TTT4250 - Acoustical Measurement Techniques

Laboratory Exercise 1: Measurement of Sound Power

performed by

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Summary

This rapport guide you through three different methods of calculating the total A-weighted sound power level of a noise source, as well as comparing and discussing the calculated values for all three methods. The first and second method, based on the ISO3747-and ISO3746 standard calculate the sound power level through pressure levels, with-and without a reference sound source, while the third method, ISO9614, uses intensity. The calculated total A-weighted sound power level was found to be 84.7dB for the first method, 85.0dB for the second method and 85.6dB for the third method. For all three methods the total A-weighted Sound Power Level is around 85.1dB with a spread of 0.9dB from the lowest til the highest value.

The rapport will discuss the differences for the three methods and try distinguish which method that proves to be better and easy to conduct than the others. The third method proves to be hard to conduct while the first and second method are easy to test while also getting good results.

Contents

1 Introduction

This rapport will calculate the sound power level of a noise source by the use of three different techniques. The first method will take use of the standard ISO 3747:2010[1] where the sound pressure level is measured in octave bands, by placing the microphone at five different locations, for both a reference-and test source. The second method takes use of the standard ISO 3746:2010[2] where a reference box is created around the test source hence creating five measurement surfaces. Microphones are placed at the center of each surface and measure the sound pressure level in octave bands to find the total A-weighted sound power level. The third method takes use of the intensity method ISO 9614-2:1996[3]. This method measure the intensity by sweeping the intensity probe along the surfaces of the hypothetical measurement box. The test are done in a reverberate chamber containing smaller objects that has negligible effect. The object of the lab is to discuss the three methods and try decide what method proves to be the better for the given test parameters.

2 Theory

2.1 Method 1: Sound Pressure Method with a Reference Sound Source(ISO 3747:2010)

The first method calculates the sound power level with the use of a reference sound source(RSS) and a test source(ST). To ensure valid data the first step is to check for the need of correction. This is done by checking the difference in sound pressure level between the background noise and the measured sound pressure level for each microphone position for both ST and RSS at each octave band. This difference for both ST and RSS is respectively $\Delta L_{\text{pi,ST}}$ and $\Delta L_{\text{pi,RSS}}$. If the value exceed 15dB the measured sound pressure levels must be corrected[1].

$$L_{\text{pi(Meas)}} = 10 \cdot \log\left(10^{L'_{\text{pi(Meas)}}/10} - 10^{L'_{\text{pi(B)}}/10}\right) \text{dB} \tag{2.1}$$

Where $L_{\text{pi(Meas)}}$ is the corrected sound pressure level of the measured sound source, $L'_{\text{pi(Meas)}}$.

When measuring in a free field the effect of reverberation is neglected, but when measuring in a reverberate room the indicator ΔL_f has to be found. This indicator define the accuracy of the measurements and determines to what grade of accuracy the measurements can receive and what upper bound for the standard deviation of reproducibility the A-weighted sound power level has. The indicator can be found using equation (2.2).

$$\Delta L_f = L_{\text{pi(RSS)}} - L_{\text{w(RSS)}} + 11 + 20 \cdot \log\left(\frac{r}{r_0}\right) \text{dB} \tag{2.2}$$

$L_{\text{w(RSS)}}$ denotes the sound power level of the reference sound source which can be found in Table A.1. When doing the measurements the frequency spectrum of interest is every octave band from 125-8000Hz [1]. To find the total sound power level, the sound power level for each octave band has to first be found using equation (2.3) [1].

$$L_W = L_{W(RSS)} + 10 \cdot \log\left(\frac{1}{N}\sum_{i=1}^{N} 10^{0.1\left(L_{pi(ST)} - L_{pi(RSS)}\right)}\right) \text{dB} \tag{2.3}$$

With the sound power level for each octave band calculated, the total A-weighted sound power level can be calculated as

$$L_{W,A} = 10 \cdot \log\left(\sum_k 10^{0.1(L_{Wk} + A_k)}\right) \text{dB} \tag{2.4}$$

where k denotes each octave bands of interest and A_k are the A-weighting constants for each octave band. The A-weighting constants are listed in Table D.1 in [1].

To ensure that the placement has negligible effect on the sound power level, the ratio between the distance from the microphone to the ST and RSS must be within

$$0.8 \leq \frac{d_{ST}}{d_{RSS}} \leq 1.2 \tag{2.5}$$

where d denotes the distance of the respective subscript to the microphone. If this criteria is fulfilled the zoning effect has negligible effect on the sound power level [1].

2.2 Method 2: Sound Pressure Method without a Reference Sound Source(ISO 3746:2010)

In this method a hypothetical reference box is created around the ST. Furthermore, a measurement box surrounding the reference box needs to be defined. The microphones are placed in the center of each measurement surface with the microphones pointing normal to the measurement surface. Because of the microphones directivity its optimal to have the microphone facing the surfaces straight for maximal transfer of the pressure waves produces by the noise source to the microphone membrane . The environment correction is to be added when the measurements are done in a reverberant room. The environment correction, K_{2A}, is determined as

$$K_{2A} = 10 \cdot \log\left(1 + \frac{4S}{A}\right) \tag{2.6}$$

where S is the sum of all surface areas to the measurement box, and A is the equivalent sound absorption area defined as

$$A = \alpha \cdot S_V \tag{2.7}$$

where α is the sound absorption coefficient, defined in ISO 3746[2], and S_V is the total surface area of the reverberant chamber. The background correction factor can be determined by checking the A-weighted difference, ΔL_A, between the time averaged A-weighted sound pressure level, $\overline{L'_{pA}}$, for the measured positions as seen in equation (2.8), and the time averaged A-weighted sound pressure level to the background noise, $\overline{L'_{pA(B)}}$.

$$\overline{L'_{pA}} = 10 \cdot \log\left(\frac{1}{N}\sum_{i=1}^{N} 10^{0.1L'_{pAi}}\right) \text{dB} \tag{2.8}$$

If ΔL_A is below 10dB the correction factor K_{1A}, given as

$$K_{1A} = -10\log\left(1 - 10^{-0.1\Delta L_A}\right) \text{dB} \tag{2.9}$$

must be added to the equation for the total A-weighted sound power level[2]. The average A-weighted sound power level can then be found by averaging the A-weighted sound power level for all measurement surfaces, and with all the correction factors able to calculate the total A-weighted sound power level as

$$L_{W,A} = \overline{L'_{pA}} - K_{1A} - K_{2A} + 10 \cdot \log\left(\frac{S}{S_0}\right) \text{dB} \tag{2.10}$$

2.3 Method 3: Intensity (ISO 9614-2:1996)

Method 3 take use of the intensity method as described in ISO 9614-2[3]. The effective frequency range is determined by the thickness of the spacer between the two intensity probes. As in method 2, a Measurement box is created around the hypothetical reference box but with an shorter distance from the reference box. The sound power level is found by

$$L_W = \overline{L_{In}} + 10 \cdot \log\left(\frac{S}{S_0}\right) \tag{2.11}$$

where $\overline{L_{In}}$ is the average sound intensity level, S is the total surface area of the measurement box and $S_0 = 1\text{m}^2$.

The field indicator F_{pI} indicates the surface pressure-intensity and is defined as

$$F_{pI} = \overline{L_p} - L_W + 10 \cdot \log\left(\frac{S}{S_0}\right) \text{dB} = \overline{L_p} - \overline{L_{In}} \tag{2.12}$$

by inserting equation (2.11) for L_W. The equation is used when deciding the grade of accuracy for the measurement. The index L_d is the dynamic capability index and is determined by the measurement system and the defined grade of accuracy. For a measurement to be suitable for determining the sound power level of a sound source, the argument in equation (2.13) must me fulfilled.

$$L_d > F_{pI} \tag{2.13}$$

The dynamic capability index is calculated as

$$L_d = \delta_{pI_o} - K \tag{2.14}$$

where δ_{pI_o} is the pressure-residual intensity index, defined by the measurement system, and K is the bias error index and is selected according to the grade of accuracy required. There are three grades of accuracy, precision(grade 1), engineering(grade 2) and survey(grade 3). For most uses grade 2 is satisfactory and will be the desired goal for all methods. To achieve the argument in equation (2.13) when $L_d < F_{pI}$ three methods can be used, as stated in B.1 in [3], as well as a procedure scheme for achieving the desired grade of accuracy as seen in Figure B.1 in [3].

3 Method and Equipment

The measurements where performed in room D0016 at NTNU, Gløshaugen, Elektro D+B2. The room is a reverberant chamber with dimensions 8.5x6.0x5.2m in the x-,y-and z-direction, respectively. Illustration of the room can be seen in Figure 3.1. The room had several objects in it such as plastic screens, stairs and platforms, trolleys and several un-identified objects. The equipment used are shown in Table 3.1. All post processing of the data was done in Python[4].

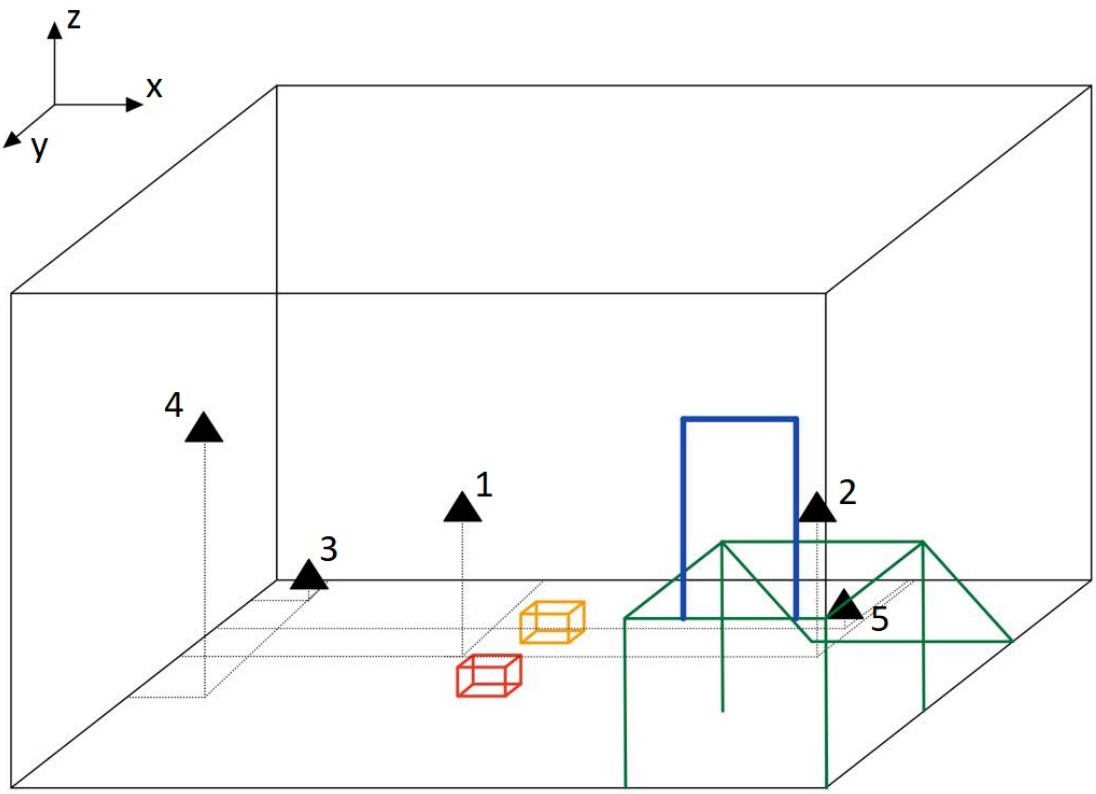

Figure 3.1: Layout of the test room for method 1. The triangles indicate a microphone position with its numerical position-value indicated by the numbers between 1-5. The red-and orange box is respectively the RSS and ST. The blue rectangle marks the entryway into the reverberant chamber and the green lines mark the platform and stairs to get down to the lower section of the room. Obstacles and other objects in the room are not included in the sketch.

3.1 Method 1: Sound Pressure Method with a Reference Sound Source(ISO 3747:2010)

Before any measurements where done the microphone was calibrated using the integrated calibration function on the NOR150 and a calibration tool with a sound pressure level of 124dB and a

Table 3.1: Equipment list.

Equipment	Model number/type	Serial number
Laser measure	Leica DISTO X310	
Vacum cleaner(Test Source,ST)	Siemens Z 5.0	
Fan (Reference sound source,RSS)	Bruel&Kjær type 4204	1265855
Sound and Vibration Analyser	norsonic Nor150	15030749
Phase and pressure Calibration set	Bruel&Kjær Pistonphone type 4220	1475923
G.R.A.S Sound&Vibration	0.5" Intensity Microphone pair 40AK	
Foam windscreen for microphone		
Microphone stand	K&M	
Cables	Norsonic Nor 1408A 5 meter	
Microphone/Measurement probe	Norsonic Type 1201/30490	
Microphone/Measurement probe	Norsonic Type 1209	

frequency at 250Hz. The ST and RSS where placed close to the centre of the room with a distance between them of 1.5m while not being to close to the walls. It is preferable to position the RSS and ST such that the emission pattern is similar for both sources at each microphone position. The microphone positions for the test where decided by the use of appendix B in ISO:3746:2010 [1] while maintaining the ratio described in equation (2.5). It is optimal to cover as much as the 5 sides of the noise source with the microphone, so the microphone positions where chosen with that in mind. The used positions are sketched in Figure 3.1 and the distance values for the microphones are given in Table 3.2.

Table 3.2: Distance from the microphone to TS, RSS and the floor and the ratio between TS and RSS for each microphone position. See equation (2.5).

	Mic-TS [m]	Mic-RSS [m]	Height [m]	Ratio
Mic. position 1	1.752	1.524	1.478	1.149
Mic. position 2	2.284	2.480	1.473	0.921
Mic. position 3	2.440	2.899	0.382	0.842
Mic. position 4	4.020	3.469	2.138	1.159
Mic. position 5	2.139	2.220	0.378	0.964

For each microphone position the sound pressure level for the background noise, ST and RSS where measured individually. Each measurement was taken for a duration of 10s. The RSS takes some time to completely turn off, so for each position the background noise was measured first and the RSS last.

3.2 Method 2: Sound Pressure Method without a Reference Sound Source(ISO 3746:2010)

For the second method the RSS was removed and the ST relocated to the center of the room. The ST is then visualized as a reference box as can be seen in Figure 3.2. The measurement box is then created around the reference box with the sides having equal distance of 1m to the corresponding side of the reference box. The sound pressure level is then measured in the center of each measurement surface using the ST as the sound source inside the reference box. Each measurement was recorded for a duration of 10s.

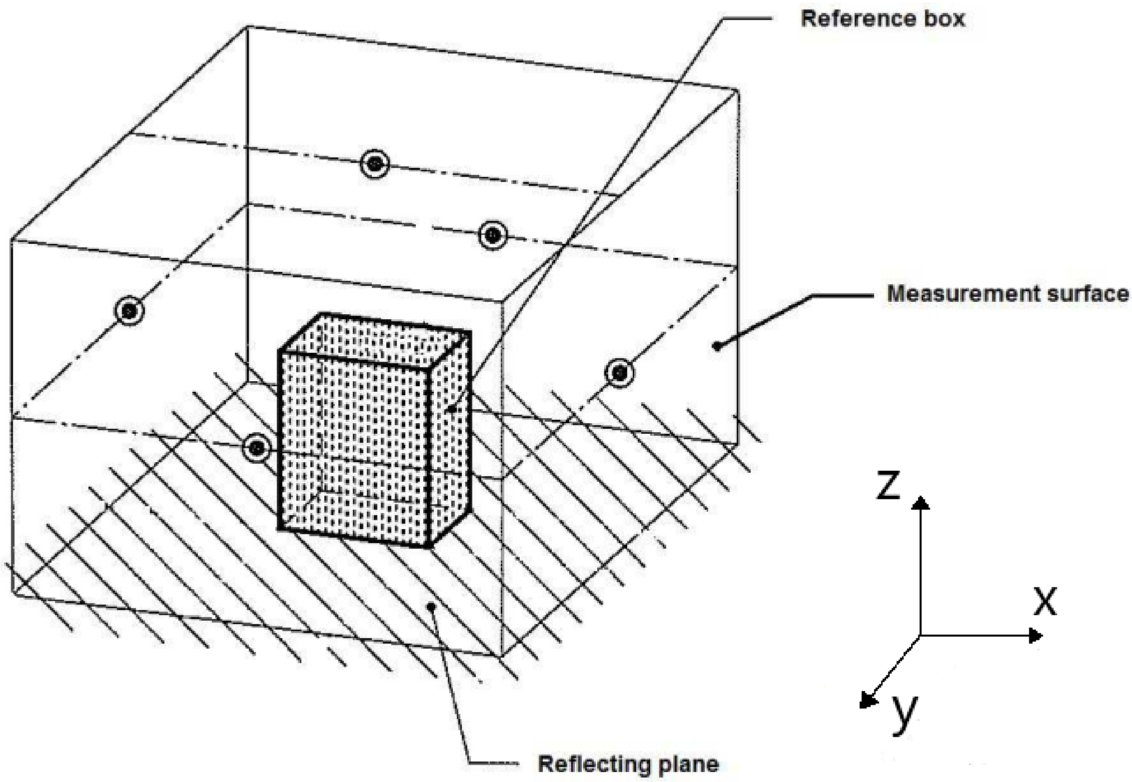

Figure 3.2: The set-up for method 2 using a reference box and a measurement box. The black dots indicate the center for each measurement surface and is the microphone positions. The imaginary measurement box is also depicted in the figure. The coordinates have the same axis as in Figure 3.1.

3.3 Method 3: Intensity (ISO 9614-2:1996)

Compared to the first two methods, the third method takes use of an intensity probe containing two microphones facing one another with a spacer in-between. Both probes are calibrated with a phase calibrator using the built in features on the NOR150 as well as pressure calibration. As in method two, a hypothetical box is created around the ST with a measurement box surrounding the reference box. The distance between the measurement box and the reference box can be the same as in Method 2, but should be greater than 0.20m. The probes can then be aligned and prepared for measuring. The direction of the microphone is important, and should be normal to the measurement surface. During the measurement the intensity probe was moved in the pattern as shown in Figure 3.3. Two measurements should be done to cover as much surface area a possible. The probe should not move faster than 0.5m/s and the total recording time for each pattern should be greater than 20s. For a surface area of size 1m^2 a time between 30-40s is optimal. The person moving the probe should stand at the side of the measuring surface to ensure minimum radiating interference with the measurement. The importance of this method is keeping the speed and pattern uniform for each measuring surface.

The surface areas for each plain had a total area of 1m^2 each.

By using equation (2.11) for each octave band the sound power levels in octave bands can be found. By inserting these values in equation (2.4) the total A-weighted sound power level can be found.

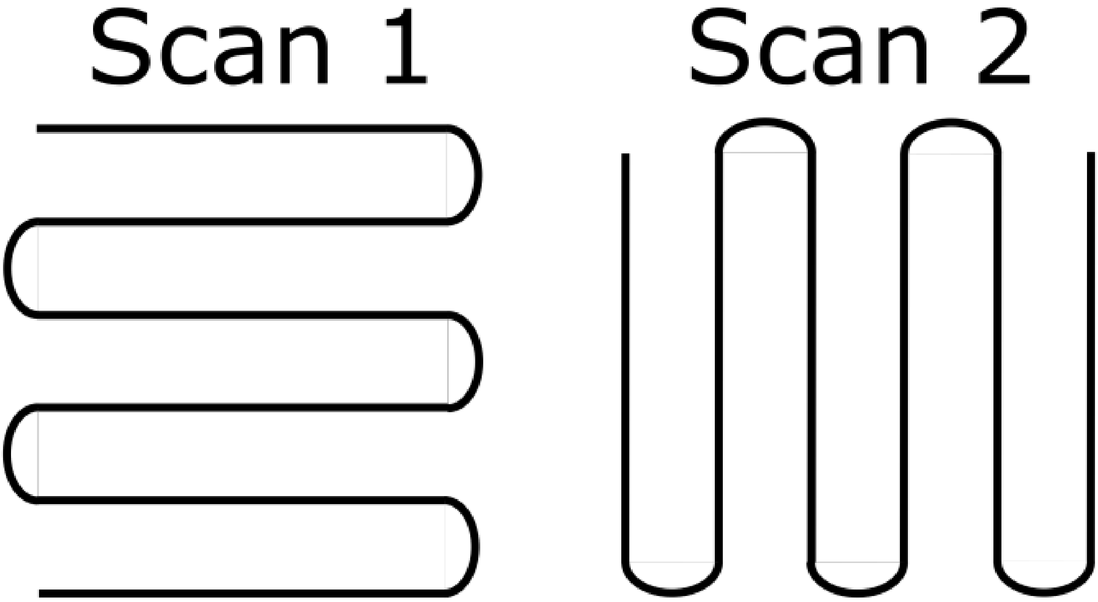

Figure 3.3: The pattern showing how to move around the measurement surface with the intensity probe.

4 Results

4.1 Method 1: Sound Pressure Method with a Reference Sound Source(ISO 3747:2010)

To first check if any correction was needed the ΔL_{pi} value for both ST and RSS was plotted. As seen in Figure 4.1, no correction is needed.

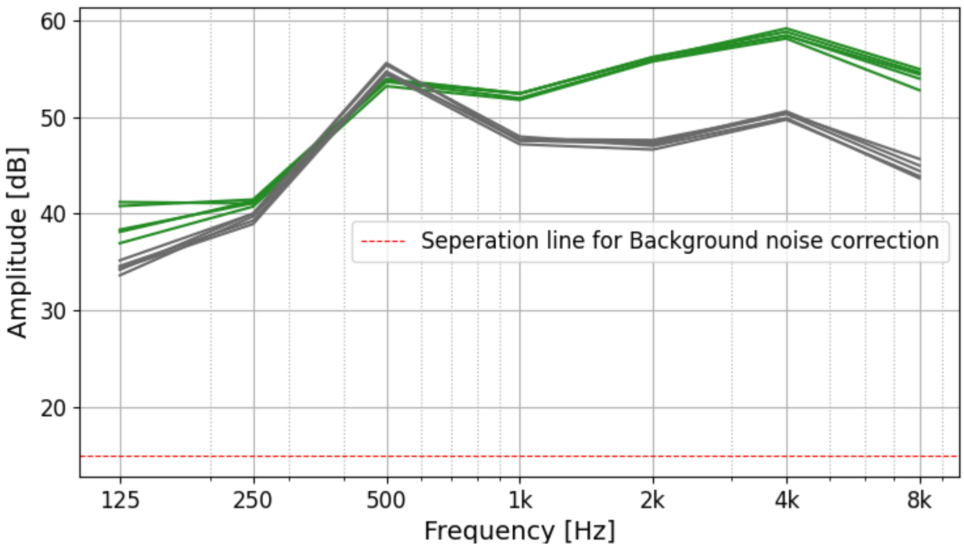

Figure 4.1: Green line is $\Delta L_{pi(RSS)}$ and the gray line is $\Delta L_{pi(ST)}$. The red dashed line indicate the threshold for whether correction is needed or not.

The first microphone position is very close to both ST and RSS and is placed almost directly above them both. When plotting the L_f value for both ST and RSS it is clear that this position gave an abnormality compared to the rest of the measurements. This is expected when measuring so close to the source. The value can be seen in Figures 4.2 and 4.3 for, respectively, ST and RSS.

After calculating the A-weighted sound power level in octave bands, the total A-weighted sound power level can be found by using equation (2.4). The A-weighted sound power level as well as the Z-weighted sound power level can be seen in Figure 4.4 with the total A-weighted sound power level listed in the title of the plot, found to be 84.7dB.

4.2 Method 2: Sound Pressure Method without a Reference Sound Source(ISO 3746:2010)

The reference box and measurement box was created around the ST with an uniform distance between each surface of the reference box to the measurement box of exactly 1m. The dimensions of the two boxes are given in Table 4.1. The measuring surfaces are named as following. The

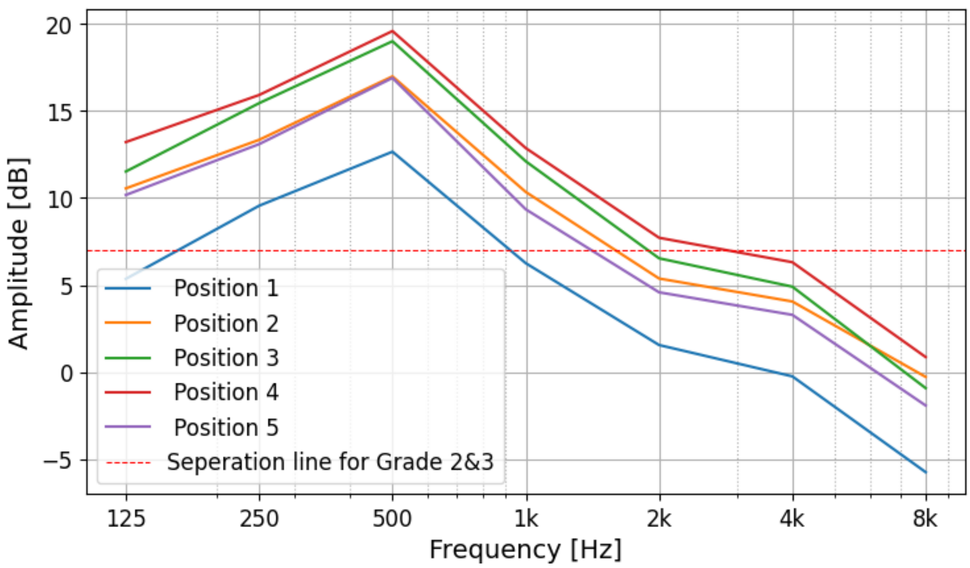

Figure 4.2: L_f for ST with the different microphone locations as well as the red dashed line indicating the threshold between grade 3 and grade 2.

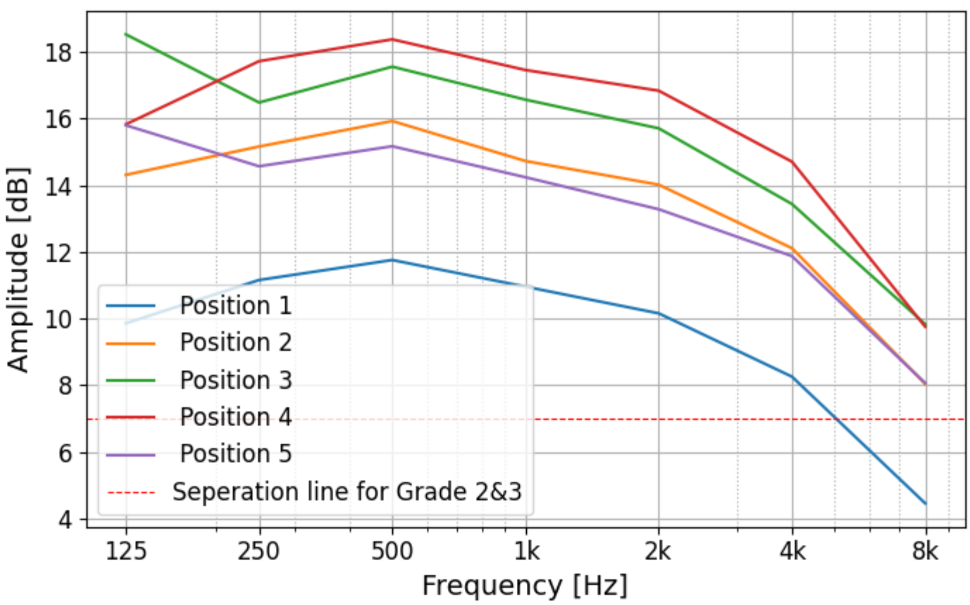

Figure 4.3: L_f for RSS with the different microphone locations as well as the red dashed line indicating the threshold between grade 3 and grade 2.

yz-plane is the back, xz-plane is the right and the xy-plane is the bottom. Hence the opposing sides are respectively the front, left and top.

The background noise found in method 1 can then be applied with the A weighted constants to find the A-weighted background noise and used with the measured sound pressure levels to

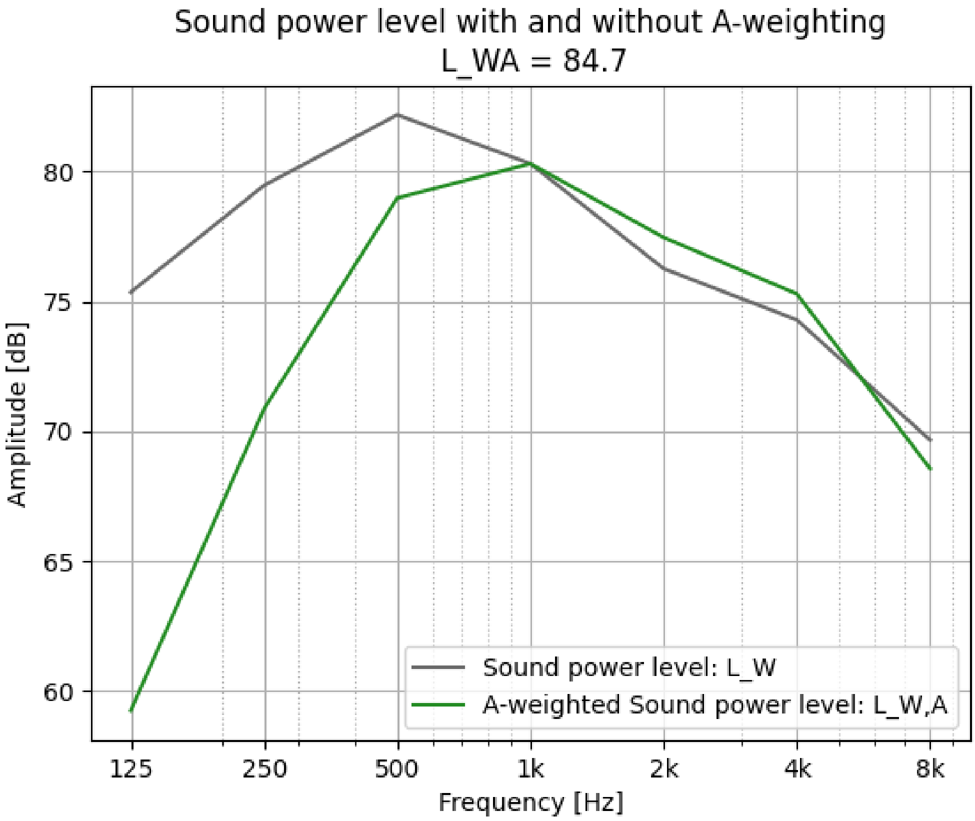

Figure 4.4: The A-weighted and Z-weighted sound power level as a function per octave band. The total A-weighted sound power level is 84.7dB.

Table 4.1: Dimensions of the reference box and the measurement box.

	length [m]	width [m]	height [m]	Surface area [m^2]
Reference box	0.465	0.3	0.25	0.522
Measurement box	2.465	2.3	1.25	17.582

calculate ΔL_A. As seen in Figure 4.5 it is clear that no noise correction is needed. The stripped line indicates the 10dB Threshold deciding whether K_{1A} can be set to zero or not. As long as the blue line is above the red dashed line, the background correction factor K_{1A} is set to be zero.

The Environment correction factor K_{2A} was found to be 8.17 by the use of equation (2.6) with an absorption coefficient at 0.05 which is recommended by ISO3746[2]. The measured sound pressure levels at each microphone position is then averaged for all positions to find the average A-weighted sound pressure level in octave bands over the measurement surface. The total A-weighted sound power level is then calculated using equation (2.10), and was found to be 85.0dB.

4.3 Method 3: Intensity (ISO 9614-2:1996)

The total surface area for the measurement box was 5m^2 due to each measurement surface area being 1m^2. The distance from the reference box to the measurement surface was 0.28m. The total A-weighted sound power level was calculated to be 85.6dB with the use of the I_{eq} in Table D. As seen in Figure 4.6 the F_{pI} value satisfy the argument in equation 2.13 for both grade 2 and 3 for

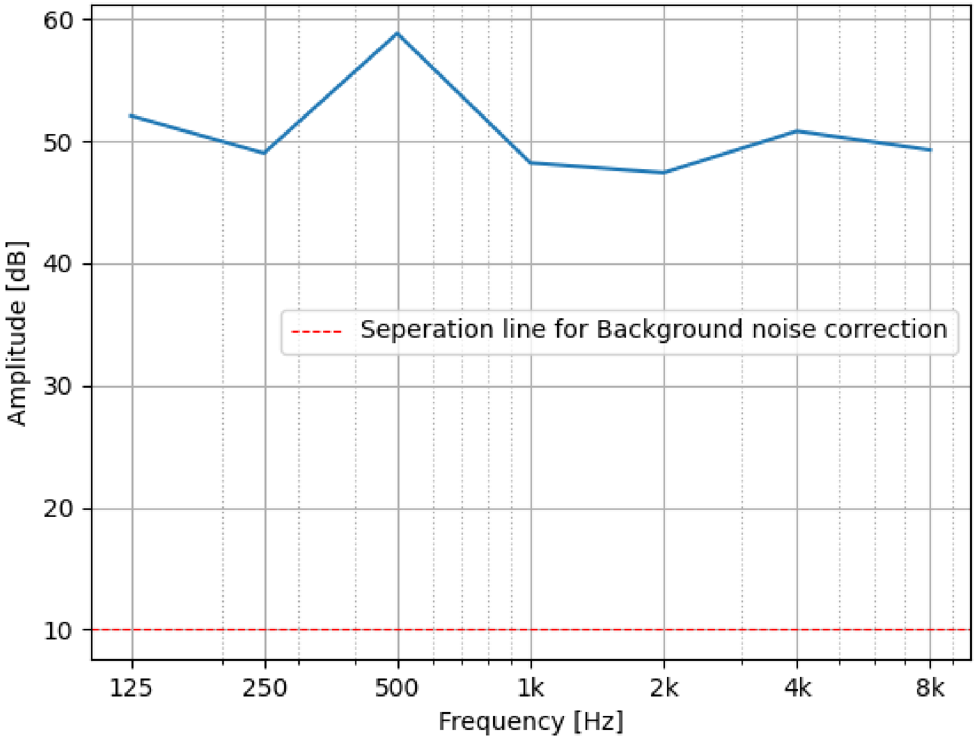

Figure 4.5: The blue line is the difference between the average A-weighted sound pressure level and the A-weighted background noise, ΔL_A. The dashed red line indicates the threshold for when the background noise correction can be zero or not.

all octave bands in the frequency range 100-5000Hz. The δ_{pI_0} value was given as 18.8dB for the used measurement system given in [5]. The K value was set to 10dB and 7dB for, respectively, grade 2 and 3. The grade of accuracy for the third method was therefore set to grade 2.

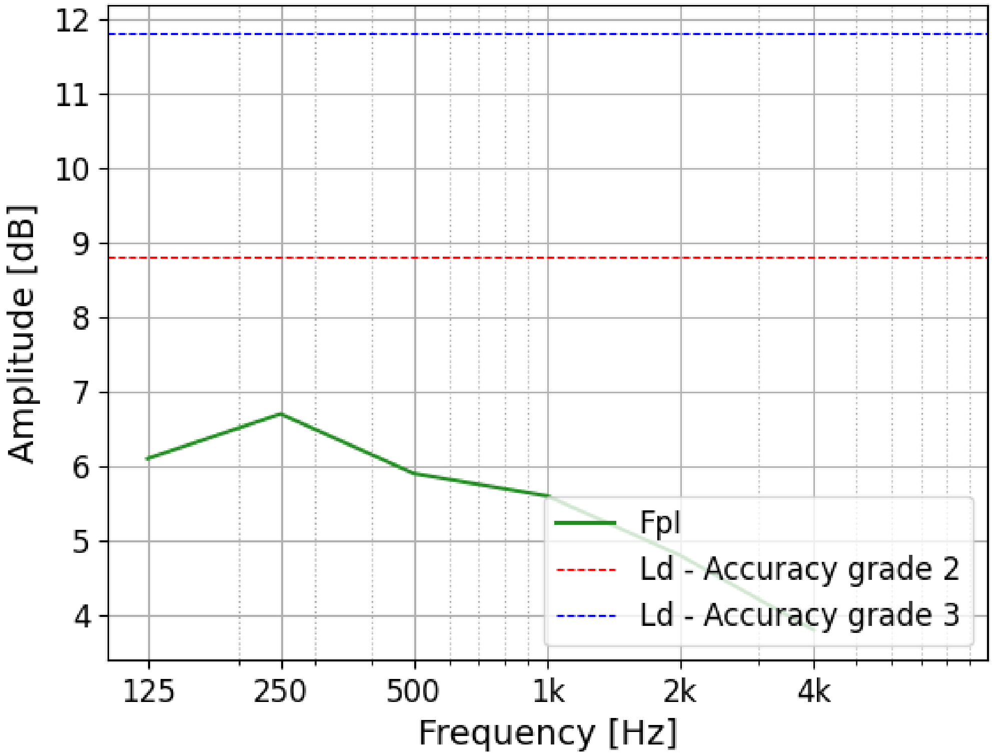

Figure 4.6: The green line marks the F_{pI} value while the red and green line indicates the L_d value for, respectively, accuracy grade 2 and 3.

4.4 Comparison

The total A-weighted sound power level can be seen in Table 4.2. The values have a spread in between them of 0.9dB before taking standard deviation given by accuracy in account.

Table 4.2: The calculated total A-weighted sound power level, $L_{W,A}$, for all three methods.

Method	Value	unit
1: ISO 3747:2010	84.7	dB
2: ISO 3746:2010	85.0	dB
3: ISO 9614-2:1996	85.6	dB

5 Discussion

From Figure 4.3 and 4.2 it is clear that for the ST the criteria for maintaining grade 2 in method 1 is not met for the entire frequency range. For the case with RSS only, the first microphone position show signs of breaching the threshold of 7dB which was expected due to its close distance to both the ST and RSS. This could have been avoided by allocating the microphone to a more suitable position.

For all methods the background noise correction was negligible. The microphone used is not an omni-directional microphone so position of the microphone surface relative to the direction of the sound source can have an impact on the calculated sound power level. For the third method the intensity probe was maneuvered by a human hand which gives room for human error. The speed over certain places may vary as well as the distance from the ST. Certain places at each measurement surface can have varying intensity of sound pressure, hence giving room for biased measurement. The grade of accuracy in method 3 was sufficient to maintaining grade 2 for all frequencies.

As seen in Table 4.2 the results vary with the highest deviation between method 1 and 3 at 0.9dB. The high power value in method 3 may be a result of the post processing where octave bands where created from the third-octave bands. The high power value could also be the consequence of the human aspect of how the measurement where done during scanning that led to non-uniform speed, directivity of the microphone and displacement along the measurement surface. For method 1 and 2 the microphone direction was not carefully enough considered and thus gave room for weaker measurements compared to in method 3 where the microphone direction was more carefully considered during measurements. For all measurements most objects in the room remained in a constant position. However, the trolley of which the NOR150 was placed upon and the two humans that where conducting the lab was not seated in a constant position for all measurements. All these objects as well as change in background noise for each individual measurement can also have an affect on the total A-weighted Sound Power Lever, but to a negligible amount.

6 Conclusions

By the use of the three ISO standards 3746:2010, 3747:2010 and 9614-2:1996 that take use of sound pressure levels and sound intensity levels, the total A-weighted sound power level of a test source was found to be 85.1 ± 0.5dB. The accuracy grade for each method was close to grade 2(engineering grade) with the exception of method 1 due to an abnormality with one of the microphone positions. The total A-weighted Sound Power Level for all methods are listen in Table 6.

Table 6.1: The calculated total A-weighted sound power level, $L_{W,A}$, for all three methods.

Method	Value	unit
1: ISO 3747:2010	84.7	dB
2: ISO 3746:2010	85.0	dB
3: ISO 9614-2:1996	85.6	dB

All three methods gave close to equal results, but method 1 and 2 was easier to conduct with a smaller rate of human error. The scanning process in method 3 was hard to conduct with an uniform speed and placement along the measurement surface, giving room for human error. The preferred method is method 1 due to its simplicity and accuracy when adding several microphone locations.

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A Appendix

Table A.1: Sound power levels for the reference sound source(RSS), $L_{W(RSS)}$ as given in [5].

Frequency [Hz]	Level [dB]
125	79.8
250	81.0
500	80.9
1000	84.9
2000	85.1
4000	82.7
8000	79.2

B Appendix

Table B.1: Data values for the measurement lab. Each Meas. number correspond to the information given in Appendix C.

Number	L_{feq} 125 Hz	L_{feq} 250 Hz	L_{feq} 500 Hz	L_{feq} 1 kHz	L_{feq} 2 kHz	L_{feq} 4 kHz	L_{feq} 8 kHz
1	35.7	35.7	23.9	29.1	24.0	17.4	14.5
2	75.0	77.5	78.0	81.2	80.6	76.3	69.0
3	70.5	75.9	78.9	76.5	72.0	67.8	58.8
4	71.465	75.455	78.995	76.36	71.59	67.87	60.04
5	75.225	77.275	77.94	80.74	80.23	75.925	68.355
6	36.38	36.23	24.205	28.745	24.275	17.46	14.37
7	38.085	36.285	24.57	28.77	24.55	17.435	14.41
8	71.08	76.205	79.66	76.765	71.395	67.365	58.04
9	78.085	77.24	78.215	81.225	80.565	75.895	68.79
10	36.605	37.865	23.67	29.185	24.775	17.74	14.65
11	71.21	75.115	78.685	75.965	71.015	67.21	58.265
12	73.825	76.92	77.475	80.555	80.135	75.605	67.155
13	37.43	34.47	25.01	28.295	24.285	17.56	14.26
14	72.05	76.17	79.87	76.325	71.76	68.065	59.36
15	77.675	77.645	78.145	81.215	80.455	76.65	69.34
16	71.845	76.765	79.75	76.41	72.655	69.36	62.69
17	73.165	76.605	79.865	77.48	73.38	69.175	62.475
18	72.9	76.175	79.74	76.78	72.985	68.835	61.005
19	73.325	76.56	79.175	76.735	72.53	68.955	62.005
20	73.01	76.96	80.915	77.585	73.475	70.17	64.14

C Appendix

Table C.1: Information about the measurements done for Method 1 and 2 as seen in Appendix B.

Measurement number	File number	Position	Measurement
1	2022-02-03 15-48-56	1	Bakgrunnsstøy
2	2022-02-03 15-51-42	1	Referansekilde
3	2022-02-03 15-54-41	1	Testkilde
4	2022-02-03 16-00-03	2	Testkilde
5	2022-02-03 16-01-01	2	Referansekilde
6	2022-02-03 16-03-50	2	Bakgrunnsstøy
7	2022-02-03 16-10-22	3	Bakgrunnsstøy
8	2022-02-03 16-11-33	3	Testkilde
9	2022-02-03 16-12-40	3	Referansekilde
10	2022-02-03 16-18-25	4	Bakgrunnsstøy
11	2022-02-03 16-19-25	4	Testkilde
12	2022-02-03 16-20-44	4	Referansekilde
13	2022-02-03 16-30-07	5	Bakgrunnsstøy
14	2022-02-03 16-30-54	5	Testkilde
15	2022-02-03 16-31-43	5	Referansekilde
16	2022-02-03 16-40-21	1	Front
17	2022-02-03 16-43-16	2	Right
18	2022-02-03 16-45-33	3	Left
19	2022-02-03 16-46-44	4	Back
20	2022-02-03 16-47-52	5	Top

D Appendix

Table D.1: Intensity values I_{eq} for method 3 using intensity probes.

Name/Band	I_{eq} Front [dB]	I_{eq} Top [dB]	I_{eq} Back [dB]	I_{eq} Left [dB]	I_{eq} Right [dB]
A	77.4	81.8	77.6	76.2	78.4
C	79.4	93.8	80.1	78.5	80.4
Z	79.5	94.6	80.2	78.5	80.5
20 Hz	43.3	95.5	75.5	46.0	47.2
25 Hz	34.6	95.5	74.0	39.1	37.0
31.5 Hz	34.2	94.7	68.9	39.1	29.3
40 Hz	36.7	93.3	67.4	29.1	40.2
50 Hz	39.7	90.1	64.5	38.8	42.0
63 Hz	47.5	88.0	59.9	47.5	47.9
80 Hz	55.0	86.9	55.4	52.7	54.0
100 Hz	60.5	85.2	59.1	64.1	59.0
125 Hz	60.2	81.9	63.5	60.7	63.0
160 Hz	65.6	77.2	68.4	63.1	66.8
200 Hz	65.7	73.7	67.6	66.4	66.3
250 Hz	67.1	65.9	69.0	66.8	69.0
315 Hz	68.4	61.3	68.8	67.8	69.1
400 Hz	69.3	70.6	69.8	69.0	69.4
500 Hz	70.6	75.3	71.2	69.8	71.5
630 Hz	71.9	75.6	70.7	69.2	73.1
800 Hz	69.8	74.5	71.4	67.9	70.8
1 kHz	66.8	71.1	67.4	64.6	68.6
1.25 kHz	65.1	68.9	65.2	64.6	67.4
1.6 kHz	63.9	67.3	63.7	64.7	65.1
2 kHz	64.2	69.2	65.2	64.2	64.5
2.5 kHz	63.5	68.2	64.0	64.5	64.3
3.15 kHz	64.8	68.1	62.3	63.0	65.0
4 kHz	62.5	65.6	60.9	60.0	62.3
5 kHz	60.0	63.4	58.2	57.1	59.1
6.3 kHz	57.8	62.1	56.5	56.3	57.7
8 kHz	55.6	59.4	53.7	53.3	54.4
10 kHz	57.8	61.6	55.4	55.2	58.5
12.5 kHz	50.4	54.0	47.8	47.7	49.3
16 kHz	45.4	50.2	43.9	44.4	46.0
20 kHz	28.5	41.1	30.8	37.1	36.5

E Appendix

Table E.1: Pressure values L_{eq} for method 3 using intensity probes.

Name/Band	L_{eq} Front [dB]	L_{eq} Top [dB]	L_{eq} Back [dB]	L_{eq} Left [dB]	L_{eq} Right [dB]
A	77.4	85.1	82.7	82.8	83.3
C	79.4	87.5	85.3	85.3	85.7
Z	79.5	87.6	85.3	85.4	85.8
20 Hz	43.3	75.8	52.9	37.0	38.7
25 Hz	34.6	76.6	51.6	35.6	39.2
31.5 Hz	34.2	75.8	48.7	44.3	44.9
40 Hz	36.7	74.3	50.0	47.8	48.2
50 Hz	39.7	71.6	51.0	50.1	49.4
63 Hz	47.5	69.9	56.4	56.9	54.4
80 Hz	55.0	70.1	62.6	63.8	63.6
100 Hz	60.5	71.3	67.5	70.8	69.7
125 Hz	60.2	71.2	69.0	69.4	68.3
160 Hz	65.6	73.7	73.1	72.2	73.0
200 Hz	65.7	73.0	72.4	72.0	71.5
250 Hz	67.1	74.7	73.8	73.8	74.4
315 Hz	68.4	74.9	74.1	74.3	74.3
400 Hz	69.3	77.1	75.3	75.5	75.1
500 Hz	70.6	79.3	76.9	77.0	77.2
630 Hz	71.9	79.2	76.6	76.9	78.1
800 Hz	69.8	78.3	76.4	75.5	76.2
1 kHz	66.8	75.1	72.6	72.2	73.4
1.25 kHz	65.1	73.0	70.7	71.0	71.9
1.6 kHz	63.9	71.3	69.2	70.3	70.0
2 kHz	64.2	72.3	69.8	69.9	69.5
2.5 kHz	63.5	71.0	68.4	69.0	68.5
3.15 kHz	64.8	70.8	66.8	67.6	68.5
4 kHz	62.5	68.4	64.8	64.8	65.9
5 kHz	60.0	65.7	61.7	61.3	62.6
6.3 kHz	57.8	63.9	59.5	59.8	60.8
8 kHz	55.6	61.0	56.2	56.6	57.0
10 kHz	57.8	62.8	57.4	57.7	60.8
12.5 kHz	50.4	54.8	49.4	50.6	51.2
16 kHz	45.4	51.2	45.9	47.5	48.3
20 kHz	28.5	45.1	38.4	41.4	40.1