Design of a Room for Voice and Music with Electroacoustic Suppor

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A concert hall is modelled at EASE, the acoustical simulation is then compared with the acoustic parameters calculated by Aurora´s module from Audacity and EASERA from the impulse response of the concert hall. The simulated building will be adjusted according to the results of the measurements. This paper presents the concert hall design, and the results from the simulation and the measurement.

Keywords: concert hall, EASE, simulation, impulse response.

1. Introduction

The Usina del Arte is located in A.R. Cafferata St. 1, in La Boca, Ciudad Autónoma de Buenos Aires, Argentina. Its purpose is multi-artistic, the building includes two main enclosures reserved for music performances. Its main auditorium for symphonic performances has a capacity of 1.200 seats. The smaller auditorium for chamber orchestras has a capacity of 400 seats. The building has been inaugurated in 2011. The acoustical planning was in charge of Eng. R. Sanchez Quintana and Eng. G. Basso. The full auditorium can be circumscribed into a parallelepiped of 45 m long by 23 m wide by 20 m tall. The interior volume informed is 14.000 m^3[1].
Figures 1 and 2 show the facade of the building and the main concert hall.

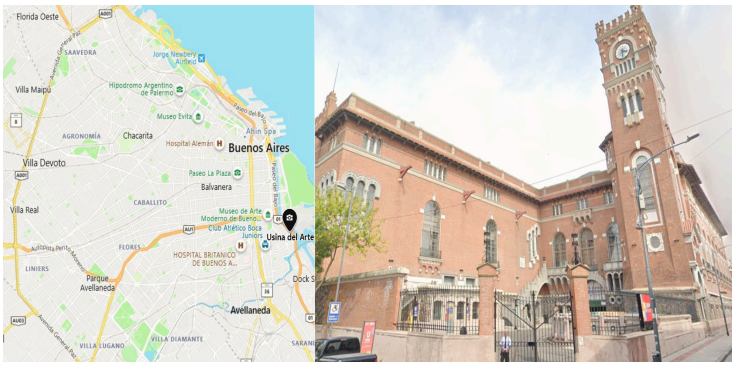

Figure 1: Location and facade of the Usina del Arte building.

Figure 2: Concert hall.

The parameters that will be compared are STI, ALcons, TR, EDT, Echo Speech, Echo Music, Lateral Fraction, SPL and D/R.
For both real and simulated impulse responses, acoustic parameters were calculated octave bands.
RT, EDT and SPL were calculated by Aurora´s module by Audacity and STI, ALcons, Echo Speech, Echo Music, Lateral Fraction and D/R are calculated with EASERA.

2. Theoretical framework.

In this section, the acoustics parameters analyzed will be described.

2.1 STI

Speech Transmission Index (STI) is a measure of speech transmission quality. The STI measures some physical characteristics of a room, and expresses its ability to carry across the characteristics of a speech signal. STI is a well-established objective measurement predictor of how the characteristics of the transmission channel affects speech intelligibility.
An STI of at least 0.5 is desirable for most applications. The Impulse response method, also known as the "indirect method," assumes that the channel is linear and requires stricter synchronization of the sound source to the measurement instrument. Figure 3 shows the relationship between STI value and a subjective intelligibility scale.

STI value	0,00 to 0,30	0,30 to 0,45	0,45 to 0,60	0,60 to 0,75	0,75 a 1,00
Intelligibility	Bad	Poor	Fair	Good	Excellent

Figure 3: Scale of intelligibility with STI values

2.2 ALcons

One method of objectively measuring speech intelligibility is Articulation Loss of Consonants (%-ALcons), showing the number of consonants being missed as a percentage. Consonants play a much more significant role in speech intelligibility than vowels. If the consonants are heard clearly, the speech can be understood more easily.
Since %ALcons expresses loss of consonant definition, lower values are associated with greater intelligibility. It is generally assumed that the maximum allowable value for typical paging applications is 10%, assuming that the environment is relatively free of masking noise. For learning environments and voice warning systems, the desired value is 5% or less.

2.3 Reverberation Time (RT)

Reverberation time is the time required for the sound to decay 60dB in a closed area. Sound in a room will repeatedly bounce off reflective surfaces such as the floor, walls, ceiling, windows or tables. When these reflections mix with each other, a phenomenon known as reverberation is created. Reverberation reduces when the reflections hit absorbent surfaces such as curtains, padded chairs and even people. Reverberation is a key parameter when qualifying the acoustic status of a room. Particularly, too much reverberation has a negative impact on the intelligibility of speech, but is desirable for music. So, rooms designed for music, lack of good ratings on STI or ALcons.

2.4 Early Decay Time (EDT)

The early decay time is derived from the Reverberation Time decay curve - the section between 0 dB and 10 dB below the initial level.
A short EDT is a good indicator of speech clarity as early reflections that reach the listener within 50 ms integrate with the direct sound and can improve speech clarity

2.5 Echo Criteria

Echo criteria is defined by Kuttruff [2] as ‘any sound reflection that is subjectively noticeable as a temporal or spatially separated repetition of the original signal’. Implying that the perception of an echo that is distant in time to the original signal, or has an intensity high enough to be assigned to another event is a nuisance to the listener.

$$t_s\,(\tau) = \frac{\int_0^{\tau} t|p(t)|^n dt}{\int_0^{\tau} |p(t)|^n dt} \qquad (1)$$

With n = 2 is the traditional center time. For music n = 1, and n = 0.66 for speech. τ the reverberation time, and p(t) the reverberation sound pressure. Finally, the echo criteria is defined as:

$$EK(\tau) = \frac{t_S(\tau) - t_S(\tau - \Delta\tau_E)}{\Delta\tau_E} \qquad (2)$$

Results from listening test found that $\Delta\tau_E$ is 9 ms for speech and 14 ms for music.

2.6 Lateral Fraction

The early lateral energy fraction is presented at Equation 3.

$$LF = \frac{\int_{td}^{ts} h_L^2(t)dt}{\int_0^{ts} h^2(t)dt} \qquad (3)$$

where h_L is the impulse response measured with a figure-of-eight microphone with one of its nulls pointed towards the source. The time limits are td, the direct time, and te, the early time. LF is normally used for music application, with direct time 5 ms and early time 80 ms. The limit 5 ms is introduced to make sure the direct sound is totally suppressed.

2.7 Sound Pressure Level (SPL)

SPL is a logarithmic measure of the effective variation of the atmospheric pressure, that living things perceive as sound or noise. The threshold value for humans is 20μPa, which is the reference value in next equation:

$$SPL\,[dB] = 10\left(\frac{p^2}{p_0^2}\right) \tag{4}$$

2.8 Direct to reverberant energy ratio (D/R)

This parameter indicates the ratio between the direct energy and the reverberant energy. It can be calculated by the Equation 3:

$$D/R = \frac{\int_0^Q p(t)^2 dt}{\int_Q^\infty p(t)^2 dt} \tag{5}$$

where p(t) is the sound pressure, and Q is the end of the direct sound.

2.9 Just noticeable difference (JND)

The just noticeable difference is a value that quantifies the minimum change of a parameter that can be perceived by the listener. These values are as following, on the table 1:

Table 1: JND for parameters evaluated [3][4].

Parameter	JND
EDT	5%
TR	5%
T30	5%
STI	0.03
Lateral Fraction	0.05
ALcons	0.11

Some of these parameters are global (such as STI) and others are defined by bandwidth (such as EDT and TR). For SPL, JND depends on the SPL and frequency. For these reasons, JND for SPL is not defined in this work.

3. Measurement

The results presented in this report are contrasted with actual RIRs measurement carried out by L. Rodiño, A. Bidondo and N. Cacavelos. Its paper Acoustic Characterization of the Acoustical Instruments & Measurements. July 10th, 2019 Usina del Arte Symphony Hall records the assessment of the Auditorium modeled in this report. The .WAV files of 6 IRs measured in the auditorium are obtained from OpenAir catalog. The acoustic parameters of interest for this report are calculated from these actual IR files using EASERA software. These results were set as the actual values for the parameters, and are used to contrast the results obtained via simulation. Furthermore, since A. Bidondo is the professor in charge of the Acoustical Instruments and Measurement course in UNTREF, certain characteristics of the auditorium are given during the course.

Figure 4 presents the locations of the sources and microphones.

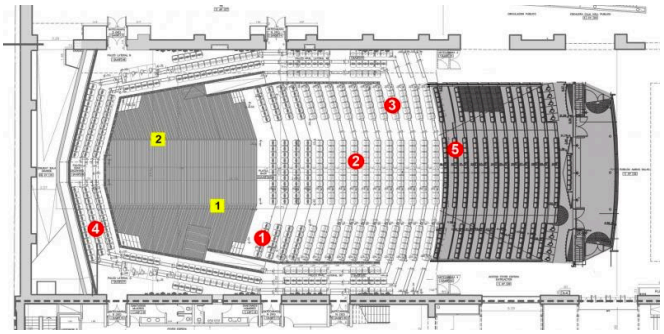

Figure 4: Sources and microphones positions for the measurement.

4. Simulation

The auditorium has been drawn in Sketchup from the architectural plans and the measurements given by the engineers. ISO, side and interior views are shown in Figure 5.

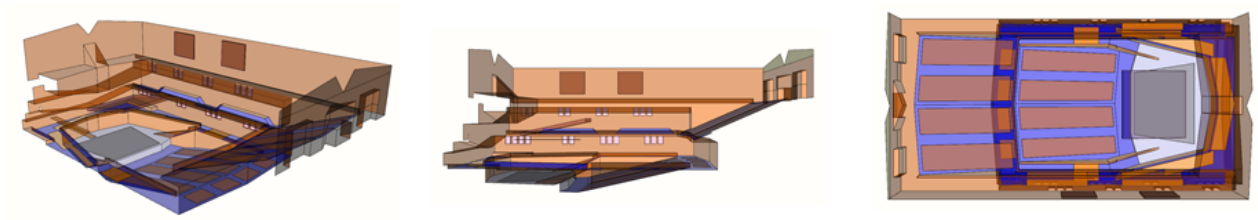

Figure 5: ISO, side and top view.

Details of the dimensions and the views can be found on the appendix 2. As expected, in order to avoid errors on EASE some distributions have been modified on purpose, as are the seating areas mainly, others may lack accuracy because of the lack of the details of the enclosure and its complexity. The room volume found on the literature is declared as 14.000 m³, while the simulated is 12% bigger with 15798 m³, this error is acceptable and is assigned to the complexity of the room and its irregular shapes, such as the ziggurat above the stage, and the slope and angles of the boundaries.

The difference of the reverberation time between the measurement and this simulation was too high, about 1s. For that reason, several modifications in the materials absorption coefficients were made. The reverberation time was calculated on EASE by the Eyring method and in order to use it as a first approach to continue with the simulations. Next step is to do small modifications on absorption coefficient such as seating and diffusers on the walls, these two surfaces covers almost entirely the surface of the room, so small adjustments on these two coefficients brings good results on the modification of the reverberation time, always having as reference the values in the bibliography. The materials finally chosen for the simulation are presented in Table 2.

Table 2: Absorption coefficients

Freq. (Hz)	125	250	500	1k	2k	4k	8k
Walls (average)	0,02	0,03	0,03	0,03	0,02	0,04	0.00
Stage floor	0,10	0,07	0,07	0,06	0,05	0,04	0,02
Audience floor	0,09	0,06	0,05	0,05	0,05	0,04	0,04
Seats (empty)	0,54	0,62	0,68	0,7	0,78	0,78	0,56

Diffusers	0,22	0,07	0,05	0,03	0,03	0.00	0.00

RT calculated on EASE by the Eyring method are similar to the average of the real measurements. Figure 6 shows the comparison.

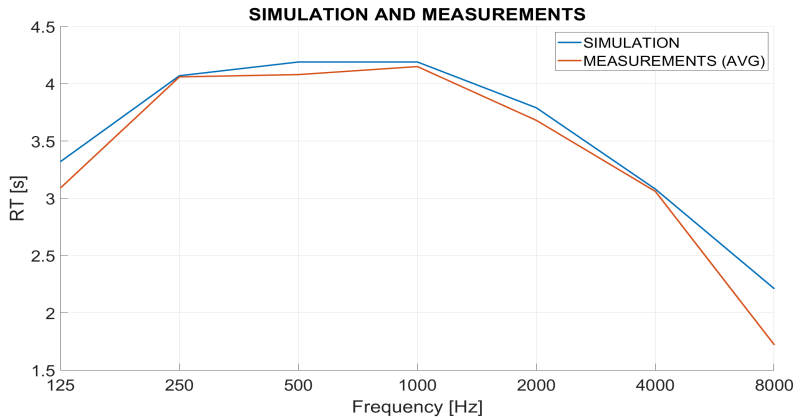

Figure 6: Difference between simulation and measurements.

For these values, the values of RT from 250 Hz to 4 kHz are below 1 JND, at 125 Hz and 8 kHz the error rises, as can be seen in the picture to 7.3% and 28%. The error on high frequencies may be due to the absorption coefficient of the seats, and also to the temperature and humidity of the real measurements, information authors do not have.

```
Ray Tracing Impact Computing Protocol
Project exporta2
Rays Per Speaker: 1250000
Impact Chance:  90.903 %

Begin    07/12/20, 14:14
End      07/12/20, 19:06
Time [s]          17513.4

         Overall:      5257 Impacts
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Figure 7 presents the impacts per order calculated by EASE.

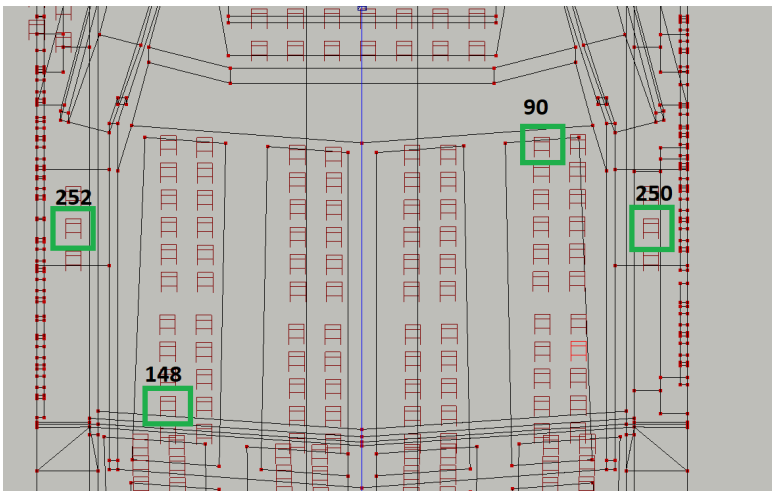


Figure 8: Seats positions simulated

5. Results

Several simulations on EASE have been made in the positions of the room where the real measurements were done. In order to minimize the errors, simulation must be long enough to evaluate them on the Aurora plugin. Once a length of 900 ms is set, this time must be divided by the mean free path provided by EASE, which is 0.03 s, to get the reflection order. With these values, order is set to 30, time is set by the software on 1051 ms, and rays are 1.250.000 to meet a 90.9% impact chance.

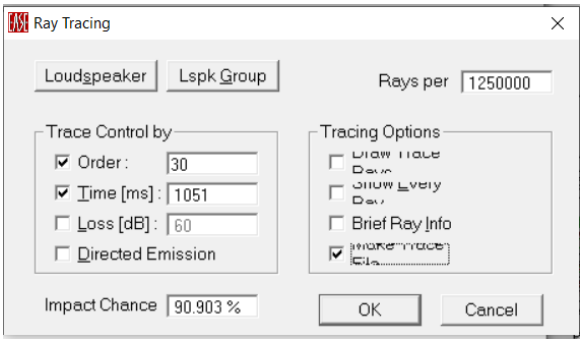


Figure 9: EASE simulation configuration.

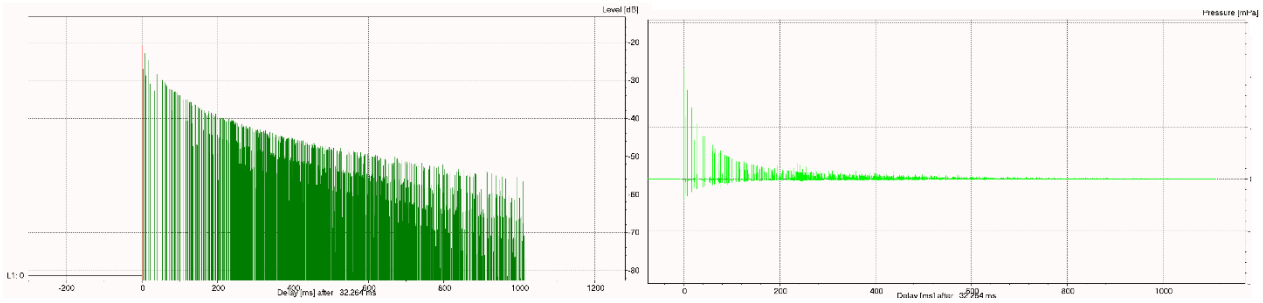


Figure 10: Reflectogram and RIR generated at position 90:

These files last 1000 ms, so calculation can be made directly on Aurora and EASERA without adding a random tail.

5.1 Comparison at position 90:

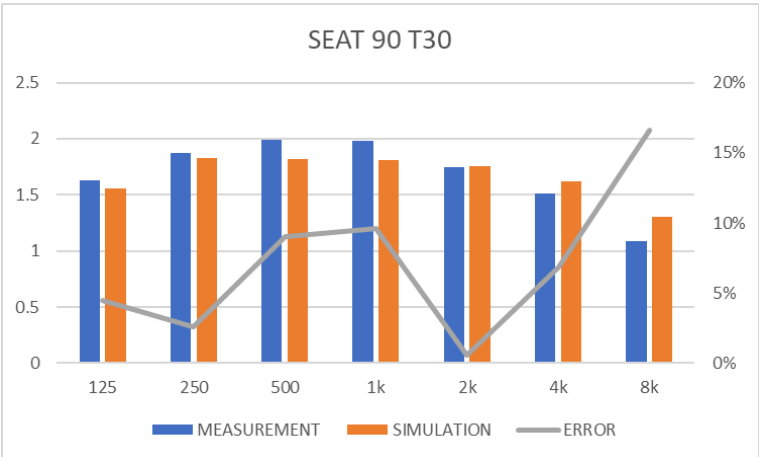


Figure 11: T30 measured vs simulated.

These results show that at some frequencies the error is low, such as 250 Hz and 2kHz, but at other frequencies the error rises, worst case is 8 kHz with 17%.
For EDT, comparison is as follows:

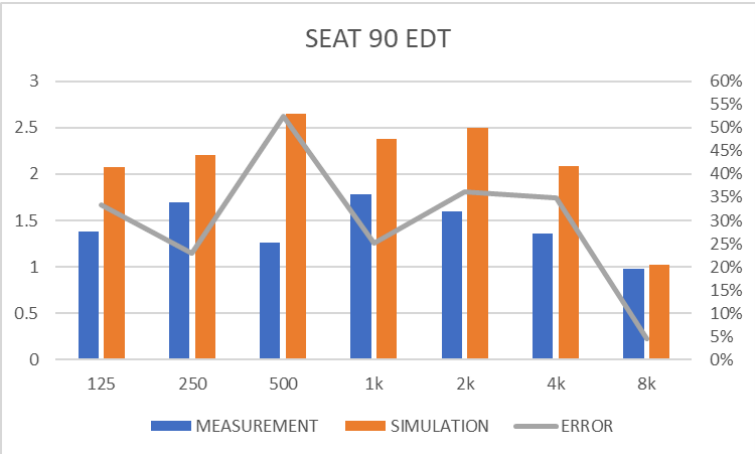


Figure 12: EDT measured vs simulated.

The error is high enough to discard this value and do further evaluation. The results on Aurora shows that EDT has bigger values than TR30, which is a contradiction, since EDT is a decay from 0 dB to -10 dB, and TR30 is -5 dB to -35 dB. Comparison on another auditorium has to be made to evaluate the behavior of the EASE software for this parameter. Note that for measurements, the results are expected, EDT is always smaller than TR30. Another point to evaluate is the position of the reflector hanging above the stage, which controls the early reflections from the ceiling.

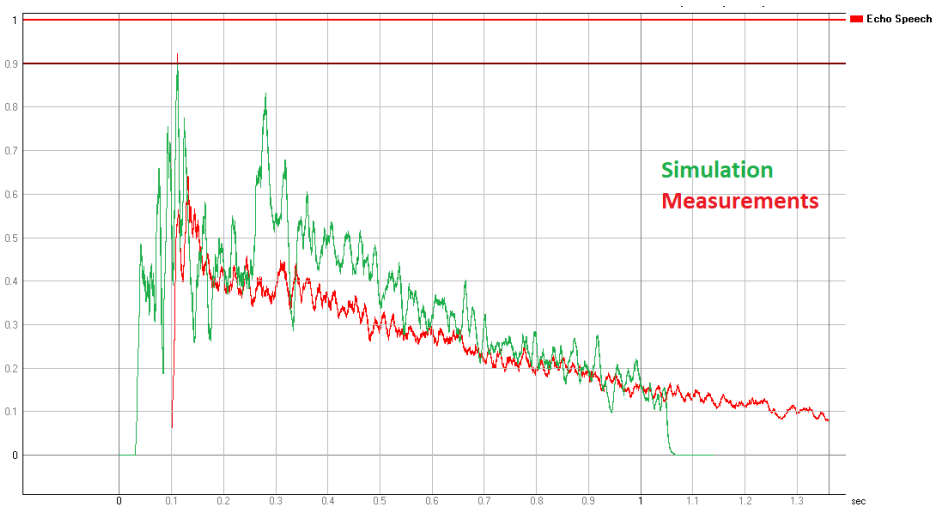


Figure 13: Echo criteria: measured vs simulation.

The echo criteria of the simulated RIRs bring higher values than the measured ones, this could be related to the values on EDT. Since EDT and C50 are somewhat linked, there is also a relationship between the early reflections and the echo criteria. Having a deeper evaluation of the EDT and its results will provide more information about the high values on echo criteria.
For STI and ALcons, results are as expected because of the results on EDT. Table 3 shows STI and ALcons results:

Table 3: Comparison for ALcons and STI.

Parameter	Measured	Simulated

STI	0.548	0.500
ALcons	8.731	11.346

As expected, STI and ALcons values are low, but it is not of importance sin the auditorium is designed for music, and not for speech. Again, worse values are obtained on the simulations, this is related to the early reflections.

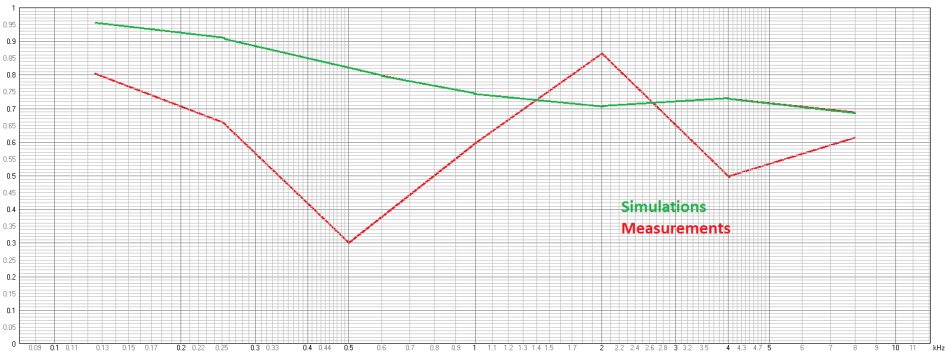


Figure 14: Lateral fraction: measured vs simulation

In this case, the measurements provide at 500 Hz a value that is very low compared to other frequencies, while the simulation is smooth and its variation is low from one value at one frequency to another. This difference might be related to the position of the reflector hanging on the building. If the measurements were done with the reflector providing relatively high energy to the listener, then is expected to have low values of LF.

5.2 Comparison at other positions to verify EDT:

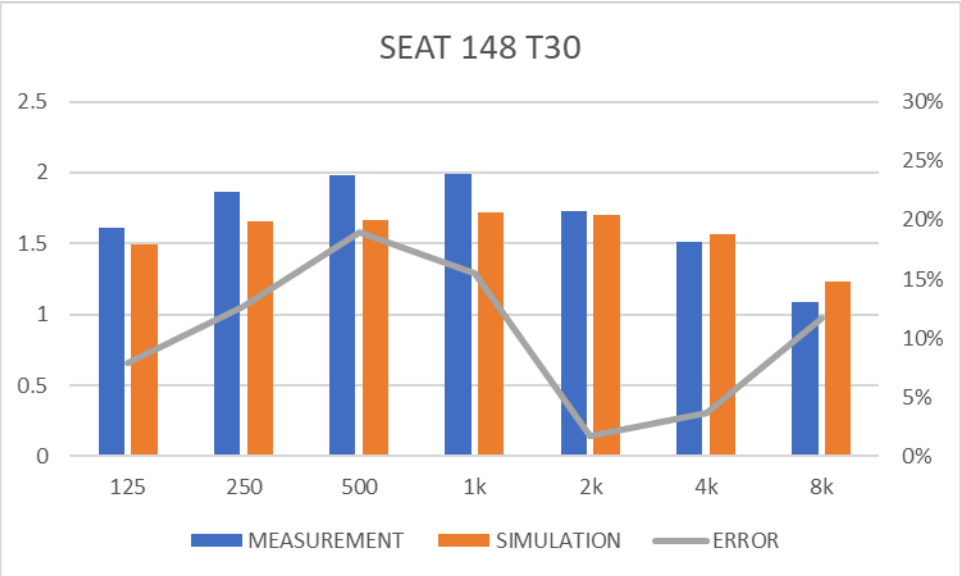


Figure 15: T30 measured vs simulated.

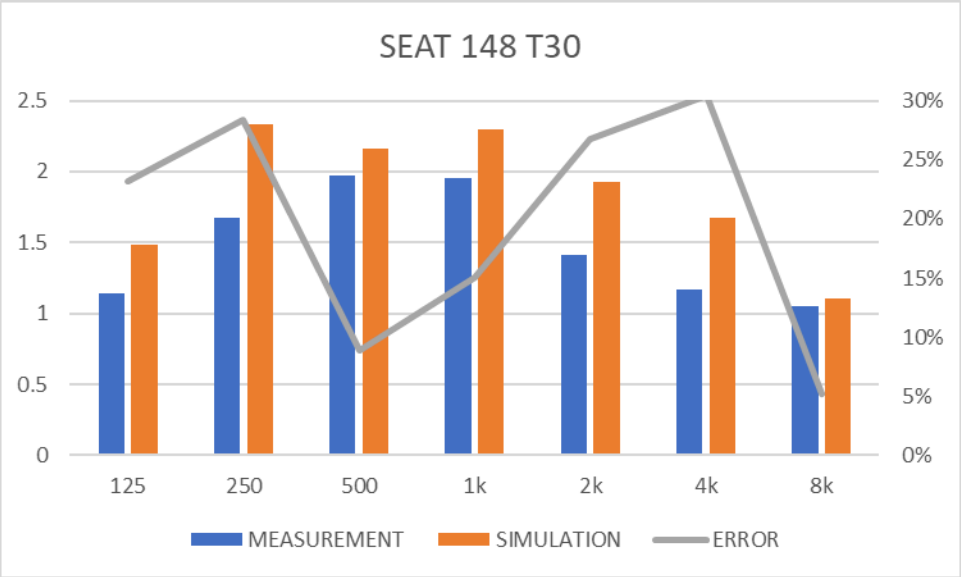


Figure 16: T30 measured vs simulated.

As seen, the simulation again provides the same kind of error (EDT being larger than TR30). This confirms that further research on this method to evaluate early reflections must be done. Also, other point to evaluate is the position of the reflector hanging from the ceiling in the simulation and the measurements. To confirm this result, evaluation on another hall must be done. Details of this reflector can be found on the appendix.

5.3 Other parameters

Mapping on EASE provides data for the listening areas for other parameters. D/R, SPL direct and Total SPL are shown in next figures for 1 kHz octave band, there is no comparison with the measurements for these results:

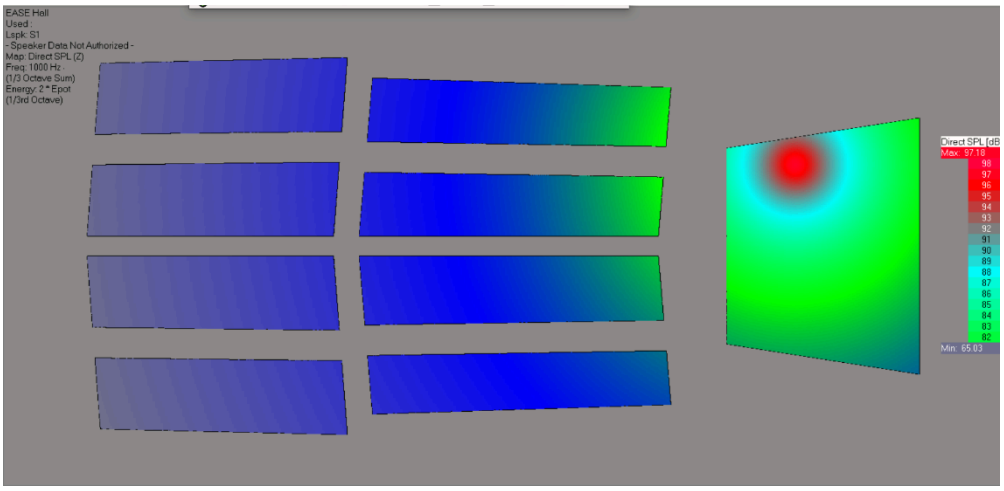


Figure 17: Direct SPL

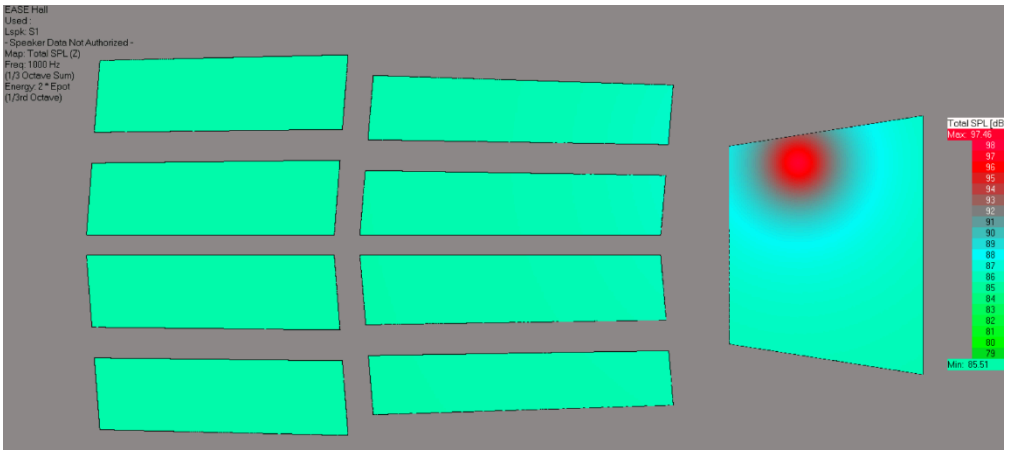


Figure 18: Total SPL

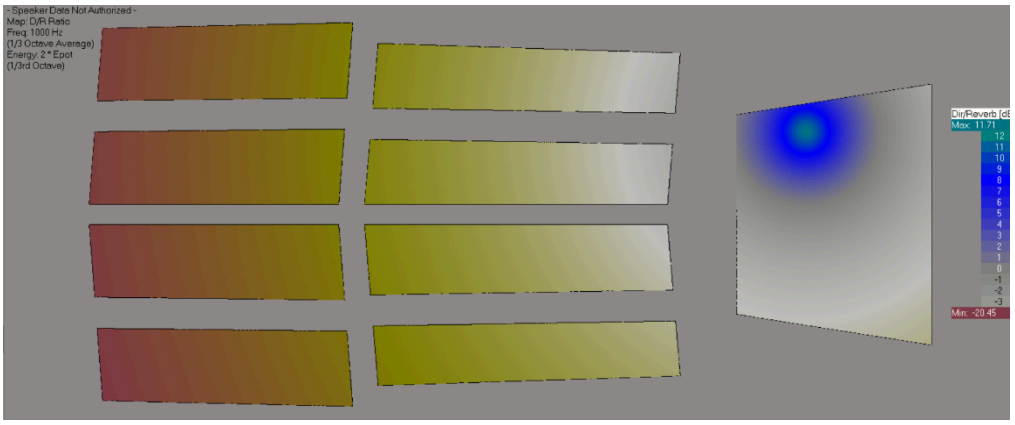


Figure 19: D/R ratio.

Source used for the mapping is an omnidirectional sphere. Due to the large reverberant time of the room,

6. Discussion

In order to avoid simulations that last too long, EASE has an option that adds a random tail to the impacts simulated. This option brought no positive results, because it modifies the RT enough to discard the simulation, this is why the order and the time of the ray tracing is that high. In the appendix are the details of the simulation with added random tail, where differences on the decay can be seen on section 9.3 on the appendix. Also, when visual evaluation is approved on the reflectogram, it has no correlation with the impulse response waveform, where one can see that results of this method need more knowledge by the user.
As results brought, further research needs to be done in order to conclude if the problem with the early reflections is a problem of the EASE software, a problem with the design, or a problem with the position of the hanging reflector.

7. Conclusions

The first conclusion, and the most notorious for the writers is that experience and practice is of great importance. Not just in the use of the EASE software or acoustical parameters knowledge,

but also the task of the design on SketchUp and make it work properly on EASE, this is a time-consuming exercise. Specially because of the complexity of concert halls in general. Also, writers of this work do not have the knowledge to simplify or eliminate details on design of the hall, which might be helpful reducing the computational time and the time used on the design.
Since most of the design was done by visual inspection from different pictures of the hall, some dimensions are not very accurate on the simulation, this is why the room volume on EASE is 15798m³, and the literature says 14000m³, this error is relevant, but authors do not know how to relate this error with the control of the early reflections, which is the most problematic parameter as seen on the results section.
Gustavo Basso's designs of the auditorium, before building it, were also checked. The designs he simulated have minor changes of the final design (e.g., pullman angle, flat ceiling, or diffusers at the ceiling). These designs have similar dimensions to the one simulated in this work, but the difference in volume on these two models is 12%, this might be related to human errors, but also to the lack of accuracy of the plans revisited, or/and the irregular shape of concert halls. Anyways, Basso's work seems to be guided by experience, because in his doctoral thesis he designed many rooms, and simulated 1 listening point every 10 seats, with a time of 3000 ms and 100.000 rays per octave band. He also declares that early reflections are highly dependent on the position of the hanging diffuser, modifying the acoustical texture of the room to match the musician's style. This might be relevant to evaluate error on this work.
Comparison between real measurements and simulation are not shown in Basso's work, but the states that at middle frequencies the RT time is around 2 seconds, which is close to proposed values for the design.
On the other hand, the use of the Eyring values as a guide to get positive results for the TR30 were not enough. Further research needs to be done in order to get enough experience to predict if Sabine or Eyring calculations are good predictors for RT done by ray tracing, because the error is too high for both cases evaluated.
A limitation of this work is the absorption coefficient of the seats, which are empty for this work. The reverberation time is highly dependent of the absorption coefficient of the seats, because it covers an important area of the hall. Probably this coefficient needs to be modified in order minimize the error. If this is done, the surface of the wood reflectors of the walls can be modified too.
The ray tracing method does not compute diffusers, this could be another reason why EDT is a high value. Since specular reflection provides much more energy than diffusive reflections. As can be seen on the pictures of the hall, diffusers are on all the walls, especially around the stage, which is the source of energy. This is a big limitation for EASE, if the room to simulate has diffusive surfaces. On Basso's work, he does the simulations on Catt Acoustic, which works with 1D diffusers, main difference with EASE.
About the use of the random tail, as stated before, it brought no positive results. Random tails often have a decay that is not the same as the reflectogram. Also, when the random tail looks good on the reflectogram, it might not look good on the IR waveform.

8. References

[1] Sánchez Quintana R. "Big halls for music in Argentine". ISMRA. (2016)
[2] Kuttruff, H., "Room acoustics", 4th edition, E & FN Spon Press, (2000)

[3] San Martin, R. Lopetegui, K, Arana, M. “Determinación del Just noticeable difference (jnd) de parámetros acústicos mediante campos sonoros reales” (2009)
[4] Rodiño L., Bidondo A., Cacavelos N. ”Acoustic Characterization of the Usina del Arte Symphony Hall”. (2016)

9. Appendix

9.1 Questions

9.1.1 How many rays were used and why?

Order is set to 30, time is set by the software on 1051, and rays are 1.250.000 to meet a 90.9% impact chance. The objective is to simulate a RIR file long enough to do the calculation on Aurora without adding a random tail. The EASE manual recommends using the free mean path times the reflection order to estimate the time of the simulation.

9.1.2 How many source positions were used and why?

For the measurement, two source positions were used. For the simulation only one omnidirectional source was used. More sources mean double computational cost, and more hours of simulations. That said, the objective was to compare 1 source with four listening positions. Since 2 of these simulations provided negative results, others are discarded.

9.1.3 Why is there a difference between the statistics calculator of the reverberation time and the Rir`s value of the reverberation time?

This is expected, since acoustical parameters depend on the position of the source and the position of the listener. Sabine and Eyring are used as first approach to the results. Both formulas are statistical, for reverberant rooms Sabine is calculated, for rooms with an absorption coefficient bigger than 0.3 Eyring suits better.
Having in mind that these two formulae do not have as input the position of the listener nor the source. This is why ray tracing and statical calculators provide such different results.

9.2 Auditorium dimensions

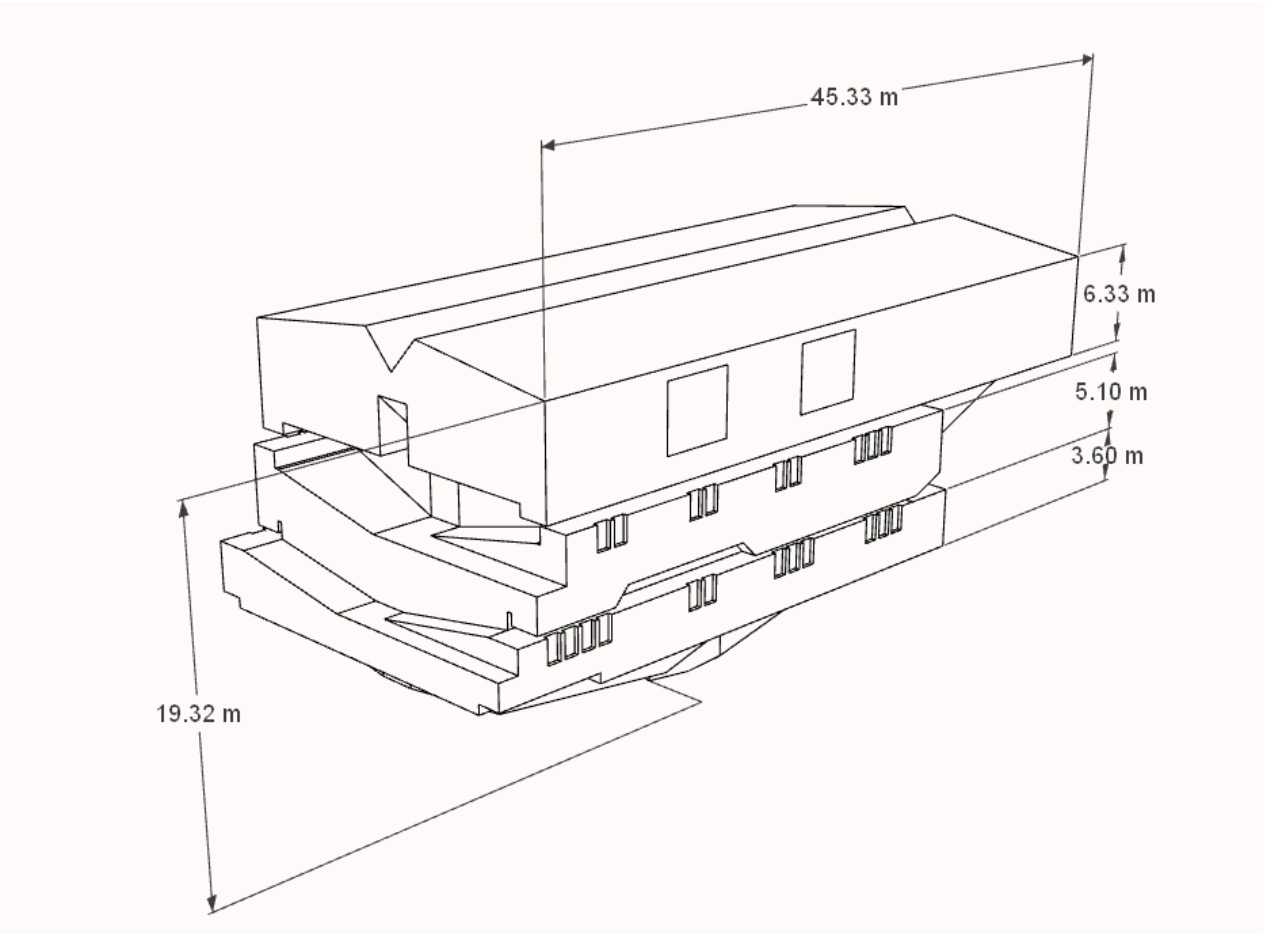


Figure A1: Exterior dimensions.

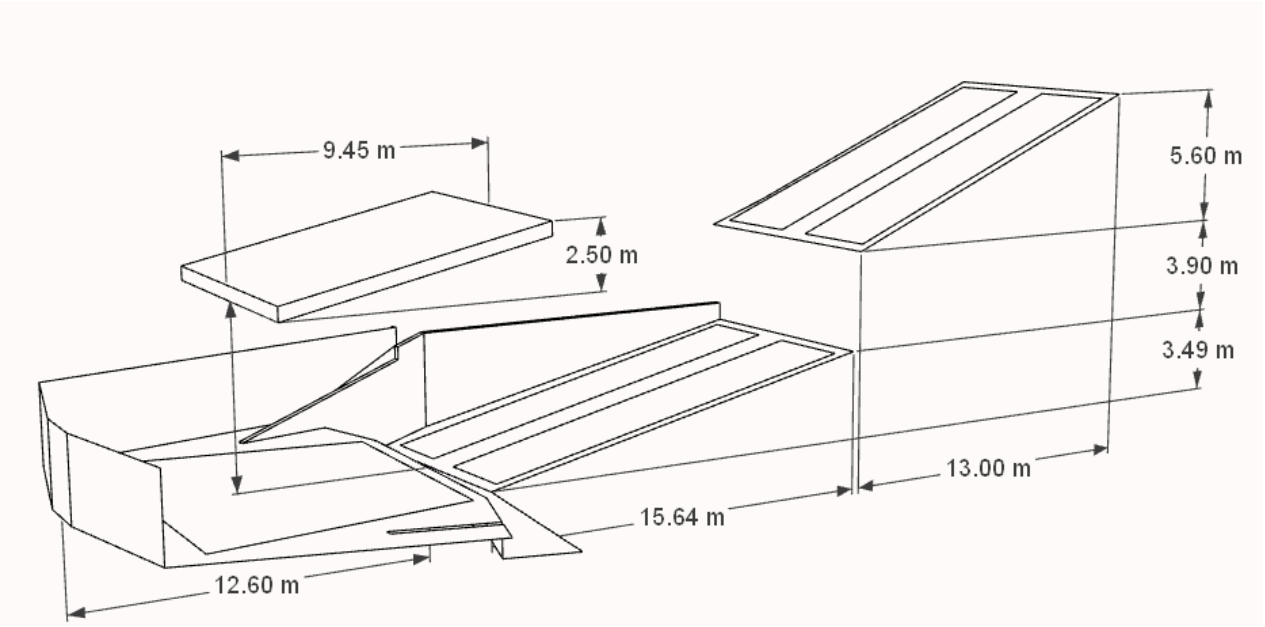


Figure A2: Length of interior dimensions.

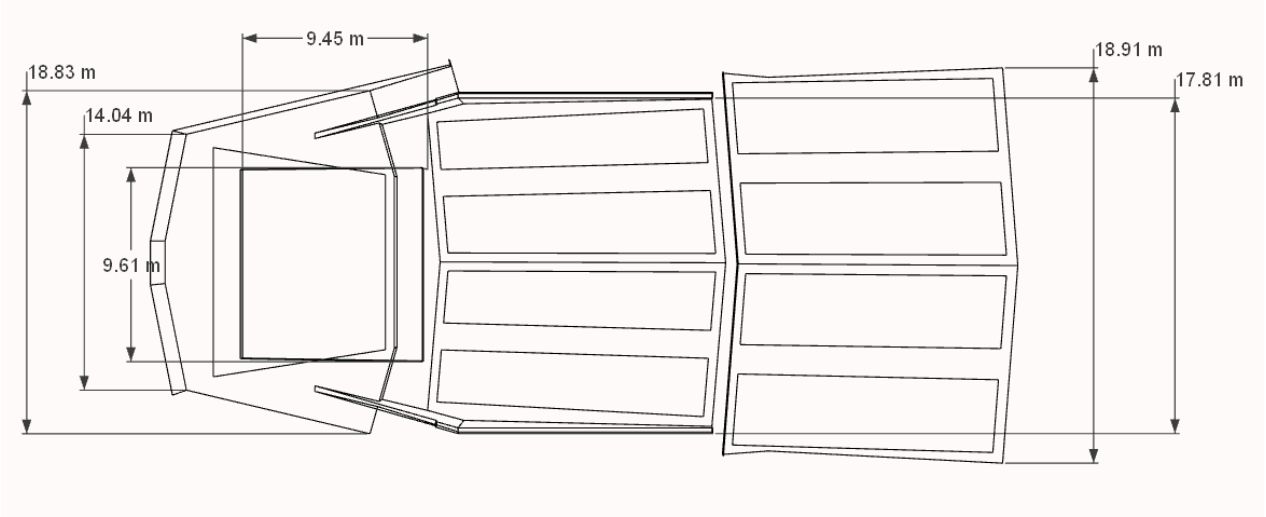


Figure A3: Width of interior dimensions.

Figure A4: Detail of the real room, with the hanging diffuser at sight.

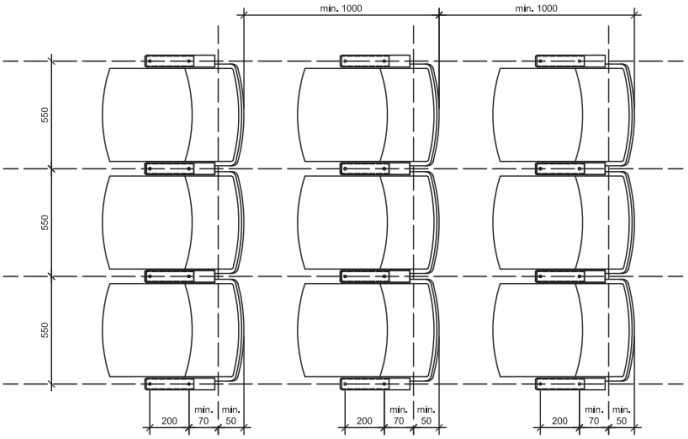


Figure A5: Seat details.

9.3 Decay, random tail and ray tracing:

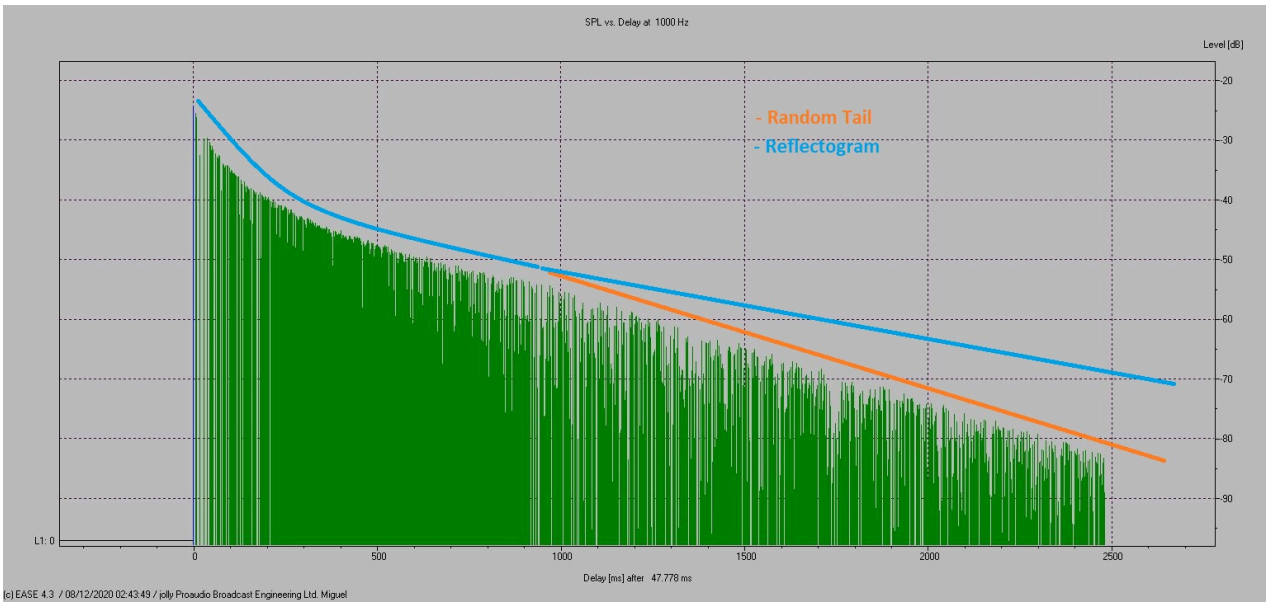


Figure A6: Reflectogram of the random tail added and its slope.

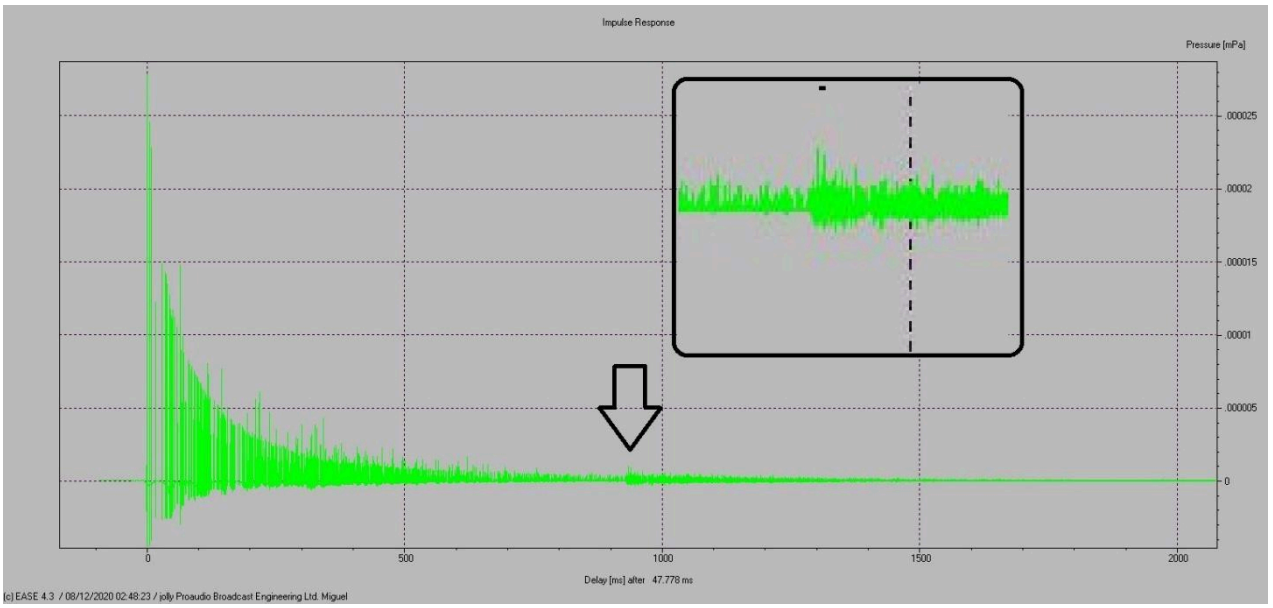


Figure A7: RIR of the added random tail with amplitude detail.

Annex 3
Parameters calculations from the RIRs measured

- **SPL**

Fq. [Hz]	P2PB	P31PISO	P3PB	P41PISO	P51PISO	P5PB	P1STAG	P2PB	avg
80,0	76,0	76,1	81,3	80,8	79,6	82,5	79,3	83,3	**81,2**
100,0	81,3	81,2	88,0	81,0	84,5	80,9	80,1	83,7	**82,3**
125,0	82,9	82,8	86,5	78,1	84,2	86,3	77,7	81,1	**82,3**
160,0	82,0	82,0	83,2	76,8	81,7	82,9	77,0	73,3	**78,7**
200,0	82,0	82,0	86,5	76,6	80,4	81,3	77,4	79,8	**79,7**
250,0	86,2	86,2	86,4	83,3	85,8	87,1	84,0	83,3	**85,0**
315,0	90,0	89,9	91,1	86,2	87,9	89,1	88,1	88,2	**88,3**
400,0	88,1	88,1	91,7	86,9	88,3	89,1	86,6	85,9	**87,5**
500,0	88,5	88,5	91,7	84,4	87,1	89,0	86,3	84,0	**86,6**
630,0	85,7	85,7	89,6	82,7	87,0	88,5	84,9	79,4	**84,9**
800,0	83,7	83,7	87,6	82,1	84,8	86,0	82,7	77,8	**82,8**
1k	85,9	85,9	87,5	82,1	83,4	86,6	83,4	77,0	**82,6**
1.25k	84,2	84,2	86,3	81,4	83,7	85,4	82,4	78,0	**82,4**
1.6k	87,1	87,1	88,8	83,5	87,1	88,5	85,1	83,1	**86,0**
2k	84,4	84,4	87,3	83,5	84,5	86,6	83,0	80,6	**83,7**
2.5k	84,3	84,3	87,7	82,1	84,4	85,6	82,8	78,0	**82,7**
3.15k	83,7	83,7	86,4	81,3	82,9	84,2	82,0	78,2	**81,8**
4k	83,1	83,1	85,6	81,4	82,7	84,0	81,1	80,5	**82,1**
5k	83,8	83,8	85,2	82,0	82,6	85,5	81,8	80,7	**82,7**
6.3k	85,5	85,5	85,9	83,9	85,0	85,6	83,8	79,0	**83,4**
8k	81,6	81,6	80,2	80,2	80,4	80,5	80,7	78,1	**79,9**
10k	76,9	76,9	75,3	74,2	75,6	75,1	76,4	76,1	**75,8**
12.5k	71,0	71,0	68,6	68,0	69,4	68,7	70,4	71,3	**70,0**

- **T20**

Fq. [Hz	P2PB	P31PISO	P3PB	P41PISO	P51PISO	P5PB	P1STAG	P2PB	avg
80,00	1,152	1,133	1,518	1,48	1,354	1,193	1,1	0,429	**1,019**
100,00	1,317	1,094	1,424	1,486	1,228	1,461	1,03	0,841	**1,14**
125,00	1,646	1,392	1,38	1,622	1,048	1,595	1,407	1,369	**1,35475**

160,00	1,906	1,835	1,672	1,664	1,741	1,825	1,463	1,48	**1,62725**
200,00	1,734	1,691	1,962	1,863	1,752	1,875	1,89	1,398	**1,72875**
250,00	1,699	1,55	1,798	1,786	1,821	1,798	2,267	1,635	**1,88025**
315,00	1,777	1,704	2,003	1,874	2,108	2,062	1,944	1,461	**1,89375**
400,00	2,036	1,916	2,049	2,256	1,948	2,109	1,859	1,515	**1,85775**
500,00	2,051	1,986	2,006	2,038	1,951	2,137	1,975	1,613	**1,919**
630,00	2,046	1,983	1,978	2,15	2	1,952	2,069	1,87	**1,97275**
800,00	1,993	1,826	2,066	1,969	2,205	2,016	2,051	1,841	**2,02825**
1k	2,012	1,965	1,925	2,015	1,987	2,079	1,669	1,72	**1,86375**
1.25k	1,965	1,941	2,004	2,056	2,088	1,91	1,943	1,672	**1,90325**
1.6k	1,809	1,772	1,99	1,973	1,869	1,912	1,775	1,572	**1,782**
2k	1,839	1,807	1,898	1,767	1,896	1,799	1,776	1,445	**1,729**
2.5k	1,718	1,701	1,829	1,746	1,753	1,736	1,67	1,403	**1,6405**
3.15k	1,693	1,687	1,633	1,594	1,648	1,575	1,601	1,367	**1,54775**
4k	1,466	1,461	1,562	1,456	1,478	1,528	1,449	1,097	**1,388**
5k	1,323	1,322	1,332	1,319	1,353	1,308	1,359	1,043	**1,26575**
6.3k	1,093	1,093	1,157	1,078	1,159	1,143	1,125	0,967	**1,0985**
8k	0,933	0,933	0,917	0,909	0,987	0,964	0,918	0,696	**0,89125**
10k	0,715	0,715	0,752	0,689	0,763	0,798	0,722	0,528	**0,70275**
12.5k	0,504	0,504	0,556	0,514	0,583	0,552	0,527	0,432	**0,5235**

- **EDT**

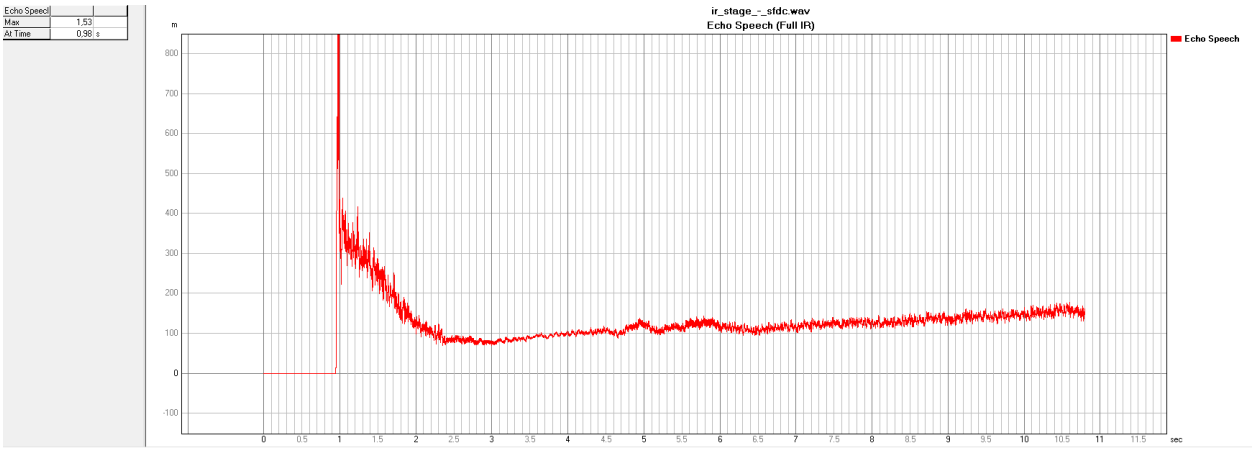
Fq. [Hz	**P2PB**	**P31PISO**	**P3PB**	**P41PISO**	**P51PISO**	**P5PB**	**P1STAG**	**avg**
80,00	2,115	2,088	0,835	1,239	1,55	1,234	0,356	**1,09475**
100,00	1,633	1,287	1,296	1,015	1,797	1,818	0,309	**1,23475**
125,00	1,311	1,18	2,008	1,289	0,943	1,42	0,286	**0,9845**
160,00	1,271	2,106	1,869	1,514	0,981	2,307	0,739	**1,38525**
200,00	1,088	0,951	1,415	1,588	1,958	1,207	0,166	**1,22975**
250,00	1,787	2,061	2,129	1,641	1,992	1,428	0,474	**1,38375**
315,00	1,531	1,933	1,89	1,666	2,05	1,824	0,096	**1,409**
400,00	1,686	2,212	1,588	2,1	2,349	2,456	0,396	**1,82525**
500,00	1,435	2,2	2,276	2,015	1,992	1,78	0,688	**1,61875**

630,00	1,964	2,059	2,273	1,721	1,799	2,058	0,85	**1,607**
800,00	2,007	2,151	2,219	1,912	2,194	2,134	0,795	**1,75875**
1k	1,811	1,744	2,244	2,281	2,144	2,188	0,956	**1,89225**
1.25k	2,088	2,146	1,956	2,038	2,33	1,873	0,738	**1,74475**
1.6k	1,857	1,986	1,923	1,87	1,813	1,833	0,601	**1,52925**
2k	1,697	1,87	1,748	1,79	1,604	1,756	0,787	**1,48425**
2.5k	1,664	1,68	1,575	1,694	1,791	1,732	0,897	**1,5285**
3.15k	1,415	1,664	1,611	1,657	1,746	1,543	0,833	**1,44475**
4k	1,502	1,457	1,509	1,528	1,497	1,507	1,004	**1,384**
5k	1,163	1,435	1,072	1,449	1,249	1,25	0,826	**1,1935**
6.3k	1,032	1,144	0,876	1,129	1,146	0,959	0,837	**1,01775**
8k	0,687	1,056	0,719	1,025	0,91	0,751	0,815	**0,87525**
10k	0,534	0,822	0,618	0,877	0,749	0,732	0,438	**0,699**
12.5k	0,5	0,627	0,468	0,7	0,598	0,695	0,055	**0,512**

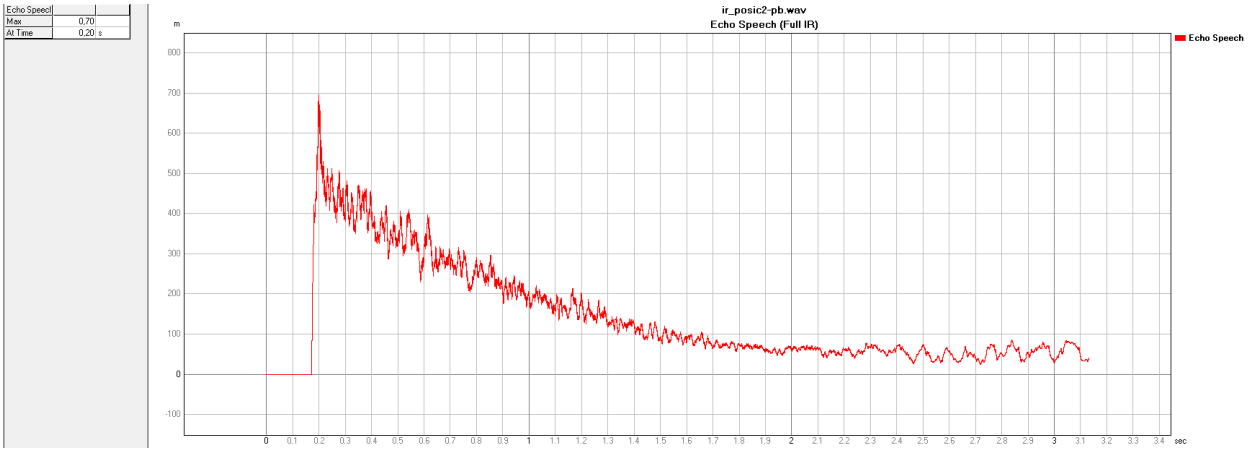
- **Echo Speech**

P1 STAGE	1.53
P2PB	0.72
P31PISO	0.61
P3PB	0.76
P41PISO	0.68
P51PISO	0.75
P5PB	0.65

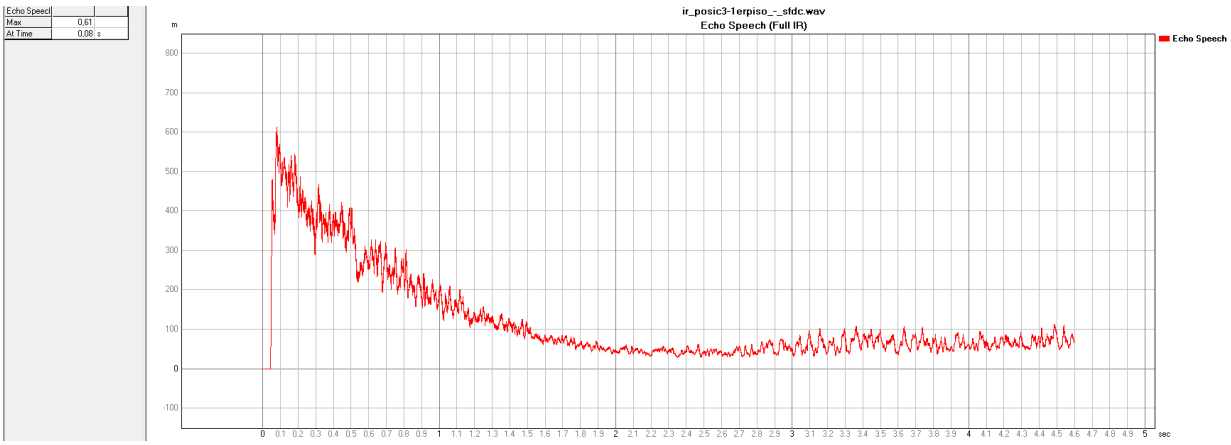
P1 STAGE



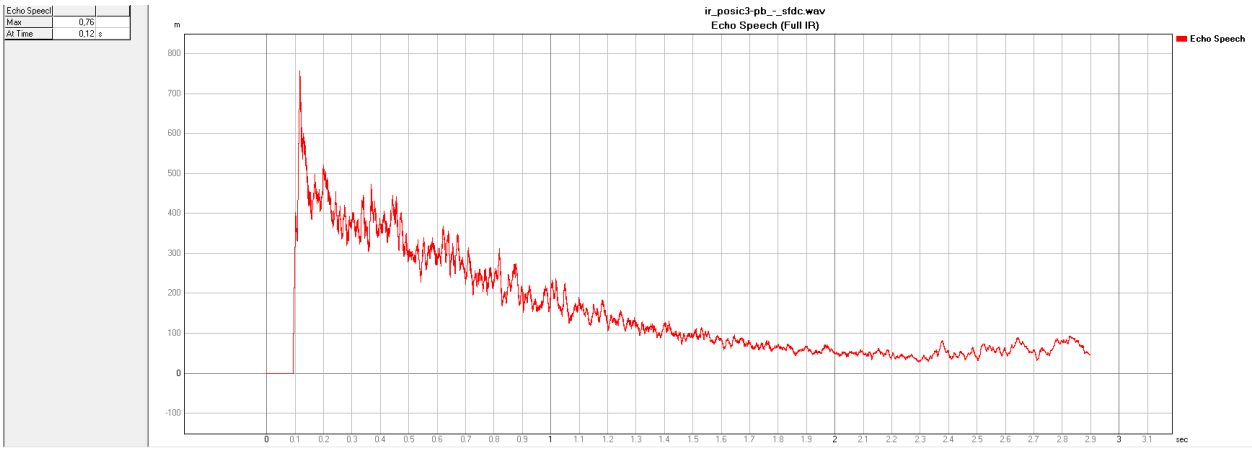
P2PB



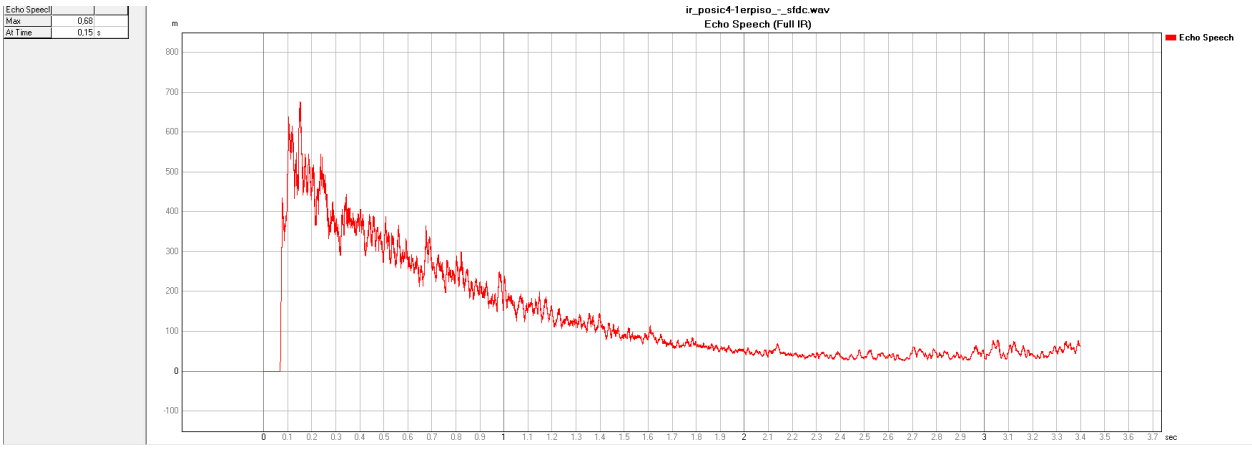
P31PISO



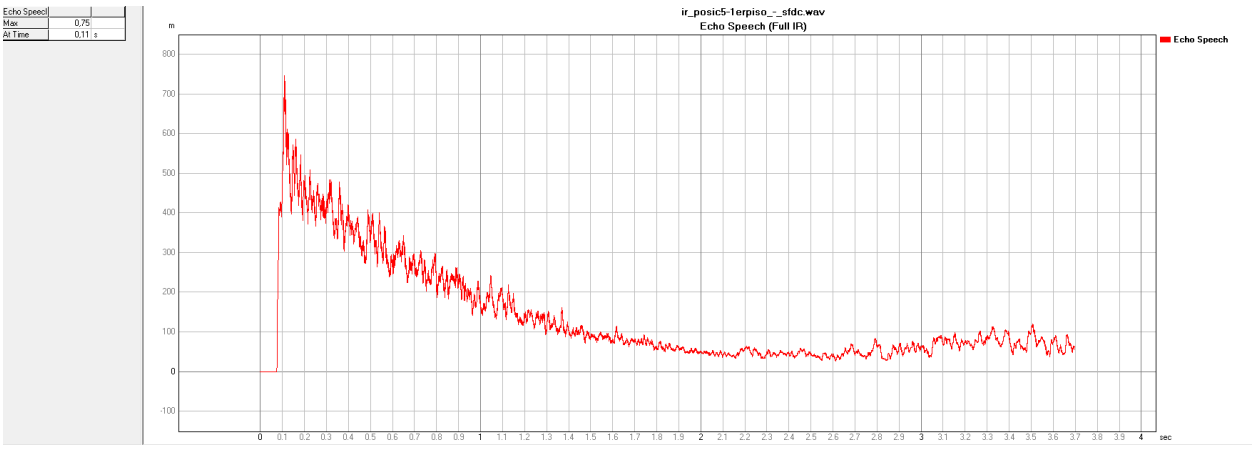
P3PB



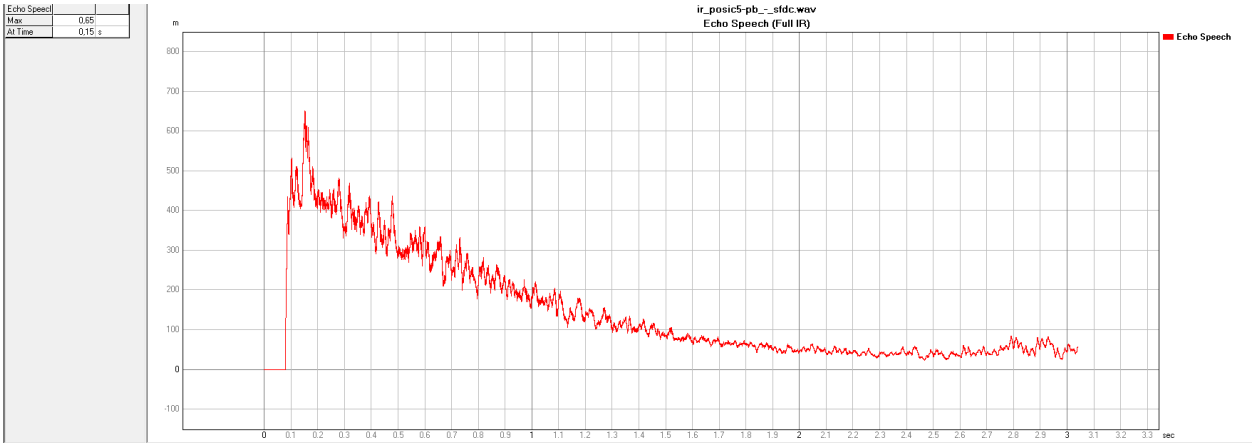
P41PISO



P51PISO



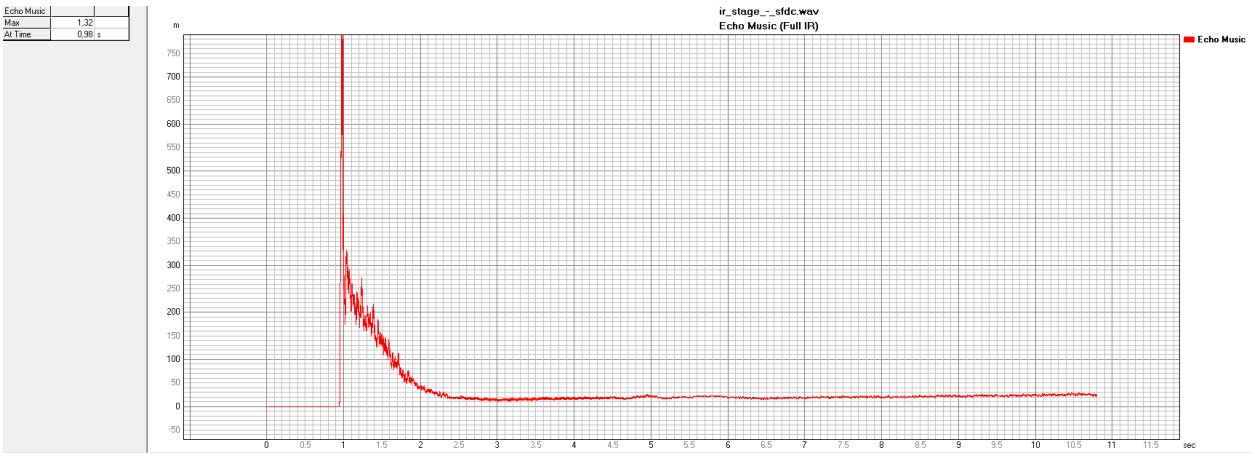
P5PB



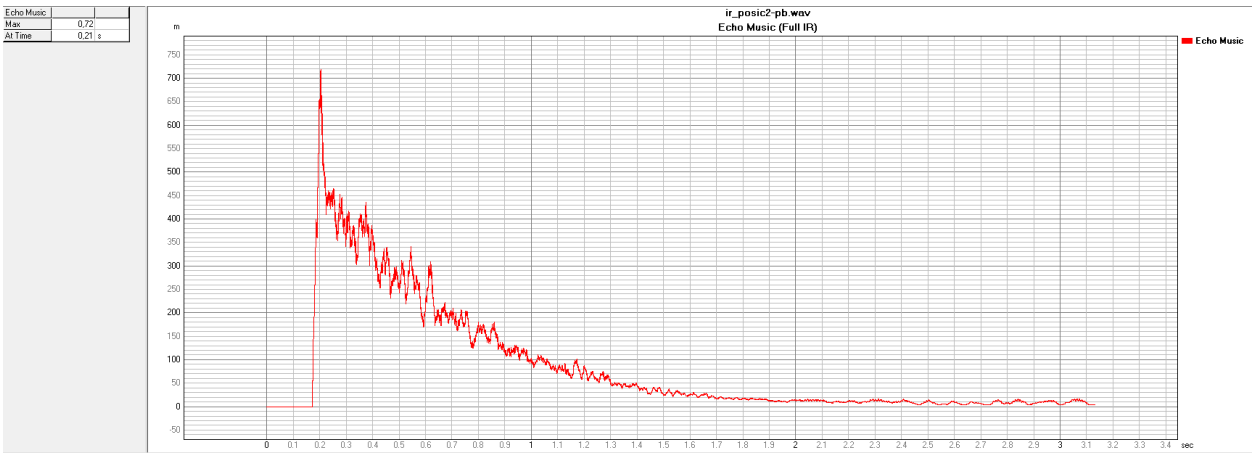
- **Echo Music**

P1 STAGE	1.32
P2PB	0.72
P31PISO	0.64
P3PB	0.74
P41PISO	0.72
P51PISO	0.77
P5PB	0.68

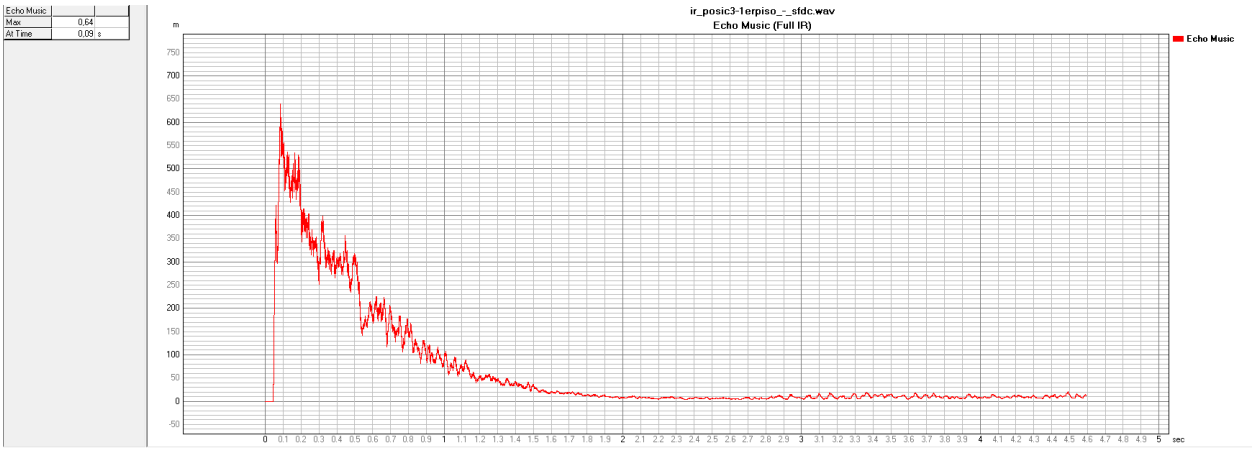
P1 STAGE



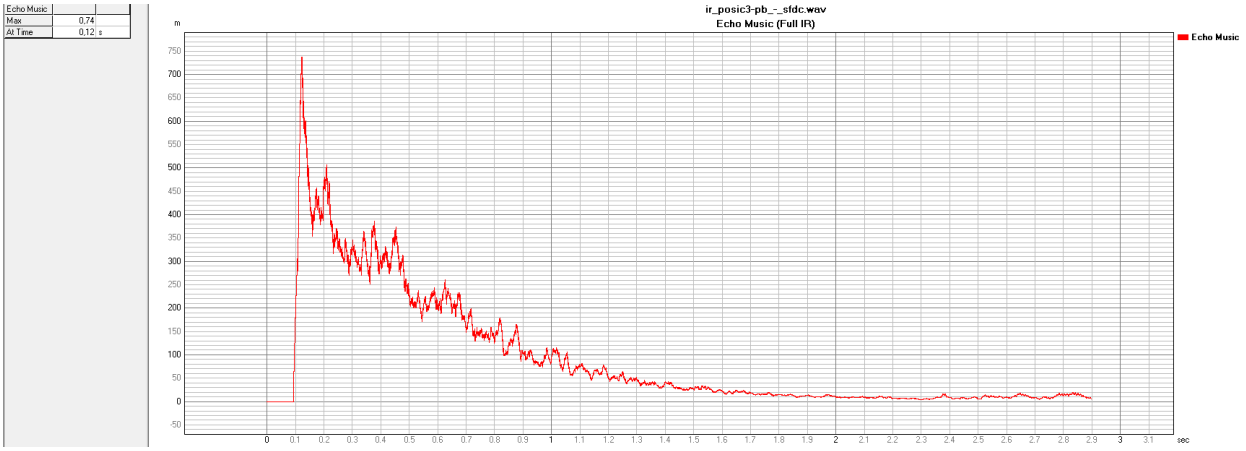
P2PB



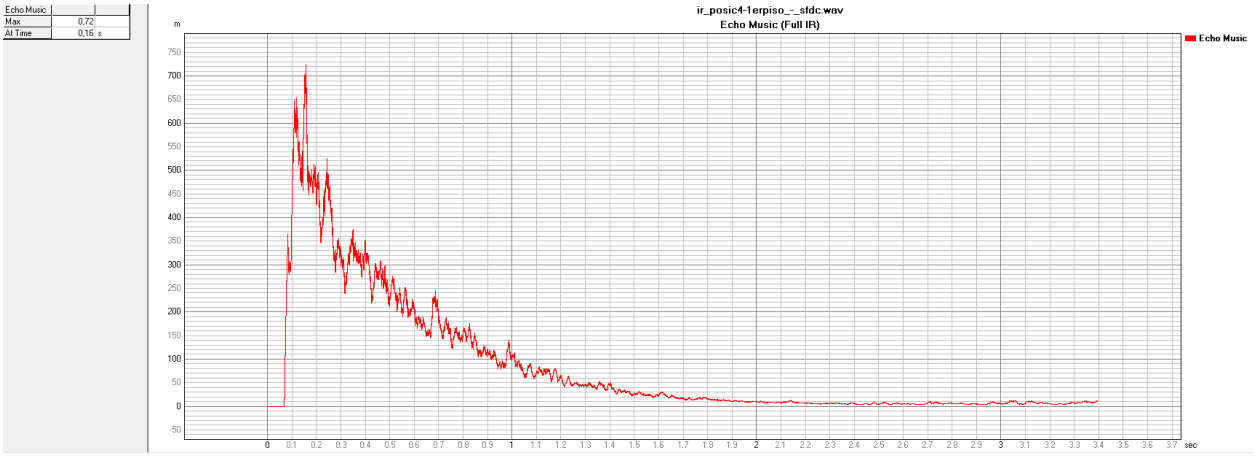
P31PISO



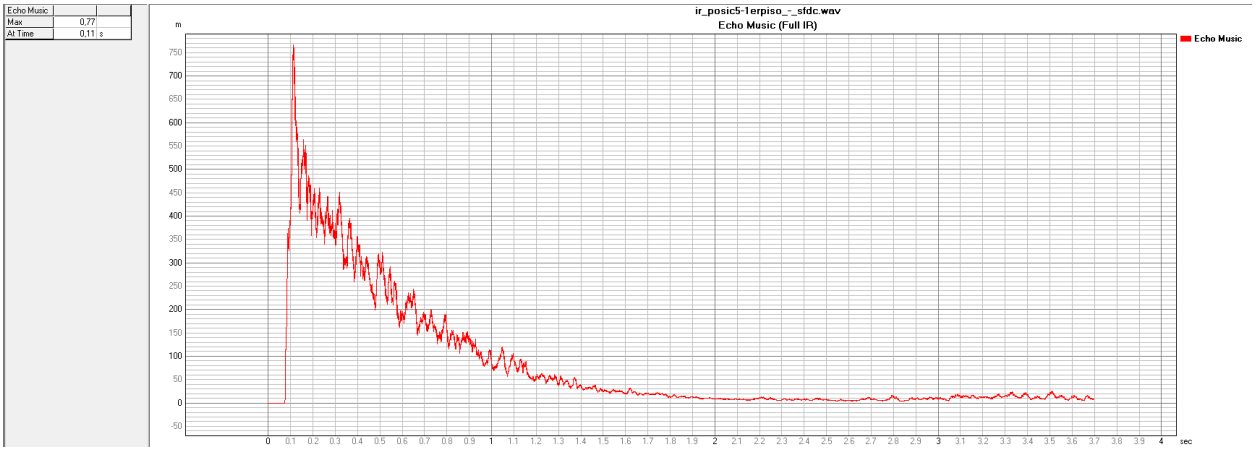
P3PB



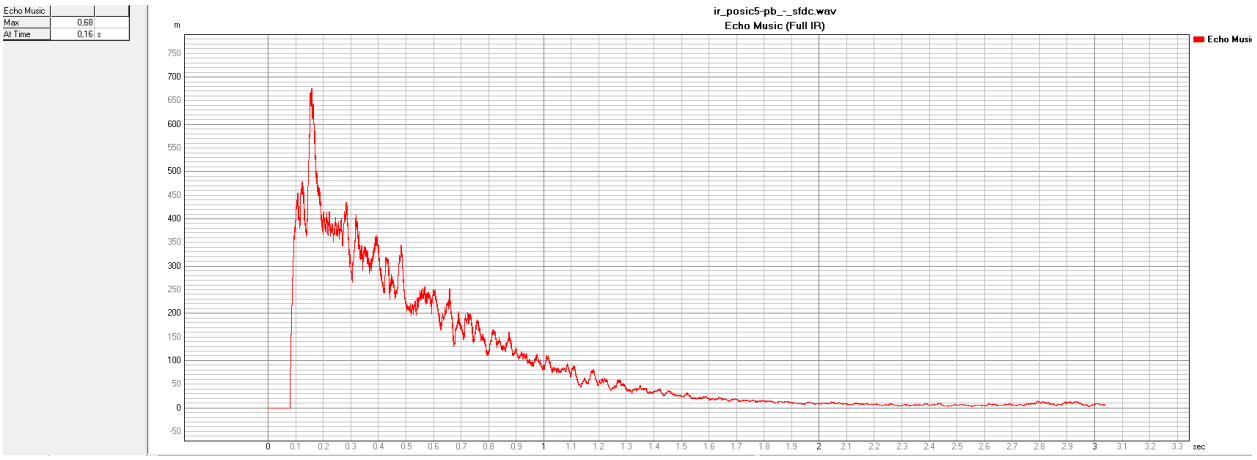
P41PISO



P51PISO



P5PB



- **STI**

P1STAGE

EASERA 1.0, Results of Data: ir_stage_-_sfdc.wav : Measures							
STI, MTF, MTI							
Fq. [Hz]	**MTF 125Hz**	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,987	0,983	0,975	0,958	0,972	0,98	0,987
0,8 Hz	0,981	0,976	0,964	0,94	0,958	0,97	0,98
1 Hz	0,974	0,967	0,951	0,92	0,943	0,957	0,97
1,25 Hz	0,965	0,957	0,937	0,896	0,923	0,939	0,956
1,6 Hz	0,956	0,945	0,921	0,868	0,898	0,915	0,935
2 Hz	0,946	0,935	0,905	0,839	0,872	0,888	0,911
2,5 Hz	0,936	0,923	0,888	0,805	0,842	0,858	0,881
3,15 Hz	0,926	0,911	0,868	0,764	0,806	0,821	0,845
4 Hz	0,914	0,898	0,85	0,719	0,767	0,778	0,801

5 Hz	0,891	0,887	0,835	0,675	0,73	0,736	0,755
6,3 Hz	0,873	0,875	0,821	0,624	0,693	0,701	0,713
8 Hz	0,854	0,871	0,828	0,609	0,659	0,688	0,692
10 Hz	0,818	0,862	0,826	0,63	0,641	0,704	0,706
12,5 Hz	0,783	0,867	0,813	0,638	0,666	0,735	0,734
MTI	0,87	0,867	0,816	0,71	0,748	0,772	0,792
STI	0,794						
AlCons [%]	2,309						
STI (Male)	0,771						
STI (Female)	0,772						
RaSTI	0,781						
Equiv. STIPa (Male)	0,775						
Equiv. STIPa (Female)	0,776						

P2PB

EASERA 1.0, Results of Data: ir_posic2-pb.wav : Measures							
STI, MTF, MTI							
	MTF 125Hz	MTF 250Hz	MTF 500Hz	MTF 1000Hz	MTF 2000Hz	MTF 4000Hz	MTF 8000Hz
0,63 Hz	0,92	0,909	0,893	0,871	0,895	0,928	0,964
0,8 Hz	0,88	0,866	0,846	0,814	0,847	0,893	0,945
1 Hz	0,832	0,815	0,792	0,75	0,789	0,848	0,918
1,25 Hz	0,77	0,752	0,728	0,678	0,722	0,791	0,883
1,6 Hz	0,688	0,672	0,649	0,597	0,643	0,717	0,831
2 Hz	0,602	0,595	0,575	0,527	0,571	0,644	0,776
2,5 Hz	0,509	0,518	0,507	0,456	0,502	0,568	0,715
3,15 Hz	0,392	0,45	0,439	0,393	0,437	0,49	0,652
4 Hz	0,25	0,426	0,337	0,356	0,372	0,406	0,589
5 Hz	0,253	0,433	0,262	0,304	0,306	0,321	0,529
6,3 Hz	0,343	0,384	0,207	0,246	0,25	0,232	0,461

8 Hz	0,404	0,287	0,093	0,172	0,138	0,152	0,398
10 Hz	0,284	0,232	0,146	0,162	0,065	0,101	0,34
12,5 Hz	0,111	0,251	0,116	0,125	0,084	0,079	0,293
MTI	0,519	0,536	0,476	0,473	0,473	0,508	0,638
STI	0,517						
AlCons [%]	10,334						
STI (Male)	0,505						
STI (Female)	0,511						
RaSTI	0,465						
Equiv. STIPa (Male)	0,524						
Equiv. STIPa (Female)	0,531						

P31PISO

EASERA 1.0, Results of Data: ir_posic3-1erpiso_-_sfdc.wav : Measures							
STI, MTF, MTI							
	MTF 125Hz	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,942	0,875	0,859	0,872	0,878	0,917	0,953
0,8 Hz	0,913	0,818	0,797	0,815	0,823	0,876	0,928
1 Hz	0,876	0,752	0,727	0,748	0,758	0,824	0,893
1,25 Hz	0,828	0,674	0,649	0,667	0,682	0,759	0,846
1,6 Hz	0,762	0,578	0,561	0,567	0,589	0,672	0,776
2 Hz	0,69	0,494	0,488	0,473	0,505	0,585	0,696
2,5 Hz	0,603	0,42	0,43	0,386	0,421	0,493	0,601
3,15 Hz	0,486	0,345	0,364	0,313	0,337	0,397	0,489
4 Hz	0,316	0,253	0,24	0,23	0,259	0,3	0,371
5 Hz	0,122	0,224	0,199	0,178	0,206	0,214	0,277
6,3 Hz	0,085	0,076	0,203	0,129	0,138	0,13	0,202
8 Hz	0,257	0,031	0,216	0,045	0,054	0,041	0,112
10 Hz	0,303	0,061	0,168	0,047	0,034	0,057	0,02

12,5 Hz	0,224	0,048	0,161	0,052	0,029	0,117	0,055
MTI	0,528	0,403	0,455	0,402	0,406	0,455	0,506
STI	0,449						
AlCons [%]	14,986						
STI (Male)	0,439						
STI (Female)	0,438						
RaSTI	0,438						
Equiv. STIPa (Male)	0,442						
Equiv. STIPa (Female)	0,449						

P3PB

EASERA 1.0, Results of Data: ir_posic3-pb_-_sfdc.wav : Measures							
STI, MTF, MTI							
	MTF 125Hz	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,915	0,889	0,879	0,859	0,892	0,931	0,969
0,8 Hz	0,872	0,839	0,827	0,797	0,843	0,896	0,952
1 Hz	0,819	0,78	0,769	0,727	0,785	0,852	0,929
1,25 Hz	0,754	0,713	0,706	0,649	0,718	0,798	0,897
1,6 Hz	0,672	0,638	0,639	0,563	0,639	0,728	0,851
2 Hz	0,588	0,578	0,587	0,493	0,567	0,659	0,799
2,5 Hz	0,487	0,535	0,553	0,434	0,497	0,589	0,737
3,15 Hz	0,392	0,517	0,53	0,387	0,43	0,518	0,665
4 Hz	0,379	0,477	0,459	0,343	0,363	0,451	0,583
5 Hz	0,392	0,338	0,297	0,261	0,29	0,386	0,498
6,3 Hz	0,438	0,226	0,224	0,182	0,215	0,31	0,411
8 Hz	0,405	0,167	0,172	0,064	0,16	0,253	0,351
10 Hz	0,331	0,087	0,23	0,024	0,148	0,228	0,311
12,5 Hz	0,377	0,132	0,266	0,093	0,098	0,171	0,245

MTI	0,549	0,491	0,508	0,424	0,481	0,548	0,639
STI	0,521						
AlCons [%]	10,132						
STI (Male)	0,508						
STI (Female)	0,515						
RaSTI	0,488						
Equiv. STIPa (Male)	0,498						
Equiv. STIPa (Female)	0,512						

P41PISO

EASERA 1.0, Results of Data: ir_posic4-1erpiso_-_sfdc.wav : Measures							
STI, MTF, MTI							
	MTF 125Hz	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,941	0,889	0,872	0,862	0,887	0,914	0,956
0,8 Hz	0,911	0,841	0,815	0,804	0,835	0,871	0,933
1 Hz	0,872	0,786	0,748	0,736	0,772	0,816	0,901
1,25 Hz	0,821	0,724	0,669	0,659	0,697	0,746	0,858
1,6 Hz	0,747	0,653	0,569	0,566	0,603	0,652	0,796
2 Hz	0,662	0,586	0,472	0,479	0,514	0,556	0,729
2,5 Hz	0,558	0,507	0,383	0,405	0,428	0,453	0,654
3,15 Hz	0,431	0,426	0,303	0,344	0,334	0,343	0,572
4 Hz	0,272	0,331	0,202	0,276	0,226	0,238	0,484
5 Hz	0,088	0,233	0,136	0,183	0,131	0,169	0,414
6,3 Hz	0,106	0,144	0,052	0,112	0,081	0,137	0,37
8 Hz	0,191	0,179	0,008	0,021	0,033	0,126	0,368
10 Hz	0,197	0,252	0,108	0,083	0,098	0,163	0,404
12,5 Hz	0,147	0,178	0,126	0,049	0,144	0,21	0,467

MTI	0,502	0,489	0,401	0,404	0,42	0,473	0,614
STI	0,472						
AlCons [%]	13,183						
STI (Male)	0,454						
STI (Female)	0,461						
RaSTI	0,396						
Equiv. STIPa (Male)	0,459						
Equiv. STIPa (Female)	0,469						

P51PISO

EASERA 1.0, Results of Data: ir_posic5-1erpiso_-_sfdc.wav : Measures							
STI, MTF, MTI							
	MTF 125Hz	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,938	0,863	0,859	0,856	0,892	0,918	0,955
0,8 Hz	0,909	0,801	0,799	0,792	0,842	0,877	0,93
1 Hz	0,873	0,728	0,729	0,717	0,782	0,826	0,897
1,25 Hz	0,828	0,64	0,649	0,63	0,71	0,76	0,851
1,6 Hz	0,771	0,528	0,552	0,528	0,62	0,674	0,785
2 Hz	0,712	0,419	0,462	0,44	0,536	0,589	0,711
2,5 Hz	0,648	0,314	0,378	0,37	0,455	0,502	0,627
3,15 Hz	0,568	0,237	0,297	0,315	0,378	0,415	0,532
4 Hz	0,46	0,255	0,22	0,266	0,299	0,327	0,429
5 Hz	0,366	0,269	0,171	0,24	0,234	0,249	0,325
6,3 Hz	0,276	0,129	0,135	0,209	0,17	0,155	0,211
8 Hz	0,255	0,101	0,124	0,116	0,07	0,073	0,102
10 Hz	0,214	0,096	0,079	0,079	0,037	0,025	0,061
12,5 Hz	0,166	0,096	0,019	0,026	0,02	0,092	0,133
MTI	0,561	0,417	0,406	0,414	0,427	0,459	0,534

STI	0,46
AlCons [%]	14,124
STI (Male)	0,445
STI (Female)	0,445
RaSTI	0,42
Equiv. STIPa (Male)	0,467
Equiv. STIPa (Female)	0,474

P5PB

EASERA 1.0, Results of Data: ir_posic5-pb_-_sfdc.wav : Measures							
STI, MTF, MTI							
	MTF 125Hz	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,893	0,887	0,858	0,865	0,892	0,924	0,964
0,8 Hz	0,84	0,839	0,798	0,804	0,842	0,886	0,944
1 Hz	0,773	0,786	0,73	0,732	0,78	0,837	0,917
1,25 Hz	0,688	0,727	0,657	0,648	0,706	0,774	0,88
1,6 Hz	0,57	0,66	0,575	0,547	0,611	0,688	0,825
2 Hz	0,441	0,598	0,5	0,456	0,52	0,598	0,763
2,5 Hz	0,295	0,535	0,419	0,381	0,432	0,501	0,689
3,15 Hz	0,161	0,474	0,347	0,316	0,35	0,403	0,598
4 Hz	0,147	0,394	0,3	0,227	0,254	0,307	0,487
5 Hz	0,142	0,282	0,224	0,113	0,158	0,208	0,363
6,3 Hz	0,111	0,151	0,169	0,029	0,074	0,113	0,22
8 Hz	0,259	0,065	0,185	0,087	0,023	0,021	0,058
10 Hz	0,197	0,282	0,273	0,14	0,075	0,073	0,108
12,5 Hz	0,146	0,421	0,328	0,105	0,124	0,173	0,209
MTI	0,433	0,501	0,472	0,403	0,421	0,463	0,565
STI	0,464						
AlCons [%]	13,759						

STI (Male)	0,455
STI (Female)	0,462
RaSTI	0,445
Equiv. STIPa (Male)	0,462
Equiv. STIPa (Female)	0,469

Annex 3
Parametros calculados a partir de la simulación

- **SPL**

Fq.[Hz]	A148	A250	A252	A90	Avg
80	38,607	38,607			38,607
100	56,165	56,165			56,165
125	39,255	39,254			39,2545
160	61,479	61,479	61,264	61,264	61,3715
200	65,305	65,305	63,216	63,217	64,26075
250	66,739	66,739	62,257	62,257	64,498
315	68,76	68,76	66,764	66,764	67,762
400	68,892	68,892	65,659	65,659	67,2755
500	69,652	69,652	66,32	66,32	67,986
630	71,751	71,751	66,65	66,65	69,2005
800	72,275	72,275	68,993	68,993	70,634
1k	73,907	73,907	69,886	69,886	71,8965
1.25k	74,52	74,52	70,933	70,933	72,7265
1.6k	75,377	75,377	71,598	71,598	73,4875
2k	75,875	75,875	72,041	72,041	73,958
2.5k	76,417	76,417	72,709	72,709	74,563
3.15k	77,238	77,238	73,776	73,776	75,507
4k	78,152	78,152	75,102	75,102	76,627
5k	78,431	78,431	75,578	75,578	77,0045

6.3k	78,657	78,657	75,908	75,908	77,2825
8k	78,49	78,49	76,268	76,268	77,379
10k	76,517	76,517	75,01	75,01	75,7635
12.5k	62,809	62,809	61,335	61,335	62,072

- **T20**

Fq.[Hz]	A148	A250	A252	A90	Avg
80	--	--	0,726	--	0,726
100	0,476	--	0,55	--	0,513
125	--	--	--	--	
160	1,723	1,271	1,176	1,28	1,3625
200	1,44	1,614	1,577	1,771	1,6005
250	1,403	1,41	1,668	1,683	1,541
315	1,539	1,47	1,502	1,968	1,61975
400	1,401	1,905	1,81	1,71	1,7065
500	1,67	1,357	1,54	1,856	1,60575
630	1,65	1,819	1,409	1,818	1,674
800	1,712	1,468	1,535	1,765	1,62
1k	1,535	1,664	1,649	1,548	1,599
1.25k	1,679	1,793	1,559	1,662	1,67325
1.6k	1,627	1,498	1,526	1,81	1,61525
2k	1,662	1,707	1,608	1,583	1,64
2.5k	1,801	1,746	1,622	1,727	1,724
3.15k	1,609	1,633	1,71	1,608	1,64
4k	1,588	1,622	1,564	1,61	1,596
5k	1,53	1,6	1,451	1,569	1,5375
6.3k	1,308	1,433	1,407	1,492	1,41
8k	1,139	1,302	1,215	1,334	1,2475
10k	0,928	1,028	1,018	1,064	1,0095
12.5k	0,838	0,907	0,904	0,973	0,9055

- **EDT**

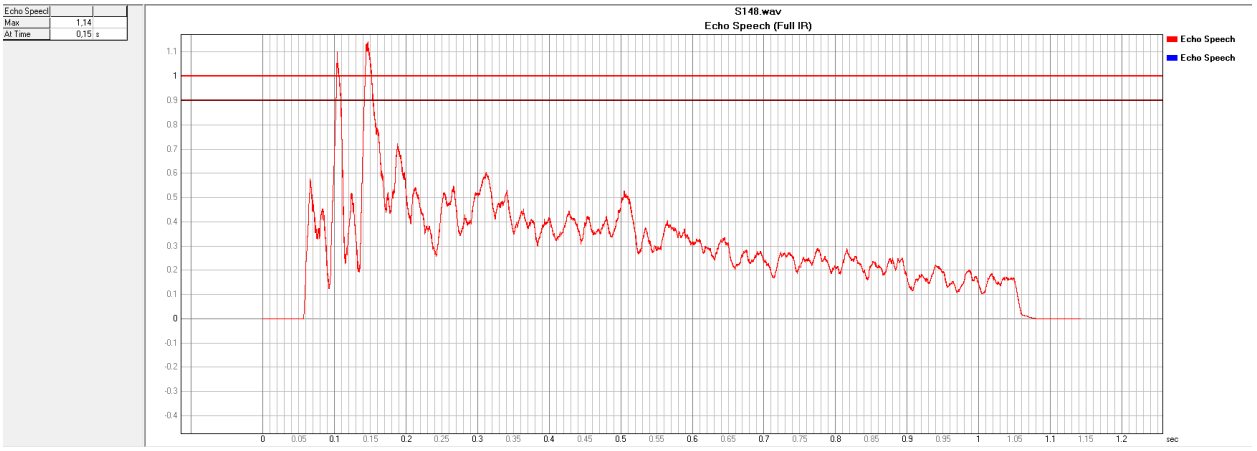
Fq.[Hz]	A148	A250	A252	A90	Avg
80	1,29	0,663	2,091	--	1,348
100	1,383	2,041	2,775	--	2,066333333
125	--	2,294	--	--	2,294
160	0,98	2,335	2,396	2,464	2,04375
200	1,67	2,727	1,835	1,808	2,01
250	1,99	1,941	2,183	2,084	2,0495
315	2,633	2,524	2,083	1,774	2,2535
400	2,609	2,515	2,088	2,887	2,52475
500	2,068	2,375	2,987	2,071	2,37525
630	2,034	2,551	2,268	2,482	2,33375
800	2,277	2,568	2,319	2,266	2,3575
1k	2,189	2,424	2,24	2,217	2,2675
1.25k	2,223	2,362	2,407	2,34	2,333
1.6k	1,986	2,487	2,691	2,269	2,35825
2k	1,955	2,27	2,223	2,53	2,2445
2.5k	1,703	2,236	2,297	2,365	2,15025
3.15k	1,731	2,042	2,136	2,389	2,0745
4k	1,693	2,189	2,061	2,116	2,01475
5k	1,582	1,698	2,002	1,775	1,76425
6.3k	1,379	1,457	1,645	1,369	1,4625
8k	1,032	1,079	1,243	0,922	1,069
10k	0,922	0,836	1,083	0,765	0,9015
12.5k	0,872	0,666	0,841	0,646	0,75625

-Echo Speech

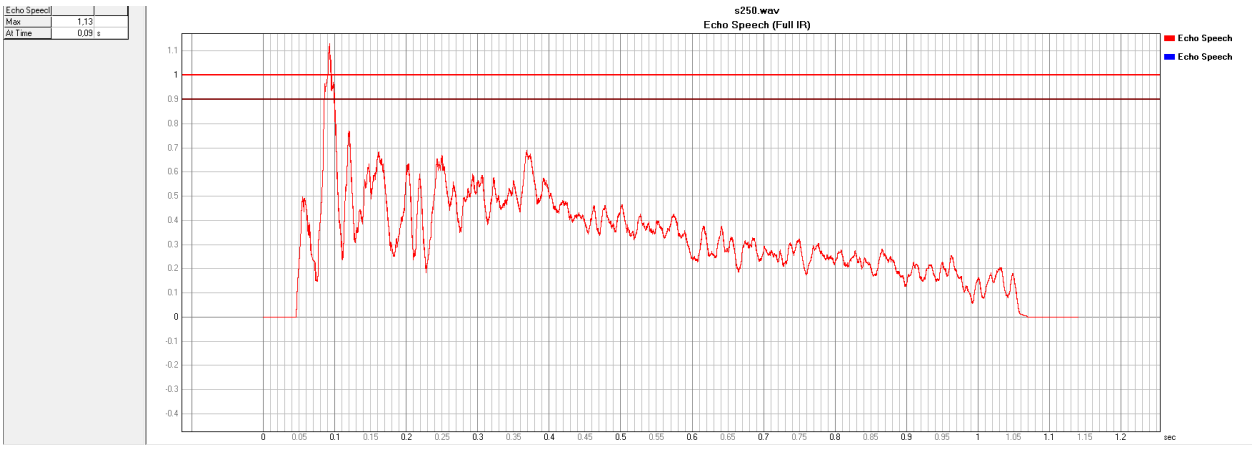
A148	**1.14**
A250	**1.13**

A252	**1.11**
A90	**0.92**

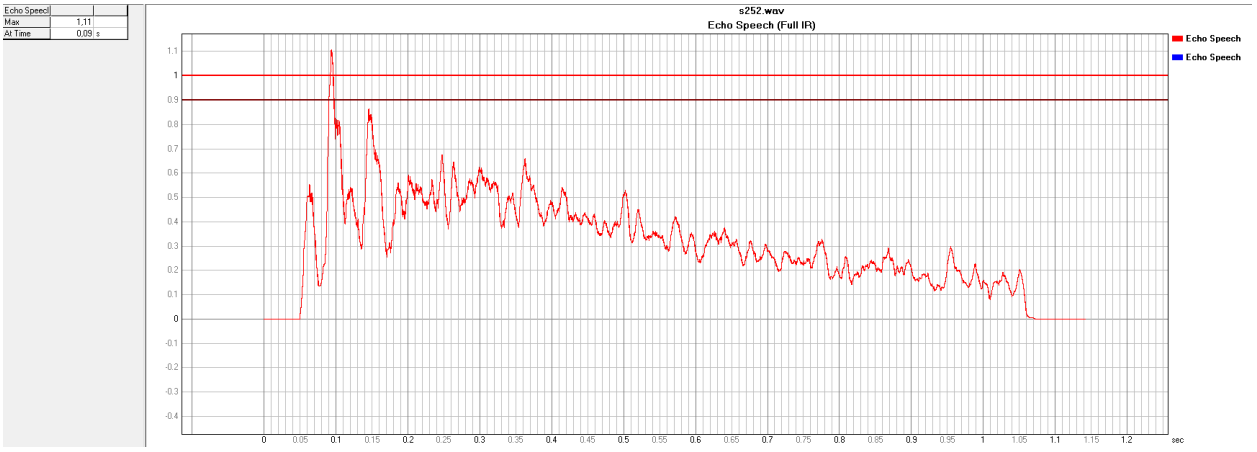
A148



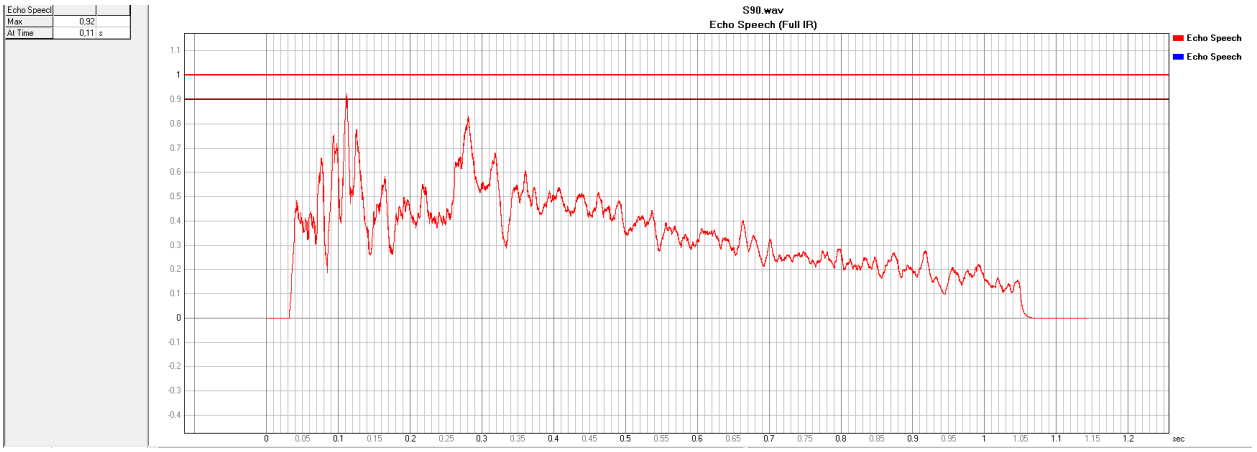
A250



A252



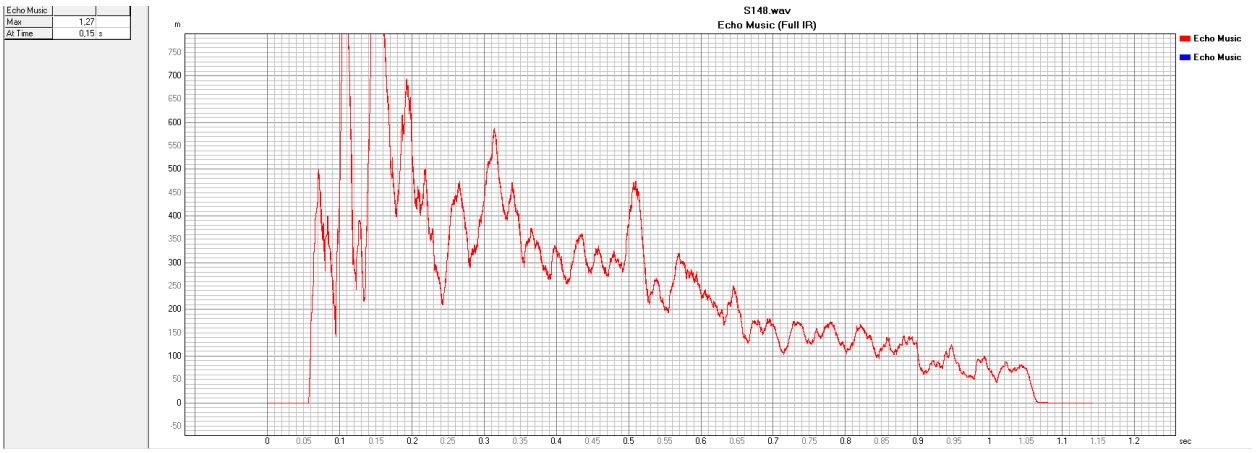
A92



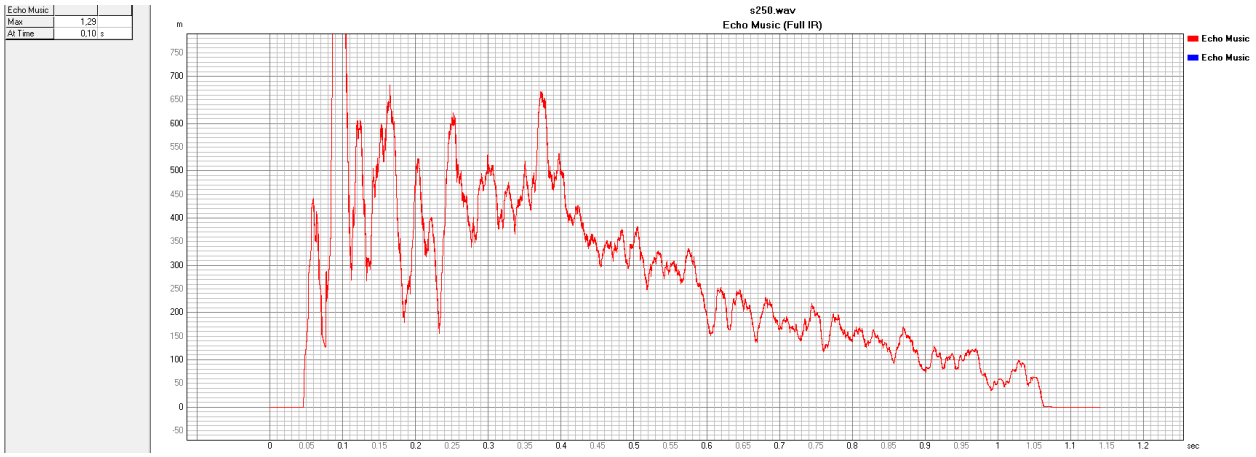
- **Echo Music**

A148	**1.27**
A250	**1.29**
A252	**1.21**
A90	**0.83**

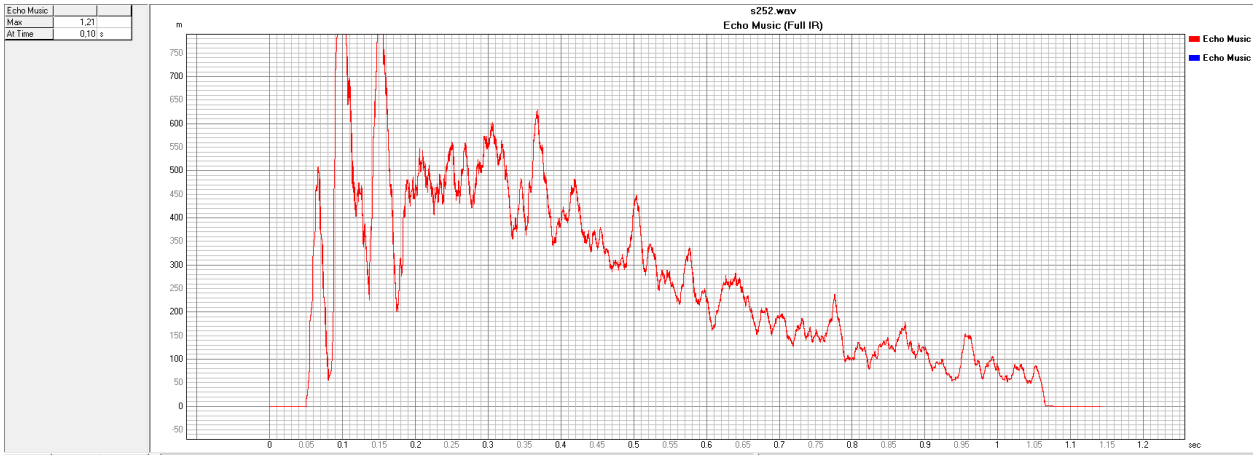
A148



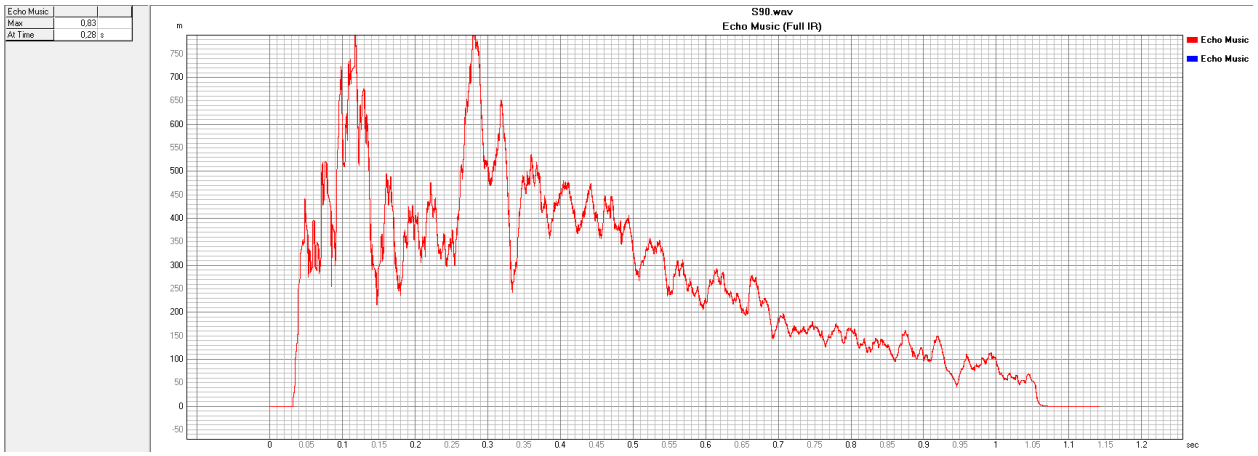
A250



A252



A90



- **STI**

EASERA 1.0, Results of Data: S148.wav : Measures							
STI, MTF, MTI							
	MTF 125Hz	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,901	0,843	0,849	0,848	0,873	0,899	0,946
0,8 Hz	0,854	0,773	0,78	0,778	0,813	0,851	0,918
1 Hz	0,801	0,695	0,701	0,697	0,745	0,792	0,88
1,25 Hz	0,743	0,613	0,615	0,608	0,667	0,722	0,83
1,6 Hz	0,68	0,534	0,521	0,516	0,578	0,638	0,759
2 Hz	0,63	0,489	0,449	0,454	0,5	0,563	0,682
2,5 Hz	0,574	0,469	0,382	0,401	0,423	0,487	0,595
3,15 Hz	0,471	0,386	0,28	0,297	0,324	0,389	0,491
4 Hz	0,351	0,245	0,199	0,203	0,243	0,281	0,372
5 Hz	0,266	0,139	0,15	0,16	0,176	0,178	0,241
6,3 Hz	0,135	0,093	0,05	0,05	0,015	0,024	0,091
8 Hz	0,012	0,185	0,142	0,109	0,143	0,154	0,165
10 Hz	0,179	0,161	0,211	0,124	0,149	0,154	0,196
12,5 Hz	0,235	0,177	0,064	0,05	0,113	0,133	0,17
MTI	0,482	0,436	0,406	0,395	0,425	0,452	0,526
STI	0,447						
AlCons [%]	15,138						
STI (Male)	0,436						
STI (Female)	0,44						
RaSTI	0,423						
Equiv. STIPa (Male)	0,421						
Equiv. STIPa (Female)	0,426						

EASERA 1.0, Results of Data: s250.wav : Measures

STI, MTF, MTI							
	MTF 125Hz	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,87	0,815	0,819	0,827	0,851	0,883	0,942
0,8 Hz	0,807	0,732	0,74	0,749	0,783	0,827	0,912
1 Hz	0,731	0,638	0,654	0,66	0,704	0,761	0,874
1,25 Hz	0,644	0,54	0,568	0,565	0,618	0,684	0,825
1,6 Hz	0,549	0,444	0,488	0,461	0,527	0,599	0,762
2 Hz	0,489	0,383	0,444	0,386	0,465	0,534	0,701
2,5 Hz	0,489	0,36	0,42	0,354	0,432	0,487	0,641
3,15 Hz	0,552	0,335	0,375	0,347	0,407	0,44	0,575
4 Hz	0,574	0,279	0,307	0,289	0,356	0,364	0,491
5 Hz	0,436	0,23	0,273	0,141	0,26	0,268	0,4
6,3 Hz	0,316	0,217	0,181	0,087	0,195	0,212	0,306
8 Hz	0,292	0,035	0,146	0,045	0,089	0,108	0,17
10 Hz	0,278	0,097	0,116	0,146	0,12	0,113	0,101
12,5 Hz	0,229	0,078	0,033	0,118	0,04	0,015	0,039
MTI	0,515	0,394	0,416	0,395	0,429	0,451	0,534
STI	0,448						
AlCons [%]	15,025						
STI (Male)	0,439						
STI (Female)	0,441						
RaSTI	0,423						
Equiv. STIPa (Male)	0,452						
Equiv. STIPa (Female)	0,455						

EASERA 1.0, Results of Data: s252.wav : Measures							
STI, MTF, MTI							
	MTF 125Hz	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,823	0,838	0,826	0,839	0,84	0,872	0,933
0,8 Hz	0,737	0,765	0,747	0,762	0,764	0,81	0,897

1 Hz	0,633	0,682	0,659	0,672	0,674	0,735	0,852
1,25 Hz	0,513	0,591	0,564	0,565	0,573	0,646	0,794
1,6 Hz	0,379	0,49	0,465	0,433	0,462	0,541	0,718
2 Hz	0,283	0,4	0,401	0,319	0,384	0,456	0,646
2,5 Hz	0,249	0,317	0,365	0,257	0,336	0,393	0,577
3,15 Hz	0,259	0,276	0,318	0,262	0,301	0,338	0,508
4 Hz	0,271	0,284	0,258	0,263	0,272	0,29	0,433
5 Hz	0,166	0,188	0,231	0,193	0,217	0,234	0,357
6,3 Hz	0,086	0,184	0,159	0,118	0,141	0,152	0,273
8 Hz	0,052	0,239	0,148	0,074	0,105	0,115	0,196
10 Hz	0,072	0,131	0,172	0,08	0,099	0,131	0,174
12,5 Hz	0,023	0,072	0,05	0,079	0,077	0,14	0,143
MTI	0,352	0,42	0,412	0,384	0,405	0,441	0,533
STI	0,423						
AlCons [%]	17,27						
STI (Male)	0,422						
STI (Female)	0,431						
RaSTI	0,41						
Equiv. STIPa (Male)	0,423						
Equiv. STIPa (Female)	0,432						

EASERA 1.0, Results of Data: S90.wav : Measures							
STI, MTF, MTI							
	MTF 125Hz	**MTF 250Hz**	**MTF 500Hz**	**MTF 1000Hz**	**MTF 2000Hz**	**MTF 4000Hz**	**MTF 8000Hz**
0,63 Hz	0,875	0,85	0,839	0,843	0,843	0,884	0,948
0,8 Hz	0,818	0,787	0,77	0,773	0,772	0,829	0,922
1 Hz	0,754	0,722	0,699	0,696	0,692	0,765	0,888
1,25 Hz	0,686	0,662	0,632	0,614	0,61	0,692	0,846
1,6 Hz	0,618	0,613	0,58	0,532	0,533	0,615	0,793

2 Hz	0,571	0,587	0,558	0,479	0,489	0,563	0,742
2,5 Hz	0,537	0,557	0,536	0,444	0,463	0,53	0,689
3,15 Hz	0,486	0,486	0,488	0,41	0,43	0,5	0,627
4 Hz	0,399	0,406	0,412	0,377	0,376	0,454	0,552
5 Hz	0,243	0,305	0,333	0,29	0,317	0,379	0,46
6,3 Hz	0,106	0,138	0,181	0,108	0,213	0,266	0,344
8 Hz	0,113	0,033	0,175	0,157	0,243	0,245	0,323
10 Hz	0,248	0,193	0,252	0,21	0,225	0,202	0,342
12,5 Hz	0,252	0,261	0,24	0,292	0,284	0,278	0,406
MTI	0,482	0,467	0,485	0,461	0,479	0,513	0,608
STI	0,5						
AlCons [%]	11,346						
STI (Male)	0,498						
STI (Female)	0,503						
RaSTI	0,477						
Equiv. STIPa (Male)	0,502						
Equiv. STIPa (Female)	0,51						

.

```
Ray Tracing Impact Computing Protocol
Project exporta2
Rays Per Speaker: 1250000
Impact Chance:  90.903 %

Begin   07/12/20, 14:14
End     07/12/20, 19:06
Time [s]         17513.4
         1.Order:        11 Impacts
         2.Order:        23 Impacts
         3.Order:        49 Impacts
         4.Order:        86 Impacts
         5.Order:        84 Impacts
         6.Order:        122 Impacts
         7.Order:        146 Impacts
         8.Order:        173 Impacts
         9.Order:        189 Impacts
         10.Order:       214 Impacts
         11.Order:       262 Impacts
         12.Order:       269 Impacts
         13.Order:       268 Impacts
         14.Order:       263 Impacts
         15.Order:       296 Impacts
         16.Order:       266 Impacts
         17.Order:       253 Impacts
         18.Order:       255 Impacts
         19.Order:       219 Impacts
         20.Order:       249 Impacts
         21.Order:       217 Impacts
         22.Order:       201 Impacts
         23.Order:       193 Impacts
         24.Order:       180 Impacts
         25.Order:       161 Impacts
         26.Order:       137 Impacts
         27.Order:       119 Impacts
         28.Order:       119 Impacts
         29.Order:       122 Impacts
         30.Order:       111 Impacts
           Overall:      5257 Impacts
```