Acoustics 08

Experimental analysis of the acoustical behaviour of Musikverein in concert and ballet configurations

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Topics

- *Configurations of the room*

- *Standard room acoustics measurements*

- *Coupling with the storage space under the stalls*

- *Surface intensity measurements*

- *Analysis of the results*
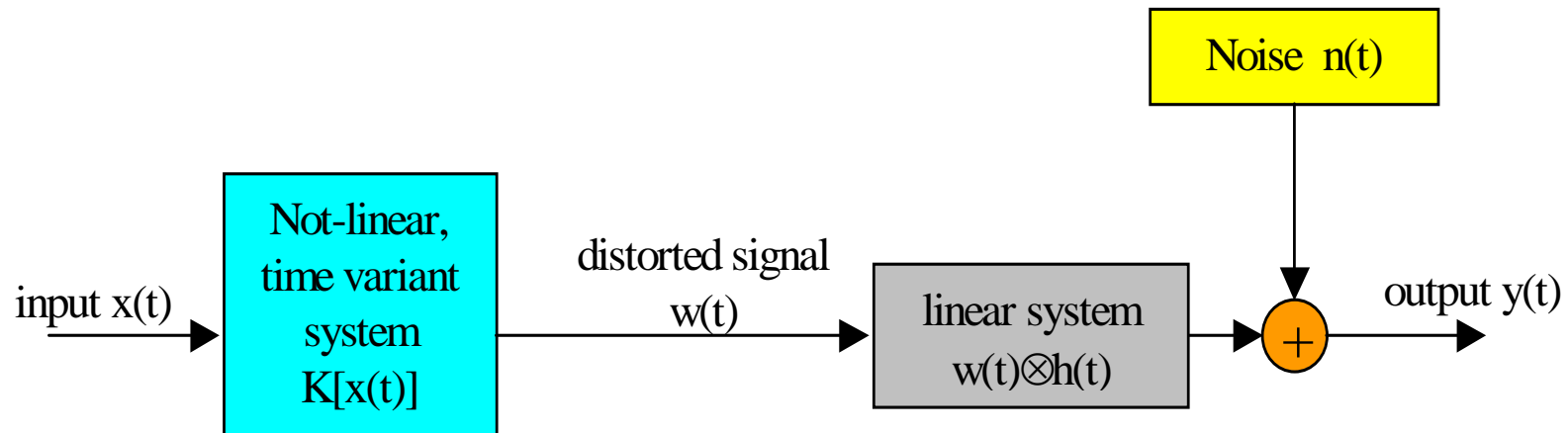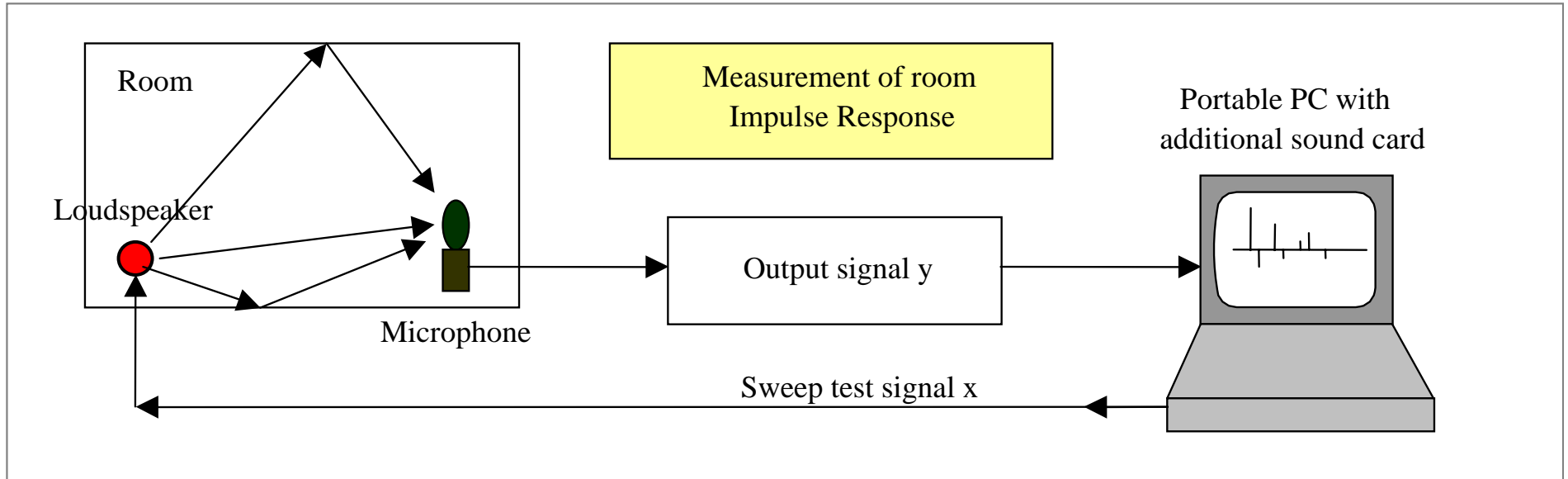
Concert configuration

Concert configuration

Ballroom configuration

Ballroom configuration

Measurement method: Exponential Sine Sweep

Room

Loudspeaker

Microphone

Measurement of room
Impulse Response

Output signal y

Portable PC with
additional sound card

Sweep test signal x

Noise n(t)

input x(t)

Not-linear,
time variant
system
K[x(t)]

distorted signal
w(t)

linear system
w(t)⊗h(t)

output y(t)

+

Exponential Sine Sweep method

- x(t) is a sine signal, which frequency is varied exponentially with time, starting at f_1 and ending at f_2.

$$x(t) = \sin\left[\frac{2 \cdot \pi \cdot f_1 \cdot T}{\ln\left(\dfrac{f_2}{f_1}\right)} \cdot \left(e^{\frac{t}{T} \cdot \ln\left(\frac{f_2}{f_1}\right)} - 1 \right) \right]$$

Test Signal – x(t)
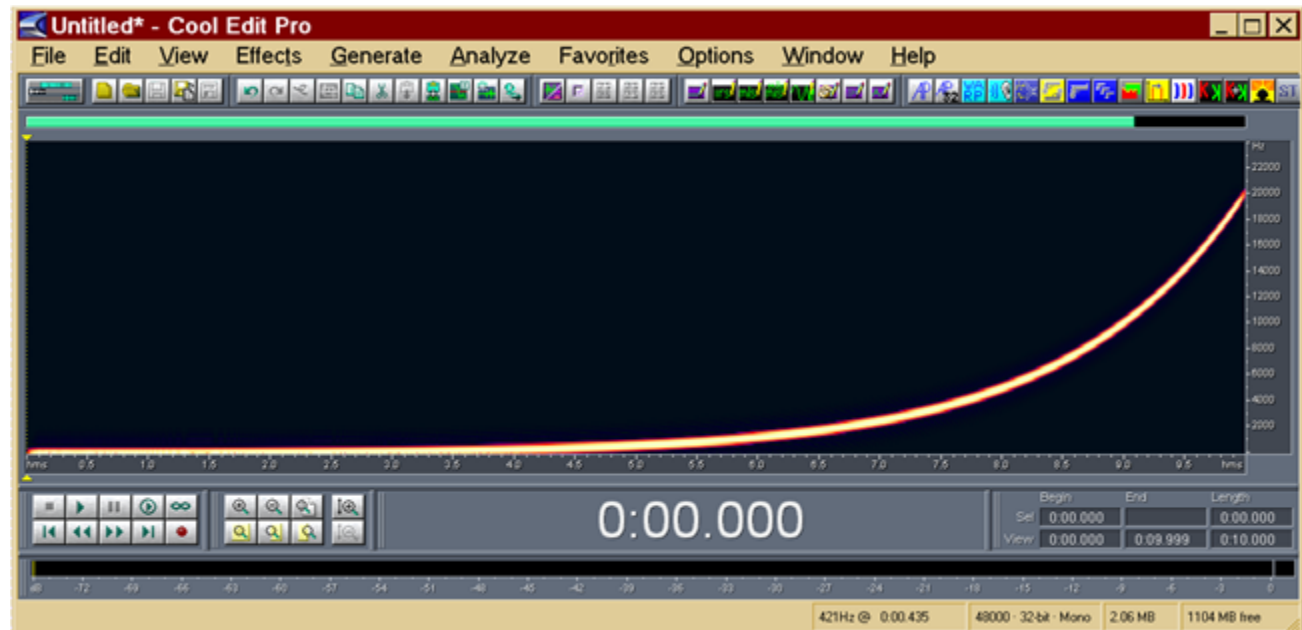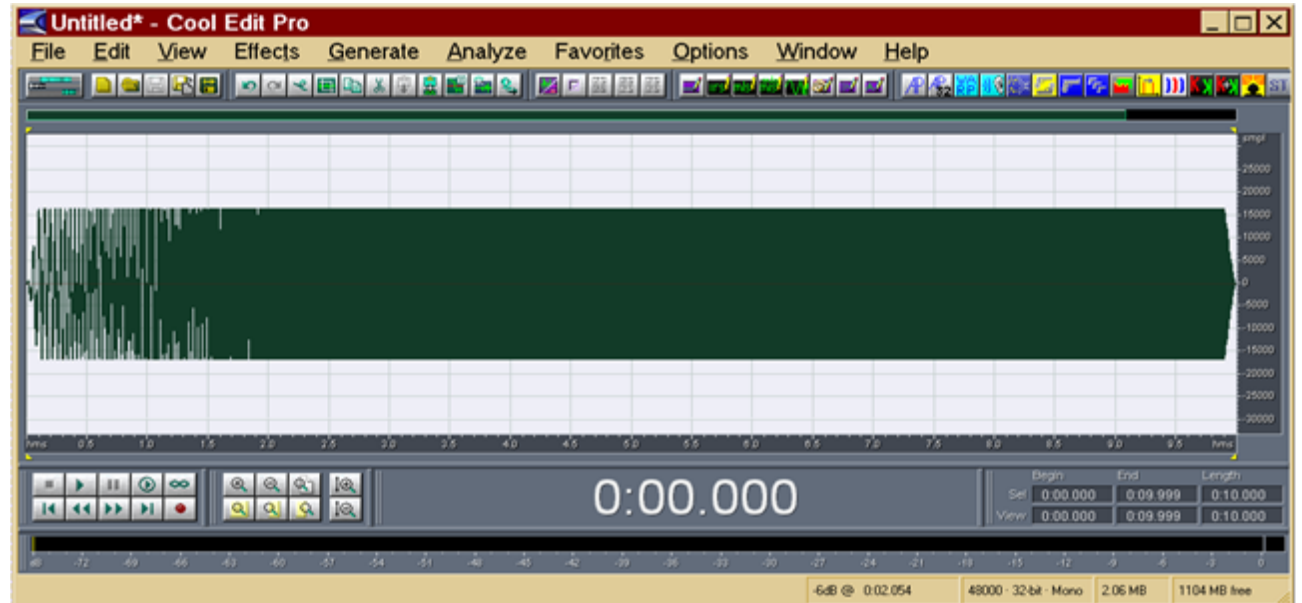
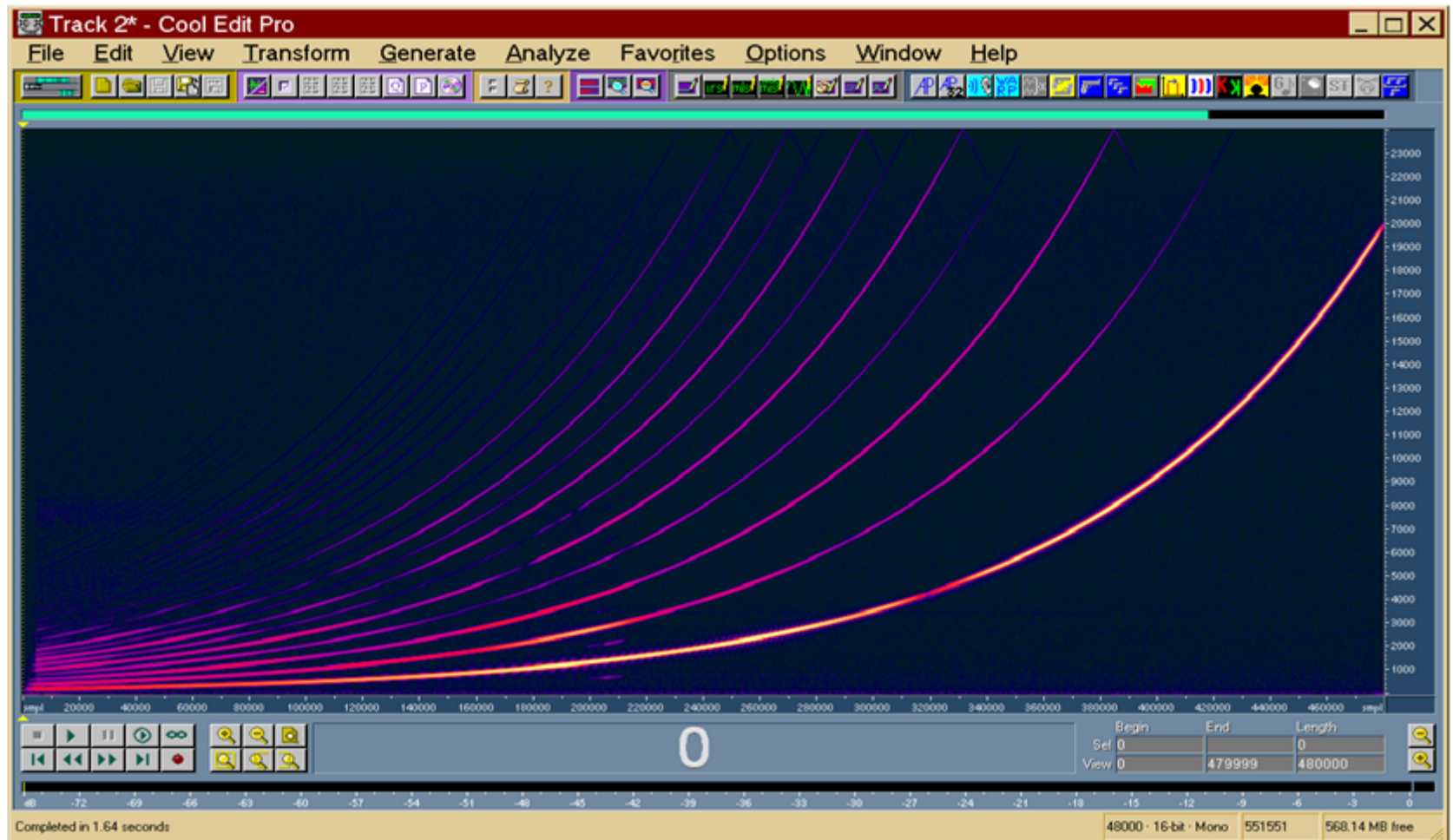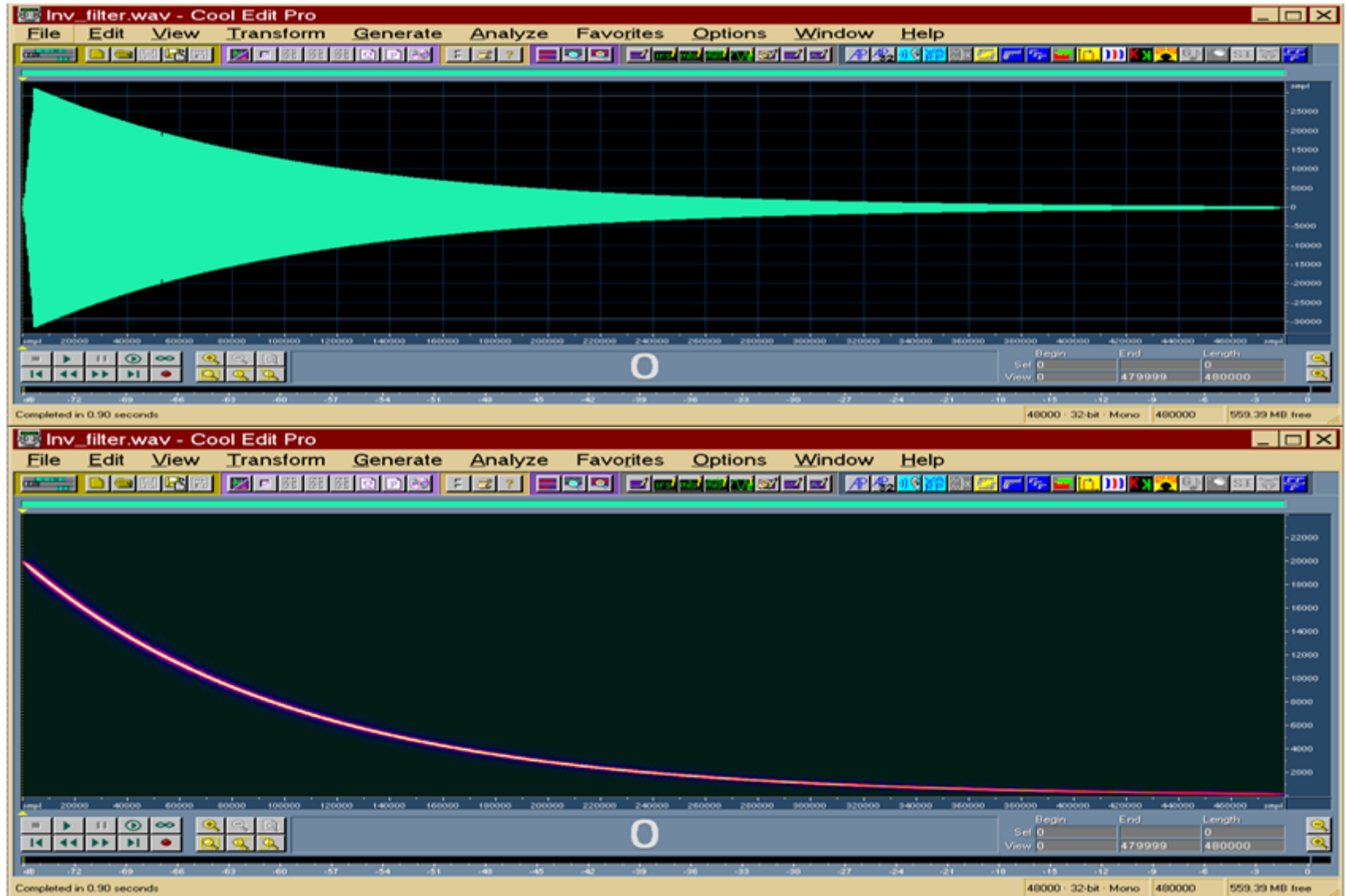# Measured signal - y(t)

- The not-linear behaviour of the loudspeaker causes many harmonics to appear
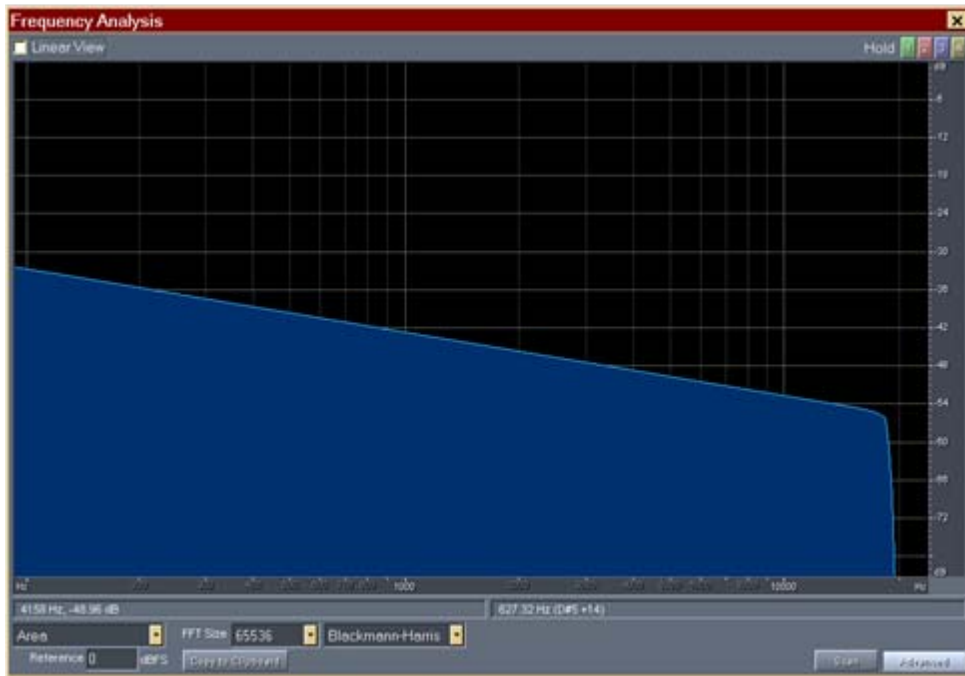
Inverse Filter – z(t)

The deconvolution of the IR is obtained convolving the measured signal y(t) with the inverse filter z(t) [equalized, time-reversed x(t)]

Deconvolution of Exponential Sine Sweep

The "time reversal mirror" technique is employed: the system's impulse response is obtained by convolving the measured signal y(t) with the time-reversal of the test signal x(-t). As the exp. sine sweep does not have a "white" spectrum, proper equalization is required

Test Signal x(t)
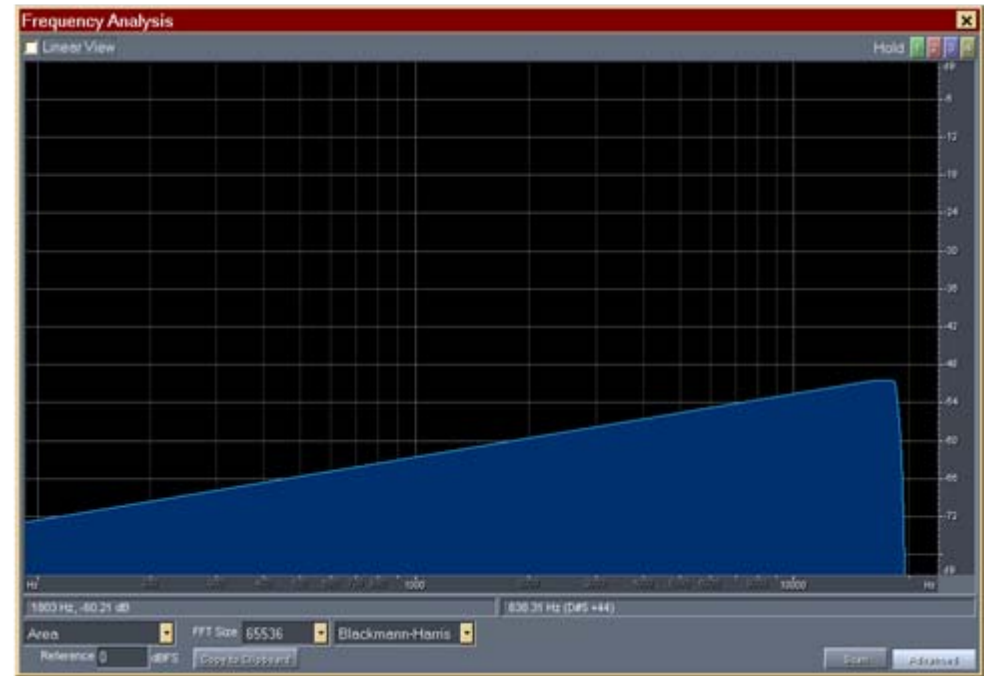
Inverse Filter z(t)

Result of the deconvolution
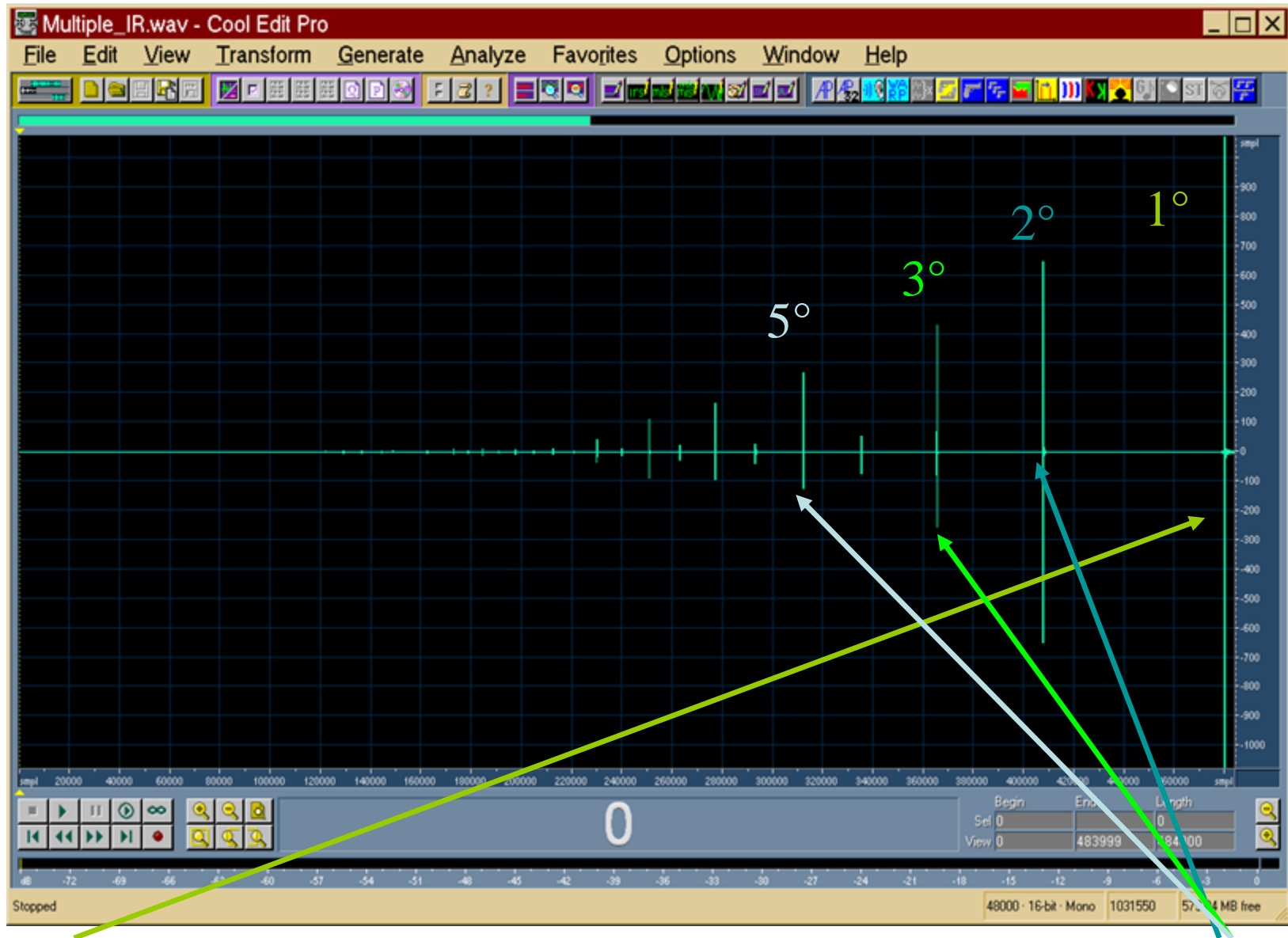
The last impulse response is the linear one, the preceding are the harmonics distortion products of various orders

IR Selection

- After the sequence of impulse responses has been obtained, it is possible to select and insulate just one of them:
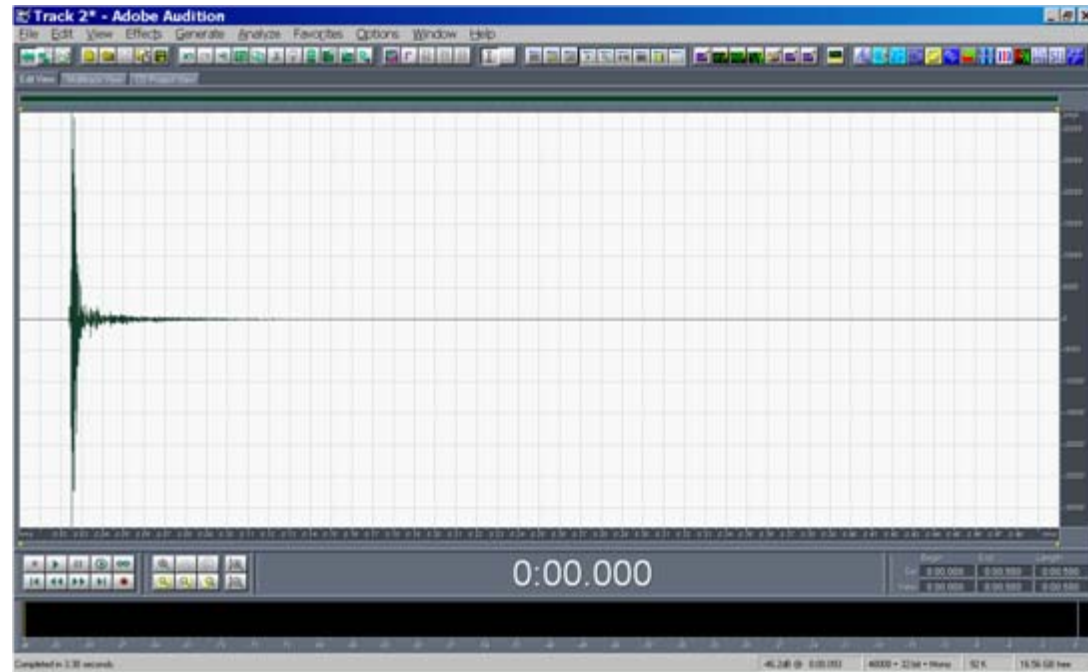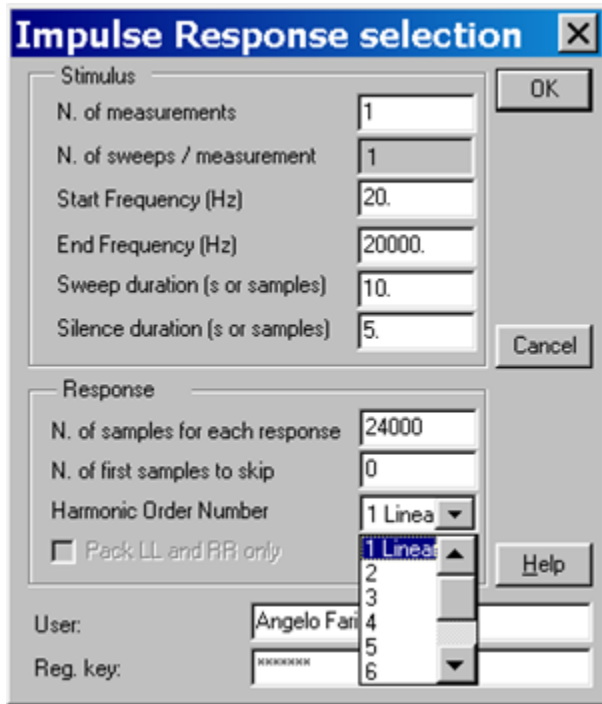
Maximum Length Sequence vs. Sweep
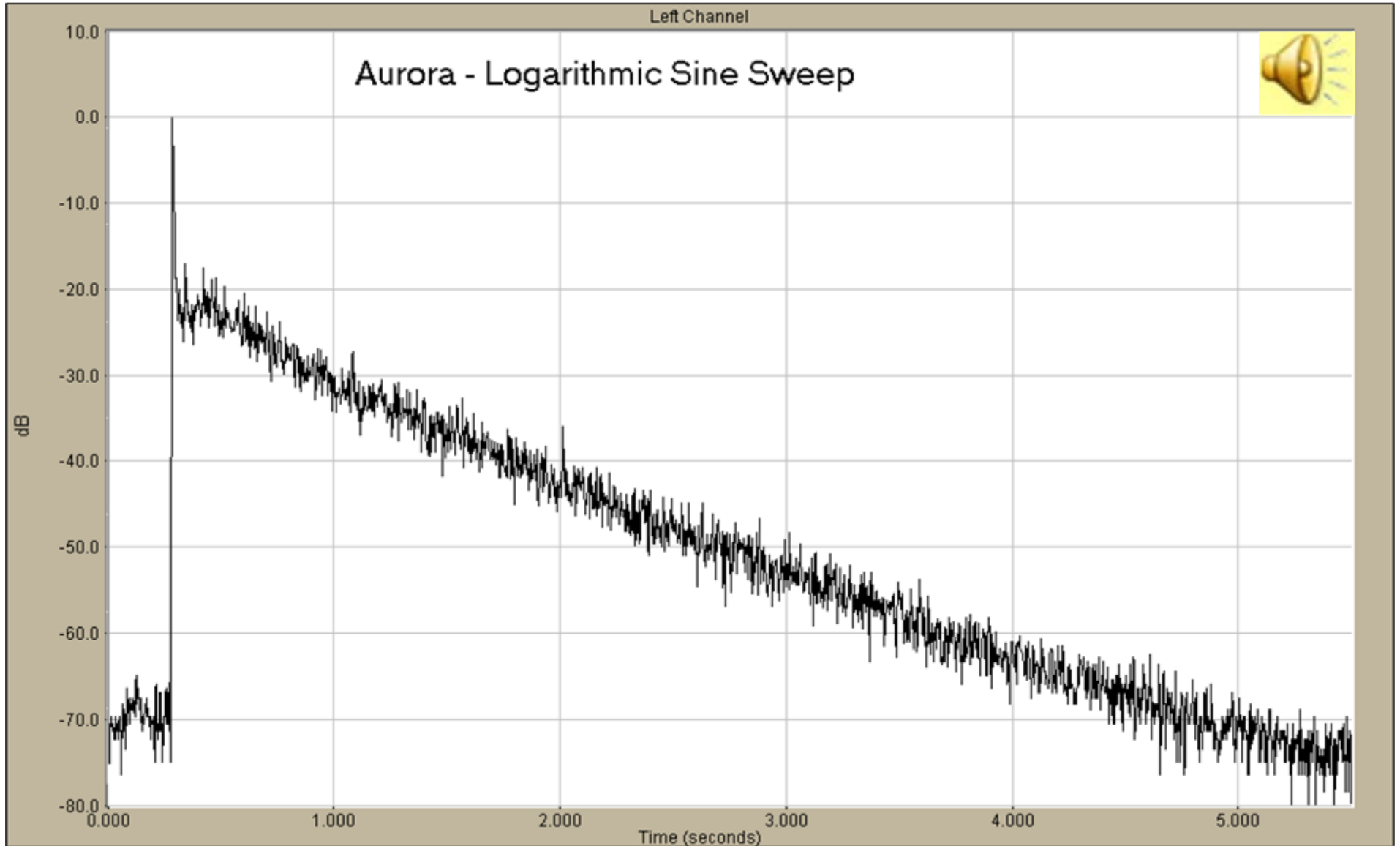
Hardware: loudspeaker & microphone

Dodechaedron loudspeaker

Soundfield microphone
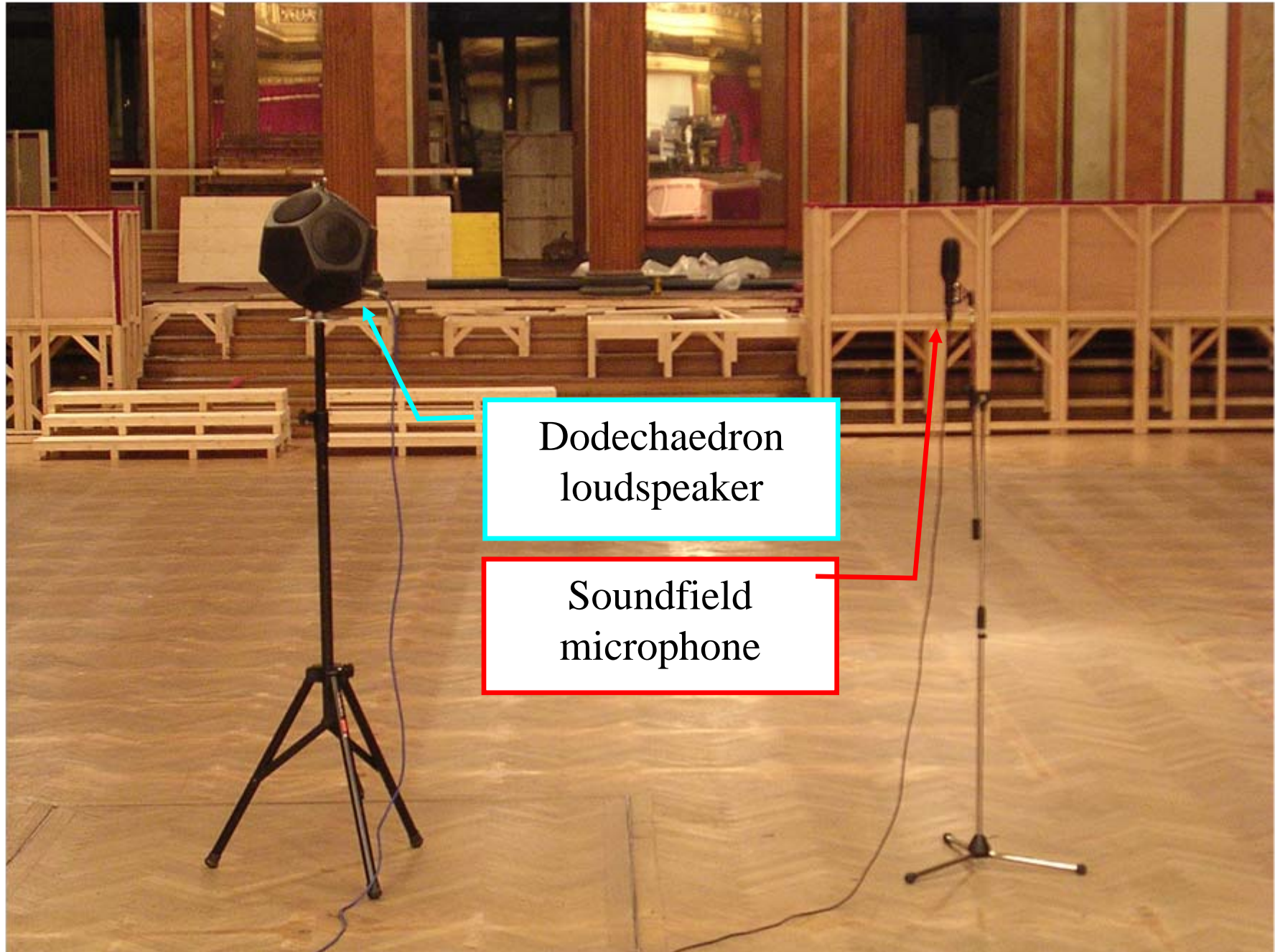
Equipment: computer & sound interface

Laptop PC

MOTU Traveler
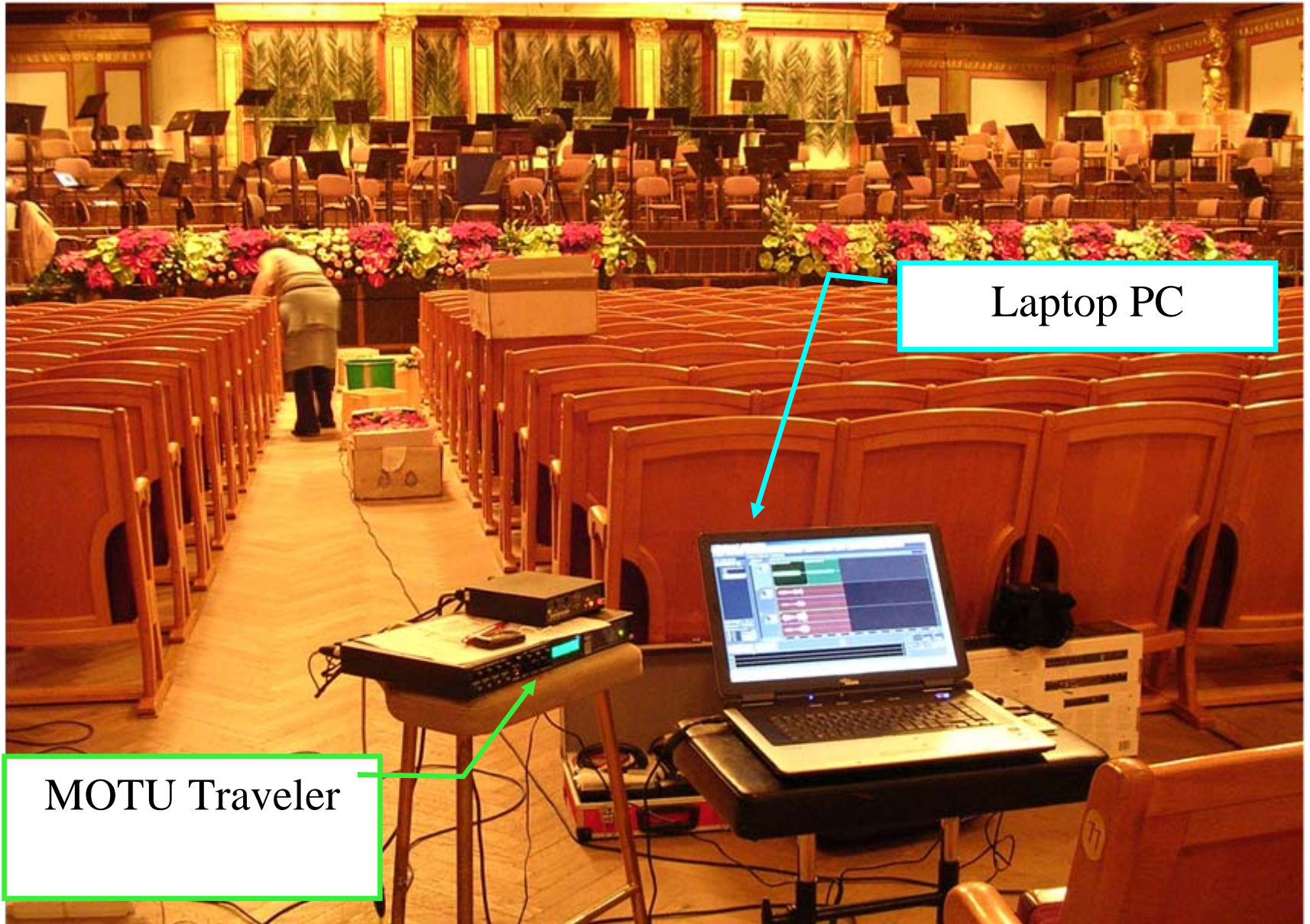
Directivity of transducers

LookLine D200 dodechaedron
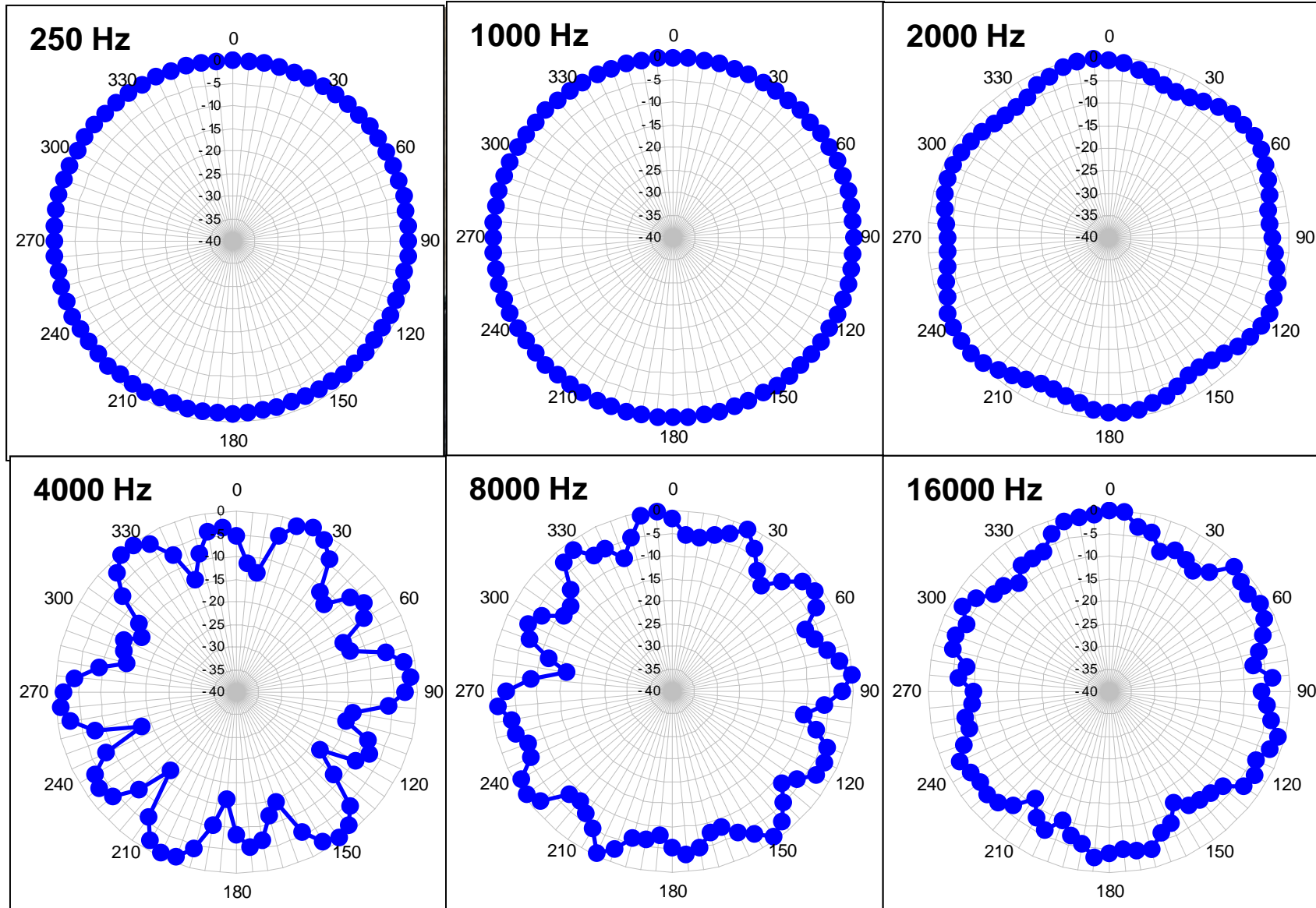
pressure-velocity microphone

- The Soundfield microphone allows for simultaneous measurements of the omnidirectional pressure and of the three cartesian components of particle velocity (figure-of-8 patterns)
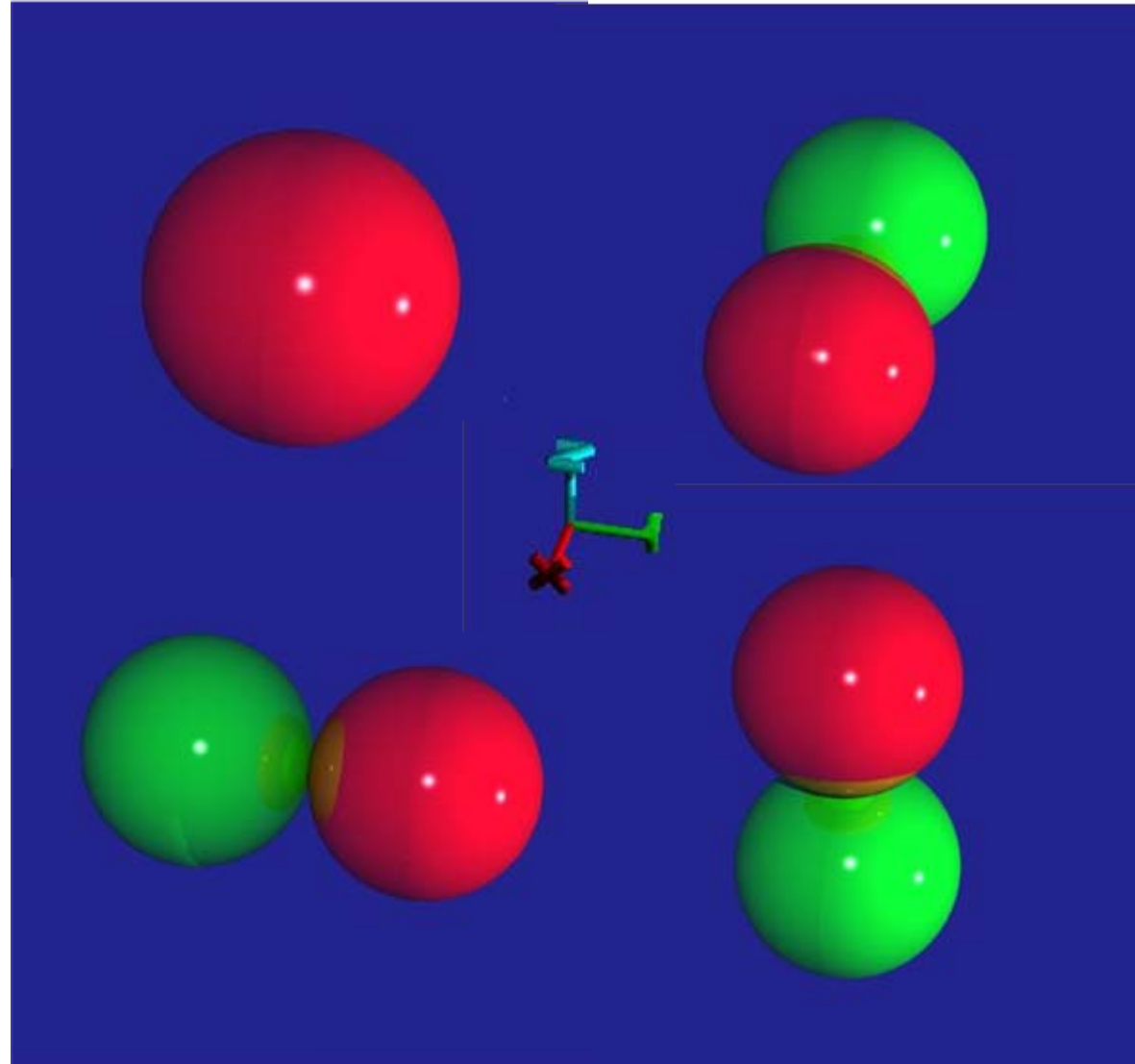
Directivity of transducers

Soundfield ST-250 microphone
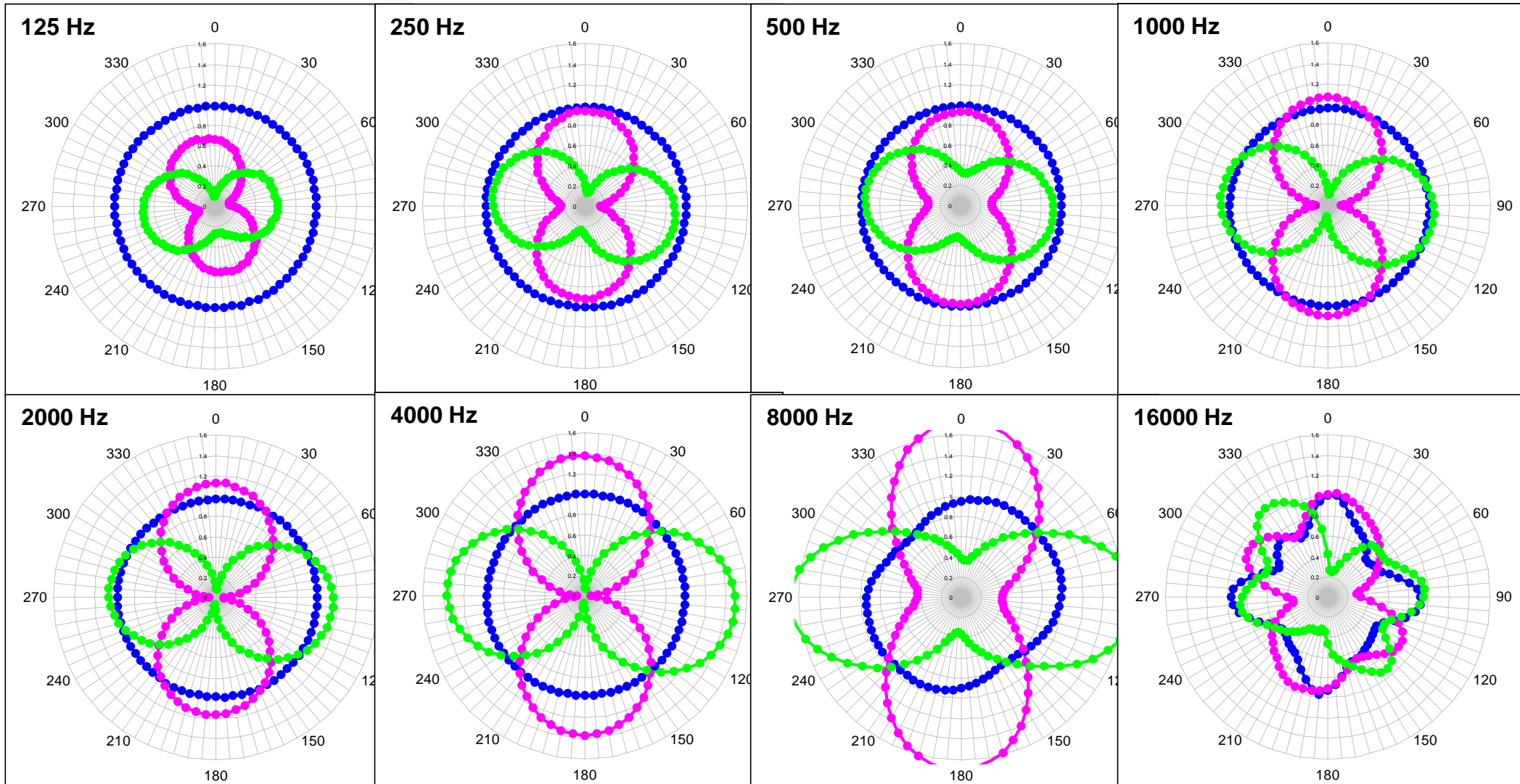
Measurement method:
B-format Impulse Response
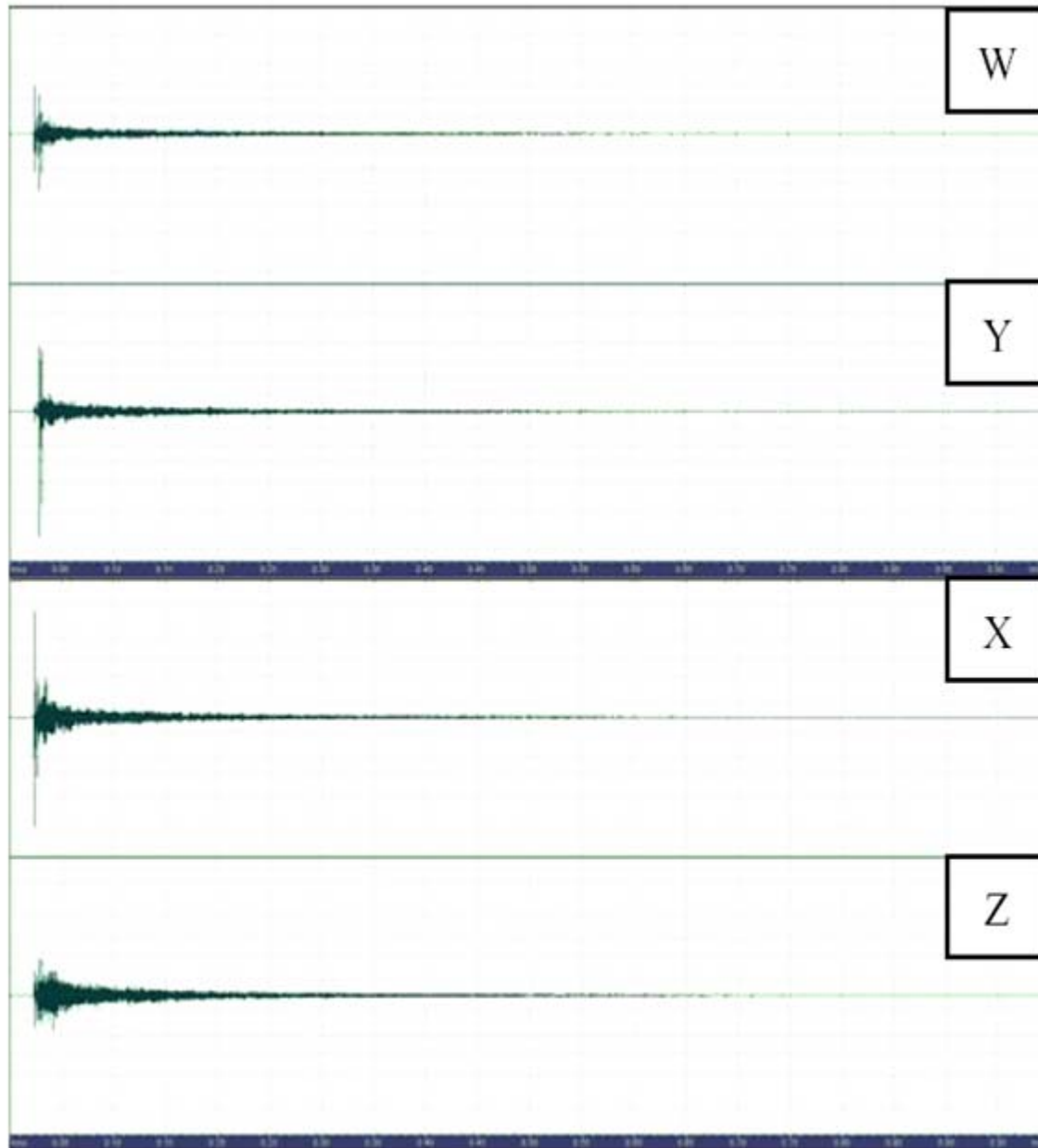
3D Impulse Response (Gerzon, 1975)

Original Room

Sound Source

SoundField Microphone

Measurement of B-format Impulse Responses

Portable PC with 4-channels sound board

B-format Imp. Resp. of the original room

B-format 4-channels signal (WXYZ)

MLS or sweep excitation signal

Sound Source

Mono Mic.

Convolver

B-format 4-channels signal (WXYZ)

Ambisonics decoder

Convolution of dry signals with the B-format Impulse Responses

Speaker array in the reproduction room

Measurement positions

ISO3382 Parameters

Acoustical Parameters according to ISO3382 (v. 4.2)

Close | Help
OK - keep processed
Save Results to File...
Copy Results to Clipboard
Store G Reference Signal

Channel: ● Left ○ Right

Tuser limits: (-5 dB, -15 dB)

Point15-W-Y

31.5	63	125	250	500	1k	2k	4k	8k	16k	A	Avg	Freq. (Hz)
61.41	73.54	70.44	75.10	78.34	79.08	87.14	91.20	90.76	95.96	97.02	79.91	Signal (dB)
40.99	39.19	28.48	27.56	27.23	30.92	28.01	34.00	38.73	46.13	50.49	28.43	Noise (dB)
17.79	26.51	14.97	8.60	9.53	7.73	8.34	6.29	2.05	-4.22	25.66	8.55	G (dB)
-1.07	-3.14	-5.57	-0.34	-2.04	-1.44	0.15	2.34	7.16	15.29	5.12	-0.92	C50 (dB)
2.22	-0.11	-0.91	0.55	-0.52	0.25	1.23	4.33	10.09	19.19	6.80	0.38	C80 (dB)
43.88	32.65	21.71	48.05	38.46	41.78	50.88	63.18	83.87	97.12	76.46	44.79	D50 (%)
126.03	131.78	177.20	166.29	147.00	140.12	106.44	62.29	23.63	8.86	44.52	139.96	Ts (ms)
1.16	1.52	2.75	3.15	2.24	2.40	1.89	1.25	0.59	0.13	1.09	2.42	EDT (s)
1.05	1.25	2.88	2.64	2.93	2.54	2.19	1.34	0.73	0.28	1.47	2.57	Tuser (s)
2.89	2.19	2.68	2.74	2.84	2.61	2.19	1.38	0.75	0.38	1.84	2.60	T20 (s)
2.92	2.25	2.67	2.80	2.73	2.65	2.20	1.46	0.80	0.38	2.06	2.59	T30 (s)
0.09	0.64	0.45	0.26	0.19	0.25	0.36	0.69	0.96	0.53	0.65	0.27	LF
0.22	0.59	0.50	0.32	0.27	0.27	0.43	0.61	0.75	0.48	0.60	0.32	LFC
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Results

T30 Musikverein - No Audience

	125	250	500	1000	2000	4000	[Hz]
B	3.0	3.3	3.4	3.2	2.4	1.4	
C	2.6	2.7	2.7	2.6	2.1	1.4	
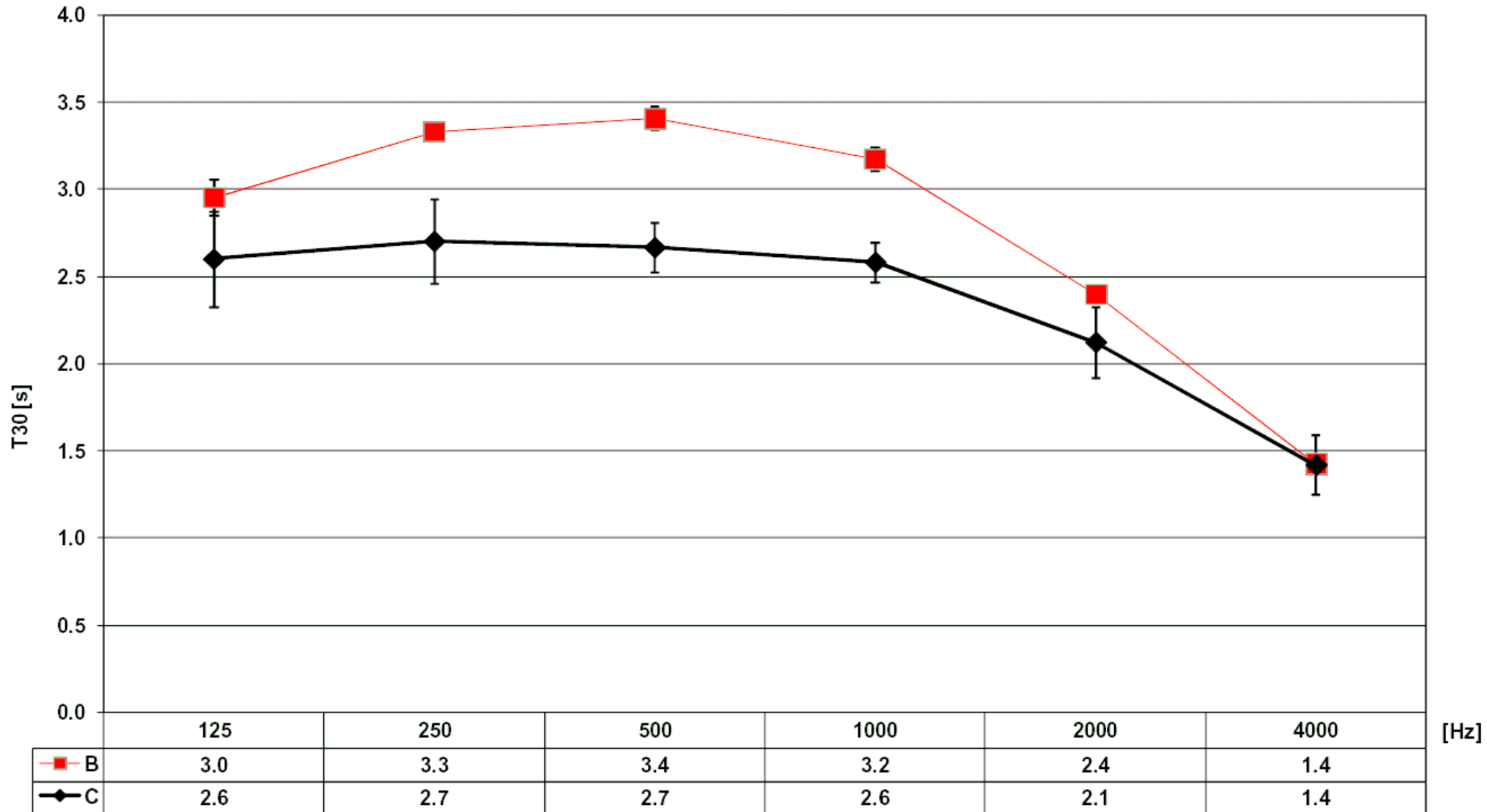
Results

EDT - Muskverein - No Audience

	125	250	500	1000	2000	4000	[Hz]
B	2.4	3.2	3.3	3.0	2.1	1.1	
C	2.5	2.5	2.5	2.4	2.0	1.3	
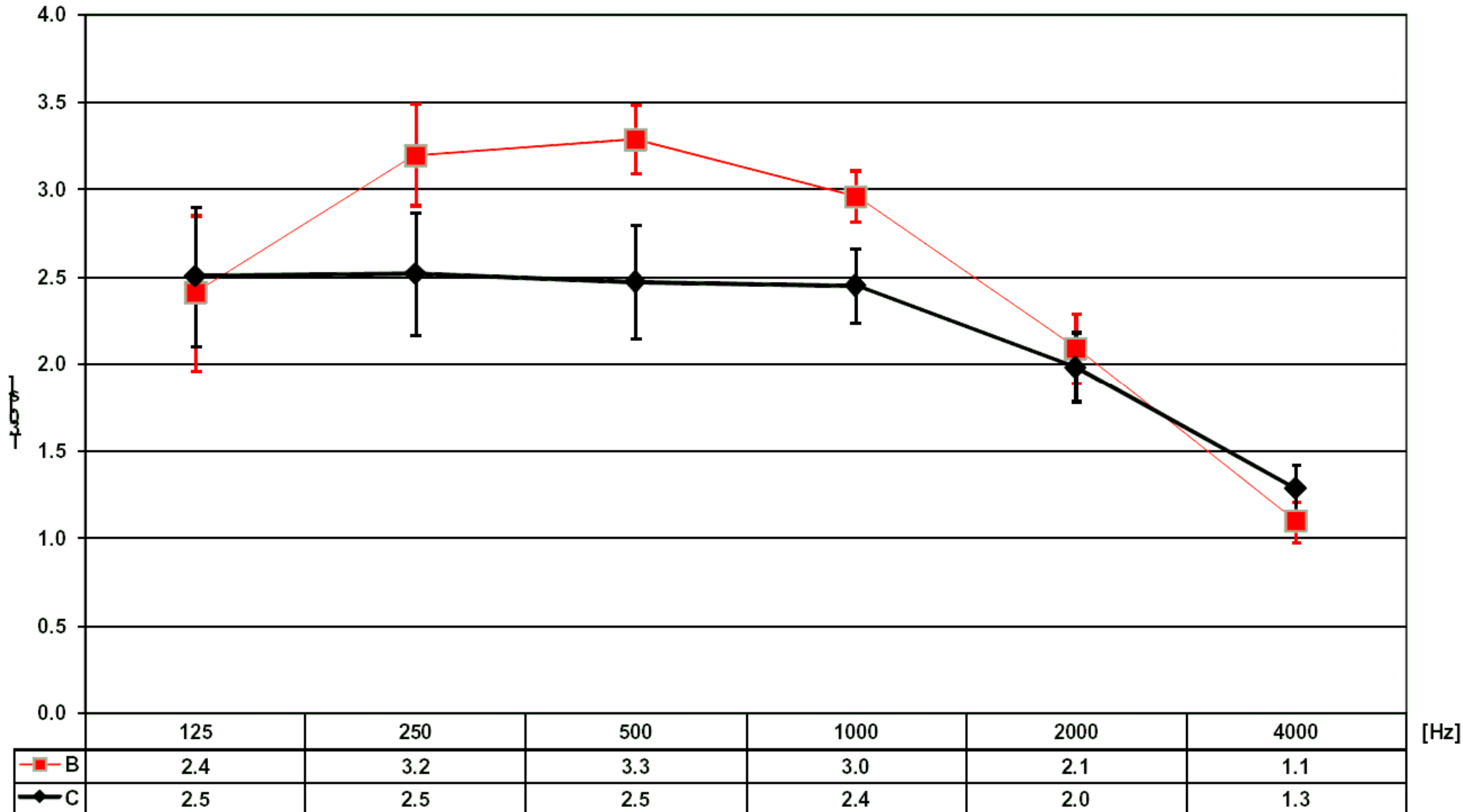
Results

C80 - Musikverein - No Audience

	125	250	500	1000	2000	4000	[Hz]
B	-0.2	-0.9	-3.4	-0.8	2.1	6.7	
C	-1.8	-2.2	-3.1	-0.6	1.8	4.1	
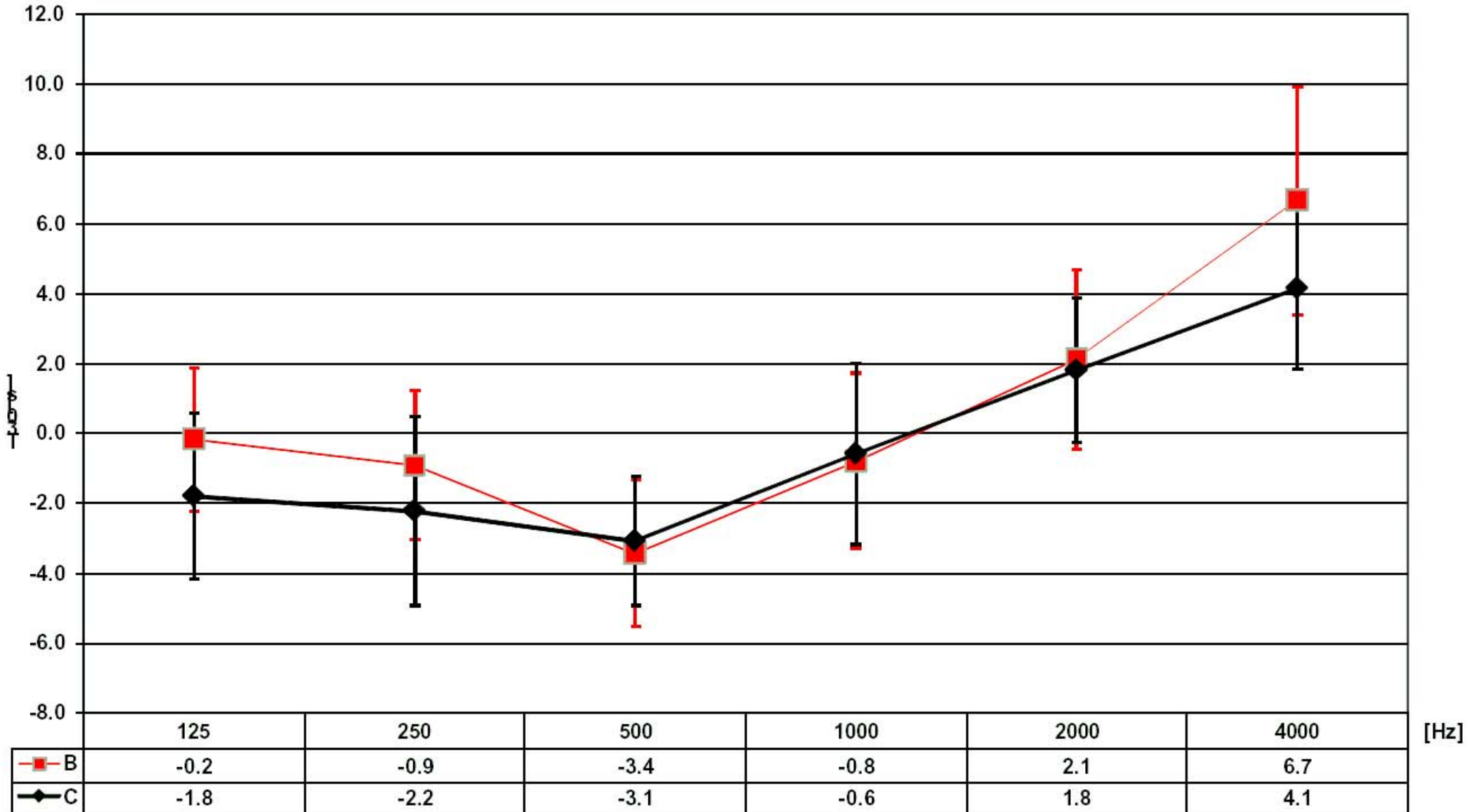
Results

G - Muskverein - 500, 1000, 2000 Hz
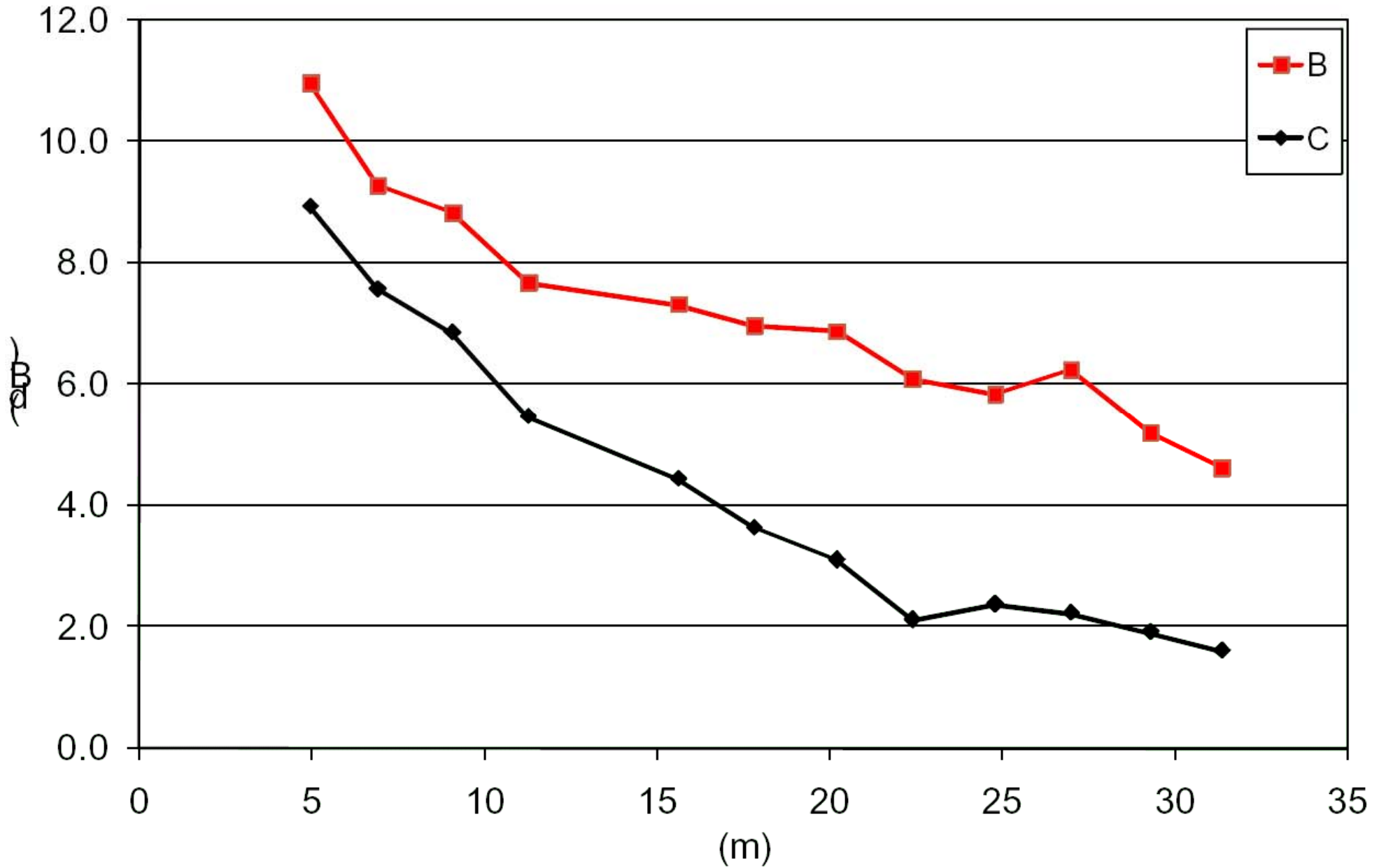
Results

LF - Musikverein - No Audience

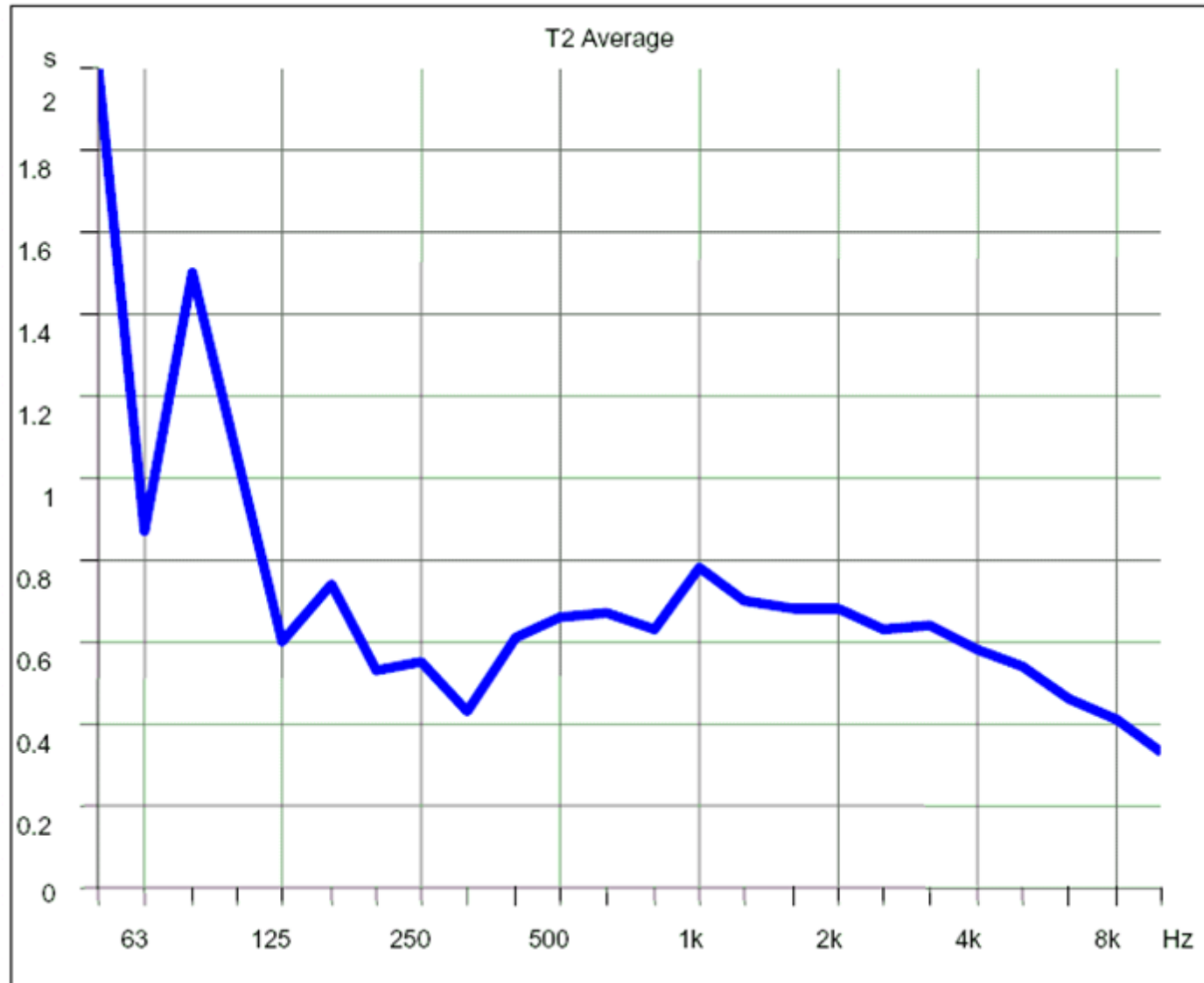|	125	250	500	1000	2000	4000	[Hz]
B	0.10	0.14	0.23	0.18	0.20	0.28	
C	0.11	0.24	0.20	0.19	0.21	0.42	
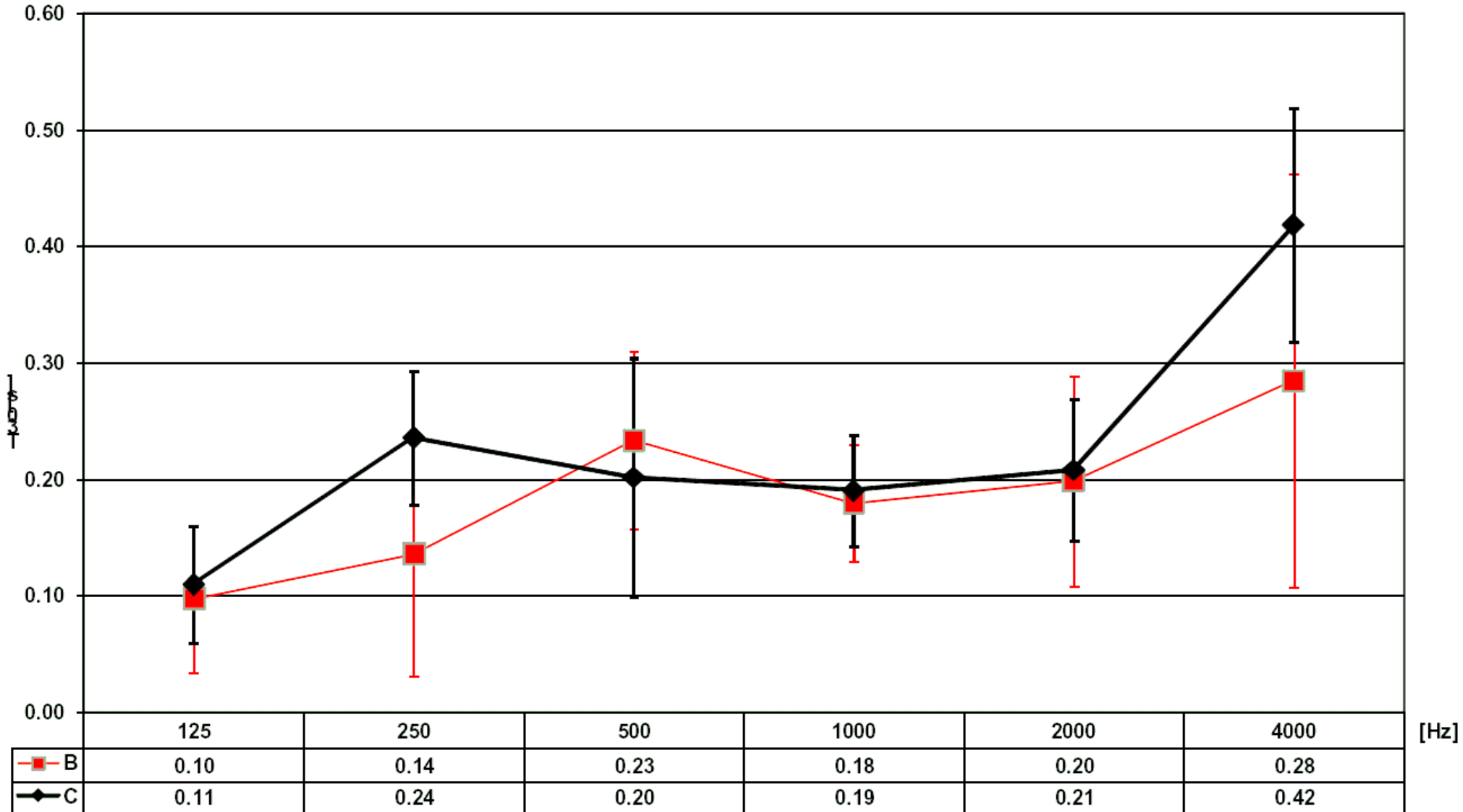
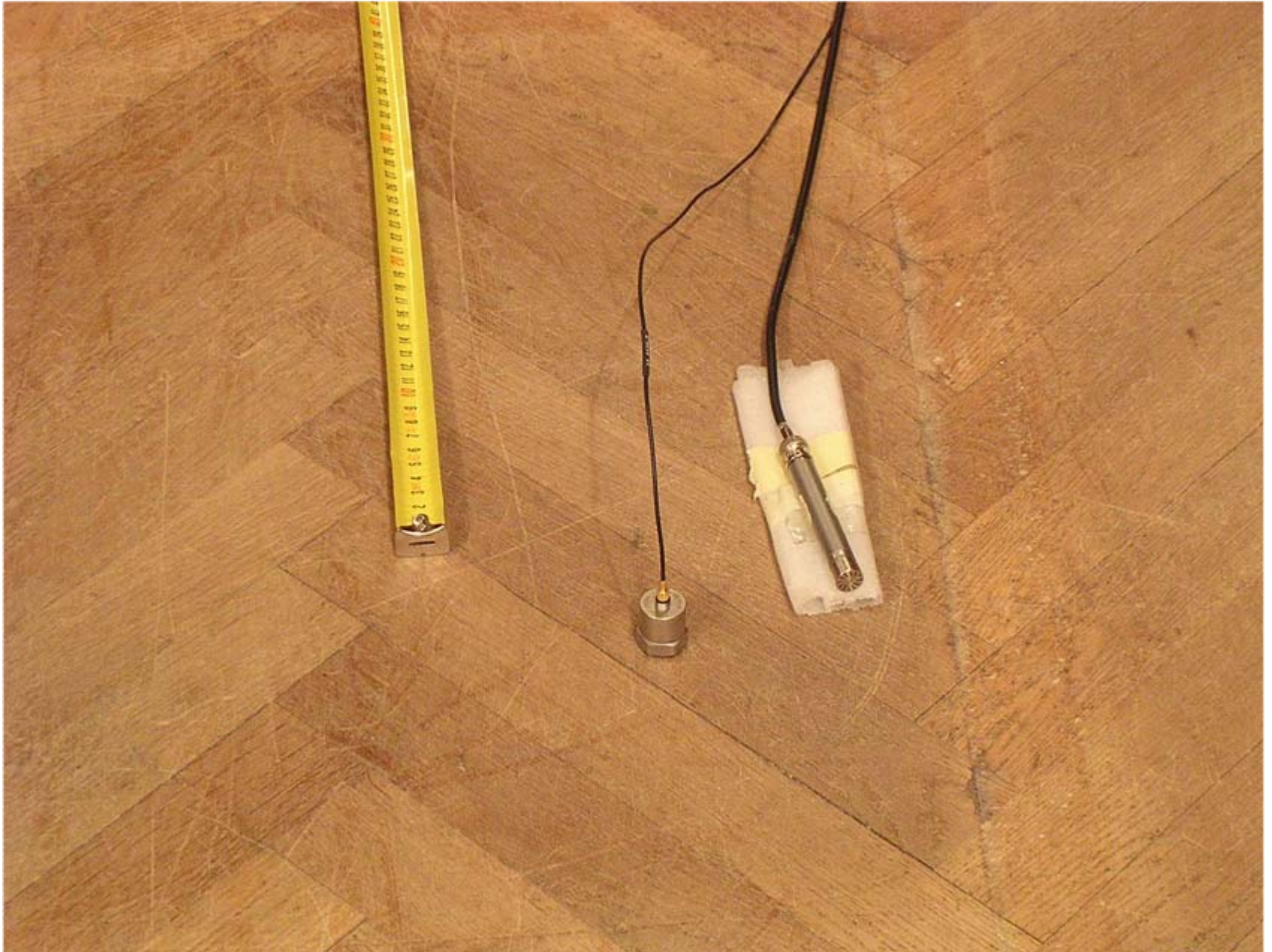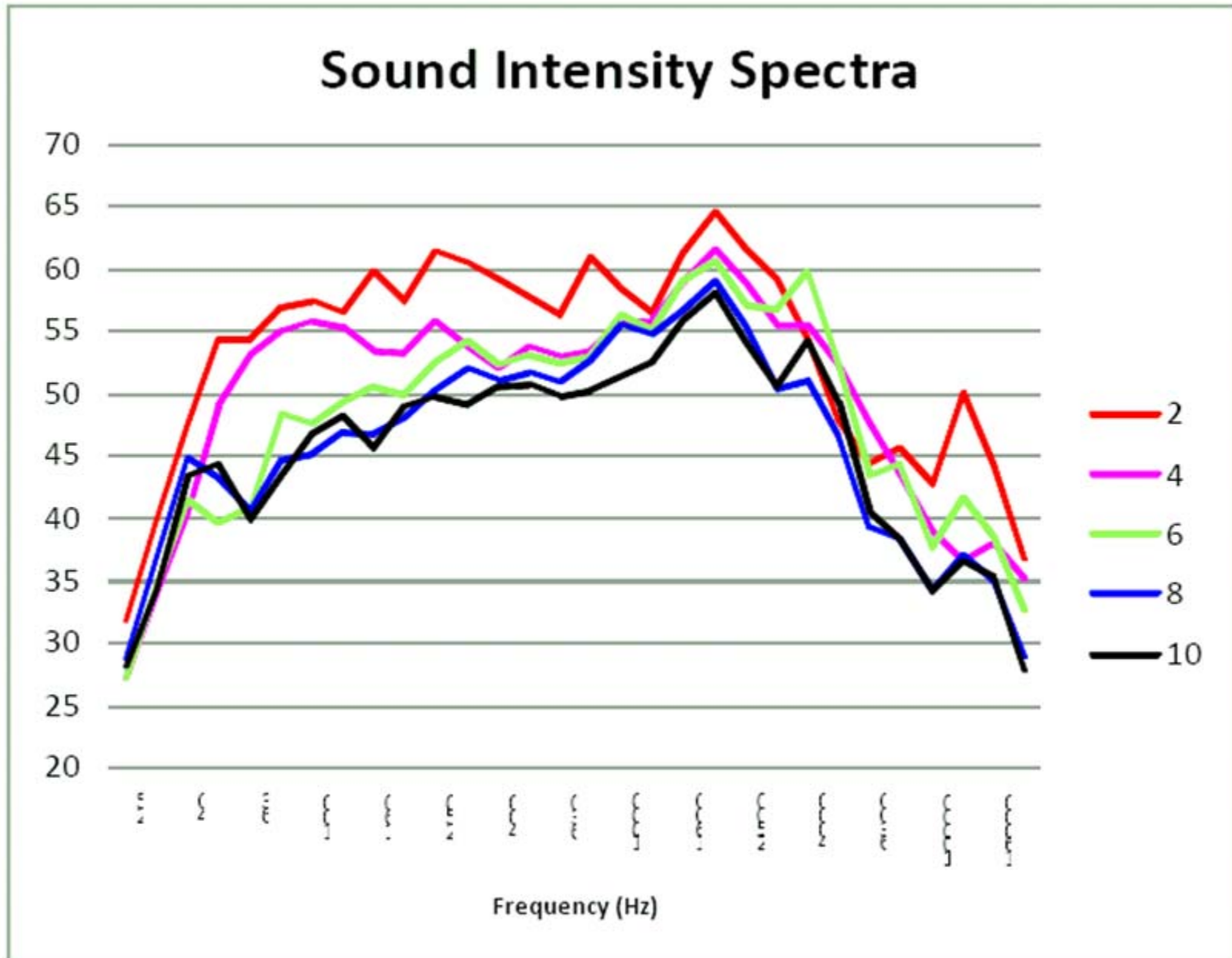# Storage room under the stalls

Sound reduction index
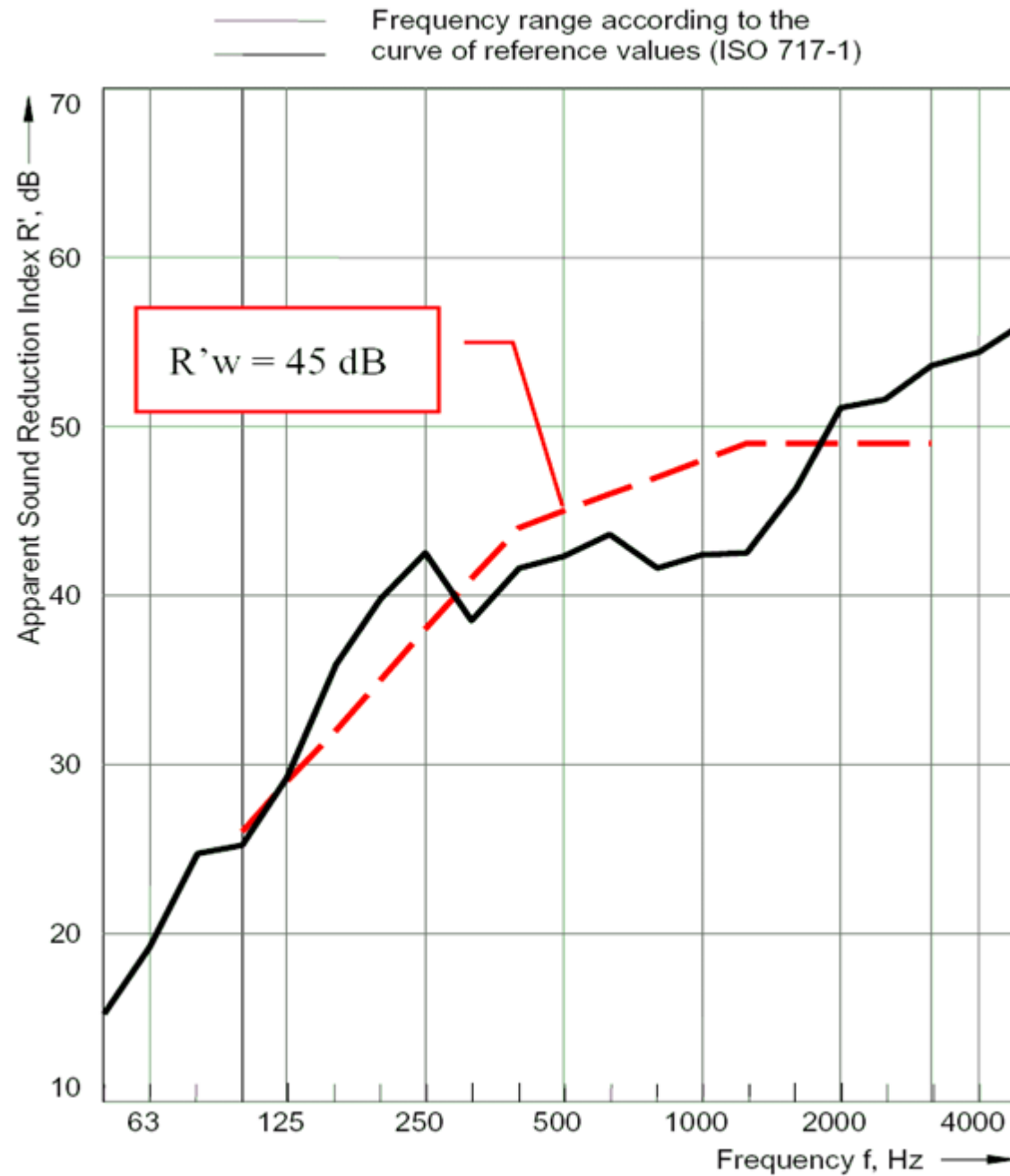
Reverberation time of storage room (empty)

Surface Sound Intensity

Surface Sound Intensity

Conclusions

- Musikverein is a truly variable acoustics room

- The Ballroom configuration exhibit reverberation times significantly larger than the Concert configuration, particularly at medium frequencies

- Also G is significantly different

- However, C80 and LF do not change remarkably, ensuring good acoustical quality also in Ballroom configuration

- The storage room under the stalls is heavily insulated, hence it cannot have any effect

- The effect of the audience should be taken into account, particularly in Ballroom configuration, where it would be probably much larger than in Concert configuration.