A study of hearing damage caused by personal MP3 players

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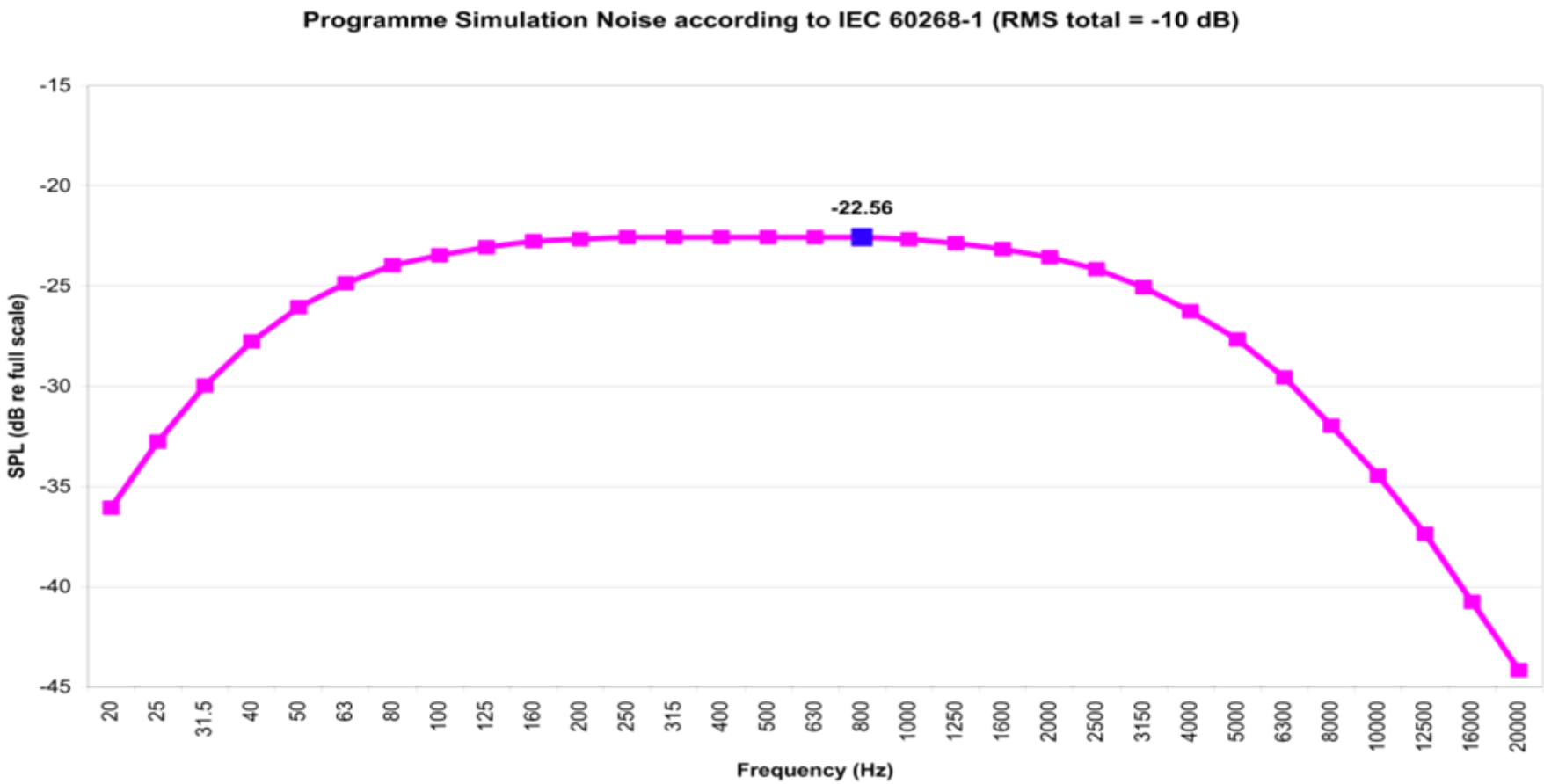
Objectives

Measuring noise exposition of teenager subjects with real-life volume settings and complying with the following:

- Following international and european standards about measurements techniques
- Using a test signal that is both standard and similar to real-life music

The “IEC” test signal

The first test signal employed was the one prescribed by standard IEC 60268-1



Generating the signal

- One minute of pink noise was generated
- It was equalized in order to obtain the desired spectrum
- The resulting sound had an average RMS value of -16dBFS instead of the standard -10

Generating the signal

- In order to obtain the correct RMS value we employed the Hard Limiting module of Adobe Audition, with a 6dB gain
- The Graphic Equalizer was again used to correct the minor distortion caused by the Hard Limiting
- The resulting sound was measured compliant with the IEC standard

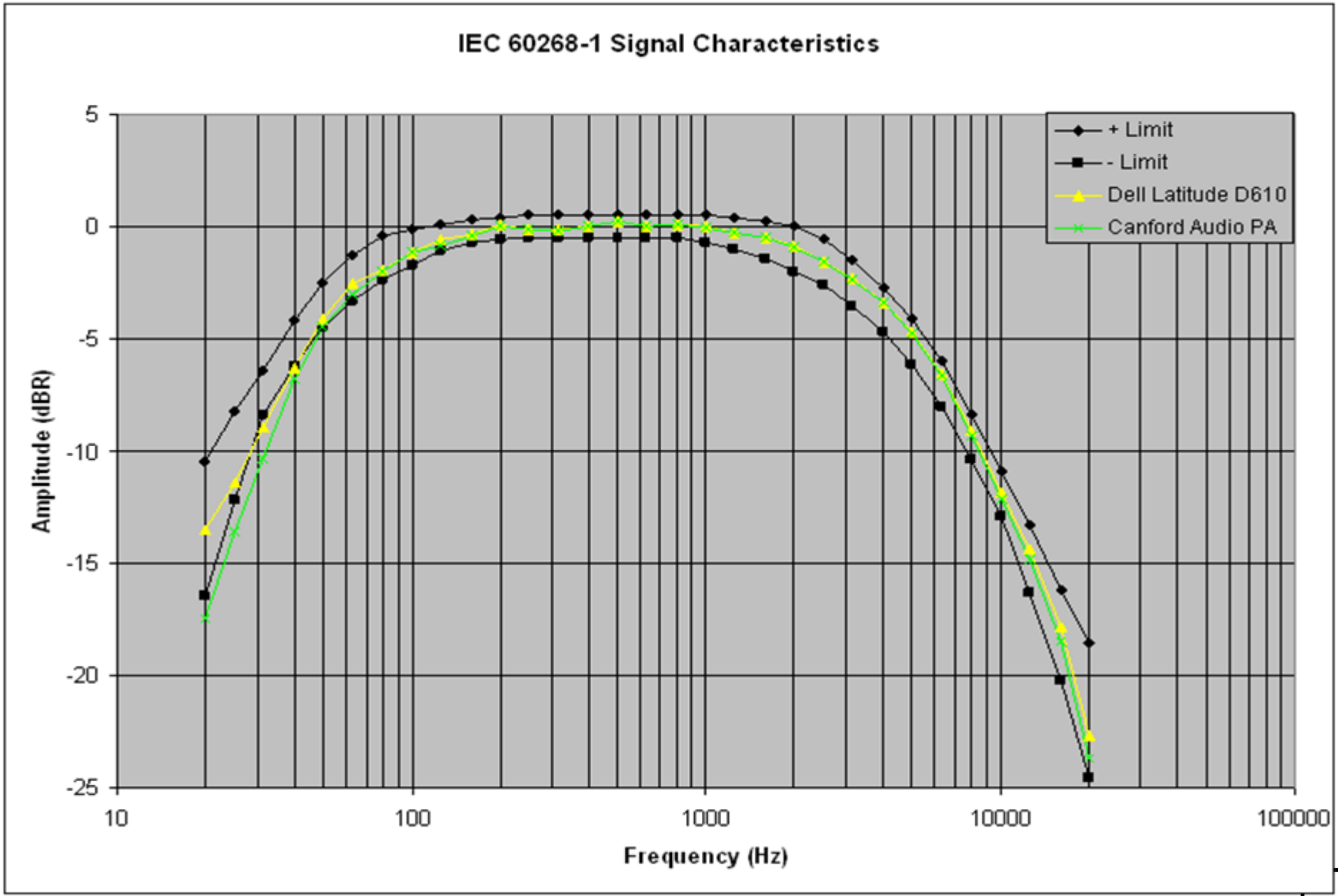
- However, it was noted by Alastair Hardie, a Senior Electronic Engineer for Frontier Silicon, that the Crest Factor had a 3.1373 / 3.1372 ratio, instead of the 1.8/2.2 specified in section 5.1 of standard EN 50332-1:200

Crest Factor Problem

- While the IEC standard states that the programme simulation noise must have a crest factor ranging between 1.8 and 2.2, it was technically impossible to generate such a noise. In fact the standard is written considering an analog crest factor measurement.

- Analog measurements were performed using a quasi-peak detector, which systematically underestimated the result.
- It was thence attempted to emulate it employing the Statistical Analysis tool of Adobe Audition.
- Specifying a window width of 35 ms, this tool computes correctly the pseudo-peak value as maximum RMS, if you add 3dB to the result (or by specifying that 0 dB = FS sine wave). It was checked that with these settings one gets the readings specified in table A-II of the IEC standard, employing a 5kHz tone burst of 1ms length.

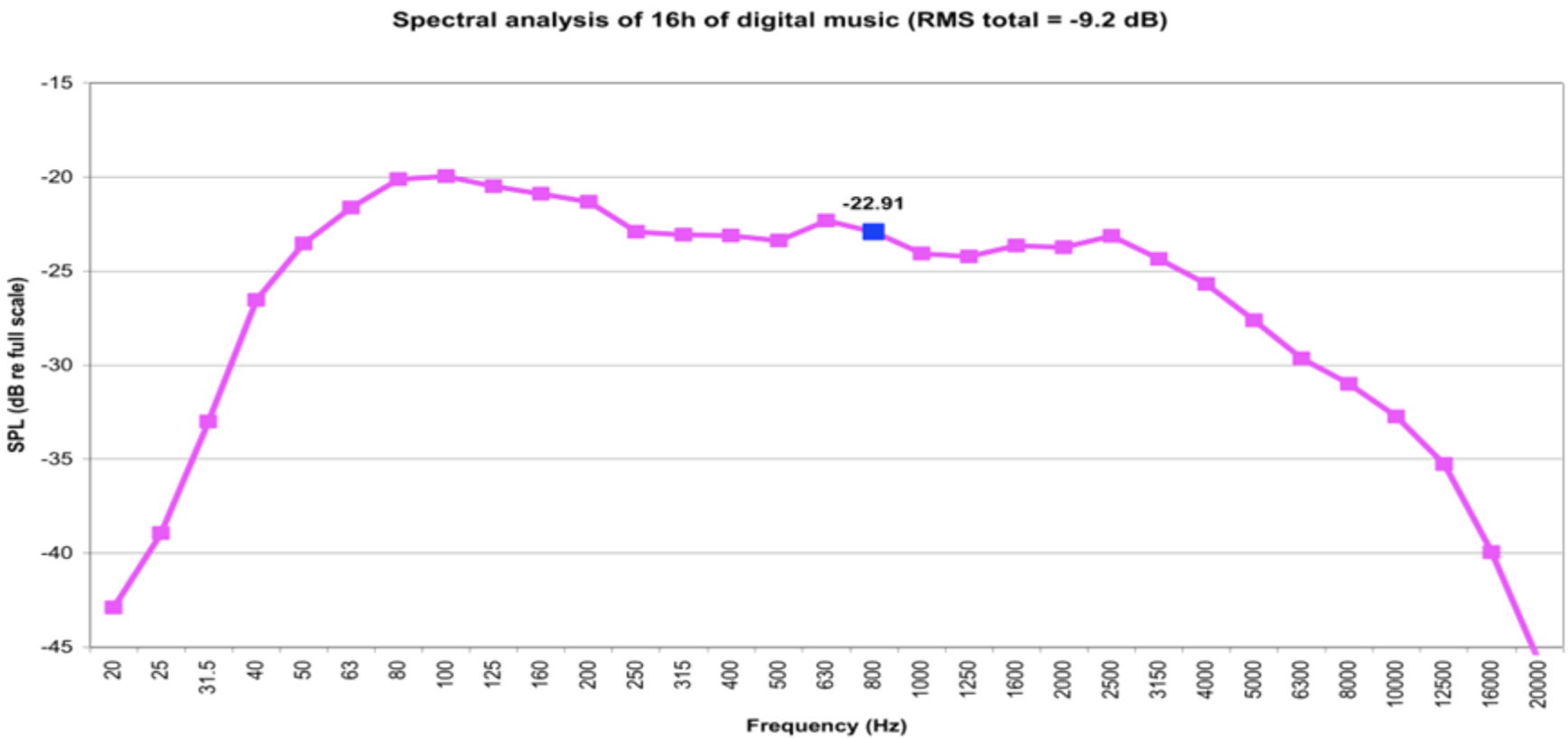
- After calibrating such a quasi-peak digital detector, I analyzed again my WAV file, and the result found was that the maximum peak value detected is roughly -4.58 dB FS. Hence, the peak-to-RMS ratio is 5.42 dB, which means a ratio equal to 1.87, which is inside the range dictated by the EN standard
- Furthermore Mister Hardie had the signal tested both by the National Physical Laboratory of London and by another independent lab, and was found standard-compliant (not considering a 0.09 dB error to be relevant).

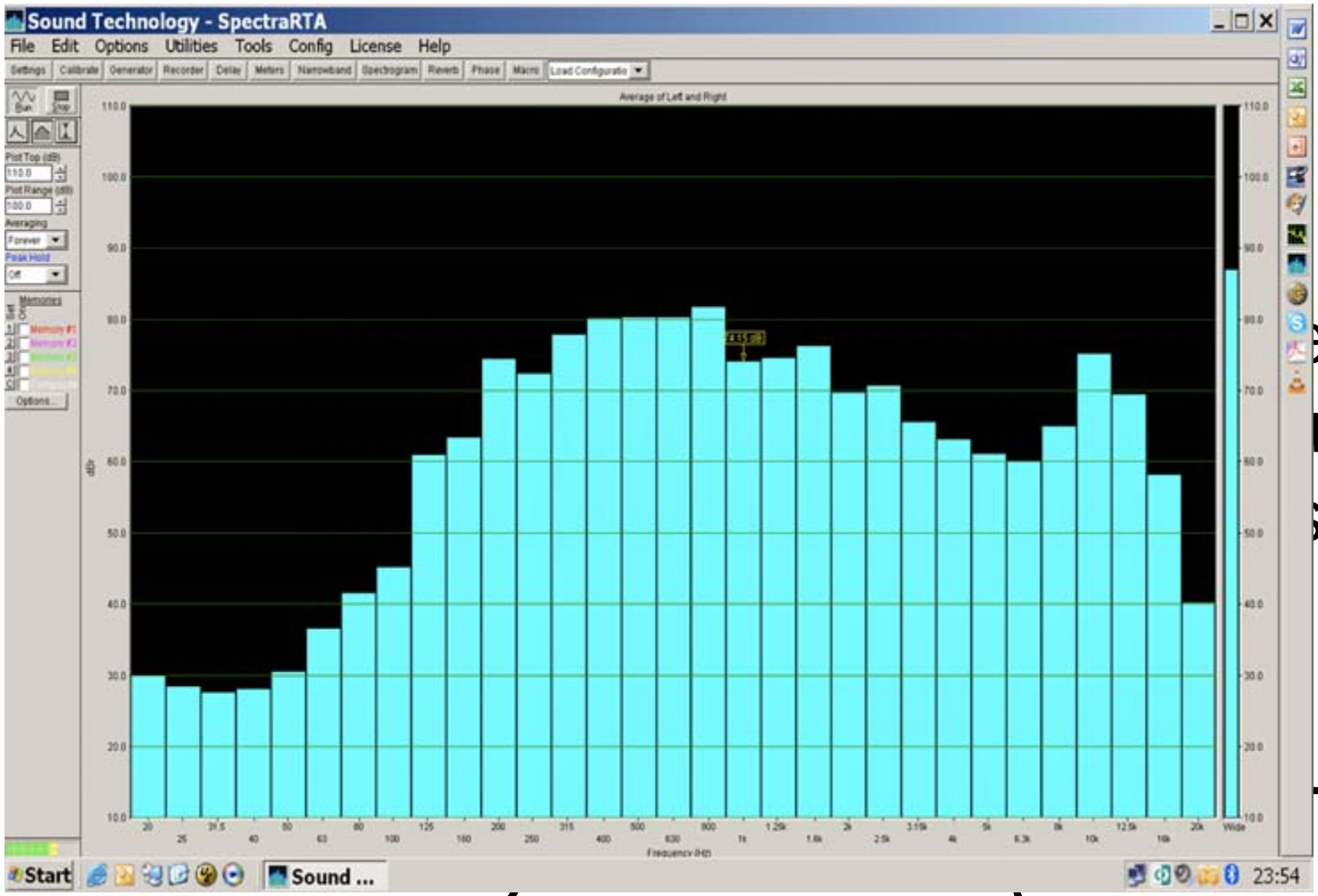

IEC 60268-1 Signal Characteristics
+ Limit
- Limit
Dell Latitude D610
Canford Audio PA
Amplitude (dBR)
5
0
-5
-10
-15
-20
-25
10
100
1000
10000
100000
Frequency (Hz)

Since the “IEC” test signal is made to measure the maximum SPL possible for a device, we also used a signal representative of music

The “Music” test signal

The second test signal employed was the “Music” signal, which was based on the average 1/3 of octave spectrum of all the music pieces stored on the measured DAPs (more than 30 GB)



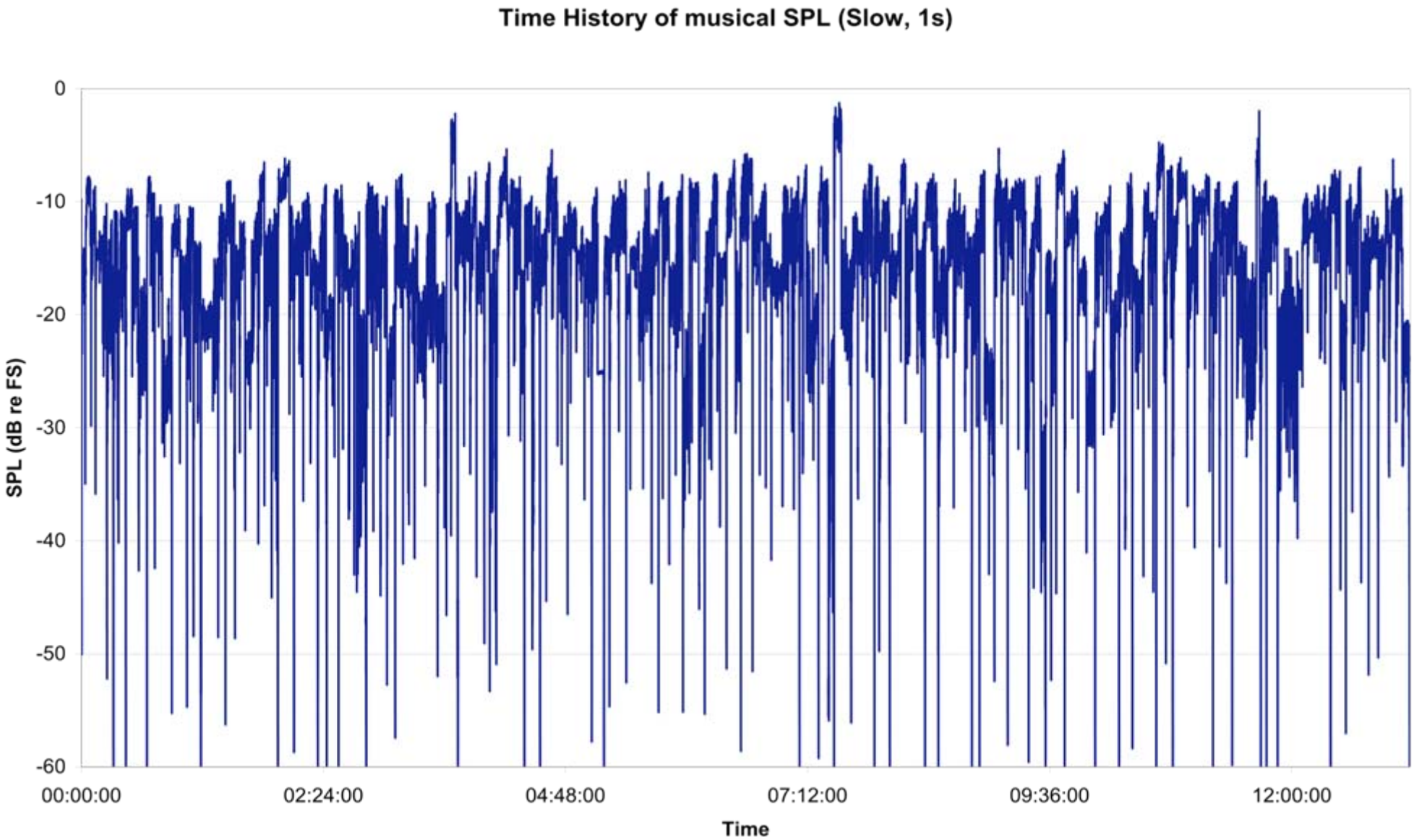


erage
usic, which
stem:

Measures 1/3
of octave
spectrum

Digitally reroutes audio output to input

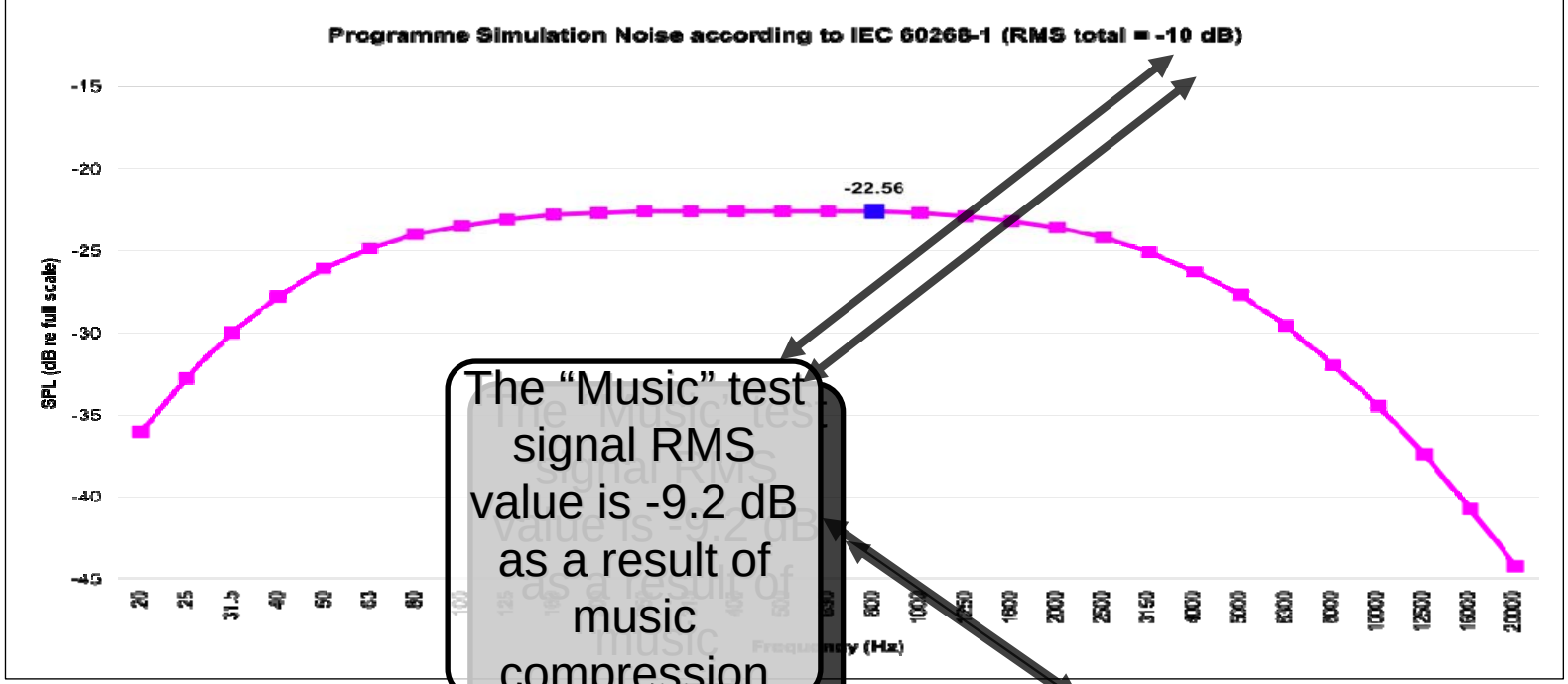
Plays the collected music


Time History of musical SPL (Slow, 1s)
0
-10
-20
-30
-40
-50
-60
SPL (dB re FS)
00:00:00
02:24:00
04:48:00
07:12:00
09:36:00
12:00:00
Time

Generating the signal

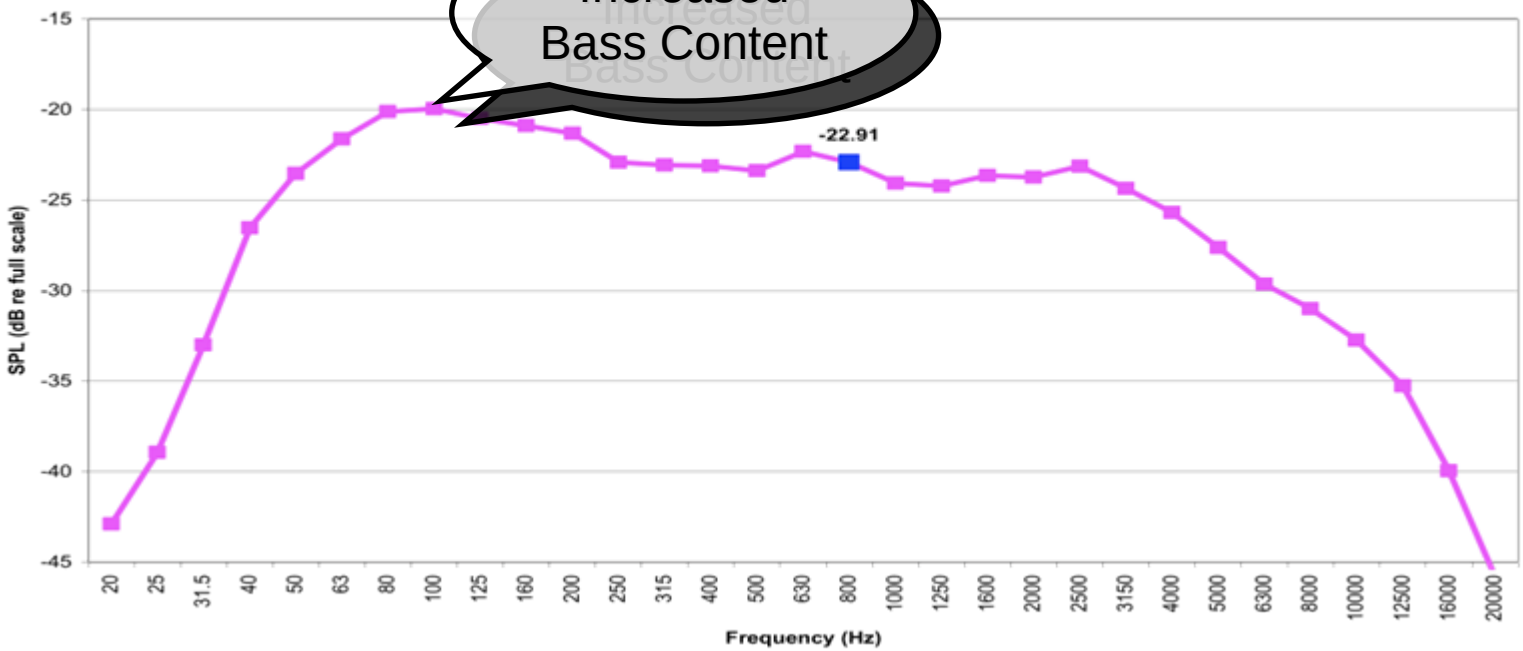
- We then proceeded to generate the signal using the same method employed for the IEC one

Signal Comparison



The "Music" test signal RMS value is -9.2 dB as a result of music compression

Increased Bass Content



File formats employed

- In order to perform the measurements the test signals were put on the digital audio players using the best codec available for each device (uncompressed wav when available). The formats employed are the following:

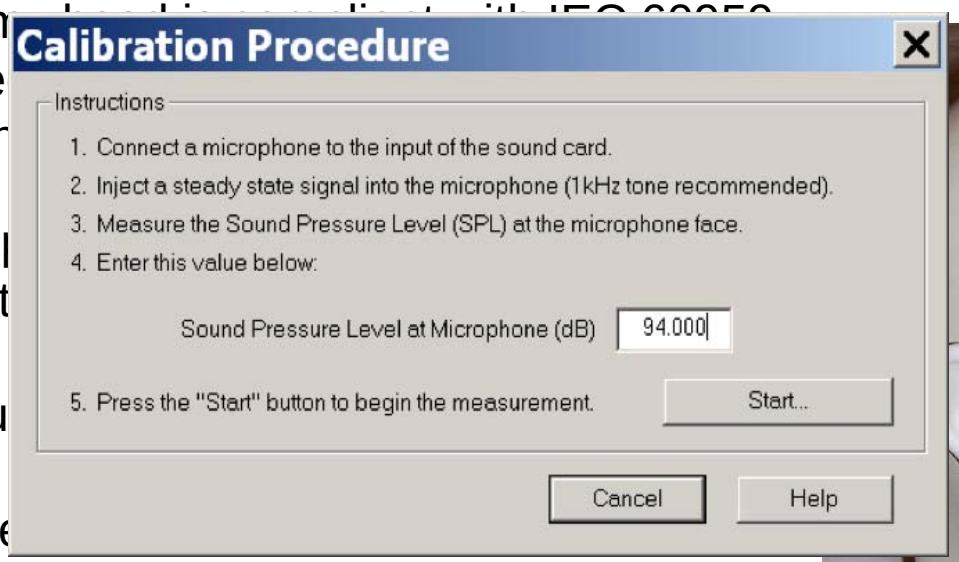
- Uncompressed WAV (44100 Hz, 16 bits, stereo)
- WMA Lossless
- WMA 192 kbps
- WMA 128 kbps
- MP3Pro 144 kbps
- MP3 192 kbps
- MP3 128 kbps
- Apple Lossless
- AAC 192 kbps
- AAC 128 kbps

As the difference between the same recording in different formats is very subtle, and does not usually require that the user adjusts the playback gain, we discarded the fact that different file formats were employed on different devices.

Equipment and calibration

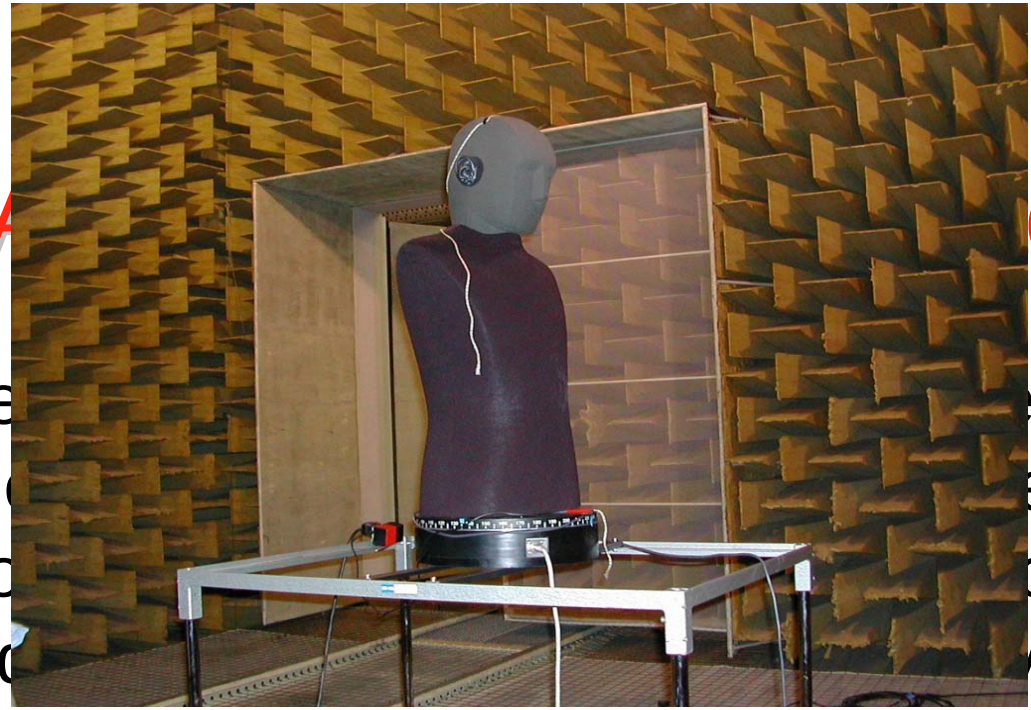
Ambassador dummy head

- This dumm… and is spe… “internal” h…
- The microp… removing t… capsule a… sound sou… frequency … pressure le…
- The calibration signal was employed for setting the calibration of the SpectraRTA program, as shown here:

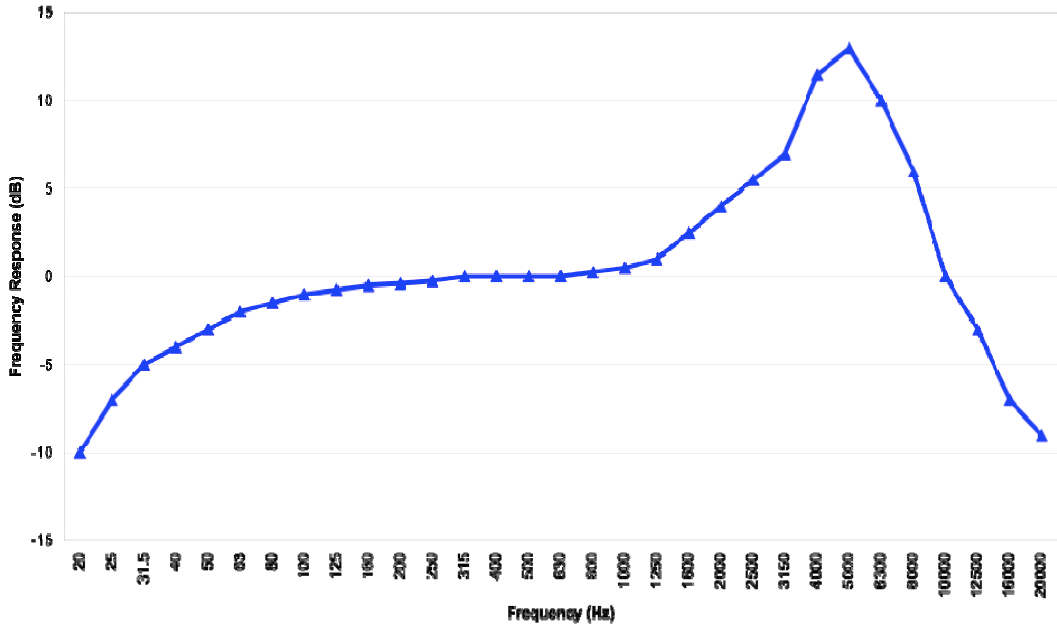


A d

- Howe ct for the frequ ead and Torso oes not provi response for t it was nece choic impu h had bee cific dum of Win available by F

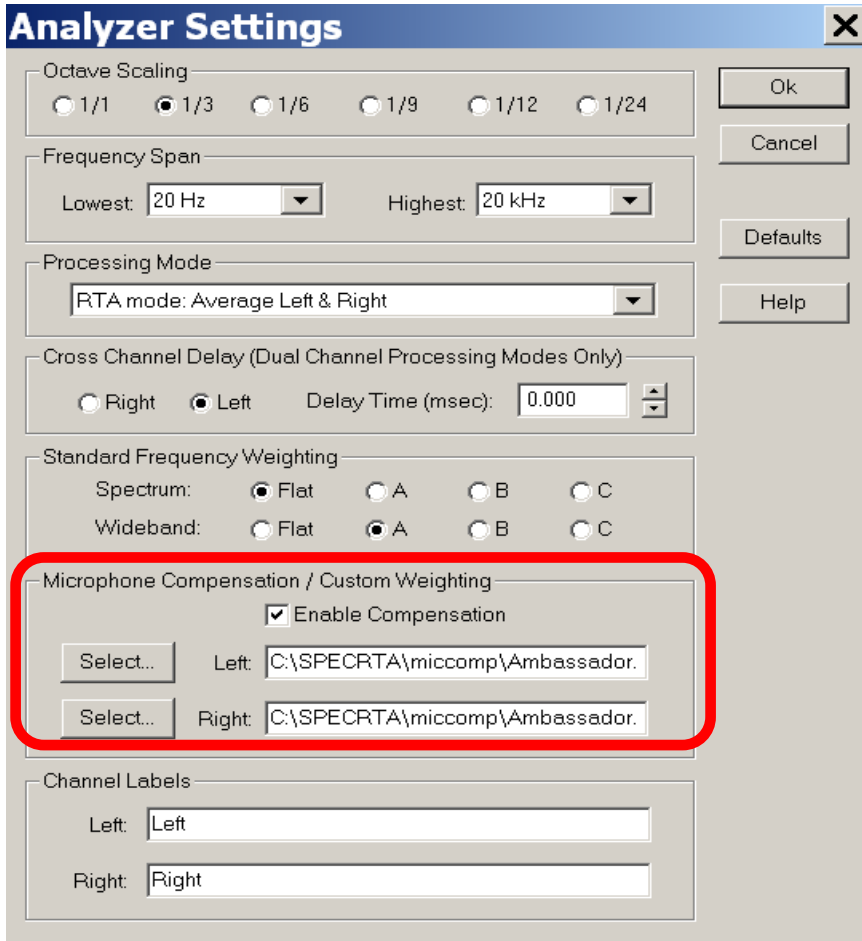


Ambassador Dummy Head

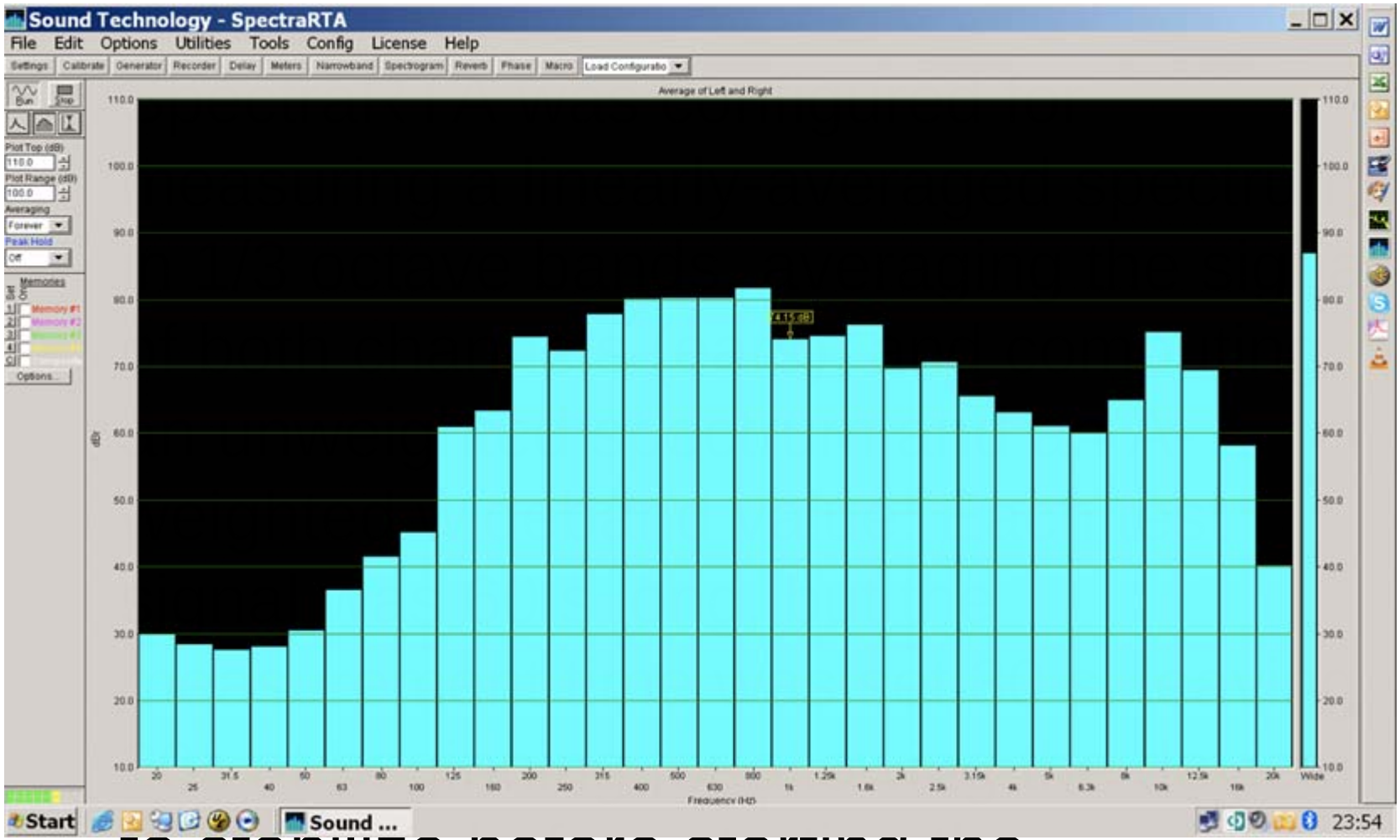


Frequency Response Correction

- SpectraRTA already provides the capability of correcting for the frequency response of the microphones employed, so the compensation of the frequency response of the Ambassador dummy head did not



Spectra RTA



to stabilize before starting the measurement.

Measurement procedure

- Each device was measured 5 times, dismounting and remounting the headphones each time, as recommended by standard EN 50332, in order to reduce the mounting error. The results were then averaged.
- For ensuring a better correlation between the results and in order to minimize the measurement time, we used the same headphone position with both test signals (IEC and MUSIC). The headphone was inserted, then the two signals were measured and then the headphones were removed and reinserted.
- The volume control of the player was left untouched since the last usage from the owner of the device. These results are thence not significant for discriminating "dangerous" devices from "safe" devices.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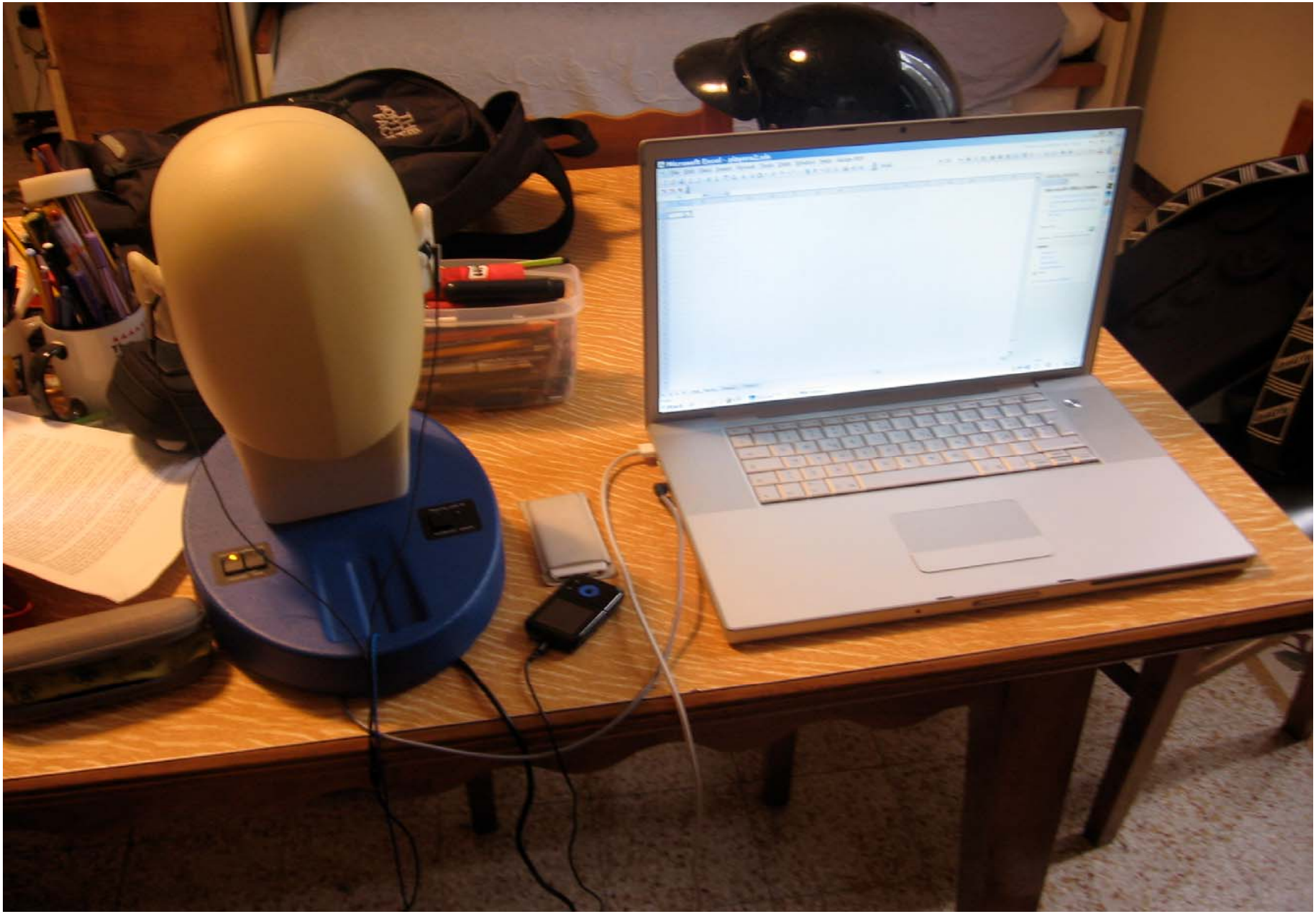


Results

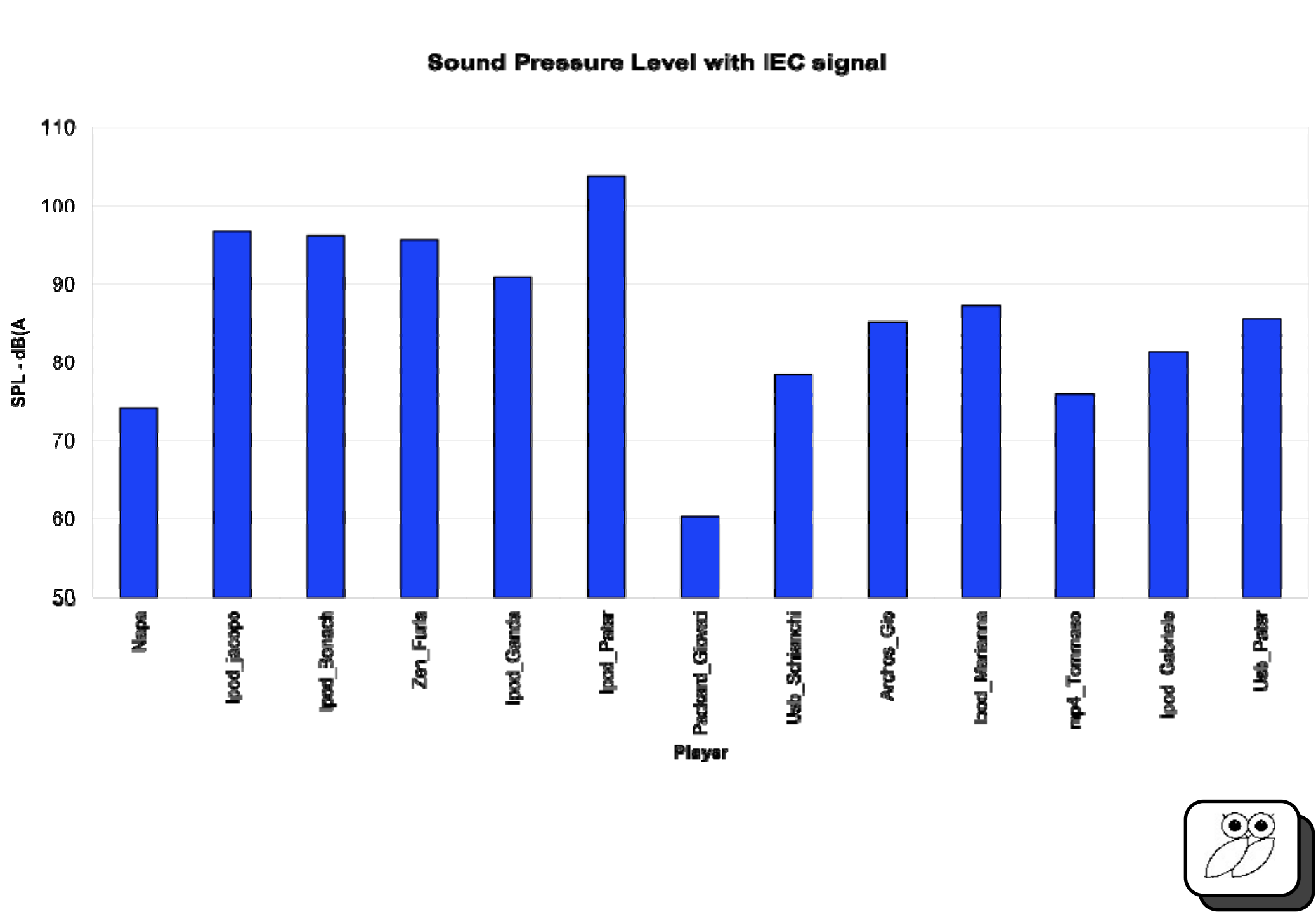
SPL Measurements

- For each device under test it was possible to obtain two values of the “exposure sound pressure level”: the first based on the IEC programme test signal, the second on the MUSIC test signal. The following table shows the results, in terms of average SPL +/ the standard deviation.

Player	IEC	Std.Dev.	MUSIC	Std.Dev.
Napa	74.2	3.1	74.2	2.7
Ipod_jacopo	96.8	2.7	94.7	1.8
Ipod_Bonach	96.2	3.2	96.4	3.7
Zen_Furla	95.7	6.0	95.1	5.7
Ipod_Ganda	91.0	2.6	90.9	2.6
Ipod_Pater	103.9	1.4	103.4	0.8
Packard_Giovati	60.2	4.3	62.0	3.2
Usb_Schianchi	78.4	1.3	77.8	2.6
Archos_Gio	85.2	1.2	85.7	1.2
Ipod_Marianna	87.4	5.9	88.0	6.0
mp4_Tommaso	76.0	3.2	75.2	2.9
Ipod_Gabriele	81.4	3.6	80.5	4.1
Usb_Pater	85.5	1.1	85.8	1.0

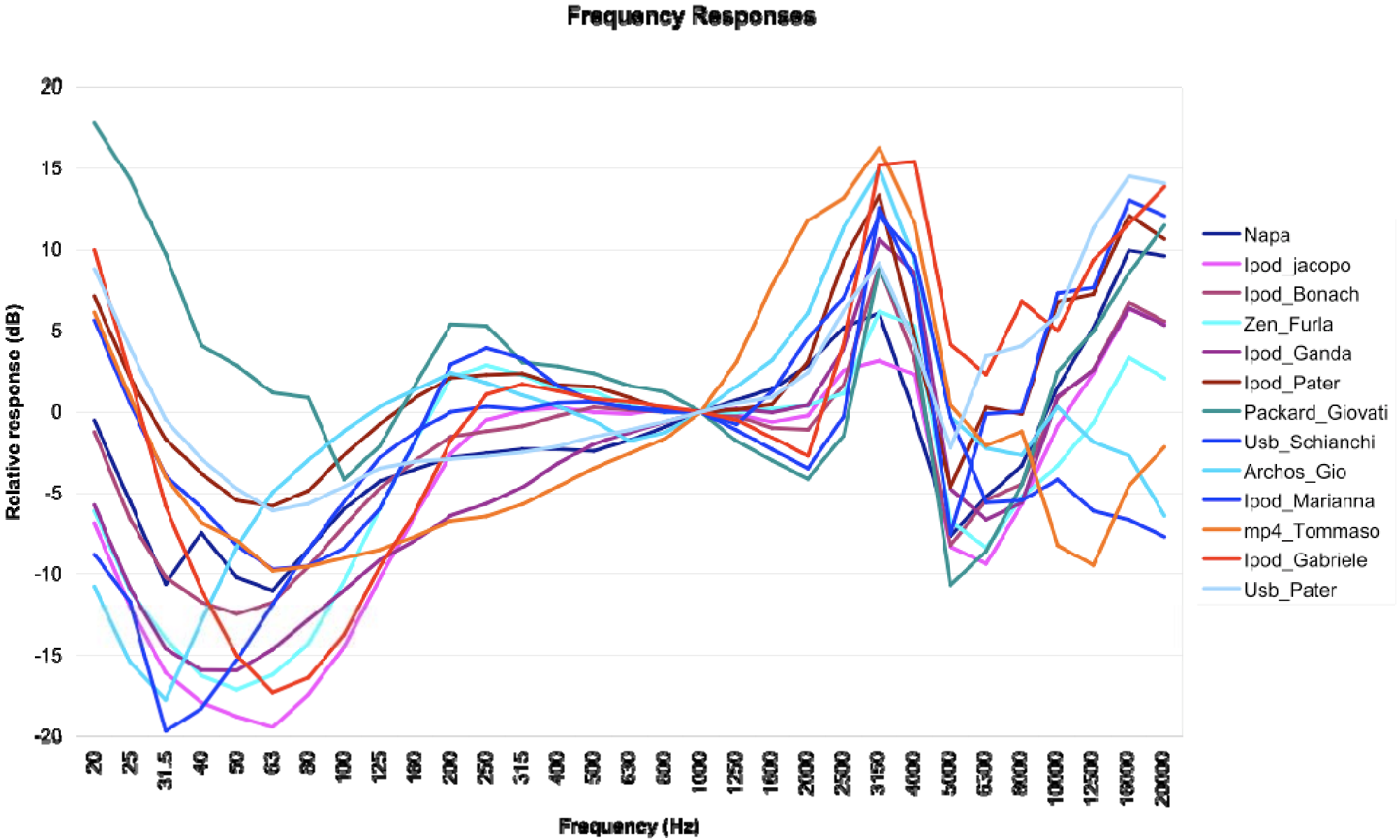
Dispersion of the results

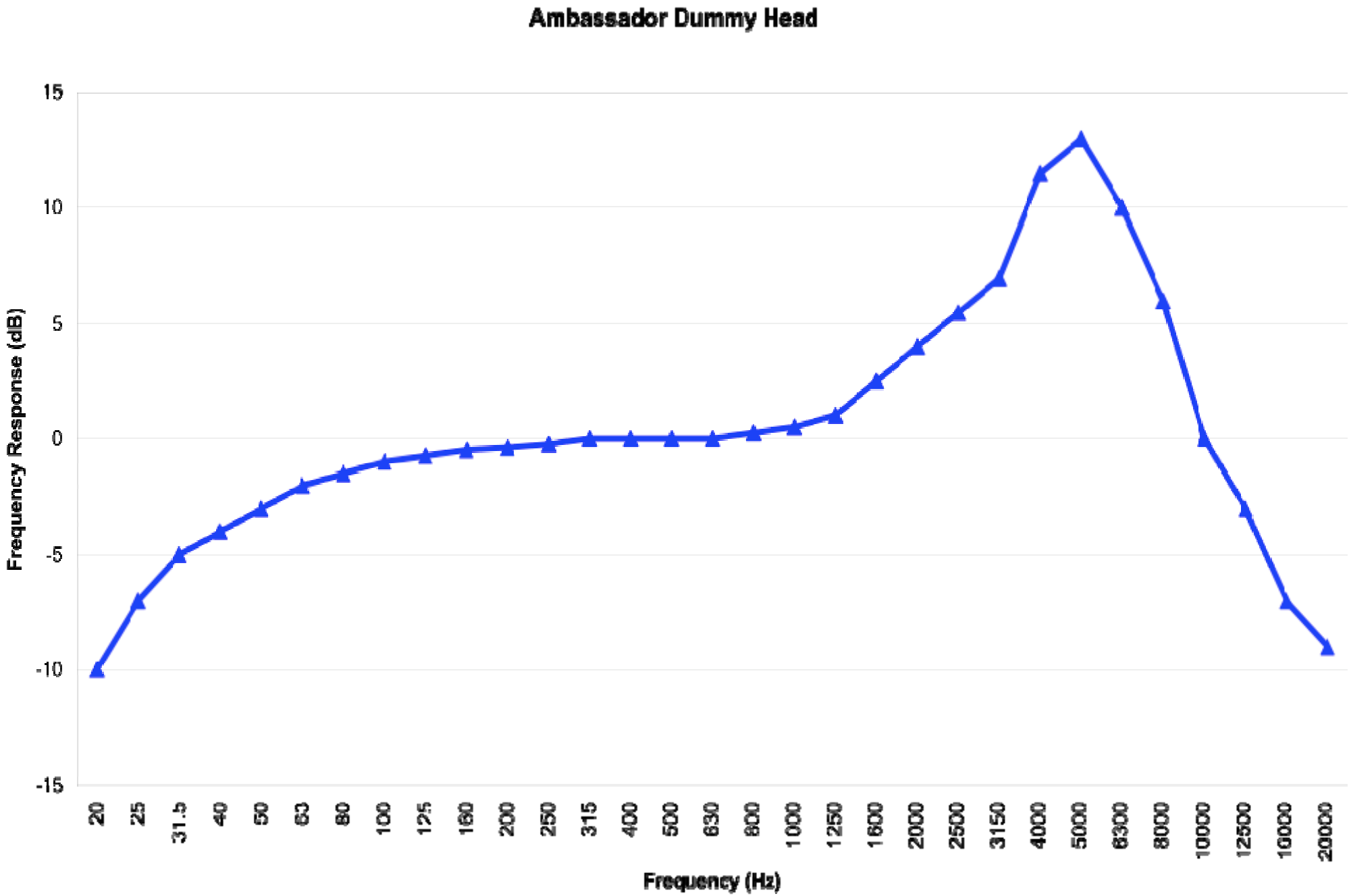
- Results are usually quite similar for the same device
- Huge differences between devices
- No difference between the signals


Sound Preesure Level with IEC signal
110
100
90
80
70
60
50
SPL - dB(A
Napa
Ipod_jacopo
Ipod_Bonach
Zen_Furla
Ipod_Garda
Ipod_Palar
Packard_Giovani
Usb_Schianchi
Archos_Gio
Ipod_Marianna
mp4_Tommaso
Ipod_Gabriele
Usb_Palar
Player

Frequency Response

- At 3150 Hz a strong ear duct resonance is present, due to the air trapped behind the ear bud.
- Looking at the free-field frequency response of the Ambassador dummy head, the peak in the frequency response was instead at 5 kHz, corresponding to the “dip” in the curves of the figure.


Frequency Responses
Relative response (dB)
20
15
10
5
0
-5
-10
-15
-20
20
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
12500
16000
20000
Frequency (Hz)
Napa
Ipod_jacopo
Ipod_Bonach
Zen_Furla
Ipod_Ganda
Ipod_Pater
Packard_Giovati
Usb_Schianchi
Archos_Gio
Ipod_Marianna
mp4_Tommaso
Ipod_Gabriele
Usb_Pater


Ambassador Dummy Head
Frequency Response (dB)
15
10
5
0
-5
-10
-15
20
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
12500
16000
20000
Frequency (Hz)

Frequency Response

- It is wrong to employ the free-field frequency response for correcting the recorded signals, as the free-field response does not take into account the modification of the ear duct resonance occurring when an ear bud is inserted in the pinna.
- This can be seen as a severe inconsistency of the current EN 50332-1 standard.
- It could be more advisable to employ a diffuse-field response (which is usually smoother)

Analysis of human exposure

- A significant number of the devices under test was found set for over 90 dB(A) playback levels.
- In terms of assessment of noise-induced health risk, usually a “safe” value is considered to be a daily exposure of 8 h at 80 dB(A).
- Whenever higher SPL values are present, the duration of the exposure should be reduced, in order of keeping the same daily “noise dose”. An energetic equivalence principle is assumed, which means that the exposure should be reduced at 4h for an SPL of 83 dB(A), to 2h for an SPL of 86 dB(A), and so on.
- For each of the devices under test, it was computed what is the maximum time allowed daily for employing it for listening to music, as shown in the following table:

Player	Time (hh:mm)
Napa	06:13
Ipod_jacopo	00:10
Ipod_Bonach	00:11
Zen_Furla	00:12
Ipod_Ganda	00:38
Ipod_Pater	00:01
Packard_Giovati	No Limit
Usb_Schianchi	11:30
Archos_Gio	02:26
Ipod_Marianna	01:27
mp4_Tommaso	20:11
Ipod_Gabriele	05:46
Usb_Pater	02:14

Conclusions

- 5 of the 13 devices have a time limit below 1h
- Most users declared a 1 to 2 hours average usage
- A proper hearing risk assessment should consider a whole day, with all its activities.
- A lot of money has been spent for reducing the noise at the workplace, but this will be wasted if we allow our teenagers to be over-exposed for years due to the usage of personal digital audio players capable of dangerous levels.