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# Application of an Ambisonic Microphone for the Measurements of Room Acoustic Parameters

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**Abstract** The most commonly used measurement technique in room acoustics employs a single omnidirectional microphone for recording the room impulse response and further derivation of such acoustical parameters as T30, EDT, C50 or C80. Instead, ambisonic technology makes it possible to measure a spatial room impulse response. Ambisonics decomposes the signal from the spherical microphone array into spherical harmonics to shape the directivity. Ambisonics lets to go beyond basic acoustical parameters and allows to determine spatial features of a sound field at the measurement point. This study presents the comparison of fundamental acoustic parameters measured in the recording studio by an actual omnidirectional microphone and virtual omnidirectional microphones derieved from ambisonic microphones of the first and third order. The results show the usefulness of ambisonic technology in terms of assessing basic room parameters.

**Keywords:** room acoustics, ambisonics, spatial impulse response, acoustical measurements.

## 1. Introduction

The evolution of signal processing technology, especially in the field of ambisonics affects also the measurement techniques in room acoustics [1-3]. Currently, the measurements of the room impulse response (RIR) is the most commonly used technique. RIR is generally recorded with the use of omnidirectional microphone, thus it does not contain any spatial information about the acoustic field at the measurement point. To obtain certain spatial features regarding the acoustic field, it is necessary to use at least two microphones at the same measurement point, such as additional figure of eight microphone for calculation of spatial parameters or binaural microphones of the acoustic manikin which leads to recording of the Binaural Room Impulse Response (BRIR). This commonly used measurement technique is described in the ISO 3382-1 standard [4]. Ambisonic technology employs spherical microphone array, that makes it possible to represent the directivity with the use of spherical harmonics [1, 5]. This makes it possible to obtain both omnidirectional and spatial parameters by measurements that use a single device.

This study focuses on the comparison of fundamental room acoustic parameter from the ISO 3382-1 standard [4]. Reverberation Time T30, Early Decay Time EDT, Speech Clarity C50 and Music Clarity C80 were compared between the RIRs acquired from the virtual omnidirectional microphone (the W channel, [1, 5]) calculated from the directional signals of the ambisonic microphones of the first and third order with an actual omnidirectional microphone.

## 2. The multipurpose recording studio

The measurements were carried out in a multifunctional recording studio at the Institute of Radioelectronics and Multimedia Technology, WUT. The room is acoustically treated and intended for sound recordings, as well as auditory presentations. The reverberation time equals 0.8 s (average in 500 – 1000 Hz band) and a volume equals 325 m$^3$. Figure 1 shows the plan of the studio with marked measurement points.

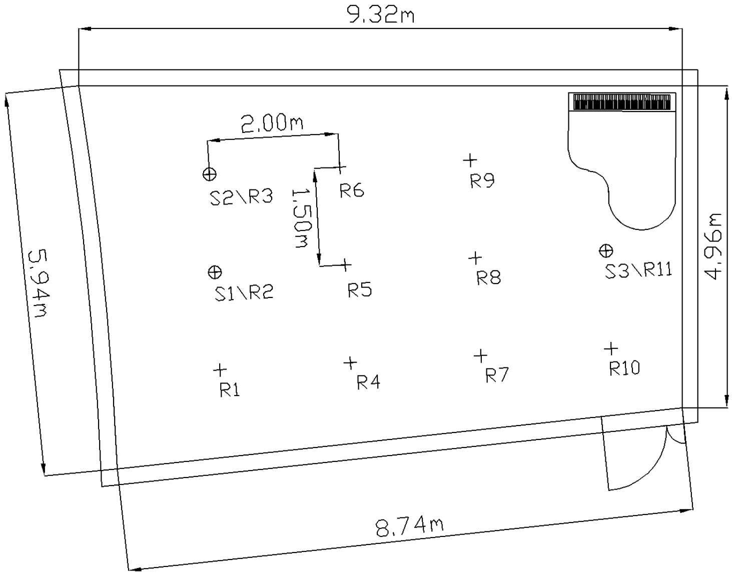


**Figure 1.** Location of source (S) and receiver (R) positions on the plan of the recording studio.

### 3. Measurement method

The measurements were carried out in accordance with the guidelines given in the ISO 3382-1 standard [4]. The impulse responses were recorded at 10 measurement points for each of 3 sound source positions. Locations of the sound source and receiver positions are shown in Figure 1. The omnidirectional sound source Brüel & Kjær (B&K) type 4292 was placed on a stand 1.5 m above the floor. The microphones were positioned on stands at the height of 1.2 m.

Three different microphones were chosen to obtain mutual comparison of measured room acoustic parameters. An omnidirectional B&K type 4189 microphone (as a reference microphone), 1st order ambisonics Sennheiser Ambeo microphone and 3rd order ambisonics Zylia ZM-1 model 3E spherical microphone array.

The impulse responses from the omnidirectional microphone were acquired with the use of the B&K Dirac v6.0 software. The impulse responses from ambisonic microphones were recorded with the use of Aurora Plugin for Audacity, that allows multichannel recording [6]. The swept-sine method was used for obtaining the impulse responses. As the signals recorded with Aurora are stored in A-format ambisonics, the conversion to B-format was made with the use of software dedicated for each of the microphones [7, 8]. For further analysis, only the "W" channel of the B-format ambisonic signal was used, as it contains the omnidirectional signal averaged over all microphones in the array [1, 5]. After extracting the W channel, acoustic parameters were calculated using the B&K Dirac v6.0 software.

### 4. Results

For comparison, four fundamental parameters described in ISO 3382-1 standard were chosen: Reverberation Time T30, Early Decay Time EDT, Speech Clarity C50 and Music Clarity C80. According to the standard, all the parameters were calculated in 1/1 octave bands. The results of T30, averaged spatially over all source-microphone positions are shown in Figure 2. Figures 3-5 show spatial distribution of single-number values (averaged in 500 and 1000 Hz frequency bands) of EDT, C50 and C80 parameters respectively. These data was shown for the case of active S1 source, chosen as the most frequent usage scenario of the room.

The differences between the measurements made with ambisonic microphones and the reference omnidirectional microphone were compared against the Just Noticeable Difference (JND), as described in [4].

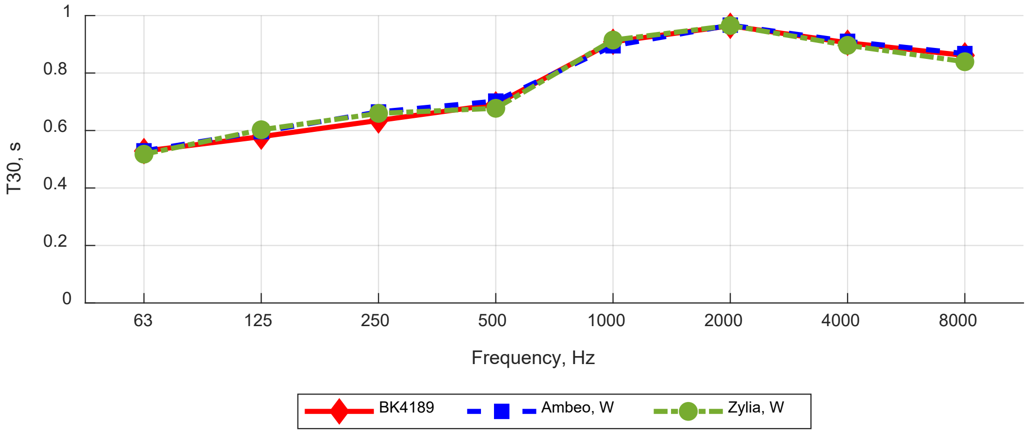


**Figure 2.** Comparison of Reverberation Time T30 values measured with Omnidirectional BK 4989 microphone, Sennheiser Ambeo Microphone and Zylia ZM-1.

The values of T30 reverberation time are similar within the JND value across all three types of microphones in each frequency band. Differences between the mean values measured with the use of "W" channel of Ambeo microphone and B&K 4189 range from -0.01 s in 1 kHz frequency band to 0.03 s in 250 Hz frequency band. The differences between the "W" channel of Zylia microphone and B&K 4189 range from -0.02 s to 0.02 s. The mean differences of T30 parameter, both for Ambeo and Zylia microphones, does not exceed 5% of the reference T30 in all frequency bands greater than or equal to 500 Hz. For Ambeo microphone, the highest mean difference equals 7% for 125 Hz, while for Zylia, 6% in 63 and 250 Hz frequency bands.

Figures 3-5 show spatial distribution of EDT, C50 and C80 respectively. The results of each parameter measured with B&K 4189 and sound source in S1 position are presented. Corresponding Tables 1-3 contain the information of differences between the two considered ambisonic microphones and the reference microphone B&K 4189. The measurement points, in which the difference between the ambisonic and the reference microphones exceeds the JND value are marked in the figures. Solid line of the border surrounding the measurement point indicates the positive sign of the difference, while dashed line stands for the negative sign. The letter above the right corner of the boxes indicates the microphone, for which the difference was observed: *A* denotes Ambeo and *Z* – Zylia.

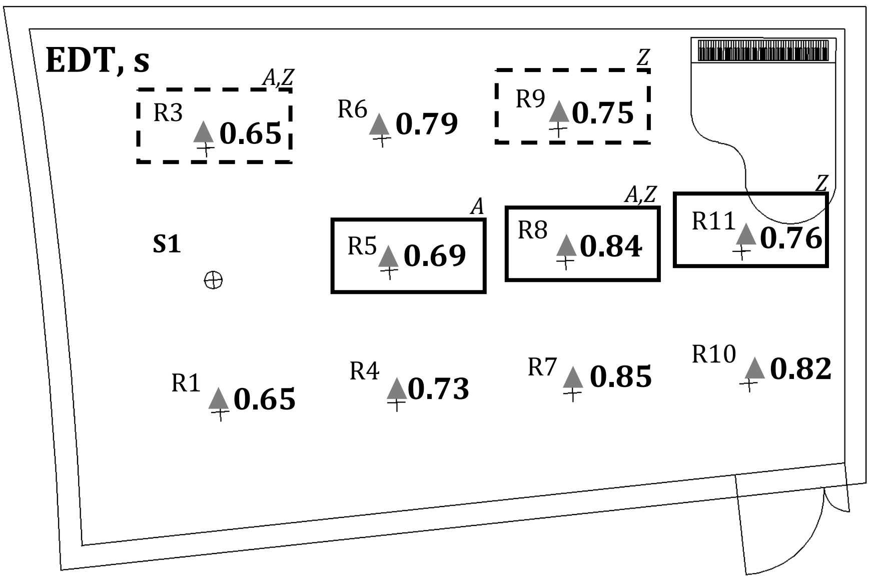


**Figure 3.** Spatial distribution of Early Decay Time, EDT values measured with Omnidirectional B&K 4989 microphone. The borders surrounding the measurement points indicate the differences between the Ambeo (A) and Zylia (Z) microphones and the B&K 4189 microphone, that exceed the JND value. Solid line shows the positive sign of difference and dashed line – the negative sign.

**Table 1.** Early Decay Time, EDT values measured with the B&K 4189 reference microphone along with the differences of values measured with the use of Ambeo and Zylia ambisonic microphones.

| EDT [s] | Receiver position | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 |
| **B&K 4189** | **0.65** | **0.65** | **0.73** | **0.69** | **0.79** | **0.85** | **0.84** | **0.75** | **0.82** | **0.76** |
| Δ Ambeo | 0.01 | -0.13 | 0.01 | 0.14 | -0.01 | 0.00 | 0.08 | 0.01 | 0.02 | 0.01 |
| Δ Zylia | -0.02 | -0.13 | 0.01 | -0.02 | -0.02 | 0.00 | 0.11 | -0.04 | 0.02 | 0.03 |

The single-number values of EDT measured with the B&K 4189 microphone range from 0.65 s in R1 and R3 receiver positions to 0.85 s in the R7 position. The smallest values are observed in measurement points located in the closest proximity to the sound source position. The differences of values measured with the Ambeo microphone range up to -0.13 s in the R3 position and 0.14 s in R5 position. In R3 and R5 measurement points, the relative difference from B&K 4189 value is 20% and in R8 measurement point it equals 10%. In all other cases, the relative difference does not exceed the 5% JND value. In case of Zylia microphone, observed differences range up to -0.13 s in R3 microphone position. The difference from reference measurements exceed the JND in R8 position (20%), R3 position (20%) and is equal to 5% in R9 position.

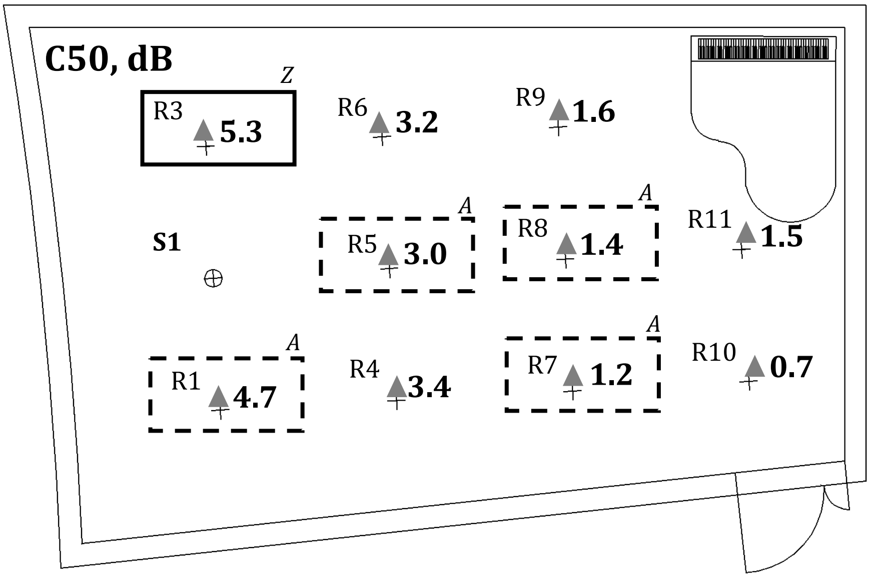


**Figure 4.** Spatial distribution of Clarity C50 values measured with Omnidirectional B&K 4989 microphone. The borders surrounding the measurement points indicate the differences between the Ambeo (A) and Zylia (Z) microphones and the B&K 4189 microphone, that exceed the JND value. Solid line shows the positive sign of difference and dashed line – the negative sign.

**Table 2.** Clarity C50 values measured with the B&K 4189 reference microphone along with the differences of values measured with the use of Ambeo and Zylia ambisonic microphones.

| C50 [dB] | Receiver position | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 |
| **B&K 4189** | **4.7** | **5.3** | **3.4** | **3.0** | **3.2** | **1.2** | **1.4** | **1.6** | **0.7** | **1.5** |
| Δ Ambeo | -1.7 | 0.2 | -0.2 | -3.2 | 0.1 | -1.2 | -1.2 | -0.2 | -0.2 | -0.4 |
| Δ Zylia | 0.7 | 2.7 | 0.7 | -0.5 | 0.1 | -0.8 | -0.7 | -0.1 | -0.1 | 0.2 |

The values of C50 measured in the studio range from 0.7 dB in R10 up to 5.3 dB in R3 measurement point. Differences with values measured with the use of Ambeo microphone in 6 out of 10 positions are less than 1 dB. Differences above 1 dB and thus exceeding JND are observed in R1, R5, R7 and R8 receiver positions. In case of the Zylia microphone, only in 1 out of 10 measurement positions the difference exceeds the JND value of 1 dB and equals 2.7 dB in R3 receiver position.

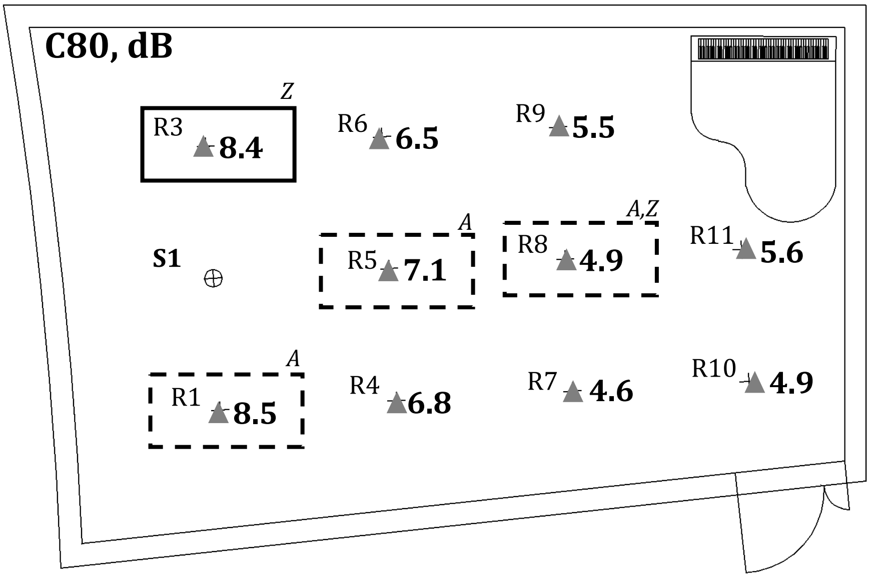


**Figure 5.** Spatial distribution of Clarity C80 values measured with Omnidirectional B&K 4989 microphone. The borders surrounding the measurement points indicate the differences between the Ambeo (A) and Zylia (Z) microphones and the B&K 4189 microphone, that exceed the JND value. Solid line shows the positive sign of difference and dashed line – the negative sign.

**Table 3.** Clarity C80 values measured with the B&K 4189 reference microphone along with the differences of values measured with the use of Ambeo and Zylia ambisonic microphones.

| C80 [dB] | Receiver position | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 |
| **B&K 4189** | **8.5** | **8.4** | **6.8** | **7.1** | **6.5** | **4.6** | **4.9** | **5.5** | **4.9** | **5.6** |
| Δ Ambeo | -1.2 | -0.2 | -0.3 | -2.1 | 0.7 | -0.8 | -1.4 | 0.1 | -0.2 | -0.3 |
| Δ Zylia | 0.4 | 1.9 | 0.1 | 0.3 | 0.4 | -0.9 | -1.3 | 0.2 | 0.3 | 0.0 |

The C80 parameter ranges from 4.6 dB in R7 to 8.5 dB in R1 receiver position. The differences of values measured with Ambeo microphone are lower than 1 dB in 7 out of 10 positions. In R1, R5 and R8 receiver positions the differences are -1.2, -2.1 and -1.4 dB respectively. In case of Zylia microphone, the 1 dB difference is exceeded in R3 (1.9 dB) and R8 receiver position (-1.3 dB).

## 5. Conclusions

The aim of this study was to compare the basic room acoustic parameters calculated from the impulse responses recorded with the use of the first and third order ambisonic microphones. Four fundamental parameters were taken into account – reverberation time T30, Early Decay Time EDT, Clarity C50 and C80. The differences between ambisonic microphones and the reference microphone were compared against the Just Noticeable Difference (JND) values [4]. The results of measurements made with ambisonic microphones are close to ones made with the ISO 3382-1 compliant procedure at most of the measurement points. However, in some of the measurement points, the difference in the results is significant. Further research will focus on identifying the conditions causing the variance of results. As it is possible to shape the directivity of virtual microphones from ambisonic signal, further works will also focus on directional analysis of acoustic parameters and spatial nature of the acoustic field with the use of ambisonics.

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**Additional information**

The authors declare: no competing financial interests and that all material taken from other sources (including their own published works) is clearly cited and that appropriate permits are obtained.

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