CAFE OTO

ACOUSTIC ANALYSIS OF THE ENVIRONMENT

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INDEX

ACOUSTIC ENVIRONMENT

What is Cafe OTO?

Founded in 2008 and located in the Dalston district of London, United Kingdom, **Cafe OTO** is a venue for experimental music ranging across all genres from folk, rock, noise, electronica, free jazz, experimental and free improvisation performances.

Cafe OTO provides a home for creative new music that exists outside of the mainstream with an evening programme of adventurous live music seven nights a week. The venue is also open as a cafe during the day, serving a range of pastries and snacks and sellings books, records, tapes and CDs.

Oto means 'noise' or 'music' in Japanese and "*that is exactly what you get at this truly amazing and innovative venue*"[1]. Italian Vogue has named this cafe as "*Britain's coolest venue*".

Use of the environment

Cafe OTO hosts live performances every day of the year. "*People don't come because they think it's a cool place to hang out, but because they want to hear stuff*", said the founder Hamish Dunbar.

Cafe OTO also runs **OTOROKU**, an in-house label which documents the venue's programme of experimental and new music, alongside re-issuing crucial archival releases. All the recordings are made with a *JoeCo Black Box Recorder* and are available to download[2].

The Guardian has reviewed the acoustics of the venue:

"*Generally very good. The width of the room, the low ceiling and the brick interior create an ideal sound environment and when the room is full it can sound superb. Some shows are played completely unamplified, if the line-up allows, and the respectful nature of the crowd can make that a treat.*"[3]

[1] Cafe Oto – A perpetual musical discovery - by Andrew Sidford
[2] www.cafeoto.co.uk/shop/category/oto-roku/
[3] The gig venue guide: Cafe Oto, London - by Noah Payne-Frank

Dimensions and materials

Cafe OTO 3D model

The floor surface is 172m^2 with a capacity of 200 people. The wall's surface is 138m^2. The total surfaces of the room are approximately 482m^2. The total volume of the room is approximately 476m^3.

Walls are made of bricks covered with stucco. The longest wall has three big windows without curtains.

Furnitures

The furniture in **Cafe OTO** is arranged on an ad-hoc basis depending on the act and the number of people expected to attend. Most nights the front half of the venue is taken up by tables and chairs. There are two pillars quite close to the front of the performance space and there is no raised stage.

SETUP OF THE MEASUREMENT

Software

The software used for the analysis is REW - Room Acoustic Software, a free software for room acoustic measurement, loudspeaker measurement and audio device measurement. The audio measurement and analysis features of REW help you optimise the acoustics of your listening room, studio or home theatre and find the best locations for your speakers, subwoofers and listening position. It includes tools for generating audio test signals; measuring SPL and impedance; measuring frequency and impulse responses; measuring distortion; generating phase, group delay and spectral decay plots, waterfalls, spectrograms and energy-time curves; generating real time analyser (RTA) plots; calculating reverberation times; determining the frequencies and decay times of modal resonances; displaying equaliser responses and automatically adjusting the settings of parametric equalisers to counter the effects of room modes and adjust responses to match a target curve.

PA System

For the acoustic measurements, FOH speakers have been used to give more coherent results. The equipment used for the acoustic measurement are listed below.

Amplifier:
- D&B Audiotechnik 30D – 4 channel amp

Speakers:
- D&B Audiotechnik Vi10p – 3-way mains x 2
- D&B Audiotechnik Yi7p – 3-way sides x 2

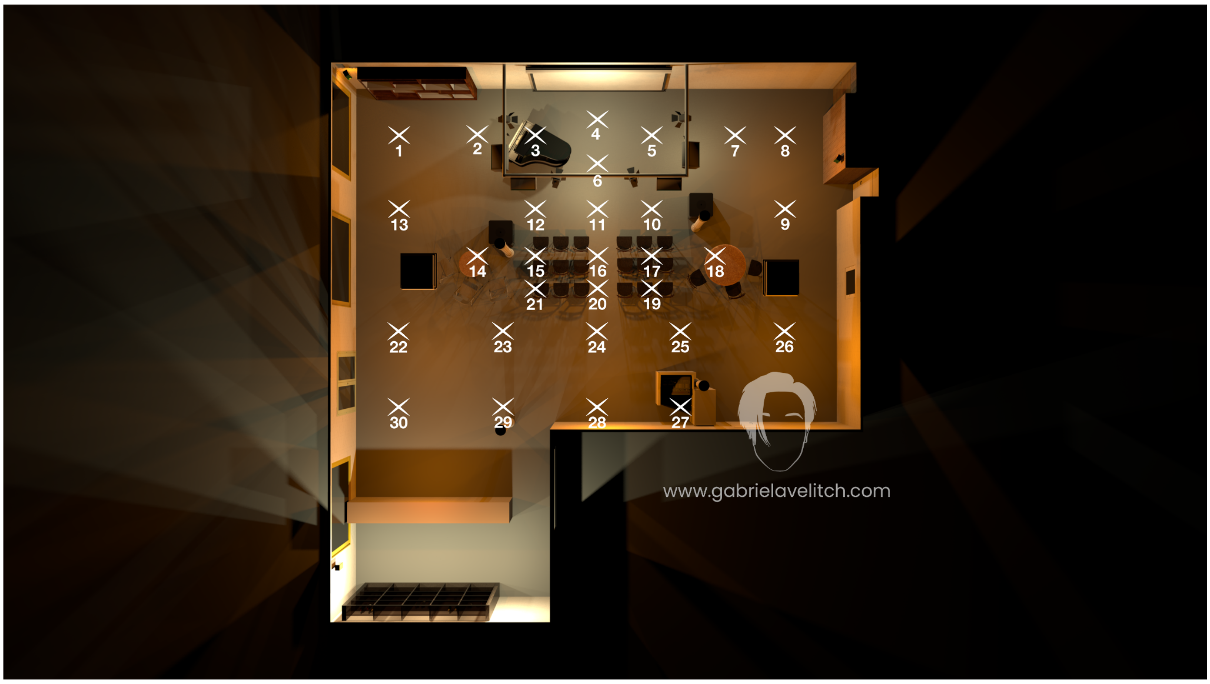
Audio Interface:
- RME Fireface 802 (calibration file)

Microphone:
- Behringer ECM8000 (calibration file)

SPL meter:
- Lutron SL-4001

Capture Positions

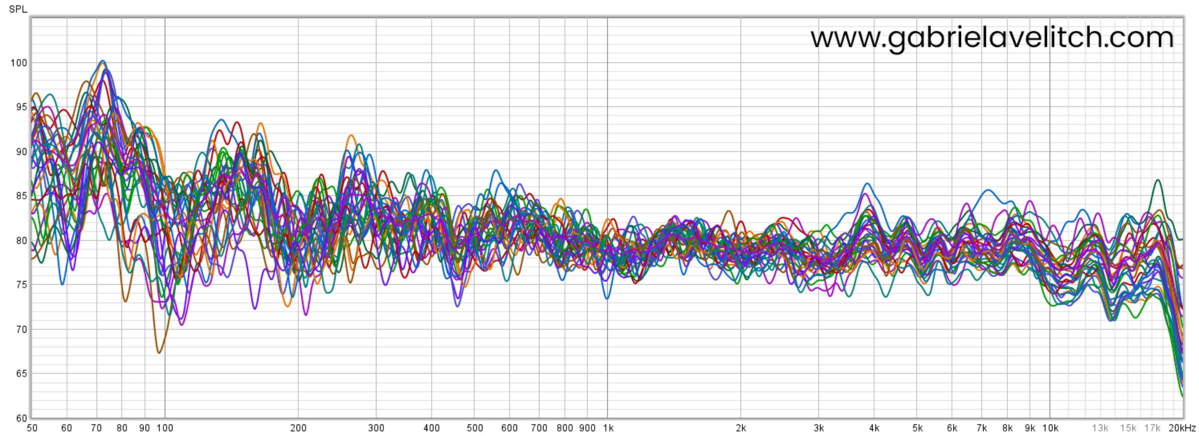
The acoustic analysis of the environment has been made with 30 capture positions spread all around the room. The microphone has been placed with a height of 1.40m from the floor; this value is an average between standing and sitting audience.



Capture Positions

IMPULSE RESPONSE

The image below shows the SPL levels of the acoustic measurement. All measurements have been taken at a level of 80dB.



SPL
(50 Hz - 20.000 Hz; 1/12 smoothing)

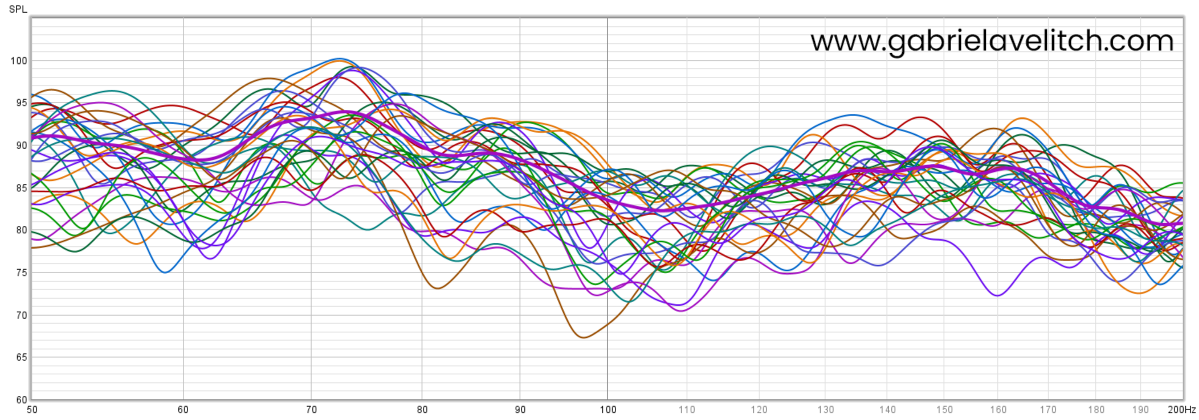
From the first view of this graph we can say that the room has not been treated. Emphasis was found in the frequency zones around ~ 34 Hz, ~ 68 Hz and ~ 102 Hz which could be recognized as the colours donated by the modal frequencies of the environment. Modal Frequencies graph can be found at the end of this paper.

SPL peaks go from a minimum of 75 dB to a maximum of 101 dB. To avoid this level difference, some sound traps might be allocated in specific positions depending on modal frequencies.

Other emphases peaks are found after 3 KHz; this is probably caused by the frequency response of the FOH system[4].

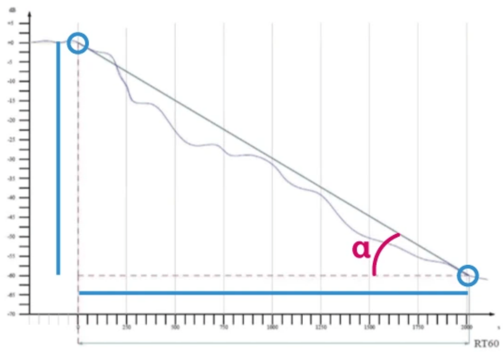
RMS average of all SPL measurements (20 Hz - 20.000 Hz; 1/12 smoothing)

[4] Speakers technical sheets can be found at the end of this paper.



SPL (50 Hz - 200 Hz; 1/12 smoothing)

RT60

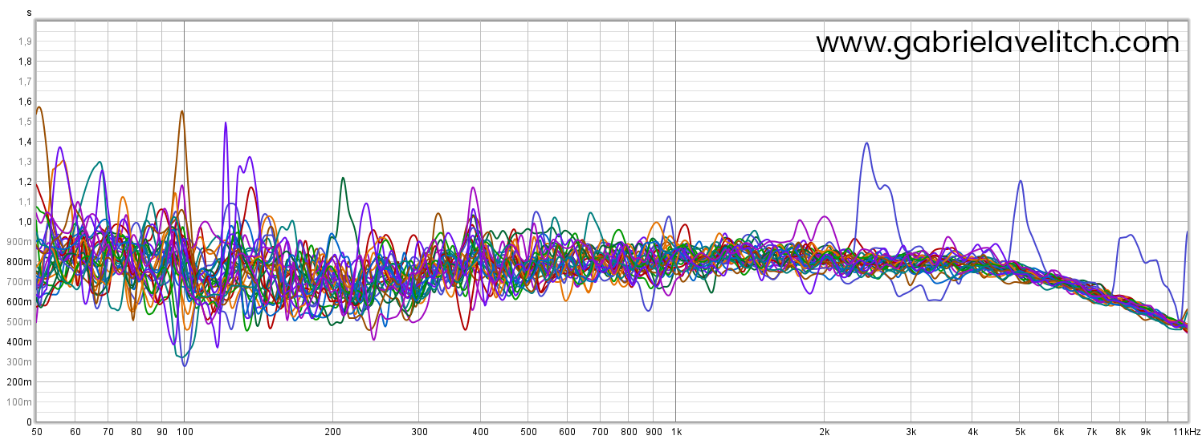


Reverberation Time is the time it takes for the impulse response to decay by 60dB. On the ordinates we have the dB, while on the abscissas we have the ms of RT60.

We can see that, as an exponential representation, this graph expresses a straight line. The slope of the line is the coefficient of x.

This line gives us an idea of how the decrease of the RT60 occurs. We therefore discover that these decrease exponentially. The approximative RT60 of the environment is about **800ms.**

The T60 is the same and does not change as the space measurement points change. The T60 makes sense from a certain size of a room onwards, as in a small space we are more in the field of diffusion than natural modes.



T60 (50Hz - 11.500Hz; 1/12 smoothing)

Through the angle of this line we can get RT60. This procedure is used also to identify the EDT, T20 and T30 which are used to identify when the sound decays by tot dB. These parameters are useful, because they give us more precise information on whether the real decay curve is uniform or not. The rate of diversity between these reverberation times tells us how erratic and how uniform the impulse response is at first.

Schroeder Frequency

Schroeder Frequency is that frequency above which the statistical approach makes more sense as the field behaves in a widespread manner. It is calculated with the formula:

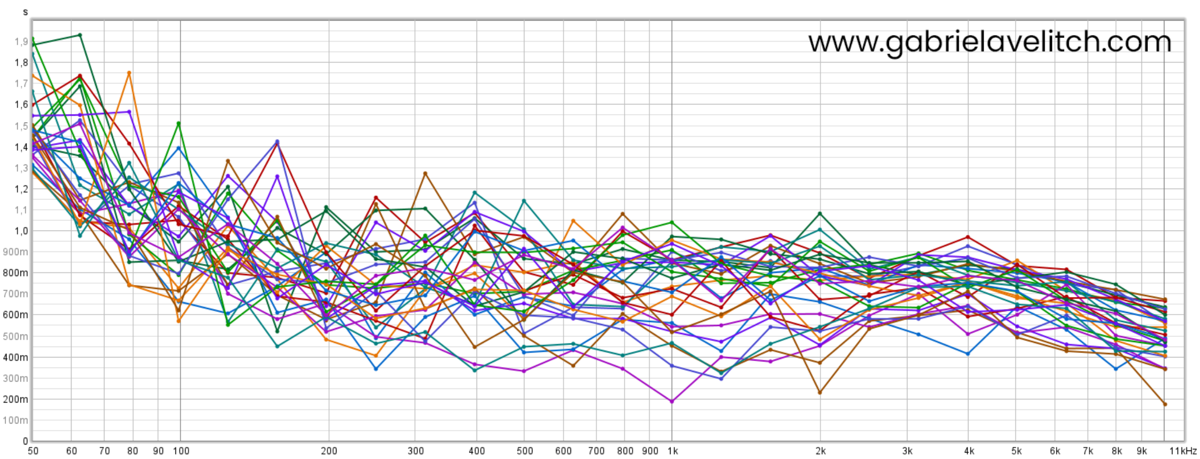
Schroeder Frequency = 2000 (√(T60/V))

Schroeder Frequency = 2000 (√(0.8/476)) = 81.99 Hz

The Schroeder Frequency of the Cafe OTO environment is about **82 Hz**. After this value, a statistical approach must be considered.

EDT - Early Decay Time

Early decay time is the reference time of the first reflections. It is calculated by drawing a line at -10dB until it meets the impulse response curve.



EDT - Early Decay Time

The EDT obtained from a 10dB drop is compared with RT60. The EDT aims to understand what is the uniformity between the decay profile of early reflections and the decay profile of the diffuse response.

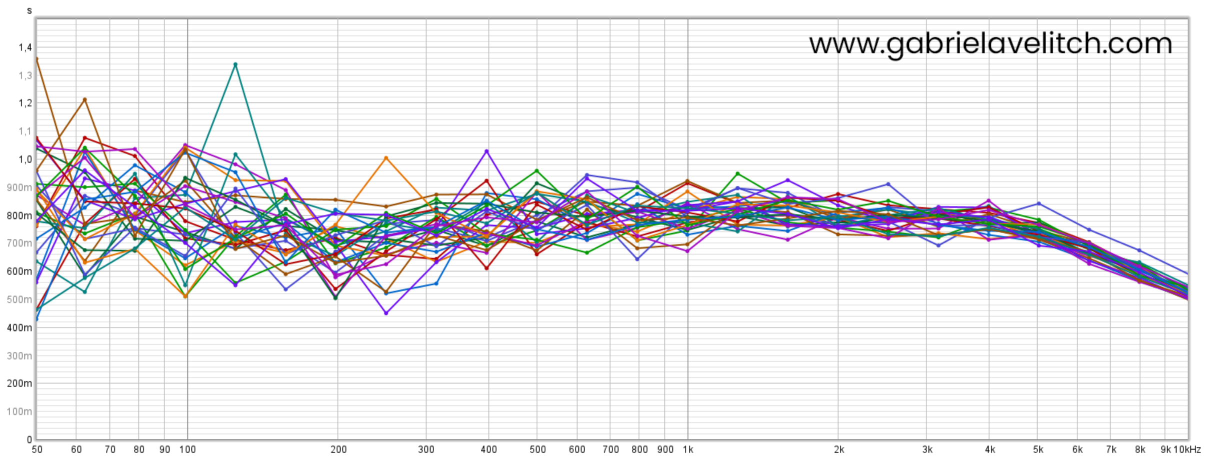
The EDT gives us the RT60 estimated on early reflections. Clearly in most cases the values of the EDT are lower than those of the RT60 and the magnitude of this difference guarantees an indication of the lack of diffusion of the field at that point.

EDT changes a lot from where I take the impulse response, as early reflections are much more important in it.

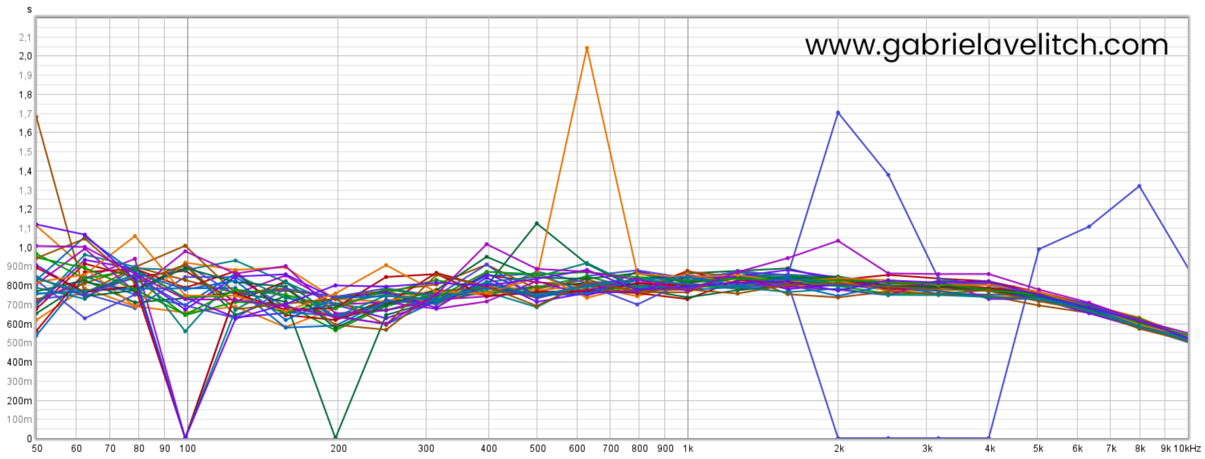
EDT is defined by very precise perceptual characteristics and it gives me indications on perceptual parameters and psychoacoustic sensations.

T20 and T30

Other parameters similar to RT60, i.e. 3 different slopes and decay profiles that have the purpose of characterising the impulse response at different times. This is because a uniform impulse response should have EDT, T20 and T30 equal, while in reality the parameters differ from each other, and how much they differ and what their values are give an idea of the homogeneity of the IR.



T20



T30

BR (Bass Ratio)

Bass Ratio expresses a relationship between reverberation times (ms) taken at specific frequencies. This value gives us indications of the fullness of the sound in the medium-low register. Typically the best rooms are those that have the BR between 1.1 and 1.5.
L.L. Beranek defines the formula to calculate BR as:

BR = RT(125Hz) + RT(250Hz) / RT(500Hz) + RT(1kHz)

The Bass Ratio average of the Cafe OTO is **0.897**. To increase the warmth, one should increase the low frequency RT while maintaining or decreasing mid to high frequency RT. One way to do this is to add materials in the space which absorb energy at high frequencies better than at low frequencies.

Bass Ratio values list can be found at the end of this paper.

Brilliance

Brilliance has a similar definition to the BR but on different frequencies. Brilliance and Bass Ratio describe the brightness of the environment at the acoustic level, i.e. how much there is of medium-low and medium-acute contribution. These two parameters are obviously related to the materials of the space. Very smooth and rigid materials increase the Brilliance parameters, while wood contributes to the BR. Wood has the ability to preserve the medium-low region of the spectrum (depending on the essence and finish of the wood it changes a lot for the resonator qualities). These two parameters are evaluated for acoustic adaptation work.

Brilliance = RT (500Hz) + RT (1kHz) / RT (2kHz) + RT (4kHz)

The Brilliance average of the Cafe OTO[5] is **0.978**. This value is close to the music venues standards.

[5] Brilliance values list can be found at the end of this paper.

STATISTICAL DESCRIPTOR RELATING TO ENERGY

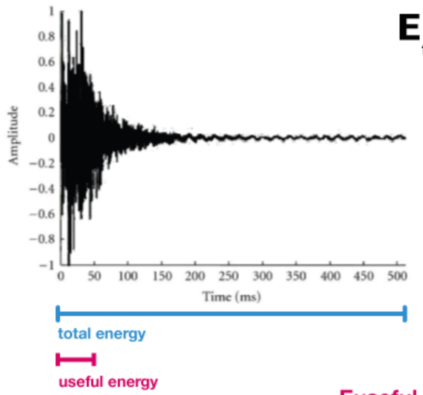
We now enter a family of parameters that give information of an energetic nature, useful above all for determining the intelligibility of the signal, both for speech and for music. Energy is relative to the square of the pressure. Doing the square and the sum of all the samples gives the total energy.

If we want to evaluate the intelligibility of the signal, it is important to understand how much of the signal is contained in the first part of the IR with respect to the total energy.

D50 (Definition)

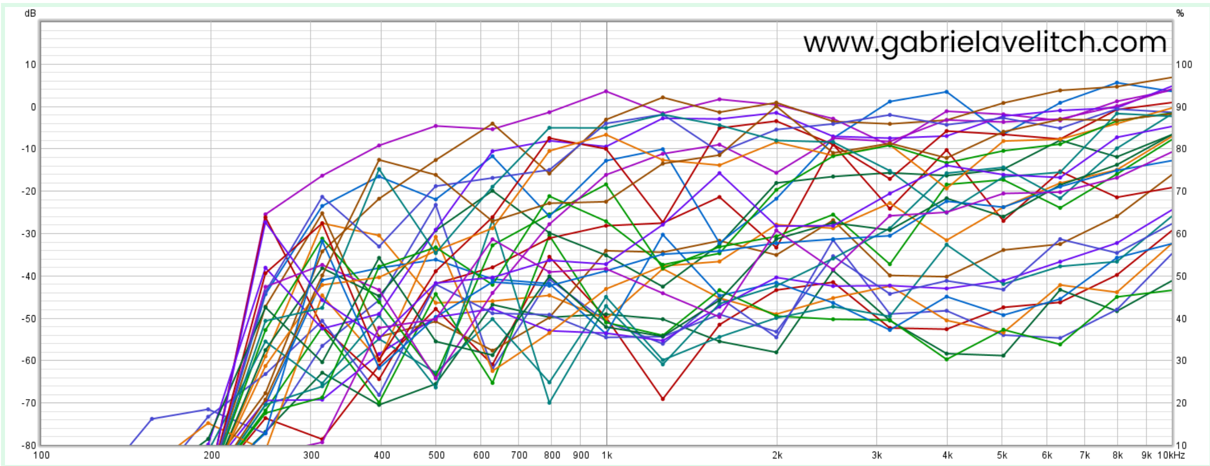
D50 is the ratio between useful energy and total energy. The useful energy in this case ranges from 0 to 50 ms, while the total energy ranges from 0 to infinity. In the case of speech, the D50 must be greater than 0.5. In the first 50ms there must be at least half of the total energy for speech to be intelligible.

Cafe OTO's Definition (D50) is optimal at the centre of the environment but less so when close to corners or to the stage.



$$E_t = \sum_i S^2[i]$$

$$D50 = \frac{E_{useful}}{E_{total}} = \frac{\sum_{i=0}^{50ms} S^2[i]}{\sum_{i=0}^{\infty} S^2[i]}$$

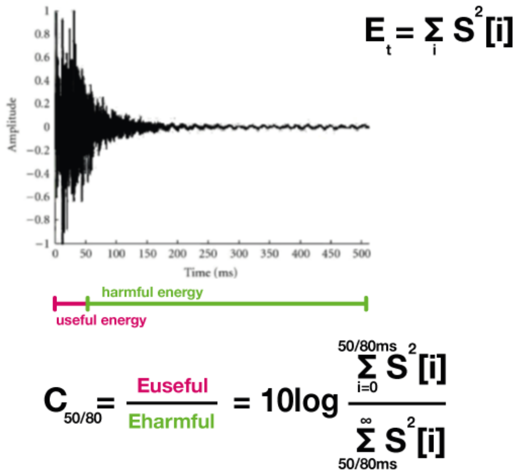


D50

C50/C80 (Clarity)

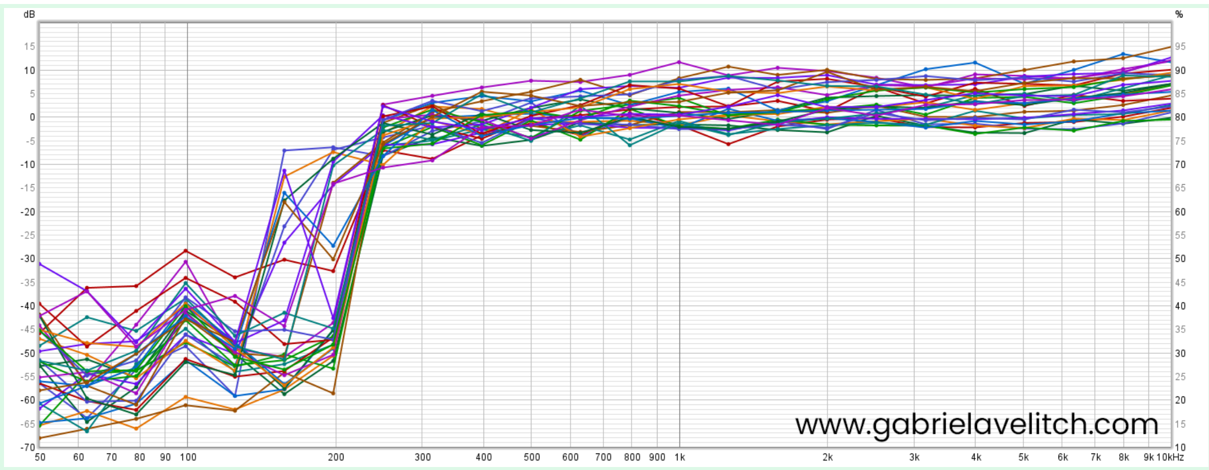
Clarity indices are the C50 and C80. They are defined as the relationship between useful energy and harmful energy. Now the measurements are logarithmic.

At the numerator we have the useful energy and in the denominator we have the harmful energy from 50/80 ms up to infinity. They are used for the intelligibility of speech (C50) and music (C80). The C50 needs all articulations to be perceptible. For music the C80 is fine because the articulations are slower than the speech. For music the level of intelligibility can be even lower than in speech.



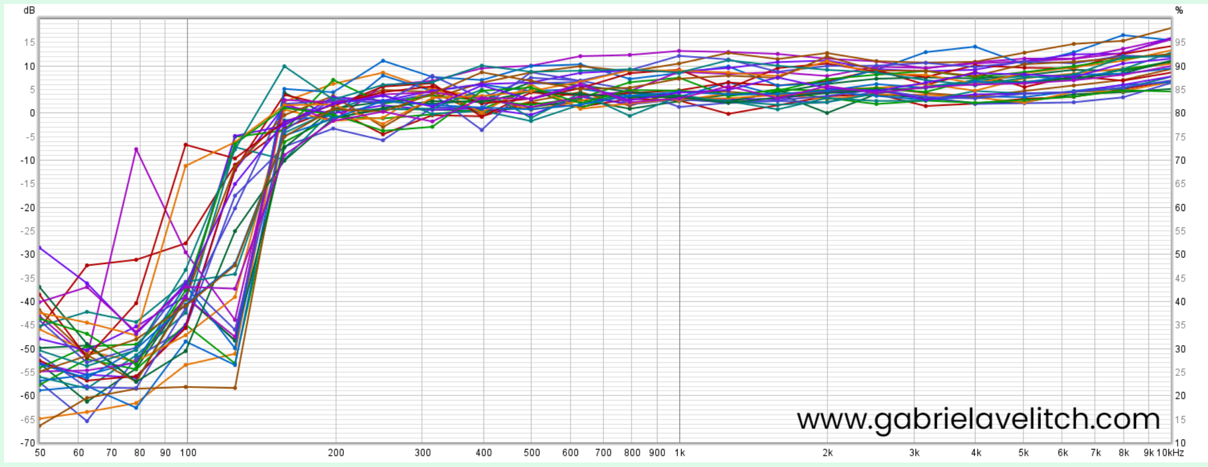
C50		C80
<0dB	unsuitable	<-4dB
0dB <C50 <3dB	discreet	0 <C80 <2dB
3dB	suitable	> 2dB

Cafe OTO's speech clarity (C50) is optimal at the centre of the environment but less so when close to windows or to the stage. To increase clarity, one should increase the amount of early sound energy relative to late sound energy. This could be accomplished by adding absorption in areas farther from the sound source.



C50

Cafe OTO's music clarity (C80) is optimal in any of the 30 capture positions.



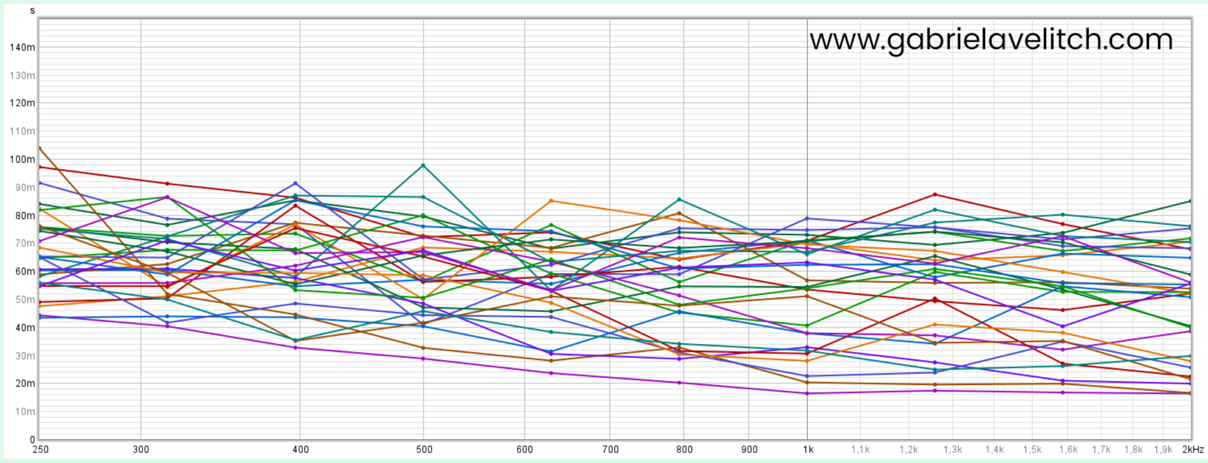
C80

D50, C50 and C80 of all capture positions

TS (Centre Time)

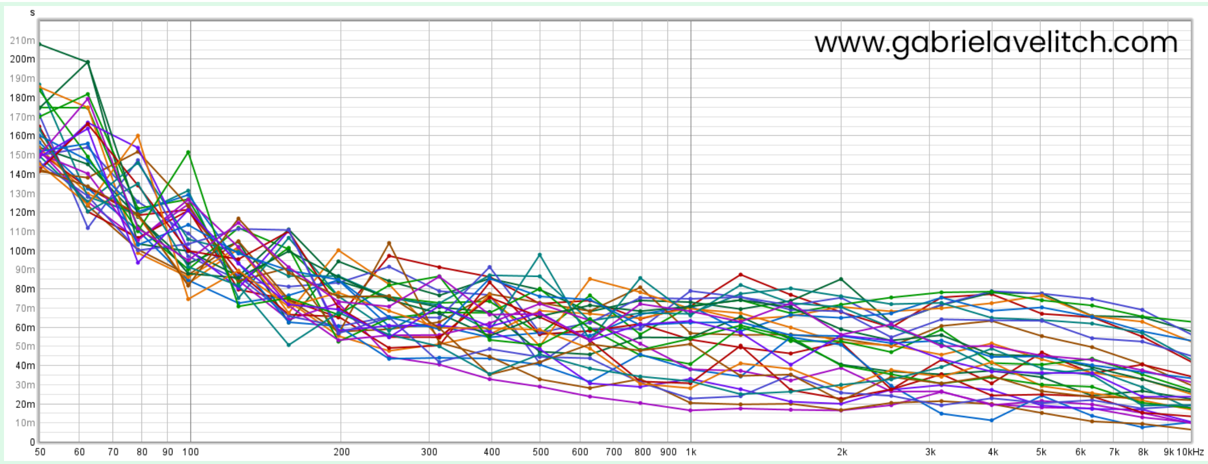
This definition assumes that the useful energy decays in the first 50/80 ms. But this state is not the same in all situations. Then another parameter is defined, namely the Centre Time: barycentric time of the impulse response, i.e. it is the time that separates 50% of the energy before an instant and after an instant, thus identifying half of an IR from the energetic point of view, therefore the time after which, we were invested by 50% of the energy.

Centre Time calculates the energy of the IR (in the discrete time domain) by taking and adding the squares of the IR. By doing this we have all the IR. This is related to the C50 and C80, as it gives me a measure of the clarity of the sound, as the lower the Central Time, the clearer the sound will be, as 50% of the energy is shifted to the early reflections; the greater the Central Time, the more the energy is spread over the whole IR and therefore the reverberation of the diffuse part is stronger. Typically for music and speech applications, the TS value is between 140 and 180 ms, in a band between 250 and 2000 Hz.



TS between 250 Hz and 2.000 Hz

Centre Time tells how IR is made from an energetic point of view; if it is too high, the second 50% of the energy is present on the tail of the IR, that is, on the diffuse part. We have a much more homogeneous IR (it goes down more slowly), if we have a very strong IR at the beginning and very quick to go down, then the diffuse part of the IR is very short and we have less reverberation, and therefore we will have a smaller unbalanced TS towards the beginning.



TS between 50 Hz and 10.000 Hz

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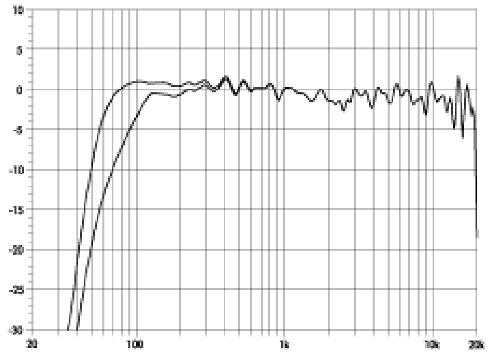
Vi7P and Vi10P Technical Data Sheets

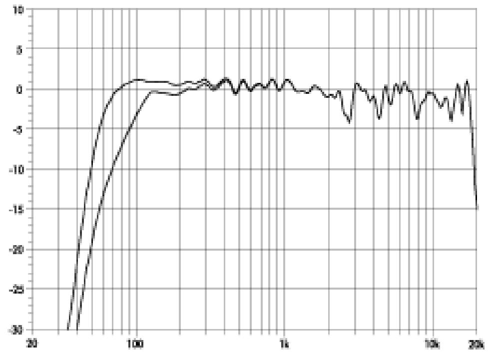


Vi7P frequency response, standard and CUT modes

2.5 Technical specifications

Vi7P/Vi10P system data

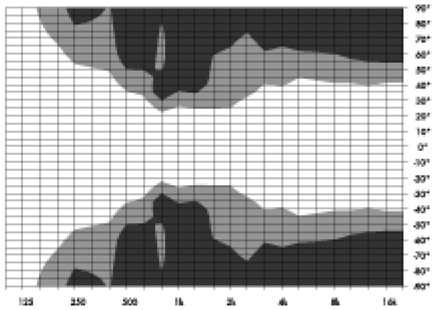
Frequency response (-5 dB standard) .... 59 Hz - 18 kHz
Frequency response (-5 dB CUT mode) .... 100 Hz - 18 kHz
Max. sound pressure (1 m, free field) ....
Vi7P with D12/D20/30D .... 137 dB
Vi7P with D80 .... 140 dB
Vi10P with D12/D20/30D .... 136 dB
Vi10P with D80 .... 139 dB
.... (SPLmax peak, pink noise test signal with crest factor of 4)



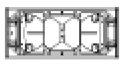
Vi10P frequency response, standard and CUT modes

Vi7P/Vi10P loudspeaker

Nominal impedance .... 8 ohms
Power handling capacity (RMS/peak 10 ms) .... 500/2000 W
Nominal dispersion angle (horizontal) Vi7P .... 75°
Nominal dispersion angle (horizontal) Vi10P .... 110°
Nominal dispersion angle (vertical) .... 40°
Components .... 2 x 10" LF driver with neodymium magnet
.... 1 x 8" MF driver with neodymium magnet
.... 1.4" exit compression driver
.... Passive crossover network
Connections .... 2 x NL4 M
.... 1 x screw terminal (ST - up to 4 mm^2/AWG 11)
Optional fixed cable (PG): ....
.... H07-RN-F, 2 x 2.5 mm^2 (AWG 13), 5.5 m (18 ft)
Pin assignment .... NL4 M: 1+/1-
.... Fixed cable (PG): Brown: (+) / Blue: (-)
Weight .... 33 kg (75 lb)

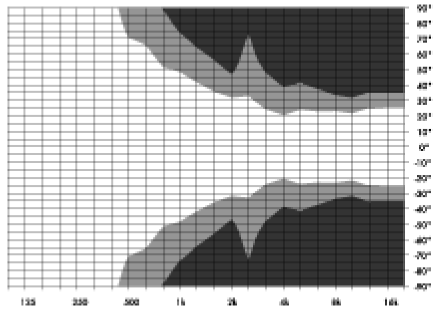


Isobar diagram horizontal

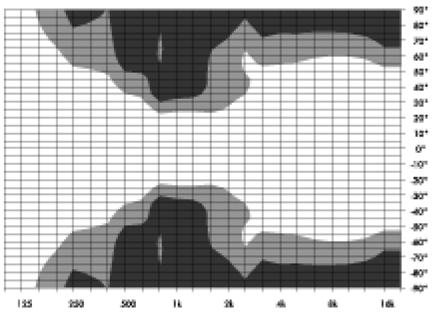


Vi7P

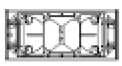
horizontal setup,
horn rotated



Isobar diagram vertical

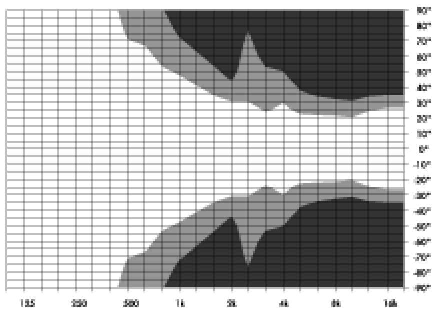


Isobar diagram horizontal



Vi10P

horizontal setup,
horn rotated



Isobar diagram vertical

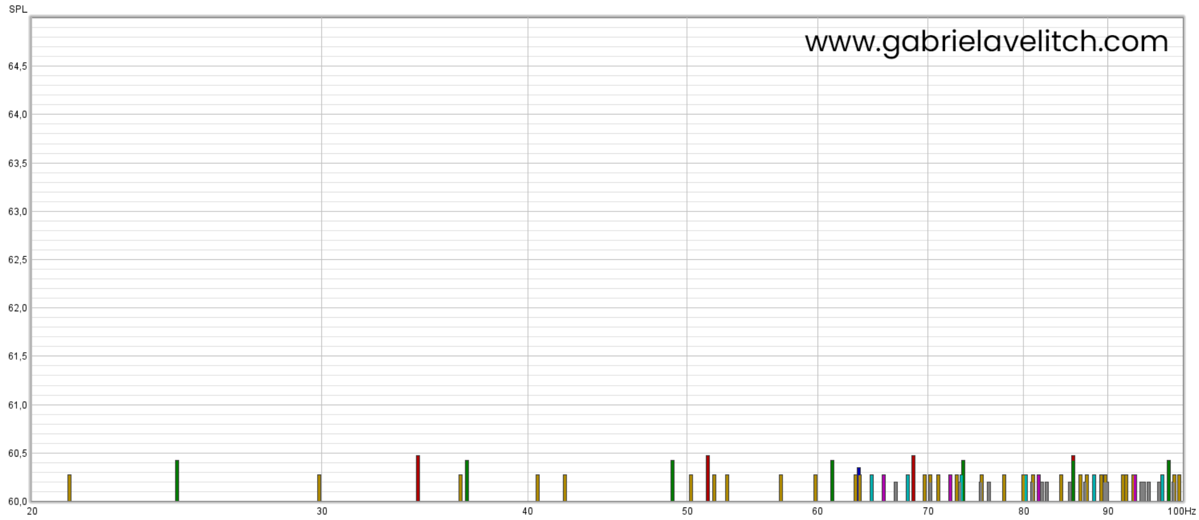
Bass Ratio List

Position 1: (621 + 689) / (768 + 895) = **0.788**
Position 2: (720 + 775) / (813 + 837) = **0.906**
Position 3: (1090 + 641) / (717 + 846) = **1.107**
Position 4: (693 + 769) / (691 + 880) = **0.931**
Position 5: (646 + 716) / (768 + 798) = **0.870**
Position 6: (841 + 589) / (748 + 844) = **0.898**
Position 7: (795 + 717) / (757 + 812) = **0.964**
Position 8: (770 + 740) / (650 + 869) = **0.994**
Position 9: (768 + 907) / (687 + 814) = **1.116**
Position 10: (679 + 753) / (724 + 784) = **0.950**
Position 11: (830 + 819) / (739 + 773) = **1.091**
Position 12: (838 + 668) / (961 + 798) = **0.856**
Position 13: (825 + 713) / (815 + 789) = **0.959**
Position 14: (865 + 796) / (798 + 889) = **0.985**
Position 15: (887 + 751) / (739 + 862) = **1.023**
Position 16: (895 + 749) / (818 + 781) = **1.028**
Position 17: (684 + 664) / (682 + 735) = **0.951**
Position 18: (735 + 698) / (719 + 822) = **0.930**
Position 19: (934 + 774) / (747 + 804) = **1.101**
Position 20: (889 + 664) / (783 + 859) = **0.946**
Position 21: (833 + 895) / (778 + 770) = **1.116**
Position 22: (885 + 654) / (703 + 820) = **1.011**
Position 23: (459 + 738) / (719 + 852) = **0.762**
Position 24: (570 + 911) / (737 + 807) = **0.959**
Position 25: (878 + 829) / (767 + 851) = **1.055**
Position 26: (977 + 836) / (704 + 861) = **1.158**
Position 27: (664 + 557) / (660 + 771) = **0.853**
Position 28: (675 + 803) / (798 + 768) = **0.944**
Position 29: (735 + 765) / (761 + 853) = **0.929**
Position 30: (756 + 524) / (824 + 712) = **0.833**

Brilliance List

Position 1: (768 + 895) / (818 + 786) = **1.037**
Position 2: (813 + 837) / (876 + 805) = **0.982**
Position 3: (717 + 846) / (873 + 765) = **0.954**
Position 4: (691 + 880) / (766 + 822) = **0.989**
Position 5: (768 + 798) / (811 + 796) = **0.974**
Position 6: (748 + 844) / (817 + 807) = **0.980**
Position 7: (757 + 812) / (806 + 791) = **0.982**
Position 8: (650 + 869) / (812 + 808) = **0.938**
Position 9: (687 + 814) / (818 + 795) = **0.931**
Position 10: (724 + 784) / (800 + 815) = **0.934**
Position 11: (739 + 773) / (798 + 785) = **0.955**
Position 12: (961 + 798) / (831 + 749) = **1.113**
Position 13: (815 + 789) / (809 + 792) = **1.002**
Position 14: (798 + 889) / (842 + 765) = **1.050**
Position 15: (739 + 862) / (799 + 778) = **1.015**
Position 16: (818 + 781) / (729 + 769) = **1.067**
Position 17: (682 + 735) / (743 + 791) = **0.924**
Position 18: (719 + 822) / (785 + 745) = **1.007**
Position 19: (747 + 804) / (809 + 807) = **0.960**
Position 20: (783 + 859) / (804 + 756) = **1.053**
Position 21: (778 + 770) / (790 + 807) = **0.969**
Position 22: (703 + 820) / (810 + 797) = **0.948**
Position 23: (719 + 852) / (767 + 840) = **0.978**
Position 24: (737 + 807) / (848 + 807) = **0.933**
Position 25: (767 + 851) / (838 + 777) = **1.002**
Position 26: (704 + 861) / (820 + 749) = **0.997**
Position 27: (660 + 771) / (799 + 775) = **0.921**
Position 28: (798 + 768) / (813 + 770) = **0.989**
Position 29: (761 + 853) / (828 + 849) = **0.962**
Position 30: (824 + 712) / (1020 + 846) = **0.823**

Modal Frequencies



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- Modellazione e Simulazione del Campo Acustico in Cavità a Geometria e Caratteristiche Acustiche Variabili, Tesi di Marco Giordano
- Acoustics for Engineers
- Principi Base di Acustica, capitolo 1 - Angelo Farina
- Transfer-Function Measurement with Sweeps - MULLER, MASSARANI
- CONSIDERING THE BASS RATIO IN ACOUSTICALLY OUTSTANDING CONCERT HALLS

SITOGRAPHY

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- REW - Room Acoustics Software
- AMROC - The Room Modes Calculator
- AMROC - Ray Tracing sketchpad
- Hyperphysics
- Acoustic Glossary
- Norma ISO 3382 Part 1
- AKUTEK.INFO (Concert Hall Acoustics)
- Acoustic Parameters in Concert Halls
- Room Acoustical Parameters: Can concert hall preference be predicted?
- Room Acoustic Calculator
- RT60 Calculator
- Sweet Home 3D - interior design application

www.gabrielavelitch.com