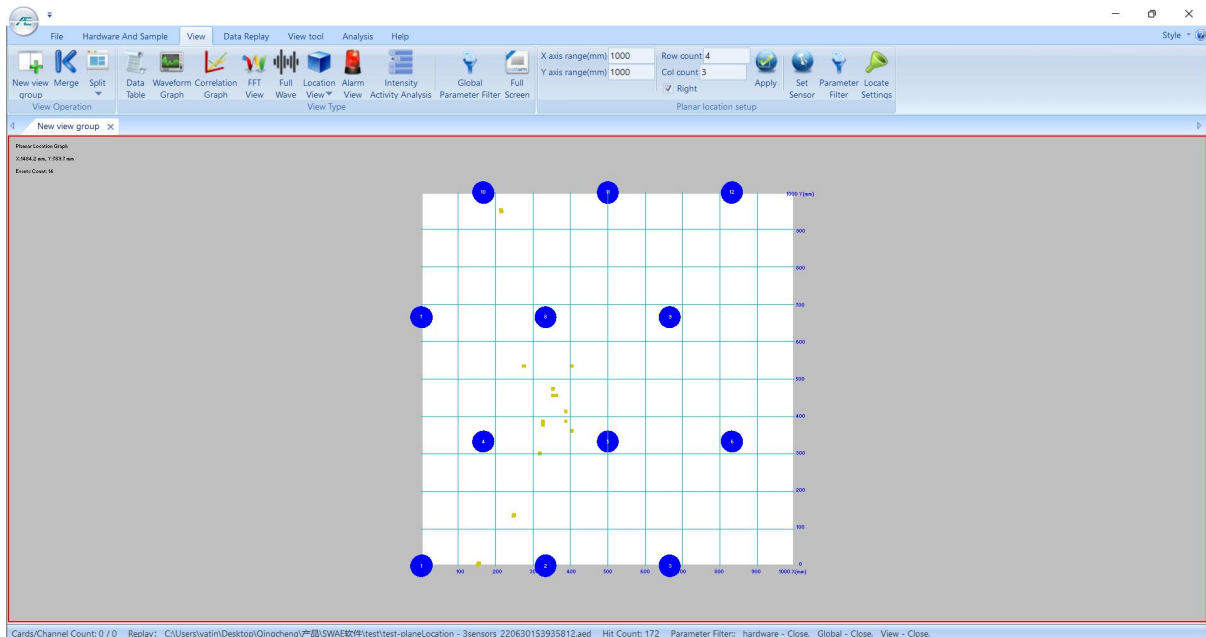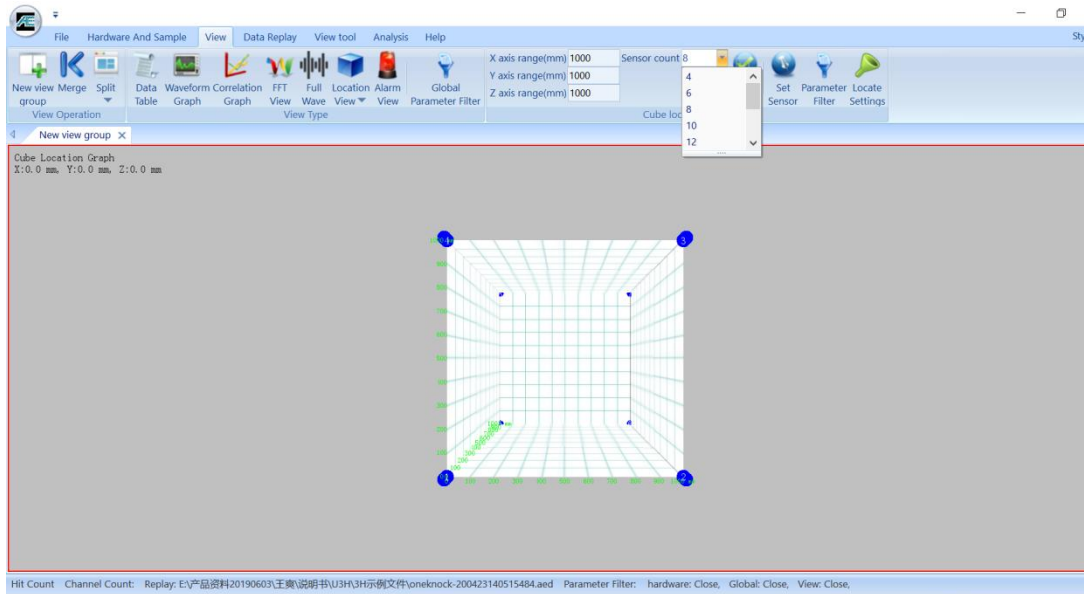Fig. 6-67 Default view of Cube Location Graph

2) View modification

The modification of Cube Location Graph involves the number of sensors, coordinates and detection size. The software supports quick modification mode, that is, after inputting the size of detection area and selecting the number of sensors, the software automatically allocates the sensors; or the number of sensors and relative distances can also be modified manually according to the actual situation. The optional number of sensors is 4, 6, 8, 10, 12, 14, etc. If the actual number of sensors is not available, you can manually adjust in the [Set Sensor] to add or delete.

Simple modification

a) Select the default Location view (red border appears), and then modify "X / Y / Z axis range", where the X, Y, Z ranges are the actual measured object size;

b) Select the number of sensors. If there is no corresponding number available, select the closest number; then, refer to the "Manual setup" method for adjustment;

c) Click **[Apply]** to update the setting. Then the sensors are arranged automatically according to the coordinate positions given by the software.

Manual setup

a. First, know that all sensors X / Y / Z axis coordinates related to Sensor#1, and after the simple modification steps, click the **[Set Sensor]** button to modify the sensor numbers and coordinates;

b. The number under the "channel" column is the sensor number, which is generally consistent with the channel numbers to the AE host, or can be changed to the user's desired number. Note that the modified number should not be repeated with the existing number;

c. The value under column X is the horizontal distance from the coordinate origin, the value under column Y is the vertical upward distance from the coordinate origin, and the value under column Z is the vertical outward distance from the coordinate origin, which can be directly input according to the actual situation.

d. When there is a difference between the actual sensor number or coordinates and that of the software setup, right-click in the "Set Sensor" table and select "Add" or "delete" to adjust, as well as modifying the coordinates according to the actual position;

e. Click [OK] to modify the current interface.

3) Explanation of interface terms

X-axis range / Y-axis range / Z-axis range: "X-axis range", "Y-axis range" and "Z-axis range" refer to the length, height and width of the detected area;

Number of sensors: the total number of sensors to be used, which can be 4, 6, 8, 10, 12, 14, etc.;

Events count: the number of valid location events generated on the current location Graph;

X/Y/Z coordinates: the current X, Y and Z coordinates where the mouse cursor stays on the view, which is shown at the upper left corner of the view under the "Events count".

4) View property function

View Param: enable it to call out the red circle used to filter out the parameters within the circle area. Move the red circle to the interested area, if there are location points, the parameters of the circled location points will be filtered and displayed in the "Data Table";

Output to Excel: to export the location info, including coordinate info and parameter info to Excel format;

Color: click "Color" to modify the background color.

View Coordinate: open the window to show all the location points coordinates.

6.2.6.2.6.4. Tank Bottom Location Graph

Tank bottom location is generally suitable for flat disk or disk structure with large radius of curved surface. In engineering inspection, it is often used for bottom plate corrosion of atmospheric tank and source location of pressure vessel end caps.

1) **View creation:** select a blank view (red border appears), click **[View]**, then click **[Location view]**, and select **[Tankbottom Location Graph]** to create the default tank bottom location graph;
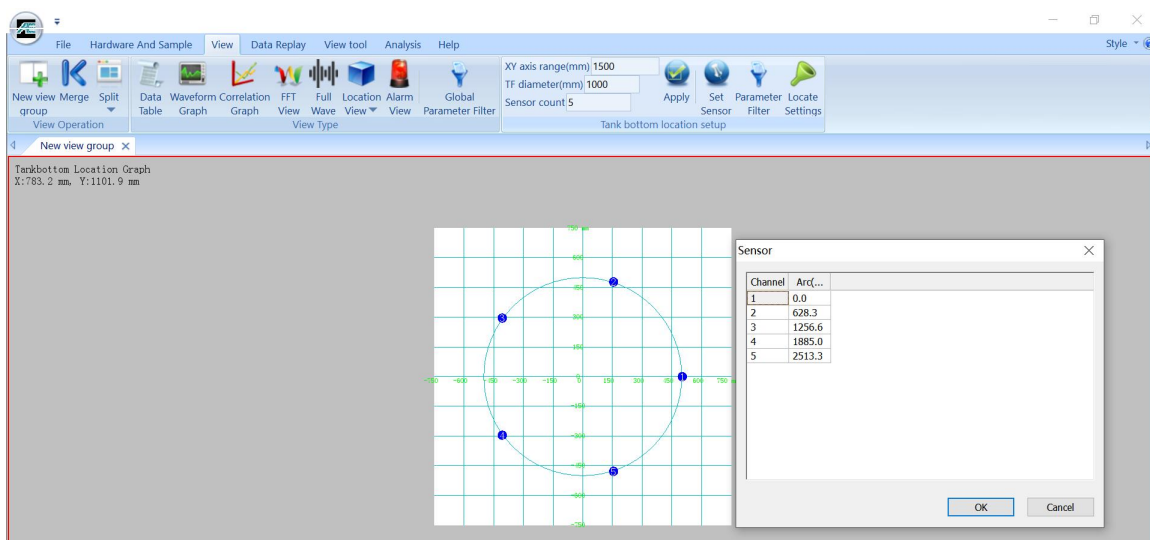
Fig. 6-68 Default view of Tank Bottom Location Graph

2) View modification

The modification of tank bottom location graph involves the setting of the number of sensors, the diameter of detection area and the size of display area. The software supports the quick modification mode, that is, with the number of sensors, the diameter of detection area and the size of display area, the software automatically arranges the sensor locations with equal spacing; on the other hand the number of sensors and the arc length can be modified according to the actual situation for manual setting.

Simple modification

a. Select the default location view (red border appears), and then directly modify "X/Y range", "TF diameter" and "Sensor count" in the "View" interface;

b. Click **[Apply]** to update the settings. Then the sensors are arranged according to the coordinate position given by the software.

Manual Setup

a. Firstly, confirm the counter clockwise arc length distance of all sensors relative to Sensor #1, and then on the basis of simple modification, click the **[Set Sensor]** button to pop up the dialog box as shown in Figure 6-68.

b. The number under the "channel" column is the sensor number, which is generally consistent with the host channel number, and can also be changed to the user's desired number. Note that the modified number should not be repeated with the existing number;

c. The value under "Arc length" is the counter clockwise axial arc length of the distance from Sensor #1, which can be directly entered according to the actual situation.

d. After modification, directly click the **[OK]** button.

3) Explanation of View Setup Functions

X/Y axis range(mm): it refers to the display range of the horizontal and vertical coordinates of the sensor layout;

TF diameter(mm): refers to the diameter of the actual inspected area. In order to make the location view fully display the distribution of tank bottom location sensors, it is recommended to set "XY axis range" slightly larger than "TF diameter";

Sensor count: the number of sensors to be used, which can be determined by referring to the distance equally divided by the circumference length. The more sensors are used, the smaller the blind edge detection area is;

Events count: the number of valid location events generated on the current location Graph;

X/Y coordinates: the current X and Y coordinates where the mouse cursor stays on the view, which is shown at the upper left corner of the view under the "Events count".

4) View property function

View Param: enable it to call out the red circle used to filter out the parameters within the circle area. Move the red circle to the interested area, if there are location points, the parameters of the circled location points will be filtered and displayed in the "Data Table"; as shown in Figure 6-69;

Output to Excel: to export the location info, including coordinate info and parameter info to Excel format;

Calibrate with the Point Selected: when there is any point selected by the red circle, select this option to open the calibration window as Figure 6-65. The selected point location is calculated in the software and it should be same coordinates as the actual source position. If they are different, by adjusting the X or Y coordinates of the point as well as the sound velocity to make it closer to the actual source location coordinates.

Calibrate with the Point of Maximum Amplitude: similar to "Calibrate with the Point Selected", but the select point is with the maximum amplitude.

Color: click "Color" to modify the background color.

View Coordinate: open the window to show all the location points coordinates.

3D Coordinates: change the planner view in 3D dimensions.

Fig. 6-69 Tank Bottom Location Graph View Parameters

6.2.6.2.6.5. Cylinder Location Graph

Cylinder Location is generally applicable to the detection of cylindrical components, including with or without end caps. It is generally applicable to tank type pressure vessels with or without end caps in industrial field, such as various chemical reactors, gas cylinders, horizontal tanks, column tanks, towers, etc., as well as ring barrel components in the laboratory.

1) **View creation:** select a blank view (with red border), click **[View]**, and click **[Location Graph]**, then click **[Cylinder Location Graph]** to create the default cylinder location graph;
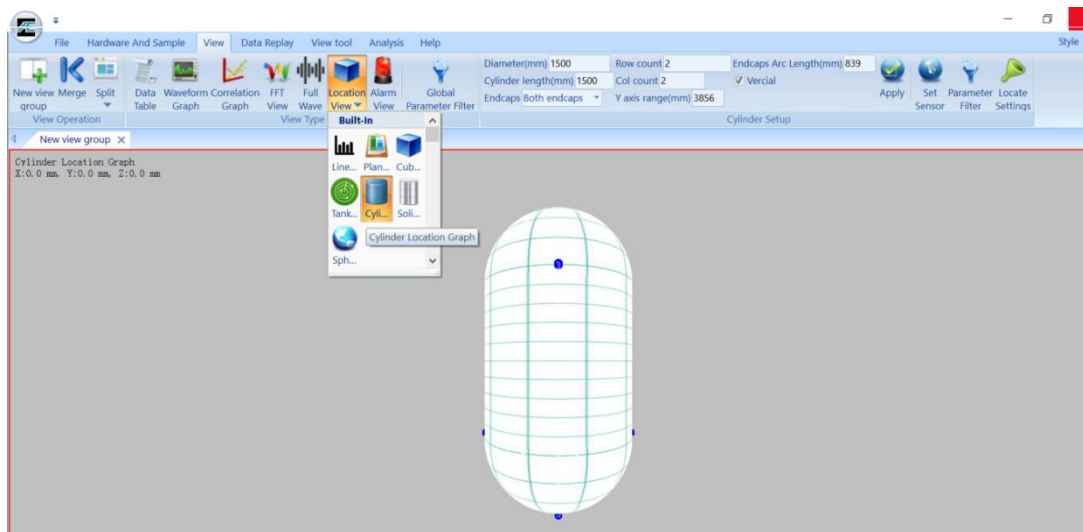
Fig. 6-70 Default Cylinder Location Graph

2) View modification

The Cylinder Location Graph supports simple modification, which can be done by setting the diameter, cylinder length, sensor numbers and other information, and then the software automatically distributes sensors with the equal spacing; or can manually set the number of sensors and relative distances according to the actual situation.

Simple modification

a. Select the default location view (red border appears), and then modify "Diameter", "Cylinder length", "Endcaps, "Row count", "Col count", "Y-axis range" and "□Vertical" in the "View" interface;

b. Click **[Apply]** to update the settings. Then the sensors are automatically arranged according to the coordinate positions given by the software.

Manual Setup

a. Firstly, confirm the X and Y coordinates info of all sensors relative to Sensor #1, and then on the basis of simple modification, click the **[Set Sensor]** button to directly modify the value in the interface;

b. The number under the "channel" column is the sensor number, which is generally consistent with the host channel number, and can also be changed to the user's desired number. Note that the modified number should not be repeated with the existing number;

c. The value below the "X(mm)" column is the horizontal distance from the coordinate origin, and the value under the "Y(mm)" column is the vertical distance from the coordinate origin, which can be directly input according to the actual situation.

d. After modification, directly click the **[OK]** button in the current interface.
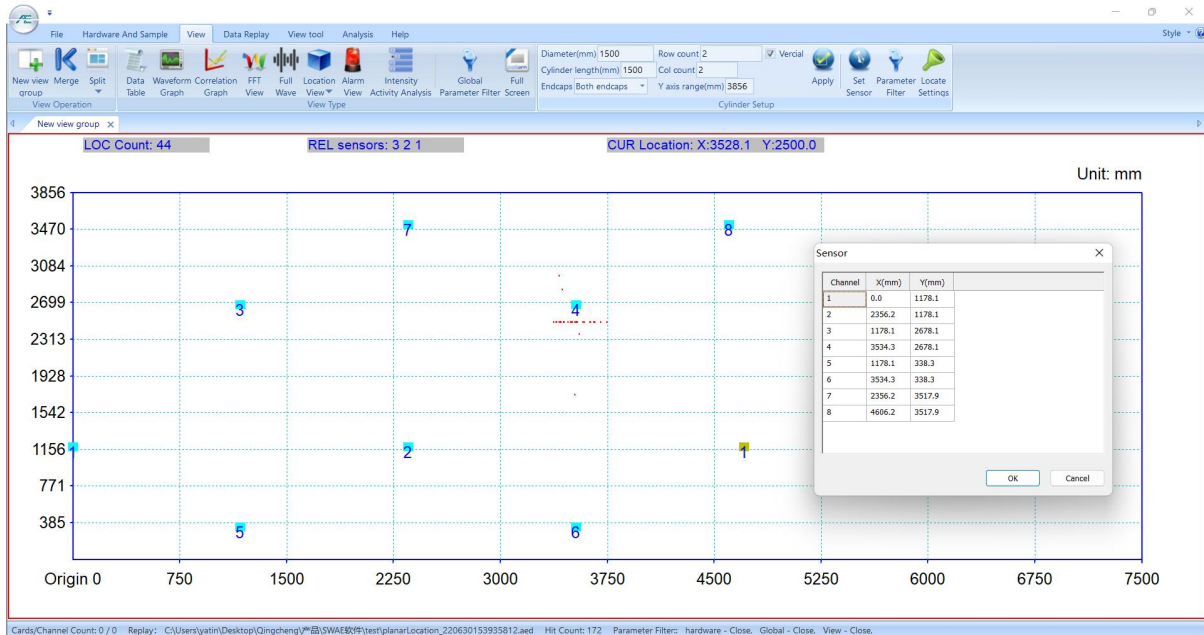
Fig. 6-71 Axis modification of Cylinder Location Graph

3) **Explanation of Interface Terms**

Diameter: it is the outer diameter of the cylinder part, unit of mm;

Cylinder length(mm): generally, refers to the length of the cylinder block without the end caps (cylinder heads);

Endcaps: the "endcaps" here refer to the cylinder headers, on the top or bottom parts of the cylinder block, including "no endcaps", "only top endcaps", "only bottom endcaps" and "both endcaps";

Row count: refers to the number of circles (rows) of sensors arranged along the cylinder height direction (excluding the sensors on the cylinder heads). The setting range is 1-50 (integer);

Col count: the number of sensors arranged in each circle (row) (excluding the sensors on the cylinder heads), the setting range is 1-50 (integer);

Y axis range: the display range in Y axis, generally set to be larger than "Cylinder length" + "2 times endcaps height";

Vertical: whether to display the cylinder view vertically, which is enabled by default.

X/Y/Z coordinates: the current X, Y and Z coordinates where the mouse cursor stays on the view, which is shown at the upper left corner of the view.

Events count: the number of valid location events generated on the current location Graph.

4) View property function

View Param: enable it to call out the red circle used to filter out the parameters within the circle area. Move the red circle to the interested area, if there are location points, the parameters of the circled location points will be filtered and displayed in the "Data Table";

Output to Excel: to export the location info, including coordinate info and parameter info to Excel format;

Calibrate with the Point of Maximum Amplitude: when there are some points selected by the red circle, select this option to open the calibration window. The point with the maximum amplitude among the selected circle will be used for calibration. The selected point location is calculated in the software and it should be same coordinates as the actual source position. If they are different, by adjusting the X or Y coordinates of the point as well as the sound velocity to make it closer to the actual source location coordinates.

Planar display: convert 3D modeling to a 2D planner display. The numbers in yellow orange color are the repeated sensor numbers which is also the first sensor in the row. So that it can round up in the 3D dimension.
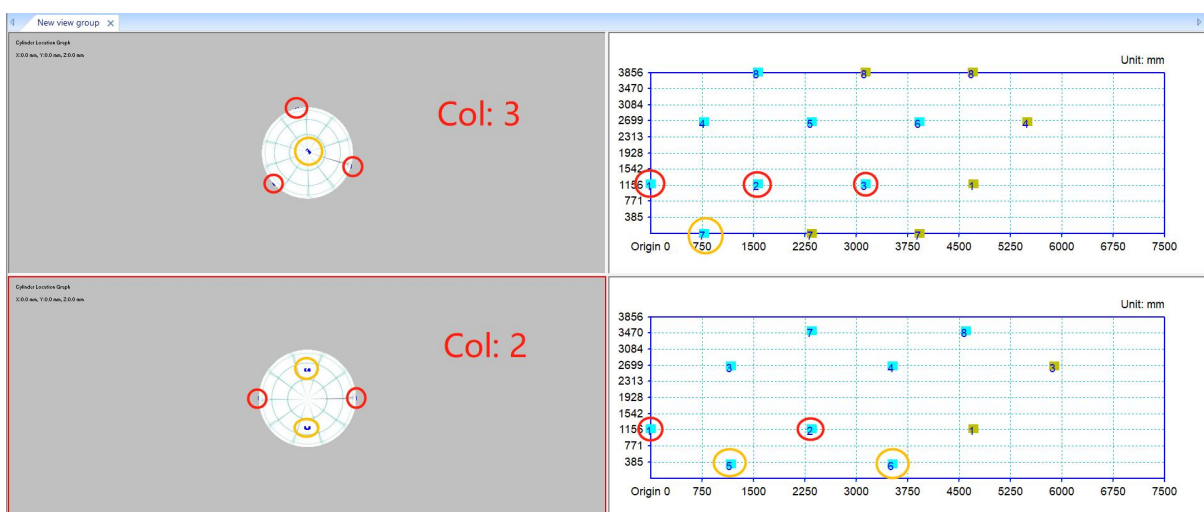
Fig. 6-72 Planer view and sensors Cylinder Location Graph

Note: If the column counts is less than 3, it will apply two additional sensors on each cylinder head (if it exits) instead of one on each head, in order to identify the source location on which half area of the cylinder head.

6.2.6.2.6.6. Solid Cylinder Graph

Slid cylinder location is generally applicable to the detection of solid cylinder structure, and is widely used in laboratory research direction, such as mechanical experiment process, rock block mechanical experiment, etc. The average material density of the measured object has a great influence on the Location results.

(1) View creation: select a blank view (with red border), click **[View]**, click **[Location View]**, then select **[Solid Cylinder Graph]** to create the default Solid Cylinder Graph;
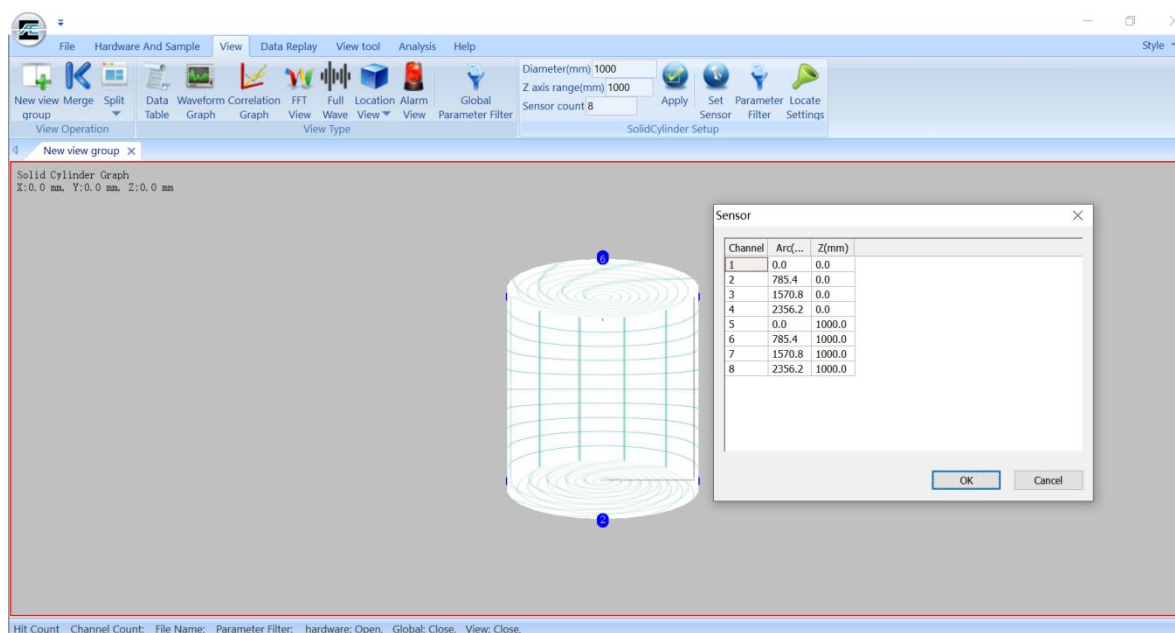
Fig. 6-73 Axis Setting interface of Solid Cylinder Graph

(2) View modification

The modification of **Solid Cylinder Graph** involves the number of sensors, coordinates and the size of the measured area. The software supports simple modification mode, that is, after entering the size of the detection area and the number of sensors, the software automatically allocates the sensors; but also the number of sensors and the relative distance can be modified manually.

Simple modification

1) Select the default location view (red border appears), and then modify the "Diameter" of the cylinder block and the "Z-axis range" as the cylinder block height;

2) Input the total number of sensors in the "Sensor Count". The number can be 4, 6, 8. If there is no corresponding number, the nearest number can be selected; then, refer to the "Manual setup" method for detail adjustment;

3) Click **[Apply]** to update the settings of simple modification. Then the sensors are arranged according to the coordinate positions given by the software.

Manual setup

a. Firstly, the horizontal arc length and vertical height from all sensors referring to Sensor #1 should be known;

b. Then, on the basis of simple modification, click the **[Set Sensor]** button;

c. The number under the "channel" column is the sensor number, which is generally consistent with the host channel number, and can also be changed to the user's desired number. Note that the modified number should not be repeated with the existing number;

d. The value under the "Arc(mm)" column is the clockwise arc length of the distance from Sensor #1, and the value below the "Z(mm)" column is the vertical distance from the coordinate origin;

e. To add or delete sensors, right-click on the "Set Sensor" window and select "Add" or "Delete". If adding sensors, enter the sensor number, arc length and Z axis values. To delete a sensor, click on the sensor number row and when the row background color turns blue, right click and select "Delete";

f. After modification, click the **[OK]** button in the current interface to update the view.

(3) Explanation of interface terms

Diameter / Z-axis range: "Diameter" and "Z-axis range" refer to the diameter and height

of the detected area, which can be input directly in the text box;

Sensor Count: the number of sensors to be used, including 4, 6 and 8;

X/Y/Z coordinates: the current X, Y and Z coordinates where the mouse cursor stays on the view, which is shown at the upper left corner of the view.

Events count: the number of valid location events generated on the current location Graph.

(4) View property function

View Param: enable it to call out the red circle used to filter out the parameters within the circle area. Move the red circle to the interested area, if there are location points, the parameters of the circled location points will be filtered and displayed in the "Data Table"; as shown in Figure 6-69;

Output to Excel: to export the location info, including coordinate info and parameter info to Excel format;

Calibrate with the Point Selected: when there is any point selected by the red circle, select this option to open the calibration window as Figure 6-65. The selected point location is calculated in the software and it should be same coordinates as the actual source position. If they are different, by adjusting the X or Y coordinates of the point as well as the sound velocity to make it closer to the actual source location coordinates.

Calibrate with the Point of Maximum Amplitude: similar to "Calibrate with the Point Selected", but the select point is with the maximum amplitude.

Color: click "Color" to modify the background color.

View Coordinate: open the window to show all the location points coordinates.

6.2.6.2.6.7. Spherical Location Graph

Spherical Location is generally applicable to the detection of spherical hollow shell structures. It is generally applicable to the detection of spherical vessel or hemispherical end caps in

industrial field.

1) **View setup**:

select a blank view (with red border), click **[View]**, then click type in view menu, and select **[Spherical Location Graph]** in the pop-up location graph type to create the default spherical location view;
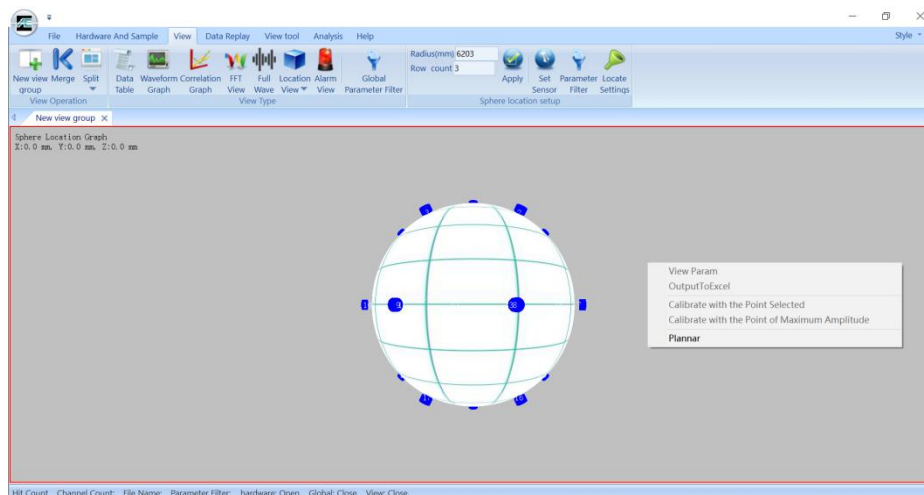
Fig. 6-74 Spherical Location Default Graph

2) View modification

After entering the sphere radius and the number of layers to be set, and then the software will assign the sensors based on standards. The sensor number and their relative positions can also be manually set according to the actual situation. It is recommended to adopt the default setup of software, and then adjust the position of individual sensors appropriately.

Setting method

a. Select the default location view (red border appears), and then modify the information of "Radius", "Volume" and "Row count" in the "View" interface. The volume and radius are related parameters, the modification of radius will affect volume, and the modification of volume will also affect the value of radius. The number of rows exclude the two sensors on the top and bottom of the sphere;

b. Click **[Apply]** to update the settings. Then the sensors are arranged according to the coordinate positions given by the software.

c. When some sensors are not arranged as they should be in the actual sphere structure, it can be modified manually by adjusting the coordinates. The reference origin of coordinates is the top center of the spherical. Click **[Set Sensor]** to add or delete and modify the sensor information.

d. After modification, click the **[OK]** button in the current interface to update the settings.
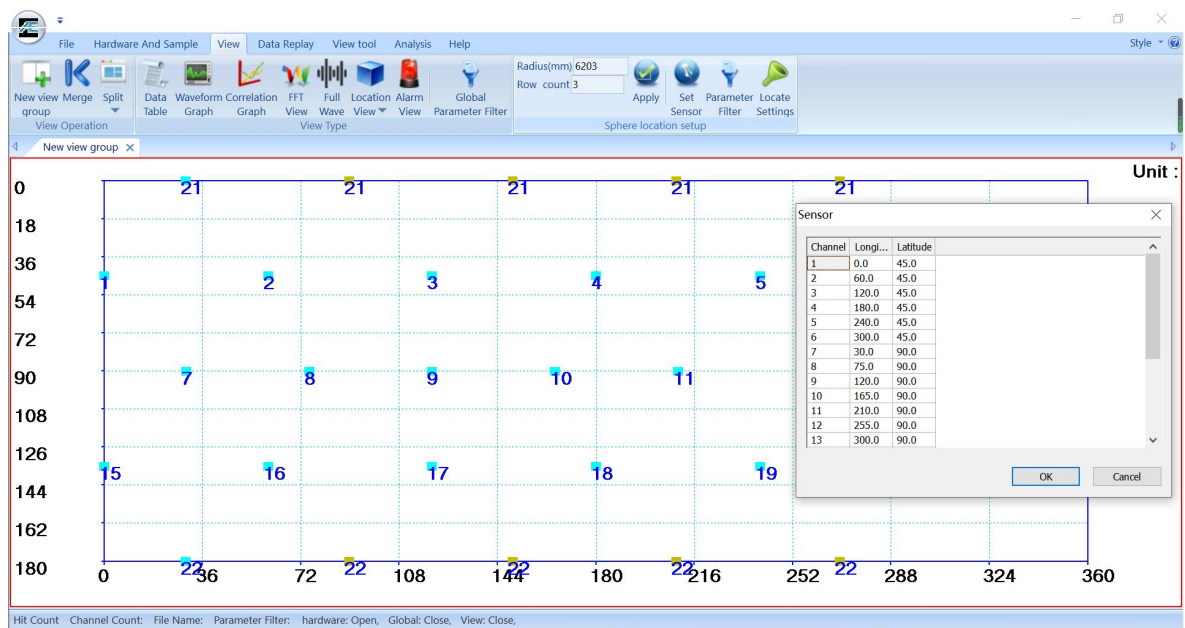
Fig. 6-75 Axis modification of Spherical Location Graph

3) Explanation of interface terms

Radius: the calculation formula of the radius of sphere: R = $\sqrt[3]{\dfrac{3V}{4\pi}}$, where V is the nominal volume, and π = 3.14; "R" is the radius in unit of millimeters;

Volume: The formula for calculating the volume of a sphere is V= (4/3) πR^3, where π is 3.14 and R is the radius of the sphere; The unit of V is m^3;

Row count: it refers to the layer number of the sensors on the spherical surface, excluding the sensors on the top or bottom center of the sphere; the reference row number can be: $\text{row\#} = \pi \times \text{radius(mm)} \div 5000\text{mm}$, by rounding up the result as integer.

X/Y/Z coordinates: the current X, Y and Z coordinates where the mouse cursor stays on the view, which is shown at the upper left corner of the view.

Events count: the number of valid location events generated on the current location Graph.

4) View property function

View Param: enable it to call out the red circle used to filter out the parameters within the circle area. Move the red circle to the interested area, if there are location points, the parameters of the circled location points will be filtered and displayed in the "Data Table"; as shown in Figure 6-69;

Output to Excel: to export the location info, including coordinate info and parameter info to Excel format;

Calibrate with the Point Selected: when there is any point selected by the red circle, select this option to open the calibration window as Figure 6-65. The selected point location is calculated in the software and it should be same coordinates as the actual source position. If they are different, by adjusting the X or Y coordinates of the point as well as the sound velocity to make it closer to the actual source location coordinates.

Calibrate with the Point of Maximum Amplitude: similar to "Calibrate with the Point Selected", but the select point is with the maximum amplitude.

Planar display: convert 3D modeling to a 2D planner display. The numbers in yellow orange color are the repeated sensor numbers which is also the first sensor in the row. So that it can round up in the 3D dimension.

Color: click "Color" to modify the background color.

View Coordinate: open the window to show all the location points coordinates.

6.2.6.2.6.8. Parametric Filter

After selecting any location view, click **[Parameter filter]** to pop up "HIT-Data Filter Setup" interface. The filter is a view specific filter, which is only effective for the current view. Refer to Chapter "6.2.5.3.2 Hardware Parameter Filter" for setting method. After the function is enabled, the parameter data conforming to the setting rules will participate in the TDOA location calculation of the location graph, and the stored data files will not be changed.

6.2.6.2.6.9. Locate Settings

6.2.6.2.6.9.1. Event Setting

After selecting any location view, click **[Locate Settings]** to open the "Event Setting" window.

All parameter settings in this window are valid only for the current location graph.
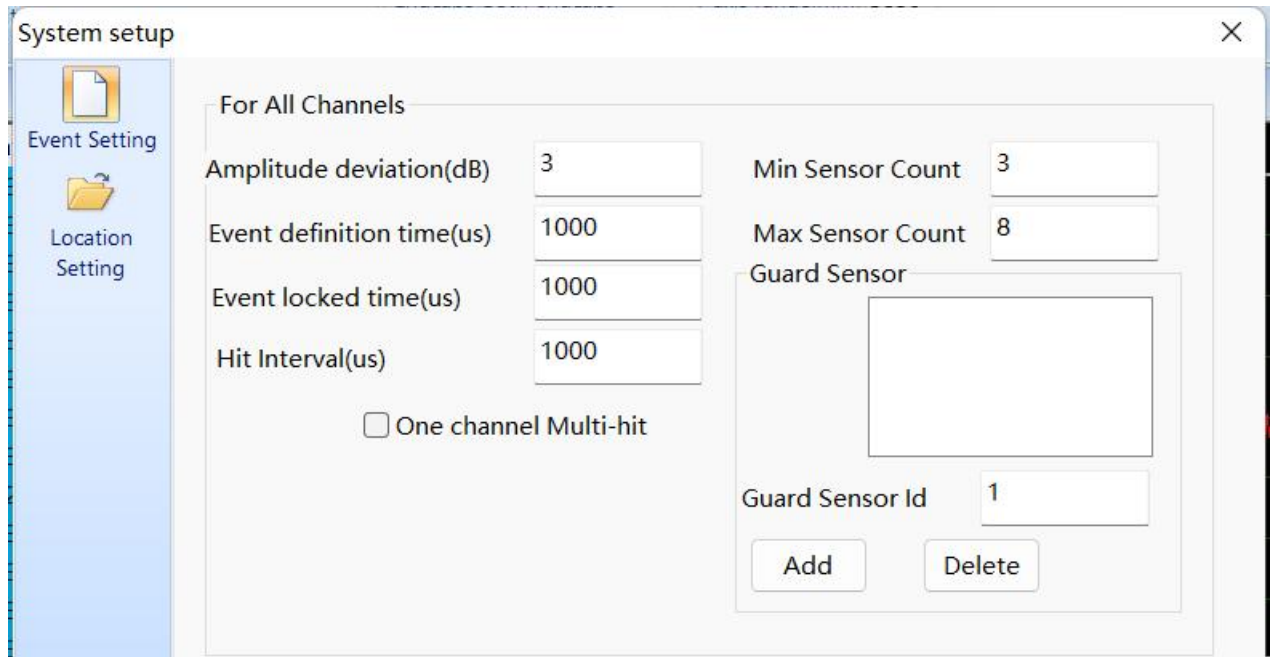
Fig. 6-76 Event Generation Settings

For the convenience of understanding, we give an example of rectangular sensor array to illustrate: *S1-S4* are sensors, [*a, b, d*] are distance values, the proposed sound speed is *C*, and four sensors are used to participate in the positioning calculation.
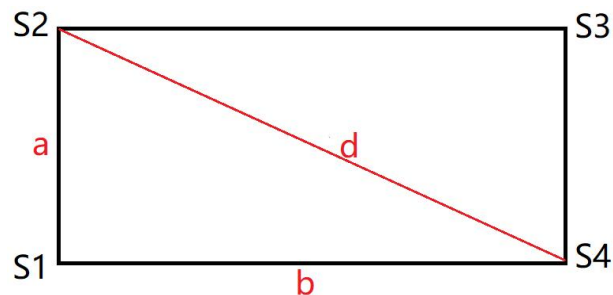
Fig. 6-77 Schematic diagram of sensor arrangement array

● **Amplitude deviation:** Set the amplitude deviation to eliminate the pseudo events. For example, if the first hit is smaller than the second hit and the difference exceeds the deviation, the event group is invalid and the first hit should be selected again. If the hit

amplitude in the event group is smaller than its subsequent hits and the difference exceeds the deviation, that hit should be eliminated. **The amplitude deviation should be a reasonable value, which depends on the difference between the maximum sensor sensitivity and the minimum sensitivity among all sensors (i.e. S1-S4 in the array) during the sensor sensitivity test**. The amplitude deviation should be slightly larger than the difference. If the maximum sensitivity difference of all sensors in the array is 4dB, the amplitude deviation setting should be slightly greater than 4dB, maybe 6dB. But it should not be too large, otherwise there will be too many pseudo-events;

- **Event definition time:** the time is counted from the first hit. When the set time is reached, even if there is no hits received from all the relevant channels, the event will be forced to end. It can be considered as the time within which all signals received by the location sensor group are considered from the same acoustic emission source. Therefore, when setting this value, the critical case of the positioning sensor group is considered, such as polygonal shape sensor array arrangement. Select the maximum distance between two sensors, which is the boundary generated by the location event. Divide the maximum distance by the sound speed, which will obtain the maximum definition time of a location event. It can also include some the error range, such as 20%. In summary, the event definition time can be

$$[(\text{Maximum sensor spacing} / \text{measured sound velocity}) \times 1.2]$$

In the example rectangular array, the value is $[(d/C) \times 1.2]$;

- **Event locked time**: starting from the last hit of the previous event. Any hit received within this set duration will not be regarded as the first hit of the next event group. If the 3-probe plane location algorithm is used, the event locked time can be set to 0. If the multi-probes plane Location algorithm is used, the locked time can be set to be the same as the hit definition time (HDT).

- **Hit Interval**: the timing starts from the first hit. Before the end of this set duration, the event group will continue to execute if there is any hit data received from other channels

in the array. If no other channel hit is received, the event group will be forced to cut off and re-select the first hit. Select the maximum distance between two adjacent sensors in the same array, and divide it by the sound speed, which is the maximum defined value of a location event. When the error range is set appropriately, such as 20%. The event hit interval can be

$$[(\text{Maximum adjacent sensor spacing} / \text{measured sound velocity}) \times 1.2]$$

In the rectangular array, the value to be input is $[(b/C) \times 1.2]$.

- **Min / Max sensors counts:** the Min / Max sensors counts refers to the number of hits used for location calculations. If the number of hits received are below the minimum counts, the event is invalid, while if the hit number is greater than the maximum number, the exceeded hits upon reception are abandoned and the event will be forced to end but still valid. The larger the maximum sensors counts, the more hits are used for TDOA (Time difference of Arrival) location calculations. In the process of multiple regression calculation, more source locations will be involved in verification and averaging, which can theoretically increase the accuracy of positioning. However, for different sensor arrangements and different sensor spacing, it should also set a more reasonable number of calculated sensors (hits) counts. For the general surface location, according to the material attenuation curve and sensor layout spacing, as well as the noise threshold on site, the number of sensors (hits) should be set smaller if the signal attenuates lower than the threshold after the maximum distance in such number of sensors locating array. For example, in the 6-sensor position array, if the maximum sensor spacing is 6 meters, the signal attenuation of such distance is 58 dB and the threshold is set to 45 dB, the standard pencil lead breaking signal cannot be detected. So that the position of the location source cannot be calculated or other random noise is mixed in during this period, which will lead to inaccurate location calculation results. Therefore, for this case, the minimum sensor counts cannot be set to 6. In general, the linear location view, the minimum and maximum sensor counts involving in the source location calculation are both 2. For other types of location views, the default minimum sensors counts are 3,

because the triangle positioning array is normally used for general surface source location. The maximum sensor counts are 8 by default. For example, when 10 sensor parameters in the array meet the positioning conditions, the first 8 calculations are directly selected.

- **Guard sensor:** it is used to eliminate the false location calculation caused by remote noises. When the channel is defined as the guard sensor and it receives the first hit, the event group will not take effect and the location point will not be calculated within the event definition time. Enter the channel number in the "Guard Sensor ID" and click **[Add]**; or select the channel number in the "Guard Sensor" window and click **[Delete]** to delete from the channel list.

6.2.6.2.6.9.2. Location Setting

After selecting any location view, click **[Locate Settings]** to open the "System Setup" interface. Click the **[Location Setting]** button on the left to display the interface shown in Figure 6-78. This interface involves the sound velocity setting and arrival time selection.
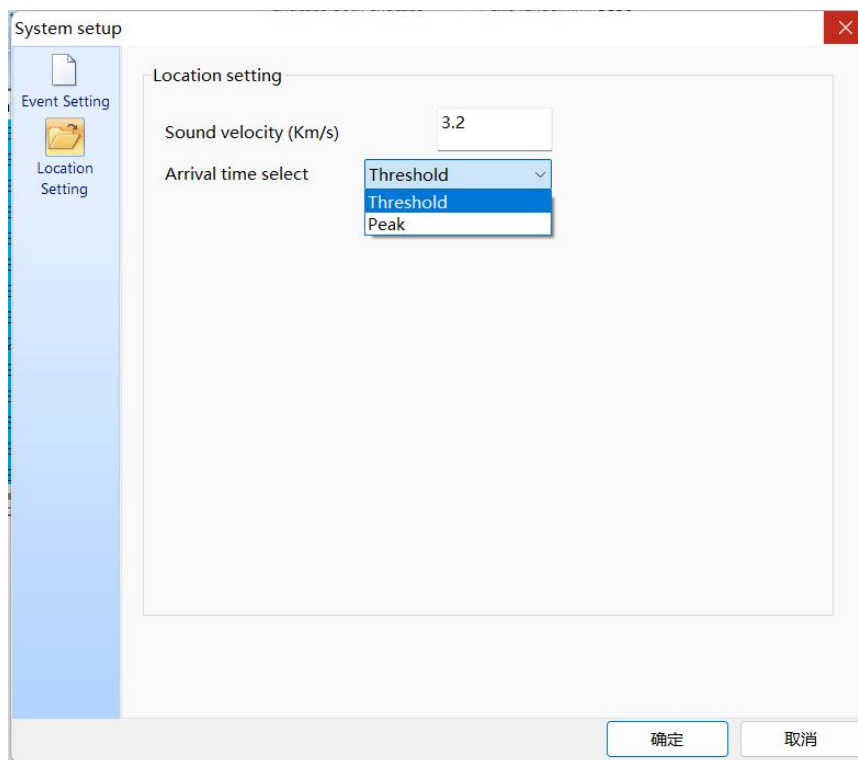

Fig. 6-78 Location settings

Sound velocity is generally obtained in measurements, and a reasonable sound velocity is very important for the location accuracy. The default sound velocity is the common metal surface wave sound velocity, which is suitable for plane plate layout with a sensor spacing of 1-5 meters.

Arrival time selection: the default is "Threshold", that is, when calculating the positioning point, the time difference is calculated based on the time when the signal passes the threshold; "Peak", that is, the time difference is calculated based on the time when the peak amplitude is located.

There are two ways to measure the sound velocity, one of which is a direct measurement and calculation, while the other is through curve fitting.

1) Direct measurement of sound velocity

Use two channels and make the two sensors be installed in the direction where the sound velocity is to be tested (the sound speed may be anisotropic). Measure the distance L in advance, and set the sample settings. Break the pencil lead on the extension line of the two sensors. Check the arrival time difference (Δt) received by the two sensors, and calculate ($L/\Delta t$). Repeat the pencil breaking for a few times and average the multiple ($L/\Delta t$) to obtain the sound velocity. For example, Channel #2 and #4 (Figure 6-77) are used to measure the sound velocity test. If the pencil lead is broken at the extension line of [d] near S2, S2 receives a signal with a larger amplitude first, and S4 receives a smaller signal later than S2 (S1 and S3 are ignored in this test). The two arrival times is subtracted to get (Δt). The sound velocity should be $C = d/\Delta t$, in unit of km/s. Note: the arrival time format is [DD:HH:MM:SS:mmm uuunnn]. The arrival time of No. 2 can be interpreted as: on the 15th (of the month) 09:11:29 and 619ms, 110µs and 900ns.

No	Arrival time(d...	AE channel	Amplitude(dB)	Counts	Duration(us)	Energy(KpJ)	Rise co
1	15:09:11:29:108 620200	2	40.3	1	0	0.001	1	0.0
2	15:09:11:29:619 110900	2	93.6	780	11438	2410.952	6	19.0
3	15:09:11:29:619 888400	4	60.0	214	3061	3.898	22	365.0
4	15:09:11:29:620 966800	3	43.3	91	3527	1.010	2	73.0

Fig. 6-79 Arrival time

2) Sound velocity measurement by curve fitting

Calibrated with the Point Selected: except for the linear location graph, the sound velocity is calculated according to the location position of the selected measured point and the actual acoustic emission source location;

Calibrate with the Point of Maximum Amplitude: except for the linear location graph, the software performs the hyperbolic fitting calibration of the sound velocity according to the position of the measured selected point with the maximum amplitude and the actual acoustic emission source location.

The two calibration methods are different only in the way of selecting measured points, and the calibration methods are the same, take "**Calibrated with the point selected**" for example**:**

a. Firstly, move the mouse cursor to the measured location points to be selected, and then right-click menu and select "**Calibrated with the point selected**";

b. Adjust the X-axis and Y-axis coordinates of the "Target Point". In the "Locating Hyperbolic Graph", the purple point is the target point, and the target point refers to the real AE source, such as the location of pencil lead breaks;

c. Adjust the sound velocity through the sound speed velocity button. When all hyperbolas intersect at one point and coincide with the target point, or make the target point be the center of all intersection points of hyperbola, the calibration is completed. The red point in the "Location Graph" on the right is the calculated location point;

d. Click the **[Save]** button, and then input this calibrated sound velocity to the "Sound Velocity" column in Figure 6-78 interface.
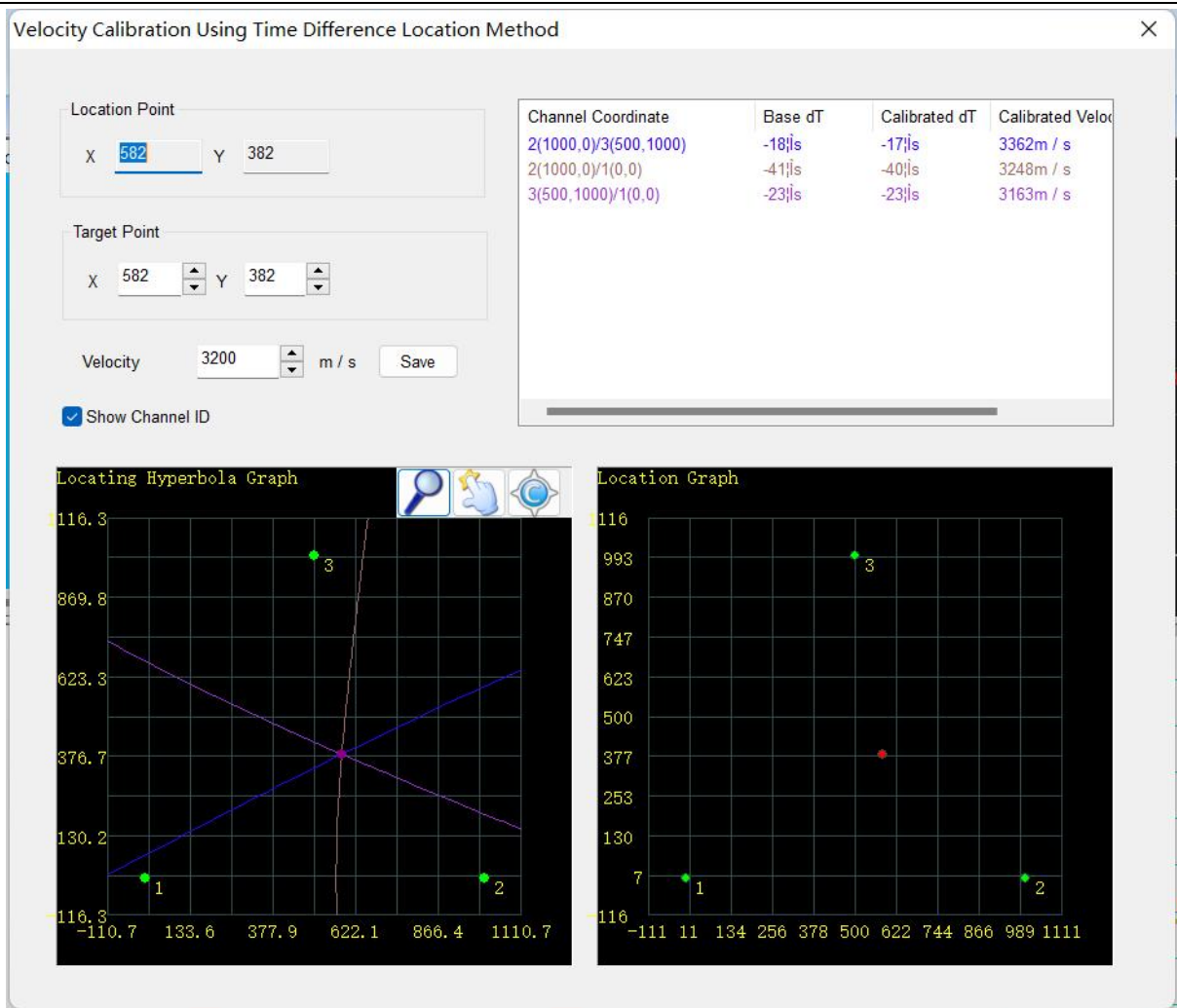
Fig. 6-80 Calculation of sound velocity interface by sound velocity fitting

6.2.6.2.7.   Alarm View

The **alarm view** is the output alarm display diagram based on the alarm settings set by users, as shown in Figure 6-81. The number of alarms shown in the diagram means the corresponding triggered hits (row numbers of the parameters) in the corresponding channels.

Note: The alarm view is valid only during data acquisition, not during the data replay analysis.

Alarm information

Channel ID   Number of alarms
4   4
1   2

Fig. 6-81 Alarm display view

Select a blank view (red border appears) and click **[Alarm view]** in the "View" menu to complete the establishment of the alarm view.

After the alarm view is selected, click **[Alarm Settings]** on the right side of the view menu to set alarm rules in the pop-up "Hit Data Alarm Setup" interface, as shown in the following figure.

Fig. 6-82 Setting alarm parameters

Select Hit Data: You can set "Arrival Time", "AE Channel", "Amplitude", "Counts", "Duration", "Energy", "Rise Counts", "Rise Time", "RMS", and "ASL" (select from the drop-down list) as

the alarm trigger rules and modify the minimum and maximum values. The data within the set range of those parameters is retained. When multiple rules are configured, the relationship between rules is **"and"**. That is, only the data that meets all rules can be recorded and displayed.
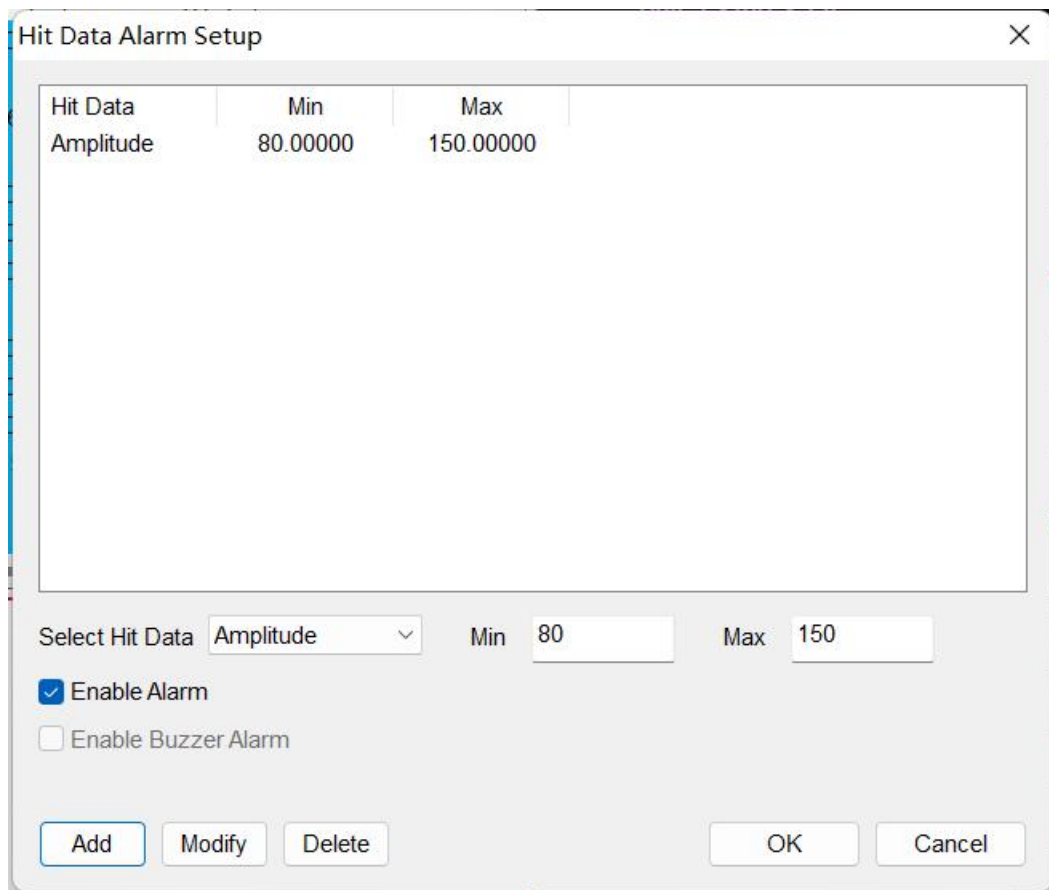
Add: To add a new rule, select the corresponding AE featured parameters from the drop-down menu, enter the minimum and maximum values in the text box, and click **[Add]** to add the rule to the list.

Modify: To modify an existing rule, click the corresponding rule in the selected list (the line turns blue after the rule is selected), enter the minimum and maximum values again in the text box, and click **[Modify]** to update the new value range.

Delete: To delete a rule, click the corresponding rule in the selected list (the row turns blue after the rule is selected) and then click the **[Delete]** button to remove it.

Enable Alarm: Check this to indicate that all rules in the list are in effect during data collection, otherwise they will not take effect.

6.2.6.2.8. Intensity Activity Analysis

Intensity activity analysis refers to that the user sets some rating rules according to the requirements, and the software carries out the intensity rating, activity rating and comprehensive rating analysis based on the collected parameter data.

The intensity rating is determined by the values of the selected parameters, and the activity rating is determined by the number of times when an intensity rating level triggers. If any of the collected parameters exceeds a specified level of intensity or activity, it is assessed as such level of intensity or activity.

The comprehensive rating is the highest level of intensity and activity combined over a period of time, giving the highest level of the composite rating. The comprehensive level meets the NBT47013.9-2015 standard.

Table 6-13 Comprehensive Level complying to NBT47013.9-2015 standard

Comprehensive level		Activity level			
		4	3	2	1
Statistical intensity level	3	4	4	3	2
	2	4	3	2	1
	1	3	3	2	1

Important note: the intensity levels of the comprehensive rating should not exceed 3 and the activity levels should not exceed 4. Otherwise, a comprehensive rating cannot be given.

6.2.6.2.8.1. Established intensity activity analysis view

Select a blank view (red border appears) and click **[Intensity Activity Analysis]** in the "View" menu to complete the addition of the intensity activity analysis view (the initial analysis mode is "Intensity alarm").
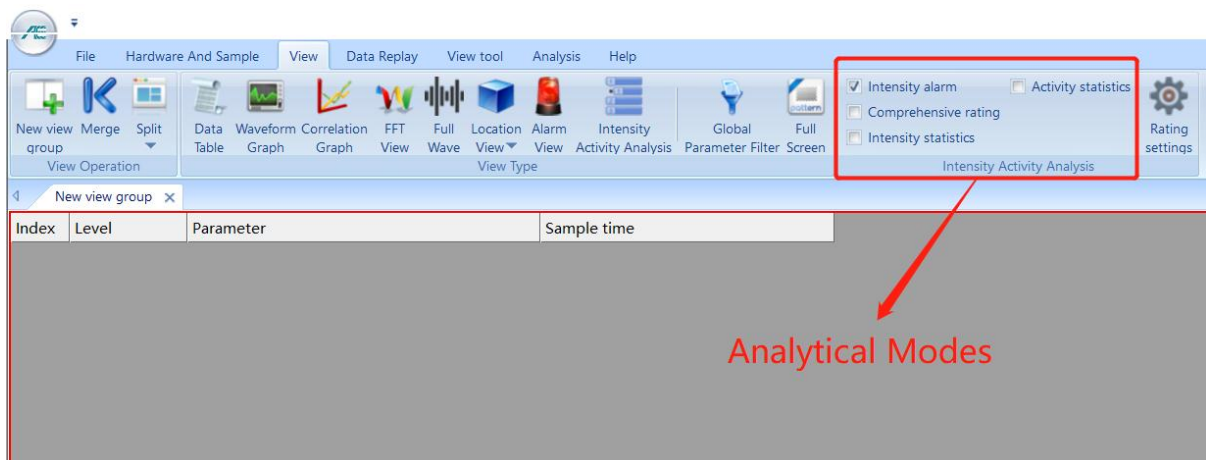

Fig. 6-83 Default view of intensity activity analysis

6.2.6.2.8.2. Analytical Modes

Select a analytical mode to display in the current window including: "Intensity alarm", "Intensity statistics", "Activity statistics", "Comprehensive rating" respectively. Check to take effect.

1) **Intensity alarm:** Show the list of parameters triggering the intensity levels with their

corresponding triggered levels and sample time in the table;

2) Intensity statistics:

● Time-level chart: Display the highest intensity level of each statistical period and draw a statistical chart;

● Level-quantity chart: Display the number of occurrence for each intensity level over the time and draw a statistical chart;

3) Activity statistics:

● Time-quantity chart: display the number of occurrence of all intensity levels in each statistical period and draw a statistical chart;

● Time-level chart: displays the activity level of each statistical period and draws a statistical chart;

4) Comprehensive rating: it lists the highest intensity level and activity level, and the result comprehensive rating of each statistical period, with the detail intensity data, activity data, statistical length and the sample time.
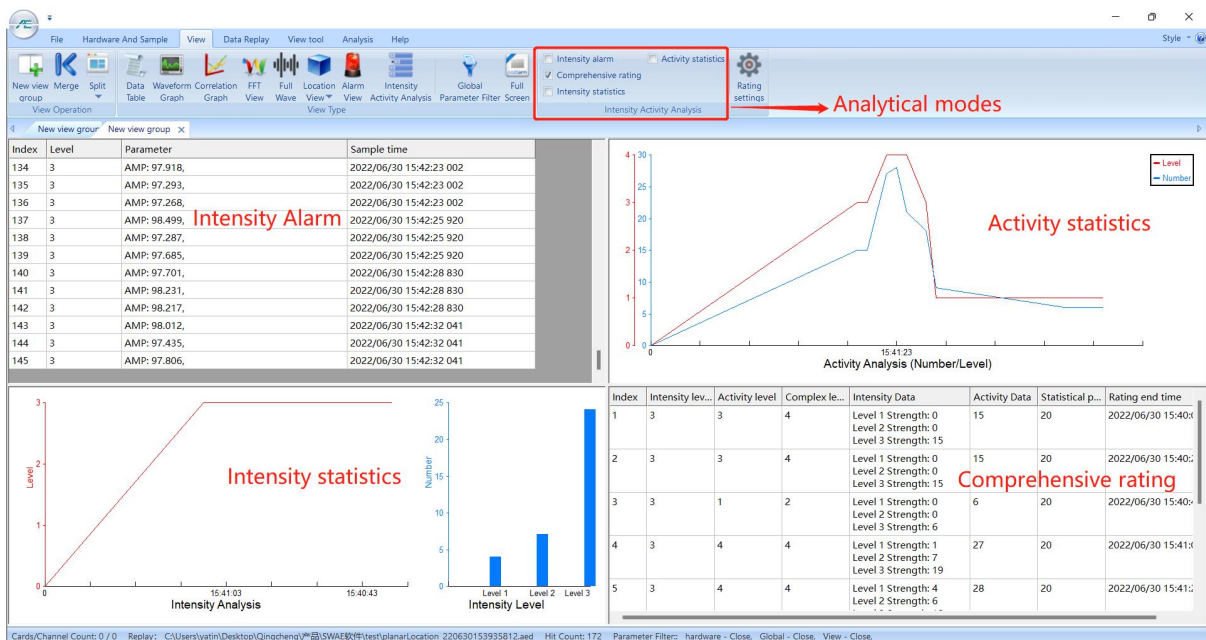

Fig. 6-84 Intensity activity analysis 4 analytical modes

6.2.6.2.8.3. Rating setting

Select the intensity activity analysis view and click the **[Rating settings]** on the right of the "View" menu to enter the intensity/activity setting interface.

Note: All the four analytical modes use the same **[Rating Settings]** as shown below, rather than each view setting being independent.
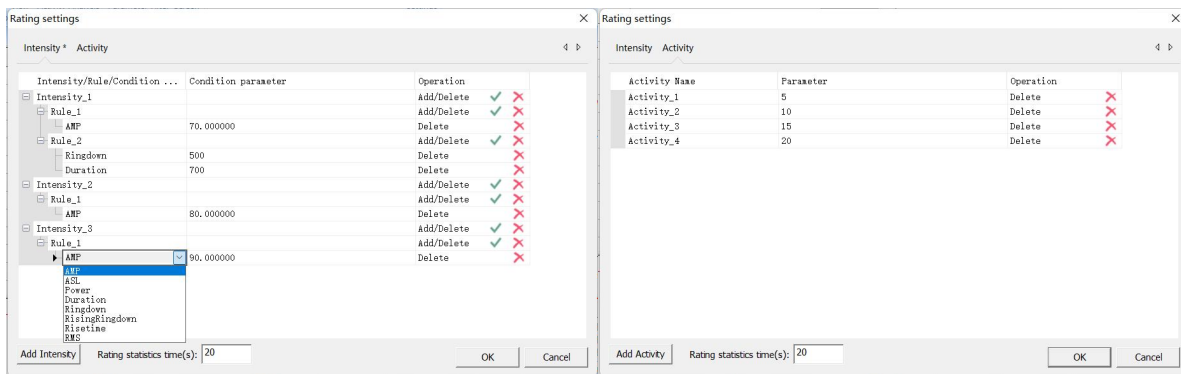
Fig. 6-85 Setting screen for intensity activity analysis

● **Rating statistics time(s):** Enter the statistical time (seconds) as the length of each statistical period in the intensity statistics mode, activity statistics mode, and comprehensive rating mode. It is 20 by default.

● **Intensity setting:**

Click the lower left corner **[Add Intensity]** to add the intensity conditions or rules; Click **[√]** to the right of "Add/Delete" to add "Rule" to the "Intensity_1" level; then click **[√]** again on the right of "Add/Delete" to add a parameter to "Rule_1".

Click on the name of the parameter to modify the parameter type. Click on the value of the parameter to modify the value.

Click **[×]** to the right of the intensity_1/rule_1/parameter name to delete the corresponding intensity/rule/parameter.

Note: There are up to a maximum of 3 "Intensity" levels and 8 "parameters" to be added.

● **Activity setting:**

Click the [Activity] at the upper left corner and then click on the lower left corner **[Add Activity]**

to add the activity rules; click on the value under the "Parameter" column to modify the activity value; click **[×]** to the right of "Activity_x" to delete the "activity".

Note: There are up to a maximum of 4 "activity" levels to be added, and the activity values must be greater than 0 and increasing level by level.

◆ **Intensity rating criteria:**

If the value of the parameter is in between Intensity_1 and Intensity_2, its intensity level is level 1; if in between Intensity_2 and Intensity_3, its intensity level is level 2; and if it is above Intensity_3, it is level 3 (up to 3 intensity levels are set).

As shown in Figure 6-85, if there are multiple rules under the same intensity, it only takes one rule to reach this intensity level. If there are multiple parameters under one rule, it needs to have all parameter conditions at the same time to meet the rule.

◆ **Activity rating criteria:**

Count the number of occurrence of the intensity level triggers for each statistical period. If the number is in between Activity_1 and Activity_2, its activity level is level 1; if in between Activity_2 and Activity_3, it is level 2; if in between Activity_3 and Activity_4, it is level 3; and if it is above Activity_4, it is level 4 (maximum 4 activity levels are set).

◆ **Comprehensive rating criterion:**

The highest level of comprehensive rating is given by synthesizing the highest level of intensity and activity in each statistical period. The comprehensive level meets the NBT47013.9-2015 standard.

Table 6-14 Comprehensive Level complying to NBT47013.9-2015 standard

Comprehensive level		Activity level			
		4	3	2	1
Statistical intensity level	3	4	4	3	2
	2	4	3	2	1
	1	3	3	2	1

6.2.6.2.9.　Global Parameter Filter

The global parameter filter is effective for all views at the same time, which only affects the data display and does not affect the data storage. By setting the upper and lower limits of different AE parameters, the parameters that do not meet the range will not be displayed in the replay process, and the filtered parameters will be drawn in the correlation Graph, location graph calculation and other processes. Refer to Chapter "6.2.5.3.2 Hardware Parameter Filter" for similar setting methods.

As shown in the figure below, the common filter settings for the metal pressure vessel inspection include increasing the amplitude threshold, filtering the parameters of small counts, and filtering the parameters with excessive rise time. The values in the figure do not have any reference value, just only for examples. These filter settings can refer to the relevant research literature of acoustic emission signal of metal materials, and the parameter filters should be based on the field noises in each working condition to determine carefully.
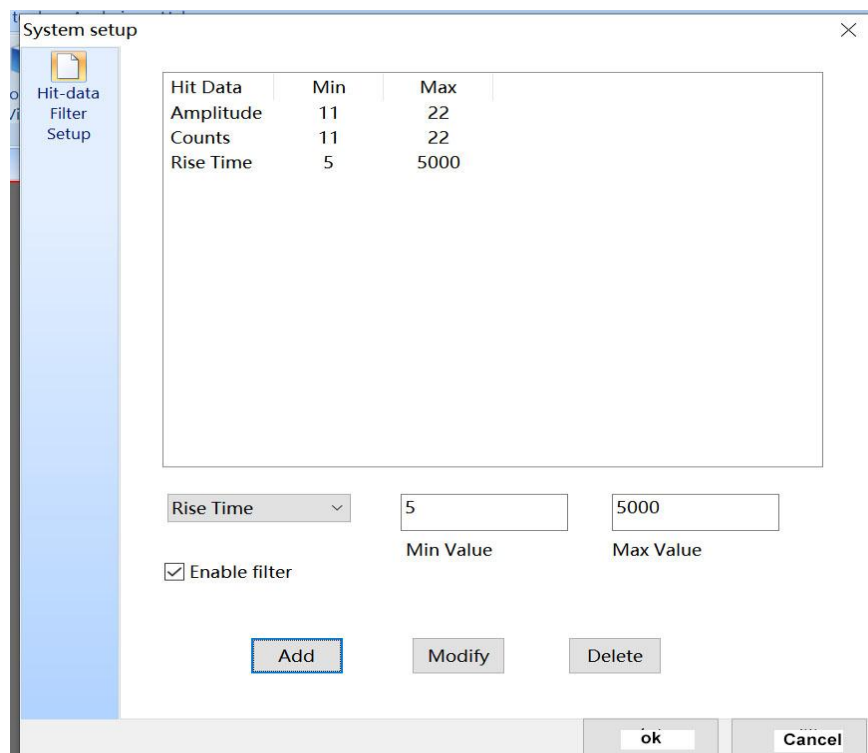
Fig. 6-86 Global Parameter Filter Setting up

6.2.6.2.10. Full Screen

Click **[Full Screen]** button to display the view in full screen for a larger view area. Click **[Exit Full screen]** to exit the full screen mode.
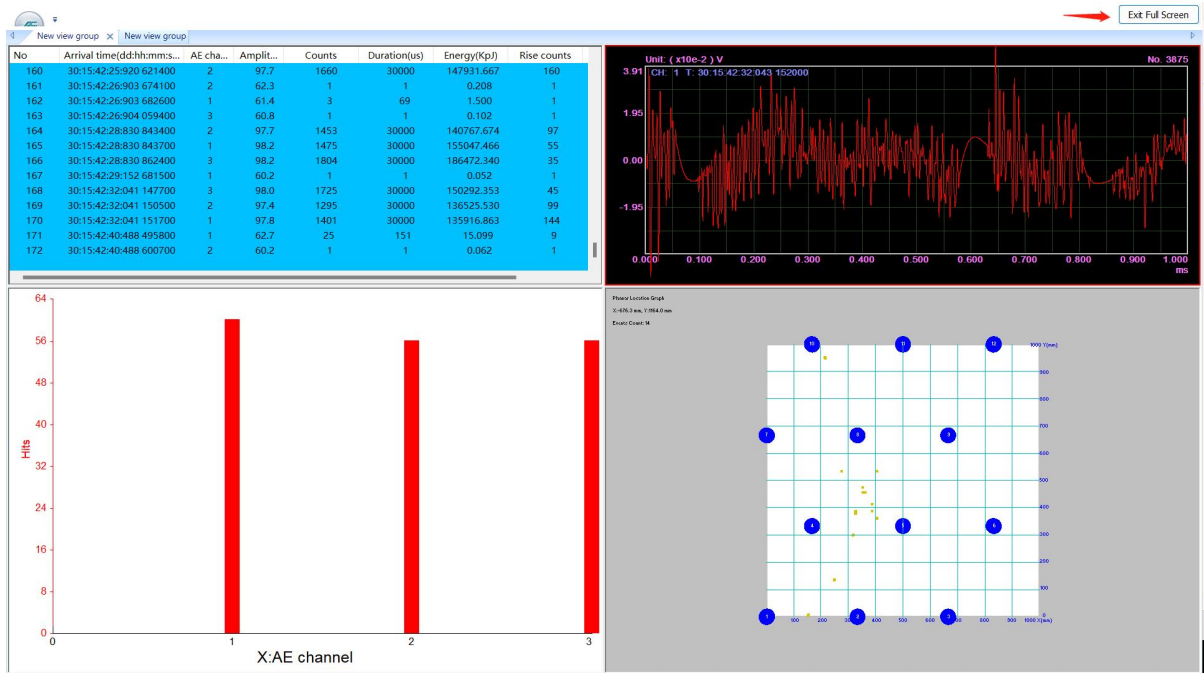
Fig. 6-87 Displays the full-screen screen

6.2.7. Data Replay Menu

After the completion of data acquisition, the main work is data analysis. Generally, the stored data are replayed. In the process of replay, data processing means are selected, and the authenticity and choice of data results are processed in order to get the correct result.

Fig. 6-88 Data Replay function

- **Replay settings:** including the selection of replay data files and the replay mode;

- **Global parameter filter**: equivalent to global parameter filter in Chapter 6.2.6.2.9;

- **Replay:** start the continuous replay of data;

- **Pause:** pause during the data replay. Click it again to resume the data replay;
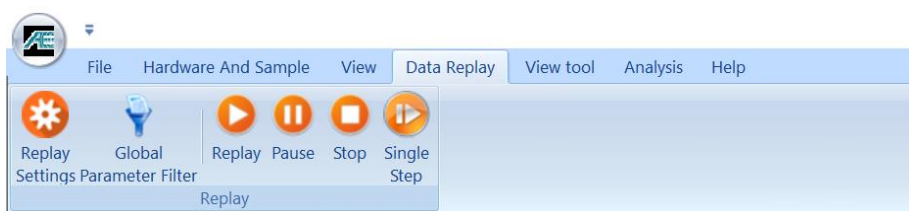
- **Stop:** force to termination during data replay;

- **Single step:** for the replay of waveform data, it is to replay the waveform frame by frame. Click once to replay one frame at a time; for the replay of parameter data, it is to replay in a batch by batch which batch value is set as the "Replay Speed" in the "Replay Settings". Click once to replay one batch at a time.

6.2.7.1.   Replay Settings

Click **[Replay Settings]** in "Data Replay", and select the data file to be played back in the pop-up file selection window. The data file has been described in the previous article, mainly including the waveform file with suffix of (.aed) or the parameter file with suffix of (.pra). For most detection cases, data processing results and analysis are based on acoustic emission characteristic parameters, so it is necessary to improve the performance of the system data replay speed and efficiency by selecting the parameter file for replaying.

6.2.7.1.1.   Data Replay

- When playing a continuous data file which is automatically split into multiple files by the system, the automatic recognition sequence can be selected to play continuously;

- By default, "Replay Parameter" and "Replay Waveform" are selected, and the data replay type can be selected according to the needs. When the "Parameter" and "Waveform" are checked at the same time, the parameter files and waveform files will be replayed back at the same time;

- If "Waveform to Parameter" is selected, a new parameter file will be generated automatically when the waveform is replayed;

● The replay speed (FPS) can be set, with a maximum of 100000;

Press the [Space] to replay the data step by step, and press the [Enter] key to continuously replay the waveform and parameters to the end. After the data replay, it will automatically stop. If you need to pause or stop during the replay process, click the [Pause] or [Stop] button in the replay control bar.
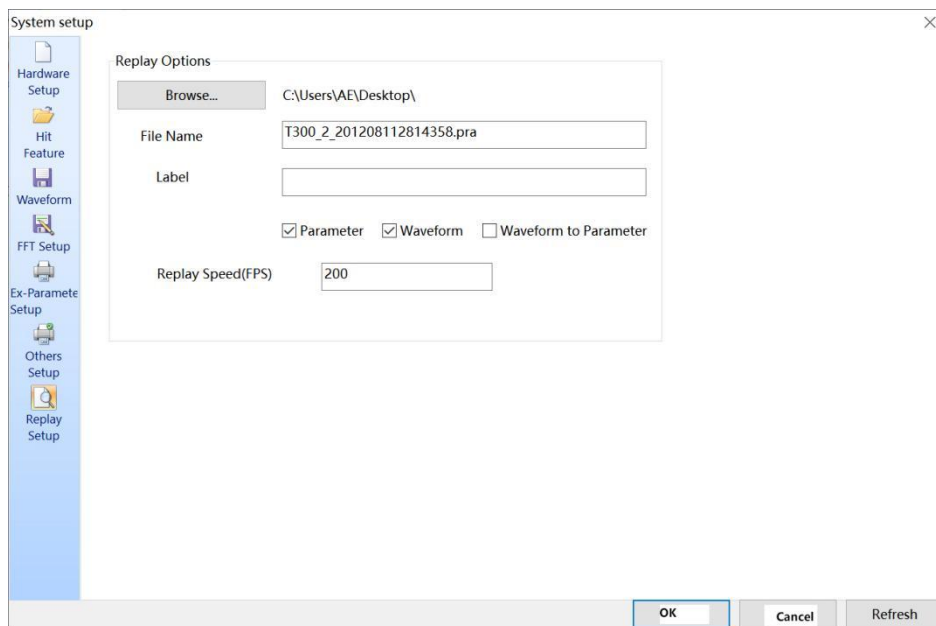
Fig. 6-89 Data Replay Settings

6.2.7.1.2. Waveform to Parameter

Waveform generation parameters are mainly aimed at the function of "Continuous Waveform Sample", and it is also meaningful for the stored single waveform with large sampling length. When using this function, users can extract new (.pra) parameter files by setting new "Threshold", "HDT", "HLT" and "Peak Definition Time". When selecting data files to be played back, only waveform files with suffix of (.aed) can be selected.

Steps/Methods:

1) Click **[Data Replay] > [Replay Settings]**, and select the waveform data file to be replayed in the pop-up file selection window. Then click **[Open]**, and the setting window is displayed. Then check the "Waveform to Parameter" next to the checkbox of "Parameter" and "Waveform";

2) Then in the same window, select **[Hit Feature]** tap on the left side of the window, and set "Threshold", "HDT", "HLT" and "PDT" in the interface. Finally click "OK" to close the window. Please note that the "parameter threshold" set should be higher than the "waveform threshold" value used in waveform data acquisition;

3) Click the **[Replay]** button to pop up a prompt box. In order to prevent the parameter data from being rewriting, the suffix (.bak) is added after the original parameter file name, which will become (.pra.bak). Click "OK" again. **Note:** To replay the original parameter file, the suffix (.bak) needs to be removed.
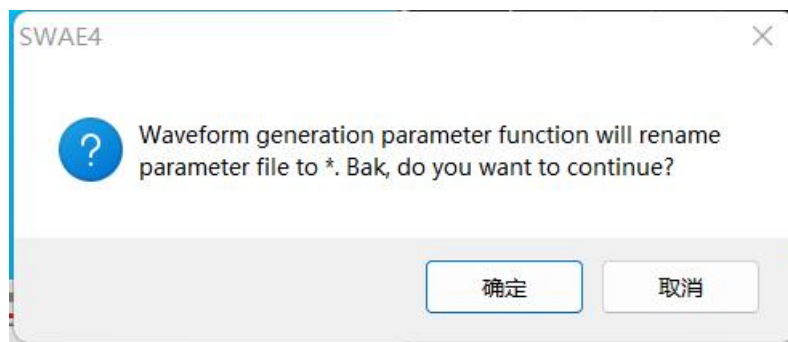
Fig. 6-90 Prompt box of secondary generation parameters

6.2.8. View Tools menu

Click **[View tool]** in the main menu to switch to the "View tools" page, which is divided into "Common" and special view tools such as "Data table", and "Waveform Graph".

Fig. 6-91 View tool Interface

View tools refer to some view operation tools that are commonly used and can be put into the shortcut toolbar as shortcut keys. They do not necessarily include all the tools that may be used. Some tools are put into the right-click options of view according to usage habits. The right-click menu may not be used as a tool in the view, and it may be used as a tool in the

view.

6.2.8.1. Common functions

The common view tools include "View Reset" and "Save Picture". The above two functions can be used in data acquisition phase and data replay phase.
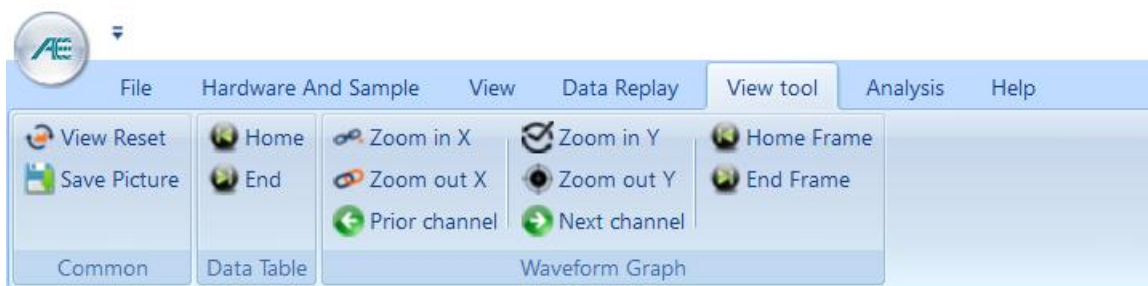
View Reset: restore the original state of the view after zooming in, zooming out, dragging and rotating. Click the **[View Reset]** button to restore the selected view to the default initial state without changing the data content already displayed on the view;

Save Picture: the selected view will be copied to the clipboard in the form of pictures, so as to paste it into the edited document.

6.2.8.2. Function of parameter table

There are two tool buttons for special view tools for the "Data Table" view, **[Home]** and **[End]** buttons respectively. It is mainly used for the data table pointing to the beginning and end parts. For data in the middle stage of the table, you can use the function of "**Locate to**" a parameter on the right-click menu of the "Data table".

6.2.8.3. Function of Waveform

The waveform graph tool is only used to process the time domain waveform "Waveform Graph" in time domain. When the waveform view is selected, the following functions can be used by clicking the corresponding button:

- **Zoom in Y**: zoom in the Y axis by twice and display the vertical coordinates of waveform in the window, which is equivalent to the keyboard key "↑";

- **Zoom out Y**: zoom out in the Y axis by 0.5 time, which is equivalent to the keyboard key "↓";

● **Zoom In X**: stretch the abscissa of the waveform in the window to both ends with the center as the reference point, and then the waveform information at both ends will not be displayed in the window;

● **Zoom out X**: compress the abscissa of the waveform in the window to the center with the center as the reference point, and the waveform at both ends that cannot be observed in the current waveform graph will be recorded and displayed in the window;

● **Prior channel**: when there are many channels, a single view cannot display the waveform view of all channels. Click this button to switch to display the waveform data of the previous channel in the current view; it is equivalent to the mouse wheel scrolling up operation;

● **Next channel:** similar to the description of "previous channel", switch to display the waveform data of the next channel; it is equivalent to the mouse wheel scrolling down operation;

The above function buttons can be used both in the data acquisition and data replay stages; the description of the function buttons below can only be used in the data replay phase.

● The **[Home Frame]** and **[End Frame]** functions can switch the waveform frame by clicking the corresponding button after the waveform data replay is finished. When [Pause] or [Stop] is executed during data replay, the [End frame] will be switched to the last frame of the waveform that has been replayed, and the data that has not been played back will not be pointed.

according to the decimation rate ([Hardware and Sample] > [Sample Settings] > [FFT Setup]). Select [Analysis] > [FFT Analysis] or right-click menu on the "Waveform View" and select "FFT Analysis" to enter the interface. The upper window is "Time -domain waveform", and the lower window is the corresponding "FFT waveform". The dragging operations such as zoom in and zoom out of waveform introduced in the waveform diagram are also applicable to this interface.

Right mouse button can modify the spectrum color; or export the spectrum graph data and save it as csv file. When setting the file name, the * must be removed, but the suffix must remain.

Fig. 6-93 Fast Fourier Transform

Open Wave File: select the waveform file with suffix (.aed) to be processed in the pop-up box; at this time, information related to data will be displayed below the file name, such as start point, end point, sampling length, sampling rate, waveform counts, etc. The values of "start point" and "end point "are related to the start and end points of the data contained in the "Time -domain waveform" below.

Specified location: input the corresponding frame of the waveform in the box, and then

click to display the corresponding frame in the "Time -domain waveform" graph;

Begin /End: refer to the first and last frame of the waveform;

Previous / Next: click to switch the current waveform frame to the "Prior frame" or "Next frame", which is equivalent to the "→" and "←" keys in the "Waveform View".

Vertical zoom in / Vertical Shrink: it is only effective for "FFT" view. Vertically zoom in and out of the FFT waveform, which is equivalent to the "↑" and "↓" keys in the "Waveform View";

Reset: Reset to the original waveform state after clicking;

View Mouse Operations: The mouse wheel allows you to switch channels. The operations described in the waveform area, such as zooming in and out, also apply to this screen. For details, see Figure 6-48 Mouse Operations on the Waveform Area.

6.2.9.3. Wavelet Analysis

The Time-domain waveform data are processed in different frequency layers and displayed in the form of several same time domain but different frequency waveform. Click on "Analysis" menu or right click on the "Waveform Graph" view, and select the [Wavelet Analysis] option to enter the interface. The first graph on the top is the original time-domain waveform, and the lower graphs are the corresponding waveform that has been "wavelet transformed". The wavelets are extracted by 1/2 frequency band.

Click the right mouse button on the graph to "export the waveform data on the current graph" and save it as a csv file. When setting the file name, the * must be removed, but the suffix must remain.
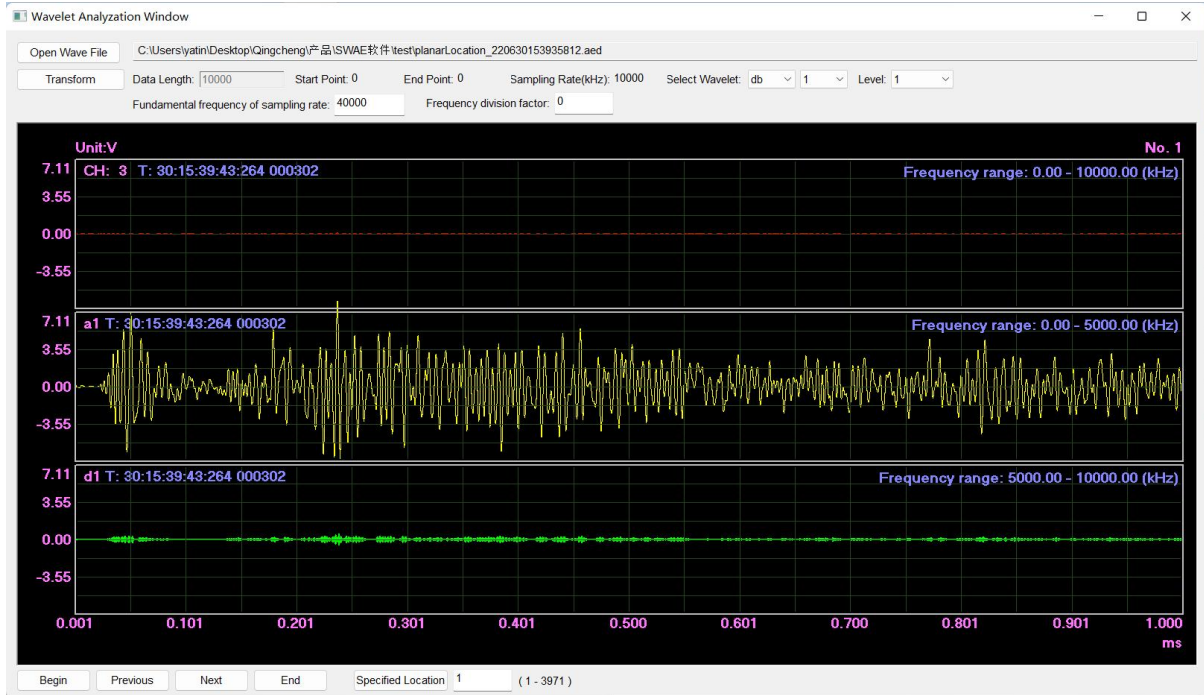
Fig. 6-94 Setting interface of Wavelet Analysis interface

Open Wave File: after clicking, select the waveform file with suffix of (.aed) in the pop-up box; at this time, the information related to data will be displayed under the file name, such as data length, start point, end point, sampling rate and the wavelet settings.

Select Wavelet: select the rule of stripping from the drop-down menu, for example stripping one layer every 3dB;

Level: the number of layers to be peeled off by wavelet transform, which generally needs to combine the original waveform sampling rate and the expected frequency setting of the lowest signal;

Fundamental frequency of sampling rate: lowest frequency;

Frequency division coefficient: the frequency of a single frequency signal is reduced to the original 1/N, called N frequency division;

Transform: After modifying the fundamental frequency and frequency division

coefficients of wavelet selection, grade and sampling rate, click "transform" to apply;

Start/ End Points: directly point to the first and last frame of the waveform;

Previous / Next frame: click to switch the current waveform frame to the "Prior frame" or "Next frame", which is equivalent to the "→" and "←" keys in the "Waveform View".

Specified position: input the corresponding frame of waveform directly in the front window, and the corresponding wave frame will be directly displayed in the "time domain waveform" diagram after clicking;

View Mouse operations: The mouse wheel allows you to switch channels. The operations described in the waveform area, such as zooming in and out, also apply to this screen. For details, see Figure 6-48 Mouse Operations on the Waveform Area.

6.2.9.4.   Digital Filter

By setting the digital filter type and frequency band range, and then performing a secondary filtering on the time domain waveform data. Click on "Analysis" menu or right click on the "Waveform Graph" view, and select the [Digital Filter] option to enter the interface. The upper left corner of the view is the "original waveform" diagram. The digital filter is set at the bottom right corner, and then the filtered waveform will be displayed in the lower left corner. When the filtering performance is not clear, the "frequency response characteristics" in the upper right corner can be observed.
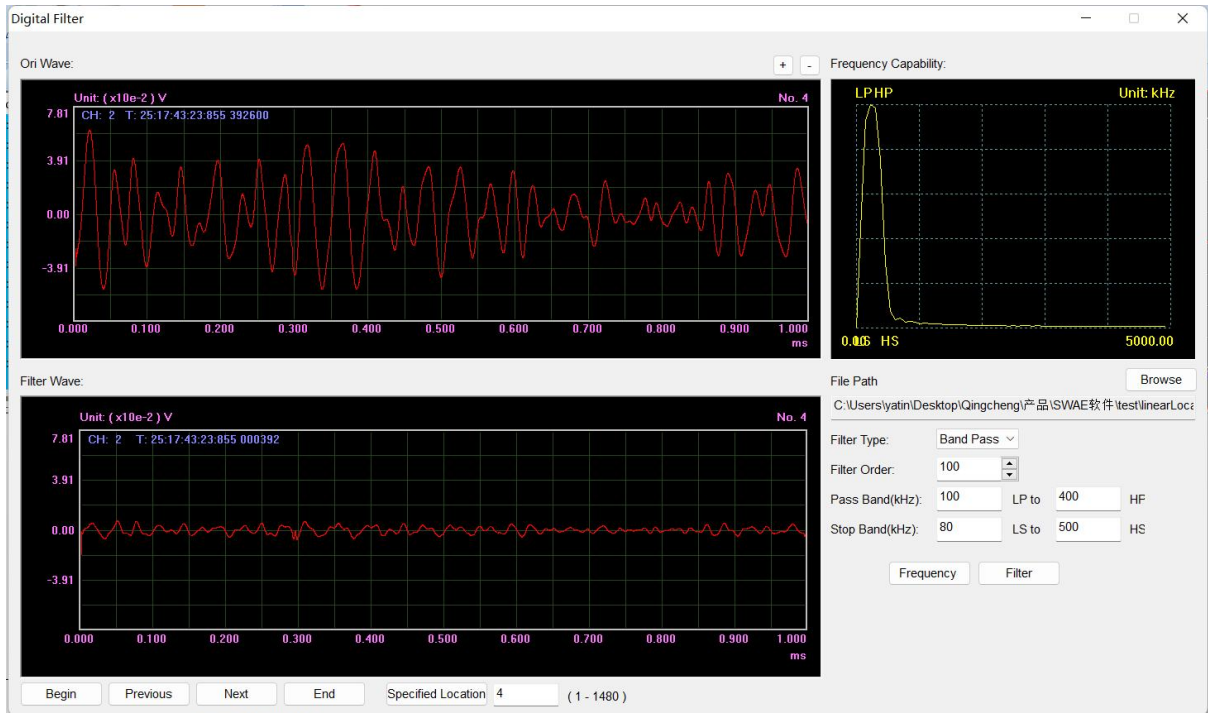
Fig. 6-95 Digital Filter Setting interface

Browse: after clicking, select the waveform data file with the suffix of (.aed) to be processed in the pop-up box;

Filter type: select the filter type to be used from the drop-down menu, including band-pass, band stop, low pass and high pass filters;

Pass band: the upper and lower limits of the signal band allowed to pass, LP corresponding to the lower limit of the pass band, HP corresponding to the upper limit of the pass band;

Stop band: the upper and lower limits of the signal band to be blocked, LS corresponding to the lower stop band limit, HS corresponding to the upper stop band limit;

+/-: Click it to vertically zoom in or out the current graph, which is equivalent to the up/down key of the keyboard;

Begin / End: direct to the first and last frame of the waveform;

Previous / Next: click to switch the current waveform frame to the "Prior frame" or "Next frame", which is equivalent to the "→" and "←" keys in the "Waveform View".

Specified location: input the corresponding value of waveform frame directly in the front window, and click to display the corresponding frame in the "original waveform" graph;

6.2.9.5. Waveform Generation Parameter

The waveform to parameter function can convert the AE waveform file (.aed) into a new AE parameter file (.pra).

Click **[Open File]**, to select the waveform file to be converted (multiple files collected in the same batch can be converted at the same time).

After the selected file is opened, the software automatically names the newly to-be generated parameter file (.pra), which is consistent with the waveform file name.

The initial conversion settings is the current system setting. You can adjust the parameter threshold, HDT, HLT, and PDT.

You can select the time range to select the time period to be converted. The waveform frame range and channel number can be selected. Check "Report conversion information" to show the conversion information after the waveform conversion is completed. You can check "Replay Param File" to automatically replay the generated parameter data in the view after conversion.

By default, the generated parameter file has the same name as the waveform file. If there is a parameter file with the same name already existing, the software uses another name to store the new parameter file. The "Replay Param File" option only replay the parameters, not the waveform.

If there is no converted parameters, the size of the converted parameter file is set to 128KB.
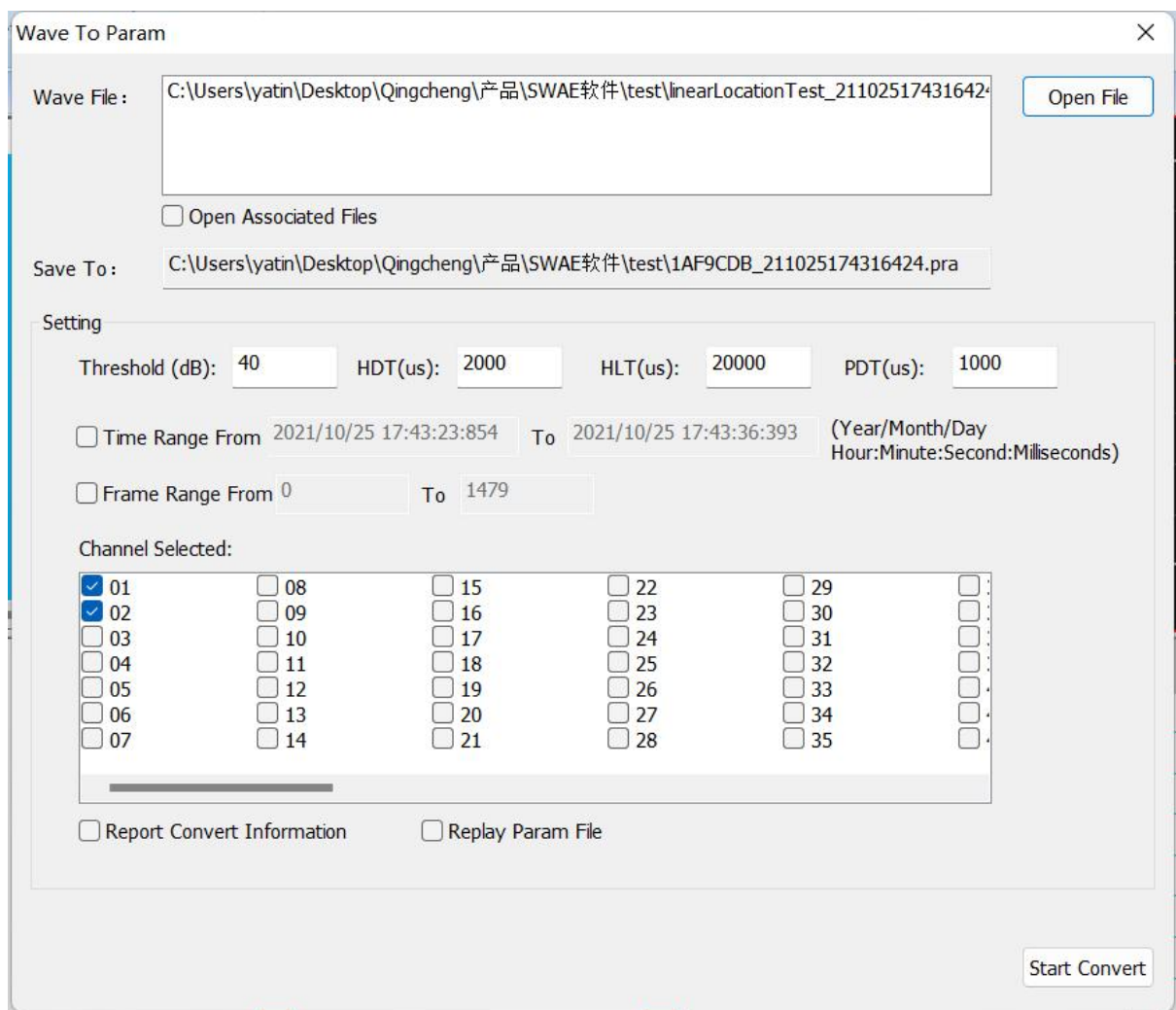
Fig. 6-96 Waveform parameters page

6.2.9.6.   Intensity Activity Analysis

Intensity activity analysis refers to that the user sets some rating rules according to the requirements, and carries out intensity rating, activity rating and comprehensive rating

analysis based on the collected parameter data.

The AE parameter file (.pra file) generated by the software can be rated and analyzed.

In the "Analysis" menu, select the "Intensity Activity Analysis" option to enter the rating screen.
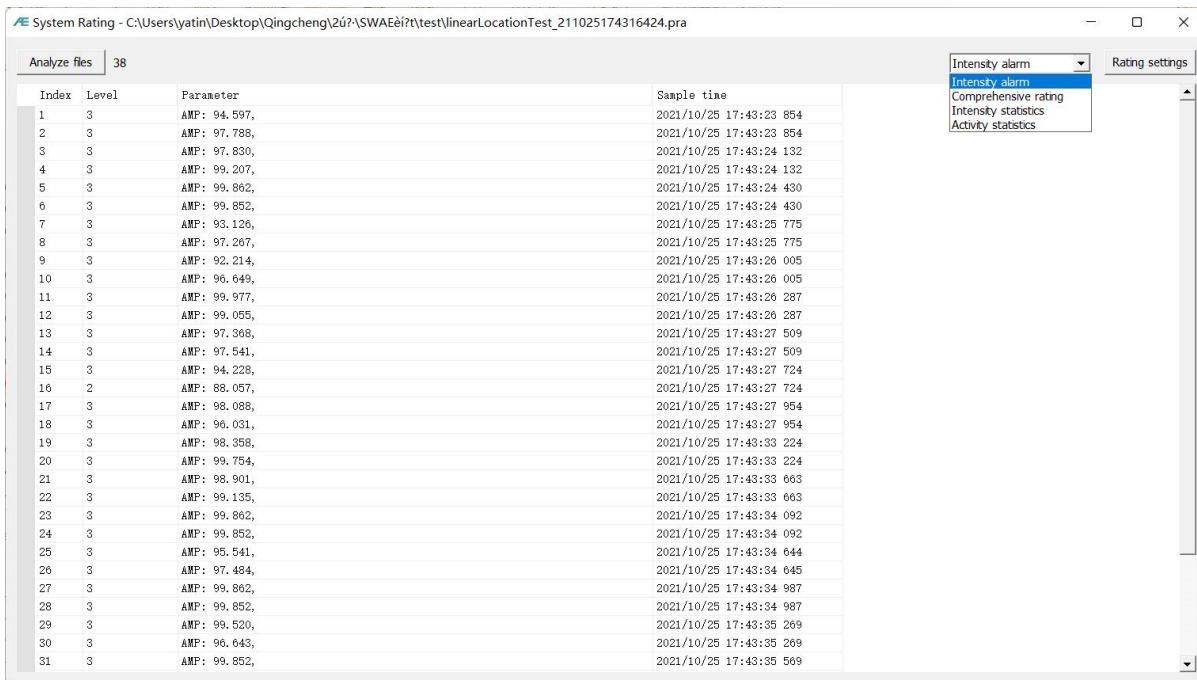
Fig. 6-97 Default system rating page

Analyze files: Click Analyze File and select the parameter file (suffix.pra) that you want to analyze in the displayed file selection box.

Intensity alarm/ Comprehensive rating/ Intensity statistics/ Activity statistics: these are the Intensity activity analysis modes. You can click the list box to switch modes (the initial mode is "Intensity alarm"). For details about the mode, please refer to Chapter "6.2.6.2.8.2. Analytical Modes".

Rating settings: After clicking [Rating Setting], you can set the intensity and activity rating rules in the pop-up rating setting interface. For details about the setting rules, see Chapter "6.2.6.2.8.3. Rating Setting".
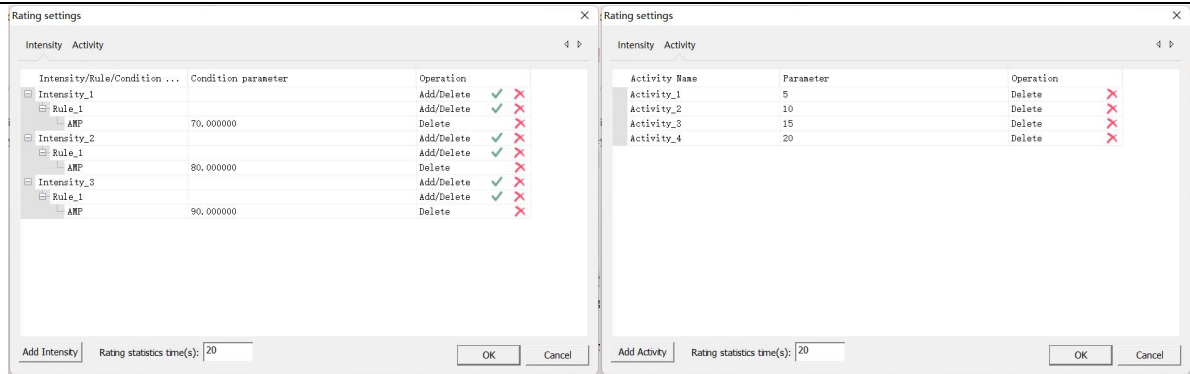
Fig. 6-98 Intensity/activity setting screen

6.2.9.7. Cluster Analysis (Location Concentrated Area)

This setting is mainly used to set the "radius" value of the circle which is used to circle out the location concentration area in the Location Graph, which can be enabled by right-click and select "View Param" on the location views. The circle is used in the location view. When "View Param" is selected, a red circle shows up in the location view and it moves along with the mouse. Left click to put down the red circle to circle out where the points are concentrated. Then the related parameters of these circled points will be filtered and displayed in the "Data Table". Modify the circle radius by pressing the "Cluster Analysis".
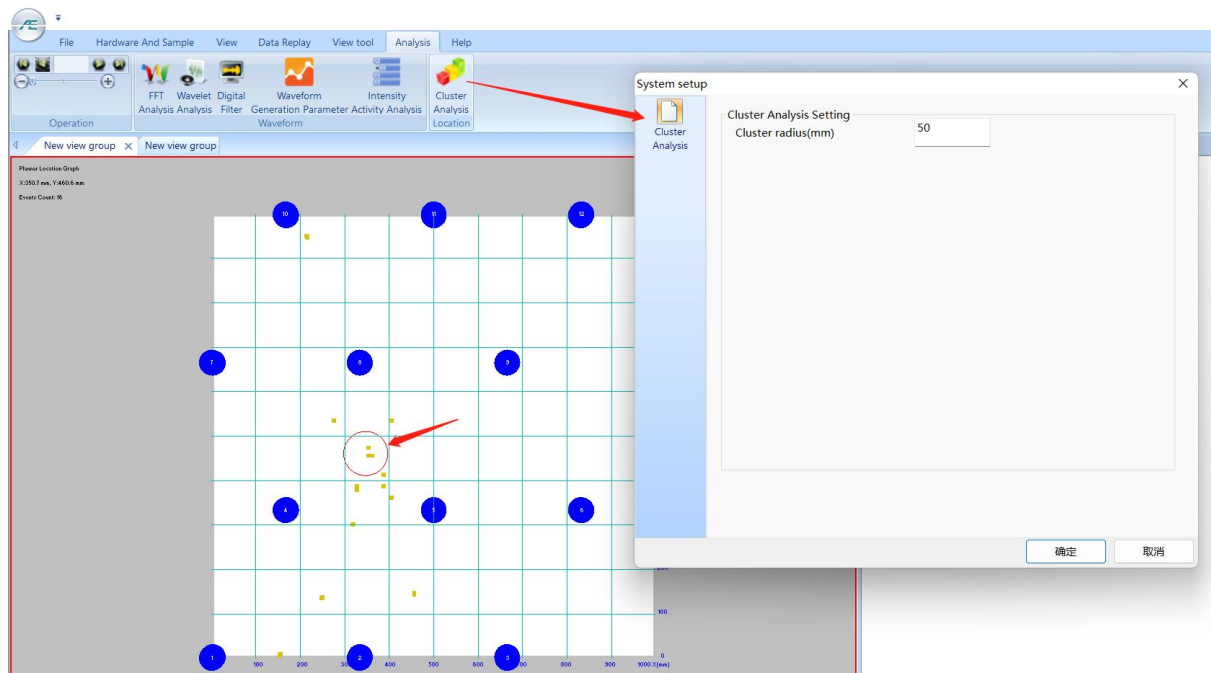
Fig. 6-99 Setting interface of Cluster analysis

6.2.10. Help Menu

Click the **[Help]** button in the main menu, and the "Language" and "About" option will appear on the page.
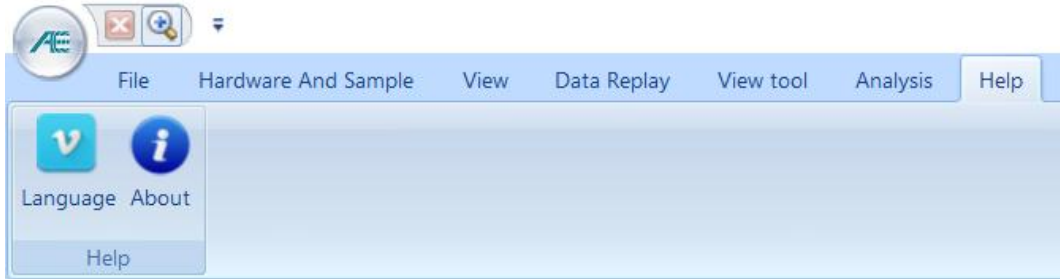
Fig. 6-100 Help page

Click [Language] to switch between Chinese and English. After you select a language, you need to manually restart the software.

Click the [About] button to view the version number of the current software and the firmware version number of the acquisition board in the pop-up window, as shown in the following figure:
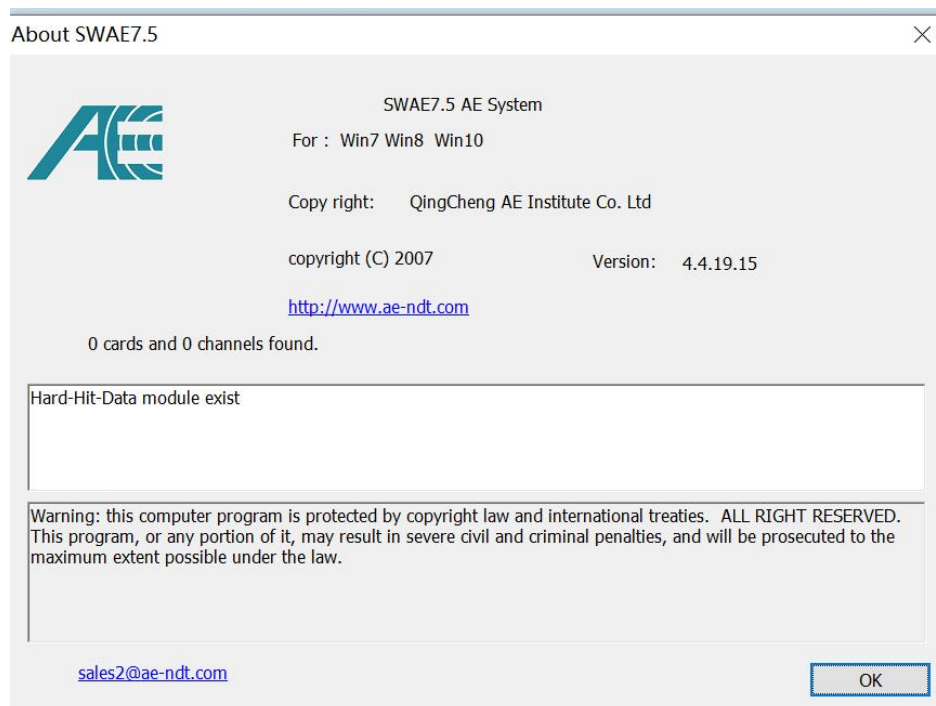
Fig. 6-101 Software / Hardware version information

6.3. View Display Area

Multiple "View groups" can be set in the view display area, and each view group can contain multiple views and types. By setting different grouping forms, data can be viewed more effectively and intuitively

View group title bar: you can choose to view different view groups. Each view group contains multiple custom view group names;

View area: display data table, location graph, waveform graph, correlation graph, etc. You can arbitrarily drag the border between adjacent views to adjust the scale, and split and merge each view position.
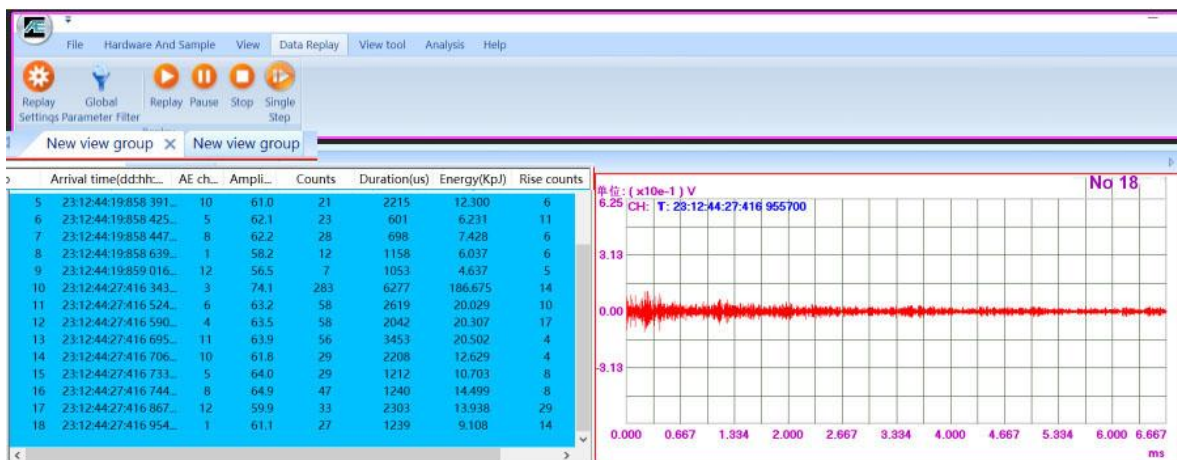
Fig. 6-102 View display area

6.4. Status Statistics Area

The statistical area can display the statistical information in the process of data acquisition or replay. Users can customize the information items displayed in the alternative types by directly checking the corresponding item name. The optional items include total number of collisions, total number of channels, acquisition / replay status, data file name, parameter filter, etc.
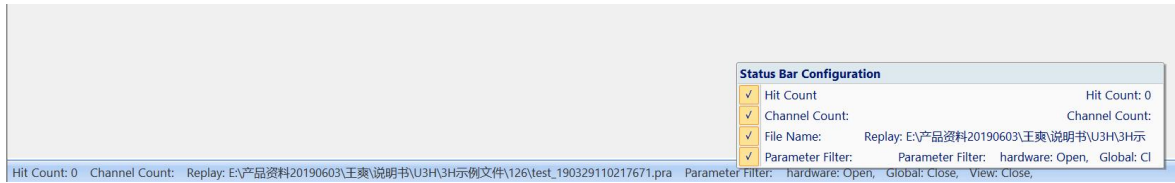
Fig. 6-103 Status statistics column and setting interface

Hit count: the parameter lines that have been recorded or displayed during data acquisition or replay are equal to the parameter lines in the Data table;

Channel Count: the number of channels used in the data acquisition process, or the number of channels receiving data during data replay;

Sample / Replay: data source, when "Sample" is displayed in the acquisition process, and "Replay" is displayed in the data replay process; the next adjacent information is the path and file name of the data;

Parameter filter: It includes hardware filter, global filter and view filter, which correspond to "Hardware", "Global" and "view" respectively. The States after "Hardware" and "Global" are unchanged in the same data sample or data replay back stage. The "view" takes effect for the selected view. If the filter states set for each view are different, the state will be "off" when switching views and "on" transformation.

Part 3 Quick Use Guide

7. Testing cases of acoustic emission

For some personnel who have experience in acoustic emission testing or want do a quick AE test to obtain some acoustic emission data, they can refer to this part. Take the pressure vessel test in the special equipment industry as the example, and explain the acoustic emission testing or experimental process. The laboratory test can refer to this part and adjust it according to the actual situation.

7.1. General Steps of Acoustic Emission Testing /Experiment

1) **Preparation before testing:** understand the site situation, equipment operation processes and the testing conditions;

2) **Determination scheme:** location modes, sensor layout positions, detection processes, etc.;

3) **Equipment hardware connection**: sensor installation, equipment connections, etc.;

4) **Software debugging**: determine the view type and data sample rules;

5) **Threshold determination:** the acquisition threshold is determined by testing the background noise level;

6) **Sensitivity test:** ensure the consistency of sensitivity of all sensors or meet the test standard as far as possible;

7) **Attenuation test:** after the sensor scheme is determined, the attenuation test is to verify the minimum signal can be received;

8) **Sound velocity test**: it is needed when the time difference of arrival (TDOA) locating algorithm is used. If there is no the regional location or no location requirements, it can be ignored;

9) **Location calibration test:** it is needed when the time difference of arrival (TDOA) locating algorithm is used. If there is no the regional location or no location requirements,

it can be ignored;

10) **Data acquisition:** according to the proposed scheme, data acquisition can be done at each stage or experimental phases;

11) **Secondary sensitivity test:** the post sensitivity test is to determine the validity of the data especially after the long-term detection, or when the test environment is unstable or tough;

12) **Location reverse calibration test**: for large component detection, the simulation source test is carried out in the location concentration area;

13) **Data processing:** issue the experiment report or test report with the data analysis.

7.2. Example of Testing Procedure

7.2.1. Preparation Before Testing

Before the acoustic emission detection or test, it is necessary to understand and check the object to be tested. According to the size, structure, material and working conditions of the tested object, the approximate test processes of acoustic emission detection is determined. It is very important to acquire and obtain effective AE data.

7.2.1.1. Review of The Inspected Containers

1) Review the qualification certificate, quality certificate and as built drawing of the tested object to obtain the basic parameters, such as equipment diameter, height, wall thickness, material, internal structure, design pressure and working pressure, as well as the location of suspected defects in delivery acceptance;

2) Operation data review to obtain operation information, such as actual working pressure and working medium of equipment;

7.2.1.2.   Scheme Determination

1) **Sensor layout scheme**: the number of channels and sensors of the AE instrument is determined by the external diameter and height of the measured object (when the attenuation curve and the sensor spacing of the similar material and structure is known). Generally, the distance between the crack signal of metal special equipment and the sensor array is not more than 5m, and the location diagram of different containers can refer to Fig. 7-1; for the tested object in the laboratory, it can be determined according to the structure, or material or the research direction of the tested object, such as using 2 sensors for the tensile strength test and using 2 or 8 sensors for rock mechanic tests.

Sensor layout of plate structure

Sensor layout for spherical vessels

Sensor layout for vertical and horizontal vessels

| Sensor layout of high-pressure cylinder | Layout of tank bottom sensor |

| Sensor layout for horizontal vessels |
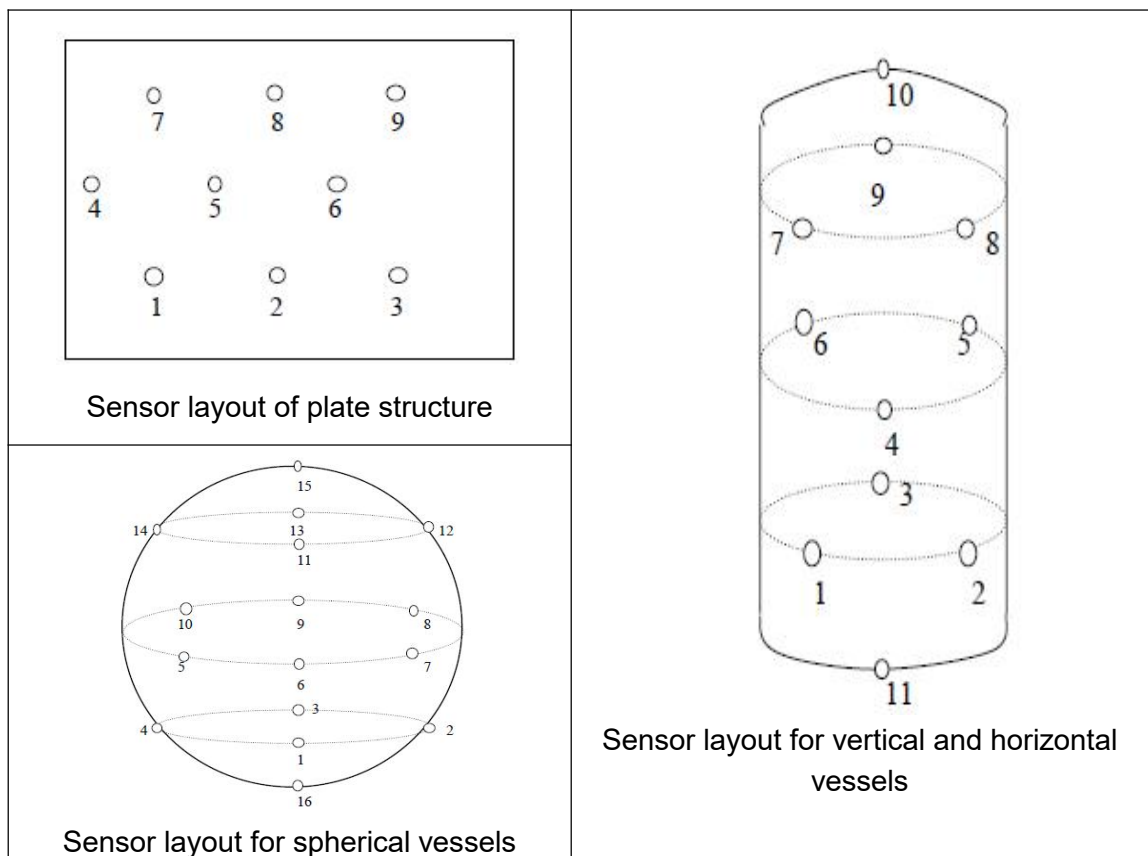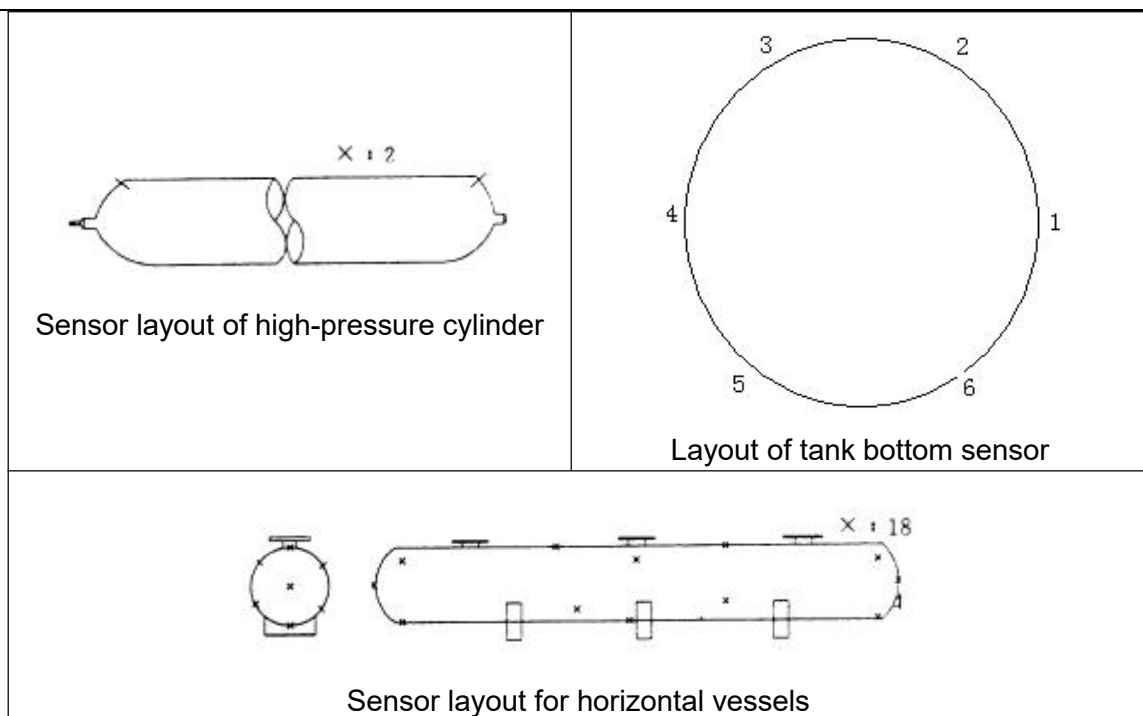
Fig. 7-1 Sensor Layout of Pressure Vessels

2) **Determination of test process:** for example, the pressure and pressure rate of acoustic emission test are determined according to the working pressure of the vessel; for laboratory use, it can be the factors such as speed, temperature, load, etc.;

3) Determine the approximate time of acoustic emission testing and the auxiliary conditions to be provided by the tested party; select relatively no external interference environment for acoustic emission detection or test if possible; when the third party is required to complete, the scheme negotiation shall be conducted as early as possible.

7.2.1.3.   On Site Confirmation

1) Make sure the load requirements and auxiliary conditions to be provided for acoustic emission testing with the tested party, such as the provision of power supply (220V AC), scaffolding for sensor placement or provision of crown block required for the placement of sensors;

2) Make sure the AE Host placement and sensor installation position; under the premise of

ensuring the safety of the AE host position, the operator should observe the computer display and the measured object at the same time; when the existing conditions don't allow directly installing the sensors, it is necessary to consider the way of thermal insulation breaking or waveguide rods;

3) Propose the fixing method of preamplifier and coaxial cable, and estimate roughly the length of coaxial cable to the AE Host;

7.2.1.4. Instrument Preparation

1) Prepare and test the acoustic emission system and its accessories to ensure the normal operation of the whole system. Cancel the standby mode and the screen protection functions of the computer; for computers without software installation, please refer to Chapter 4.2.3 installation of upper computer software and 4.2.4 installation of USB driver;

2) Prepare the safety facilities according to the safety requirements of the testing site;

3) Prepare on-site grinding tools and fixing materials, such as scraper, sandpaper, tape, etc.

7.2.2. On Site Installation

7.2.2.1. Placement of Instruments

1) Select the appropriate time for the AE detection, such as no rain, snow, breeze, and no cross-operation period;

2) Place the instruments to the allowed positions on site. Keep a safe distance between the pressure vessel and the tested vessel. Place the instruments outside the firewall for the

container containing flammable and explosive media;

3) The power supply (220V AC) is placed near the instrument, and the ground wire of the safety protection device should be installed if possible. Ensure the continuous and stable power supply of the power supply during the acoustic emission test.

7.2.2.2.   System Connection

1) **Determine the installation positions of the sensors**: select the reference starting point and determine the sensor installation position. It is recommended to mark the corresponding sensor number near the position point, and record the reference point positions.

2) **Surface preparation of sensor installation positions**: sand the installation area to remove the thermal insulation layer, anti-corrosion coating and protective paint, and to expose the metal luster;

3) Connect the signal line to the sensor, and pay attention to the interface connection tightness;

4) Coating some coupling agent on the receiving surface of the sensor or the sanded area. And couple the sensor to the surface of the container;

5) Fix the sensor with a magnetic holder or using some adhesive tapes. The method is flexible as long as it can hold the sensor tightly and well-coupled to the surface;

6) The output end of the signal line (BNC interface end) is connected with the input (BNC) port of preamplifier. When using the PAS preamplifier, it is necessary to pay attention to the switch position of the inputs (single or differential);

7) Select the appropriate length of the coaxial cable and connect it the output (BNC) of the preamplifier;

8) Referring to the number marked next to the sensor installation position, connect the other end of the coaxial cable to the corresponding channel number on the acoustic emission

instrument (SAEU3H) front panel;

9) Check the channel connection between the sensor position number and the channel number on the instrument one by one to make sure the channel number is not mixed up;

10) Connect the acoustic emission host instrument (SAEU3H) with the computer through the standard USB data cable, and then turn on the computer;

11) Open the SWAE software. Only then turn on the acoustic emission host instrument (SAEU3H).
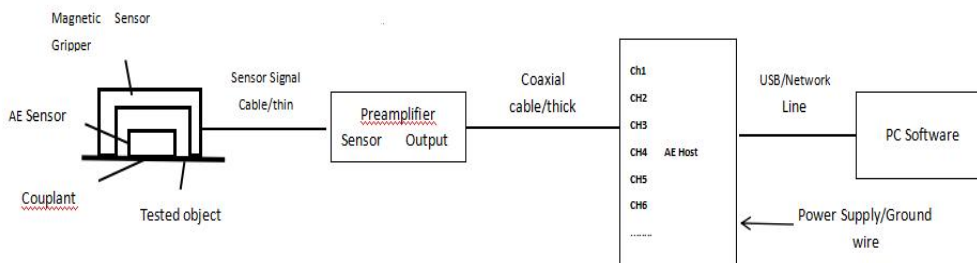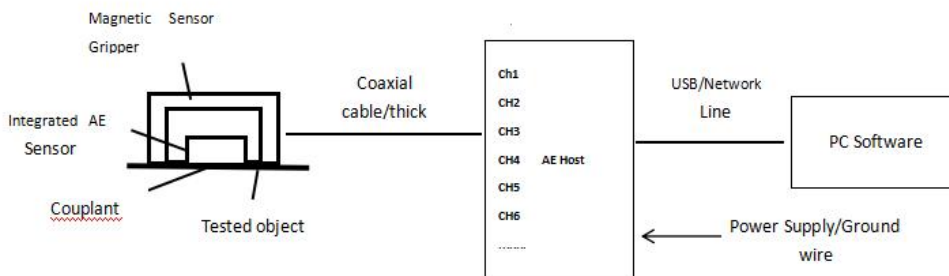
Fig. 7-2 Connection Diagram of Split Sensor

Fig. 7-3 Connection Diagram of Integrated Sensor

7.2.3. Basic Software Settings

The software setting part includes "View setup" and "Sample setting". The view setting is mainly to establish the corresponding views to display the AE data, and the sample setting is mainly to set up the hardware parameters and sample rules.

7.2.3.1. Software Startup

Double click the **[SWAE]** icon on the desktop with the left mouse button to open the software. The default views appeared when the software opens are the Data Table and the waveform views. In order to facilitate the subsequent setting operations, click on any view, and then click the **[View]** and then **[Merge]** buttons in the menu bar, so that the view area will be restored to one gray area.

Note: the current supporting device of the software must correspond to the connected acoustic emission device; the same applies to the [Data Replay], [Analysis] and other operations. You can click the "AE" icon in the upper left corner to view the current supported devices. To modify, click the "AE" icon in the upper left corner, then click the "Yes" button in the popup window, and wait for the software to start.
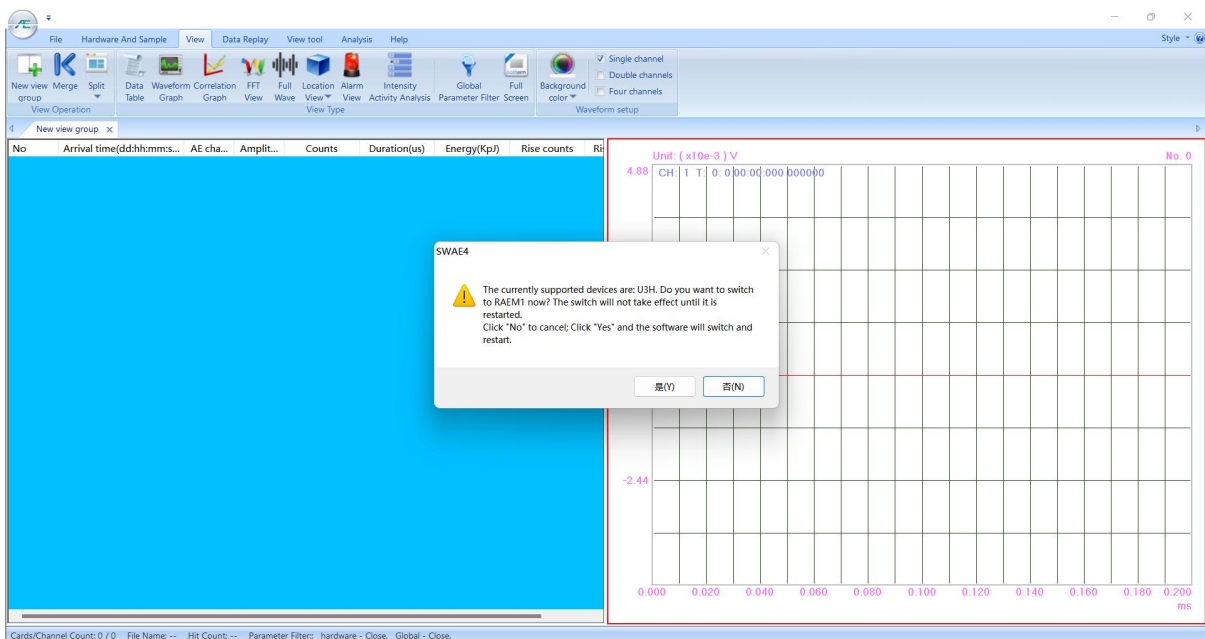

Fig. 7-4 Initial interface of SWAE software and the supported device window

7.2.3.2. View Settings

General inspections or tests need to establish four types of views, including "Waveform", "Data Table", "Correlation Graph" and "Location Graph". Users can select the types and

quantity of views according to actual needs. The latter three types are the most common in industrial detection applications, and the first three types are mostly in laboratory purposes.

7.2.3.2.1. View Segmentation

Select a new view group in the graphic display area (select the frame to turn red). Click **[Split]**, and move the mouse to select the view array (such as 2 rows and 2 columns) according to the demand, as shown in the figure. Click the mouse again to complete the view group segmentation and generate multiple view windows. In the same way, any view can be divided for more than once.
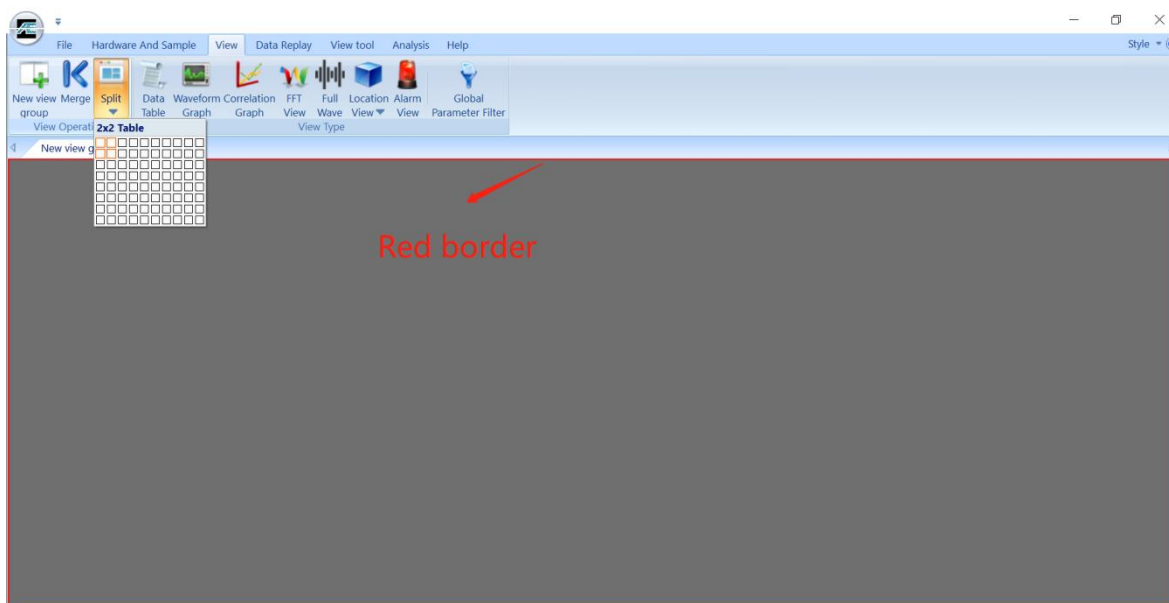
Fig. 7-5 View Splitting

7.2.3.2.2. Establishment of Waveform Graph

Select the first blank view in the upper left corner with the mouse, and click [Waveform graph] in the "View type" under the "View menu" to complete the addition of waveform view. The number of channels displayed in the view window can be selected through "Waveform setup" section next to the "View Type".

Fig. 7-6 Waveform Graph

7.2.3.2.3.   Data Table Setup

Select the blank view in the upper right corner, and of select **[Data Table]** to finish adding the "Data Table View". If the default AE parameter types cannot meet the actual needs, click **[More data]** to enter the parameter selection interface. After checking the required parameter name, click **[OK]**.

Fig. 7-7 Data table view and parameter selection

7.2.3.2.4.　Correlation Graph Setup

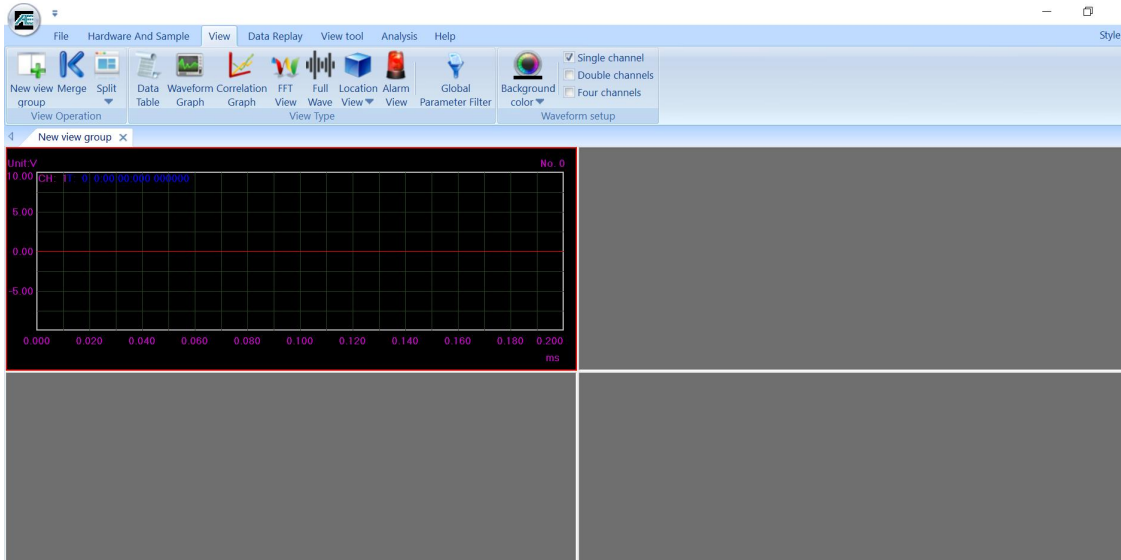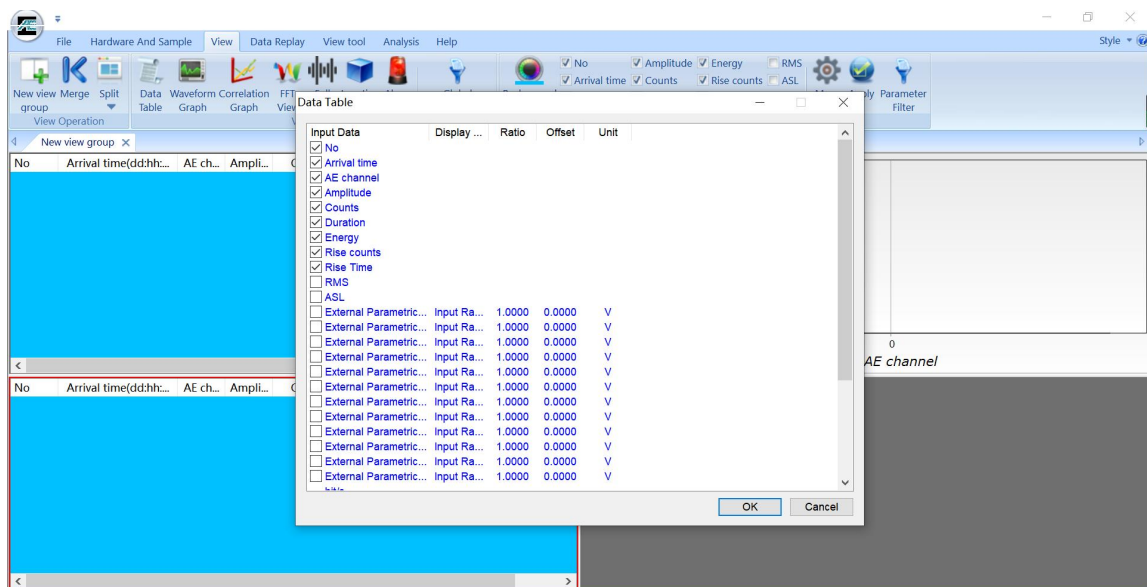Select the blank view in the lower left corner, click "View", the choose **[Correlation Graph]** to complete the addition of correlation graph view. The default "Hits- AE channel" scatter diagram is a common correlation chart, which can directly observe the data received by each channel. When it is necessary to change or add multi- coordinate statistics, please refer to Chapter 6.2.6.2.3.2 "Parameters Modification of Correlation Graph".

7.2.3.2.5.　Location View Setup

1)　Default Location View setup

Select the blank view in the bottom right corner, and click **[Location View]**, and a list of "the location graph" type appears. In the industrial inspection, cylinder containers are the majority. Take a cylinder location graph as an example. In the pop-up location Graph type, select **[Cylinder Location Graph]** to add the default cylinder Location view.
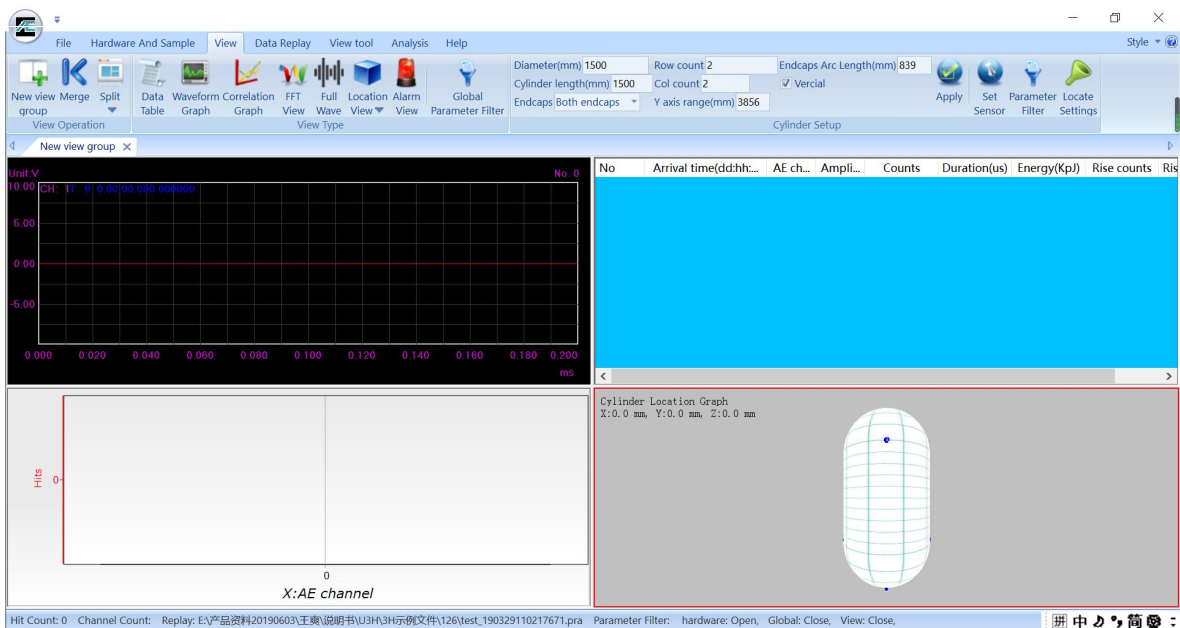

Fig. 7-8 Four Types of View Interface

2)　Basic Info Modification

First, select the location graph, and modify the relevant data directly on the right side of the secondary menu of the "view" menu. After modifications, click **[Apply]**. For example, the

diameter of the cylinder is 1500mm, the cylinder length is 5000mm, and the distance between the circumferential seam and the center of the end caps arc length is 1000mm. Three rows (circles) of sensors are arranged along the length direction, and there are three (columns) sensors for each circle (row). The corresponding information can be input into the corresponding position. The "Y-axis range" should not be less than the surface distance between the center of the two end caps, and the recommended setting should be equal to it.
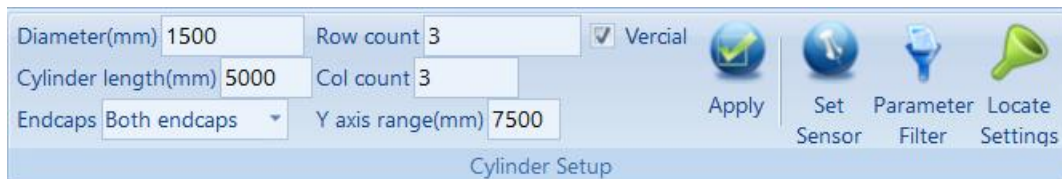
Fig. 7-9 Basic Info Modification of Cylinder Location Graph

3) Axis Adjustment

After the operation of the above steps, the software will give the default recommended sensor location coordinates, which basically adopts the principle of equal division. The X-axis of the coordinate origin is the sensor #1 near the circumferential seam, and the Y-axis of the origin is the center of the end caps near Sensor #1. The rest sensors are arranged clockwise from bottom to the top, following by the sensors at the end caps. Users can use this as a reference to install the sensors. When the actual installation position is different, the coordinates can be modified by clicking the **[Set Sensor]** button.

Fig. 7-10 Modification of sensor position coordinates

7.2.3.3.　Sample Settings

After the operations on Chapter "7.2.3.2 View Settings", it is necessary to set the hardware and sampling settings and sampling rules. Only the basic functions are introduced, **[Hardware Setup], [Hit Feature], [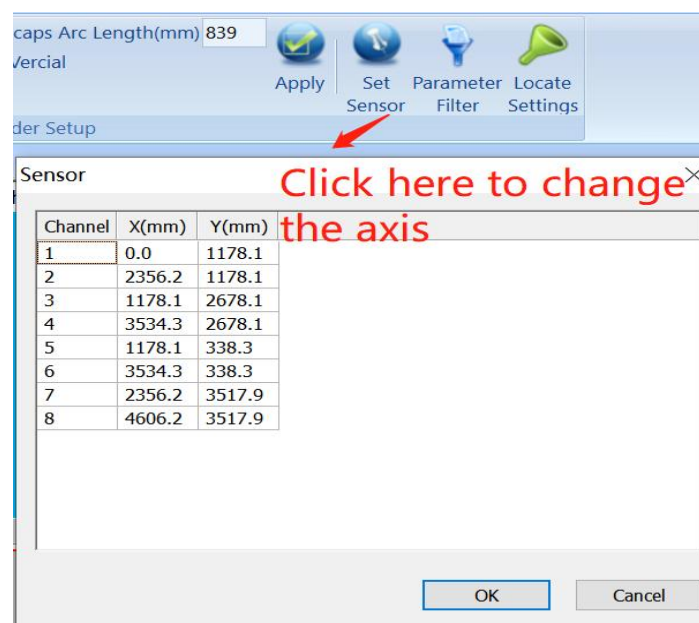Waveform]** and **[Saving]** respectively. With the set views, it ensures that users can acquire and save the original data, so as to carry out the subsequent research and analysis.

The setup of this stage requires the hardware connection and good communication between the computer and the AE host, and the installation of drivers.

7.2.3.3.1.　Hardware Identification

1) Turn on the computer and enter the windows system desktop. Connect the USB cable from the AE instrument to the computer;

2) Double click the [SWAE] icon on the desktop to start the AE application, and then the software will load the default configuration.

3) Turn on the SAEU3H instrument.

4) In the "SWAE" software, click **[Hardware and Sample] > [Sample Settings]** in turn to open the following window, and click **[Refresh]** button at the bottom right corner to recognize all the AE boards connected.

5) After clicking **[Refresh]**, if the AE boards driver are installed and well connected, it should display "Channel count: XX" below the table.
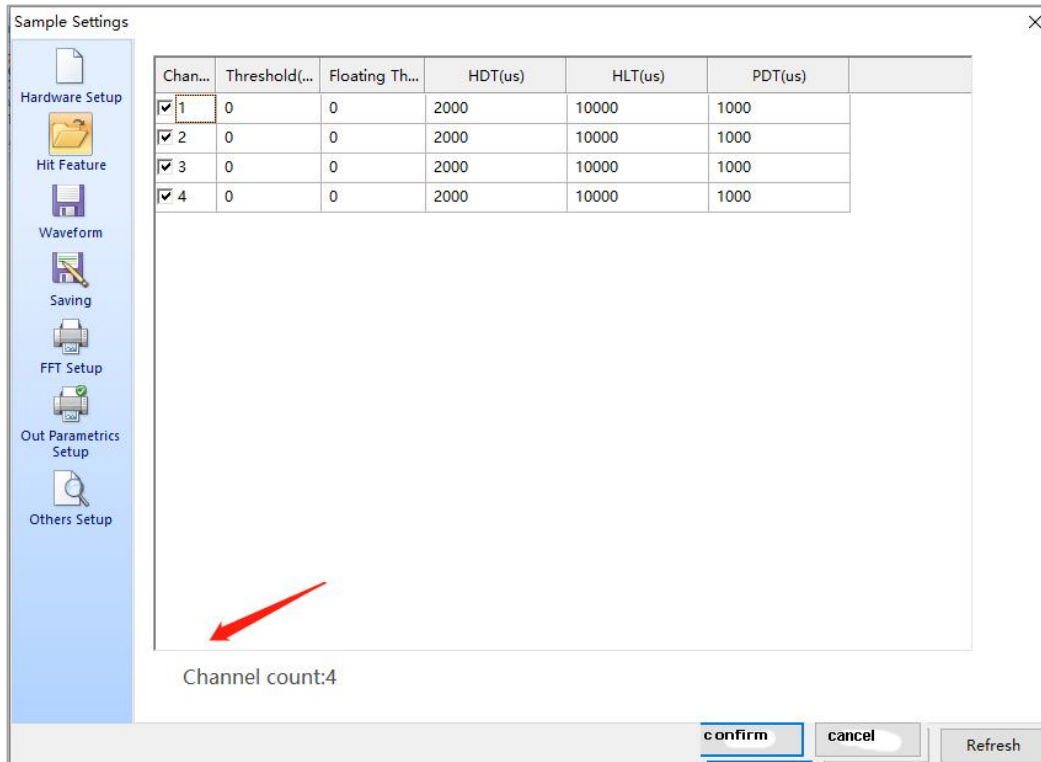
Fig. 7-11 Acoustic Emission Host Hardware Identified

7.2.3.3.2. Hardware Setup

7.2.3.3.2.1. Hardware parameter setting

Generally, the setting of this interface should be combined with the actual hardware settings. Click **[Hardware Setup]** on the left menu bar. Select the appropriate situation for corresponding settings in Chapter 6.2.5.1.2 "Recommended Inspection Setup on Site". The figure shows the pressure vessel detection settings.
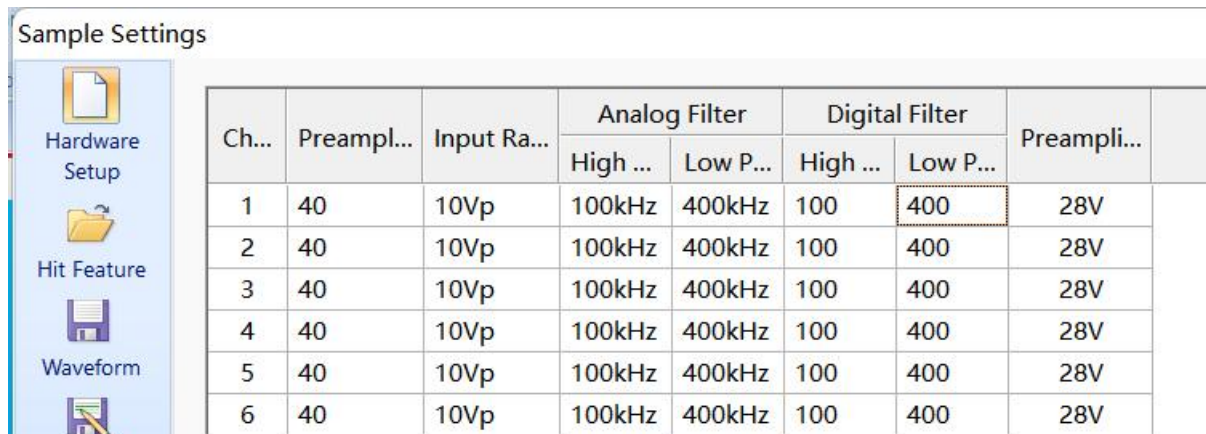
Fig. 7-12 Hardware setting interface

Set current column: when the setting of a column needs to be modified, after modifying the first row value of the column, then click the column name of that column, and then click **[Set Current Column]** to update the whole column with the value in the first row.

Set all columns: when the settings of all channels need to be modified with the same values, after modifying all parameters of "Channel 1", click **[Channel]** column name in the upper left corner, and then click **[Set All Columns]** to set all channels with Channel 1 values.
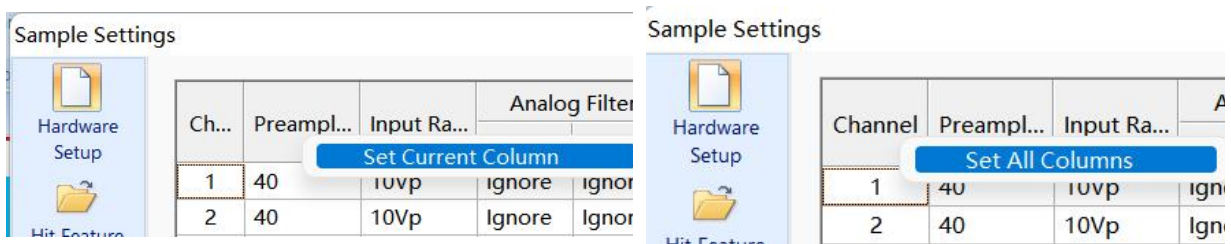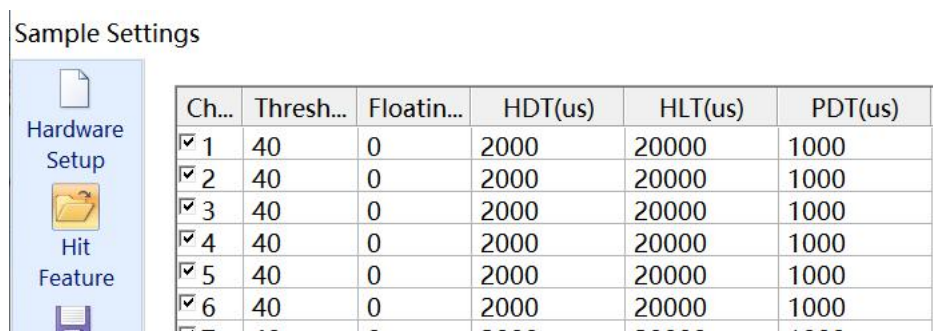

Fig. 7-13 Setting current / all columns

7.2.3.3.2.2. HIT Feature Setup

HIT Feature Setup determines whether the extracted characteristic parameters are accurate or not, which is very important for the subsequent analysis based on the characteristic parameters, such as the data table, correlation graph statistics, location graph calculation, etc. Click the left menu bar [Hit Feature]. Select the appropriate situation for corresponding settings in Chapter 6.2.5.1.2 "Recommended Inspection Setup on Site". The figure shows the pressure vessel detection settings.

Fig. 7-14 Hit Parameter Interface

7.2.3.3.2.3. Waveform Settings

The value setting of this interface determines whether the extracted waveform data has use value, which is very important for subsequent waveform-based analysis methods, such as FFT, wavelet, waveform generation parameters and other functions. Click **[Waveform]** on the left menu bar. Select the appropriate situation for corresponding settings in Chapter 6.2.5.1.2 "Recommended Inspection Setup on Site". If the checkbox in "Channel" column is not checked, the waveform data of that channels will not be saved and displayed. Generally, for the industrial testing appli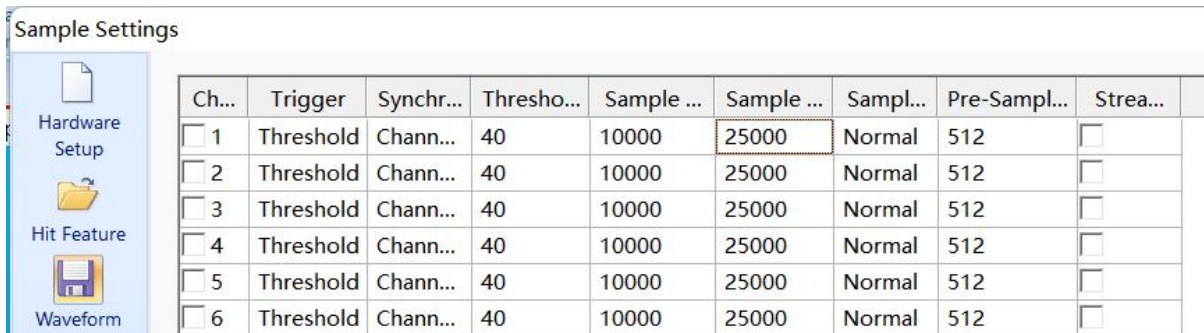cation the channel waveform is not checked. But for the laboratory applications the waveform can be saved according to the actual needs. Waveform data occupies large disk space and may affect the "storage" settings.

Fig. 7-15 Waveform sampling settings

7.2.3.3.2.4. File storage settings

Whether to save the data files, including waveform file with suffix of (.AED) and parameter file with suffix of (.PRA), the user can decide according to the actual situation. Click **[Saving]** on the left menu bar to set in the interface:

● Data file path: click **[Browse...]** button to locate to the target folder for the files to be saved;

● **File Name**:　letters, numbers and characters can be input directly in the text box, but special characters such as _ \ / : * ? ″ < > | etc. cannot be included;

● **Tag Label**: the time mark of the data generation time, in the form of ″YYMMDDHHMMSS″. For example, "200426143359" means that the file generation time is "14:33:59, April 26, 2020″. This time is from the computer system time and is not

recommended to be changed;

- **Save Acquired Data**: if it is selected, the data file will be saved, and the corresponding .aed and/or .pra files will be generated in the target folder. Otherwise the collected data will not be saved;

- **Notice Before Acquisition**: only used to prompt whether to save data or not. If it is selected, you will be prompted "save/not save data" before each acquisition starts.

- **Maximum File Size (MB)**: when the data size is larger than this set file size, it will created another new file to keep on saving the coming data until the acquisition stops. The setting range is 1-4000 integer, in MB, which can be directly input in the text box;

- **Maximum File Number**: the maximum number of files (including both the .AED and .PRA files) after reaching this value, no longer save the data (stop in the collection state) or continue to store data by overwriting the previously stored data. The combination of this value and the setting value of "maximum file size" shall not exceed half of the available capacity of the hard disk. The setting range is 1-1000 (positive integer), which can be directly in the text box;

- **Autosave Setup**: check the box to allow files overwriting, when the maximum file number is reached.
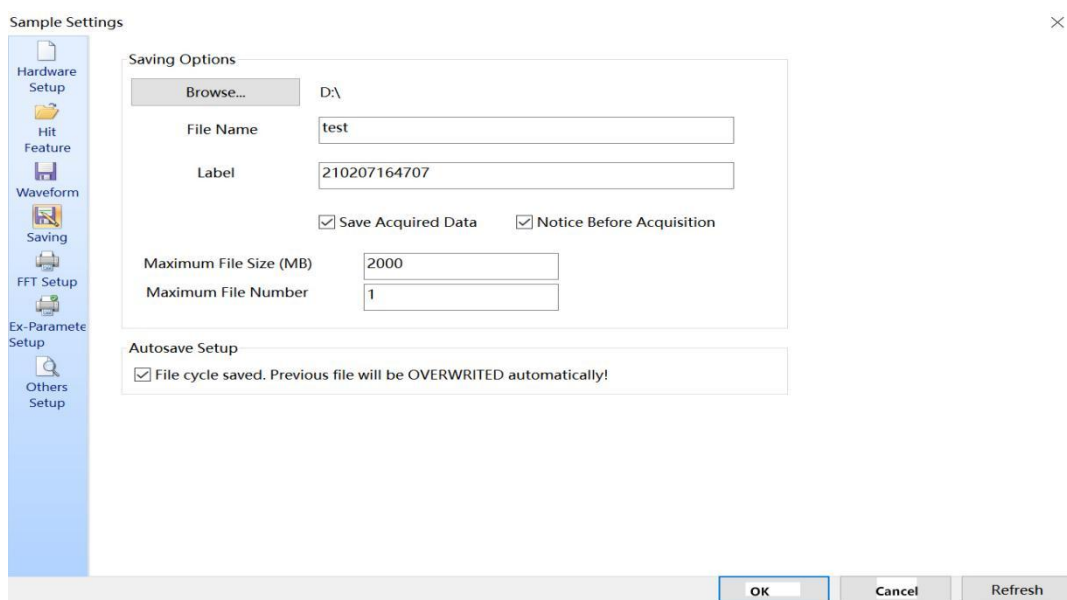
Fig. 7-16 Saving Settings

7.2.4. Threshold Determination

1) Set the "parameter threshold" in [Hit Feature] and the "waveform threshold" in [Waveform] of all channels to 28dB;

2) Click the **[Sample]** button in the **[Hardware And Sample]** interface, and stop the acquisition after about 3-5min;

3) Click "Amplitude" column in the "Data Table" to sort the table in an ascending or descending order.

4) Find the maximum amplitude value that also appears most frequently to be the background noise level. As shown in Figure 7-17, the most frequent value (noise level) is around 40dB. But some channels have higher noise values constantly so that it is necessary to redo the coupling of those channels;

5) Repeat steps 1-4 until the amplitudes of all channels are close to 40dB;

6) The threshold value is the noise value plus some buffer space, which generally increases by 3~6dB, and 35~55dB is the commonly used threshold value. Users can control the threshold level according to the actual detection site.

   Remarks: the acoustic emission test of atmospheric tank bottom plate corrosion has no way to decide on the noise level, which can be set between 35 and 50dB according to the site conditions.

No	Arrival tim...	AE chan...	Ampli...	Counts	Duration(us)	Energy(KpJ)	Rise cour
96	27:17:03:11:215 205...	6	48.9	763	30000	160.270	32
99	27:17:03:11:244 605...	7	46.7	431	21284	6.974	4
102	27:17:03:11:249 560...	5	46.5	412	26803	4.955	14
100	27:17:03:11:246 207...	6	43.5	229	13113	2.434	6
97	27:17:03:11:217 580...	8	42.6	822	30000	104.601	29
27	27:17:02:16:208 184...	1	42.4	3	28	0.035	2
83	27:17:03:10:557 280...	8	42.2	614	26841	10.157	35
84	27:17:03:10:558 184...	5	41.5	737	30000	31.970	32
40	27:17:02:28:657 374...	7	40.8	4	53	0.023	3
30	27:17:02:16:208 189...	6	40.6	1	8	0.006	1
26	27:17:02:16:208 181...	5	40.3	3	30	0.017	2
101	27:17:03:11:248 630...	8	40.3	161	11413	1.279	3
17	27:17:02:11:890 757...	7	40.1	9	117	0.037	6
6	27:17:01:56:645 732...	1	39.5	3	39	0.007	1

Fig. 7-17 Background Noise Measurement Results

7.2.5. Channel Sensitivity

1) Only the parameters data is collected, and the "parameter threshold" in [Hit Feature] of all channels is set to 50dB for data acquisition;

2) The sensitivity of each channel is calibrated by breaking the pencil lead for three times at at the same position by a certain distance from the sensor (for example, the pressure vessel is specified as 100 mm from the sensor). The pencil lead breaking angle, lead core length and pressure strength are as consistent as possible. When it is obvious that the pencil lead breaking effect is greatly different, repeat the step;

3) The first three maximum "amplitudes" received by each channel are recorded;

4) The average value of the three maximum "amplitudes" is the current channel sensitivity; when it is obvious that the sensitivity of a certain channel is abnormal, the sensor and other accessories of the channel can be replaced or re-coupled; then, repeat step 2) to

4);

5) Then average all channels' sensitivity as the system sensitivity;

6) According to the standards or combined with the test requirements, the results of step 5) and step 4) are compared one by one to evaluate whether the channel sensitivity meets the requirements, such as the difference between the channel sensitivity and the system sensitivity is generally ± 3dB or ± 4dB, which is required for the detection of special equipment.

7.2.6. Attenuation Test

Attenuation test has two basic purposes in AE detection. The first purpose is to ensure that the whole sensor array can receive the desired AE signal, and the other purpose is to calculate the original source AE signal amplitude based on the attenuation curves. In general, the spacing in the sensor layout scheme is usually based on similar test experiences. According to some known experiences, the acquisition of acoustic emission signal can be basically realized. When encountering the test of unknown materials and structures, this step should be advanced before the determination of the sensor layout scheme, so as to determine the sensor layout scheme and quantity based on the attenuation characteristics.

7.2.6.1.   Making of Compensation Curve

1) The typical positions on the tested AE components, such as the curved surface diameter change, thickness reduction, weld number and welding mode change, should be tested separately;

2) Make test points along the longest line in a sensor array, such as 0.1m, 0.5m, 1m, 2m, 3m etc. and make test distance not shorter than the maximum length of the connecting line. The above test positions need to be polished to expose the metallic

luster.

3) Only enable one channel in the array for data acquisition and saving, and the "parameter threshold" of the channel is set to the determined threshold value for data acquisition, such as 50dB;

4) Break the pencil lead for three times at at the test positions from the sensor, and record the maximum amplitude received. Repeat twice;

5) Calculate the average value of the three maximum amplitudes at each position, which is the attenuation measurement value at that distance from the sensor; subtracting the attenuation measurement value with 100 is the attenuation amount of that position;

6) Repeat step 4) and 5) until all the test distance positions are complete. The distance v.s amplitude attenuation curve is obtained with all the distances and attenuation values, which can be directly used to calculate the source original acoustic emission signal;

7.2.6.2. Spacing of Attenuation Curve

1) Firstly, a sensor is installed, and the "parameter threshold" of the channel is set to the determined threshold value for data acquisition, such as 50dB;

2) Make test points along the longest line in a sensor array, such as 0.1m, 0.5m, 1m, 2m, 3m etc. and make test distance not shorter than the maximum length of the connecting line. The above test positions need to be polished to expose the metallic luster.

3) At each location point, break the pencil lead for three times at at the test positions from the sensor, and record the maximum amplitude received. Repeat twice. Move on to the next test

distance position and repeat this step.

4) Calculate the average value of the three maximum amplitudes in each position;

5) Draw the attenuation curve. The abscissa is the distance from the sensor and the Y axis is the average value at each distance positions. If the 80dB signal is expected to be received, and the threshold is 50dB, it means only 30dB signal attenuation is allowed. When the distance attenuation curve is obtained as below, the maximum distance between TDOA location algorithm sensors is 2.2m, and the regional location sensor spacing is 2.2x1.5 = 3.3m;

6) The maximum distance between sensors is used to arrange the sensor positions and determine the sensor location arrays.
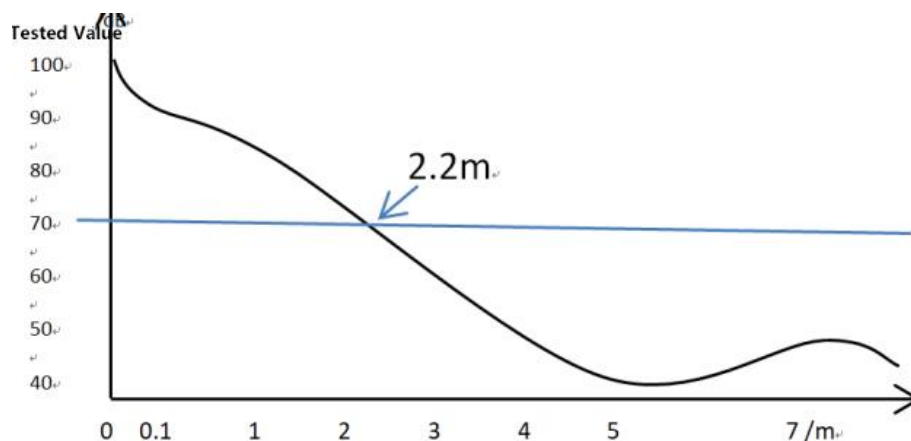

Fig. 7-18 Distance attenuation curve

7.2.7. Acoustic Velocity Test

When the acoustic emission detection involves source locations, the sound velocity used is generally the compound wave velocity, which needs to be measured on site. Generally, two sensors in the same array arranged on the tested component are used to calculate the arrival time difference. The steps are as followed:

1) Measure the distance **L** between the two sensors in advance;

2) Set the "parameter threshold" of the channel used as the determined threshold value for data acquisition, such as 50dB;

3) In the extension lines of the two sensors, break the pencil lead once;

4) Check the arrival times of the signals received by the two sensors with the maximum amplitudes, and calculate the time difference **ΔT**; the value of the time of arrival represents: X day (of the month), XX hour, XX minute, XX second, XXX millisecond, XXX microsecond, XXX nanosecond.

5) **The sound velocity v = L / ΔT.** In the calculation of sound velocity, **ΔT** is taken as the average value of lead breaking of multiple simulated sources;

6) Input the calculated sound velocity into the **[Sound velocity]** in the **[Location setting]** of the **[Locate Setting]** function of the corresponding location graph.

7.2.8. Location Calibration Test

The location calibration test compares the location point generated by artificial simulation source with the actual acoustic emission source location to determine whether the two are consistent. In the industrial detection, the error range of pressure vessel is based on whether the calculated point is the unique corresponding point and whether it conforms to the location error range. The error range of the pressure vessel is within 5% of the maximum distance between sensors. The location calibration test is generally based on the approximate modeling view with location requirements and software supports, and the test in this stage should be the same as that used in the later detection. The analog stimulation source used in location calibration should be as similar as possible to the signal characteristics from the

material itself, such as simulating crack propagation by breaking pencil leads or simulating corrosion signals by sandpaper grinding.

In general applications, the steps and methods related to the source locating have great differences in accuracy due to different location methods. Therefore, as a general reference, a reasonable location setting should be made for each location type according to the actual needs.

For general detection applications, the location setting steps are as follows:

1) The sensor layout scheme and location graph type are defined

2) According to the structure and attenuation characteristics, the grouping mode of sensors is defined, and several sensors participate in the TDOA location of the current array;

3) The sound velocity used in TDOA location is defined;

4) Clearly known the sensor sensitivities;

5) Enter the "Location setting" interface corresponding to the location graph, and input the corresponding settings, such as sound speed, event settings, etc. Refer to Chapter 6.2.6.2.6.9.

6) Enable all channels to be used, set the corresponding "waveform threshold" and "parameter threshold", and then start acquisition.

7) Then try to locate the typical position by simulating the source, to see if the location results are consistent with the expected results. Otherwise, the above steps need to be repeated until the location meets the requirements. Generally, it can be achieved by adjusting the sound speed and the "Event Settings".

7.2.9. Data Acquisition

After the location calibration is completed, the AE signal acquisition for the official AE test can be carried out. The data acquisition in this stage is the generation and capture of real AE

signals, and it does not need to manually apply the analog source signals on. The acoustic emission detection of pressure vessels generally includes the data acquisition in the pressure boosting and pressure maintaining stages; the data acquisition in each stage can be carried out according to the proposed test scheme in the laboratory;

Before and after this stage of work, the set configuration file can be saved to facilitate the subsequent use of the same specification test and subsequent data analysis and processing; click **[File]** in the menu bar, and then select **[Save Settings as]** to store the configuration file in the specified folder.

7.2.10. Secondary Sensitivity Test

When the acoustic emission test is carried out continuously for a long time or the installation position of the sensor is in a harsh environment, the coupling state of the sensor may change. The method is the same as that in Chapter "7.2.5 Channel Sensitivity". If there is a big difference between the post sensitivity and the sensitivity before detection, it is necessary to refer to the data in the process of data analysis or to develop a new detection scheme to conduct the test again.

7.2.11. Reverse Location Calibration

For the obvious source location concentrated areas indicated in the location graph, use the same detection settings and the simulation source to do the reverse location calibration. The reliability and accuracy of the acoustic emission source locations are determined by combining the actual location of the source point and the position of the tested component. The method is the same as that in Chapter "**7.2.8 Location calibration test**".

7.2.12.   Data Analysis

After the completion of data acquisition, the main work after is the data analysis. Data analysis refers to the replay of stored data, and the selection of data processing means in the replay process. The authenticity and trade-off of data results are targeted to obtain the correct results, which can be implemented by referring to the corresponding standards or technical literature. For example, the inspection of pressure vessels can refer to <NB/T 47013.9-2012 nondestructive testing of pressure equipment Part 9: acoustic emission testing> or <GB/T 18182-2012 method for acoustic emission testing and result evaluation of metal pressure vessels>.

7.2.12.1.   Parametric Filter

Parameter filter is to set the upper and lower limit values of different characteristic parameters, which will not be displayed in the replay process, and the filtered parameters will be drawn correlation graph, location graph calculation and other processes.

In metal pressure vessel detection, the common filter settings include increasing the amplitude threshold, filtering the parameters of small counts and too long of the rise time. The values in the figure do not have any significance, and are only for example. These filter settings can refer to the relevant literature on acoustic emission signal of metal materials. The parametric filter should be analyzed according to the field noise of each working condition Be careful. When you do not select a view, click [Global Parameter Filter] in the location to add a global parameter filter, which is valid for all views related to parameters; when a view is selected, clicking [Parameter Filter] only takes effect for the current view, and attention should be paid to the specific use.
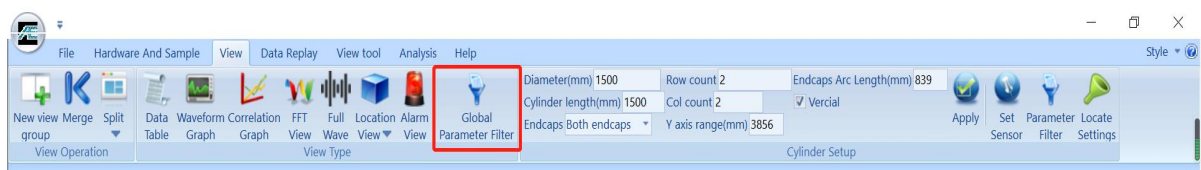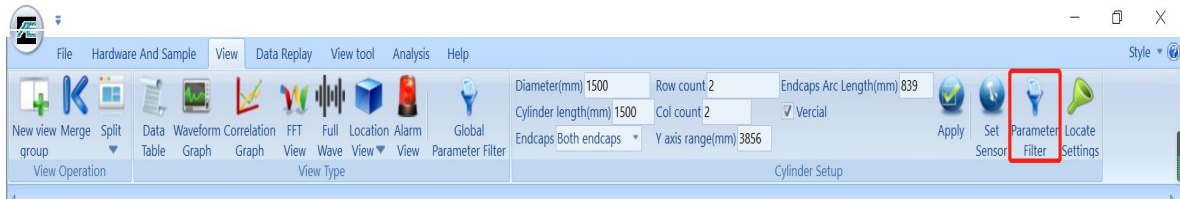

Fig. 7-19 Global Filter

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Fig. 7-20 Parameter filter setting

7.2.12.2. Location Rule Adjustment

If, after the parameter filter, the distribution of location events in the location graph is still scattered and disordered except for the location concentrated area, it can be considered to adjust the location rules appropriately to remove the scattered location points, on the premise that the scattered location points can be identified as noise interference or other meaningless signals according to the data distribution. The adjustment of location rules is mainly "event definition time" and "event lock time". When the location points are disordered and scattered, the "event definition time" and "amplitude deviation" can be appropriately reduced, and the "event locking time" can also be appropriately increased.