

Calibration of the BATmode-System

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Calibration of the BATmode-System is essential to make recorded bat activity data comparable. As we are continually asked calibration related questions, we would like to briefly explain and demonstrate in this article how you can ensure correct calibration of your system.

General information

The aim of the calibration of a microphone is to relate the electrical output of the microphone to the actual sound pressure level. This sound pressure level L_p (SPL) is generally expressed in the unit dB SPL and describes the logarithmic ratio of the squared effective value of sound pressure \tilde{p} of a sound event to the square of the reference value p_0 . For airborne sound this reference value is set to $p_0 = 20 \mu\text{Pa}$.

$$L_p = 10 \cdot \log_{10} \left(\frac{\tilde{p}^2}{p_0^2} \right) \text{dB} = 20 \cdot \log_{10} \left(\frac{\tilde{p}}{p_0} \right) \text{dB}$$

The sound pressure level L_p can either be positive (sound pressure is greater than the reference value) or negative (sound pressure is smaller than the reference value). In short, the sound pressure level L_p in dB SPL indicates how much louder or quieter a sound event is in relation to a specified reference value. For example, a sound event with a sound pressure level of 6 dB SPL, is twice as loud as the related reference value and a sound event of -20 dB SPL corresponds to a 10 times lower sound pressure in relation to the reference value.

The unit of the electrical output value U of a microphone is given in dBFS (dB full-scale), which is, similar to the sound pressure level L_p , a logarithmized ratio of electrical output value U to the maximum output value (Full scale, FS) of the microphone. Consequently, the microphone output signal U is always smaller than the reference value and thus can only accept negative dBFS values.

As the essential factor in the determination of bat activity is not the loudness of calls per se but their number, it is especially important to define exactly for which real sound pressure level L_p a bat call can trigger a recording. This so-called "Trigger Level Threshold" $A_{\text{dB SPL}}$ thus represents a parameter for the sensitivity of the detection system and make results comparable. In general, it can be said that the quality of a bat activity monitoring can be increased by selecting lower trigger thresholds $A_{\text{dB SPL}}$. This makes it possible to detect quieter calls and therefore calls of distant animals. In turn, this of course also increases the chance to obtain recordings of noise, which have to be laboriously removed from the resulting data set.

For the evaluation of the recorded data with the tool Probat that results from the research projects RENEBAT and thus is compatible with the BMU guidelines, a trigger threshold $A_{\text{dB SPL}}$ of 37 dB SPL is recommended when using the BATmode system. In the case of a wind turbine, which has a particularly high noise level, the trigger threshold $A_{\text{dB SPL}}$ can also be increased to 50 dB SPL to avoid the recording of noise. However, due to the lower sensitivity of the detection system in this case we can expect a significant reduction of quality of the monitoring. For data evaluation, it is of utmost importance that all data was recorded with a uniform $A_{\text{dB SPL}}$ trigger threshold (that is, either 37 or 50 dB SPL). If one part of the data has been recorded with a lower trigger threshold $A_{\text{dB SPL}}$, it is possible to reevaluate them

for a higher trigger threshold $A_{\text{dB SPL}}$ using the RECORDER software. Hereby, quieter calls, which would not have been recorded using the higher trigger threshold $A_{\text{dB SPL}}$, are removed from the data set. Logically, this is not possible in the reverse direction and a data set, which was recorded with a trigger level of 50 dB SPL, cannot be converted to 37 dB SPL.

How does a calibration work in general?

To calibrate a measurement system, it is essential that a reference signal with a known value is given to which the measured values can be related. In case of an ultrasonic recording system, the reference would be an ultrasonic signal with a known sound pressure level L_p .

By exposing the microphone which have to be calibrated to this sound pressure level L_p , the electrical output signal U generated by the microphone can be related to this known sound pressure level L_p .

Calibration of the BATmode-System with microphone discs of bat bioacoustictechnology

The microphones of bat bioacoustictechnology are delivered with a calibration certificate, as exemplified in Figure 1.

Calibration Certificate	
Date of calibration:	XXX
Serial number:	XXX
Calibrated by:	XXX
Calibration Results:	
Full Scale Level of Reference Signal:	-20.0 dBFS
SPL of Reference Signal:	90.0 dB SPL
<small>Note: Please enter the values of calibration in the software BATcontrol of your BATmode-System. For further information concerning this matter, please see the user manual.</small>	
_____ Signature	
<small>bat bioacoustictechnology GmbH Brunnengasse 1 D-90610 Winkelhaid www.bioacoustictechnology.de</small>	

Figure 1: Exemplary calibration certificate of a microphone

On this certificate the so-called *SPL of Reference Signal* (L_T) and the *Full Scale Level of Reference Signal* (U_T) are given. The first one represents the sound pressure level in dB SPL of the in the microphone integrated test signal generator, which arrives at the microphone capsule. The value *Full Scale Level of Reference Signal* indicates the resulting amplitude of the microphone output signal in dBFS, if the test signal generator is activated. For microphones without a test signal generator, only the *Full Scale Level of Reference Signal* value is given, which results from a 96dB SPL reference signal.

For calibration enter the two values, which are also noted on the microphone, for the respective microphone channel in the calibration dialog of BATcontrol (available on the page "Monitoring" by clicking on the button "Calibration", see Figure 2). Furthermore, insert the desired trigger threshold $A_{dB SPL}$ in the field "Level of Trigger Threshold" and select whether your microphone has an integrated test signal generator or not. Then click on the "Calibrate now!" button. By confirming the opening warning your system is calibrated. The calibration is also visually confirmed and the resulting trigger level threshold is displayed in % ($A\%$). This value can be checked in the Configuration dialog of the RECORDER software (see Figure 3).

Figure 2: Calibration dialog in BATcontrol

How were the calibration values on the certificate determined?

1. First, a sound event with a frequency of 40 kHz and a sound pressure level L_{Ref} of 96 dB SPL is produced in an anechoic acoustic chamber at room temperature using a measuring microphone from Brüel & Kjaer and an ultrasonic piezo.
2. The microphone of the disc, which has to be calibrated, is exposed to this precisely defined sound signal and the resulting microphone output value U_{Ref} is determined in dBFS (root mean square).
3. Subsequently, the microphone output value for the built in test signal generator is determined in the same anechoic acoustic chamber. For this purpose, it is excited with a frequency sweep from 30 to 50 kHz in order to compensate for temperature- and type-induced variations of its resonance frequency. The resulting maximum microphone output U_T corresponds to the Full Scale Level of Reference Signal in dBFS (root mean square) specified in the calibration certificate.
4. Subsequently, the SPL of Reference Signal Value (L_T) specified in the certificate is calculated to

$$L_T = L_{Ref} + U_T - U_{Ref}$$

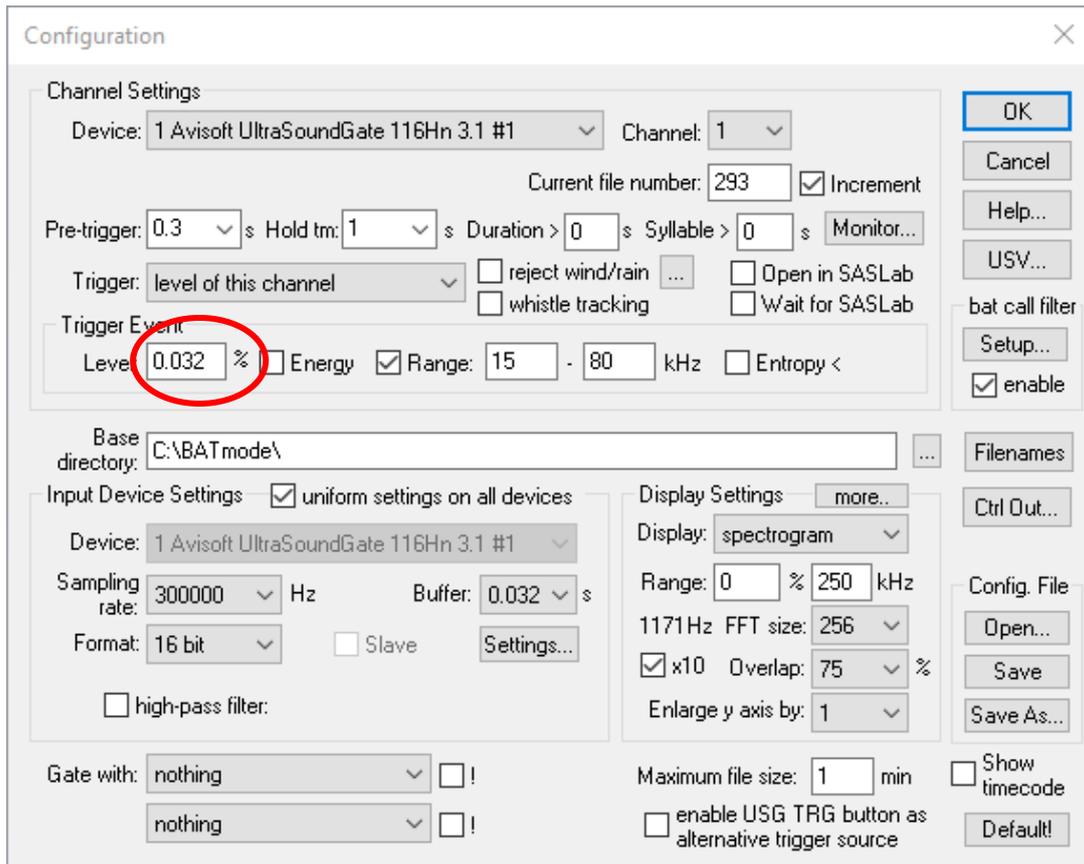


Figure 3: Configuration Dialog of the software RECORDER

Calibration of the BATmode-System with a microphone disc of Avisoft Bioacoustics

In the following, the calibration of the RECORDER software is explained in detail for the case that you are using a microphone or a microphone disc, which is not original from bat bioacoustic technology. Since Avisoft Bioacoustics only indicates the sound pressure level of the test signal generator on its microphone disc, but not the resulting microphone output U_T in dBFS, the output must be measured by utilizing the software RECORDER. (Please perform this measurement at room temperature and, if possible, in an anechoic chamber or hold the disc during the measurement away from walls, so that no possible sound reflective object is in close proximity in front of the microphone disc!):

1. Close BATcontrol.
2. Open RECORDER USGH of Avisoft Bioacoustics.
3. Open the Trigger Level Calibration dialog of the software RECORDER (see Figure 4) (Monitoring -> Trigger level calibration).
4. Select „absolute dB SPL“, „x10“ and „take max signal level“.
5. Enter your desired trigger threshold $A_{\text{dB SPL}}$ (for example, 37 dB SPL) in the field trigger level (threshold).
6. Insert the value L_T of your Avisoft disc in the field reference signal level.

7. Wait 60s and then write down the value of U_T which can be found at reference signal level (root mean square) [dBFS].
 8. Close RECORDER.
 9. Open BATcontrol.
 10. Open the calibration dialog of BATcontrol (see figure 2).
 11. Enter the noted full-scale level of reference signal (U_T) in the appropriate field.
 12. Enter the reference signal level L_T in dB SPL of your Avisoft disc in the appropriate field.
 13. Enter your desired trigger level threshold $A_{\text{dB SPL}}$ in the field Level of Trigger Threshold.
 14. Click on "Calibrate now!" and confirm the opening warning.
1. The calibration is visually confirmed and the resulting trigger level threshold $A_{\%}$ in % is indicated. This value can be checked in the Configuration dialog of the RECORDER software (see figure 3).

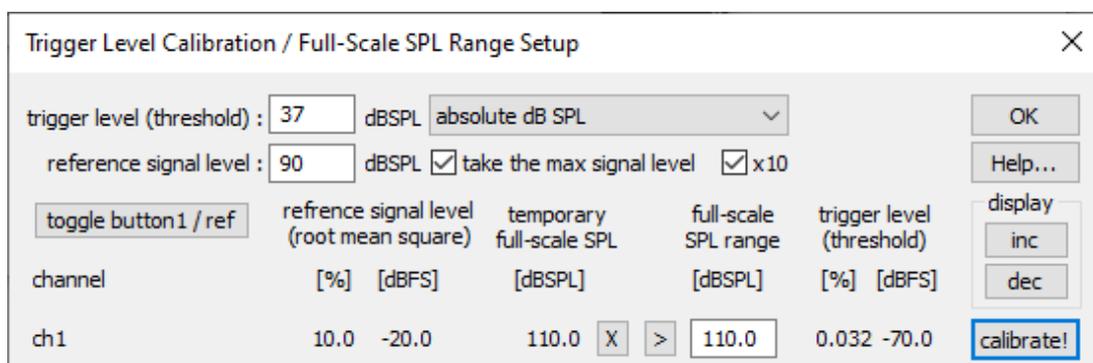


Figure 4: Trigger level Calibration dialog of the software RECORDER

General information about the Trigger Level Calibration dialog of the software RECORDER

At this point, we want to refer to the official user manual of the software RECORDER of Avisoft Bioacoustics, in which the calibration of the software is described for a general case. You can download the manual from www.avisoft.com.

Below, the Trigger Level Calibration dialog of the software RECORDER is explained in detail to give you a broad background knowledge of the calibration functionality of RECORDER software.

Information, which have to be provided by the user:

- Trigger Level (threshold) $A_{\text{dB SPL}}$ [dB SPL]: Determines the trigger level threshold $A_{\text{dB SPL}}$ in dB SPL, for which a trigger event is triggered.
- Reference Signal Level L_{Ref} [dB SPL]: Indicates the reference sound level of a known sound source in dB SPL and serves as reference value for calibration.

Values determined by measurement:

- Reference Signal Level (root mean square) $U_{Ref,dBFS}$ and $U_{Ref,\%}$: Depicts a measured microphone output value in dBFS or %, respectively.

$$U_{Ref,\%} = 10^{\frac{U_{Ref,dBFS}}{20}} \cdot 100$$

If the field "take the maximum signal level" is activated, the maximum value over the entire period of time for which the dialog is open is displayed. Otherwise, the current microphone output value is displayed.

Resulting values:

- Full-scale SPL: Specifies the maximum sound pressure level L_{max} in dB SPL the microphone can record, if a calibration has been performed with the current Reference Signal Level U_{Ref} .

$$L_{max} = L_{Ref} - U_{Ref,dBFS}$$

- Trigger Level (threshold) A_{dBFS} and $A_{\%}$: Specifies the Trigger Level (threshold) in dBFS or %, which represents the desired Trigger Level (threshold) $A_{dB SPL}$ after calibration. These values are updated by clicking on the button "calibrate".

$$A_{dBFS} = -(L_{max} - A_{dB SPL} - 3dB)$$

$$A_{\%} = 10^{\frac{A_{dBFS}}{20}} \cdot 100$$

Here, 3 dB must be subtracted to account for the reference signal level given as RMS (root mean square) value*. After calibration, the trigger level (threshold) $A_{\%}$ [%] corresponds with the value of the Trigger Event Level in the Configuration dialog the software RECORDER (see figure 3).

*Before RECORDER version 4.3.02, due to the "x10" gain option, it was necessary to correct the Trigger Level (Threshold) A_{dBFS} by +20 dB to achieve the desired Trigger Level (Threshold) $A_{dB SPL}$.

$$A_{\%} = 10^{\frac{A_{dBFS}+20dB}{20}} \cdot 100$$