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ACOUSTIC ASSESSMENT REPORT - THE WESLEY MUSIC CENTRE MUSIC ROOM

Date: 19 February 2012
Location: Wesley Music Centre
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Introduction:

This report aims to assess in detail the acoustic qualities of the Music Room of the Wesley Music Centre, against a standard set of criteria applicable to concert spaces. The data collected is broadly compatible with the data set from a recent survey of Canberra's main acoustic music venues so a comparative study will be presented. As the Music Centre has variable acoustic elements, we will examine the effect of these and give advice on their application to different use situations.

Methodology:

We were given access to the Wesley Music Centre for several hours without audience. This allowed detailed acoustic testing and analysis using the respected EASERA software made by SDA/AFMG in Berlin. This uses accurate equipment to generate specially designed sounds into the space, which are then recorded and analysed. The EASERA software can extract musically relevant criteria from otherwise raw acoustic measurements and we have presented the results in a way that permits direct and meaningful comparison.

The room was tested in a dozen different setup configurations at between one and four microphone positions each and no-one in the room. From this large collection of data we have been able to deduce the effect of the various acoustic elements. The setup configurations start with the room in its fully "live" state. This is incrementally modified one step at a time, which reveals the relative effect of each physical variable when graphed in Appendix 4.

- * all louvres closed side *ie. the empty room in side orientation*
- * all louvres closed *ie. the empty room*
- * vertical louvres open *ie. relative effect of vertical panels*
- * all louvres open *ie. relative effect of horizontal panels*
- * all louvres open & back wall sliding panels revealed *ie relative effect of back panels*
- * all louvres open & back wall sliding panels revealed & stage curtain fully across *ie relative effect of front curtains*
- * all louvres open & back wall sliding panels revealed & stage curtain fully across & chairs in rows *ie relative effect of chairs*
- * all louvres open & back wall sliding panels revealed & chairs in rows *ie relative effect of front curtains with chairs*
- * horizontal louvres open & back wall sliding panels revealed & chairs in rows *ie relative effect of vertical panels with chairs*
- * horizontal louvres open & chairs in rows *ie relative effect of back panels with chairs*
- * all louvres closed & chairs in rows *ie relative effect of horizontal panels with chairs*
- * all louvres closed & chairs in rows & doors open *ie relative effect of doors open*

As well as the audience perceptions of these configurations we have evaluated the performers' impression of how the room supports their playing. The sound source was placed in a typical performer's position. This

was monitored by microphone arrays in three representative audience positions as depicted in Table 1. Position 1 was chosen to be an ideal recording location at near front centre, position 2 was midway back and quite left, position 3 was at the rear and right of centre. Most tests were done assuming the performer is on stage, but as an alternative we also tested in a basic way an orientation of the performer against a side wall.

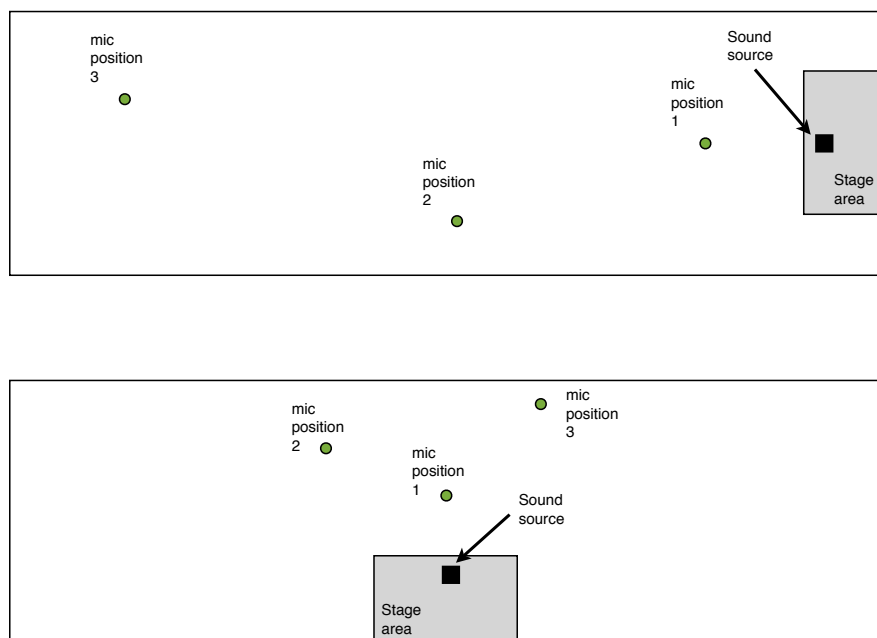


Table 1: testing layout

All data was tabulated in spreadsheets which then allowed us to generate two main sets of graphs in Appendix 4. The first set shows the effect of altering physical room variables on each of the acoustically relevant criteria, as perceived from a “good” audience position. As only one variable is incremented at a time, it is easy to use the graphs to deduce how the variables affect the sound at position 1. The second set uses a reduced number of setup configurations to show how the audience would perceive the space at the three different positions.

Results and discussion:

The Wesley Music Centre, as it is a purpose built performance space, has performed well in our evaluation of the acoustic tests. It is a predictable and good sounding venue, capable of delivering an excellent sound from the performer to an audience. As a recording venue it is equally good. The ability to adjust the acoustics using movable panels, chairs and a curtain is very useful though potentially confusing to the uninitiated.

To simplify an initial assessment we present a table of results with the venue in a fairly “live” configuration, that is with all panels closed and the stage curtain minimised. As most of the time we need to consider how an audience perceives the sound, we left the chairs in rows for this initial general assessment.

Please refer to Table 2. As well as the measured values we have colour coded the fields to interpret the absolute values with regard to accepted standards where they exist and by our judgement where not. Please refer to Appendix 1 for more information about the criteria used.

According to standard concert hall criteria the Wesley Music Centre performs very well in its usual configuration, that is with a performer on stage. The audience should hear a clear, accurately defined, well controlled and smooth sound at most places in the room and the performers should easily hear each other and the effect of the room on their playing. Speech should be easily intelligible throughout the space.

Category:	Results:	Descriptor: (App. 1)	Location:			
			source at end stage			
			mics at position 1	mics at position 2	mics at position 3	mics on stage
Overall Criteria:	RT30	(reverb time)	1.20s	1.22s	1.25s	
	Echogram (App. 2)	(Level of interfering echoes)				
	Frequency Response (App. 3)	(frequency smoothness)				
	Noise Level	(background noise)	50dBC	50dBC	50dBC	
Speech Criteria:	C50	(definition)	7.1dB	2.4dB	2.6dB	
	ALCons	(consonants intelligibility)	5.07%	8.14%	7.09%	
	STI	(syllable intelligibility)	0.65	0.56	0.58	
Music Criteria:	Bass Ratio	(bass fullness)	1.2	1.04	1.25	
	Centre Time 1kHz	(clarity)	65.28ms	100.55ms	88.11ms	
	C7	(directness)	4.4dB	-3.2dB	-5.3dB	
	C80	(temporal and register clarity)	8.7dB	4.2dB	4.5dB	
	Early IACC	(width)	0.75	0.25	0.25	
	Late IACC	(envelopment)	0.28	0.09	0.12	
	ST1	(performers hear each other)				-12.62dB
	ST2	(performers hear room)				-11.32dB
Interpretation Key: (Absolute Ratings)			not rated			
			very poor			
			problematic			
			indifferent			
			fine			
			excellent			

Table 2: Results according to concert hall criteria

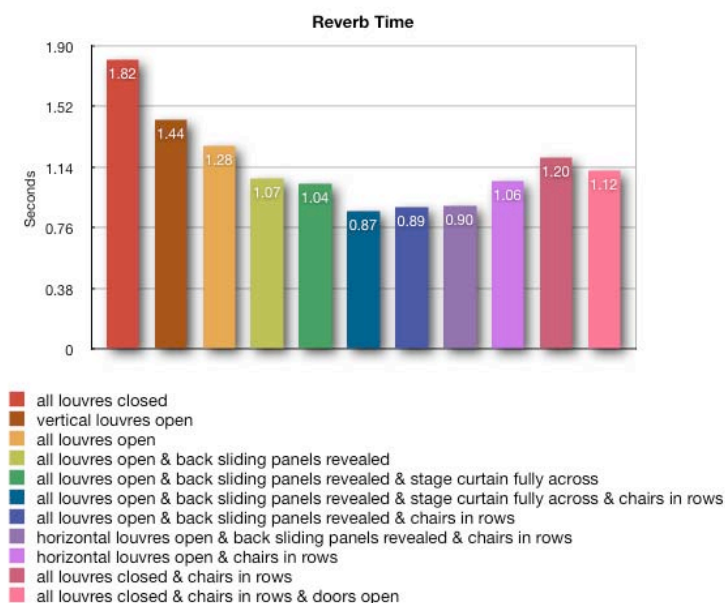


Table 3: Reverb times with various room configurations

The most commonly referred to acoustic parameter is reverb time. The overall measured value of 1.2 seconds with the room in its live concert configuration with chairs is comfortably within the 0.75 seconds to 1.5 seconds recommended for a room of volume 795 m³. For this room volume without chairs the maximum reverberation time of 1.82 seconds is outside the accepted range for concert halls. However this has little relevance since concerts would usually involve chairs and people.

Of interest is how the reverberation time changes according to the various materials and furnishings in the room. For a frequency independent set of results which can be interpreted easily please refer to the

reverberation time graph from Appendix 4, shown in Table 3 above. As expected the longest time is achieved with all panels and louvres at their most reflective settings, no chairs in the room and the stage curtains minimised. As more absorbent surfaces are added to the room, the reverberation time is lessened from the maximum value of 1.82 seconds to a minimum value of 0.87 seconds.

A related parameter is bass ratio. It varies considerably from 0.81 to 1.46 depending on the position of the louvres, whether there are chairs, etc. The ideal range for music is 1.0 to 1.3. With chairs in the room and all louvres open the bass ratio of 1.46 is too high, but if either the vertical or horizontal louvres are opened it falls back to the acceptable range. This is because the mid and high frequency absorption relative to the low frequency absorption (which is not controllable in the current room - see below) becomes appropriate.

For more detail on how the standard concert hall parameters are affected by the materials in the room and also how they vary at three notional audience member positions, please refer to Appendix 4. The greater the absorption by louvres, chairs and the sliding back panel, the less spaciousness is heard in the sound and more clarity and definition will result.

We briefly surveyed the alternative stage at side performance position. Its reverb time and bass ratio was comparable to the normal layout. With most tested criteria the side layout was comparable to or better than the standard layout. However it should be remembered that all testing was done with one sound source corresponding to a single performer. With multiple performers in the side layout, an audience member at extreme left or right seats may perceive an unusual or unintended balance. For the performer in terms of what they hear, the side layout was found to be not much different to the standard layout.

The echograms (Appendix 2) are smooth with all layouts and measurement positions, apart from the fully reflective room with chairs installed. Looking at the echograms, they all look different but what is important is that the decays are smooth and relatively linear. Any visible spikes in the decays represent echoes and in that case the small echoes do not seem very intrusive.

The frequency response curves (Appendix 3) are not particularly revealing, except for a rise in the low frequencies between 50Hz and 100Hz, variable corresponding to measurement position. This is highly likely to be a function of the room resonances described above.

One quite revealing result is how the reverberation time changes with frequency, as perceived at position 1, the ideal listener's seat. Each graph is shown in one third octave bands format to show the response of the room over the audible frequency range, in other words three frequency points per octave over a seven octave range. Looking at Table 4 below we can summarise that:

- * altering room surfaces has the most effect on frequencies between 300Hz and 6kHz
- * the frequencies above 3kHz are predictably more damped according to amount of absorbent surfaces
- * low frequencies below 1kHz are less predictably damped according to amount of absorbent surfaces
- * the onstage curtains have little effect on the listening experience for the audience
- * a reverb time hump in the 650-800Hz region is effectively controlled by adding chairs and opening louvres
- * opening the doors reduces low and low mid frequencies in the reverb
- * there are two humps in the low frequencies that merit more investigation at 160Hz and 250Hz.

Our explanation for the last finding is that room resonances are causing certain frequencies to be more emphasised and that the room surfaces, including the movable louvres, are not effectively controlling these low frequencies. The average room length is 16.82m and the average width is 8.32m which is very close to a two to one ratio. These dimensions would result in resonances corresponding to six times the width and twelve times the length at 245Hz, and a second hump at around 164Hz corresponding to four times the width and eight times the length. In theory one would also expect a resonance at 82Hz, but the graph doesn't show frequencies below 100Hz.

As well as the resonant reinforcement of frequencies corresponding to two, four and six times the room width we see dips in the reverberation times around 125Hz and 200Hz. This can be explained in terms of odd multiples of the room width being out of phase causing cancellations, in theory found at 124Hz and 207Hz.

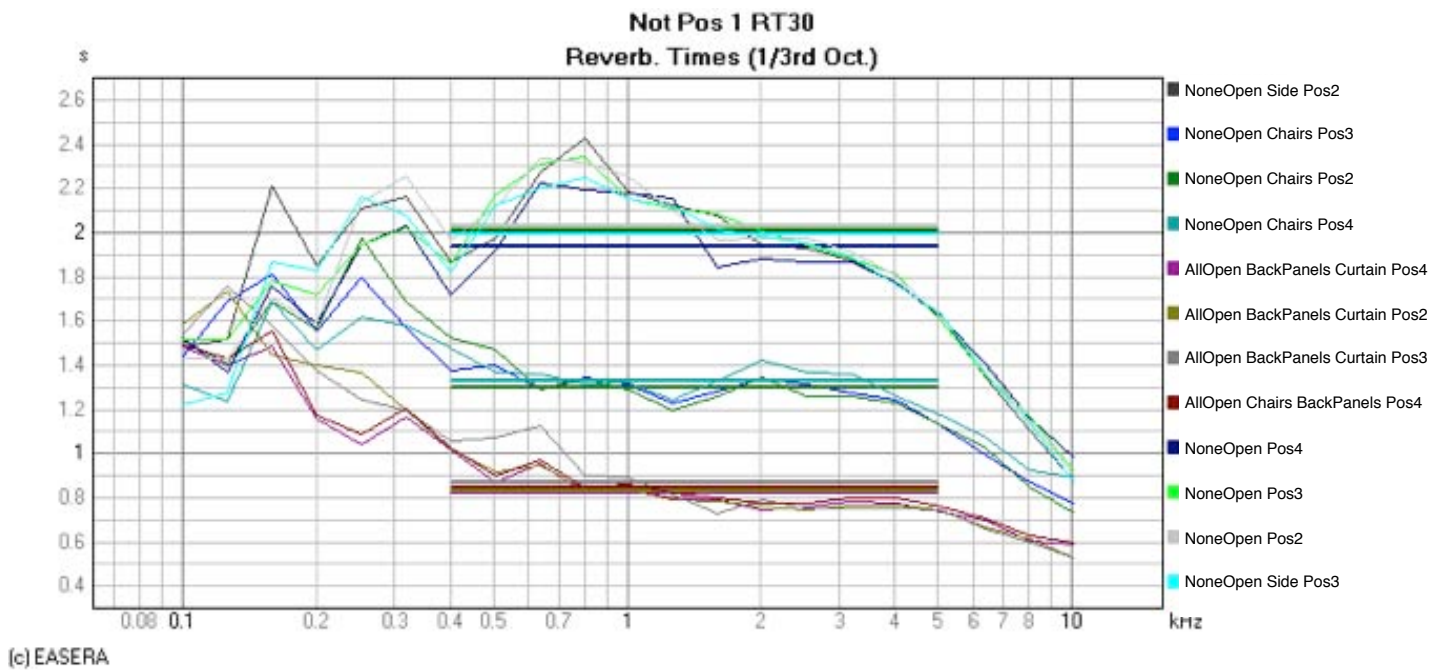


Table 4: Reverb times at different frequencies, position 1

For good measure we also plotted the reverb times for all non position 1 locations, (see Table 5) in case the central position was peculiar or non representative in some way. It can be seen that the reverb time humps at the lower frequencies remain and thus we can conclude that this effect is broadly position independent.

We believe that the low frequency reverb time and frequency response anomaly is caused by the room having close to a two to one ratio in length versus width and we have shown that the existing absorbent surfaces are not able to control this.

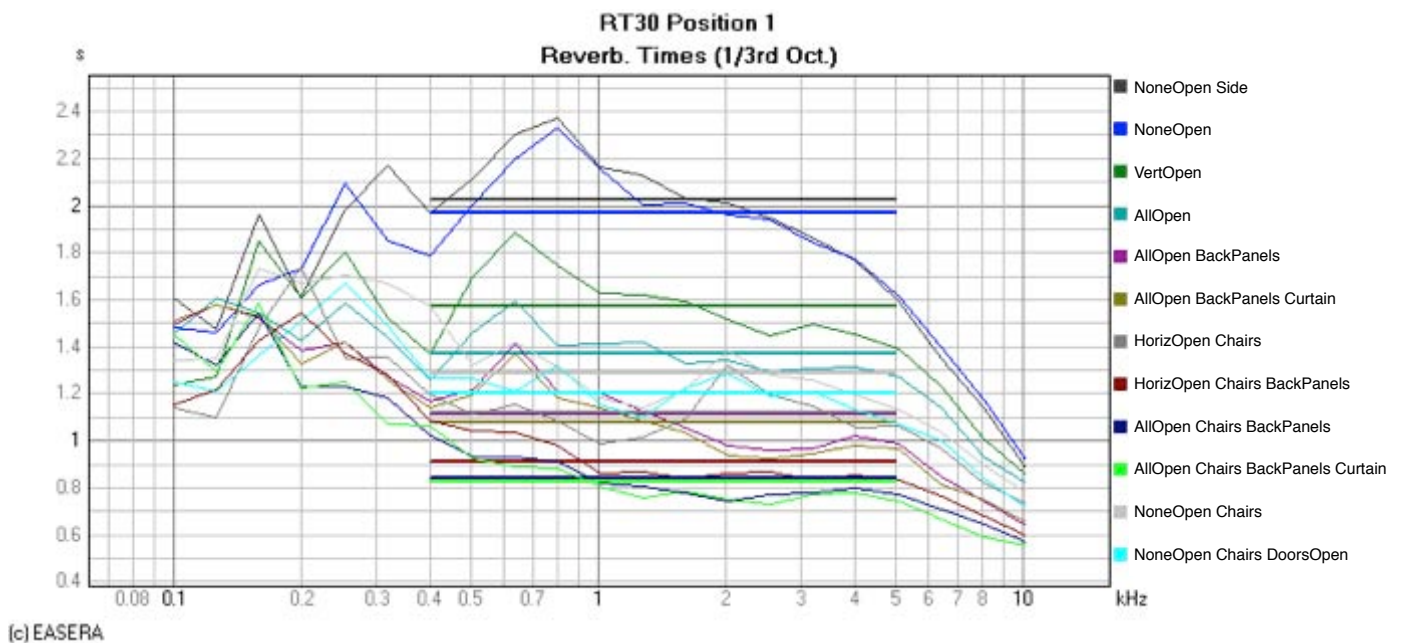


Table 5: Reverb times at different frequencies, not position 1

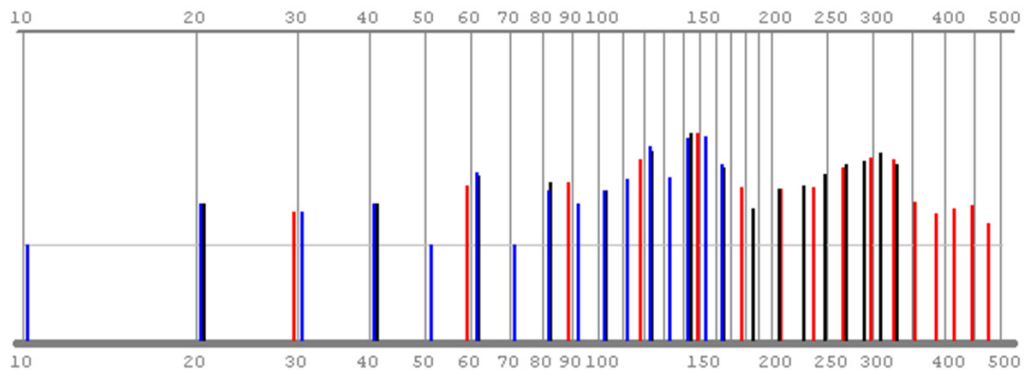


Table 6: Room modes

Another tool for understanding the effects of room dimensions is to do a room mode analysis. Ideally room modes are evenly distributed at the low frequencies and not bunched together. In Table 6 above we have shown the fifteen lowest modes relating to length (blue), width (black) and height (red). It is clear that due to the two to one ratio in length versus width the corresponding room modes coincide around 20Hz, 40Hz, 80Hz and so on.

This, as we have shown, generates resonances and cancellations in the low frequencies, which manifests as an uneven frequency response in the bottom end. As the room is “amplifying” some low frequencies and not others this also causes some low frequency reverb times to be longer. In effect some bass notes may be heard as being louder or lasting longer than others. It would be interesting to do some real world musical testing with instruments that produce tuned frequencies below 200Hz, like double bass and cello. Anything that has fundamentals at 80Hz, like electric bass or bodhran, could excite the resonances.

Given this low frequency finding, one has to ask how significant it is and how big an effect it has on what is otherwise an excellent acoustic space. We have to question how important this bass response finding is in the context of the actual musical programs presented in the Music Room. Most performances are classical music and there is rarely any significant low bass energy being generated in the first place. Anecdotal evidence and feedback from musicians (provided by the Centre) is overwhelmingly positive and with only one group commenting on low frequency response since the Centre opened.

If in the future this low frequency finding becomes an issue that needs to be addressed, then it has to be acknowledged that it is “built in” to the room. One solution is to alter the room dimensions, which is prohibitively expensive and unreasonable considering all the other positive aspects of the room acoustic. Any major changes to dimensions would not be preserving what is already excellent.

Another solution, which is not as complete as changing room dimensions but doesn’t risk altering or losing the current good acoustic is to treat the resonances with tuned absorption. By removing energy at the frequencies that relate to the width and length dimensions the low frequency response of the room can be evened out somewhat. This would also reduce the overall energy in the bottom end which would alter the bass response of the room - probably requiring the existing acoustic panels to be set to be more absorptive to get a equivalent bass ratio to the current situation. Tuned low frequency absorbers would have to be custom made and there is a lot of good mathematics behind the design of them. For implementation there would need to be some initial low frequency testing, a design process, then construction off site, followed by installation and fine tuning of them to get them to work optimally in the room.

If tuned absorbers are introduced, we view them as a fixture to address the fixed nature of the room dimensions, and not another variable acoustic treatment. In other words the room would still have a fixed low frequency response, but it would be more even than currently is the case.

Venue Details:				Overall Criteria:				Speech Criteria:		
Name	Seating Capacity	Floor space	Volume	RT ₂₀	Echo Rating	Frequency Response Rating	Noise Level	C ₅₀	ALcons	STI
				(reverb time)	(level of interfering echoes)	(frequency smoothness)	(background noise)	(definition)	(consonants intelligibility)	(Syllable intelligibility)
Albert Hall	480	656 m²	4917 m³	3.16s	2	3	53dBC	4.3dB	10.14%	0.52
position 2				3.37s	3	1		-1.8dB	18.55%	0.41
position 3				3.32s	3	3		-2dB	17.90%	0.42
FW stage end	400	498 m²	4052 m³	8.42s	7	6	53dBC	0.3dB	17.30%	0.42
position 2				8.59s	7	6		-3.4dB	26.33%	0.35
position 3				8.33s	8	9		-4.4dB	26.38%	0.34
FW stage side	400	498 m²	4052 m³	9.09s	6	1	53dBC	7.6dB	8.59%	0.55
position 2				10.83s	9	5		-5.2dB	30.32%	0.32
position 3				7.28s	9	6		-1.8dB	21.07%	0.39
Llewellyn Hall	1336	940 m²	14000 m³	1.8s	9	9	57dBC	10dB	4.75%	0.66
position 2				1.86s	8	2		1.6dB	11.20%	0.50
position 3				1.92s	4	7		3.0dB	8.18%	0.56
Sitsky Room	120	188 m²	1000 m³	1.43s	1	7	54dBC	3.9dB	6.66%	0.60
position 2				1.41s	1	4		1.9dB	7.88%	0.57
position 3				1.44s	1	5		2.5dB	7.08%	0.59
St Andrew's Church	600	550 m²	6090 m³	1.74s	8	2	56dBC	5.1dB	6.68%	0.60
position 2				1.73s	6	9		1.8dB	10.29%	0.52
position 3				1.67s	7	2		2.7dB	9.12%	0.54
St Christopher's Cathedral	700	655 m²	6320 m³	3.26s	4	4	59dBC	5.2dB	7.46%	0.58
position 2				3.31s	2	8		-1.9dB	19.00%	0.41
position 3				2.94s	2	4		-2.0dB	17.55%	0.42
Wesley Church	350	260 m²	2367 m³	1.77s	3	5	50dBC	4.2dB	7.12%	0.59
position 2				1.76s	4	3		1.4dB	10.99%	0.51
position 3				1.65s	6	1		1.6dB	8.99%	0.54
Wesley Music Centre	140	140 m²	795 m³	1.20s	5	8	50dBC	7.1dB	5.07%	0.65
position 2				1.22s	5	7		2.4dB	8.14%	0.56
position 3				1.25s	5	8		2.6dB	7.08%	0.58
Interpretation Key:	Size:			Time:	In General:			For Speech:		
	smallest	smallest	smallest	shortest	worst	worst	loudest	worst	worst	worst
	biggest	biggest	biggest	longest	best	best	quietest	best	clearest	clearest

Table 7: Comparative study results

Venue Details:		Music Criteria:						
Name	Bass Ratio	Centre Time 1kHz	C ₇	C ₈₀	Early IACC	Late IACC	ST1	ST2
	(bass fullness)	(Clarity)	(directness)	(temporal & register clarity)	(width)	(envelopment)	(performers hear each other)	(performers hear room)
Albert Hall	0.83	190.78ms	3.4dB	4.7dB	0.89	0.22	-18.05dB	-15dB
position 2	0.81	255.81ms	-5.2dB	-0.1dB	0.32	0.10		
position 3	0.81	265.92ms	-9.4dB	-0.2dB	0.25	0.09		
FW stage end	0.66	532.95ms	-0.8dB	1.3dB	0.78	0.25	-15dB	-12.4dB
position 2	0.71	656.79ms	-6.7dB	-2.6dB	0.38	0.10		
position 3	0.73	612.1ms	-11.3dB	-2.6dB	0.27	0.10		
FW stage side	0.69	367.55ms	5.7dB	7.9dB	0.93	0.19	-15dB	-11.35dB
position 2	0.77	672.45ms	-12dB	-3.4dB	0.32	0.08		
position 3	0.73	624.87ms	-4.7dB	-0.7dB	0.34	0.09		
Llewellyn Hall	1.27	69.08ms	9.2dB	10.6dB	0.90	0.38	-22.4dB	-19dB
position 2	1.22	112.47ms	-1.4dB	3.2dB	0.63	0.18		
position 3	1.12	73.14ms	-1.8dB	4.8dB	0.17	0.10		
Sitsky Room	0.75	105.93ms	0.1dB	5.3dB	0.47	0.16	NA	NA
position 2	0.90	112.79ms	-2.7dB	4.7dB	0.31	0.17		
position 3	0.79	88.99ms	-6.3dB	5.4dB	0.17	0.11		
St Andrew's Church	0.98	82.79ms	4dB	6.5dB	0.91	0.33	NA	NA
position 2	0.90	156.9ms	-1.3dB	4.7dB	0.38	0.15		
position 3	1.57	143.22ms	-5.1dB	4.6dB	0.35	0.13		
St Christopher's Cathedral	0.73	149.11ms	3.6dB	6.5dB	0.90	0.33	-14.85dB	-12.65dB
position 2	0.77	294.27ms	-5.2dB	-0.5dB	0.41	0.09		
position 3	0.69	287.21ms	-6.2dB	-0.4dB	0.33	0.16		
Wesley Church	0.76	101.45ms	2.5dB	6dB	0.86	0.29	NA	NA
position 2	0.74	166.12ms	-1.9dB	3dB	0.41	0.09		
position 3	0.75	139.61ms	-4dB	3.3dB	0.33	0.16		
Wesley Music Centre	1.20	55.28ms	4.4dB	7.1dB	0.75	0.28	-12.62dB	-11.32dB
position 2	1.04	100.55ms	-3.2dB	2.4dB	0.33	0.09		
position 3	1.25	88.11ms	-5.3dB	2.6dB	0.33	0.11		
Interpretation Key:	For Music:							
	worst	worst	worst	worst	worst	worst	worst	worst
	best	best	best	best	best	best	best	best

Comparative Study:

The Wesley Music Centre results were inserted into a table made recently comparing seven local acoustic music venues, utilising the same testing methodology.

Three venues ie. St Christopher's Cathedral, St Andrew's Church and Wesley Uniting Church have all been used for music performances for a long time. The latter has also had a successful history of acoustic improvements carried out in recent decades. All three are characterised by high ceilings and many hard surfaces making them very appropriate for choral music. The Albert Hall is a well known mid-large size space which has been recently refurbished with performance in mind. The Llewellyn Hall at the ANU School of Music is a versatile "flagship" venue with purpose built acoustics and a diverse range of performers appearing there, sometimes amplified and sometimes not. The Larry Sitsky Room at the ANU School of Music completed in 2011 is a recent addition to the music scene, aiming at delivering an excellent acoustic experience to a smaller audience. Although it can appear empty there is a lot of acoustic treatment on the walls and ceiling which controls reverberation and echoes. The Fitters' Workshop was evaluated as a raw untreated and unfurnished space in two orientations. It is a very reverberant room that is very sensitive to the addition of chairs and people, which then change its characteristics to something approaching a Gothic cathedral.

Please refer to Table 7 for the results, ranked by colour code. Darker shades are intended to convey a better result. Whereas Table 2 uses colour to signify absolute correlation to accepted standards, in Table 7 the colour shading represents relative ranking. The definitions in Appendix 1 were used to discriminate between and numerically quantify the rankings,

Comparing the Wesley Music Centre to the other venues is simple. It performs very well in the speech criteria offering similar definition and intelligibility to the School of Music venues and better than the churches, the best of which is St Andrew's.

In the music criteria it performs well too. Bass ratio at all three positions is excellent, meaning most audience members will hear a full bass sound that makes the music sound warmer due to low frequencies reverberating a little longer than other sounds. Centre time is fine for the non-ideal locations, but in the "best seat" it is a little low and outside the ideal range of 70-150ms, due to being a smaller venue. The perception of directness is good still and so is the temporal and register clarity. The width of the perceived sound image is excellent and the envelopment is a bit variable (though not at all problematic) depending on location, whereas some larger venues like the untreated Fitters' Workshop was more consistent with position. The performers' criteria were the best surveyed, meaning that musicians should hear each other very clearly as well as the assistance the room is giving their playing. This should assist them to achieve the best possible performances and it is interesting to note that Llewellyn Hall is very clearly inferior in this regard.

The weakest area for the Wesley Music Centre is frequency response. Low frequency peaks below 100Hz are most likely caused by the room related resonances discussed elsewhere. The echogram results are good, although there are smoother rooms in Canberra, they are mostly larger in size and the Wesley Music Centre performs well considering its dimensions.

Usage Recommendations:

As previously stated, the Wesley Music Centre offers a lot of flexibility with the acoustic surfaces and it is useful to know how to set it up to optimise its sound for a given style of event.

It is not usually advisable to give recommendations for any specific instrument, due to the many genres being played these days. Although many instruments have well known fundamental frequency ranges, they also produce many harmonics across a wide frequency range depending on playing style. A piano playing Arvo Part would need a different acoustic to a Mozart performance for instance. We believe it better to adjust acoustics based on knowledge about genre, tempo, number of performers and audience numbers.

From the testing, a key finding is that it is simple to adjust the mid and high frequency performance of the room, but there is much less control of low frequencies. Once we start going below 300Hz the acoustic treatments have little effect. This is not a problem in itself but merely a fact that needs to be acknowledged and factored in when setting up the room for a concert or recording. We accept that the low frequency response of the room is fixed and the rest is variable according to how the louvres and panels are set and the number of people in the room (which have a similar absorption profile to the treatment in the room). When the room is fully live the bass ratio is too low and when the room is fully dead the bass ratio is too high. So to tune the room for a performance we need to take into account what the music requires in respect of reverb time, how big the audience is and then adjust the acoustic louvres and panels accordingly.

To achieve a good bass ratio, that is, a good balance of low frequencies to the rest, we need to have some idea of expected audience size. If the audience is large then more louvres can be closed to keep the reverb time up. conversely if the audience is small then louvres can be opened to keep the reverb time down.

So as a practical rule of thumb, it is not advised that all the louvres are opened (ie are fully absorbtive) if all the chairs are used, in anticipation of a full house. In that case the no more than half the louvres should be open. Conversely if an event is expected to have low attendance then the room may need “deadening” by opening some or all the louvres so that the reverb time is not excessive and bass ratio is good.

Another rule of thumb is that for slow music a longer reverb time could be desirable, translating to most louvres closed and room surfaces being reflective. Much medieval music is slow and not very complex, so would benefit from longer reverb time. Correspondingly fast music would suffer from too much long reverberation and opening some of the louvres, plus revealing the back panel could be helpful.

For instance a single performer on guitar, playing to a large and therefore absorbtive audience, would be aided by the reverb gained by closing most or all louvres. At the other extreme a chamber music ensemble playing faster music to a small audience might need a more defined, clear sound less clouded by reverb, so closing most louvres and revealing the rear absorbing panels would help.

Loud, bright instruments like saxophones, clarinets and brass may be aggravating in a small yet very reverberant acoustic, so calming down the mid and high frequency reverb in the room may be helpful. This would again mean opening some louvres and revealing the sliding back panels.

The stage curtain has been found to have minimal effect on what the audience perceives. However they could help slightly reduce sound levels and mid to high frequency reverberation for the performers, if there are loud or bright instruments on stage. But mostly the curtains are best not used if performers need to hear each other clearly.

Instruments producing significant low frequency energy (like timpani, cello, double bass) may excite the room resonances. It is recommended that such instruments not be placed close to walls or in corners. We have found that opening the doors reduces low frequency reverb times and this may also be useful in a recording situation.

If a more intimate performance is wanted, there is no need for a stage, there are not many performers and a less than full capacity audience expected then the side orientation could be worth trying. The room could be kept more “live” by keeping louvres closed and not putting out all the chairs.

Conclusion:

The Wesley Music Centre is a fine and versatile room, adaptable for many occasions by its variable acoustics design. As seen in the comparative study it holds its own among Canberra’s best acoustic music venues. Having surveyed its performance in detail, we can report that there are no disruptive echoes, the reverberation is smooth and controllable in the mid and high frequencies and the clarity is very good. It is very immune to external noise meaning it is highly useful as a recording venue.

As with any hall, the low frequency performance is “locked in” by the chosen dimensions and in this case we have found that its length being very close to twice its width may be giving rise to some low frequency resonances potentially affecting the low register of some instruments. This could be worthy of further investigation. Specific low frequency absorption tuned to these frequencies would be advised if the Music Centre agrees there is an issue to be addressed. Any future modifications to the room should also address these observations.

We have made some usage recommendations for the variable acoustics, based on knowledge about genre, tempo, instrument playing style and audience expected.

Disclaimer:

This report is for the benefit and use of the client the Wesley Music Centre. The information and assumptions used in writing this report have been provided to us by the client and by direct measurements in the field. Although every care has been taken to ensure the accuracy of our findings and to provide a good appraisal of the acoustic spaces for the client, this report does not contain results or recommendations that can be implemented without further consultation.

KVDL Acoustic Consultants
Kimmo Vennonen
Duncan Lowe

Appendix 1: Descriptions of Criteria

RT₂₀ (reverb time) The reverberation time RT is the time taken by a stopped sound to reduce to one millionth (or 60dB) of its initial volume. In our case to get the most reliable readings we chose the RT₂₀ method. According to ISO 3382 the sound pressure is measured as it drops from -5dB and -25dB and then this drop of 20dB is extrapolated to arrive at the figure of how long it would take to drop 60dB. Rooms with long reverberation times sound "lush" to the point of being "washy" if too long, whereas too short a time can make something sound "dry" or even "tunnely".

Echo Rating (level of interfering echoes) We examined an echogram from each position and venue and compared them to each other to rate them best to worst. The echogram is a graph of the volume of a stopped sound (typically an "impulse") versus time, allowing any echoes to be identified. A good echogram would look very smooth, ideally a straight line sloping downwards as the sound level decays. An average one would look like a saw blade, (ie many insignificant small echoes) and a bad one would have obvious large bumps representing audible echoes.

Frequency Response Rating (frequency smoothness) Ideally every room is a level playing field for sounds, that is, it doesn't favour one note or octave over another. However in practice this is never the case. Measured responses are graphed as volume versus frequency so a flat line response is the best. The measurements we took are affected by sound source placement, plus the response of the source and the microphone as well. All anybody can do is compare one graph to another, factor out the test related variations and look for relative flatness.

Noise Level (background noise) Every venue has some level of background noise, expressed in dB. Too much noise can impair recordings and spoil the performance for a live audience. We use the dBC weighted scale which is more effective at measuring the effect of low frequency rumbles caused by traffic and air conditioning.

C₅₀ (definition) This is a measure relevant to speech definition and is calculated from the log (or dB) ratio of sound energy arriving in the first 50ms versus all that follows. In other words a lot of late reverberation can mess up how we hear a stream of words. A value of -2dB is considered to be the minimum for good speech intelligibility.

ALCons (consonants intelligibility) The Articulation Loss of Consonants is an alternative measure to C₅₀ for the assessment of speech intelligibility. Ideally, less than 3% of consonants are lost and a good result is 3% to 8%. 8% to 11% is still good intelligibility, 11% to 20% loss is poor and more than 20% loss is accepted as worthless intelligibility.

STI (Syllable intelligibility) This is a well known measure of how speech is conveyed from a source to a listener, taking into account background noise as well as room effects. A poor result is less than 0.3, whereas a satisfactory result is 0.3 to 0.45. The index is good from 0.45 to 0.6, very good 0.6 to 0.75 and excellent above that.

Bass Ratio (bass fullness) For music it is often desirable for the room reverberation times of low frequencies to be longer than for mid frequencies whereas for speech the opposite is true. A preferred bass ratio for music according to Beranek is 1.0 to 1.3. Too small a bass ratio would make low notes below about 350 Hz feel less "full" in the room than the "live" sounding notes higher up. However a low bass ratio in a room would not necessarily spoil the experience hence we have rated this as indifferent in the case of the empty Fitters' Workshop.

Centre Time 1kHz (Clarity) This measure corresponds to the point in time when the sound energy received before then is equal to the energy received after then. A long centre time makes music sound more "spacious" and for concert halls a value of 70 to 150ms is considered best.

C₇ (directness) It can be useful to know the ratio of the sound level coming directly from a source, compared to all the reverberation and reflections afterwards. This is done by expressing in dB the value of sound energy received in the first 7ms divided by all the later energy. With the C₇ measure according to Ahnert it is

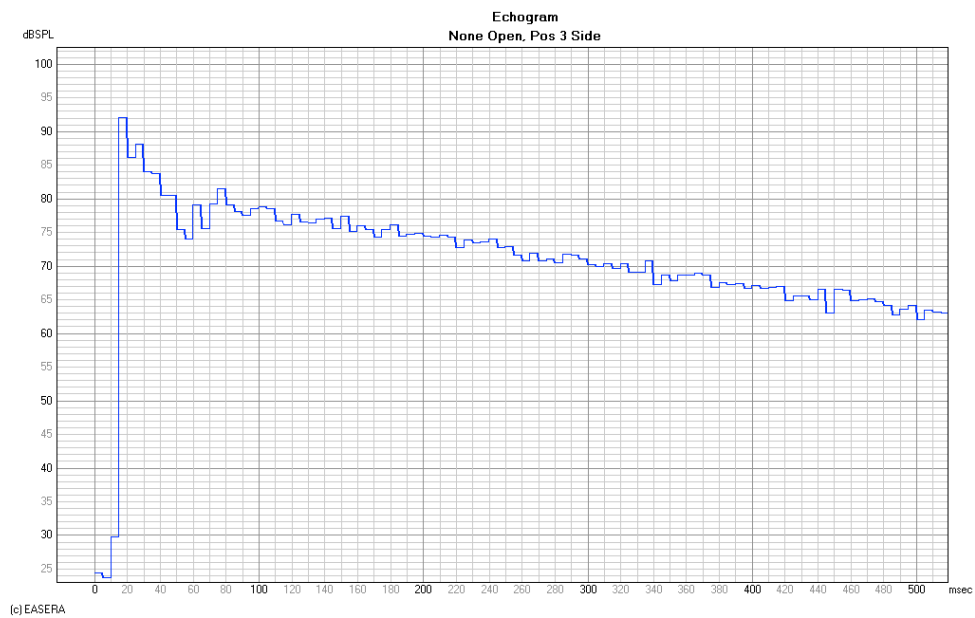
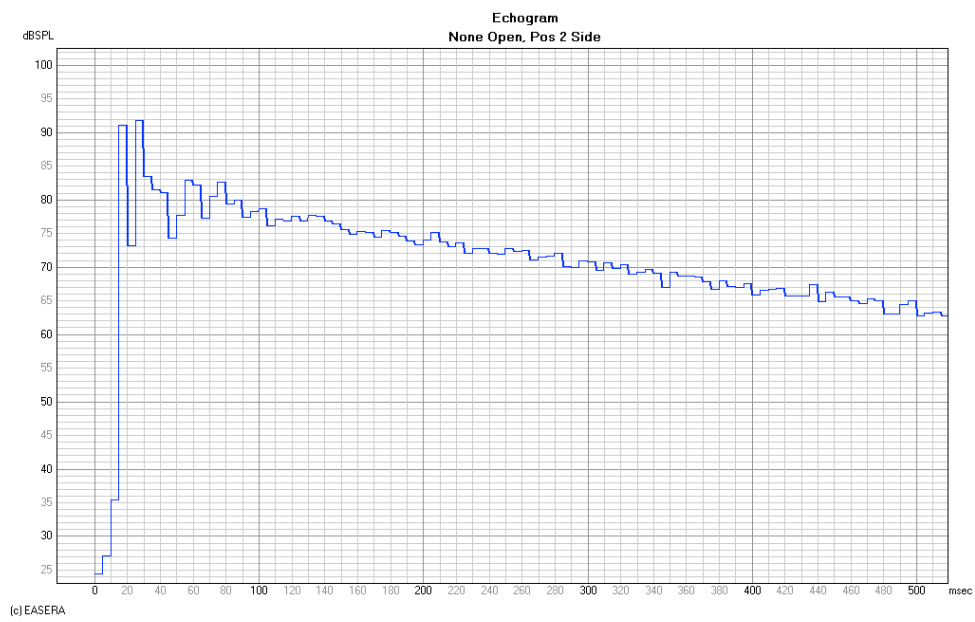
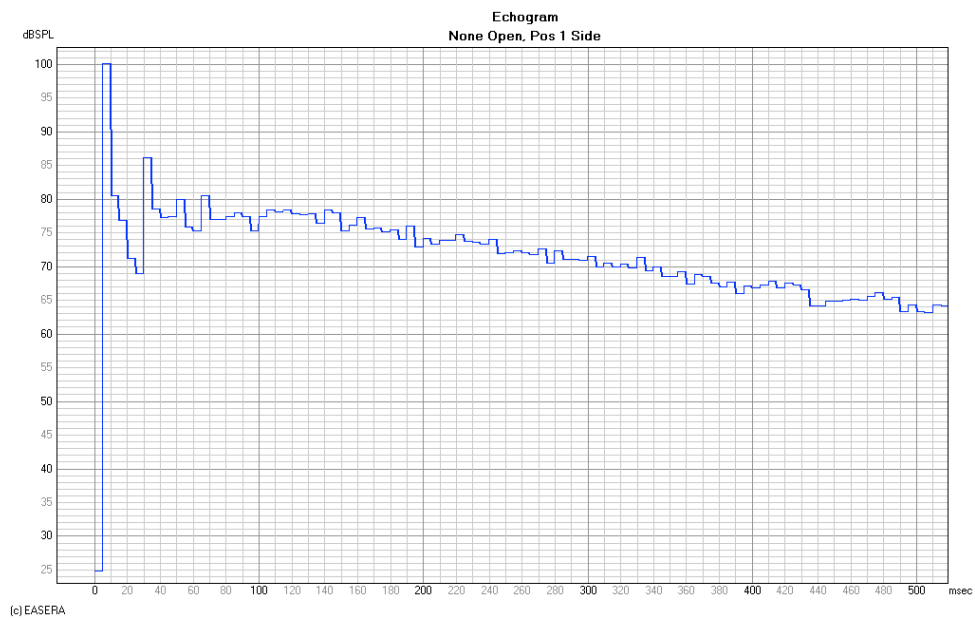
said that the direct sound level should not fall below a range of -10 to -15dB. It is to be expected that listeners further back from the sound source will hear less direct sound and more room reflections and reverberations.

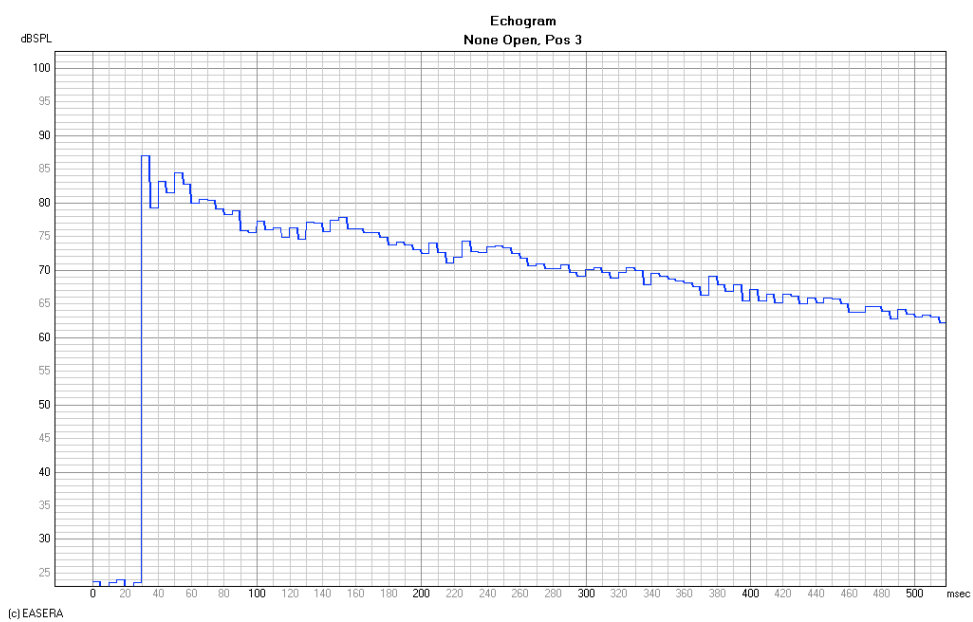
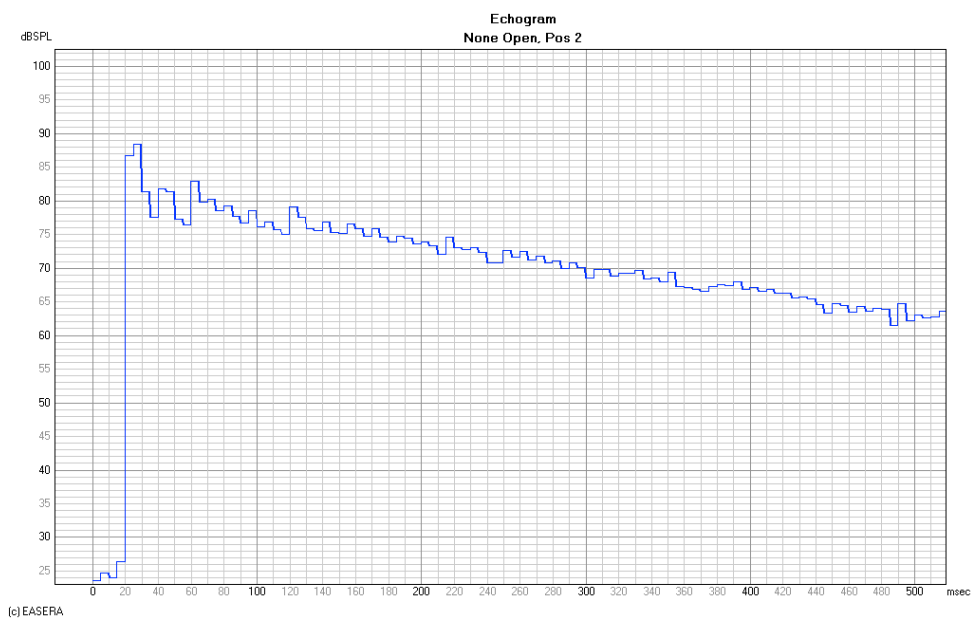
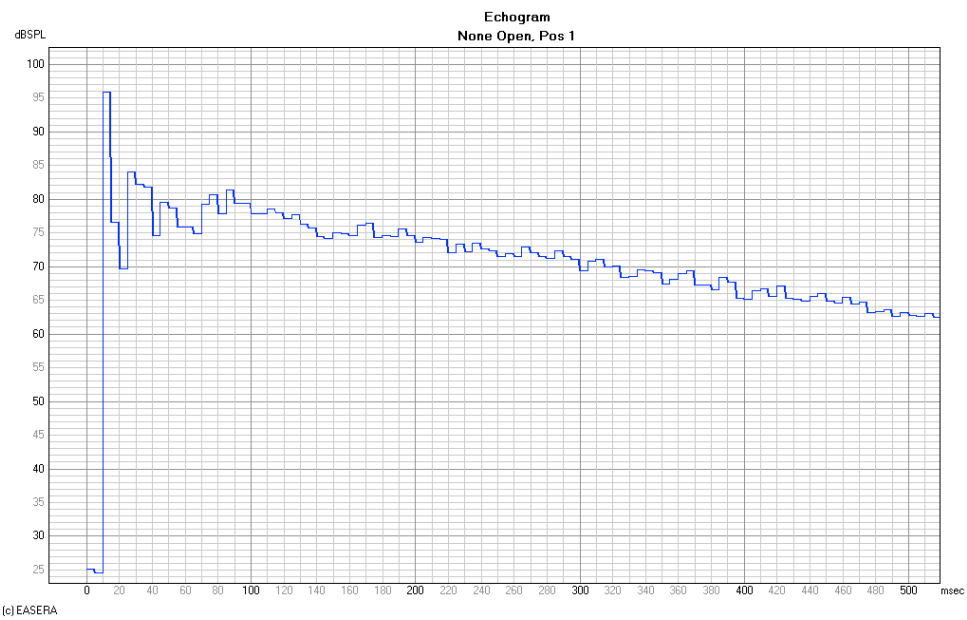
C₈₀ (temporal & register clarity) This is a useful measure of clarity for music especially when it has fast passages. It is calculated similarly for C₅₀ except that the relevant time is 80ms. According to Abdel Alim classical music like Mozart and Haydn requires a C₈₀ figure of more than -1.6dB, but Brahms and Wagner need greater than -4.6dB. A compromise figure for all classical music is said to be -3dB but for slow sacral music a C₈₀ of -5dB is acceptable.

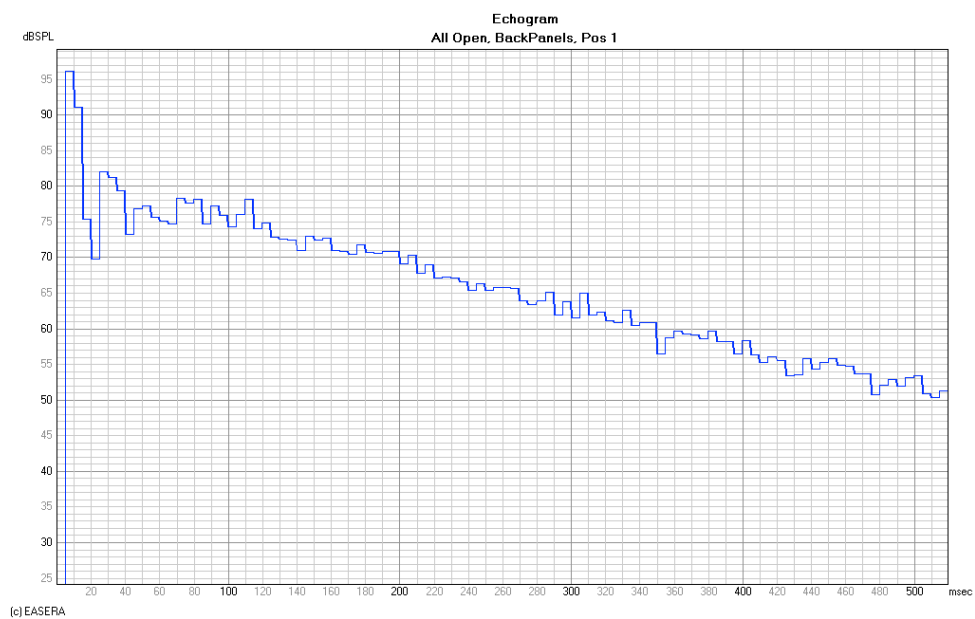
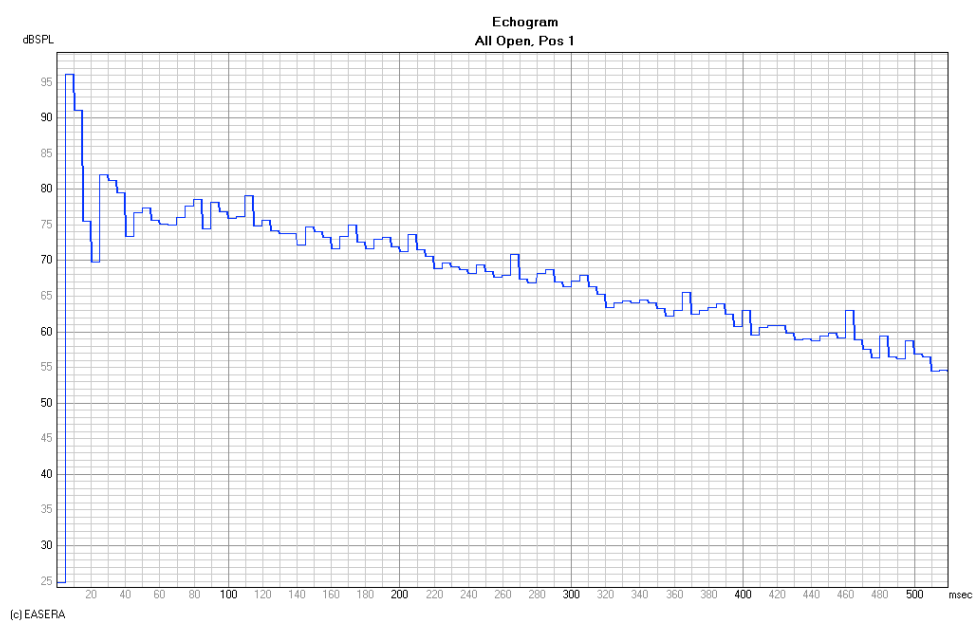
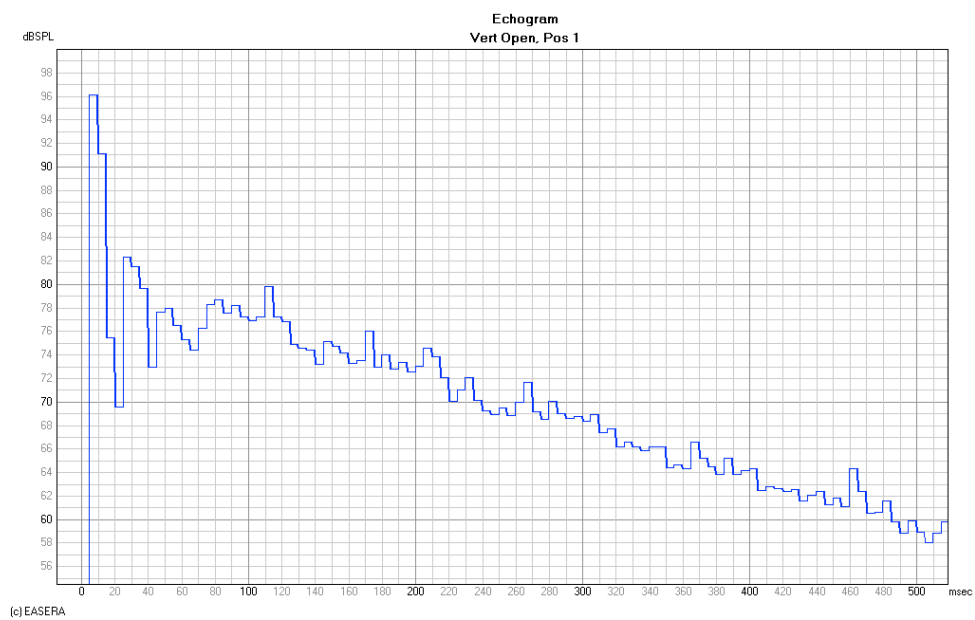
Early IACC (width) & **Late IACC** (envelopment) Interaural Cross Correlation according to ISO 3382 is a measure of the spatial aspects of music corresponding to perceptions of width (0 to 80ms) of the sound source and being enveloped (80 to 500ms). It is measured using binaural dummy head microphones and low correlation values are considered good. According to Beranek an excellent to superior concert hall has an early IACC of 0.28 to 0.38, good to excellent halls are 0.39 to 0.54 and fair to good halls are 0.55 to 0.59. In our measurements the close ones in position 1 could be disregarded for IACC purposes as there would be too much direct sound causing high correlation.

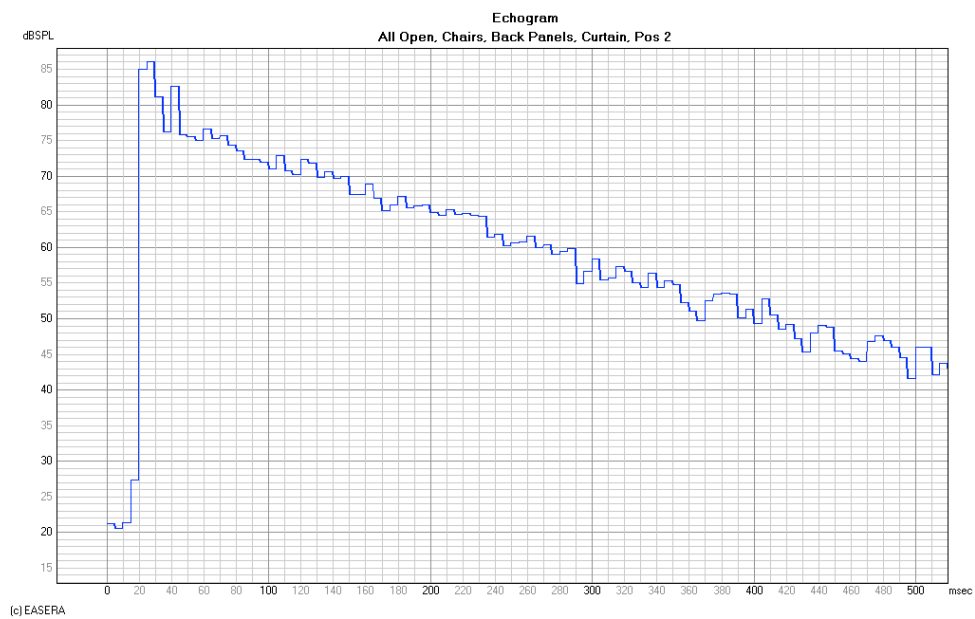
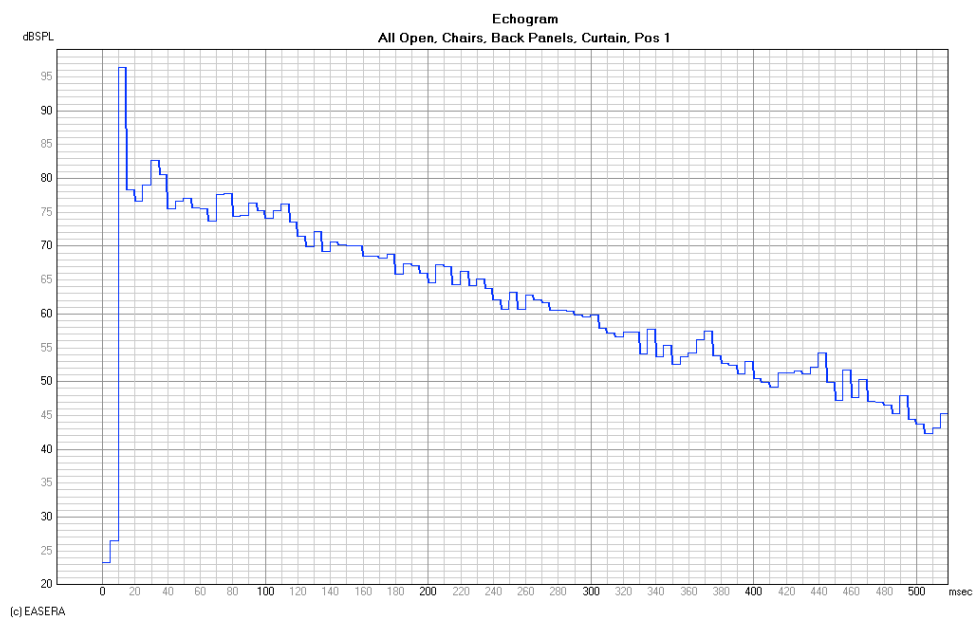
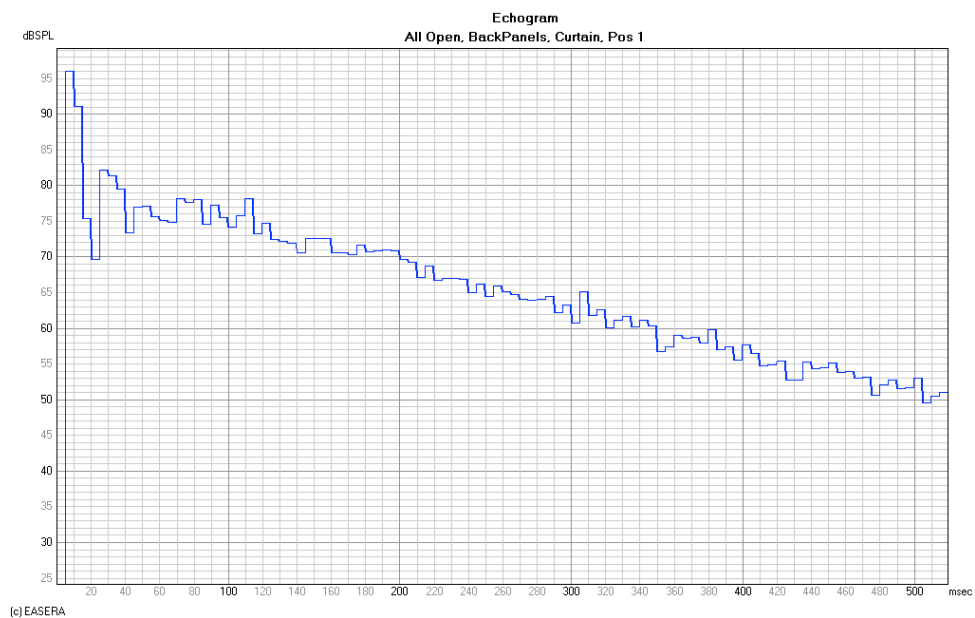
ST1 (performers hear each other) and **ST2** (performers hear room). These are both measures of room support for musicians and are measured on stage. Typical ST1 values for European concert halls are between -15dB and -12dB. ST1 is important as musicians need good acoustics on stage to hear each other clearly. There is no consensus on what the ideal ST2 value is, but lower means less sound coming back from the room to assist the performer to make creative judgements.

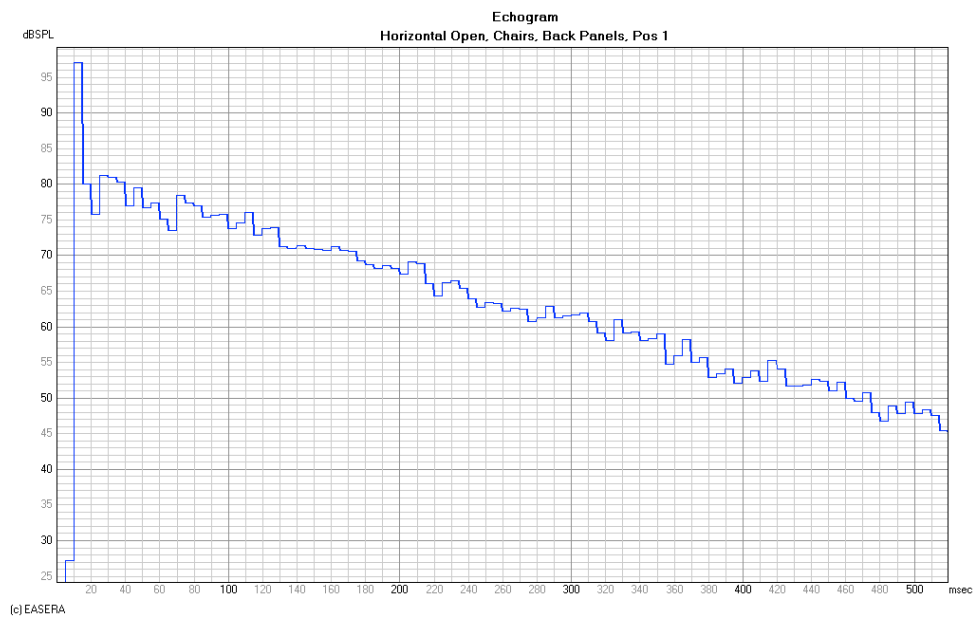
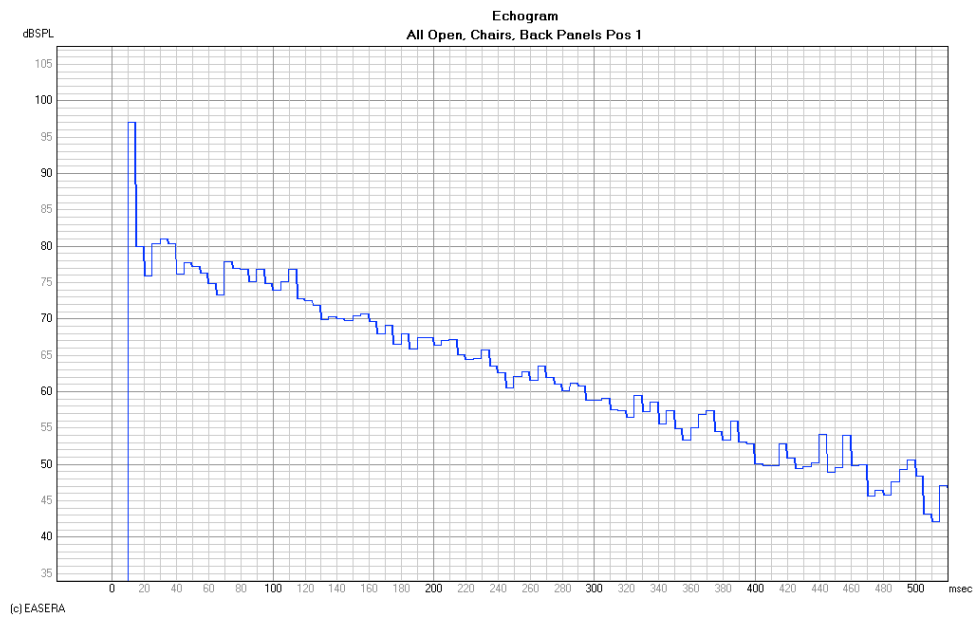
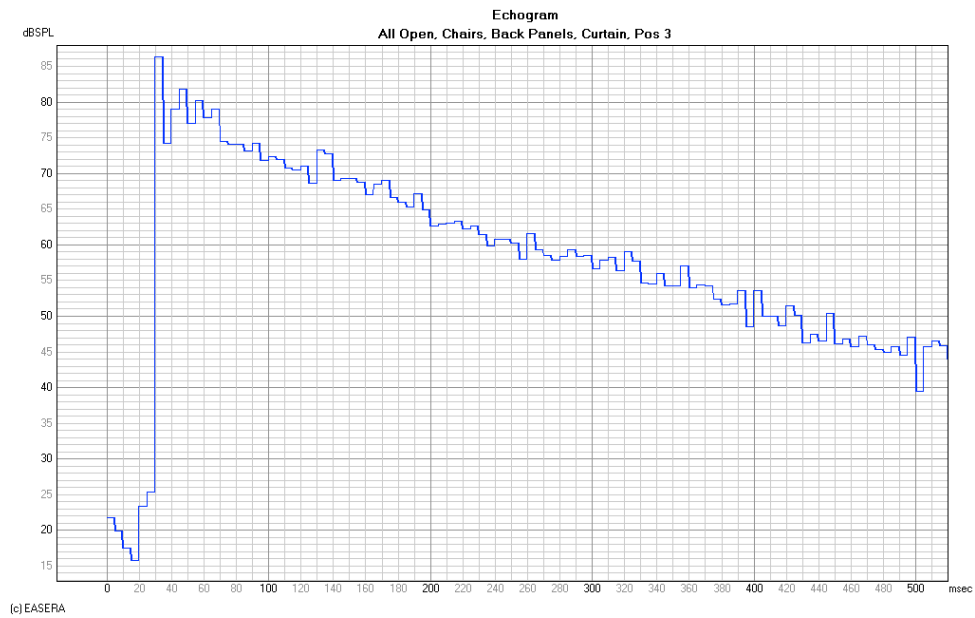
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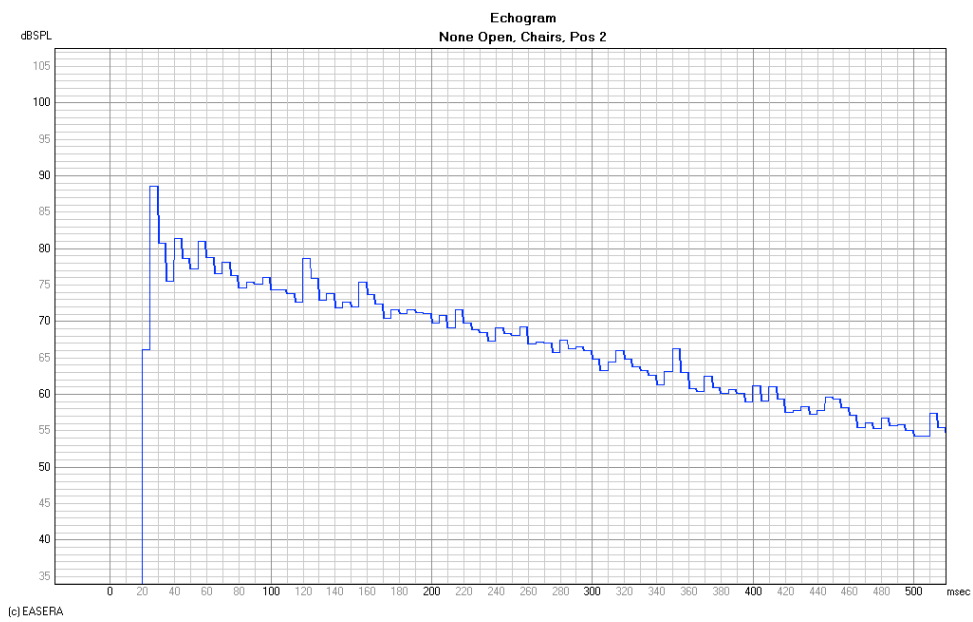
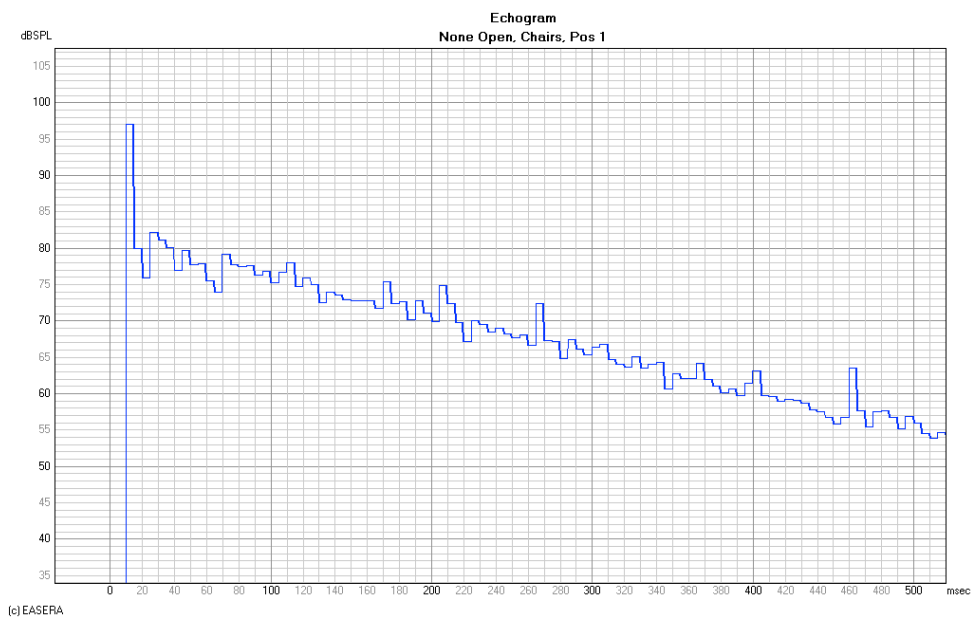
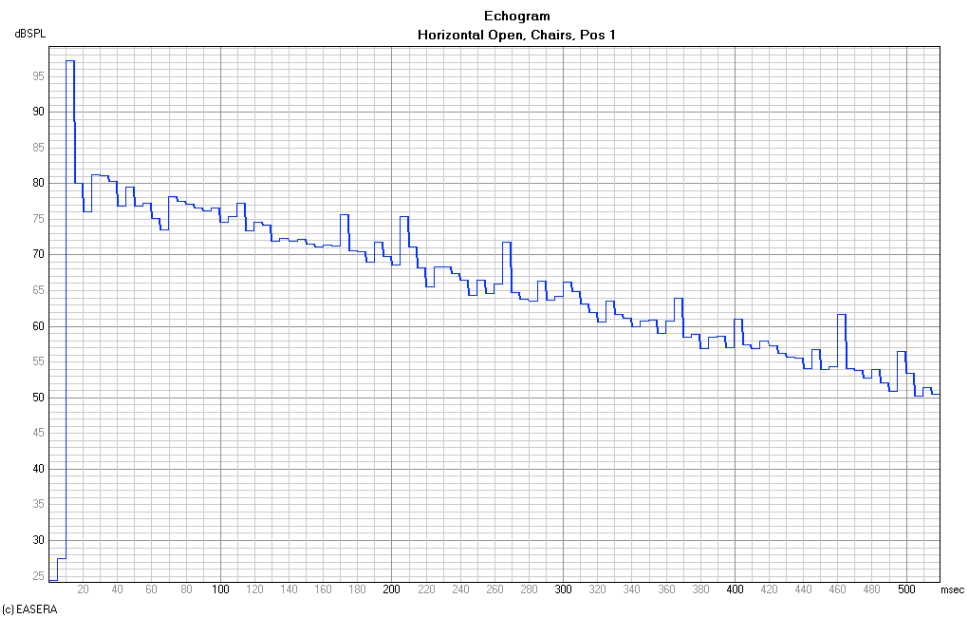


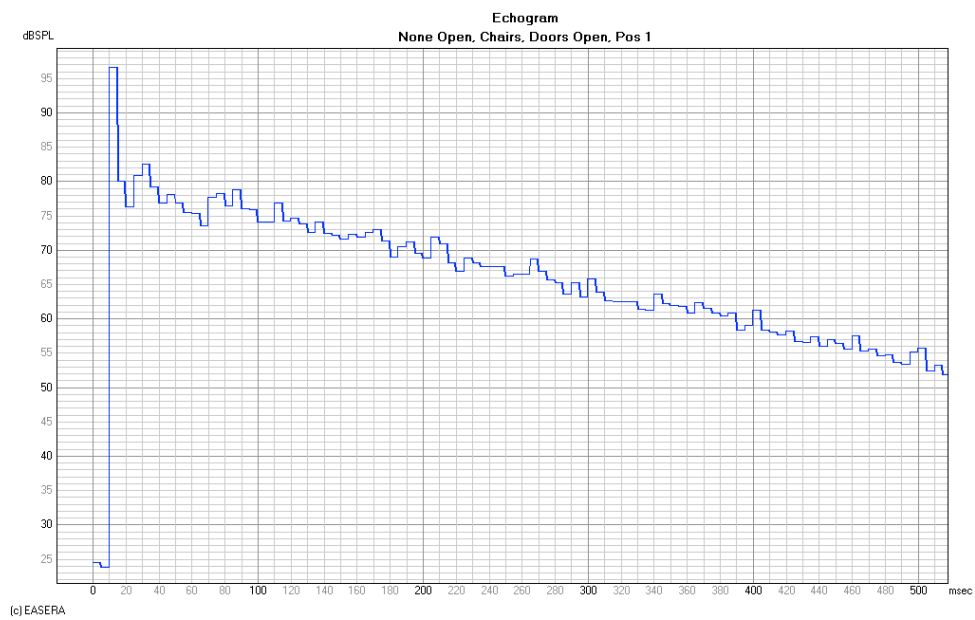
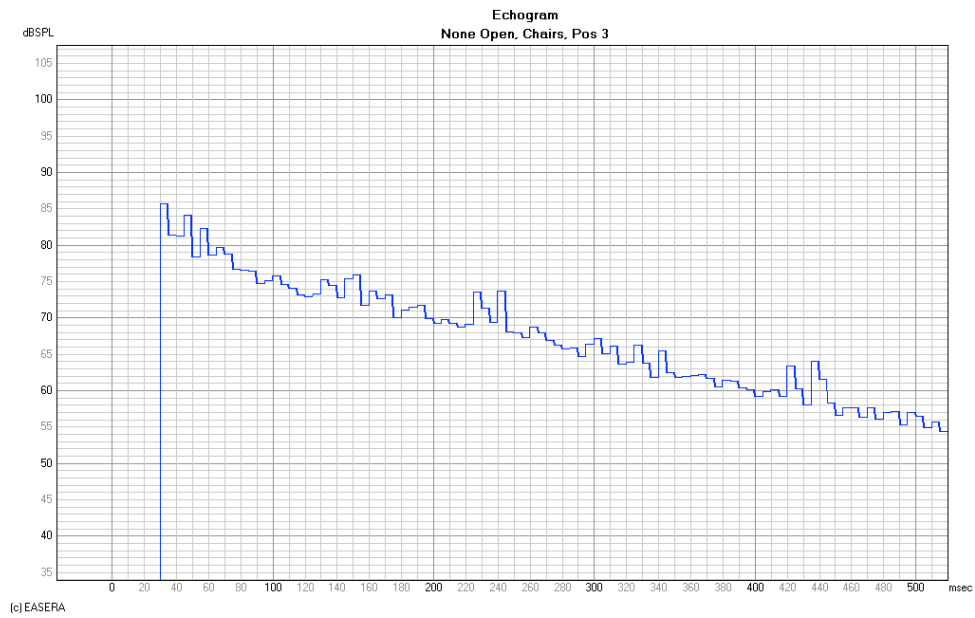




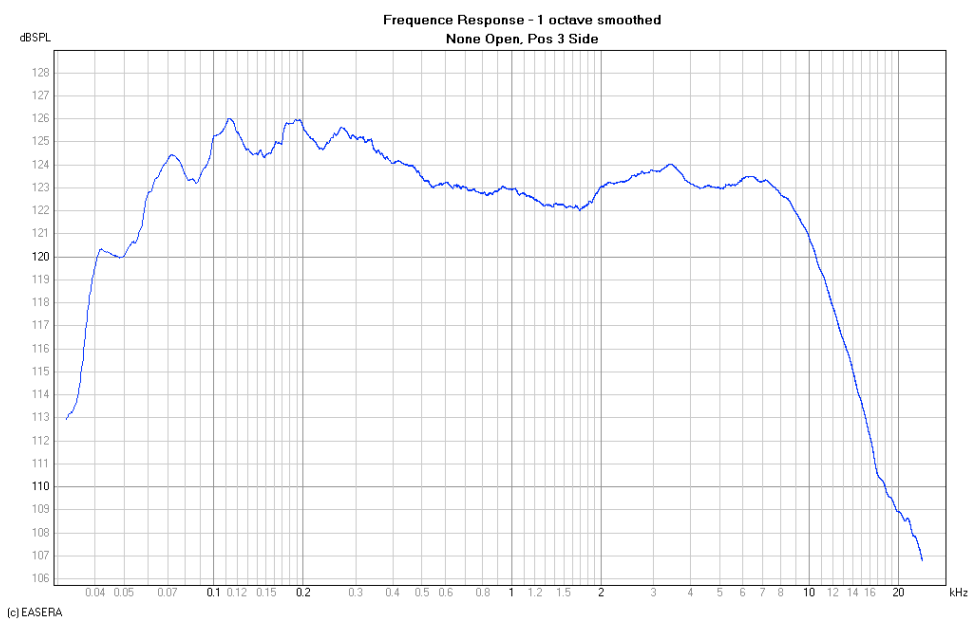
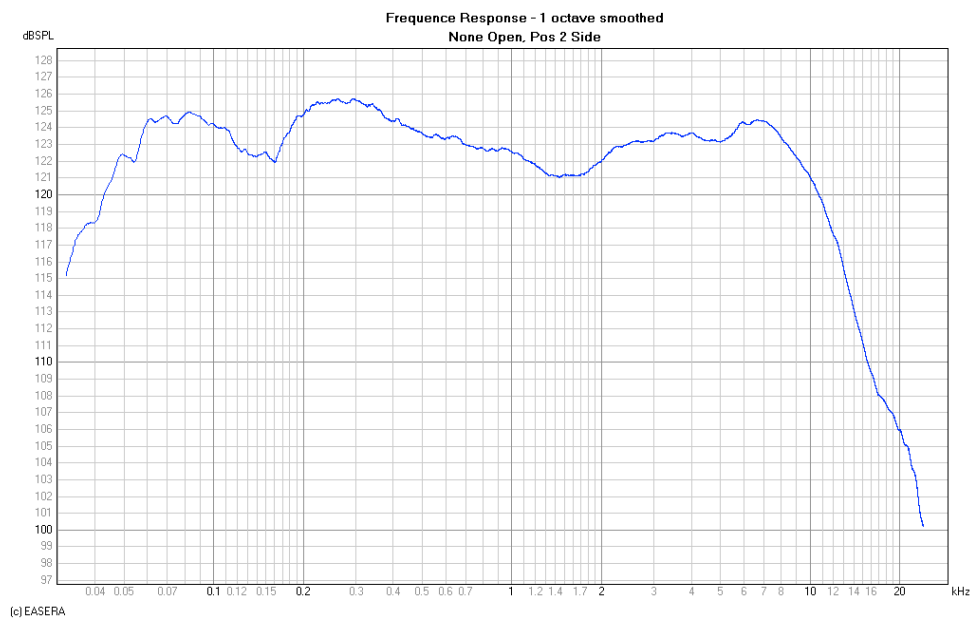
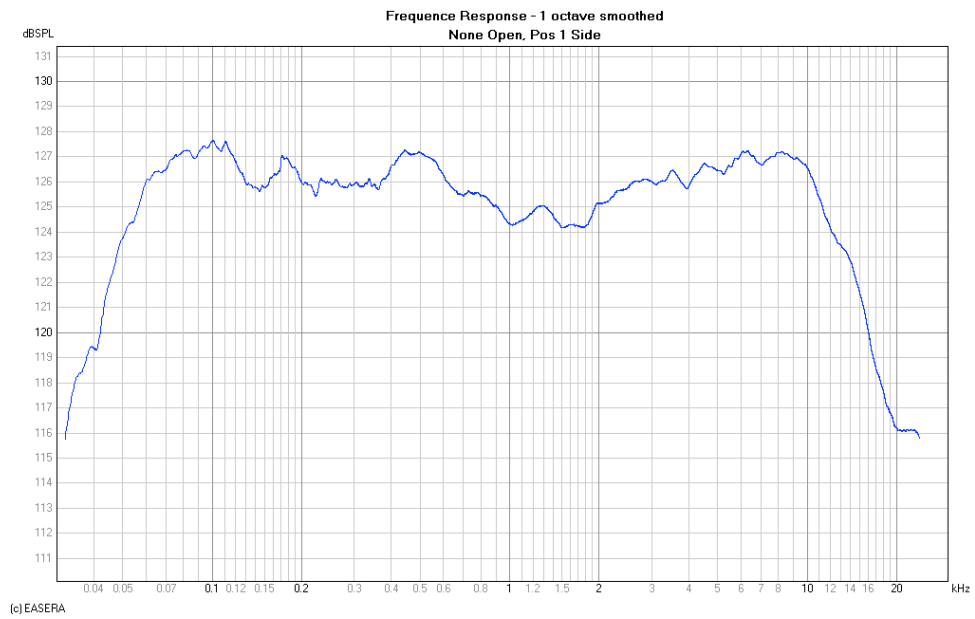


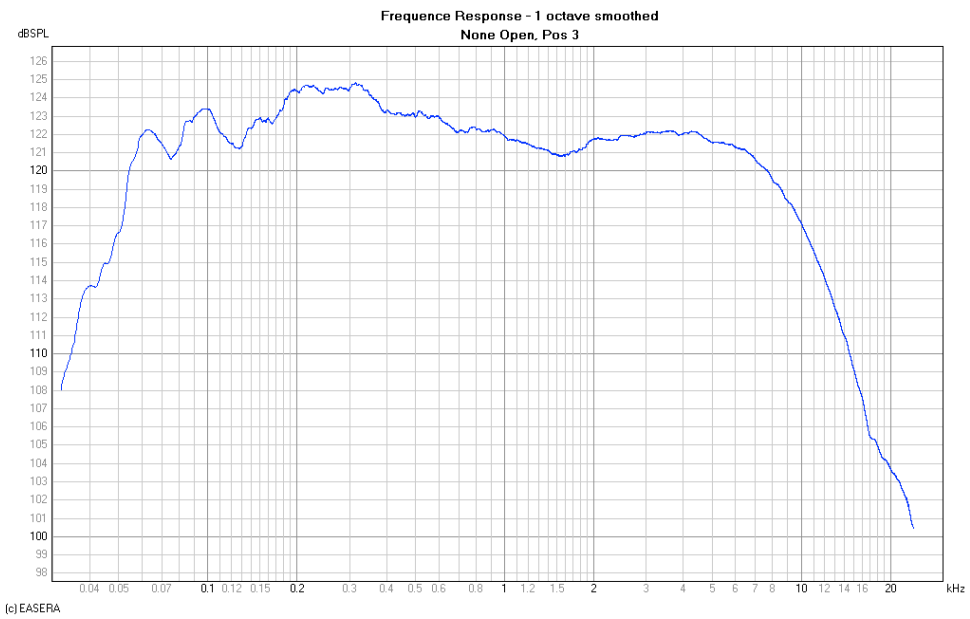
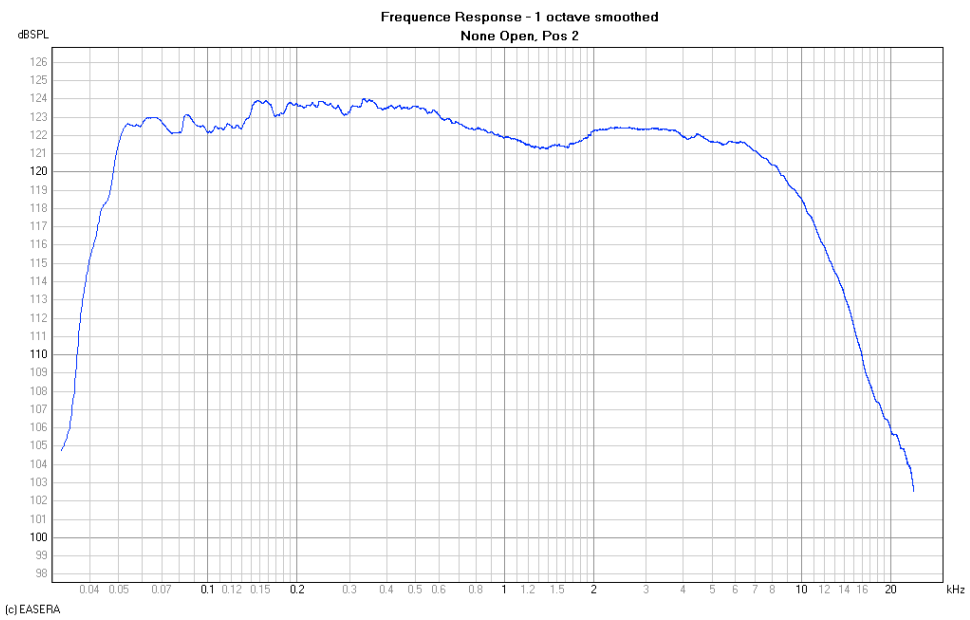
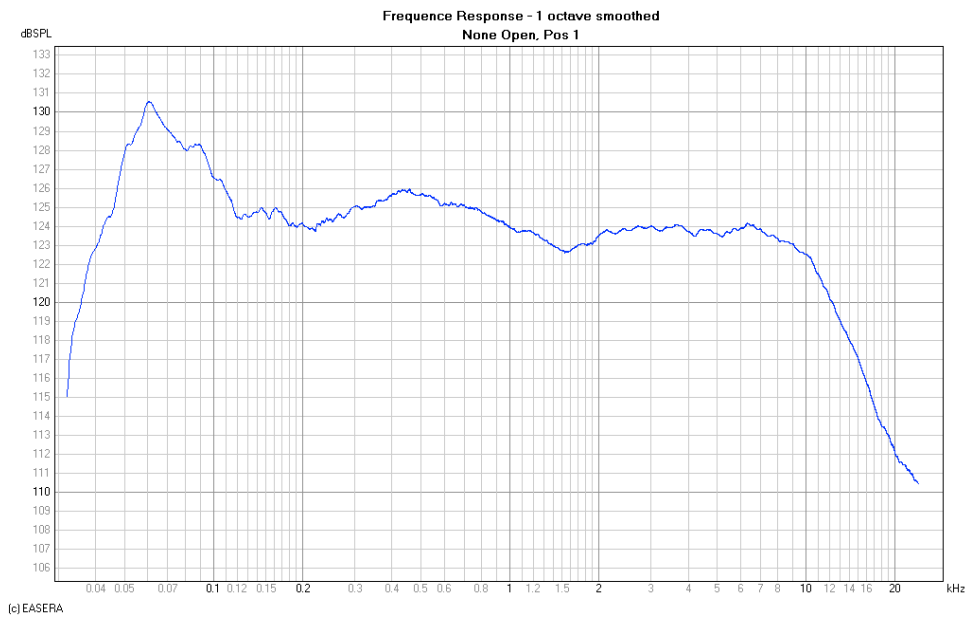


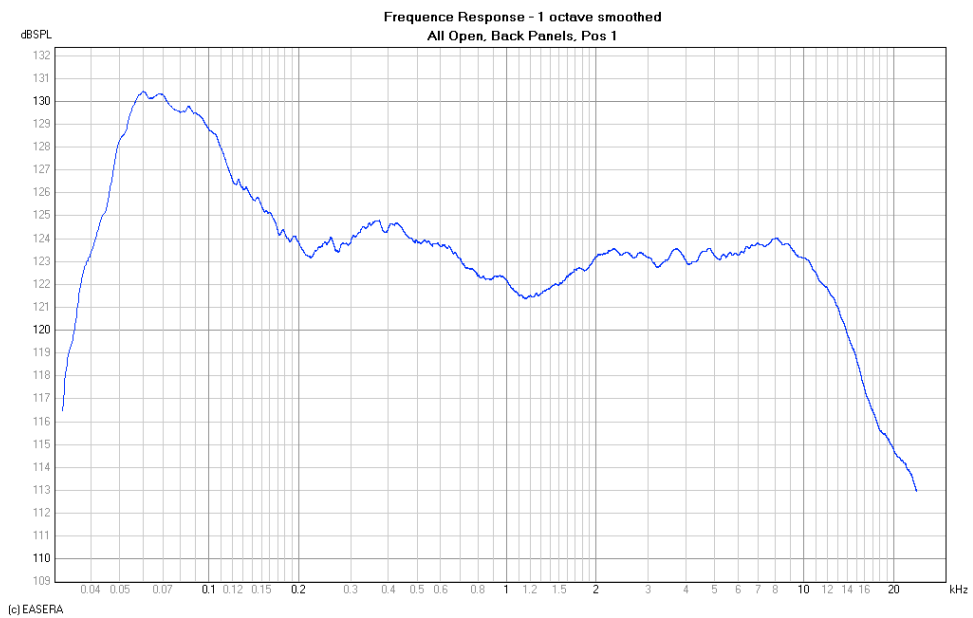
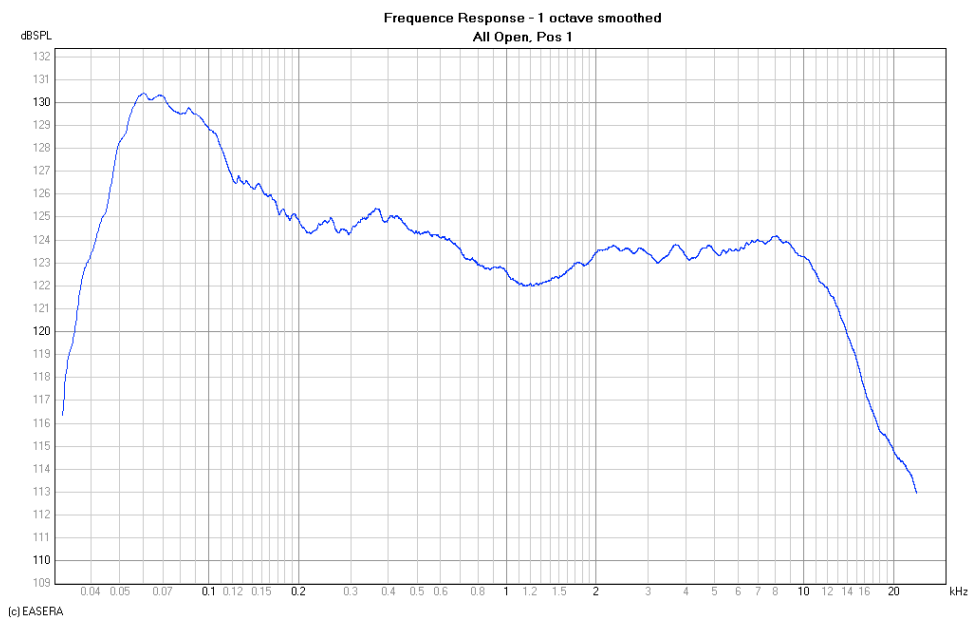
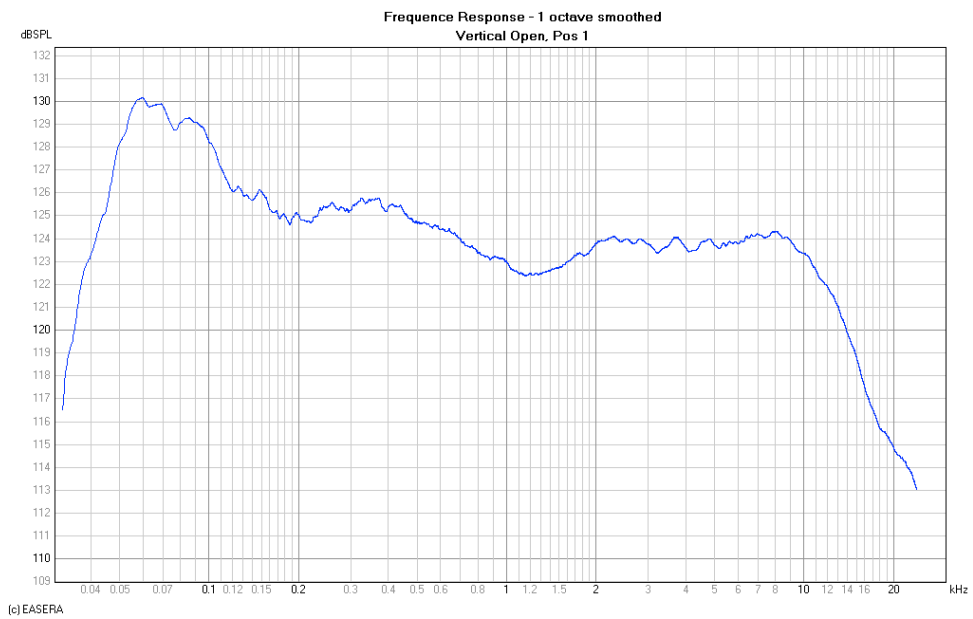


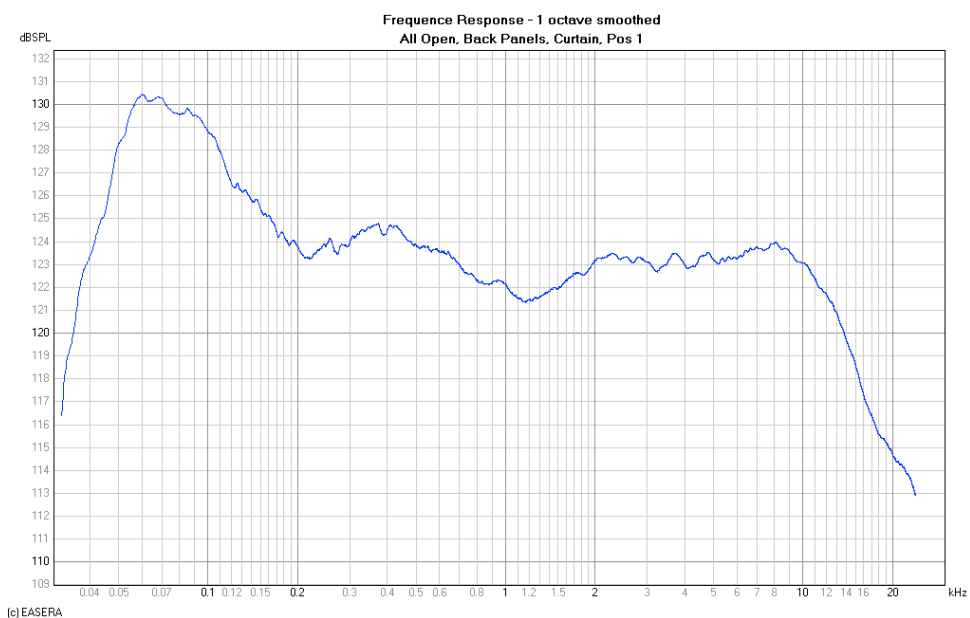


Appendix 3: Frequency Response

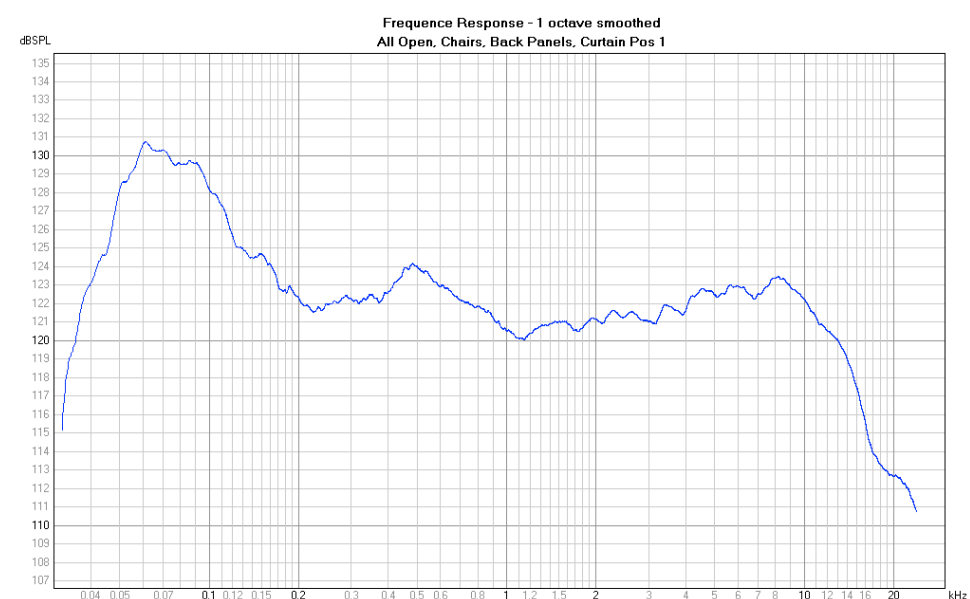




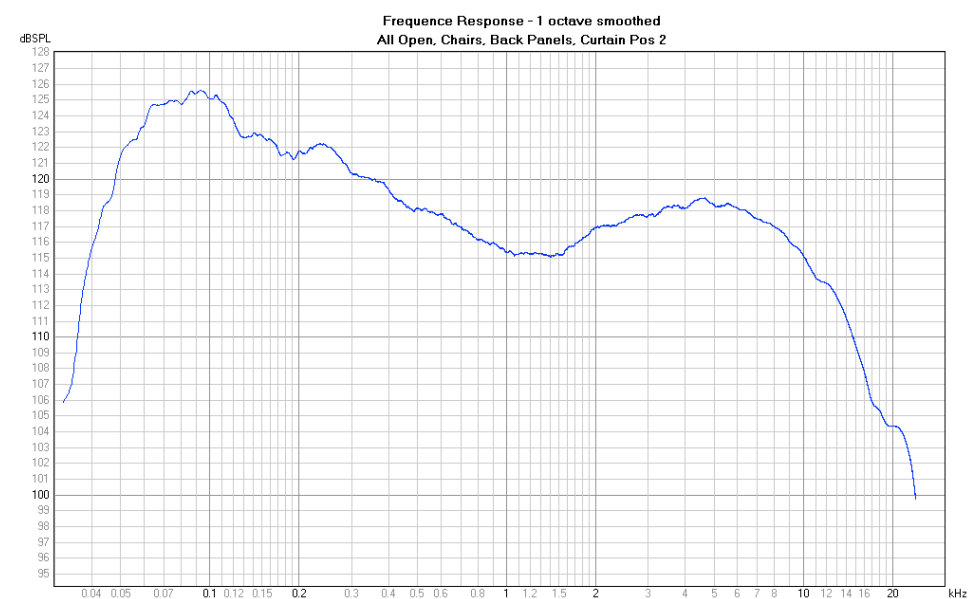




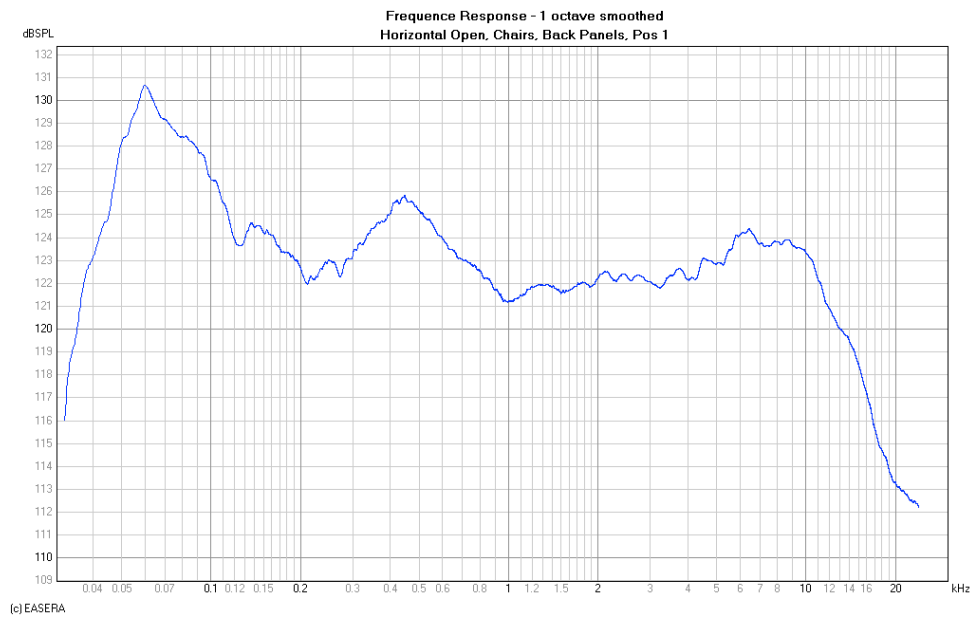
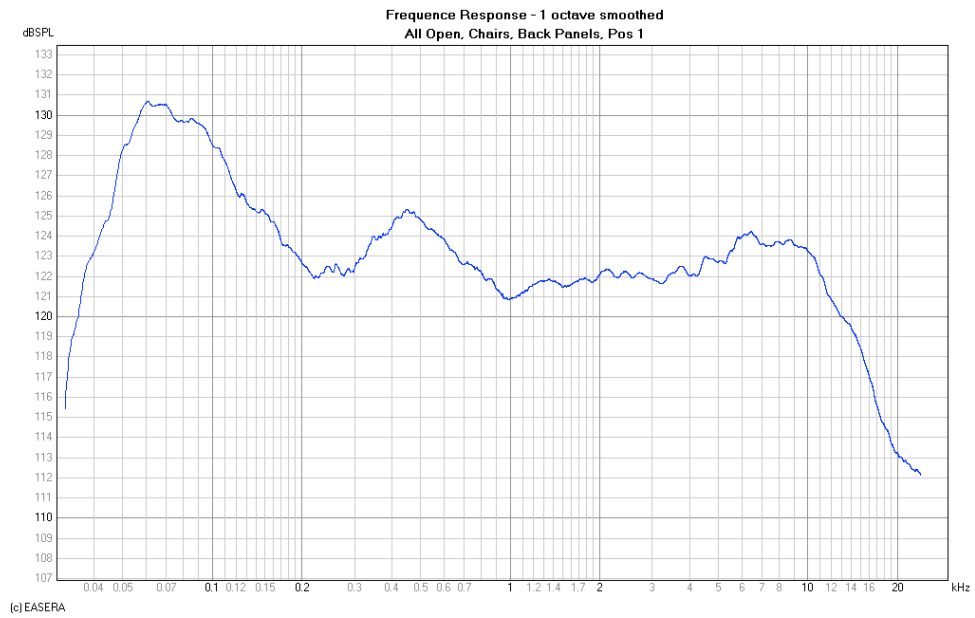
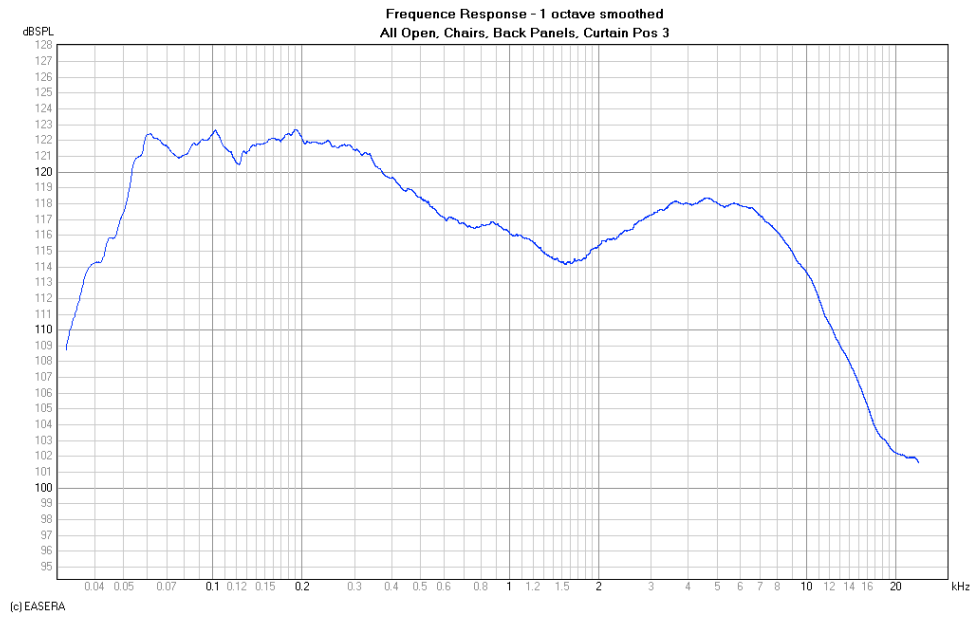
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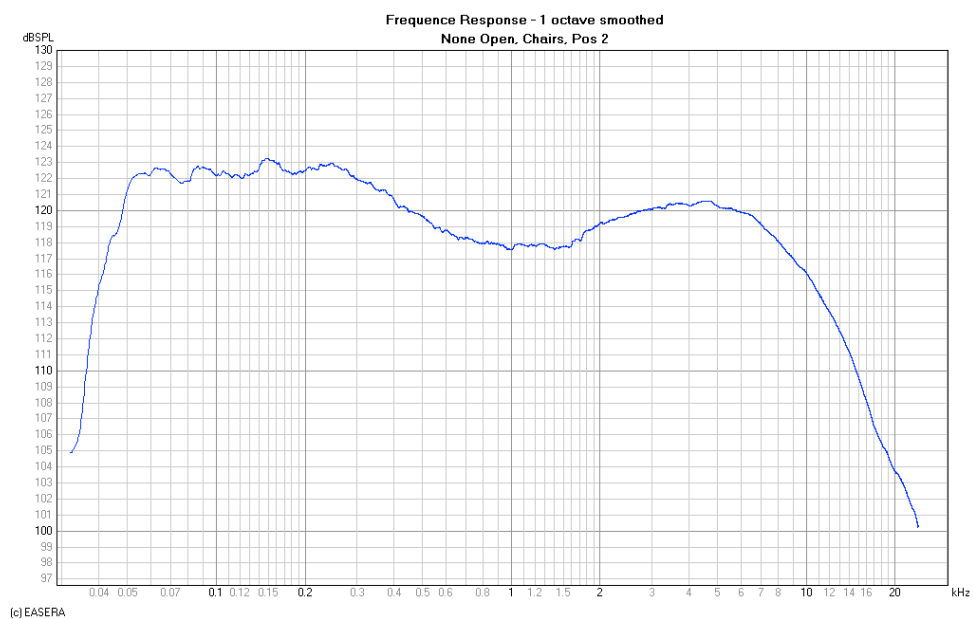
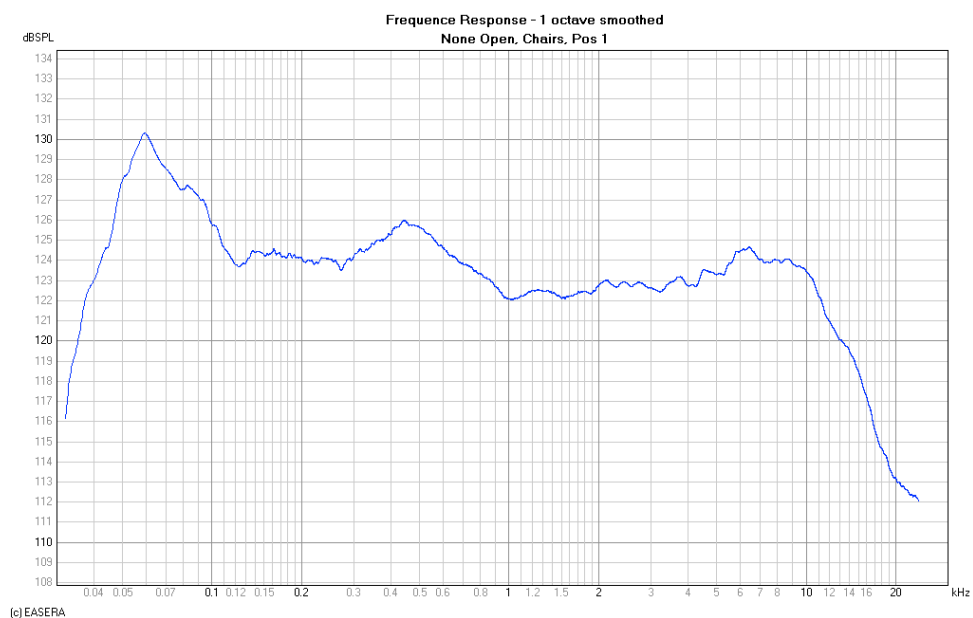
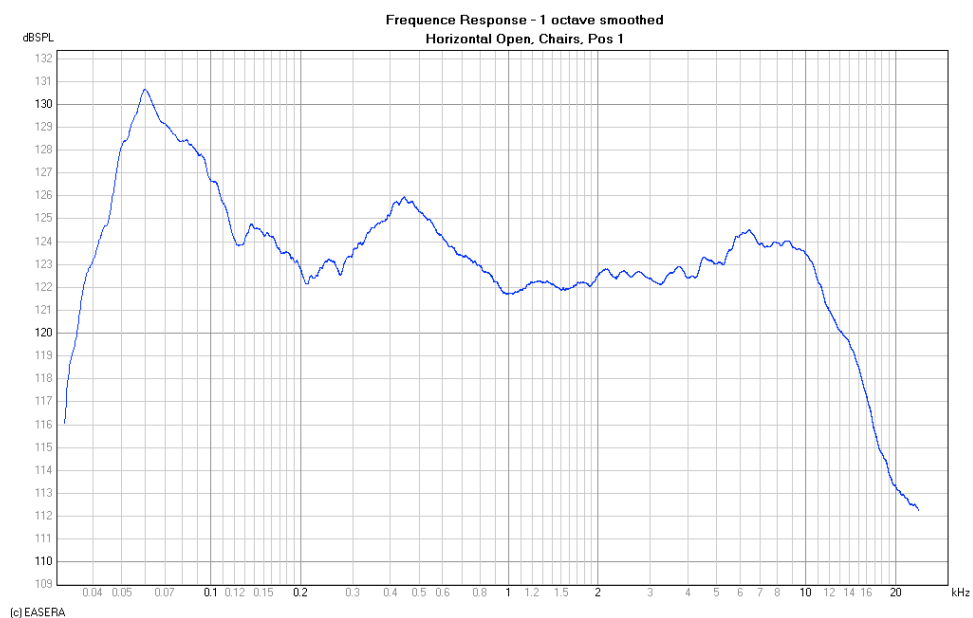


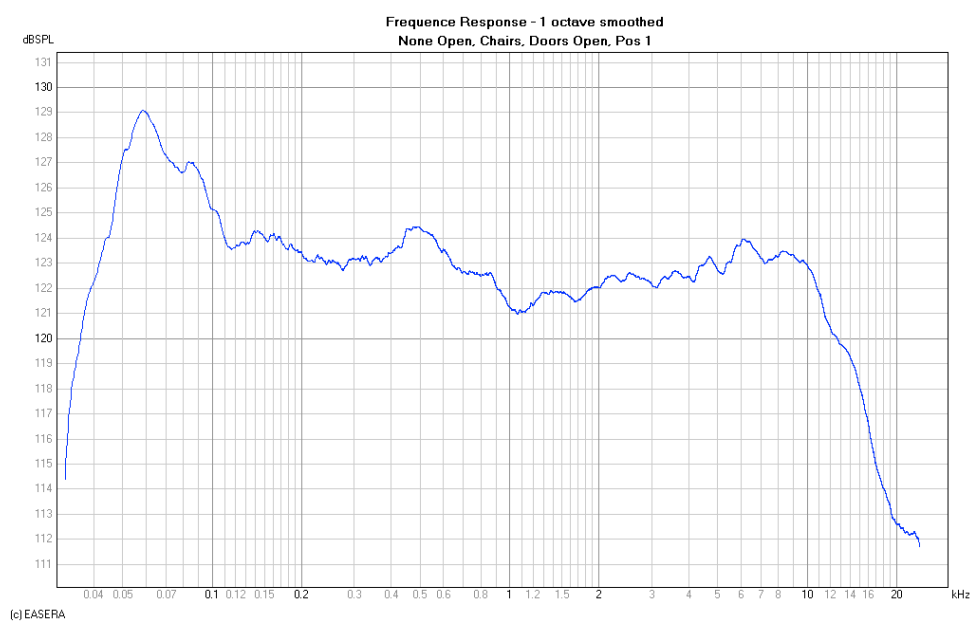
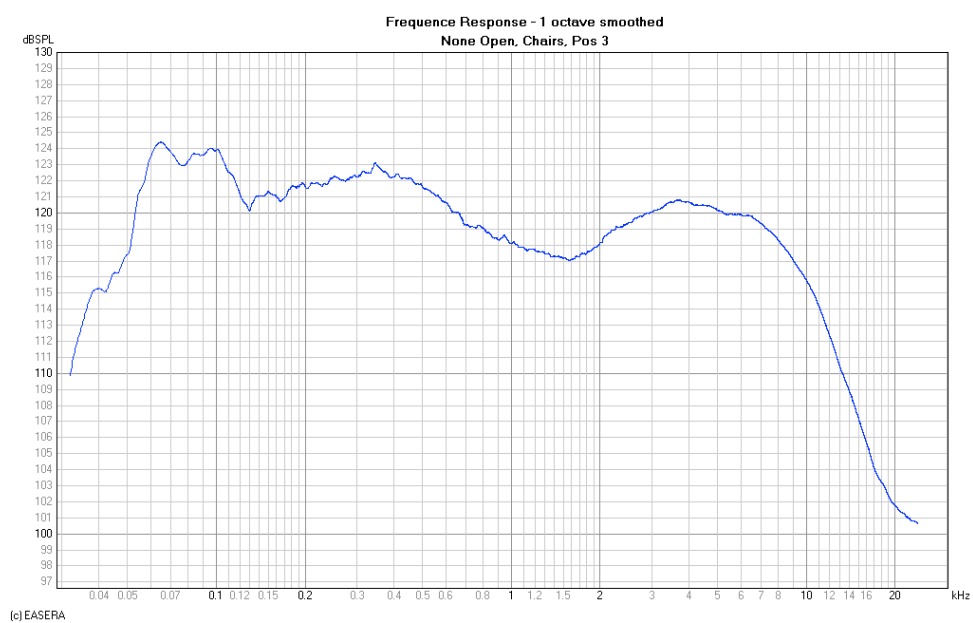
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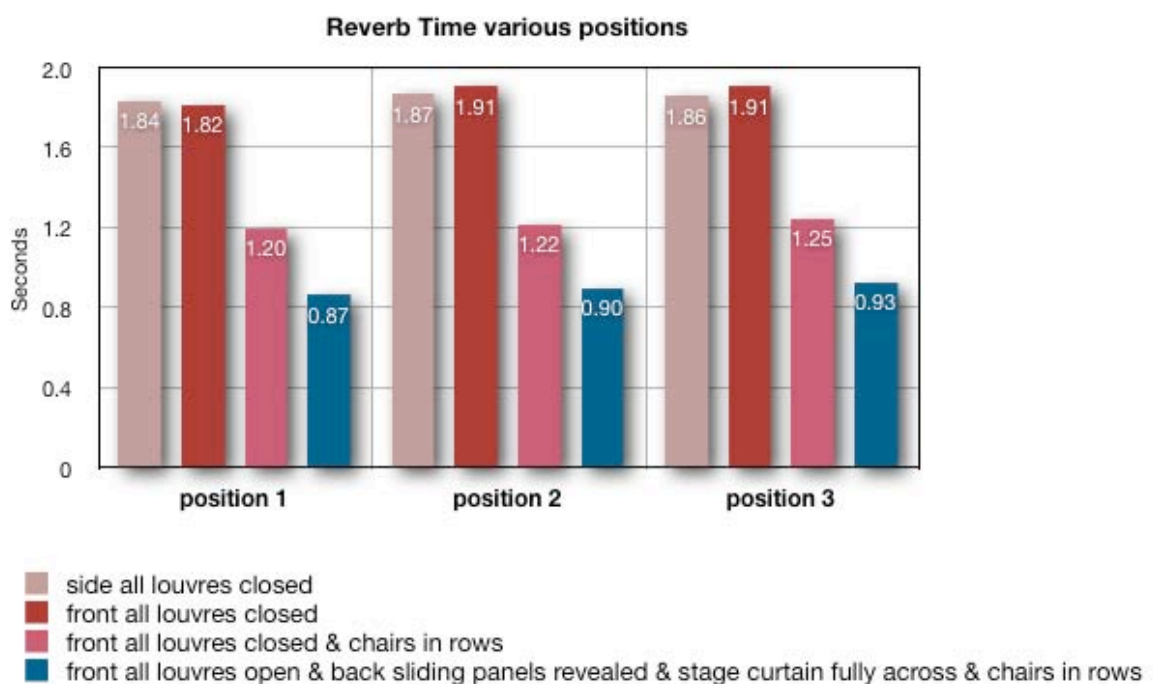
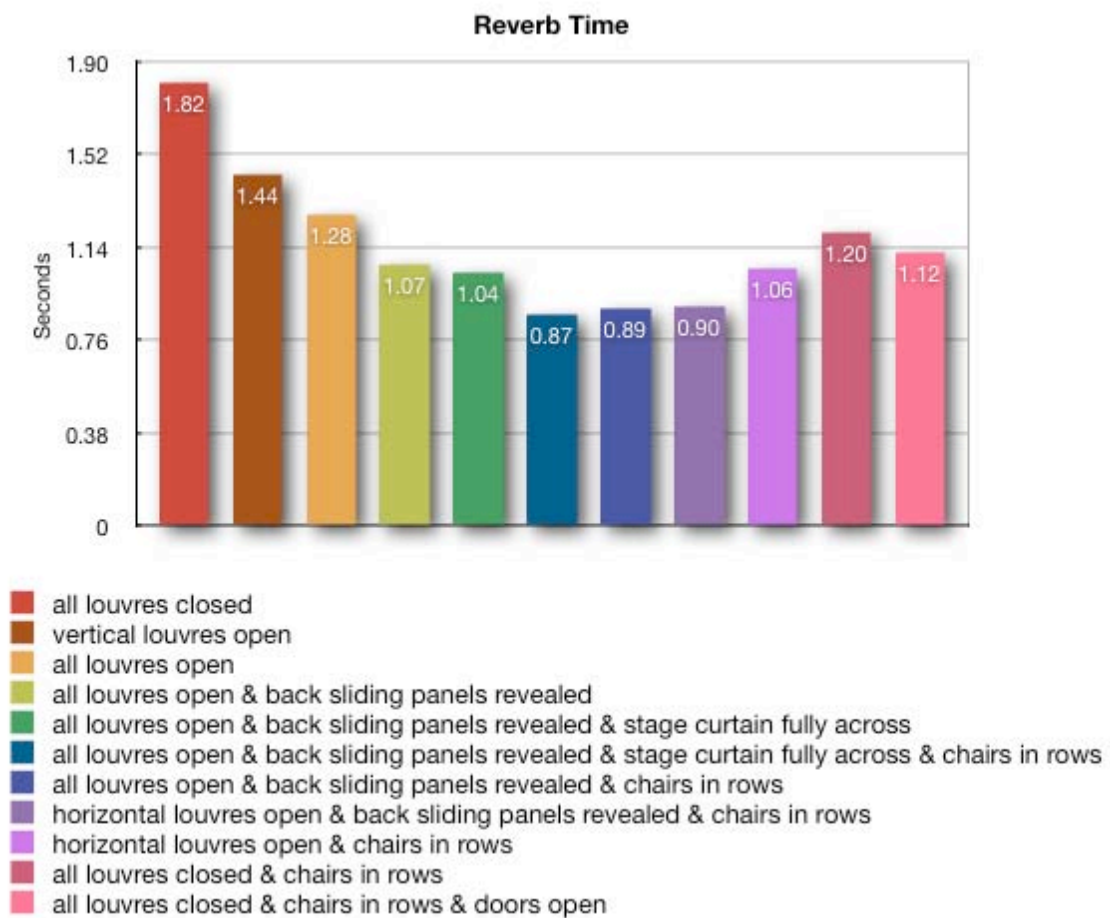
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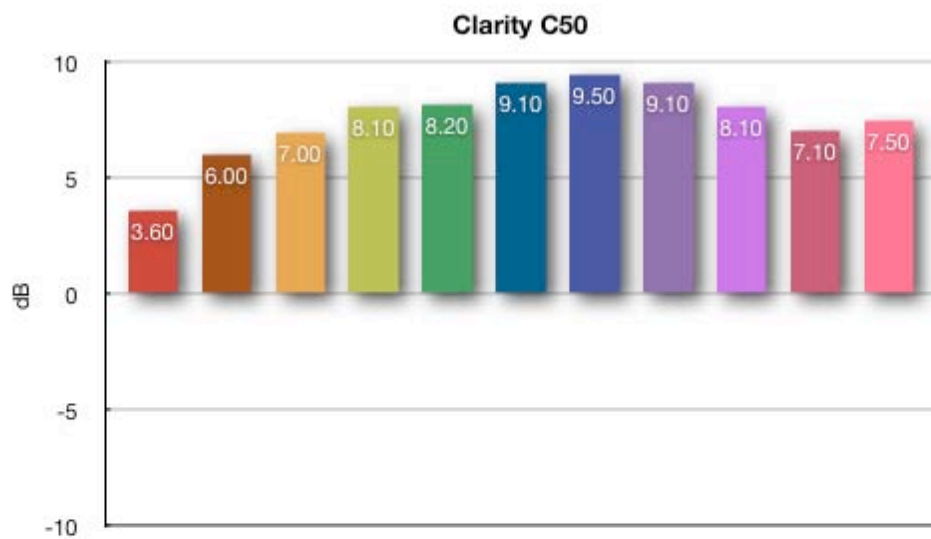




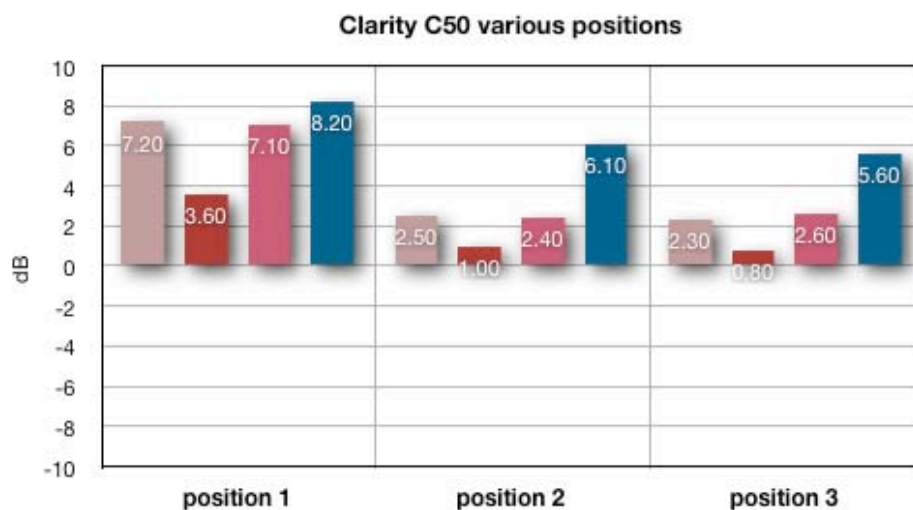


Appendix 4: Detailed Results With Different Room Configurations

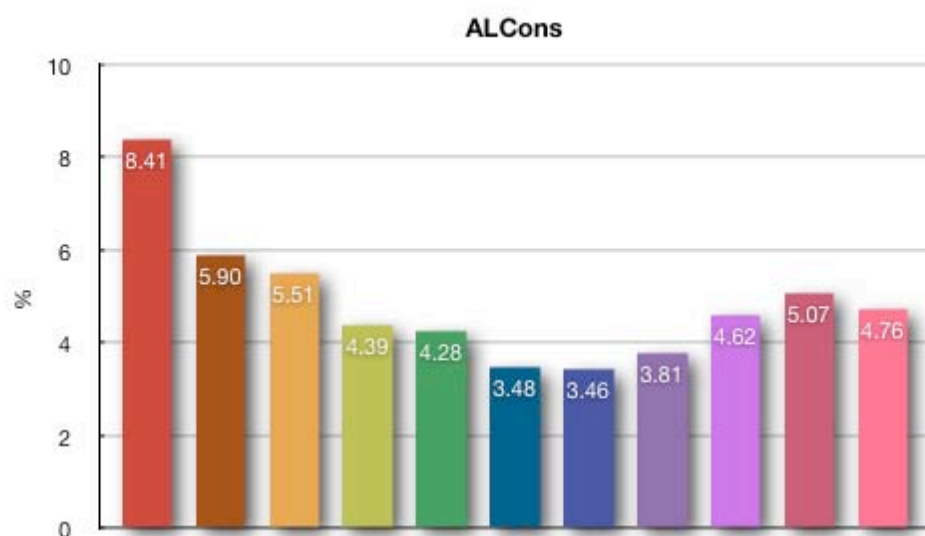




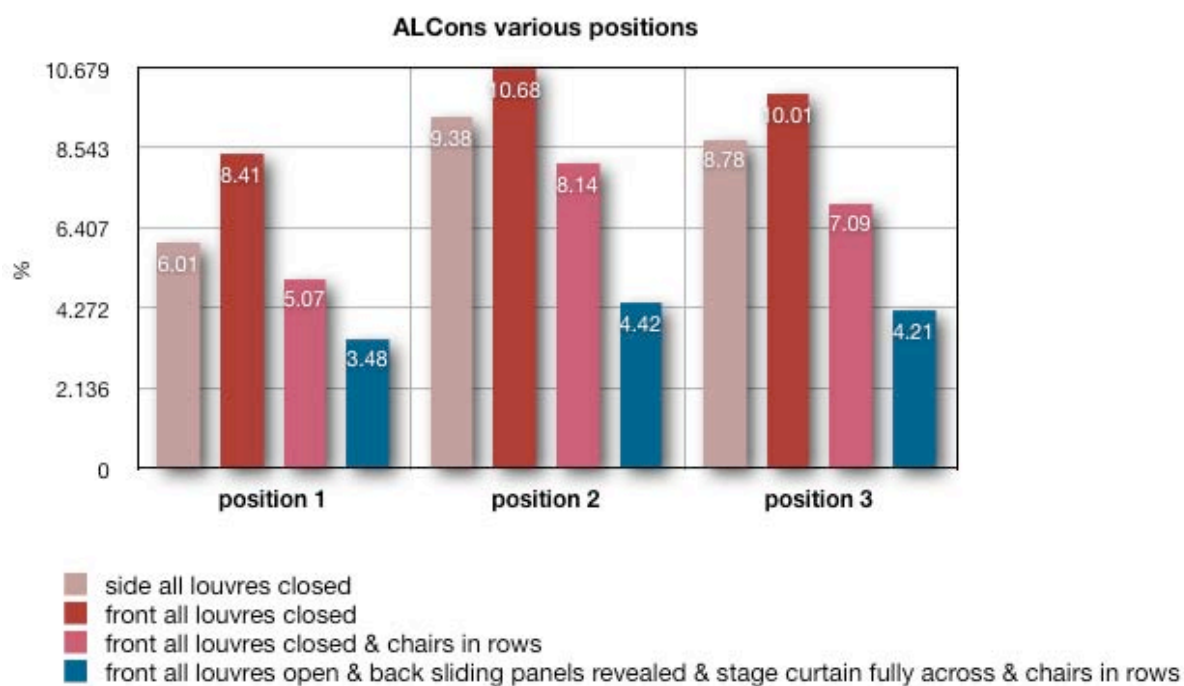
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- vertical louvres open
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- all louvres open & back sliding panels revealed & stage curtain fully across
- all louvres open & back sliding panels revealed & stage curtain fully across & chairs in rows
- all louvres open & back sliding panels revealed & chairs in rows
- horizontal louvres open & back sliding panels revealed & chairs in rows
- horizontal louvres open & chairs in rows
- all louvres closed & chairs in rows
- all louvres closed & chairs in rows & doors open



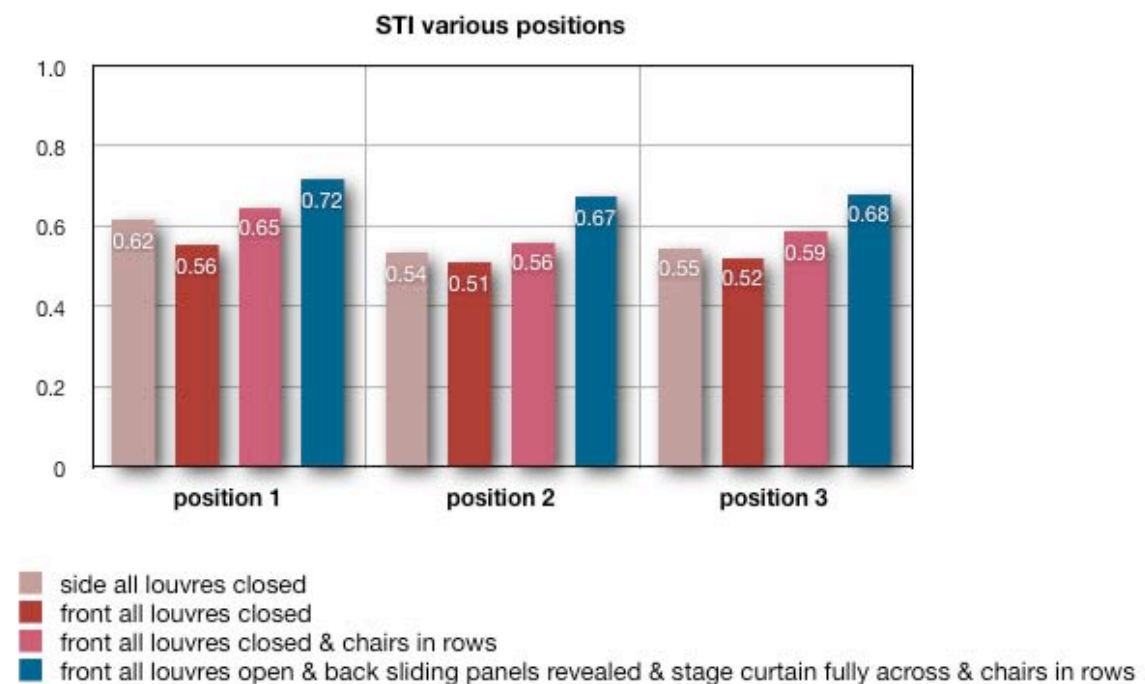
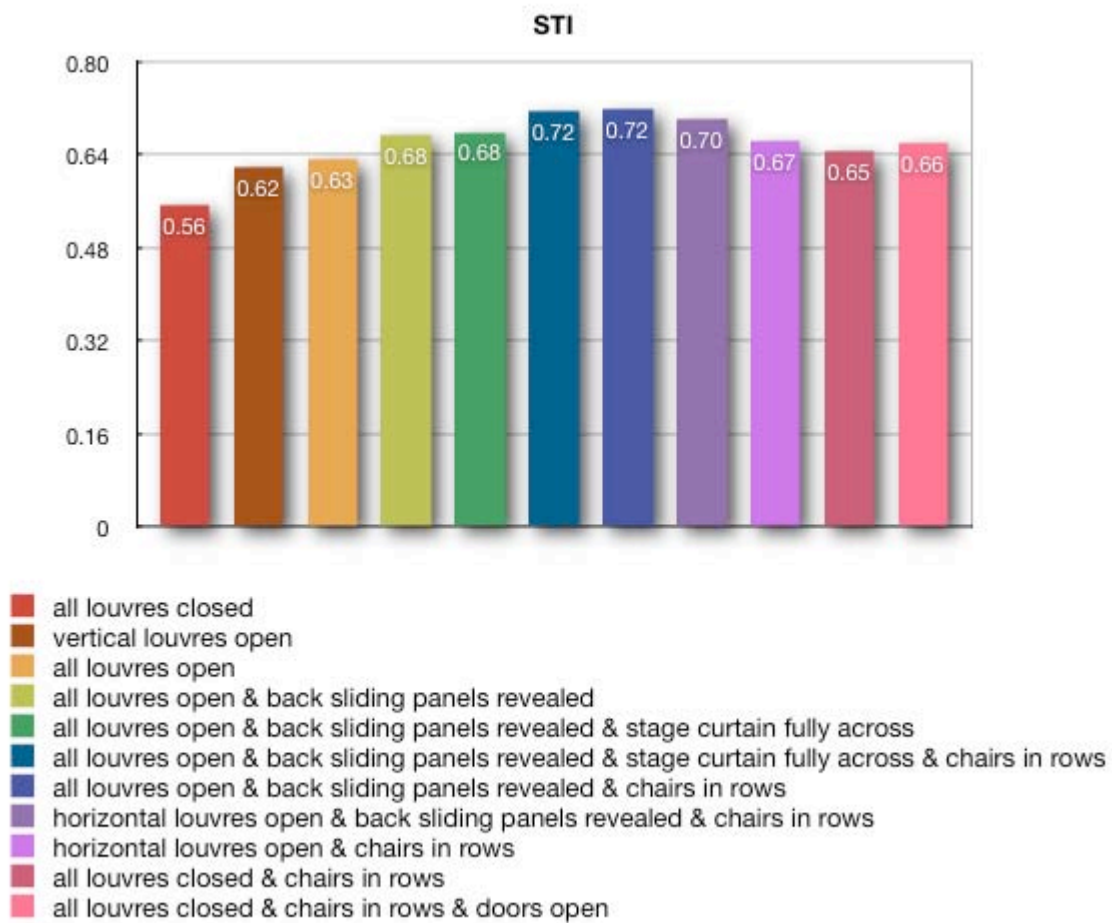
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- front all louvres open & back sliding panels revealed & stage curtain fully across & chairs in rows

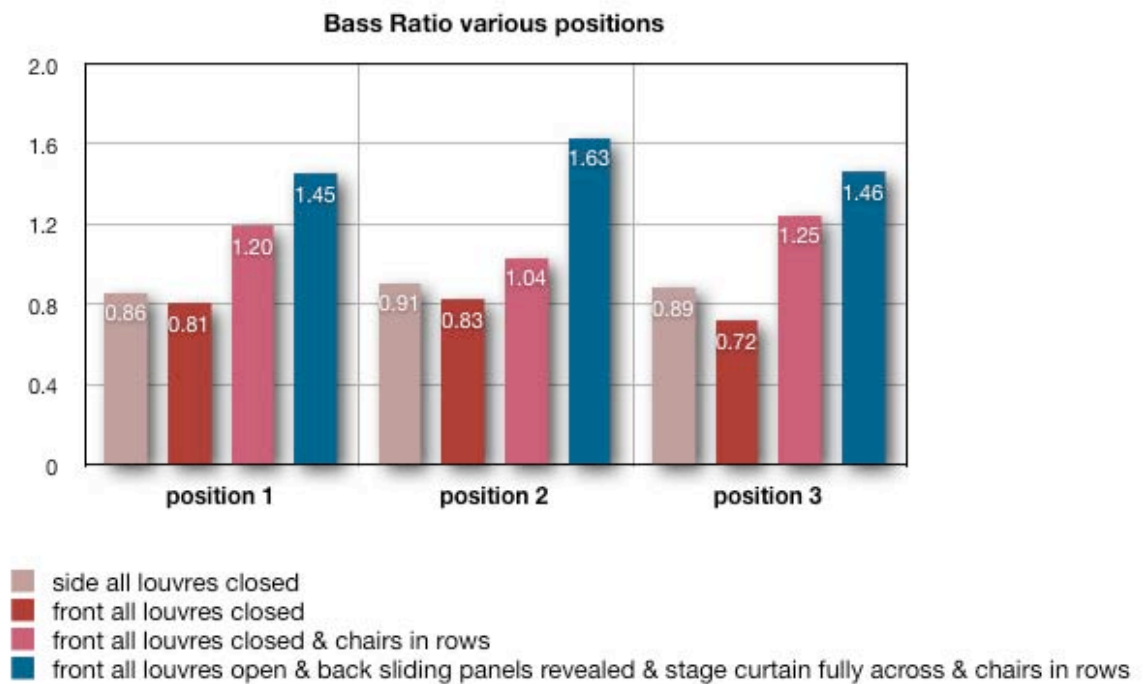
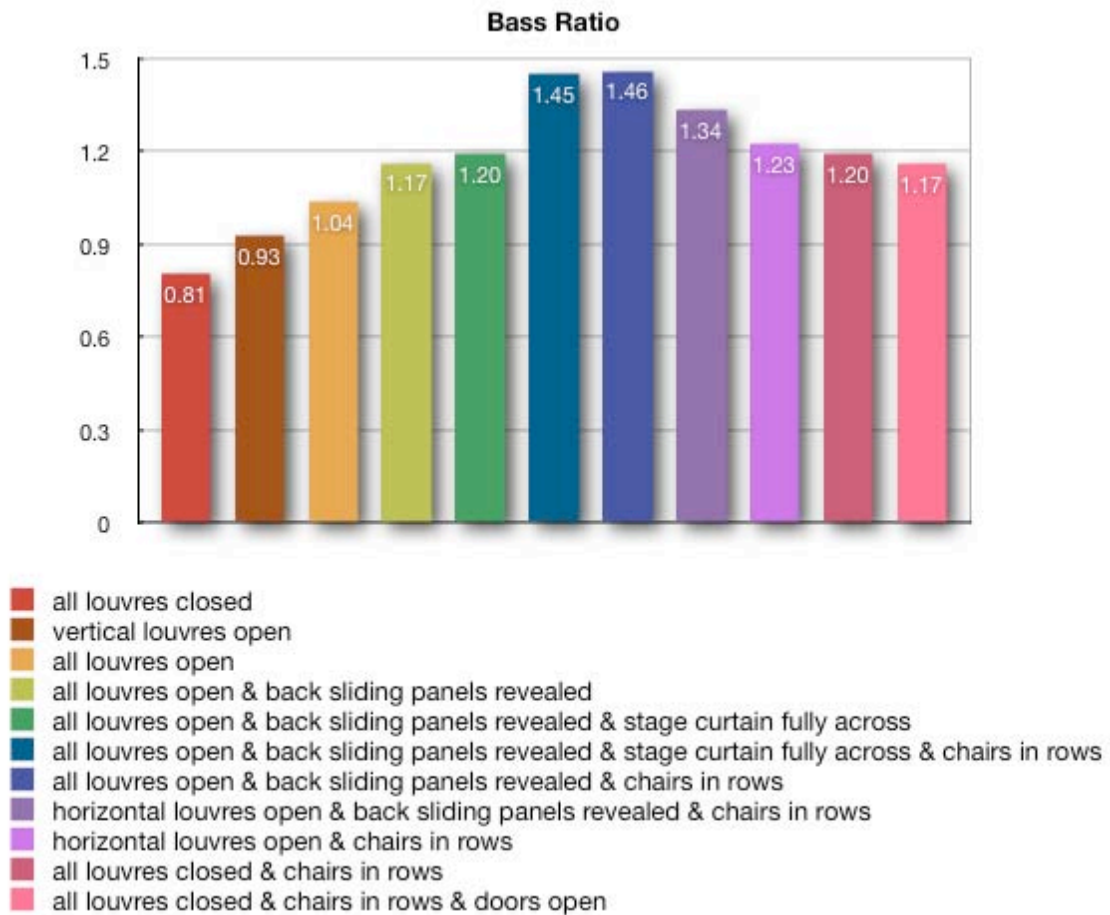


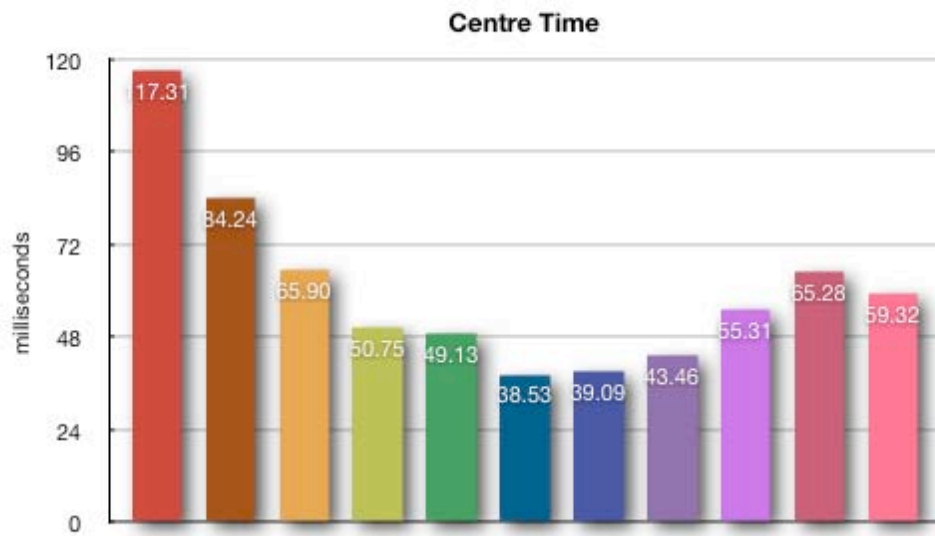
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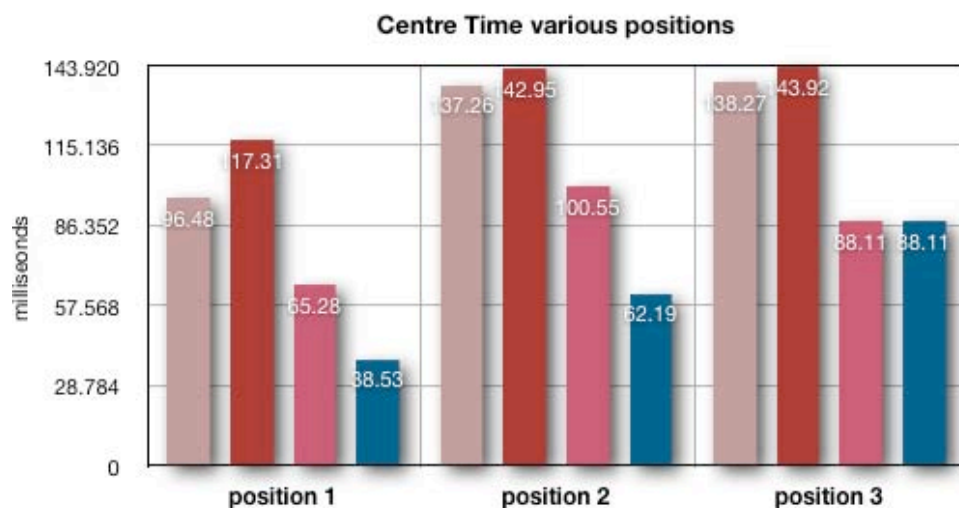
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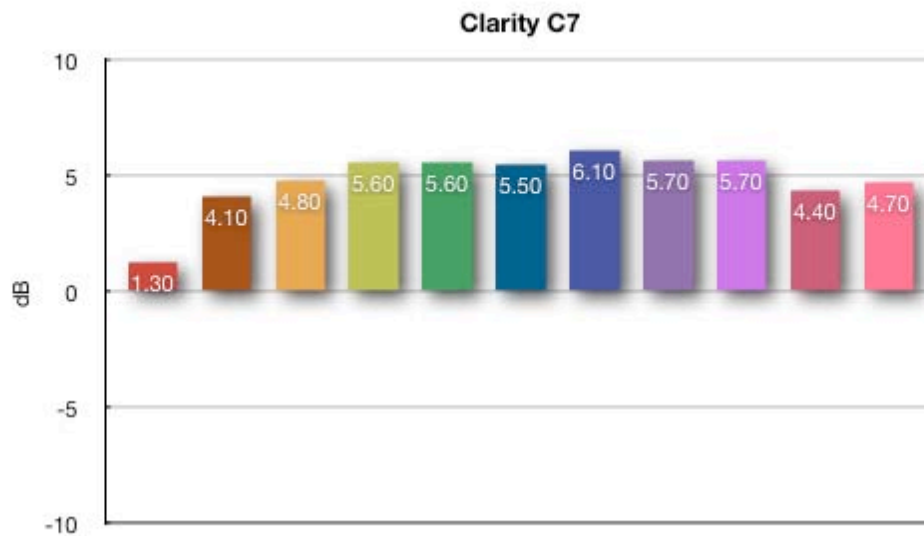




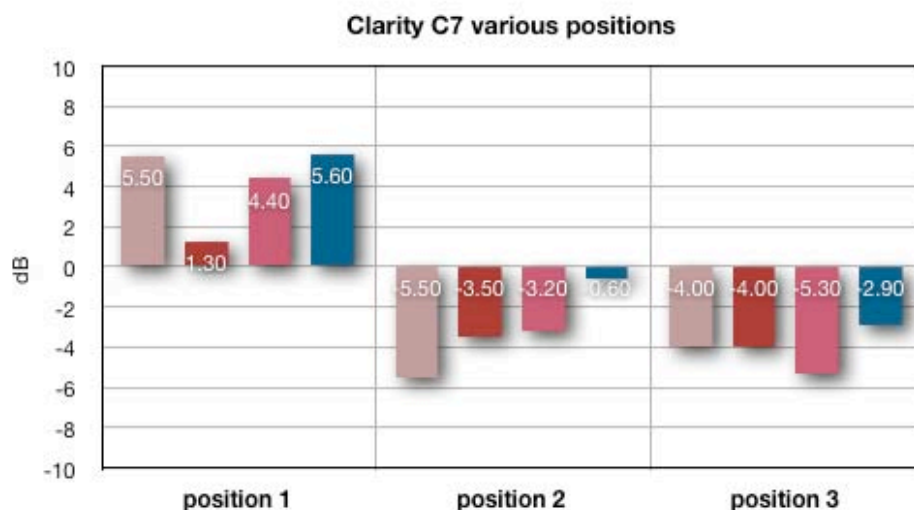
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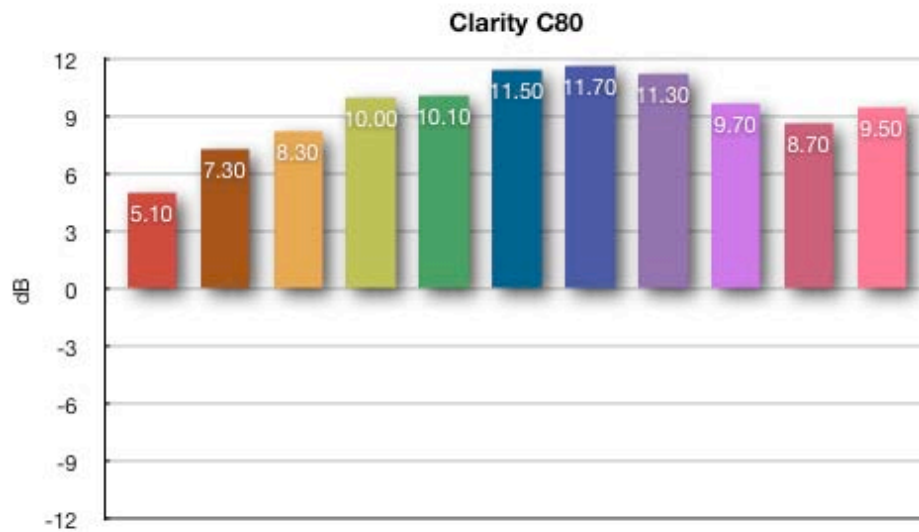
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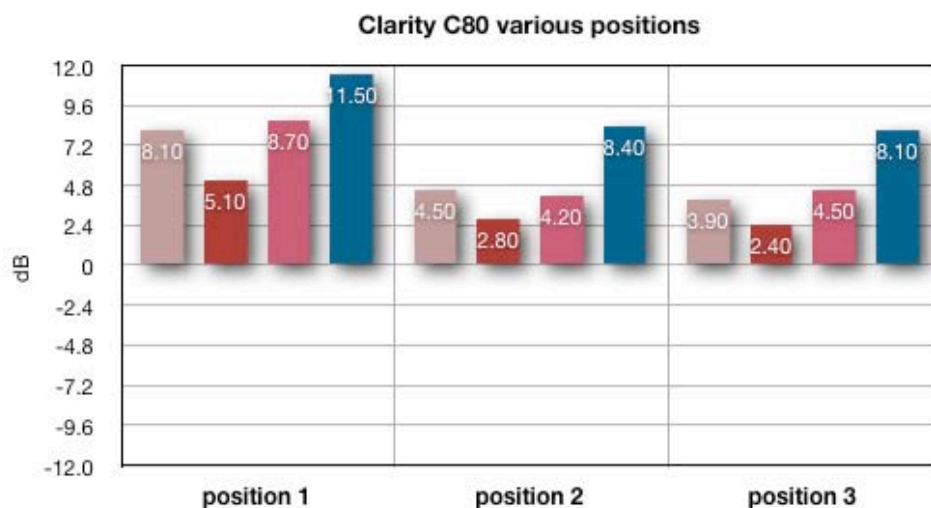
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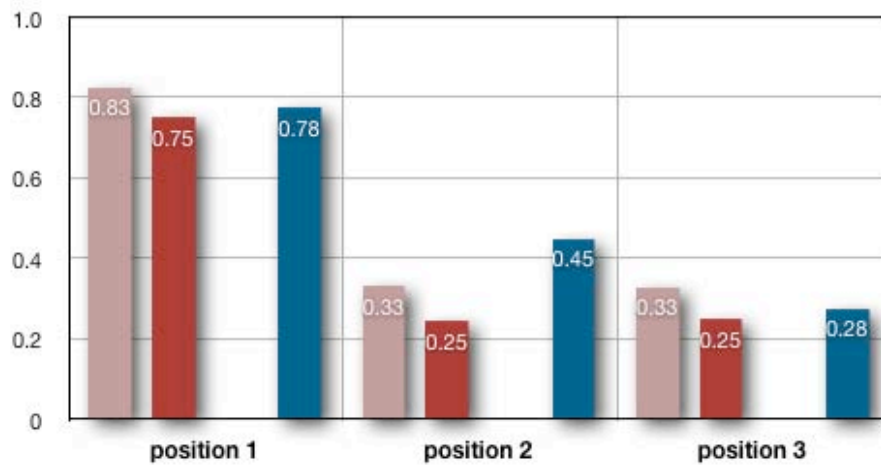


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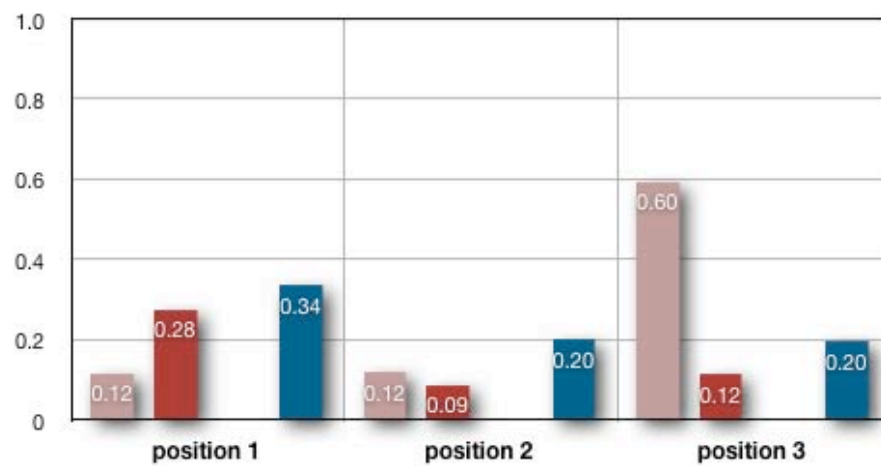
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Early IACC various positions

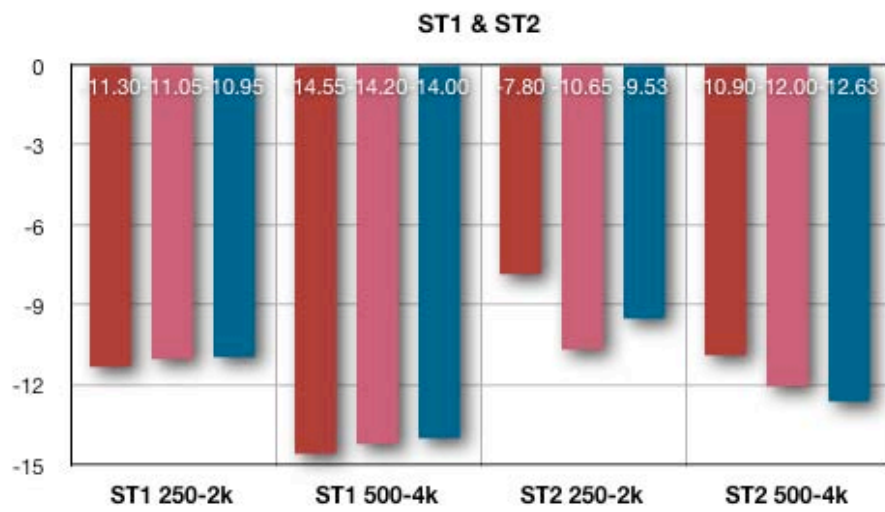


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Late IACC various positions



- side all louvres closed
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- front all louvres closed
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