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# Quick Manual: Determination of the Sound Reflection Index of Noise Barriers in situ

Determination of the sound reflection index and sound absorption coefficient

- of noise barriers at roads in situ according to DIN EN 1793-5:2018-12
- of noise barriers at railways in situ according to DIN EN 16272-5:2024-02

with the measuring system AcoustiAdrienne and the analysis software AcoustiStudio.

AcoustiAdrienne®

Version of manual: 1.0

Software version: 3.6.x



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# 1 Introduction and Measurement Principle

The measuring system AcoustiAdrienne together with the analysis software AcoustiStudio - module Sound Reflection in situ is an efficient tool for determining the sound reflection index and the sound absorption coefficient of noise protection devices on roads and railway tracks in situ. Based on this, the reflection loss is determined in accordance with ZTV Lsw 22 for the product qualification of noise barriers in non-reverberant environments.

The non-destructive measurement of spectral sound absorption (sound reflection index and sound absorption coefficient) on noise barriers is carried out utilizing the Adrienne method described in DIN EN 1793-5 and DIN EN 16272-5. Two impulse response measurements are carried out in each case, one measurement on the test specimen (noise barrier) and one measurement without test specimen (free field).

The impulse response determined from the measurement on the test specimen basically consists of a direct component, a component reflected from the front of the test specimen and other components reflected from the ground or surrounding obstacles. The latter are excluded by applying a time window (Adrienne window) (see Figure 1.1).

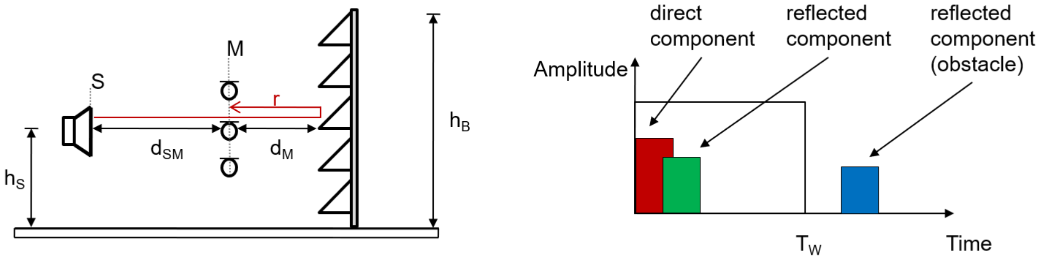


**Figure 1.1: schematic measurement setup for the measurement at the test specimen (left) and general result (right)**

The measurement without test specimen (free field) results in an impulse response that only contains a direct component and the later reflections excluded via the time window (see Figure 1.2).

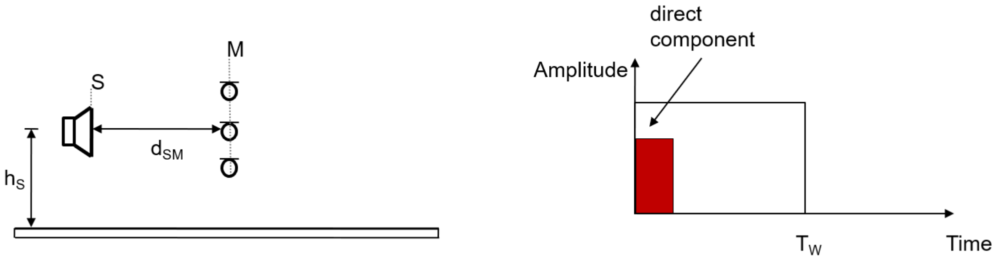


**Figure 1.2: schematic measurement setup for the free field measurement without test specimen (left) and general result (right)**

Finally, the reflected component is isolated by subtracting the two measured impulse responses and the sound reflection index of the test specimen is calculated as the spectral energy ratio of the reflected and direct components (see Figure 1.3).

reflected component

$$RI_j = \frac{1}{n_j}\sum_{k=1}^{n_j}\left[\frac{\boxed{\int_{\Delta f_j}\left|\mathcal{F}\{t \cdot h_{r,k}(t) \cdot w_{r,k}(t)\}\right|^2 df}}{\boxed{\int_{\Delta f_j}\left|\mathcal{F}\{t \cdot h_{i,k}(t) \cdot w_{i,k}(t)\}\right|^2 df}}\right] \cdot C_{\mathrm{geo},k} \cdot C_{\mathrm{dir},k}(\Delta f_j) \cdot C_{\mathrm{gain},k}(\Delta f_g)$$

direct component

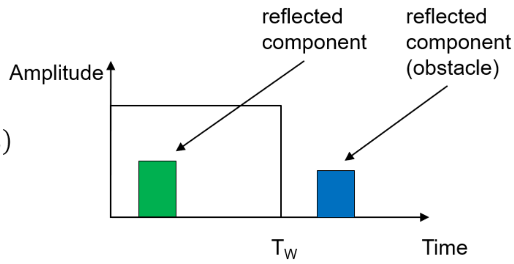


**Figure 1.3: Left: Calculation procedure for determining the sound reflection index RI; right: isolated reflected component as a result of subtracting the impulse responses with and without test specimen.**

## 2 Hardware Setup

Before measuring the reflection index of a noise barrier in situ, the measuring system AcoustiAdrienne must be set up and configured as shown in Figure 2.1. The setup, in particular the cabling of the components, depends in detail on the individual hardware configuration. Thus, this quick guide is limited to a schematic representation.

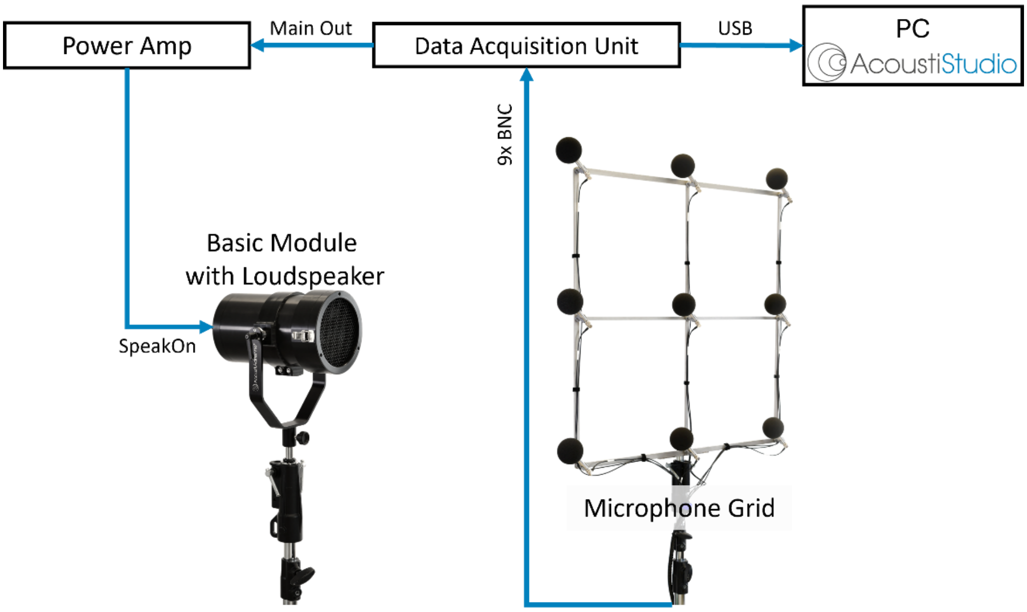


**Figure 2.1: schematic setup of the main components of the measuring system AcoustiAdrienne – module Sound Reflection in situ**

When aligning the microphone grid for the measurements, the correct position of the microphones in relation to the noise barrier as well as the basic module with loudspeaker must be ensured. In particular, it must be checked that the channel assignment corresponds to the following figure and that the microphone side of the microphone grid faces the noise barrier. The required distances between the microphones in accordance with DIN EN 1793-5 and DIN EN 16272-5 are ensured by the microphone grid itself, while the distance between the microphones and the test object can be easily adjusted using the included spacers. Only the alignment of the sound source, at a distance of 1.25 m in the centre in front of microphone M5, is carried out manually by the user.

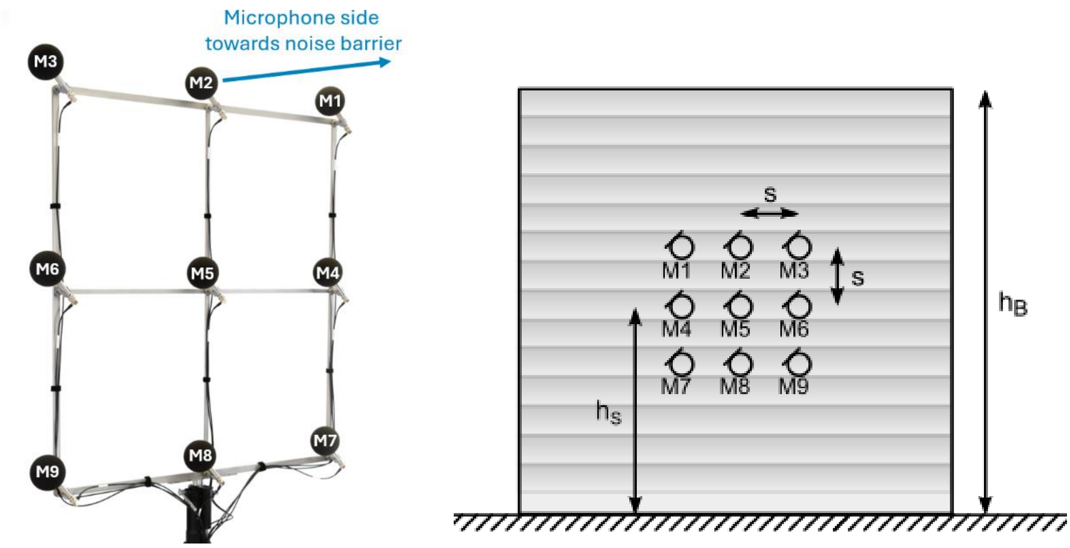


**Figure 2.2: Left: Microphone grid with indication of the alignment to the noise barrier; right: schematic representation of the microphone positions from the viewing direction of the sound source**

The following figure shows two exemplary measurement setups of the AcoustiAdrienne - module Sound Reflection in situ in front of different types of noise barriers.

**Figure 2.3: Exemplary setups of the measuring system AcoustiAdrienne - module Sound Reflection in situ on noise barriers**

# 3 Software Setup

Before starting a measurement of the sound reflection index in situ, the corresponding module is started in the AcoustiStudio by simply clicking on the icon in the menu bar. This opens the **Initialising Measurement....** dialogue window. The basic settings for the data acquisition unit(s) are made here using the drop-down menus.

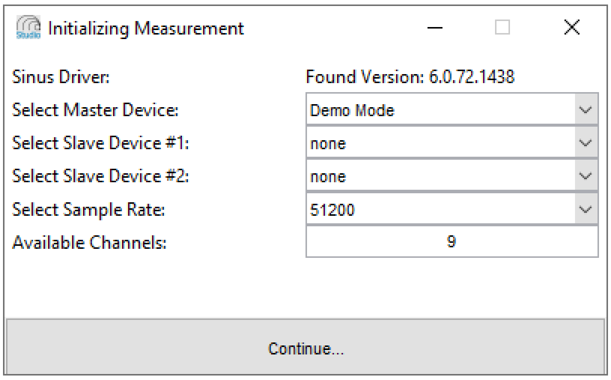


**Figure 3.1: Dialogue window for the selection of the data acquisition units**

In addition to displaying the installed hardware driver, the required nine input channels can be combined from up to three synchronised data acquisition units, depending on the existing hardware.

Once the configuration of the data acquisition units has been completed, the module Sound Reflection in situ is started by clicking on the **Continue...** button.

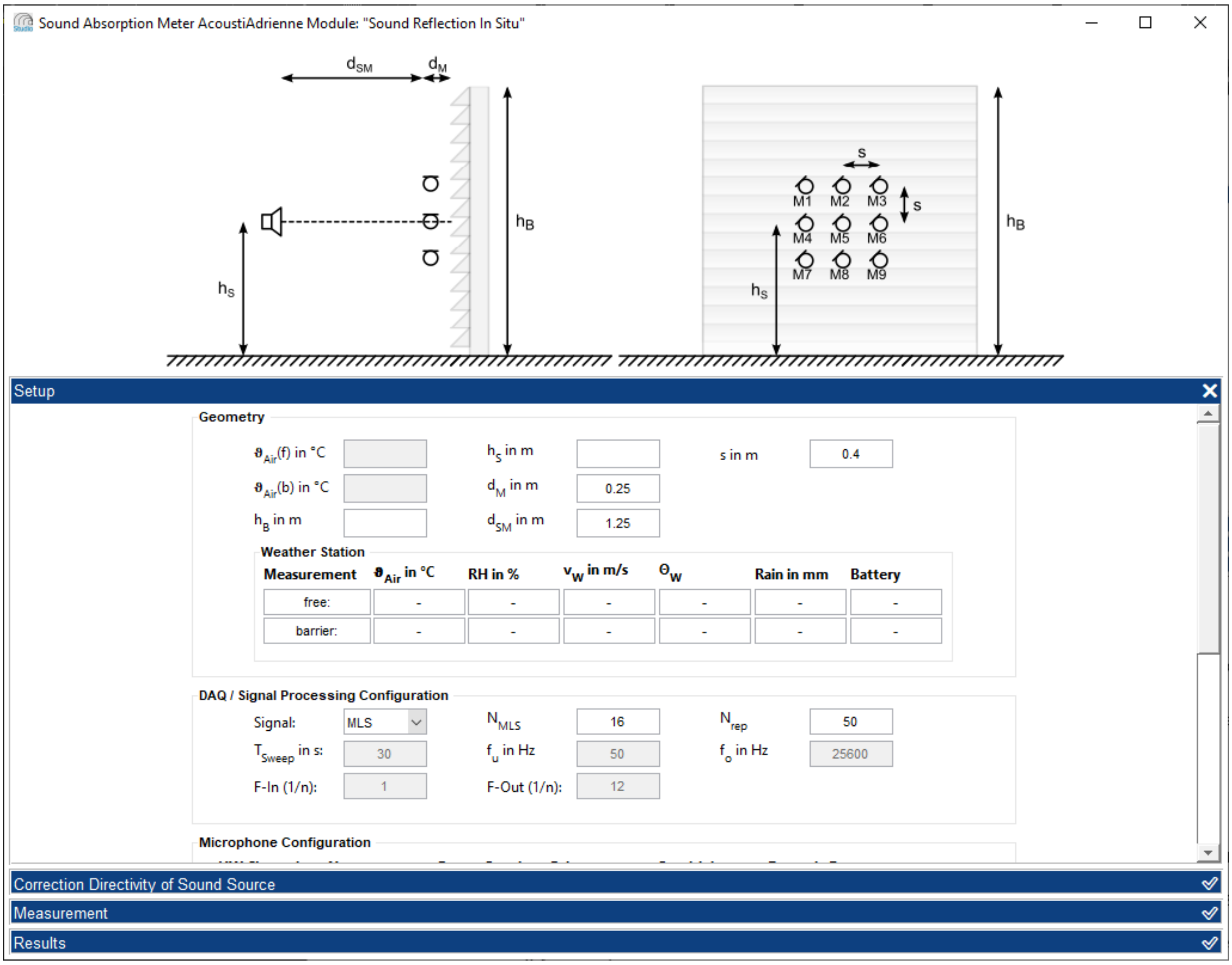


**Figure 3.2: User Interface of the module Sound Reflection in situ after starting the software**

At the top of the user interface of the Sound Reflection in situ module is a schematic representation of the measurement system. This provides the user with simple visual feedback on the required measurement setup in each measurement step. The operating elements and input fields for controlling the measurement are arranged below this. After starting the module, the **Setup** tab is opened first. The basic settings for the respective measurement are made here.

In the first segment **Geometry**, the dimensions and distances of the measuring system and test object as well as the ambient conditions are specified. In particular, the user can set the parameters:

- **$h_B$**... height of the noise protection device
- **$h_S$**... reference height, i.e. the height of the sound source and the centre microphone above the ground

must be defined. To determine the sound reflection index over the entire available height of the noise protection device and thus the maximum possible frequency range, **$h_S$** should be set to half the height **$h_B$**.

If the optionally available weather station is connected, the input fields for the temperature (**$\vartheta_{Air}$(f)** and **$\vartheta_{Air}$(b)**) are disabled. Instead, the **Weather Station** segment appears in which the temperature **$\vartheta_{Air}$**, the relative humidity **RH**, the wind speed **$v_W$** and direction **$\Theta_W$** and the amount of rain are displayed for both the free-field measurement and the measurement with test object. This data is recorded automatically during the respective measurement so that no user input is required.

Below the geometry parameters, the measurement signal can be adjusted in the **DAQ / Signal Processing Configuration** segment. The software enables extensive configuration of the measurement signal so that the achievable signal-to-noise ratio of the measurement results can be specifically optimised for different environmental conditions. A full description of these options can be found in the detailed AcoustiStudio operating instructions. However, the preset default values already enable very effective measurements, even in noisy environments, e.g. next to busy motorways.

The **Microphone Configuration** is adjusted in the third area of the setup tab. To supply the active electronics of the measurement microphones, the appropriate power supply must be selected for each microphone in the **Power Supply** drop-down menu. This naturally depends on the individual hardware configuration.

Furthermore, the amplification factor of the data acquisition unit can be selected in the **Gain** drop-down menu to optimise the measurable dynamic range. The second factor influencing the dynamic range of the measurement is the **Sensitivity** of the microphones. Either a data sheet value can be entered here, or the microphone can be calibrated.

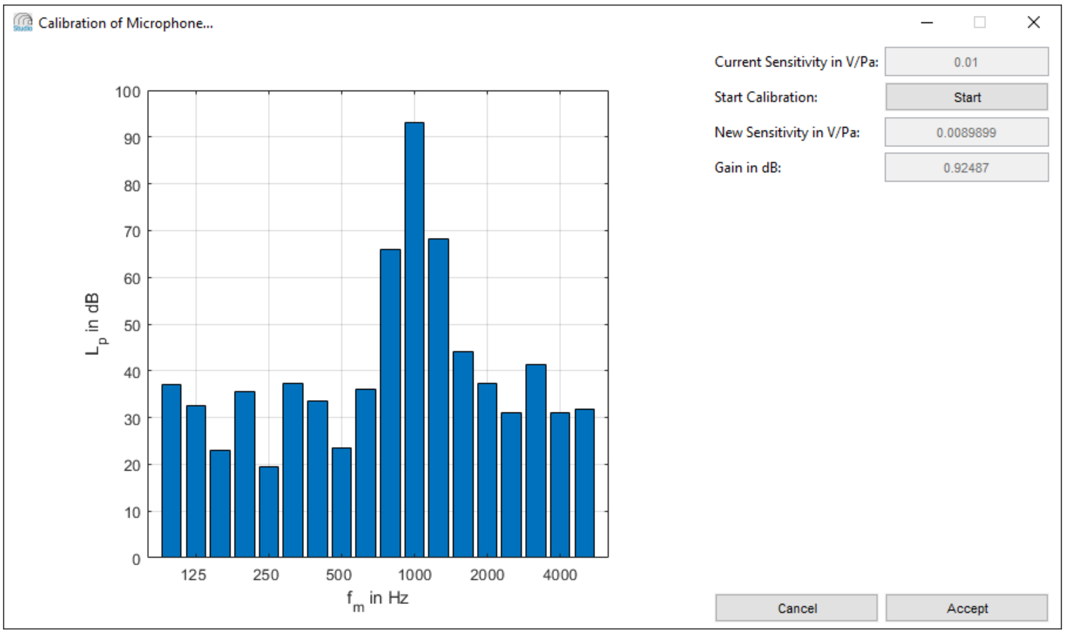


**Figure 3.3: dialogue window for the calibration of the microphones**

Click on the **Calibrate...** button to open the **Calibration of Microphone....** dialogue window. The sensitivity of the individual microphones is determined here using a calibrator.

Based on the microphone sensitivity and the gain of the data acquisition unit, the dynamic range available for the measurement is calculated and indicated in the last column for information purposes. The actual dynamic range that can be used for the measurement may be further limited by the characteristics of the microphones used.

Figure 3.4 shows an example of a fully completed setup.

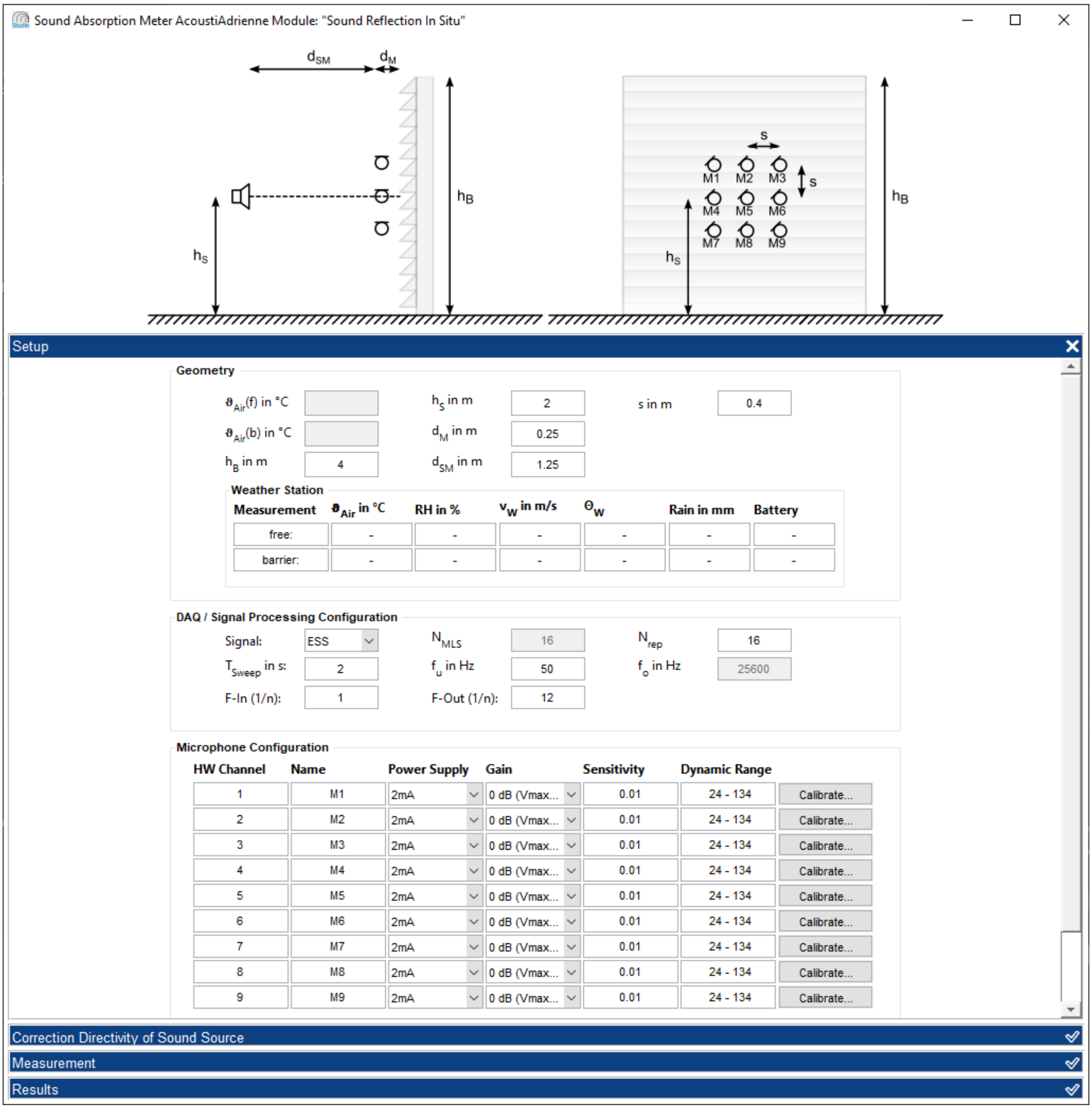


**Figure 3.4: user interface of the module Sound Reflection in situ with completed setup page**

## 4 Measurement – Determination of the Impulse Responses

Once the **Setup** has been completed, the tab for carrying out the measurement can be opened by clicking on the tick at the bottom right of the **Measurement** bar. The user interface then corresponds to Figure 4.1.

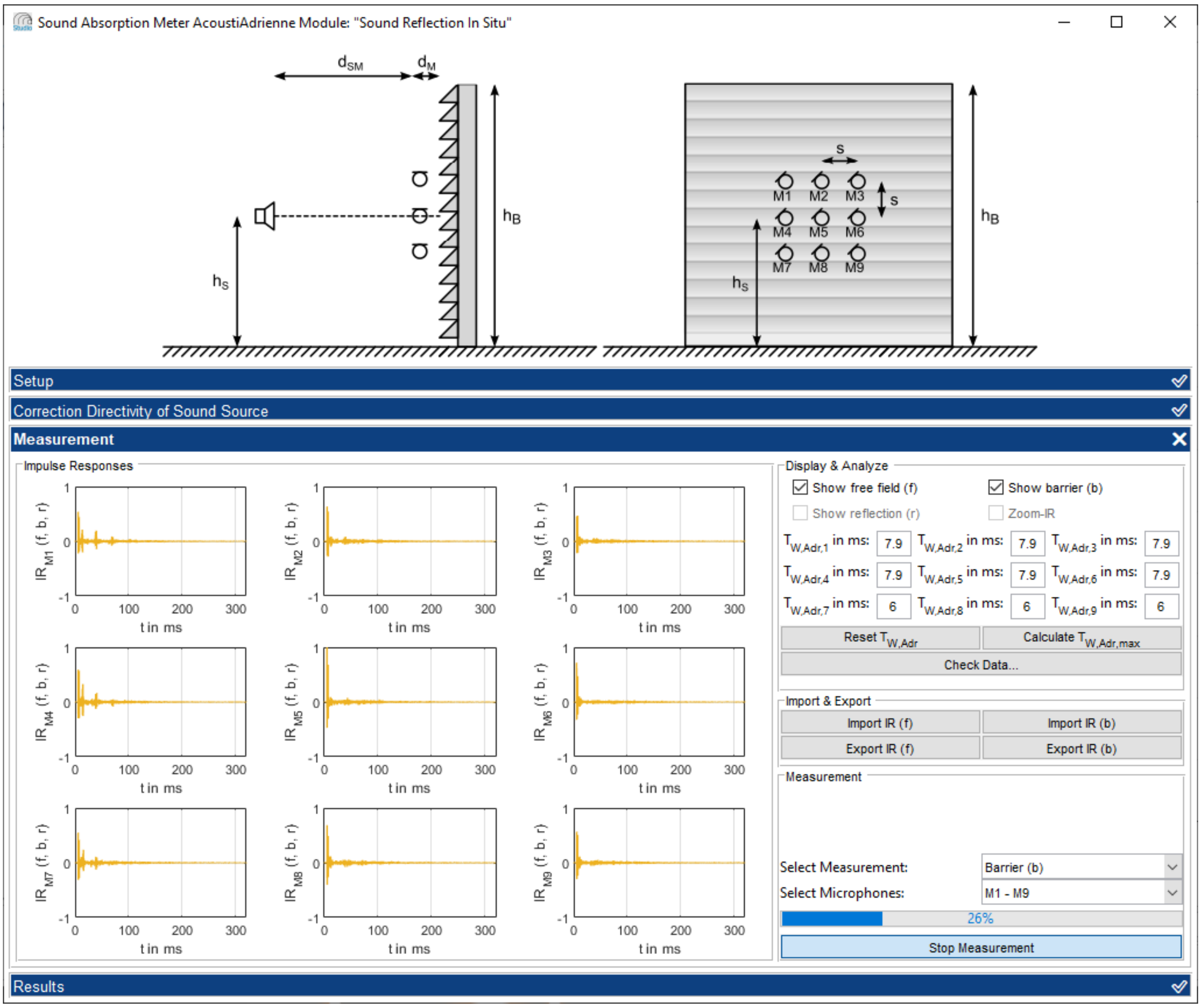


**Figure 4.1: User interface of the module Sound Reflection in situ during the measurement of the impulse rersponses**

The left-hand area of the user interface contains an area for displaying the measured impulse responses. The controls for the measurement and the graphical appearance of the impulse responses are located in the right-hand area.

At the bottom right, the **Measurement** segment controls the selection and execution of measurements. The **Select Measurement** drop-down menu allows you to choose between the free field measurement (**Free field (f)**) and the measurement in front of the noise reduction device (**Barrier (b)**).

After selecting the type of measurement (b/f), the measurement can be started by clicking on the **Start Measurement** button. During the measurement, the impulse responses are displayed in the results diagrams and updated with each additional averaging. The progress of the measurement is also displayed in a progress bar.

Once the measurement has been completed, the impulse responses determined can be exported directly. The buttons in the **Import & Export** segment are used for this purpose.

After the impulse responses in the free field and with noise protection device have been measured or loaded, the appearance and processing of the data in the **Display & Analyse** segment can be adapted. Firstly, the subtraction procedure described in DIN EN 1793-5 should be carried out. The **Check Data....** button is used for this purpose and starts the calculation of the reflected portion of the impulse response. After the calculations are completed, the **Quality of Measurement** window shown in Figure 4.2 opens.

Important parameters for evaluating the measurement performed are displayed here. The first parameter is the correction factor of the microphone sensitivity or gain $C_{Gain}$. This is used to compensate for small changes in microphone sensitivity, e.g. due to temperature fluctuations between measurements. However, if the correction factor is in the red range, at least one partial measurement must be repeated, as the recorded level differences are too large for an exact measurement.

The second parameter for the quality of the measurement is the reduction factor $\mathbf{R_{sub}}$. This indicates how effectively the direct component of the impulse response could be minimised compared to the reflected component during impulse response subtraction. The reduction factor is therefore the signal-to-noise ratio between the reflected component and the remaining proportion of the direct component. If the reduction factor is less than 10 dB (red area), the test setup, in particular the alignment of the system components, should be critically checked and the measurements repeated if necessary.

The third parameter for the quality of the measurement is the frequency-dependent signal-to-noise ratio (**SNR**). This is displayed for all nine microphones over the entire frequency range of the measurement. If the signal-to-noise ratio is less than 10 dB, the measurement should be repeated with optimised system settings. In particular, check whether the number of averages $\mathbf{N_{rep}}$ can be increased in order to achieve a higher signal-to-noise ratio.


**Figure 4.2: dialogue window Quality of Measurement**

Once the quality of the measurements has been checked by the user in the control window, the window can be closed by clicking on the **OK** button.

In the user interface of the module Sound Reflection in situ, the **Show Reflection (r)** and **Zoom IR** checkboxes are now available in the **Display & Analyse** segment. If the **Show Reflection (r)** option is activated, the reflected and windowed part of the impulse response is displayed in the result diagram. The **Zoom IR** function scales the axes of the diagrams to achieve an ideal representation of the impulse responses and the time windows. If both options have been activated, the user interface corresponds to the example in Figure 4.3.

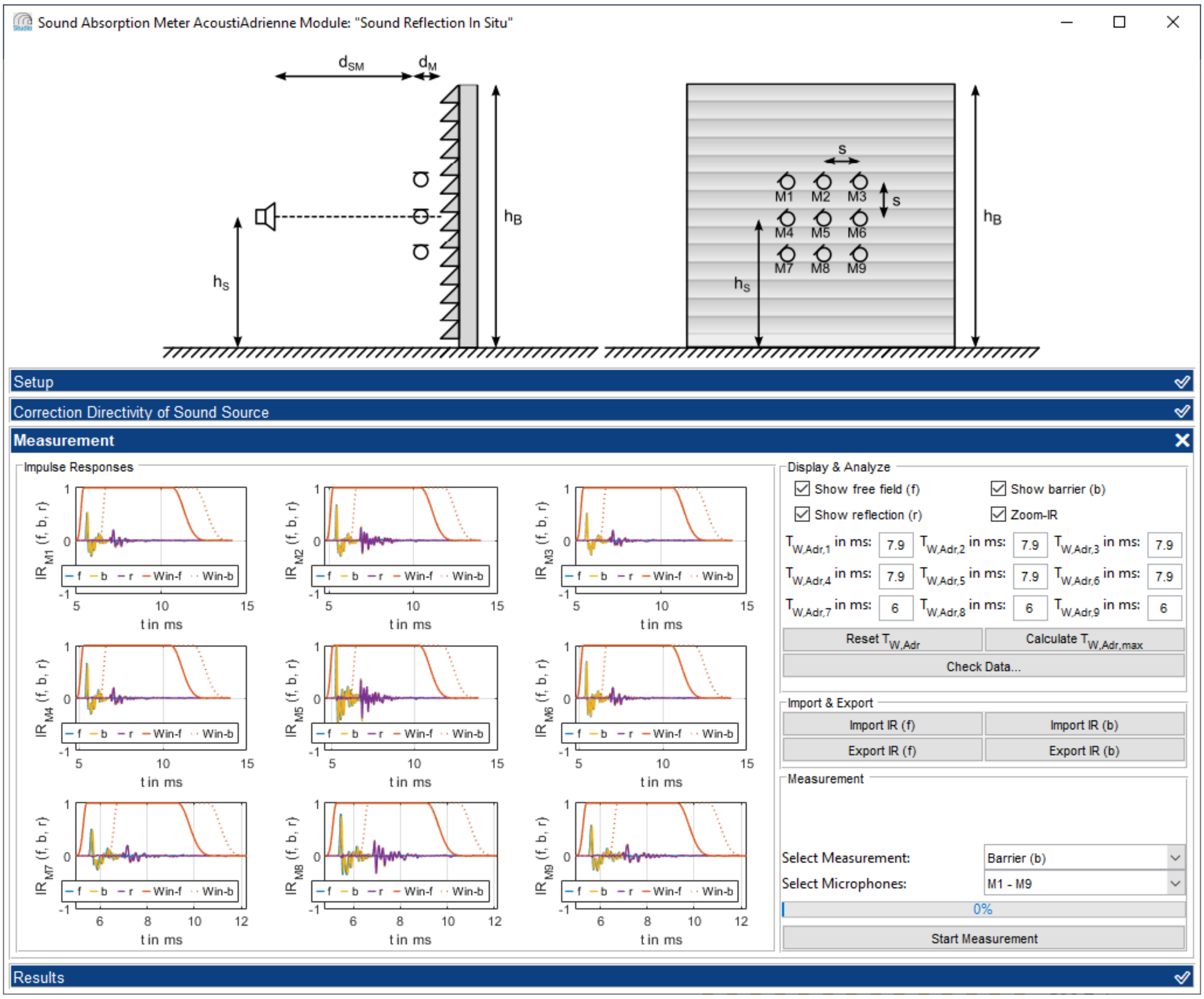


**Figure 4.3: User interface of the module Sound Reflection in situ after the full set of measurements is completed and the reflected component has been calculated**

The **Display & Analyze** segment also contains the **Reset** $\mathbf{T_{W,Adr}}$ and **Calculate** $\mathbf{T_{W,Adr,max}}$ buttons for controlling the time windowing. By clicking **Reset** $\mathbf{T_{W,Adr}}$, the window length can be reset to the value specified in DIN EN 1793-5 for a reference height $\mathbf{h_S}$ of 2 m.

If a different reference height was used for the measurements carried out, the maximum permissible window length can be calculated using the **Calculate** $\mathbf{T_{W,Adr,max}}$ button. This makes it possible to extend the valid frequency range of the measurement to lower frequencies in the case of a particularly high noise barrier. It also ensures that ground reflections are excluded from the evaluation of the impulse responses if the reference height is less than 2 metres.

## 5 Calculation of the Sound Reflection index RI and Sound Absorption Coefficient α

After the required measurements have been carried out in the **Measurement** tab and the impulse responses and their time windowing have been checked, the tab for calculating the sound reflection index can be opened by clicking on the tick in the right-hand area of the **Results** bar. Figure 5.1 shows the user interface in the **Results** tab.

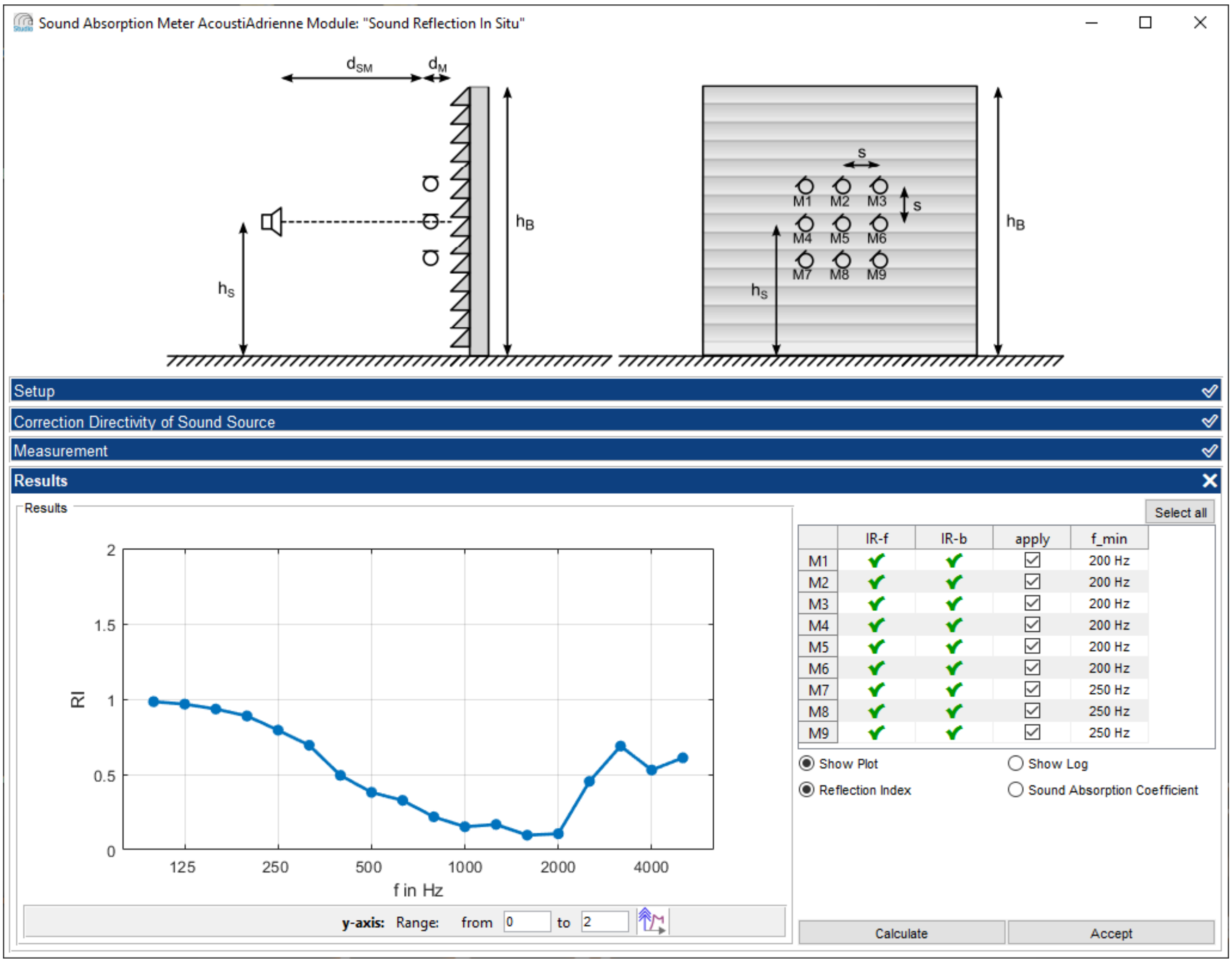


**Figure 5.1: User interface of the module Sound Reflection in situ with the graphical representation of the results of an exemplary measurement**

Here too, the user interface is divided into the **Results** segment for displaying the results on the left-hand side and the control elements for displaying and analysing the data on the right-hand side.

A table for selecting the impulse responses for the calculation is located in the upper section on the right. The first two columns **IR-f** and **IR-b** show the availability of the measured impulse responses in the free field and in front of the noise protection device. Successfully determined impulse responses are marked with a green tick, while impulse responses that are not determined are marked with a red cross. In the **apply** column, you can use the checkboxes to select which microphone positions are to be included in the calculation of the sound reflection index. For example, if only M5 is selected, the sound reflection index can be determined for normal sound incidence, while if all microphones are selected, the reflection index is averaged for different angles of incidence. To avoid having to select all checkboxes individually when using all nine microphone positions, a click on the **Select all** button selects all microphone positions for the calculation. The last column **f_min** shows the valid lower cut-off frequency for the measurement results determined from the window length.

Below the table there are buttons to control the presentation of the results. Here you can choose between a graphical display (**Show Plot**) and the display of a log file (**Show Log**). For the graphical display, you can also switch between the display of the sound **Reflection Index** and the **Sound Absorption Coefficient**. Both measured variables are always included in the log file.

Clicking on the **Calculate** button starts the calculation of the sound reflection index. As soon as the calculation is complete, the results appear on the left-hand side of the user interface, as shown in Figure 5.1.

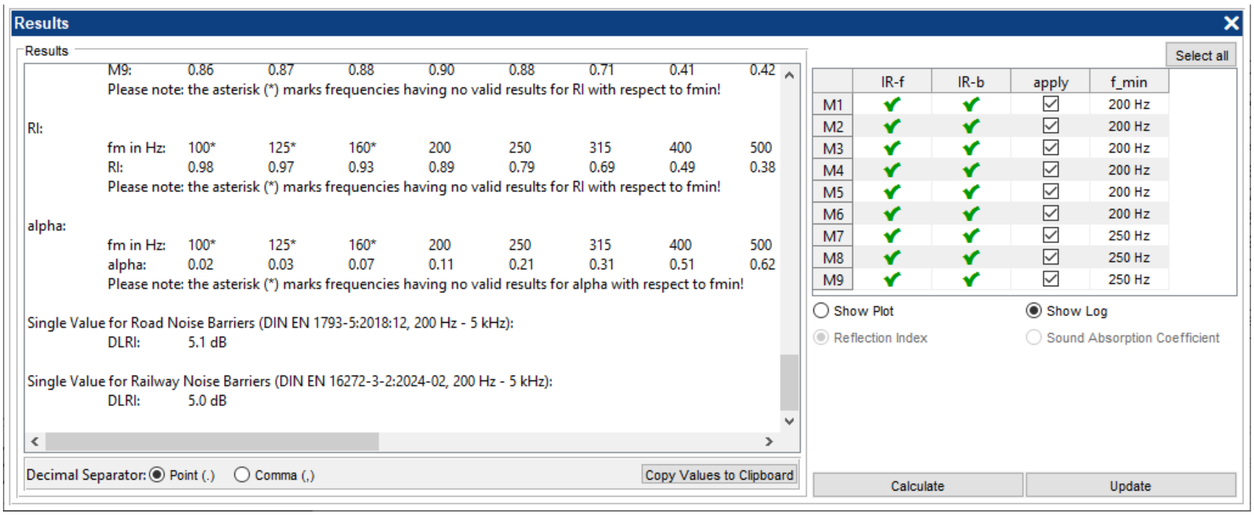


**Figure 5.2: Segment of the user interface of the module Sound Reflection in situ with the results as a log-file including the single values $DL_{RI}$**

Figure 5.2 shows the result display in text form (**Log** file). Below the text field there is a menu bar that allows you to select the decimal separator. This allows the data to be adapted for further processing in external software. By clicking on the **Copy Values to Clipboard** button, the entire content of the log file is copied to the clipboard and can therefore be easily exported.

In addition, for the sound reflection index (**RI**), the single value $\mathbf{DL_{RI}}$

- for noise barriers on roads in situ according to DIN EN 1793-5
- for noise barriers on railway tracks in situ according to DIN EN 16272-3-2

is specified in the log file. By clicking on the **Accept** button and assigning a name, the current measurement is transferred to the AcoustiStudio data viewer where it can be displayed and analysed further.

## 6 Comparison of Measurement Results and Report Generator

Completed measurements of the sound reflection index are collected in the AcoustiStudio data viewer and can be efficiently analysed and compared there. The measurement objects are collected in the tree structure on the left-hand side of the user interface, while the measurement results are displayed graphically on the right-hand side of the user interface. Figure 6.1 shows an example of the user interface with several measurement objects.

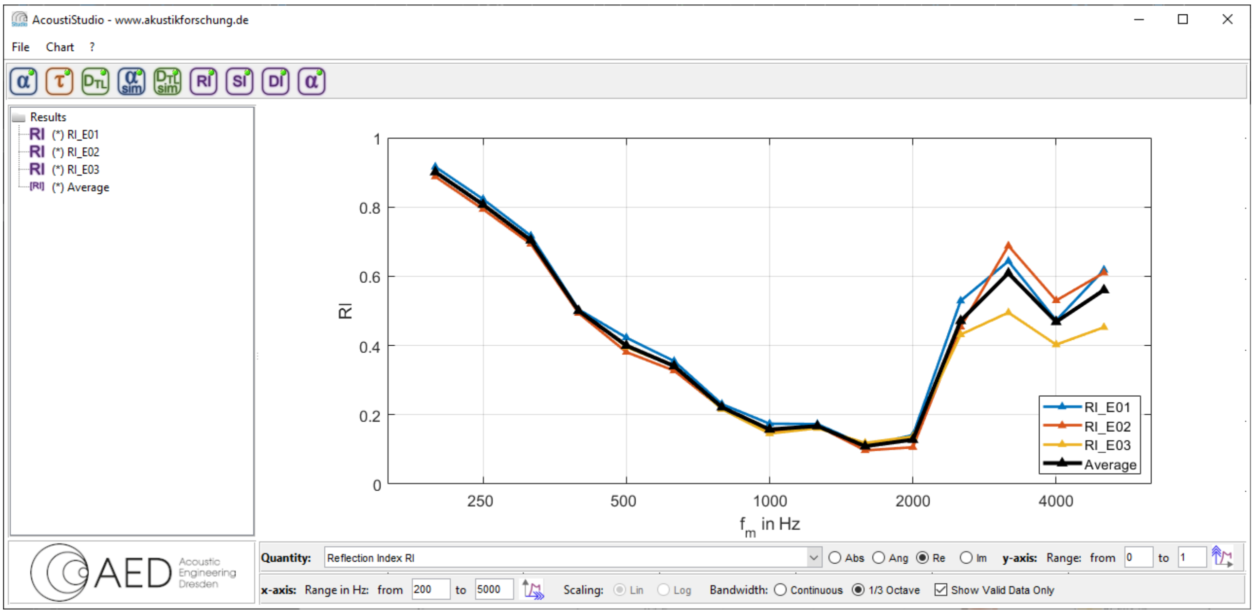


**Figure 6.1: User interface of the data viewer of the AcoustiStudio with exemplary measurements of the Sound Reflection Index of three different elements of the same noise barrier and the according average value.**

In the data viewer, the display of the measurement results can be intuitively customised via the context menus (right-click) of the individual measurement objects or in the diagram. In the **Chart** menu, the display can be further modified and the results exported as pixel and vector graphics so that images for presentations or publications can be generated directly in AcoustiStudio.

In this part of the software, average values can also be calculated from several measurements (context menu) and measurement reports can be created using the optional report generator function. The report function is started by right-clicking on a suitable data set and selecting the **Generate Report...** option.

After selecting the language, the user interface of the report generator opens, in which all further entries are made. The user interface of the report function is shown in Figure 6.2. As the report generator accesses the measurement data and all the data entered in the software for the setup and the ambient conditions, only a small amount of additional data, such as the client for the measurement, needs to be entered. As extensive loading and saving options are also available for this, the report generator is an extremely effective and fast way of creating measurement reports.

A detailed description of all options in the AcoustiStudio data viewer and the report generator can be found in the detailed AcoustiStudio operating instructions.

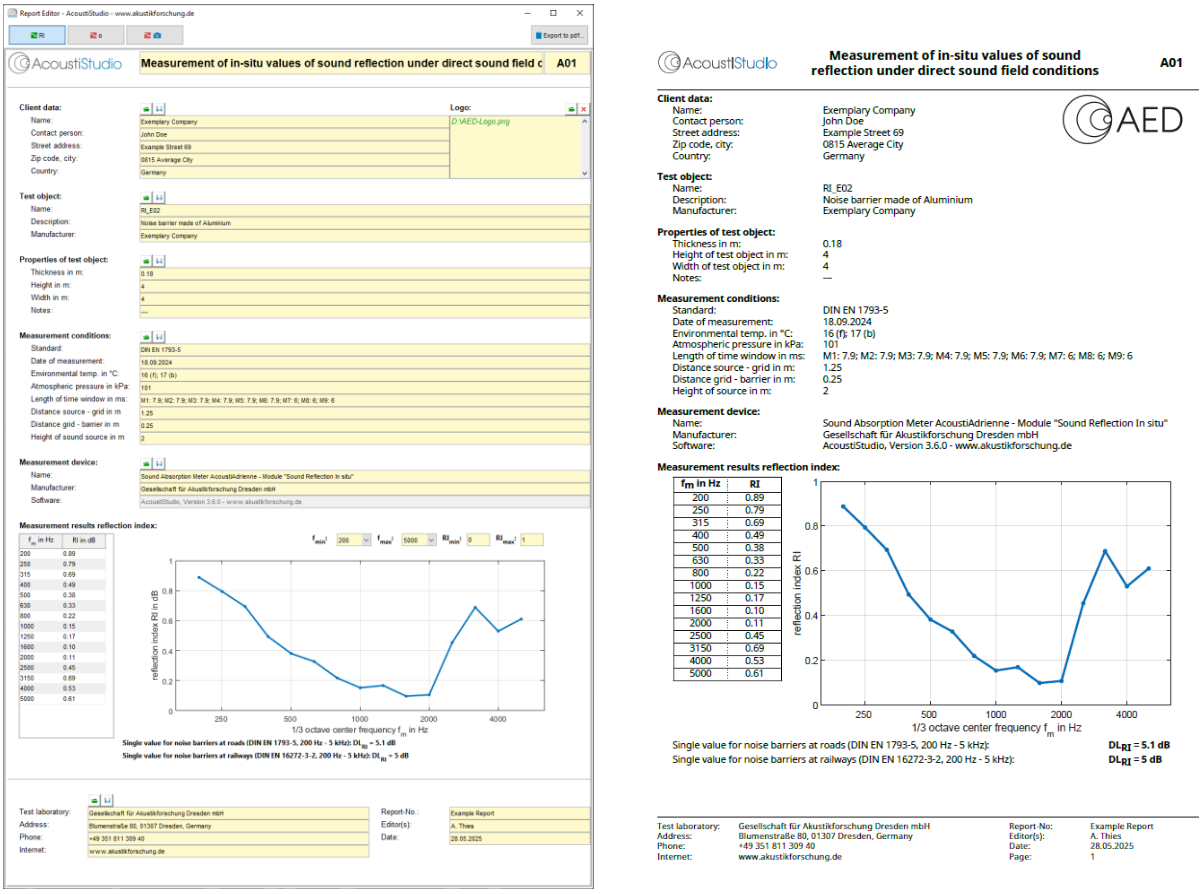


**Figure 6.2: User interface of the report generator and exported measurement report for an exemplary measurement of the Sound Reflection Index with the measuring system AcoustiAdrienne and the software AcoustiStudio – module Sound Reflection in situ**